Applied Anatomy

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SURGICAL APPLIED ANATOMY

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PREFACE TO THE SEVENTH EDITION

ALTHOUGH many additions have been made to and minor alterations effected in the present edition, this book still retains the spirit, form, and size given to it by its distinguished author. Every chapter has been revised in the light of recent surgical experience and progress. War has an influence even on such a manual as this, and yet, when we came to consider how far the experience of our Military Surgeons in the Field necessitated modifications of the text, we found that Sir Frederick Treves had already anticipated most of our modern needs. We have added considerably to what may be called "orthopædic anatomy"—the kind of knowledge which is necessary for the successful treatment of stiffened joints and disabled limbs. Twenty-seven new illustrations have been introduced.

We intended to apply, as far as was possible, the new Anatomical Nomenclature, but the further we proceeded with its application the more we felt that we should do British Anatomy and Surgery an ill service were we to abandon a tried and convenient system for one which, in many respects, is clumsy and imperfect. What we have done is to insert the new names side by side with the old (some of the new terms being advantageous), so that those who prefer the new nomenclature may still read a book which has been used so widely by a long succession of students and practitioners.

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December, 1917.

PREFACE TO THE FIRST EDITION

APPLIED ANATOMY has, I imagine, a twofold function. On the one hand it serves to give a precise basis to those incidents and procedures in practice that more especially involve anatomical knowledge; on the other hand it endues the dull items of that knowledge with meaning and interest by the aid of illustrations drawn from common medical and surgical experience. In this latter aspect it bears somewhat the same relation to Systematic Anatomy that a series of experiments in Physics bears to a treatise dealing with the bare data of that science.

The student of Human Anatomy has often a nebulous notion that what he is learning will some time prove of service to him; and may be conscious also that the study is a valuable, if somewhat unexciting, mental exercise. Beyond these impressions he must regard his efforts as concerned merely in the accumulation of a number of hard, unassimilable facts. It should be one object of Applied Anatomy to invest these facts with the interest derived from an association with the circumstances of daily life; it should make the dry bones live.

It must be owned also that all details in Anatomy have not the same practical value, and that the memory of many of them may fade without loss to the competency of the practitioner in medicine or surgery. It should be one other object, therefore, of a book having such a purpose as the present, to assist the student in judging of the comparative value of the matter he has learnt; and should help him, when his recollection of anatomical facts grows dim, to encourage the survival of the fittest.

In writing this manual I have endeavoured, so far as the space at my command would permit, to carry out the objects above described; and while I believe that the chief matters usually dealt with in works on Surgical Anatomy have not been neglected, I have nevertheless tried to make the principle of the book the principle that underlies Mr. Hilton's familiar lectures on "Rest and Pain."

I have assumed that the reader has some knowledge of Human Anatomy, and have not entered, except in a few instances, into any detailed anatomical descriptions. The bare accounts, for example, of the regions concerned in Hernia I have left to the systematic treatises, and have dealt only with the bearings of the anatomy of the parts upon the circumstances of practice. The limits of space have compelled me to omit all those parts of the "Surgery of the Arteries" that deal with ligature, collateral circulation, abnormalities, and the like. This omission I do not regret, since these subjects are fully treated not only in works on operative surgery, but also in the manuals of general anatomy.

The book is intended mainly for the use of students preparing for their final examination in surgery. I hope, however, that it will be of use also to practitioners whose memory of their dissecting-room work is growing a little grey, and who would wish to recall such anatomical matters as have the most direct bearing upon the details of practice. Moreover, it is possible that junior students may find some interest in the volume, and may have their studies rendered more intelligent by learning how anatomy is concerned in actual dealings with disease.

FREDERICK TREVES.

September, 1883.

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SURGICAL APPLIED ANATOMY

PART I.—THE HEAD AND NECK

CHAPTER I

THE SCALP

THE **soft parts covering the vault of the skull** may be divided into five layers: (1) the skin, (2) the subcutaneous fatty tissue, (3) the occipito-frontalis or epicranial muscle and its aponeurosis, (4) the subepicranial connective tissue, and (5) the pericranium. It is convenient to consider the term "scalp" as limited to the structure formed by the union of the first three layers above named (Fig. 1).

The skin of the scalp is thicker than in any other part of the body. It is in all parts intimately adherent, by means of the subcutaneous tissue, to the aponeurosis and muscle beneath it, and, from this adhesion, it follows that the skin moves in all movements of that muscle. The subcutaneous tissue is, like a similar tissue in the palm, admirably constructed to resist pressure, being composed of a multitude of fibrous bands enclosing fat lobules in more or less isolated spaces (Fig. 1, *b*). The density of the scalp is such, that in surface inflammations, such as cutaneous erysipelas, it is unable to offer (except in a very slight degree) two conspicuous features of such inflammations, viz. redness and swelling. The skin is provided with a great number of sebaceous glands, which may develop into cystic tumours or wens, such cysts being more common upon the scalp than in any other part of the body. Being skin growths, these cysts, even when large, remain, ex-

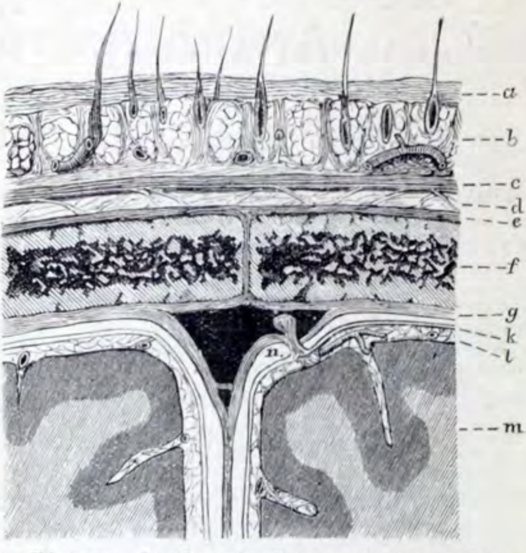

Fig. 1.—Diagram showing the layers of the scalp and membranes of the brain in section.

a, Skin; *b*, subcutaneous tissue with hair roots and vessels; *c*, epicranius; *d*, subepicranial layer; *e*, pericranium; *f*, parietal bone; *g*, dura mater; *k*, arachnoid; *l*, pia mater; *m*, cortex; *n*, in subdural space near a Pacchionian body projecting within the superior longitudinal sinus.

cept in rare instances, entirely outside the epicranius, and can therefore be removed without risk of opening up the area of loose connective tissue between the epicranial fascia and the pericranium.

There being no fatty tissue in any of the layers that cover the bony vault save in the subcutaneous layer, it happens that in cases of obesity the scalp undergoes but little change, the fat in the subcutaneous tissue being limited by the dense fibrous structures that enclose it. For the same reasons fatty tumours of the scalp are very rare. The attachment of the hairs collectively to the scalp is so strong that there are many cases where the entire weight of the body has been supported by the hair of the scalp. Agnew records the case of a woman whose hair became entangled in the revolving shaft of a machine. The hair did not give way, but the entire scalp was torn off from the skull. The patient recovered.

Dangerous area of the scalp.—Between the epicranius and the pericranium is an extensive layer of loose connective tissue, that may, for reasons to be presently given, be fairly called the dangerous area of the scalp (Fig. 1, *d*). The mobility of the scalp depends entirely upon the laxity of this layer of tissue. In extensive scalp wounds, when a part of the scalp is separated in the form of a large flap, a flap that may hang down and cover half the face, it is the very looseness of this tissue that permits such separation. The exposure of the skull in a post-mortem examination is effected by peeling off the scalp along this layer of loose tissue, and it is remarkable with what ease the skull can be exposed by this manœuvre.

Wounds of the scalp never gape, unless the wound has involved the scalp muscle or its aponeurosis. When this structure has been divided the lax layer beyond permits of great separation of the edges of even the simplest wounds. In uncomplicated incised wounds, the amount of gaping of the cut depends upon the action of the epicranius or occipito-frontalis muscle. Those wounds gape the most that are made across the muscle itself, and that are transverse to the direction of its fibres, while those show the least separation that involve the aponeurosis and are made in an antero-posterior direction. The mobility of the scalp is more marked in the young than in the old. A case recorded by Agnew serves in a strange degree to illustrate this fact in the person of an infant. A midwife attending a woman in labour mistook the scalp of the infant for the membranes, and gashed it with a pair of scissors. Labour pains came on and the head was protruded through the scalp wound, so that the whole vault of the skull was peeled like an orange. The scalp being firmly stretched over the hard cranium beneath, it follows that contused wounds often appear as cleanly cut as are those that have been made by an incision. Such wounds may be compared to the clean cut that may be made in a kid glove when it is tightly stretched over the knuckles and those parts are sharply rapped.

The scalp is extremely vascular, and presents therefore a great resistance to sloughing and gangrenous conditions. Large flaps of a lacerated scalp, even when extensively separated and almost cut off from the rest of the head, are more prone to live than to die. A like flap of skin, separated from other parts of the surface, would most probably perish; but the scalp has this advantage, that the vessels run practically in the skin itself, or are, at least, in the tissue beyond the aponeurosis (Fig. 1). Thus, when a scalp flap is torn up, it still carries with it a very copious blood supply. Bleeding from these wounds is usually very free, and often difficult to arrest. This depends not so much upon the number of vessels in the part as upon the density of the tissue through which these vessels run, the adherence of the outer arterial wall to the scalp structure, and the inability, therefore, of the artery to retract properly when divided. For the same reason it is almost impossible to pick up an artery divided in a scalp wound. The bleeding is checked by a hare-lip pin or by pressure.

In all parts of the body where a dense bone is covered by a comparatively thin layer of soft tissues, sloughing of those tissues is apt to be induced by long and severe pressure. The scalp, by its vascularity, is saved to a great extent from this evil, and is much less liable to slough than are the soft parts covering such bones as the condyles of the humerus or the sacrum. But such an effect is sometimes produced, as in a case I (F. T.) saw, where the tissues over the frontal and occipital regions sloughed from the continued application of a tight bandage put on to arrest bleeding from a frontal wound.

The **pericranium** is but slightly adherent to the bone, except at the sutures, where it is intimately united (Fig. 1, *e*). In lacerated wounds this membrane can be readily stripped from the skull, and often, in these injuries, extensive tracts of bone are laid bare. The pericranium differs somewhat in its functions from the periosteum that covers other bones. If the periosteum be removed to any extent from a bone, the underlying laminæ will very probably perish, and necrosis from deficient blood supply result. But the pericranium may be stripped off a considerable part of the skull vault without any necrosis, save perhaps a little superficial exfoliation. This is explained by the fact that the cranial bones derive their blood supply mainly from the dura mater, and are therefore to a considerable extent independent of the pericranium. A like independence cannot be claimed for the periosteum covering other bones, since that membrane brings to the part it covers a very copious and essential contribution to its blood supply. This disposition of the pericranium is also well illustrated by its action in cases of necrosis of the cranial bones. In necrosis of a long bone, the separation of the sequestrum is attended with a vigorous periosteal growth of new bone, which repairs the gap left after the removal of such sequestra. In necrosis of the vault of the skull, however, no new bone is formed, as a rule, and the gap remains unrepaired. The general indisposition of the pericranium to form new bone in other circumstances is frequently illustrated.

Abscesses in the scalp region may be situated (1) above the epicranial aponeurosis, (2) between the aponeurosis and the pericranium, and (3) beneath the pericranium. Abscesses in the first situation must always be small and comparatively insignificant, since the density of the scalp tissue here is such that suppuration can only extend with the greatest difficulty. Suppuration, however, in the second situation (in the loose tissue beneath the aponeurosis) may prove very serious. The laxity of this tissue offers every inducement to the abscess to extend when once pus has found its way between the aponeurosis and the pericranium. Suppuration in this area may undermine the entire scalp, which in severe and unrelieved cases may rest upon the abscess beneath as upon a kind of water-bed. As in scalp wounds, the aponeurosis is often divided, and as suppuration may follow the injury, it will be seen that the chief danger of those lesions depends upon the spreading of such suppuration to the area of lax connective tissue now under notice. The significance of a small amount of bare bone in a scalp wound is not so much that evils will happen to the bone as that the aponeurosis has been certainly divided and the dangerous area of the scalp opened up. Suppuration, when it occurs in this area, is only limited by the attachments of the occipito-frontalis muscle and its aponeurosis, and therefore the most dependent places through which pus can be evacuated are situated along a line drawn round the head, commencing in front, above the eyebrow, passing at the side a little above the zygoma, and ending behind at the superior curved line of the occipital bone. The scalp, even when extensively dissected up by such abscesses, does not perish, since it carries, as above explained, its blood supply with it. The abscess is often very slow to close, since its walls are prevented from obtaining perfect rest by the frequent movement of the epicranial muscle. To mitigate this evil, and to ensure closing of the sinuses in obstinate cases, Hilton advises that the whole scalp be firmly secured by strapping, so that the movement of the muscle is arrested.

Abscesses beneath the pericranium must be limited to one bone, since the dipping-in of the membrane at the sutures prevents a more extensive spreading of the suppuration.

Hæmatomata, or **blood tumours,** of the scalp region occur in the same localities as abscesses. The extravasation of blood above the aponeurosis must be of a limited character, while that beneath it may be very extensive. It fortunately happens, however, that the cellular tissue between the aponeurosis and the pericranium contains but very few vessels, and hence large extravasations in this tissue are uncommon.

Extravasations of blood beneath the pericranium are generally termed cephalhæmatomata, and are of necessity limited to one bone. They are usually due to pressure upon the head at birth, and are thus most commonly found over one parietal bone, that bone being probably the one most exposed to pressure. Their greater frequency in male children may depend upon the larger size of the head in the male fœtus. Such extravasations in early life are encouraged by the laxity of the pericranium, and by the softness and vascularity of the subjacent bone.

In the **temporal region,** or the region corresponding to the temporal muscle, the layers of soft parts between the skin and the bone are somewhat different from those that have been already described as common to the chief parts of the scalp. There is a good deal of fat in the temporal fossa, and when this is absorbed it leads to more or less prominence of the zygoma and malar bone, and so produces the projecting "cheek bones" of the emaciated. The temporal muscle above the zygoma is covered in by a very dense fascia, the temporal fascia, which is attached above to the temporal ridge on the frontal and parietal bones, and below to the zygomatic arch. The unyielding nature of this fascia is well illustrated by a case recorded by Denonvilliers. It concerned a woman who had fallen in the street, and was admitted into hospital with a deep wound in the temporal region. A piece of bone of several lines in length was found loose at the bottom of the wound, and was removed. After its removal the finger could be passed through an opening with an unyielding border, and came in contact with some soft substance beyond. The case was considered to be one of compound fracture of the squamous bone, with separation of a fragment and exposure of the brain. A bystander, however, noticed that the bone removed was dry and white, and a more complete examination of the wound revealed the fact that the skull was uninjured, that the supposed hole in the skull was merely a laceration of the temporal fascia, that the soft matter beyond was muscle and not brain, and that the fragment removed was simply a piece of bone which, lying on the ground, had been driven into the soft parts when the woman fell.

Abscesses in the temporal fossa are prevented by the fascia from opening anywhere above the zygoma, and are encouraged rather to spread into the pterygoid and maxillary regions and into the neck.

The pericranium is much more adherent to the bone in the temporal region than it is over the rest of the vault, and subpericranial extravasations of blood are therefore practically unknown in this part of the cranial wall.

Vessels and nerves of the scalp.—The supraorbital artery and nerve pass vertically upwards from the supraorbital notch, which is situate at the junction of the middle with the inner third of the upper orbital margin. Nearer the middle line the frontal artery and supratrochlear nerve ascend. This artery gives life to the flap that in rhinoplasty is taken from the forehead to form a new nose. The temporal artery, with the auriculo-temporal nerve behind it, crosses the base of the zygoma just in front of the ear. The vessel divides into its two terminal branches (the anterior and posterior) 2 inches above the zygoma. The branches of this artery, especially the anterior branch, are often very tortuous in the aged, and afford early evidence of arterial degeneration. Arteriotomy is sometimes practised on the anterior branch of this vessel. The superficial temporal vessels are very liable to be the seat of cirsoid aneurysm, as, to a less extent, are the other scalp arteries. The posterior auricular artery and nerve run in the groove between the mastoid process and the ear, and the occipital artery and the great occipital nerve reach the scalp just internally to a point midway between the occipital protuberance and the mastoid process.

Certain of the **emissary veins** are of importance in surgery. These veins pass through apertures in the cranial wall, and establish communications between the venous circulation (the sinuses) within the skull and the superficial veins external to it. The principal emissary veins are the following: 1. A vein passing through the mastoid foramen and connecting the lateral sinus with the posterior auricular vein or with an occipital vein. This is the largest and most constant of the series. The existence of this mastoid vein serves to answer the question, Why is it a common practice to apply leeches and blisters *behind the ear* in certain cerebral affections? 2. A vein connecting the superior longitudinal sinus with the veins of the scalp through the parietal foramen. 3. A vein connecting the lateral sinus with the deep veins at the back of the neck through the posterior condylic foramen (inconstant). 4. Minute veins following the twelfth nerve through the anterior condylic foramen, and connecting the occipital sinus with the deep veins of the neck. 5. Minute veins passing through the foramen ovale, foramen of Vesalius, foramen lacerum medium, and carotid canal, to connect the cavernous sinus with (respectively) the pterygoid venous plexus, the pharyngeal plexus, and the internal jugular vein.

Then, again, many minute veins connect the veins of the scalp with those of the diploë. Of the four diploic veins, two (the frontal and anterior temporal) enter into surface veins (the supraorbital and deep temporal), and two (the posterior temporal and occipital) enter into the lateral sinus.

Lastly, there is the well-known communication between the extra- and intracranial venous circulation effected by the commencement of the facial vein at the inner angle of the orbit. In this communication the angular and supraorbital veins unite with the superior ophthalmic vein, a tributary of the cavernous sinus. The veins within the cavities of the nose and middle ear also communicate with those of the meninges.

Through these various channels, and through many probably still less conspicuous, inflammatory processes can spread from the surface to the interior of the skull. Thus we find such affections as erysipelas of the scalp, diffuse suppuration of the scalp, necrosis of the cranial bones, and the like, leading by extension to mischief within the diploë, to thrombosis of the sinuses, and to inflammation of the meninges of the brain. If there were no emissary veins, injuries and diseases of the scalp and skull would lose half their seriousness. Mischief may even spread from within outwards along an emissary vein. Erichsen reports a case where the lateral sinus was exposed in a compound fracture. The aperture was plugged. Thrombosis and suppuration within the sinus followed, and some of the pus, escaping through the mastoid vein, led to in abscess in the neck.

Certain *venous tumours* are met with on the skull. They consist of collections of venous blood under the pericranium that communicate, through holes in the skull, with the superior longitudinal sinus. They are median, are reducible on pressure, and receive a faint pulsation from the brain. The holes are sometimes the result of accident, others depend upon bone disease or atrophy over a Pacchionian body, and a few are due to a varicose emissary vein or to a congenital defect in the

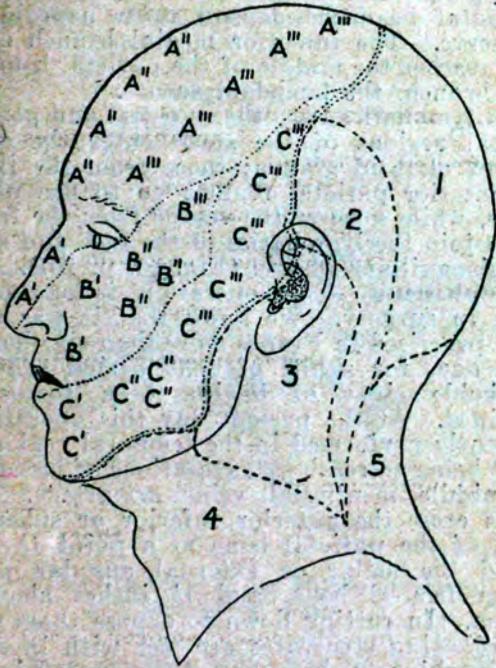

Fig. 2.—Nerve areas of the face and scalp.

A, A, Distribution of the first division of the fifth cranial nerve: A′, nasal branch; A″, supratrochlear; A‴, supraorbital.
B, B, Distribution of the second division: B′, infraorbital branch; B″, malar branch; B‴, temporal branch.
C, C, Distribution of third division: C′, mental branch; C″, buccal branch; C‴, auriculo-temporal.
1, Area of great occipital; 2, of small occipital; 3, of great auricular 4, of superficial cervical; 5 of third occipital.

cranium, especially in the neighbourhood of the parietal foramina.

The scalp **nerves**, especially such as are branches of the fifth pair, are often the seat of neuralgia (Fig. 2). To relieve one form of this affection, the supraorbital nerve has been divided (neurotomy), or paralysed by an injection of absolute alcohol at its point of exit from the orbit. Some forms of frontal headache depend upon neuralgia of this nerve. The inner or medial branch of the nerve reaches the middle of the parietal bone; the outer branch, the lambdoid suture.

The **lymphatics** from the occipital and posterior parietal regions of the scalp enter the occipital and mastoid glands; those from the frontal and anterior parietal regions go to the parotid glands, while some of the vessels from the frontal region join the lymphatics of the face and end in the submaxillary glands (Fig. 50, p. 207).

Trephining.—This operation is one of the oldest in surgery. We know that it was extensively practised in France more than six thousand years ago, for skulls of that period show unmistakable signs of having been successfully trephined. At the present day this operation is frequently performed in the temporal region, one object being to reach extravasations of blood from the middle meningeal veins or artery. These vessels cross the anterior inferior or sphenoidal angle of the parietal bone at a point 1½ inches behind the malar or external angular process of the frontal bone, and 1½ inches above the zygoma. In cutting down to expose these vessels the following structures are met with in order: (1) The skin; (2) branches of the superficial temporal vessels and nerves; (3) the fascia continued down from the epicranial aponeurosis; (4) the temporal fascia; (5) the temporal muscle; (6) the deep temporal vessels; (7) the pericranium; (8) the sphenoidal angle of the parietal bone.

Trephining for meningeal hæmorrhage and cerebral abscess.—At the sphenoidal angle of the parietal bone the anterior division of the middle meningeal artery lies with its companion veins in a deep groove or even canal in the bone. A fracture of the bone, which is comparatively thin in the region of the pterion, is almost certain to rupture the veins, and may also involve the artery, leading to a subdural hæmorrhage, with consequent compression of the brain. The pterion lies $1\frac{1}{2}$ inches behind and $\frac{1}{2}$ an inch above the notch of the fronto-malar (fronto-zygomatic) suture—a

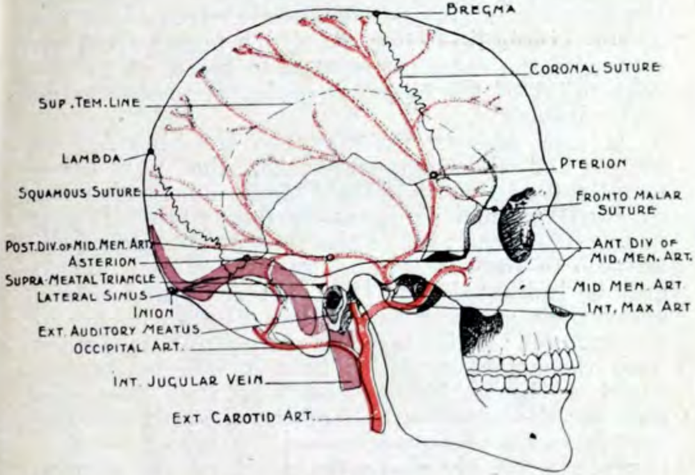

Fig. 3.—Points to trephine for middle meningeal vessels and lateral sinus.

point which can be readily felt (Fig. 3). Similar measurements—namely, $1\frac{1}{2}$ inches behind and $\frac{1}{2}$ an inch above—taken from the centre of the external auditory meatus—the meatal point, give the position of the posterior inferior angle of the parietal bone (asterion), beneath which lies the highest point of the lateral sinus (Fig. 3). A trephine opening, $\frac{3}{4}$ of an inch in diameter, made over the asterion, will expose the lateral sinus, and give access to the temporo-sphenoidal lobe above it and to the cerebellum below it. The posterior division of the middle meningeal, in the majority of cases, will be exposed by trephining at a point 1 inch above the external auditory meatus. These measurements apply to the head of the average adult; allowance must be made for youth and for the size and shape of the head. In finding the pterion, a line is drawn backwards parallel to the upper border of the zygoma; in finding the asterion, a line is drawn backwards along the meato-inionic line (Fig. 3), which passes from the centre of the external meatus to the most prominent point of the external occipital protuberance —the inion.

It may also be necessary to trephine for an abscess of the temporal lobe, the pus being usually found in that part of the lobe which lies over the tegmen tympani—a thin plate of bone which forms the roof of the tympanum and of the antrum of the mastoid. The level of the tegmen may be indicated thus (Fig. 4): A point is taken above the meatus in line with the upper border of the zygoma; this *suprameatal* point is joined with the asterion, which lies, it will be remembered, 1½ inches behind and ½ an inch above the meatus; the anterior half of the above line corresponds to the tegmen tympani. A trephine opening made 1 inch above the level of the tegmen is the most likely to give access to an abscess situated in the temporal lobe.

In dealing with an abscess of the cerebellum the best spot to select is, in the adult, 1½ inches behind the centre of the meatus and ¼ of an inch below the meato-inionic line. In some cases it is impossible to say whether the abscess is situated in the temporal lobe or the cerebellum. In such cases trephining should be performed at a point which lies 1¼ inches behind and ¼ of an inch above the centre of the meatus. The lateral sinus is thus exposed with a part of the dura mater above the tentorium cerebelli, through which the temporal lobe may be explored. By extending the trephine opening ½ an inch downwards the cerebellum may be examined.

Trephining for cerebral tumour.—The position of the opening in the skull is obviously determined by the localizing symptoms. It is remarkable that little trouble from hæmorrhage has attended these operations.

In any case, after trephining, the portion or portions of bone removed may—if properly treated—be replaced in the opening, and will

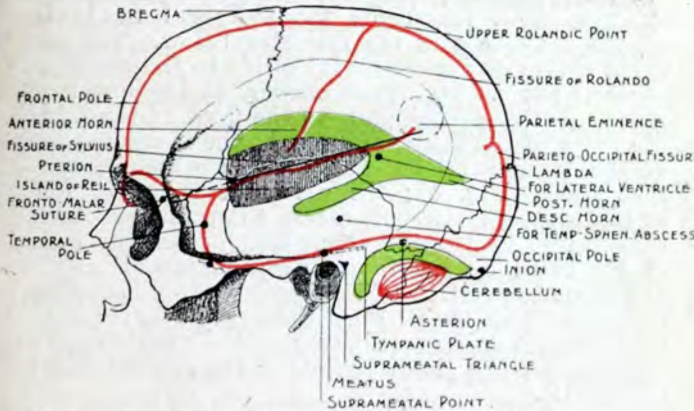

Fig. 4.—Diagram to show the position of the lateral ventricles, the insula (island of Reil), and the temporal pole.

serve, especially in youthful subjects, to make good the gap left by the operation. The osteoblasts in the fragments remain alive and retain the power of bone-formation.

In trephining the skull, the comparative thickness of the cranial wall in various parts should be borne in mind, and the large arteries of the scalp should, if possible, be avoided. In order to accommodate the instrument to the varying thickness of the skull, the pin of the trephine is not allowed to protrude more than $\frac{1}{16}$ of an inch. In the temporal fossa the bone varies in thickness from 2 to 5 mm. ($\frac{1}{12}$ to $\frac{1}{5}$ of an inch). In the vault the bony wall is thicker, varying from 5 to 10 mm. ($\frac{1}{5}$ to $\frac{2}{5}$ of an inch). (*See* p. 30.)

The **zygoma** may be broken by direct or indirect violence. In the latter case the violence is such as tends to thrust the upper jaw or malar bone backwards. When due to direct violence, a fragment may be driven into the temporal muscle, and much pain caused in moving the jaw. In ordinary cases there is little or no displacement, since to both fragments the temporal fascia is attached above and the masseter below. The zygoma serves as a most useful guide to the position of deep parts. Its upper border, in its posterior three-fourths, corresponds to the floor of the middle fossa of the skull, and marks the lower border of the temporal lobe of the brain which lies in that fossa (Fig. 4); the articular tubercle, felt so plainly near its root, marks the point at which the middle meningeal artery perforates the base of the skull by the foramen spinosum (Fig. 3), and also the position of the semilunar or Gasserian ganglion (Fig. 32, p. 131); the zygomatic tubercle (postglenoid spine), which bounds the mandibular fossa posteriorly, is directly over the carotid canal (S. Scott).

CHAPTER II

THE BONY VAULT OF THE CRANIUM

Position of the sutures. — The bregma, or point of junction of the coronal and sagittal sutures, is in a line drawn vertically upwards from a point just in front of the external auditory meatus, the head being in normal position (Fig. 3). The lambda, or point of junction of the lambdoid and sagittal sutures, lies in the middle line, about $2\frac{1}{2}$ inches above the occipital protuberance (Fig. 3). The lambdoid suture is fairly represented by the upper two-thirds of a line drawn from the lambda to the apex of the mastoid process on either side. The coronal suture lies along a line drawn from the bregma to the middle of the zygomatic arch. On this line, at a spot about $1\frac{1}{2}$ inches behind and $\frac{1}{2}$ an inch above the fronto-malar (fronto-zygomatic) junction, is the pterion, the region where four bones meet, viz. the squama of the temporal, the great wing of the sphenoid, the frontal and parietal bones (Fig. 3). The summit of the squamous suture is $1\frac{3}{4}$ inches above the zygoma.

In the normal subject all traces of the **fontanelles** and other unossified parts of the skull (Fig. 6) disappear before the age of 2 years. The frontal or anterior fontanelle is the last to close, while the occipital or posterior is already filled at the time of birth. It is through or near the frontal fontanelle that the ventricles are usually aspirated in cases of hydrocephalus. The needle is either entered at the sides of the fontanelle at a sufficient distance from the middle line to avoid the longitudinal sinus, or is introduced through the coronal suture at some spot other than its middle point. It may be noted that in severe hydrocephalus the coronal and other sutures of the vault are widely opened.

The condition known as **craniotabes,** a condition assigned by some to rickets and by others to inherited syphilis, is usually met with in the upper or tabular part of the occipital bone, and in the adjacent parts of the parietal bones, but especially in the posterior inferior angles of these bones. In this condition the bone is greatly thinned in spots, and its tissue so reduced that the affected district feels to the finger as if occupied by parchment, or, as some suggest, by cartridge paper. The thinning is mainly at the expense of the inner table and diploë. The pits are situated over the impressions of early-formed convolutions. It is, on the other hand, about the site of the frontal or anterior fontanelle that certain osseous deposits are met with on the surface of the skull in some cases of *hereditary syphilis* (Parrot). These deposits appear as rounded elevations of porous bone situated upon the frontal and parietal bones, where they meet in the middle line. The bosses are separated by a crucial depression represented by the frontal and sagittal sutures on the one hand and the coronal suture on the other. They have been termed "natiform" elevations by M. Parrot from their supposed resemblance, when viewed collectively, to the nates. To the English mind they would rather suggest the outlines of a "hot-cross bun."

It is necessary to refer to the **development of the skull,** in order to render intelligible certain conditions (for the most part those of congenital malformation) that are not infrequently met with. Speaking generally, it may be said that the base of the skull is developed in cartilage, and the vault in membrane. The parts actually formed in membrane are represented in the completed skull by the frontal and parietal bones, the squamo-zygomatic part of the temporal bone, and the greater part of the tabular portion of the occipital bone. The distinction between these two parts of the skull is often rendered very marked by disease. Thus there are, in the museum of the Royal College of Surgeons, the skulls of some young lions that were born in a menagerie, and that, in consequence of malnutrition, developed certain changes in their bones. A great part of each of these skulls shows considerable thickening, the bone being converted into a porous structure; and it is remarkable to note that these changes are limited to such parts of the skull as are formed in membrane, the base remaining free. In hydrocephaly it is only the bones formed in membrane which are unduly expanded. On the other hand, in the condition known as achondroplasia the basal or cartilaginous parts of the skull are strangely arrested in their growth, while there is a compensatory overgrowth of the membrane-formed elements.

Among the more common of the gross malformations of the skull also is one that shows entire absence of all that part of the cranium that is formed in membrane, while the base, or cartilaginous part, is more or less perfectly developed—the condition of anencephaly.

Meningocele is the name given to a congenital tumour that consists of a protrusion of a part of the cerebral membranes through a gap in an imperfectly developed skull. When the protrusion contains brain, it is called an *encephalocele*; and when that protruded brain is distended by an accumulation of fluid within the ventricles, it is called *hydrencephalocele*. These protrusions are most often met with in the occipital bone, and next in frequency in the fronto-nasal suture, while in rarer cases they have been met with in the lambdoid, sagittal, and other sutures, and have projected through normal and abnormal fissures at the base of the skull into the orbit, nose, and mouth. Their frequency in the occipital bone may be in some degree explained by a reference to the development of that part. This bone at birth consists of four separate parts (Fig. 5), a basilar, two condylic, and a tabular or expanded part. In the tabular part, about the seventh week of fœtal life four nuclei appear, an upper and a lower pair. These nuclei are to some extent separated by fissures running inwards from the four angles of the bone to meet at the occipital protuberance. The gap running up in the median line from the inferior angle at the foramen magnum to the occipital protuberance is especially distinct (the temporary occipital fontanelle of Sutton). It exists from the beginning of the third to the end of the fourth month of intra-uterine life. Meningoceles of the occiput are always in the middle line, and the protrusion probably occurs through this gap. The gap associated with meningocele may extend through the whole vertical length of the occipital bone, and very commonly opens up the foramen magnum. The lateral or transverse fissures divide the bone into two parts. The upper part is developed from membrane, the lower part from cartilage. The lateral fissures may persist, and may simulate fractures, for which they have, indeed, been mistaken; as a rare anomaly they may be so complete as entirely to separate the highest part of the occipital bone from the remainder.

Fig. 5.—The occipital bone at birth.

Parietal fissures.—In the developing parietal bone, fibres concerned in ossification radiate towards the periphery from two nuclei about the centre of the bone. An interfibrillar space, larger than the rest, is seen about the fifth month to separate the loose osseous fibres which abut on the posterior part of the sagittal border from the stronger fibres which form the rest of this border (Pozzi). This is the *parietal fissure.* It usually closes and leaves no trace, but it may persist in part as a suture-like fissure, and be mistaken for a fracture. If the fissure persists equally on the two sides an elongated lozenge-shaped gap is left, the *sagittal fontanelle* (Fig. 6). It is situate about an inch in front of the lambda, and occurs in over 4 per cent. of newly born children (Lea). The parietal foramina are remains of this interval.

Sutural or Wormian bones.—These irregular bones may be mistaken for fragments produced by fracture. They are most usually met with in the lambdoid suture. One sutural bone deserves special notice, as it may be met with in trephining over the middle meningeal artery. It exists be-

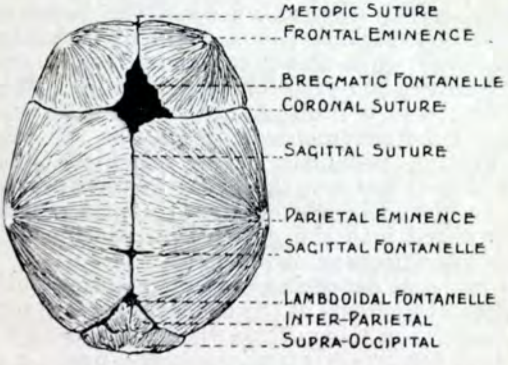

Fig. 6.—Skull of newly born child, from above.

tween the anterior inferior angle of the parietal bone and the great wing of the sphenoid. It is scale-like, and gives the impression that the tip of the great wing has been separated. It is known as the *epipteric bone.*

Necrosis is fairly common on the vault of the skull, and most often attacks the frontal and parietal bones, while, for reasons that are not very obvious, it is rare in the occipital bone. The external table is frequently necrosed alone, it being more exposed to injury and less amply supplied with blood than is the internal table. From the converse of these reasons it happens that necrosis of the internal table alone is but rarely met with. Necrosis involving the entire thickness of the bone may prove very extensive, and in a case reported by Saviard practically the whole of the cranial vault necrosed and came away. The patient was a woman, and the primary cause of the mischief was a fall upon the head when drunk.

Necrosis of the skull, as well as caries of the part, is attended by certain special dangers that depend upon the anatomical relations of the cranial bones. Thus, when the whole thickness of the skull is involved by disease, or when the inner table is especially attacked, a collection of pus may form between the dura mater and the affected bone, and may produce compression of the brain. When the diploic tissue is implicated, the veins of that part may become thrombosed, or may be the seat of a suppurative phlebitis. The mischief thus commenced may spread, the great intracranial sinuses may be closed by thrombus, or septic matter may be conveyed into the general circulation and lead to the development of pyæmia.

Mere local extension may also cause meningitis. In cases of necrosis of the external table the growth of granulation tissue from the exposed and vascular diploë plays a very important part in aiding the exfoliation of the lamella of dead bone.

Fractures of the skull.—It is not easy actually to fracture the skull of a young infant. The skull as a whole at this age is imperfectly ossified, the sutures are wide, and between the bones there is much cartilage and membrane. Moreover, the bones themselves in early life are elastic, and comparatively soft and yielding. If a blow be inflicted upon the vault in a young child the most probable effect, so far as the bone itself is concerned, is an indenting or bulging-in of that bone unassociated with a fracture in the ordinary sense. In this particular relation the skull of an infant is to that of an old man as a cranium of thin tin would be to a cranium of strong earthenware. The yielding character of the young child's skull is well illustrated by the gross deformity of the head that certain Indian tribes produce in their offspring by applying tight bandages to the part in infancy. In the Royal College of Surgeons museum are many skulls of "flat-headed" Indians, that show to what an extreme this artificial deformity may be carried. Guéniot also asserts that much deformity of the head may be produced in infants by the practice of allowing them always to lie upon one side of the body. Here the deforming agent is simply the weight of the brain.

Even in adults the skull is much less brittle than is commonly supposed, and notions derived from the study of dried specimens are apt to be erroneous. During life a sharp knife properly directed may be driven through the cranial vault so as to cause only a simple perforating wound without splintering, and without fracture of the bone beyond the puncture. Such a wound may be as cleanly cut as a wound through thick leather, and a specimen in the London Hospital museum serves well to illustrate this. A case reported in the *Lancet* for 1881 affords a strange instance of a knife penetrating the skull without apparently splintering the bone. A man wishing to commit suicide placed the point of a dagger against the skull in the upper frontal region, and then drove it well into the brain by a blow from a mallet. He expected to fall dead, and was disappointed to find that no phenomena of interest developed. He then drove the dagger farther in by some dozen blows with the mallet, until the blade, which was four inches long, was brought to a standstill. The dagger was removed with great difficulty; the patient never lost consciousness, and recovered without a symptom.

The following anatomical conditions tend to *minimize the effects of violence* as applied to the skull: the density of the scalp and its great mobility; the dome-like arrangement of the vault; the number of the bones that compose the head, and the tendency of the violence to be broken up amongst the many segments; the sutures which interrupt the continuity of any given force, and the sutural membrane, which acts as a kind of linear buffer; the mobility of the head upon the spine; and the elasticity of the cranial bones themselves.

The skull is further strengthened by the presence of six buttresses or pillars at the junction of the vault and base. Two of these are lateral, the orbito-sphenoid anteriorly and the petro-mastoid posteriorly, while the fronto-nasal and occipital strengthen the anterior and posterior ends of the skull.

In children the membranous layer between the sutures is of considerable thickness, but as age advances this membrane disappears and the bones tend to fuse together (synostosis). *The sutures begin to be obliterated* about the age of 40, the change commencing on the inner aspect of the suture, and appearing first in the sagittal suture, then in the coronal and lambdoid, and last in the squamous. As age advances, moreover, the skull bones become thicker owing to a deposit over the inner table to replace the diminishing brain, and lose much of their elasticity. They are, therefore, more readily fractured in the aged than in the young.

As a rule, in fracture, the entire thickness of the bone is involved; but the external table alone may be broken, and may even be alone depressed, being driven into the diploë, or, in the case of the lower frontal region, into the frontal sinus. The internal table may be broken without a corresponding fracture in the outer plate; and in nearly all cases of complete fracture, especially in such as are attended with depression, the internal table shows more extensive splintering than does the external.

There are many reasons for this. The internal plate is not only thinner than the external, but is so much more brittle as to receive the name of the "vitreous table." A force applied to the external table may be extremely limited, and produce, as in

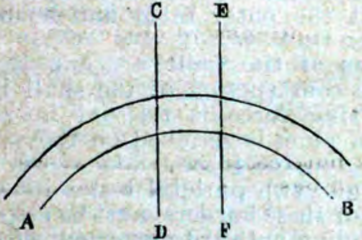

Fig. 7.

a sabre cut, but a limited lesion. As the force, however, travels through the diploë it becomes broken up, and reaches the inner plate as a much more diffused form of violence. This is especially the case when parts of the outer table are driven in. Then, again, the internal plate is a part of a

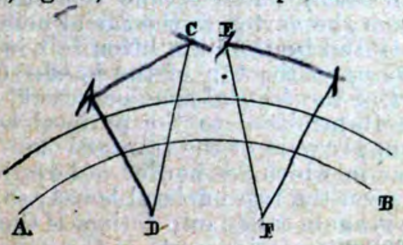

Fig. 8.

smaller curve than is the external plate; and, lastly, Agnew assigns a reason for the greater vulnerability of the inner plate that has reference to the general yielding of the bone. In Fig. 7, A B represents a section of a part of the vault through both tables, and C D and E F two vertical and parallel lines. Now, if force be applied to the vault between these parallel lines, the ends of the arch, A B, will tend to become separated, and the whole arch, yielding, will tend to assume the curve shown in Fig. 8. In such case, the lines C D and E F will converge above and diverge below (Fig. 8), so that the violence would tend to force the bone particles together at the outer table and asunder at the inner table.

Fractures of the vault are due to direct violence. The construction of the skull is such that the fracturing force is resisted in many ways. (1) When a blow is received on the vertex in the *parietal* region, the force tends to drive the upper borders of the two parietal bones inwards. Such driving-in of these borders must be associated with a corresponding outward movement of the inferior borders. This latter movement is forcibly resisted by the squamous bone and the great wing of the sphenoid, which overlap the lower edge of the parietal bone. Moreover, the force transmitted to the squamous bone is passed on to the zygomatic arch, which takes its support from the superior maxillary and frontal bones. This arch then acts as a second resisting buttress, and this transmission of force from the vertex to the facial bones is said to be illustrated by the pain often felt in the face after blows upon the top of the head. (2) If the upper part of the *frontal* bone be struck, the force is at once transmitted to the parietal bones, because the upper part of the frontal bone (owing to the manner in which its border is bevelled) actually rests upon the two parietal bones; so the same resistance is again called into action. If there be any tendency for the inferior parts of the bone to move outwards, as would certainly be the case while the mid-frontal suture existed, such movement would be resisted by the great wings of the sphenoid and by the anterior inferior angles of the parietal bones which embrace or overlap these parts of the frontal. Thus it will be seen that much depends upon the manner in which the corresponding edges of the frontal and parietal bones are bevelled. (3)

Blows upon the *occiput* are less distinctly provided for, and it must be owned that a by no means heavy fall is sufficient to break this bone. It must receive, however, much protection from its connexions with the two parietal and temporal bones, and from its articulation with the elastic vertebral column.

Fractures of the base of the skull may be due to (1) direct or (2) indirect violence, or, most commonly of all, to (3) extension of a fracture from the vault. (1) The base has been fractured by direct violence due to foreign bodies thrust through the nasal roof, through the orbital roof, and through the base as it presents in the pharynx. The posterior fossa can also be fractured by violence applied to the nape of the neck. (2) Of fractures by indirect violence the following examples may be given: Blows applied to the lower part of the frontal bone have been associated with no lesion other than a fracture of the cribriform plate or of the orbital part of the frontal, these parts being much disposed to fracture on account of their extreme tenuity. In 86 cases of fracture of the base of the skull, the orbital roof was involved in 79, the optic foramina in 63, and the cribriform plates in nearly all (Rawling). In falls upon the chin, the condyle of the lower jaw has been so violently driven against the glenoid cavity as to fracture the middle fossa of the skull. The force of a "knock-out" blow applied to the point of the chin produces concussion of the brain without fracture of the skull. When the body in falling has alighted upon the feet, knees, or buttocks, the force has been transmitted along the vertebral column, and has led to fracture of the base in the occipital region. Such accidents are most apt to occur when the spine is kept rigid by muscular action, and the mechanism involved is precisely similar to that whereby the head of a broom is driven more firmly on to the broom-handle by striking the extreme end of the stick against the ground. The theory that the base is often broken by *contre-coup* is pretty generally abandoned, though there are a few cases that appear to support the suggestion. Such a case was recorded by Sir J. Hutchinson, and in it a fracture of the occipital bone was associated with a like lesion in the cribriform plate, the intervening part of the skull being uninjured. (3) Fractures of the vault, and especially linear fractures due to such diffused violence as obtains in a fall upon the head, are very apt to spread to the base. In so spreading they reach the base by the shortest possible route, and without any regard to the sutures encountered or to the density of the bones involved. Thus, fractures of the frontal region of the vault spread to the anterior fossa of the base, those of the parietal region to the middle fossa, and those of the occipital region to the posterior fossa. To this rule there are but few exceptions. To indicate more precisely the exact bones involved in these three districts, P. Hewett has divided the skull into three zones. The anterior zone includes the frontal, the upper part of the ethmoid, and the fronto-sphenoid; the middle, the parietals, the squamous and anterior part of the petrous of the temporals, and the greater part of the basi-sphenoid; and the posterior, the occipital, the mastoid, the posterior part of the petrous bone, with a small part of the body of the sphenoid.

In all fractures of the base there is usually a discharge of blood and of cerebro-spinal fluid externally. (1) In fractures of the anterior fossa the blood usually escapes from the nose, and is derived from the meningeal and ethmoidal vessels, or in greater degree probably from the torn mucous lining of the nasal roof. To allow of the escape of cerebro-spinal fluid from the nose, there must be, in addition to the fracture in the nasal roof, a laceration of the mucous membrane below that fracture, and of the sheaths of the olfactory nerves which are derived from the dura mater and arachnoid. A profuse discharge of cerebro-spinal fluid may take place through the nasal mucous membrane independently of injury. The discharge probably occurs along the sheaths of the olfactory nerves, and is caused by a lessened absorption or increased secretion of cerebro-spinal fluid. In many cases of fracture in the frontal region, blood finds its way into the orbit, and appears beneath the conjunctiva. (2) When the middle fossa is involved, the blood escapes from the external auditory meatus, through a rupture in the tympanic membrane, and is derived from the vessels of the tympanum and its membrane, or from an intracranial extravasation, and in some cases from a rupture of the cavernous or petrosal sinuses. The blood may follow the Eustachian tube, and may escape from the nose or mouth, or be swallowed and subsequently vomited. To allow of the escape of cerebro-spinal fluid by the ear ("the serous discharge"), (*a*) the fracture must have passed across the internal auditory meatus; (*b*) the tubular prolongation of the membranes in that meatus must have been torn; (*c*) there must be a communication between the internal ear and the tympanum; and (*d*) the membrana tympani must have been lacerated. (3) In fractures of the posterior fossa an extravasation of blood may appear about the mastoid process or at the nape of the neck, or may even extend into the cervical region.

It may be added that in compound fractures of the *vault* associated with tearing of the dura mater and arachnoid, an escape of cerebro-spinal fluid has in a few rare instances been noted. After simple fracture of the vault in children a swelling may form at the injured part which fluctuates, becomes tenser when the patient cries, and may possibly pulsate synchronously with the brain. Such swellings are due to a collection of cerebro-spinal fluid beneath the scalp, and indicate a coincident rupture of the brain membranes.

Separation of sutures.—This condition, as the result of injury, is practically restricted to the young skull. In later life, force applied at the site of an obliterated suture may cause a fracture, which accurately follows the old suture line.

Separation of the sutures, independent of fracture, is very rare in the adult skull. In the few instances of such a condition the temporal bone has usually been the one displaced and the separation noted at the squamous suture. When associated with fracture, the coronal and sagittal sutures are those most frequently separated, and the next in frequency is the lambdoid.

The **thickness of the skull-cap** varies greatly, not only in different parts of the same skull, but also in corresponding parts in different individuals. The average thickness is 5 mm. ($\frac{1}{5}$ of an inch). It varies with age: at birth the parietal is little more than 1 mm. ($\frac{1}{25}$ of an inch); at three years diploë appear, marking off the inner from the outer table of the skull; in old people the parietal bone varies in thickness from 5–10 mm. ($\frac{1}{5}$–$\frac{2}{5}$ of an inch). The thickest parts are at the occipital protuberance (where the section may measure 12 or 13 mm.), the mastoid process, and the lower part of the frontal bone. The bone over the inferior occipital fossæ and orbit is very thin, while it is thinnest over the squamous bone. Here the bone may be no thicker in parts than a visiting card, and appear as a translucent area in an X-ray photograph. The skull is also thinned over the sinuses and grooves for the meningeal vessels. It is especially thin over the anterior inferior angle of the parietal bone. It is important to remember in trephining that the inner table is not always parallel with the outer.

Craniectomy.—This operation is carried out in cases of microcephaly in infants and children. It consists in the removal of a strip of bone from the vertex of the skull so as to give to the brain, as an American author expresses it, "more elbow room." The operation presumes that the arrest of growth in the brain is due to a retarded growth of the skull, but all the evidence at our disposal points to the arrest in the development of the brain as the primary lesion, the condition of the skull being a consequence. In hydrocephaly the skull is seen to respond readily to the quick expansion of the brain; if the growth of the brain is arrested, the skull remains small.

X-ray examination of the temporal region.—It is frequently necessary to examine the temporal region of the skull to discover the condition of certain deep-seated intracranial structures. To find the position of such structures, certain easily-found surface-points must be marked by pellets of lead in order that they may serve as guides. The most convenient and reliable guide-points are those indicated in Fig. 9; they are—A, the *fronto-malar* (*fronto-zygomatic*) *notch;* B, the *malar angle;* D, the *premeatal point*, on the root of the zygoma, in front of the meatus, behind the mandibular (glenoid) fossa, and immediately above the postmandibular (postglenoid) spine; C, a point on the upper border of the zygoma, midway between B and D (*midzygomatic point*). These points should be marked on both sides of the skull, and the corresponding points of the two sides should be superimposed when the skull is examined in profile. When thus examined, the region covered by the two temporal muscles becomes an illuminated area owing to the thinness of the bones underlying the muscles. The illuminated area is subdivided into an anterior or *frontal fenestra* and a posterior or *temporal fenestra* (Fig. 9) by the *fronto-temporal pillar* of bone which carries the middle meningeal vessels and marks the separation of the frontal from the temporal lobes of the brain. At the point where trephining is usually performed for meningeal hæmorrhage—namely, 1½ inches behind and ½ an inch above the fronto-malar notch—the shadow of the fronto-temporal pillar appears to divide into two—an anterior horizontal branch which corresponds to the roof of the orbit and is situated ½ an inch above the fronto-malar notch, and a descending branch which reaches the upper border of the zygoma just in front of C, the *midzygomatic point*. The descending branch represents the anterior wall of the middle cranial fossa, the spheno-orbital septum. It descends ¾ of an inch behind the temporal border of the malar bone. It will thus be seen that between the spheno-orbital septum behind, the temporal border of the malar in front, the shadow of the

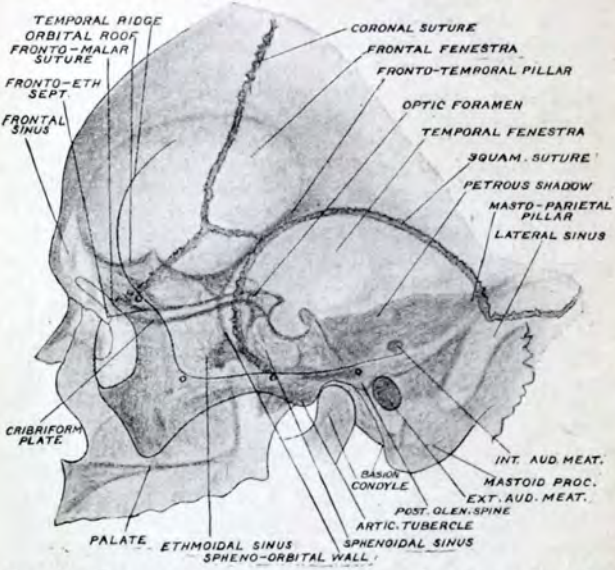

Fig. 9.—Structures seen in the temporal region when the skull is examined in profile by means of X-rays.

orbital roof above, and the upper border of the zygoma below, there is marked out a very distinct *retromalar area* in which lie the middle and posterior ethmoidal cells. The area is crossed from behind forwards, and below the level of the fronto-malar notch, by two lines, the lower of which corresponds to the level of the cribriform plate, and the upper to the junction between the lateral mass of the ethmoid and the orbital plate of the frontal bone. At the lower limit of the retromalar area lie the spheno-maxillary (pterygo-palatine) fossa, the spheno-maxillary fissure, the spheno-palatine ganglion, and the commencement of the infraorbital nerve.

Along the lower border of the temporal fenestra appear structures of the utmost consequence. Enumerating these from before backwards, we note: the lesser wing of the sphenoid, the pituitary fossa (fossa hypophyseos), crowned anteriorly by the anterior clinoid process, and posteriorly by the dorsum sellæ and posterior clinoid processes. Behind the dorsum sellæ lies the black triangular shadow of the petrous bone, ending posteriorly in the masto-parietal pillar. The floor of the pituitary fossa lies ½ an inch (12 mm.) above the upper border of the zygoma, its anterior limit lying directly above the midzygomatic point. The antero-posterior diameter of the pituitary fossa is normally about 12 mm. (½ an inch) in adults. The optic foramen lies 1½ inches (37 mm.) behind the fronto-malar notch, and 1 inch (25 mm.) above the upper border of the zygoma. The premeatal point (*see* Fig. 9) marks the hinder aspect of the basilar process; the internal auditory meatus lies ½ an inch behind and above this point; the external auditory meatus is situated immediately behind and below it, while the basion, at the anterior margin of the foramen magnum, lies ½ an inch below and behind this point. The sphenoidal sinus lies below and in front of the pituitary fossa.

CHAPTER III

THE CRANIAL CONTENTS

Membranes of the brain.—The **dura mater,** from its toughness, forms an excellent protection to the brain. It is very intimately adherent to the bone over the whole of the *base* of the skull, and consequently in this situation extravasations between the membrane and the bone are scarcely possible. Over the vault its attachments are comparatively loose, but it is very closely adherent along the lines of the sutures. This lax attachment allows large hæmorrhagic and purulent extravasations to collect between the dura mater and the bone. Such extravasations usually lead to compression of the brain, and it may be noted that in the great majority of all cases of compression the compressing force is outside the dura mater. Thus, in uncomplicated cases when symptoms of compression come on at the time of an accident, the cause is probably depressed bone; when they appear after a short interval, the cause is probably extravasated blood between the membrane and the bone; and when a long interval (days or weeks) has elapsed after the accident, the cause is probably a collection of pus in the same situation.

Sir C. Bell pointed out that the dura mater of the vault may be separated from the bone by the vibration produced by a blow. "Strike the skull of a subject with a heavy mallet; on dissecting you find the dura mater to be shaken from the skull at the point struck. Repeat the experiment on another subject, and inject the head minutely with size injection, and you will find a clot of injection lying betwixt the skull and dura mater at the part struck, and having an exact resemblance to the coagulum found after violent blows on the head." Tillaux has demonstrated that the adhesions between the dura mater and the bone are particularly weak in the temporal fossæ, the most usual site of meningeal hæmorrhage.

When blood is poured out between the dura mater and the bone in cases of fracture, the vessels which give way are the **middle meningeal**–much more frequently the companion veins than the artery. The veins form a sinus round the artery (Wood-Jones). The artery, having passed through the foramen spinosum, divides into two branches: the anterior, the larger, runs upwards across the anterior inferior angle of the parietal bone and ascends the vault a short distance behind the coronal suture; the posterior runs backwards, with a horizontal sweep across the squamous bone, and takes the course of the second temporal convolution. (*See* Figs. 3, 4, pp. 13, 15.)

The vessels are very frequently torn as they cross the anterior angle of the parietal bone. There are many reasons for this: the bone, where grooved by the vessels, is very thin; they are often so embedded in the bone that fracture without laceration of the vessel would hardly be possible; and, lastly, the particular region of the artery is a part of the skull peculiarly liable to be fractured. Mr. Jacobson shows that the vessels (usually the veins only) may be ruptured by a force that does not fracture the skull, but merely leads to detachment of the dura mater. Failing the middle meningeal, the most frequent source of extra-meningeal hæmorrhage is the lateral sinus, for reasons that will be obvious.

Nerves of the dura mater.—The dura mater is supplied with nerves. The chief source is from the fifth, but minor supplies are given off by the tenth and twelfth cranial nerves. Hence it is that in the operation of trephining there is a marked fall of blood-pressure when the membrane is scraped or cut (H. Tyrell Gray and L. Parsons). Many forms of headache are due to afferent stimuli reaching the vagal or trigeminal sensory nuclei, where they are referred by this nerve distribution to the dura mater (Cushing).

Venous sinuses.—The flaccid-walled cerebral veins, which are compressed with each pulsation of the brain, empty into the venous sinuses, rigid-walled cavities formed between the outer or periosteal and inner or supporting layers of the dura mater. At the points where the superior cerebral veins enter the superior longitudinal sinus, and where the temporo-sphenoidal and occipital veins join the lateral sinus, the arachnoid, elsewhere free from dura mater, is firmly adherent to it. From a surgical point of view the **lateral** is the more important sinus; and as it turns downwards beneath the mastoid process it comes into close relationship with the antrum and cells of the mastoid, from which a septic condition may spread to the sinus, setting up thrombosis (*see* Fig. 24, p. 96). The lateral sinus is marked out by taking the following three points (*see* Fig. 3, p. 13, and Fig. 4, p. 15): (1) The inion, (2) the asterion, (3) a point ½ an inch behind the lower border of the meatus. When these three points are joined, the lateral sinus is seen to be made up of two parts—a horizontal, which gradually ascends as it passes from the inion to the asterion; and a vertical, which rapidly descends from the asterion to the postmeatal point. The sinus is 10 mm. wide. The lateral sinus escapes from the skull to form the internal jugular vein in line with the anterior border of the mastoid process, but situated deeply beneath the parotid gland (Fig. 3, p. 13).

A line drawn over the vault of the skull from nasion to inion marks the line of the **superior longitudinal sinus.** Along the sinus there occur lateral extensions or lacunæ (parasinoids) into which many of the superior cerebral veins open. These lateral extensions are found along all parts of the superior longitudinal sinus, but the longest and most important are the *parietal*, which cover the upper parts of the central convolutions (Percy Sargent). The superior longitudinal sinus sometimes becomes occluded by the formation of a thrombus; in that case the blood has to find its way, by means of anastomotic channels, from the superior cerebral veins to inferior cerebral veins, particularly the superficial Sylvian vein, which ends in the cavernous sinus. In the majority of cases the superior longitudinal ends in the right lateral sinus, which is hence commonly larger than the left. The **cavernous sinus**, enclosing the internal carotid artery and sixth cranial nerve, with the third, fourth, and greater part of the fifth embedded in its wall, is situated on the body of the sphenoid, just over the sphenoidal air sinus, from which septic conditions may extend to it, giving rise to thrombosis. In such cases the eyes become prominent owing to the distension of the ophthalmic veins, for the venous stream from the orbit flows through the cavernous sinus to reach the lateral sinus and jugular vein by means of the superior and inferior petrosal sinuses. Tumours of the pituitary necessarily compress the cavernous sinus. The relations between the internal carotid artery and the cavernous sinus are so intimate that an arterio-venous aneurysm has followed injury involving these parts. It will be seen also with what ease this sinus could become thrombosed in cases of inflammation within the orbit by the extension of the mischief along its great tributaries, the two ophthalmic veins.

Between the dura mater and the arachnoid is the **subdural space**, which, like the pleural cavity, is merely a potential space, for in health the arachnoid is closely applied to the smooth inner surface of the dura mater. A space is formed only when fluid, blood, or pus is collected between the two membranes (Fig. 1, p. 2). The subdural space contains a small amount of fluid, and acts, like the pleural and peritoneal sacs, in preventing the effects of friction during the pulsatory movements of the brain.

A knowledge of the **subarachnoid space** is steadily becoming of greater surgical importance. The space which surrounds the spinal cord is in direct continuity with the subarachnoid spaces of the brain, and hence, when this space is tapped in the lumbar part of the spinal canal (Fig. 151, p. 663), the fluid situated in the subarachnoid spaces of the brain is also drained off (Fig. 10). Hence the practice of lumbar puncture in cases of intracranial pressure. In meningitis the cerebro-spinal fluid becomes turgid; the subarachnoid space, or parts of it, may contain pus. In the spinal column the arachnoid is widely separated from the pia mater, consequently the subarachnoid space is extensive. As the space passes into the skull it forms an expansion between the cerebellum and the roof of the fourth ventricle named the *cisterna magna* (Fig. 10); an opening in the roof of the fourth ventricle (the foramen of Magendie) allows the cerebro-spinal fluid in the ventricles of the brain to join that in the cisterna magna (Fig. 10). On the base of the skull, in front of the medulla and pons, the spinal subarachnoid space expands into the *cisterna pontis*, which in turn becomes continuous with a large space situated on the base of the brain between the temporal lobes and under the interpeduncular space—the *cisterna basalis* (Fig. 10). In this cistern are situated the circle of Willis, the third, fourth, and root of the fifth nerves, the optic chiasma and tracts and infundibulum of the pituitary body. In basal meningitis it may become distended with pus. The inflammatory adhesions which occur in the inferior medullary velum may lead to a condition of hydrocephaly by closing up the openings in that membrane.

Over the convolutions of the brain the arachnoid is bound by the **pia mater**, which here serves as a loose subarachnoid tissue. Everywhere extensions of the basilar cistern pass with the arteries derived from the circle of Willis into the pia mater in the sulci of the brain. While the interpeduncular part of the base of the brain, pons and medulla rest on these basal cisterns, the temporal and frontal lobes lie directly on the base of the skull; the occipital lobe rests on the tentorium cerebelli. The three poles of the brain—

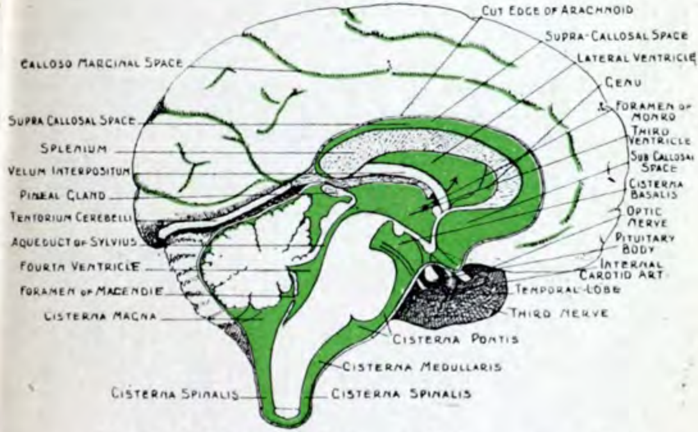

Fig. 10.—Diagram of the cranial spaces containing cerebro-spinal fluid.

the frontal, occipital, and temporal—are in direct contact with the meninges and skull, and are therefore the parts of the brain that are most liable to laceration in cases of injury to the head.

The cerebro-spinal fluid prevents the ill effects that irregularities in the blood circulation might have upon the brain, situate as it is within an unyielding cavity. If the great nerve-centres near the lateral ventricles are swollen by congestion, they are not met by an unyielding wall, but merely displace some of the cerebro-spinal fluid through the foramen of Magendie, until such time as their circulation is normal again. When the healthy brain is exposed by a trephine opening, it is seen to pulsate with each beat of the heart; if it does not pulsate, this shows that the pressure within the skull is higher than the arterial pressure (100–130 mm. Hg); normally, as Hill has shown, the intracranial pressure is that of the blood-pressure in the veins (10–15 mm. Hg). With each pulsation of the heart about 5 c.c. of arterial blood is thrown into the skull, causing the ejection of a similar amount of venous blood by the jugular vein.

Fluid may pass from the lateral to the third ventricle by the foramen of Monro; from the third to the fourth ventricle by the aqueduct of Sylvius; and from the fourth ventricle to the cisterna magna by the foramen of Magendie (Fig. 10). Many still share the opinion of Hilton that blockage of the aqueduct, or closure of the foramen of Magendie, or of the other two openings at the lateral angles of the fourth ventricle (the foramina of Key and Retzius) may prevent the exit of cerebro-spinal fluid from the ventricles and thus produce the condition of hydrocephaly. The fluid also drains into the veins of Galen, hence pressure on these may bring about a like result. It has been proposed to relieve the pressure within the lateral ventricles in cases of hydrocephaly by draining the cerebro-spinal fluid into the subdural space by means of a seton. It is absorbed under any pressure above that within the cerebral veins (Hill). If the brain, too, becomes enlarged by congestion, it is not met by unyielding bone, but rather by an adjustable water-bed, and during its period of enlargement it merely displaces into the spinal part of the subarachnoid space some of the fluid that surrounds it. This mutual effect is well illustrated in a case reported by Hilton of a man with a fracture of the base, from whose ear cerebro-spinal fluid was escaping. The discharge of this fluid was at once greatly increased by expiratory efforts when the nose and mouth were held closed and the veins compressed in the neck.

Cerebro-spinal fluid.—The total amount of fluid in the cerebro-spinal system of an adult is estimated at 130-150 c.c. (about 4½ oz.). It is secreted by the choroid plexuses (1) in the lateral ventricles, (2) in the roof of the third ventricle, and (3) in the roof of the fourth ventricle, the ependymal epithelium covering these plexuses being regarded as the actual structure carrying out the secretion. The fluid is absorbed (1) by the lymphatic spaces surrounding the nerve roots, (2) by passage into veins and venous spaces, and (3) the Pacchionian bodies also serve as a means whereby it enters the venous system. Methylene blue, when injected into the spinal subarachnoid space, quickly appears in the ventricles of the brain, from which we see that diffusion takes place rapidly. It also appears almost immediately in the circulation, being eliminated by the kidneys. It is absorbed much more slowly by lymphatics, for the glands of the neck do not become stained until some time has elapsed.

Pituitary body.—In recent years the pituitary body, enclosed within a special compartment of the dura mater, and placed on the upper surface of the basi-sphenoid, has assumed an increased surgical importance. In Fig. 11 its form and relationships are shown as seen in a young child. Its stalk descends from the floor of the third ventricle, and ends in the posterior or neural lobe. The anterior or glandular lobe is applied to the neural lobe and embraces it on each side. The glandular lobe, which arises as an outgrowth from the stomodæum or mouth-depression of the embryo, is divided into two parts—a *perineural* or intermediate part (Herring), which is closely applied to the neural lobe, and an anterior or *preneural* part. The perineural and preneural parts are separated by a central cavity, which is obliterated as adult life is reached (Fig. 11). The preneural glandular part may become hypertrophied and form a glandular tumour, and in many of these cases various parts of the body—especially the face, hands and feet—begin to grow, and attain a large size, giving rise to the condition known as *acromegaly*. If the hypertrophy occurs in youth, then all the bones of the skeleton grow rapidly, and the condition of *giantism* is pro-

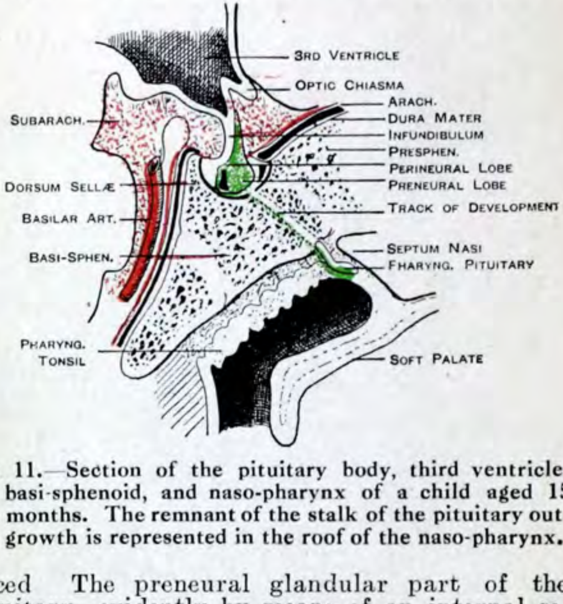

Fig. 11.—Section of the pituitary body, third ventricle, basi-sphenoid, and naso-pharynx of a child aged 15 months. The remnant of the stalk of the pituitary outgrowth is represented in the roof of the naso-pharynx.

duced The preneural glandular part of the pituitary—evidently by means of an internal secretion—regulates the growth of the various parts of the body, and, if secretion is in excess, leads to overgrowth. Numerous cases have been relieved by operation, part of the glandular lobe being scraped away. In the adult, access to the pituitary is obtained through the sphenoidal sinus, on the roof of which this body is situated. The sinus is reached by reflecting the cartilaginous part of the nose and following the septum nasi backwards until the sphenoidal sinus is reached. Another, and perhaps better, route is by the temporal fossa. In order that the temporal lobe of the brain may be lifted up to expose the pituitary body, it is necessary to trephine extensively the opposite temporal fossa. Pituitary tumours, as they expand, compress the cavernous sinuses, and, from their close relationship to the optic nerves, lead usually to a partial optic atrophy and blindness. The tumour may depress the roof of the sphenoidal sinus. In Fig. 11 a remnant of the stalk of the developing pituitary is shown in the roof of the naso-pharynx. Erdheim found that this remnant of the fœtal pituitary (the naso-pharyngeal pituitary) occurred in every one of the bodies that he examined—over fifty in number. The blood supply of the pituitary is from numerous vessels which arise from the circle of Willis and descend in the stalk of the pituitary. The pituitary is contained within a compartment of the dura mater, the roof of which is perforated by the stalk of the body. (The X-ray position and appearance of the pituitary fossa is shown in Fig. 9, p. 32).

Surface relationships of the brain (*see* Figs. 12 and 13).—The longitudinal fissure of the brain is indicated by a line drawn along the vertex from the glabella to the external occipital protuberance. It is narrow in front, but as it contains the longitudinal sinus, which rapidly enlarges as it passes backwards, it becomes of considerable breadth behind, and as a rule lies somewhat towards the right of the median line, owing to the predominance of the left cerebral hemisphere. Between the external occipital protuberance and the ear, the lateral sinus bounds the lower level of the cerebrum and the upper of the cerebellum (Figs. 4 and 12). In front of the ear the upper border of the zygoma in its posterior three-fourths marks the lower border of the temporal lobe. The pole of the temporal lobe is ¾ of an inch behind the outer margin of the orbit (*see* Fig. 4). The lower limit of the brain on the forehead may be indicated approximately by drawing a line from the glabella to the Sylvian point, ½ an inch above the upper

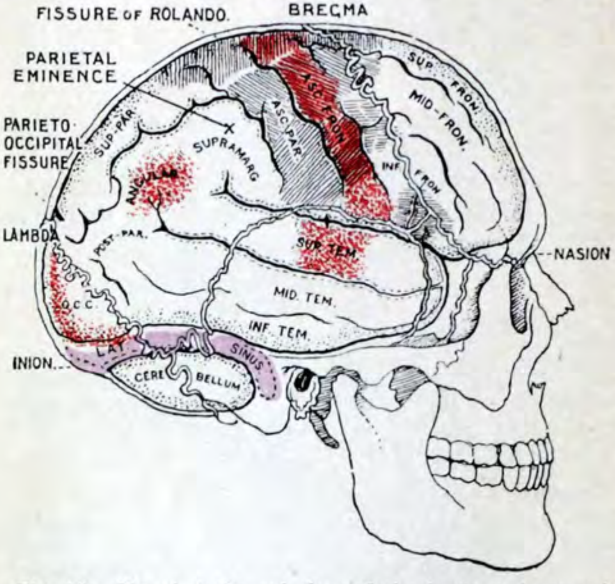

Fig. 12.—Showing the relation of the brain and sensori-motor areas of the cortex to the skull. (*Modified from Quain.*)

The sensori-motor areas are shaded—the leg and trunk areas with vertical lines; the arm and hand areas with lines slanting forwards; the face and mouth areas with lines slanting backwards; the tongue, pharynx, and larynx areas are stippled. The ascending frontal convolution, containing the areas which are strictly motor in function, is indicated by red lines. The motor centre for speech on Broca's convolution is shaded with horizontal lines. The "word-hearing" centre is indicated on the superior temporal convolution, and the "word-seeing" centre on the angular convolution. The area shaded with horizontal lines on the posterior parts of the middle and inferior frontal convolutions is the centre for combined movements of the head and eyes.

margin of the orbit. The olfactory bulbs lie at the level of the nasion (Fig. 4).

The cerebellum is best explored at a point $1\frac{1}{2}$ inches behind and $\frac{1}{2}$ an inch below the level of the external auditory meatus (*see* Fig. 4). It is deeply placed, being covered by the insertions of the occipital muscles.

Of the many methods which have been suggested for marking out the **fissure of Rolando,** the most simple and accurate is the following: A point over the sagittal suture is taken midway between the glabella and external occipital protuberance. Half an inch behind this *mid-point* the upper end of the fissure terminates (Fig. 13). A line $3\frac{1}{2}$ inches long drawn downwards and forwards from this point, at an angle of 67° to the line of the sagittal suture, will indicate the position of the fissure of Rolando in the adult. In the child the fissure is shorter and the contained angle is 5° smaller. The angle is easily obtained by folding twice the corner of a square piece of paper and removing a fourth of the right angle. This line may not lie exactly over the fissure, for it varies somewhat in position according to the shape of head. The sensori-motor areas of the brain are mostly represented in the ascending frontal and parietal convolutions which bound the fissure of Rolando. The average width of each of these convolutions is $\frac{3}{4}$ of an inch. The coronal suture is about 2 inches in front of the fissure of Rolando at its upper part and $1\frac{1}{4}$ inches at its lower.

The **fissure of Sylvius** is indicated thus (Fig. 13): A point is taken $1\frac{1}{2}$ inches behind and $\frac{1}{2}$ an inch above the fronto-malar junction, which is marked by a distinct notch. This point on the temple overlies the anterior inferior angle of the parietal bone—*the pterion.* The pterion marks the junction of the three limbs of the fissure of Sylvius with its stem. A line drawn backwards and upwards from the pterion to a point $\frac{3}{4}$ of an inch below the parietal eminence indicates the situation of the *posterior horizontal limb* or *ramus* (Fig. 13). If the parietal eminence be not well marked, then the fissure may be indicated by joining the fronto-malar notch with the pterion and prolonging the line thus formed

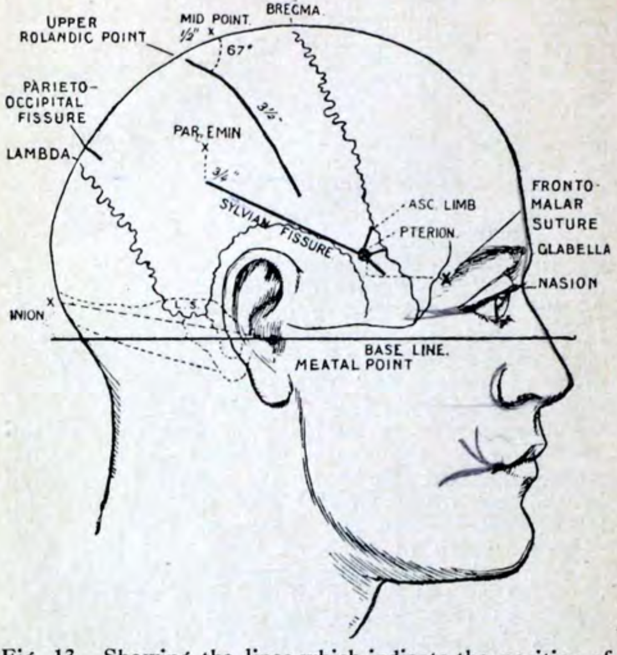

Fig. 13.—Showing the lines which indicate the position of the principal fissures of the brain.

Reid's base line is drawn from the lower margin of the orbit backwards through the meatal point.

straight backwards to the region of the parietal eminence, as shown in Fig. 4 (R. J. Berry). This ramus is bounded below by the superior temporal convolution, which contains in its middle third the "word-hearing" centre (Fig. 12). Above, it is bounded from before backwards by the basilar part of the inferior frontal convolution, the lower ends of the ascending frontal and parietal convolutions, and the supramarginal gyrus. In the three parts first named are situated centres for movements of the tongue, larynx, pharynx, and mouth. A penny piece placed directly behind the termination of the Sylvian line will cover the angular convolution in which the "word-seeing" centre is placed (Fig. 12). The parietal eminence covers the supramarginal convolution. The *ascending limb* of the fissure of Sylvius is indicated by a line $\frac{3}{4}$ of an inch long drawn upwards and slightly forwards from the pterion, while the short *anterior horizontal limb* is indicated by a line $\frac{1}{2}$ an inch long drawn forwards from the same point. Between the ascending and anterior limbs is situated the *pars triangularis* of the inferior frontal convolution in which the centre for "motor speech" is placed. Broca regarded the left inferior frontal convolution (frequently called Broca's convolution) as specially connected with speech, but more recently Pierre Marie and others have published accounts of a number of cases of disease of this part in which speech was unaffected. The *stem* of the Sylvian fissure is $\frac{1}{2}$ an inch long and runs downwards and forwards under the great wing of the sphenoid (Fig. 12). The temporal pole lies below it.

The four angles of the parietal bone have important relationships to the brain. The *anterior inferior* angle covers the posterior part of the inferior frontal convolution and the anterior horizontal and ascending limbs of the fissure of Sylvius. The anterior branch of the middle meningeal artery with its accompanying sinus ascends beneath it. The *anterior superior* angle at the bregma covers the terminal part of the superior frontal convolution and the centre for movements of the hip. The *posterior superior* angle at the lambda lies over the upper part of the occipital lobe and $\frac{1}{2}$ an inch behind the parieto-occipital fissure. The *posterior inferior* angle covers the convexity of the lateral sinus and marks the lower limit of the cerebrum. In its anterior half the posterior limb of the Sylvian fissure lies beneath the squamous suture, but behind it passes entirely beneath the parietal bone. It will be thus seen that the parietal bone covers the whole of the parietal lobe, the posterior parts of the frontal and temporal lobes, and the upper margin of the occipital.

The **inferior temporal convolution** passes backwards above the upper border of the zygoma and external auditory meatus and rests on the thin roof of the tympanum. Hence it is the most common site of abscess which may follow middle-ear disease. (Fig. 12.)

The **basal ganglia** of the brain—the corpus striatum and optic thalamus—are capped on their outer aspect by the island of Reil. The island lies buried in the anterior three-fourths of the fissure of Sylvius, and hence the surface markings for the fissure may be also used for the island and the basal ganglia (*see* Fig. 4, p. 15). A half-circle, with a radius of half an inch, drawn in front of the pterion, will indicate the anterior limit of the basal ganglia, while their posterior limit lies some distance in front of the point at which the lateral ventricles may be tapped (*see* Fig. 3, p. 13). That point is found thus: a line 5 cm. (2 inches) in length is drawn vertically upwards from the external auditory meatus; the point for tapping the lateral ventricle lies 2 cm. ($\frac{4}{5}$ of an inch) behind the upper end of this line; a trocar thrust in there enters the lateral ventricle at the junction of the body with the descending and posterior horns. (Jenkins.)

Sensori-motor areas of the brain.—A knowledge of the position of these areas is most important in enabling certain brain lesions to be localized and in guiding the surgeon in operations upon the cerebral cortex.

Formerly these areas were believed to be situated in the ascending frontal (precentral) and also ascending parietal (postcentral) convolution, but by stimulating more accurately the cortex of these convolutions in anthropoid apes, Sherrington and Grünbaum found that motor reactions were elicited only from the ascending frontal. The arrangement of the motor areas is shown in Fig. 14: in the upper third of the ascending frontal,

Fig. 14.—Showing the localization of motor areas in the precentral or ascending frontal convolution, and the sensory areas in the postcentral or ascending parietal convolution.

passing also some distance on to the mesial aspect of the brain, the movements of the lower extremity and trunk are represented; in the middle third, those of the arm; while in the lower third, those of the face, mouth, and larynx. Recently Symington and Crymble have investigated the size and shape of the central or Rolandic fissure, and have found, as shown in Fig. 15, that in the majority of brains this fissure is pushed backwards at two points by an upper and lower convolutionary buttress. The position of these buttresses, their relationship to motor areas and distance from the sagittal suture, are shown in Fig. 15.

Behind the fissure of Rolando, in the ascending parietal convolution, are situated sensory areas corresponding to the motor areas in the ascending frontal convolution. A tumour press-

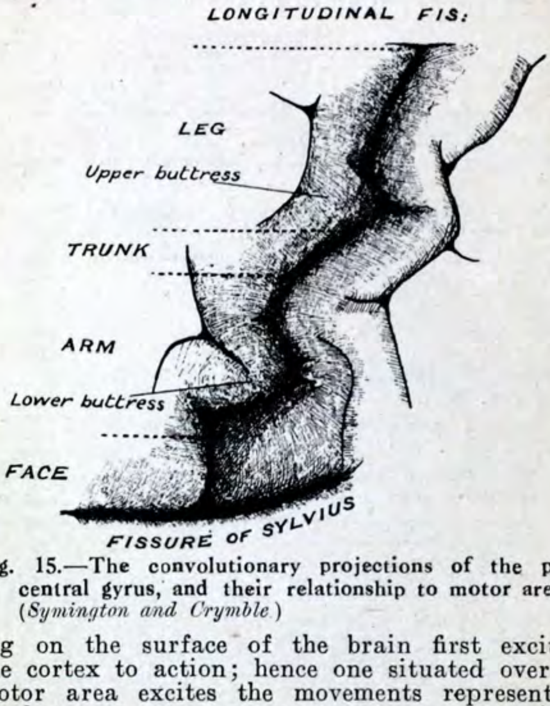

Fig. 15.—The convolutionary projections of the precentral gyrus, and their relationship to motor areas. (*Symington and Crymble*)

ing on the surface of the brain first excites the cortex to action; hence one situated over a motor area excites the movements represented in that area, or one over a sensory area excites the sensations represented there. Stimulation of the cortex is soon followed by its destruction and loss of function; hence loss of movement or loss of sensation replaces the preliminary excitement. The symptoms produced by intracranial growths are apt not to be definitely localized, because even a small tumour may produce widely distributed compression effects when it is situated within the rigid walls of the skull. Conjugate movements of the eyes are represented in the cortex at the posterior end of the midfrontal convolution (Fig. 14). There are also several primary sensory areas of cortex—areas connected with sight, hearing, and smell—which may be affected by intracranial lesions, and give signs which assist the surgeon to localize the seat of disease. The *visual cortex* is situated near the calcarine fissure and round the occipital pole; the "word-seeing" centre occupies the angular gyrus (Fig. 12); the *auditory cortex* lies in a deep or buried part of the superior temporal convolution, while the "word-hearing" centre is ascribed to the middle third of this convolution. The *olfactory cortex* is placed in the uncus, which is situated to the inner side of the temporal lobe. Tumours in the neighbourhood of the uncus, besides producing disturbance of the olfactory sensations, frequently give rise to "dreamy states."

Of the **brain generally** little has to be said. In a surgical sense, it presents itself simply as a large mass of soft tissue that may be damaged by shaking, as gelatin may be when shaken in a case. As it is of very yielding structure, and does not entirely fill the cranial cavity, it may, as it were, be thrown about within the skull, and be damaged by collision with its walls. In contusion or bruising of the brain it is noticed that the lesion is very much more frequently situate on the under surface, both as regards the cerebrum and cerebellum, than in any other part (*see* p. 39). To this statement, however, there is the striking exception that those parts of the base of the cerebrum that rest upon the large basal collection of the cerebro-spinal fluid are the least often contused. These parts include the medulla, the pons, and the interpeduncular space.

Blood supply.—The brain is very lavishly supplied with blood-vessels. The main arterial trunks (vertebral and internal carotid) both become tortuous before entering the skull, in order, probably, to diminish the effects of the heart's systole upon the brain. On entering they are almost immediately blended into an anastomosing circle (circle of Willis), which has the effect of equalizing the cerebral circulation. It is only when one of the main arteries entering into the formation of the circle of Willis becomes blocked that the communicating channels are of service. If a coloured solution be injected into the left carotid of a living dog, the colouring is confined to the left hemisphere; but if the right carotid be previously tied, then the colouring matter is found in the right as well as the left half of the brain (Kramer). Embolism of the middle cerebral artery leads to a widespread destruction of the cerebral cortex. It supplies the third frontal, the upper and middle temporal, the angular, supramarginal, and the lower two-thirds of the ascending frontal and parietal gyri. The only parts of the sensori-motor areas which escape destruction in such a case are those for the lower limbs and trunk. The anterior cerebral artery supplies these centres, the mesial surface of the frontal and parietal lobes, and the adjacent part of the cortex on the outer aspect. The occipital lobe and temporo-sphenoidal convolutions are supplied by the posterior cerebral artery. Ligature of one common carotid may produce no effect upon the brain, although the mortality after this operation is mainly due to cerebral complications. One carotid and the two vertebrals would appear to be able to bring enough blood to the brain, but some weeks will elapse before the communicating vessels are sufficiently enlarged to give a uniform distribution of blood to all parts of the brain. Both common carotids have been ligatured, or one carotid has been secured when its fellow of the opposite side has been occluded by disease, and no marked cerebral disturbances have followed. In no case, however, has the patient recovered when the interval between the closing of the two vessels was less than a few weeks. The vertebral arteries can carry a sufficient amount of blood to the brain if only the strain be thrown upon them gradually, and the brain be allowed to accommodate itself slowly to the change. After ligaturing all four arteries in the dog, the anastomosis between the spinal and cerebral arteries within the foramen magnum was sufficient to maintain life (Hill). Plugging of any of the smaller cerebral arteries by emboli, as a rule, leads at once to a disastrous result. Such embolism is met with in surgery in connexion with aneurysm of the common carotid. In simply examining such aneurysms, a little piece of the clot contained in the sac has been detached, has been carried up into the brain, and has produced a plugging of one of the cerebral vessels. Thus, hemiplegia has followed upon the mere examination of a carotid aneurysm, as in a case recorded by Mr. Teale, of Leeds. Fergusson's treatment of aneurysm at the root of the neck, that of displacing the clots by manipulation, has been abandoned on this same score. In the second case treated by manipulation by this surgeon, one of subclavian aneurysm, paralysis of the left side of the body followed at once upon the first handling of the tumour.

The pulsations of the brain may be communicated to any tumours or collections of fluid that reach the surface of the brain through an aperture in the skull. Such pulsations are synchronous with the arterial pulse, but the sphygmographic tracings of the cerebral pulsations exhibit also the "respiratory curve," conveyed directly from the thorax by the blood within the veins. The valve at the lower end of the jugular vein prevents direct regurgitation of blood from the heart to the brain, but it does not prevent the transmission of pressure.

Although wounds of the brain bleed freely, the bleeding is checked without difficulty, the vessels being capable of ready contraction. Large tumours have been excised from the cortex of the brain, without undue trouble from hæmorrhage. The terminal branches of the cerebral arteries anastomose freely in the pia mater, but the minute arteries which perforate and supply the cortex are terminal. Hence any pressure applied to the surface of the brain will lead to anæmia of that piece of cortex, and, if the pressure is continued, to its destruction.

Ligature of a cerebral vein usually leads to an atrophy of the cortex which it drains (Horsley). There is always one—sometimes more—anastomosing vein on the surface of the cerebrum, uniting the upper with the lower cerebral veins. The lower cerebral veins are four in number : three of them leave the temporal and occipital lobes to end in the lateral sinus; the other, the *superficial Sylvian vein*, ends in the sinus of the small wing of the sphenoid. The temporal and occipital lobes cannot be lifted off the tentorium without rupturing the veins joining the lateral sinus.

Nearly all the veins of the **cerebellum** end in the lateral sinus; its arteries are derived from the vertebral and basilar. The various arteries supplying the cerebellum, pons, and medulla are terminal in their distribution, each nerve-centre and area having its own vascular supply (Stopford). Tumours in the cerebellum give rise to muscular weakness and inco-ordination, giddiness, and loss of balance. The vermis, or middle part of the cerebellum, is more directly connected with bending movements of the trunk, while the lateral lobes are concerned in the co-ordination of turning movements—movements made round the vertical axis of the trunk (Horsley). The evidence is steadily increasing which makes us regard the cortex of the cerebellum as demarcated into functional and regional areas.

CHAPTER IV

THE ORBIT AND EYE

THE ORBIT

THE antero-posterior diameter of the orbit is about $1\frac{3}{4}$ inches (44 mm.), its vertical diameter at the base a little over $1\frac{1}{4}$ inches (31 mm.), and its horizontal diameter at the base about $1\frac{1}{2}$ inches (37 mm.). The diameters of the globe are: transverse, 24 mm.; antero-posterior, 24·5 mm.; vertical, 23 mm. (Brailey). The eyeball is therefore nearer to the upper and lower margins of the orbit than to the sides, and the greatest interval between the globe and the orbital wall is on the outer side. The interior of the orbit is most conveniently reached by incisions made to the outer side of the globe, and, in excision of the eyeball, the scissors are usually introduced on that side when the optic nerve has to be divided. In excising the left eye, however, it may be more convenient to divide the optic nerve from the inner side. The **bones** forming the floor, the roof, and the inner wall of the orbital cavity are very thin, especially in the last-named situation. Thus, foreign bodies thrust into the orbit have readily penetrated into the cranial cavity, into the nose and ethmoidal cells, and, when directed from above, into the antrum (*see* Fig. 26, p. 107). In several instances a sharp-pointed instrument, such as the end of a stick or foil, has been thrust into the brain through the orbit, and has left but little external evidence of this serious lesion.

Nélaton mentions a case in which the internal carotid artery was wounded through the orbit.

A reference to the **relations of the orbital walls** will show that a tumour may readily invade the orbit by spreading (1) from the base of the skull, (2) from the nasal fossæ, (3) from the maxillary sinus, and (4) from the temporal or infratemporal (zygomatic) fossæ. In any of these instances the growth may enter the orbit by destroying the intervening thin layers of bone, and in tumours of the maxillary sinus this is the usual mode of entry. It may, however, extend more readily from the cranial cavity through the optic foramen or superior orbital (sphenoidal) fissure, from the nose through the naso-lacrimal duct, and from the two fossæ named through the inferior orbital (spheno-maxillary) fissure. After violent blows upon the temple, blood has found its way into the orbit through the inferior orbital fissure, and has led to subconjunctival ecchymosis. Distension of the frontal sinus by retained mucus or pus may lead to a prominent tumour at the upper and inner margin of the orbit, above the level of the internal (medial) palpebral ligament, which may cause displacement of the globe downwards, outwards, and forwards. The bones of the orbit are peculiarly apt to be the seat of ivory exostoses, which may in time entirely occupy the orbital cavity.

The anterior third of the outer wall of the orbit is separated from the temporal fossa by the malar (os zygomaticum) (Fig. 16); the posterior two-thirds are separated by the great wing of the sphenoid from the middle fossa of the skull, which contains the temporal lobe. Kronlein removes intraorbital tumours by opening the outer wall of the orbit in the temporal fossa. In a notorious case, in which a murderer attempted to commit suicide, the bullet entered the temporal fossa, perforated the outer wall of the orbit, and destroyed the eyeball, but left the brain untouched. The pole of the temporal lobe is situated from 2 to 2·5 cm. behind the outer margin of the orbit (*see* Fig. 4, p. 15, and Fig. 9, p. 32).

Fascia bulbi (capsule of Tenon).—The best description of this structure has been given by Lockwood, of whose researches Prof. Cunningham provides the following résumé:—

"The capsule is a firm loose membrane spread over the posterior five-sixths of the globe, the cornea alone being free

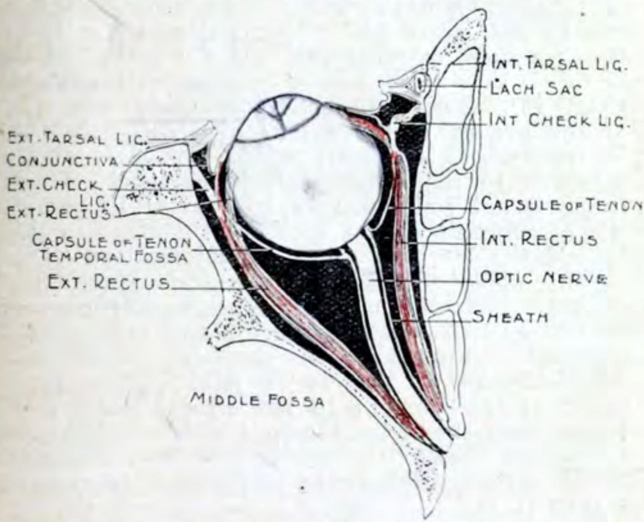

Fig. 16.—Showing the arrangement of the capsule of Tenon (fascia bulbi) and check ligaments.

The eyeball is turned outwards so that the external check ligament is taut and the internal relaxed.

from it. In front it lies under the ocular conjunctiva, with which it is intimately connected, and it ends by blending with that membrane close to the margin of the cornea [Fig. 16]. Behind, it fuses with the sheath of the optic nerve, where the latter pierces the sclerotic. The surface of the membrane towards the globe is smooth, and is connected to the eyeball by some soft yielding areolar tissue. It thus forms a kind of dome for the globe, a species of socket or bursa in which it moves. The posterior surface of the capsule is in contact with the orbital fat. The tendons of the ocular muscles pierce the capsule opposite the equator of the globe [Fig. 16]. The lips of the openings through which the four recti pass are prolonged backwards upon the muscles, in the form of sheaths, very much as the internal spermatic fascia is prolonged upon the cord from the internal abdominal ring."

Where the internal and external recti perforate, strong expansions of the capsule spread out to the inner and outer walls of the orbit. Because these expansions limit the action of the two recti they are known as the **check ligaments** (Fig. 16). They allow a side-to-side movement of the cornea to the extent of about 45°. The external check ligament is the stronger, and is attached to the outer wall immediately behind the external palpebral raphë (tarsal ligament); the attachment of the internal ligament is close behind the lacrimal sac. A prolongation of the capsule passes to the trochlea round the tendon of the superior oblique. The **suspensory ligament** of the eyeball stretches across the orbit like a hammock, supporting the eyeball. It is really a thickening of the under part of the fascia bulbi, its attachment to the orbital walls being made by means of the internal and external check ligaments. When the upper jaw is removed the surgeon should take care to preserve the attachments of the suspensory ligament. If these be destroyed the eyeball will sink downwards.

The intimate relation of the fascia bulbi to the eyeball, conjunctiva, orbital muscles, and orbital walls has to be kept in mind where operations are undertaken to remedy squint. From Fig. 16 it will be seen that, after the tendon of a rectus muscle is cut through as it lies within the capsule of Tenon, the muscle still possesses, through the continuity of its sheath with the capsule, an attachment to the eyeball and conjunctiva as well as to the orbital wall by the check ligament. Hence, when the tendon of a muscle is completely cut it can still act on the eyeball; its complete retraction is prevented by the check ligament.

The orbit behind the fascia bulbi is occupied by a large quantity of loose fat, in addition to the ocular muscles, vessels, and nerves. It is by the absorption of this fat that the sunken eye is produced in cases of emaciation and prolonged illness. This tissue affords a ready means for the spread of **orbital abscess.** Such an abscess may follow injuries, certain ocular inflammations, periostitis, etc., or may spread from adjacent parts. The pus may occupy the entire cavity, displacing the eyeball forwards, limiting its movements, and causing, by interference with the circulation, great redness of the conjunctiva and swelling of the lids.

Foreign bodies, some of them of remarkable size and shape, have lodged for long periods of time in the orbital fat without causing much trouble. Thus, Lawson reports a case where a piece of an iron hat-peg, 3 inches long, was embedded in the orbit for several days without the patient being aware of it. A stranger case, in some ways, is that reported by Furneaux Jordan: "A man who was employed in threshing became the subject of severe ophthalmia. At the expiration of several weeks, the patient, whilst pressing his finger on the lower eyelid, suddenly ejected from a comfortable bed of warm pus a grain of wheat, which had shot forth a vigorous green sprout." The orbital fat affords also an excellent nidus for growing tumours. Fractures of the inner wall of the orbit involving the nasal fossæ or sinuses may lead to extensive emphysema of the orbital cellular tissue. The air so introduced may cause the globe to protrude, may limit its movements, may spread to the lids, and will, in any case, be increased in amount by blowing the nose, etc.

Orbital muscles.—The four recti muscles end in thin, flat membranous tendons. The tendon of the external or internal rectus muscle is frequently divided for strabismus. The width of the tendons varies from 7 mm. to 9 mm. They are inserted into the sclerotic near the cornea. The internal rectus is inserted 6·5 mm. from the corneal margin, the external 6·8 mm., the inferior 7·2 mm., and the superior 8 mm. (Merkel).

While the internal and external recti are pure internal and external rotators of the eyeball, the superior and inferior recti, owing to the line in which they pull, act as internal as well as upward and downward rotators. Their tendency to act as internal rotators is counterbalanced by the two oblique muscles, which serve as external as well as upward and downward rotators.

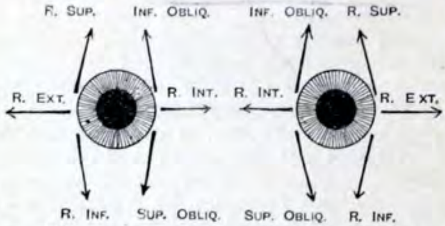

Fig. 17.—Diagram to show the action of the orbital muscles. The arrows show the direction of the action of each muscle.

The diagram given in Fig. 17 will help to make the actions of the orbital muscles clearer. Conjugate horizontal movements to the right or left are executed by the internal and external rectus muscles. When the cornea is turned upwards the muscles in action are the inferior oblique and superior rectus, the first-named tending to turn the cornea towards the temporal aspect, the second towards the nasal aspect. The two muscles involved in turning the cornea downwards are the inferior rectus and superior oblique, the first deflecting the movements towards the nasal side, the second towards the malar side. The diagram also serves to show the muscles of the right and left sides, which are co-ordinated in conjugate movements. Thus, in turning the eyes downwards and to the right, the superior oblique of the right side acts with the inferior rectus of the left. If one of these muscles is paralysed, then double-vision or diplopia occurs when this movement is carried out. Further, it must be remembered that in all of these movements the muscle which is positively in action is controlled by its opponent, which is negatively in action. If the opponent should become paralysed, the active muscle pulls on the eyeball until it is opposed by the check ligament. In life, all the orbital muscles are in a state of tonus and exert a pressure on the eyeball.

The **orbital arteries** are small, and seldom give rise to trouble when divided in excising the globe, since they can be readily compressed against the bony walls of the cavity. Pulsating tumours of this part may be due to traumatic aneurysms of one of the orbital arteries, or may depend upon an arterio-venous aneurysm formed between the internal carotid artery and the cavernous sinus. Pressure upon the ophthalmic vein (as it enters the sinus) by an aneurysm of the internal carotid vessel may also produce all the symptoms associated with pulsating orbital tumours. Thrombosis of the cavernous sinus causes dilatation of the ophthalmic veins and proptosis.

The **orbital nerves** may be damaged in wounds of the orbit, or in fractures of the orbit and of the base of the skull; they may be pressed upon by tumours from various parts, by aneurysms, hæmorrhagic and inflammatory effusions. Thus, Lawson records a case in which the optic nerve was divided by a stab through the upper eyelid, without the globe being injured, and without any bone being fractured. The same nerve has also been completely torn across in fractures of the orbit, and has been pressed upon in fractures involving the lesser wing of the sphenoid.

The third, fourth, and sixth nerves, and the first division of the fifth, may be affected in cases of aneurysm involving the internal carotid artery, where they lie in relation with the cavernous sinus. They may readily be pressed upon, also, by any growth involving the inferior orbital fissure, such as a periosteal node springing from the margin of the fissure, while the sixth nerve, from its more intimate connexion with the base of the skull, has been directly torn across in a fracture involving that part (Prescott Hewett).

In paralysis of the third nerve there is drooping of the upper lid (ptosis); the eye is almost motionless, presents a divergent squint from unopposed action of the external rectus muscle, and cannot be moved either inwards, upwards, or directly downwards. Rotation, in a direction downwards and outwards, can still be effected by the superior oblique and outer rectus muscles. The pupil is dilated and fixed; the power of accommodation is much impaired, there is diplopia, and sometimes a little protrusion of the globe from relaxation of the recti muscles These symptoms refer to complete paralysis of the nerve. In cases of partial paralysis, only one or two of the above symptoms may be present.

In paralysis of the fourth nerve there is often but little change to be seen, since the function of the superior oblique muscle, supplied by this nerve, may, in part, be performed vicariously. "There is usually only very slight defect in the mobility of the eye; what there is occurs chiefly in the inner and lower angle of the field of vision; there is deviation of the eye inwards and upwards on lowering the object, and simply upwards when it is turned far towards the healthy side" (Erb). In any case there will be diplopia, especially in certain positions of the globe.

In paralysis of the sixth nerve there is convergent strabismus, with consequent diplopia, and an inability to rotate the eye directly outwards. Paralysis of the sixth nerve may be accompanied by paralysis of the nerve to the internal rectus of the opposite side, giving rise to conjugate deviation of the eyes. Such a condition indicates a lesion in the nucleus of the sixth nerve, for, although the fibres for the internal rectus pass out with the third nerve, they take their origin with the sixth.

Sometimes all the oculo-motor nerves of the eye are paralysed, and in such cases the lesion is probably situated either at their nuclei of origin or at the cavernous sinus, in the wall of which the nerves lie close together.

In **paralysis of the first division of the fifth** there is a loss of sensation in all the conjunctiva, except such as covers the lower lid (supplied by the palpebral branch of the infraorbital nerve), loss of sensation in the globe, and in skin supplied by the supratrochlear and supraorbital nerves, and in the mucous and cutaneous surfaces supplied by the nasal (naso-ciliary) nerve. The area of anæsthesia is much less than the anatomical distribution of the nerve, owing to the extent to which cutaneous nerves overlap. No reflex movements (winking) follow upon irritation of the conjunctiva, although the patient can be made to wink on exposing the eye to a strong light, the optic nerve in this case transmitting the impression to the nucleus of the facial nerve. Neither can sneezing be excited by irritating the mucous membrane in the anterior part of the nose. Destructive ulceration of the cornea may follow this paralysis, due partly to damage to the trophic branches contained in the paralysed nerve, partly to the anæsthesia which renders the part readily injured, and partly to the loss of the reflex effect of the sensory nerves, upon the calibre of the blood-vessels, whereby the inflammation is permitted to go uncontrolled (Nettleship).

In **paralysis of the cervical sympathetic** there is narrowing of the palpebral fissure from some drooping of the upper lid, apparent recession of the globe within the orbit, and some narrowing of the pupil from paralysis of the dilator muscle of the iris, which muscle is supplied by the sympathetic. The drooping of the upper lid may be explained by the fact that each eyelid contains a layer of unstriated muscle fibre. That in the upper lid arises from the under surface of the levator palpebræ, and is attached to the tarsal cartilage near its upper margin (Fig. 20, p. 81). This layer of muscle, which, when in action, would keep up the lid, is under the influence of the cervical sympathetic. The recession of the globe is supposed by some to be due to paralysis of the orbitalis muscle. This muscle bridges over the inferior orbital fissure, is composed of unstriated fibres, and is innervated by the sympathetic. Contraction of the muscle (as produced by stimulation of the cervical sympathetic in animals) causes protrusion of the globe, while section of the sympathetic in the neck produces retraction of the eyeball (Claude Bernard). No changes are observed in the calibre of the blood-vessels of the globe. The non-striated muscle maintains the intraorbital pressure, and thus assists in the return of blood from the ophthalmic veins. In animals such as the ox, in which the veins of the orbit become dilated when the head is carried low, as in browsing, this musculature attains a great development.

The Eyeball

The cornea.—The thickness of the cornea varies from 0·9 mm. in the central parts to 1·1 mm. at the periphery. One is apt to be a little deceived as to its thickness, and on introducing a knife into the cornea, the instrument, if not entered at the proper angle, may be thrust for some little distance among the laminæ of the part. In front the cornea is covered by stratified epithelium. When this layer has been removed by abrasion, a white deposit of lead salts may take place in the exposed corneal tissue in cases where lead lotions are used. The bulk of the cornea is made up of a great number of fibrous lamellæ, between which are anastomosing cell spaces containing the corneal corpuscles. If the nozzle of a fine syringe be thrust into the corneal tissue, the network of lymph-spaces can be filled with injection. When suppuration takes place within the proper corneal tissue, it is probably

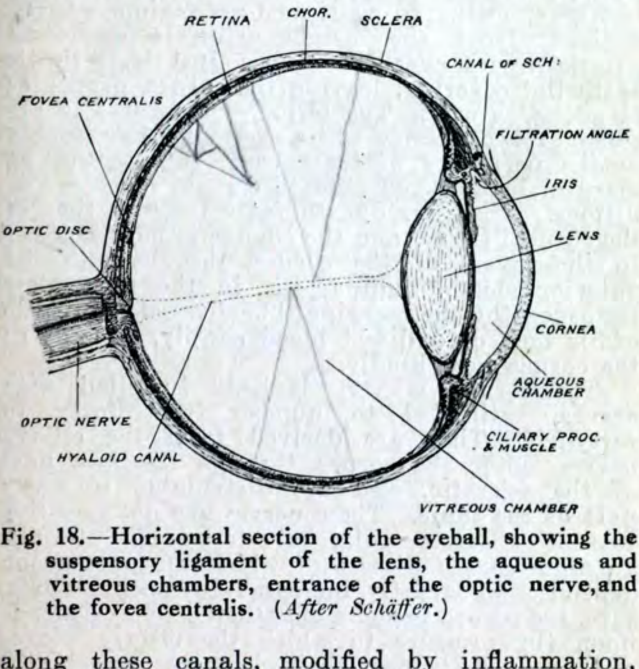

Fig. 18.—Horizontal section of the eyeball, showing the suspensory ligament of the lens, the aqueous and vitreous chambers, entrance of the optic nerve, and the fovea centralis. (*After Schäffer.*)

along these canals, modified by inflammation, that the pus spreads, thus producing onyx. The cornea contains no trace of blood-vessels, except at its extreme periphery, where the capillaries of the sclerotic and conjunctiva end in loops. When inflamed, the tissue always becomes opaque. In the affection known as **interstitial keratitis,** blood-vessels from the arteries of the margin of the cornea penetrate into the substance of the cornea for some distance. As these vessels are some little way below the surface, and are covered by the hazy corneal tissue that is the result of the disease, their scarlet colour is much toned down, and a strand of such vessels is called a "salmon patch." In the condition known as **pannus,** the cornea appears to be vascularized; but here, owing to continued irritation, vessels, derived from the neighbouring conjunctival arteries, pass over the cornea just beneath its epithelial covering, leaving the cornea proper as bloodless as ever. The term **arcus senilis** is applied to two narrow white crescents that appear at the periphery of the cornea, just within its margin, in the aged, and in certain morbid conditions. They are due to fatty degeneration of the corneal tissue, and the change is most marked in the layers of the cornea just beneath the anterior elastic lamina, i.e. in the part most influenced by the marginal blood-vessels. In spite of its lack of a direct blood supply, wounds of the cornea heal kindly.

The cornea is very lavishly supplied with **nerves,** estimated to number from forty to forty-five. They are derived from the ciliary nerves, enter the cornea through the fore part of the sclerotic, and are distributed to every part of the tunic. These nerves are not sensitive to touch, heat, or cold, only to painful stimuli. In glaucoma, a disease of which the phenomena depend upon greatly increased intraocular pressure, the cornea becomes anæsthetic. This depends upon the pressure to which the ciliary nerves are exposed before their branches reach the cornea. (*See also* Nerve Supply of the Eyeball, p. 71.)

Sclera, choroid, and iris.—The sclera or sclerotic is thickest behind, and thinnest about ¼ of an inch from the cornea. When the globe is ruptured by violence it is the sclerotic that most commonly yields, the rent being usually a little way from the cornea, i.e. in or about the thinnest part of the tunic. The sclerotic may be ruptured while the lax conjunctiva over it remains untorn. In such a case the lens may escape through the rent in the sclera, and be found under the conjunctiva. At the point of penetration of the optic nerve the sclera is thin, and pierced by numerous holes for the passage of nerve bundles. This weakened portion, the lamina cribrosa, plays an important part in glaucoma (p. 78). It gives the stippled appearance to the optic papilla. Brailey states that the lateral parts of the sclera are thinner than the upper and lower segments, the inferior part being the thickest and the external wall the thinnest. It happens, therefore, that under the influence of intraocular pressure the eye expands more laterally than in the vertical direction. It is mainly to the denseness and unyielding character of the sclerotic that must be ascribed the severe pain (due to pressure on nerves) experienced in those eye affections associated with increased intraocular tension (glaucoma, etc.).

The **choroid** is the vascular tunic of the globe, and carries its main blood-vessels. Between the choroid and sclera are two thin membranes, the lamina suprachoroidea and lamina fusca, which are separated from one another by a lymph space. In injuries to the globe, therefore, extensive bleeding may take place between these two coats, and indeed a like hæmorrhage may be the result simply of a sudden diminution in the ocular tension produced by such an operation as iridectomy or cataract extraction. The choroid alone has been ruptured (usually at its posterior part) as the result of a blow upon the front of the eye. The choroid is one of the few parts of the body that may be the seat of melanotic growths. These growths are sarcomatous tumours containing a large amount of pigment, and occur only where pigment cells are found. In the choroid coat pigment cells are very abundant.

The **iris** is very vascular, and liable to be the site of inflammation (iritis). From its relations to the cornea and sclera it happens that inflammation in those tunics can spread without difficulty to the iris. On the other hand, the vessels of the iris and choroid are so intimately related that inflammations set up in the iris itself have every inducement to spread to the choroidal tunic. When the iris is inflamed its colour becomes altered, owing to the congestion of the part and to the effusion of lymph and serum that takes place in its substance. The swelling to which it becomes subject, together with the effusion, produce a blurring of its delicate reticulated structure, as seen through the cornea. Owing also to the swollen condition of the little membrane, the pupil becomes encroached on, and appears to be contracted, while the movements of the membrane are necessarily rendered very sluggish. If it be remembered that part of the posterior surface of the iris is in actual contact with the lens capsule, it will be understood that inflammatory adhesions may readily take place between the two parts (Fig. 18). After iritis, therefore, it is common to find the posterior surface of the iris (most often its pupillary margin) adherent to the lens capsule by bands of lymph, either entirely or in one or more different points. Such adhesions constitute posterior synechiæ, the term anterior synechiæ being applied to adhesions between the iris and the cornea. In iritis also the lens may become involved, and the condition of secondary or inflammatory cataract be produced.

The iris is not very closely attached at its insertion (Fig. 19). Thus, in the case of injury to the eye, it may be torn more or less from its attachments without any damage being done to the other tunics. The iris has been completely torn away in a few instances, and has escaped through a wound of the globe. The ciliary processes have been thus exposed. Congenital absence of the iris has been recorded. In cases of penetrating wounds of the cornea the iris may easily become prolapsed. It is so delicate and yielding a membrane that in performing iridectomy the necessary piece of the iris can be seized and pulled out through the corneal incision without offering sensible resistance. The membrane also derives much support from its contact with the lens, for in cases where the lens has been displaced into the vitreous, or has been removed by operation, the iris is observed to be tremulous when the globe is moved. Although very vascular, the iris seldom bleeds much when cut, a circumstance that is probably due to the contraction of the muscular fibres that exist so plentifully within it. Sometimes the iris presents in its substance a congenital gap that runs from the pupil downwards and a little inwards. This condition is known as coloboma iridis, and is due to the persistence of the "choroidal cleft" formed during development of the optic cup. In other cases there can be seen, stretching across the pupil, some shreds of the pupillary membrane. This membrane, which is apparent for a few days after birth in some animals, is entirely absorbed long before birth in the human species.

It will now be convenient to take note of the blood and nerve supply of the globe.

Blood supply of the eyeball.—1. The **short ciliary arteries** (from the ophthalmic) pierce the sclera close to the optic nerve, run some little way in the outer coat of the choroid, and then break up into a capillary plexus that makes up the main part of the inner choroidal coat. In front this plexus gives some vessels to the ciliary processes. The veins from these vessels are disposed in curves as they converge to four or five main trunks (venæ vorticosæ), which pierce the sclera midway between the cornea and the optic nerve. In the choroid they lie externally to the arteries.

2. The two **long ciliary arteries** (from the ophthalmic) pierce the sclera to the outer side of the optic nerve and run forwards, one on either side, until they reach the ciliary region, where they

break up into branches that, by anastomosing, form a vascular circle about the periphery of the iris (the circulus major). From this circle some branches pass to the ciliary muscle, while the rest run in the iris in a converging manner towards the pupil, and at the margin of the pupil form a second circle (the circulus minor).

3. The **anterior ciliary arteries** (from the muscular and lacrimal branches of the ophthalmic) pierce the sclerotic (perforating branches) about 2 to 3 mm. behind the cornea, join the circulus major, and give off branches to the ciliary processes, where they form copious anastomosing loops. These arteries lie in the subconjunctival tissue. Their episcleral or non-perforating branches are very small and numerous, and are invisible in the normal state of the eye. In inflammation of the iris and adjacent parts, however, these vessels appear as a narrow pink zone of fine vessels round the margin of the cornea, that run nearly parallel to one another, are very closely set, and do not move with the conjunctiva. This zone is known as the zone of ciliary congestion, or the circumcorneal zone.

4. The **vessels of the conjunctiva** are derived from the lacrimal and the two palpebral arteries. These vessels, in cases of inflammation, are readily distinguished from those last described. They are of comparatively large size, are tortuous, are of a bright brick-red colour, can be easily moved with the conjunctiva, and as easily emptied of their blood by pressure. The differences presented by these two sets of vessels serve in one way to distinguish inflammation of the conjunctiva from that involving deeper parts. The conjunctival vessels around the margin of the cornea form a closer plexus of anastomosing capillary loops, which become congested in severe superficial inflammation of the cornea, and may then form a zone around the margin of the cornea, which can, however, be distinguished from the "ciliary zone" by the general characters just named.

The **retina** has a vascular system of its own, supplied through the arteria centralis retinæ, which is nowhere in direct communication with the choroidal vessels, except just at the entrance of the optic nerve. Indeed, the outer layers of the retina which are in relation with the choroid coat are entirely destitute of vessels. Thus, when the central artery of the retina becomes plugged, sudden blindness follows, and, as the meagre collateral circulation that is established by the minute anastomoses about the entrance of the nerve is quite insufficient, the retina soon becomes œdematous. A permanent plugging of the central artery means, therefore, a practical extinction of the vascular system of the retina. In some cases of embolism, only a branch of the retinal artery is plugged, the patient retaining vision except in that part of the retina supplied by the branch. The fovea centralis, the centre of acute vision, receives twigs from both the superior and inferior temporal branches of the arteria centralis retinæ.

In cases of hæmorrhage between the choroid and retina the blood must come from the choroidal vessels; and in hæmorrhage into the vitreous, which often follows injury, the blood may be derived from the retinal vessels, since they run in the inner layers of that membrane, or from the vessels in the ciliary region.

Nerve supply of the eyeball.—1. The **ciliary nerves**, derived from the ciliary (lenticular) ganglion and the nasal (naso-ciliary) nerve, pierce the sclerotic close to the optic nerve, and pass forwards between the sclerotic and the choroid, supplying those parts. They enter the ciliary muscle, form a plexus about the periphery of the iris, and then send fibres into the iris, which form a fine plexus as far as the pupil. They send branches through the fore part of the sclerotic to the cornea. Thus the eyeball obtains through these nerves its sensory fibres from the nasal or naso-ciliary branch of the first division of the fifth, its motor fibres for the ciliary muscle and sphincter iridis from the third nerve, and many sympathetic fibres, among which are those that supply the dilator muscle of the iris (*see* p. 64).

2. The **conjunctiva** is supplied by four nerves: above, the supratrochlear; inner side, the infratrochlear; outer side, the lacrimal (all branches of the first division of the fifth); below, the palpebral branches of the second division of the fifth. As the ciliary nerves pass forwards between the choroid and the sclerotic, it will be seen that they are readily exposed to injurious pressure against the unyielding sclerotic in cases of increased intraocular tension.

The **sensation of the globe itself** is derived solely from the first division of the fifth. In inflammatory affections of the globe, as in corneitis or iritis, besides the pain actually felt in the eye, there is pain referred along other branches of the first division of the fifth. The explanation of this fact has to be sought for in the common origin of the ophthalmic division from the upper sensory nucleus of the fifth nerve in the floor of the fourth ventricle. Not only are the nerve cells connected with the eyeball disturbed, but the neighbouring cells also are affected, and by a psychical error the pain is reflected along the nerves with which these neighbouring cells are connected. There is pain over the forehead along the supratrochlear, the supraorbital, and the lacrimal branches (circumorbital pain), and pain down the side of the nose following the nasal nerve. Or the pain may spread to the second division of the fifth, and discomfort be felt in the temporal region (orbital branch of the second division), or be referred to the upper jaw and teeth. These affections, too, are associated with much lacrimation, the lacrimal gland being also supplied through the first division of the fifth. Photophobia, or intolerance of light, is common in inflammatory affections of the eye. In this condition there is spasm of the orbicular muscle, keeping the eye closed, or closing it on the least exposure to irritation. Although the orbicular muscle is supplied by the facial nerve, its nerve fibres are derived, not from the nucleus of the seventh but from the oculomotor nucleus, situated near the upper sensory nucleus of the fifth, and connected with it by reflex paths. Photophobia is most marked in superficial affections of the cornea, and is often much benefited by a seton in the temporal region. Inflammation of the iris and glaucoma are accompanied by hyperæsthesia and referred pains over the outer frontal and anterior temporal areas (Head). The nerve-centres for the skin of this region and the eyeball are closely connected, a relationship which may explain the application of counter-irritation to the temples in eye disease. Inflammation of the cornea gives rise to no referred pains (Head). Strain of the ciliary muscle, which occurs with errors of refraction, is one of the commonest causes of headache, leading to referred pains and areas of hyperæsthesia over the midorbital region of the forehead.

The relations between the nasal (naso-ciliary) nerve and the orbital contents receive many illustrations in practice. Thus, if the front of the nose be struck, or the skin over its lower part be irritated, as by squeezing a painful boil, profuse lacrimation will frequently be produced. Snuff, too, by stimulating the nasal branch of the ophthalmic nerve, often makes the eyes of the uninitiated to water; and it is well known that there are many disturbances about the nose, and the anterior part of the nasal fossæ, that can "make the eyes water." Herpes zoster often provides a remarkable illustration of the intimate relation between the nasal nerve and the eye. In this affection, when the regions of the supraorbital and supratrochlear branches of the first division are alone implicated, the eye is usually unaffected; but when the eruption extends over the part supplied by the nasal nerve, i.e. runs down the side of the nose, then there is very commonly some inflammation of the eyeball.

Dangerous area of the eye.—Penetrating wounds of the cornea alone, or of the sclera alone, behind the ciliary region, are by no means serious; but wounds involving the ciliary body, or its immediate vicinity, are apt to assume the gravest characters. Inflammation in the ciliary region is peculiarly dangerous, on account of the important vascular and nerve anastomoses that take place in the part. Indeed, as regards blood and nerve supply, there is no more important district in the eyeball. From the ciliary body also inflammations can spread, more or less directly, to the cornea, iris, choroid, vitreous, and retina. Plastic, or purulent, inflammation of the ciliary body, after injury, is the usual starting-point of **sympathetic ophthalmia.** In this terrible affection destructive inflammation is set up in the opposite sound eye, which is, however, not usually involved until two or three months after the other eye has been injured. It is now generally believed that the sound eye is directly infected from the diseased one. The subarachnoid spaces which surround the optic nerves are in continuity at the chiasma, and offer a path whereby infection may spread from one eye to the other.

The **lens** measures $\frac{1}{3}$ of an inch from side to side, and $\frac{1}{5}$ of an inch from before backwards. All through life it slowly increases in size. It, together with its capsule, is in all parts perfectly transparent and perfectly non-vascular. The manner in which the lens is maintained in position is shown in Figs. 18 (p. 65) and 19 (p. 77). The circumference of the lens is fixed to the ciliary processes by a system of fine, transparent, radial fibres (the *suspensory ligament* of the lens), some of which pass in front of the lens, while others pass behind it, thus forming a sac or *capsule* for the lens. On the ciliary processes the radial fibres of the suspensory ligament become continuous with the transparent capsule of the vitreous humour—the *hyaloid membrane.* The lens may easily be loosened or displaced by partial rupture of its suspensory ligament, and may find its way into the anterior chamber, or, more commonly, back into the vitreous. If disturbed, the lens may swell, and by the pressure thus exercised cause great damage to the important structures adjacent to it. The capsule is very brittle and elastic, and when torn its edges curl outwards. It is lacerated in the usual operations for cataract, and may be ruptured by many forms of violence applied to the eyeball. "In one form of cataract operation the capsule is removed with the lens, the vitreous being retained in position by the hyaloid membrane which lies behind the capsule of the lens" (Lieut.-Colonel H. Smith). When the capsule is wounded the aqueous humour enters, and is imbibed by the lens fibres, which in consequence swell up and become opaque, thus producing a traumatic cataract. In the various forms of cataract the whole lens, or, more commonly, some portion of it, becomes the seat of opacity. This often commences in the nucleus, and for a long while remains limited to that part; or it may first involve the cortex, and in such a case the opacity takes the form of a series of streaks that point towards the axis of the lens, and are dependent upon the arrangement of the lens fibres.

Of the **retina** it is only necessary to observe that its connexion with the choroid is so slight that it may easily be detached from that membrane by hæmorrhagic or other effusions, and may indeed be so detached by a simple blow upon the globe. Even when extensively detached it remains, however, as a rule, attached at both the optic disc and the ora serrata.

The length of the **optic nerve** within the orbit is 28–30 mm. As it passes from the brain it receives its perineural sheath from the pia mater, and, in addition, two other sheaths: an outer from the dura mater, and an inner from the arachnoid. These sheaths remain distinct and separate, and the two spaces enclosed may be injected, the outer from the subdural, the inner from the subarachnoid space. Thus inflammatory affections of the cerebral meninges can readily extend along the optic nerve to the optic disc through these spaces in the nerve sheath, while in cases of intracranial disease other than meningeal the mischief may extend from the brain to the disc along the interstitial connective tissue in the nerve. These connexions may serve in part to explain the frequent association of optic neuritis with intracranial disease. As the nerve leaves the skull in the optic foramen it is in contact with the outer wall of the sphenoidal sinus, or, if that sinus be relatively small, with the posterior ethmoidal cells. In suppuration of these spaces infection may spread to the optic nerve, and thus set up optic neuritis. When the intracranial pressure is raised by the growth of a tumour, hæmorrhage, or other condition within the skull, that pressure is exerted on the optic nerve, thus interfering with a free circulation along the nerve, and leading to a change in the appearance of the optic disc.

Aqueous and vitreous humours. — The **aqueous** fills the anterior chamber; the space between the capsule and suspensory ligament of the lens and the cornea. The iris divides this space into two parts, the anterior and posterior. Since, however, the iris is largely in actual contact with the lens, is happens that the posterior part is represented by a little angular interval between the iris, the ciliary processes, and the suspensory ligament of the lens (Fig. 19). The depth of the anterior chamber is 3·6 mm. The inner stratum of the cornea, as it becomes continuous with the sclera, splits up into fibres which pass to (1) the sclera, (2) the ciliary muscle, (3) the ciliary processes. The fibres form the *ligamentum pectinatum*, and the intervals between its fibres are known as the spaces of Fontana (iridio-corneal spaces). They are filled by the aqueous humour. The fluid in these spaces is absorbed into a circular canal in the sclera—the circular venous canal, or canal of Schlemm (*see* Fig. 19). This canal is in communication with the veins of the anterior part of the sclerotic, ciliary processes, and iris. The aqueous humour is being constantly secreted by the ciliary processes behind

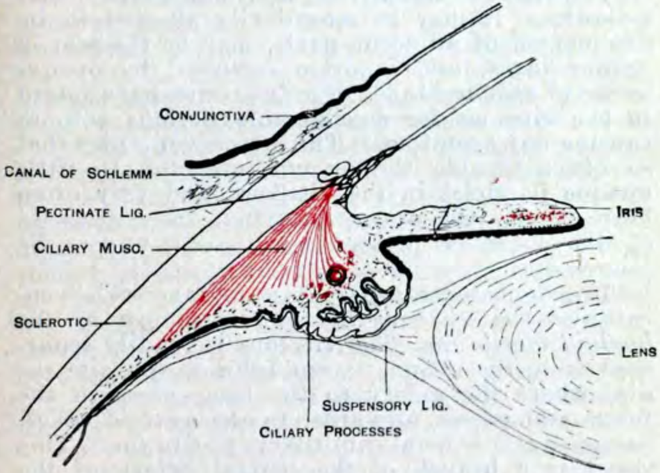

Fig. 19.—Ligamentum pectinatum, spaces of Fontana, ciliary muscle, and capsule of the lens.

the iris, and equally constantly absorbed into the canal of Schlemm, thence passing into the venous circulation. The tension of the eyeball is maintained by an exact regulation between the rates of secretion and absorption. Thus, if pus finds its way into the anterior chamber (hypopyon) it is, as a rule, easily absorbed. The same applies to moderate extravasations of blood in the chamber, and the speedy removal of such effusions contrasts with the difficulty that is experienced in the absorption of blood from the vitreous chamber.

Prof. Arthur Thomson has shown that the inner aspect of the sclera is depressed or grooved at the anterior base of the iris. When the pupil is dilated the contracted base of the iris tends to fill this groove, thus rendering the escape of the aqueous humour into the spaces of Fontana more difficult.

The **vitreous** takes little active share in ocular maladies. It may be secondarily affected in inflammation of adjacent parts, may be the seat of hæmorrhages, and is often occupied by opaque bodies of various kinds. Foreign bodies have lodged in the vitreous for considerable periods without causing any symptoms. The muscæ volitantes that so often trouble the myopic are due to little opaque particles in the vitreous, and very often have exactly the appearance that the corpuscles of the vitreous present when seen under the microscope.

The delicate transparent membrane which encapsules the vitreous humour is known as the *hyaloid membrane*. The vitreous is readily separated from the retina, except behind, opposite the disc where the artery to the lens enters in the fœtus and passes forwards, in the *hyaloid canal*, to supply the fœtal pupillary membrane. This vessel is a branch of the central artery of the retina, and may persist as a fibrous cord in adult life. In some rare cases it has continued to transmit blood, and in such instances its pulsation can be seen with the ophthalmoscope.

Glaucoma is a disease the symptoms of which are all dependent upon an increase in the intraocular tension of the globe. When the pressure within the eyeball rises above the pressure of the blood in the arterioles of the retina and choroid, then the nutrition of the eye ceases. Normally the intraocular tension is equal to that of the blood in the intraocular veins. If there is a failure in absorption of the aqueous humour into the circular venous canal of the sclera, then pressure rises. The condition is the same as in the brain; the aqueous humour of the eye represents the cerebro-spinal fluid of the brain. It is remarkable that in nearly every case of glaucoma the spaces of Fontana are occluded by the complete obliteration of the angle between the periphery of the iris and the cornea, which angle is normally occupied by the ligamentum pectinatum.

The importance of the peripheral part of the anterior chamber in relation to the outflow of fluid from the eye is shown in many ways. If this part be blocked by the iris in perforation of the cornea, or by the lens in some dislocations of that body, increased tension of the globe is apt to follow. The relief given to glaucoma by iridectomy appears to depend upon the circumstance that the operation practically opens up again these channels of communication from the aqueous, since the procedure, to be successful, should involve an incision so far back on the sclera as fully to pass through the angle just alluded to. It is needful also that the iris should be removed quite up to its attachment, and that the portion resected should be considerable. Iridectomy also exposes a fresh capillary surface of the iris to the aqueous humour, which thus finds a fresh exit. In the young the ligamentum pectinatum is cellular and open in structure; it becomes fibrous and contracted in the old. Hence the aged are more liable to glaucoma (T. Henderson).

The symptoms of glaucoma are all explained by the effects of the abnormal tension. Thus, the ciliary nerves are compressed against the unyielding sclera, and give rise to intense pain, while the disturbance in their functions shows itself in the fixed and dilated pupil and in the anæsthetic cornea. Perhaps the first parts to suffer from compression are the retinal blood-vessels, and the effect upon them will be most obvious at the periphery of the retina, i.e. at the extreme limit of the retinal circulation. Hence follows that gradual narrowing of the visual field which is constant in glaucoma, while the pressure upon the optic nerve produces those flashes of light and other spectra which occur in the disease. The weakest part of the sclera is in the disc at the lamina cribrosa. This part rapidly yields under the pressure, and so produces the "glaucomatous cup." Pressure in the opposite direction pushes the lens forwards, and thus narrows the anterior chamber; while the general interference with the ocular circulation is shown in the distended vessels that appear upon the globe.

The eyelids (Fig. 20).—The skin over the eyelids is very thin and delicate, and shows readily through its substance any extravasation of blood that may form beneath it. Its laxity, moreover, renders it very well adapted for certain plastic operations that are performed upon the part. Its loose attachments cause it to be readily influenced by traction, and the shrinking of cicatrices below the lower lid is very apt to draw that fold away from the globe, and so produce the condition of eversion of the lid known as *ectropion*. The contraction of the conjunctiva after inflammatory conditions, or after it has been subjected to destructive agencies, is prone, on the other hand, to curl either lid inwards towards the globe, and thus to produce *entropion*. The lids present many transverse folds; one of these on the upper lid, deeper and more marked than the rest, divides the lid into two parts, the part below being that which covers the globe, the part above being that in relation with the soft structures of the orbit. In emaciation the lid becomes much sunken in the line of this fold. Incisions should follow the direction of the fold. The lids are very freely supplied with blood, and are often the seat of nævi and other vascular growths.

The following layers are found in either lid in order: (1) the skin; (2) the subcutaneous tissue; (3) the orbicularis oculi; (4) the tarsal plate (superior tarsus) and its continuation to the margin of the orbit—the orbital septum (palpebral membrane); (5) the layer of tarsal (Meibomian) glands embedded in the plate; and (6) the conjunctiva. In the upper lid the levator palpebræ is found passing to the tarsal plate. The **subcutaneous tissue** is very lax, and hence the lids swell greatly when œdematous, or when inflamed, and when the seat of hæmorrhage. On this account it is inadvisable to apply leeches to the lids, because of the extensive "black eye" that may follow. This tissue is peculiar in containing no fat. At the edge of the lids are found the eyelashes, the orifices of the **tarsal glands,** and of some modified sweat- and sebaceous glands. The secretion of these glands prevents adhesion of the edges of the lid. This edge, like other points of junction of skin and mucous membrane, is apt to be the seat of irritative affections. As it is a free border also the circulation is terminal, and stagnation in the blood

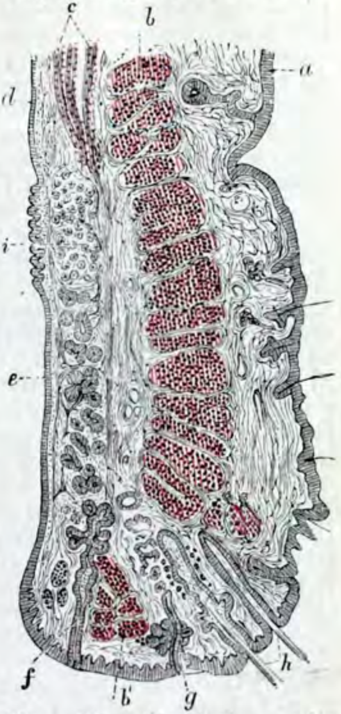

Fig. 20.—Vertical section through upper eyelid. (*After Waldeyer.*)

a, Skin; *b*, orbicularis; *b'*, its ciliary part; *c*, involuntary muscle of eyelid representing part of the insertion of the levator palpebræ; *d*, conjunctiva; *e*, superior tarsus; *f*, tarsal gland; *g*, modified sweat-gland; *h*, eyelashes; *i*, post-tarsal glands.

current is not difficult to produce. Sycosis, an inflammation involving the hair-follicles and some of the glands at the edge of the lid, is among the most common of ophthalmic affections. The common stye also is a suppuration in the connective tissue or in one of the glands at the margin. On everting the lid the tarsal glands can be seen through the conjunctiva as lines of yellowish granules. The common tarsal cyst is a retention cyst developed in one of these glands.

Two **arteries** supply either lid: a palpebral branch of the ophthalmic running along the inner part, and a branch of the lacrimal along the outer part of each lid. Four **nerves** supply the upper eyelid, the supraorbital, the supratrochlear and infratrochlear, and the lacrimal. One nerve supplies the lower lid, the infraorbital. Some of the lymphatics of the eyelids enter the preauricular glands, hence in cases of chancre of the lid the glandular enlargement has nearly always been noticed in front of the parotid gland.

The conjunctiva.—The ocular part of this membrane is thin, covered with stratified epithelium very loosely attached, and not very extensively supplied with blood; the palpebral portion is thicker, covered with columnar epithelium more closely adherent, and more vascular. At the edge of the cornea the conjunctiva becomes continuous with the epithelium covering that tunic. The looseness of the ocular conjunctiva allows it to be freely moved about, and is of great value in some operations, as, for example, in Teale's operation for symblepharon, where a bridge of conjunctiva, dissected up from the globe above the cornea, is drawn down over the cornea to cover a raw surface in contact with the lower lid. This lax tissue favours the development of œdema (chemosis), which in extreme cases may reach such a degree that the patient cannot close his eye. The vessels also, being feebly supported, are prone to give way under no great provocation. Thus, subconjunctival hæmorrhages may occur from severe vomiting, or during a paroxysm of whooping-cough. Blood also may find its way beneath the membrane in fractures of the base of the skull. Hæmorrhages beneath the membrane are unlike other extravasations (bruises), in that they retain their scarlet colour. This is due to the fact that the thinness of the conjunctiva allows oxygen to reach the blood and gives it an arterial character. Severe inflammation of the conjunctiva may lead to considerable cicatricial changes, as is the case in other mucous membranes, and especially, perhaps, in the urethra. The contraction of the conjunctiva after destructive processes is apt to lead to entropion. If both the ocular and the corresponding part of the palpebral conjunctiva have been destroyed, the two raw surfaces left will readily adhere; the lid will become fused to the globe, and the condition called symblepharon be produced. This condition concerns the lower lid, and is generally brought about by lime or other caustics being accidentally introduced between the under lid and the globe.

In one common form of inflammation of this membrane a number of little "granulations" appear upon the palpebral conjunctiva. These are not real granulations, since no true ulceration of the part takes place, but they appear to be made up, some of nodules of adenoid tissue, others of enlarged mucous follicles and of hypertrophied papillæ, all of which structures are normally found in the membrane. The condition is known as "**granular lids,**" and is associated with the formation of much new tissue in the deeper parts of the membrane. From the absorption of this new tissue and of these granulations a contracting cicatrix results, leading to much puckering of the membrane, and often to entropion and inversion of the eyelashes.

Lacrimal apparatus.—The **lacrimal gland,** which is situated in the upper and outer quadrant of the orbit (Fig. 21), is separated by the lateral expansion of the tendon of the levator palpebræ into two parts—a large superior, lying between the expansion and the roof of the orbit, and a small inferior, which lies between the expansion and the reflection of the conjunctiva from the eyeball to the upper eyelid. The ducts, minute in size and about twelve in number, open in the outer part of the conjunctival reflection. Excision of the gland presents no technical difficulty, as it is loosely bound to the structures in its neighbourhood. It may inflame, and become so enlarged as to appear as a tumour, which may displace the globe downwards and inwards, and press forwards the oculo-palpebral fold of conjunctiva. If an abscess forms, it most usually breaks through the skin of the upper lid. Cysts of the gland (dacryops) are due to obstruction and distension of some of its ducts. The normal secretion of the gland keeps the exposed surface of the eye moist, yet the gland may be excised without giving rise to any untoward effect.

The **lacrimal sac** is situated at the side of the nose, near the inner canthus (medial palpebral commissure), and lies in a groove on the lacrimal and superior maxillary bones (Fig. 21). On its outer side, and a little anteriorly, it receives the two lacrimal canaliculi. In front of the sac is the *internal palpebral ligament* or *tendo oculi.* If the two lids be forcibly drawn outwards this ligament can be readily felt and seen, and serves as a guide to the sac. It can also be felt as it is tightened when the lids are firmly closed. It crosses the sac at right angles, and at about the junction of its upper third with its lower two-thirds. A knife entered immediately below the ligament would about open the middle of the sac; and it may be noted that a lacrimal abscess, when about to discharge, always points below the ligament. **Epiphora,** or overflow of tears, is due in the main to two causes: (1) to an obstruction in any part of the lacrimal passages, from the puncta to the opening of the nasal or naso-lacrimal duct in the nose; (2) to any cause that removes the lower punctum from its contact with the globe, as may be the case in ectropion, in entropion, in swelling of the lower lid, etc. It is the *pretarsal* part—the fibres of the *orbicularis oculi* which span the lids near their free margin—that keeps the eyelids appressed to the eyeball. These fibres end behind the lacrimal sac on the posterior lacrimal crest, and form the muscle

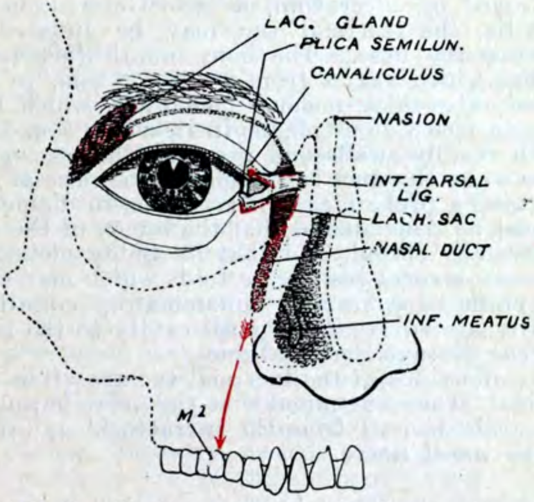

Fig. 21.—Diagram of the lacrimal apparatus.

The arrow points to the first molar tooth, showing the direction of the nasal duct.

at one time known as the *tensor tarsi* or Horner's muscle (Whitnall). Facial palsy causes epiphora, because, the orbicular muscle being relaxed, the punctum falls away from the globe, and, moreover, the passage of the tears is no longer aided by the suction action effected by the muscle in the process of winking. The canaliculi may readily be slit up with a proper knife, and a probe can without difficulty be passed down the nasal duct from the lacrimal sac.

The **nasal duct** (naso-lacrimal) is a little over ½ an inch in length, and the probe that traverses it should pass downwards, and a little backwards and outwards, in the direction of the first molar tooth (Fig. 21). The nasal duct perforates the mucous membrane of the nose below the inferior turbinate process very obliquely, so that its inner wall acts as a valve. If this is destroyed by ulceration, as sometimes occurs in syphilis, the lacrimal sac may be inflated by blowing the nose. The bony nasal duct has a calibre which varies from 2·5 to 7·5 mm. in diameter; the thick mucous membrane which lines it has a rich venous plexus in its submucous layer which readily swells and prevents the passage of tears when the duct is inflamed. The normal duct will take a probe measuring 3·5 mm. in diameter; it must be remembered that the lumen of the duct is normally closed, and that its lining membrane possesses several transverse folds which may catch the point of a probe. Inflammatory conditions readily ascend from the nasal cavity to the lacrimal sac through the nasal duct.

As affections of the lacrimal sac are often very painful, it may be noted that the nerve supply of the sac is derived from the infratrochlear branch of the nasal nerve.

CHAPTER V

THE EAR

The pinna.—The pinna may be congenitally absent, or there may be accessory auricles situated upon the cheek or side of the neck. In the latter situation the so-called accessory or supernumerary auricle consists of an irregular leaf of fibro-cartilage developed from the margins of one of the lower branchial clefts (*see* p. 209). The tag-like supernumerary auricles that are found on the cheek just in front of the pinna or meatus are due to the irregular development or want of fusion of one or more of the six tubercles from which the pinna itself is developed. The pinna may present a congenital fistula dependent on a defective closure of the first branchial cleft. The position of this cleft is represented in the normal ear by the Eustachian tube, the tympanum, and the external auditory meatus, the pinna being developed from the integument bordering the cleft. Some of the smaller and more superficial fistulæ are due not to a defective closure of the branchial cleft but to want of complete fusion between certain of the tubercles from which the pinna is primarily developed. Accidental removal of the pinna is usually associated with but comparatively little diminution in the acuteness of hearing.

The skin covering the auricle is thin and closely adherent. The subcutaneous tissue is scanty, and contains but very little fat. In inflammatory conditions of the surface, such as erysipelas, the pinna may become extremely swollen and very great pain be produced from the tenseness of the parts. The pinna and cartilaginous meatus are very firmly attached to the skull, so that the body, if not of great weight, may be lifted from the ground by the ears; but the experiment is cruel and dangerous.

The **external auditory meatus** is about $1\frac{1}{4}$ inches long. It is important to remember that the meatus is directed forwards as well as inwards; to reach and expose the middle ear the surgeon takes the posterior wall of the meatus as a guide. The external meatus, the promontory, the cochlea, and the internal meatus lie nearly in the same line. The canal has a vertical curve about its middle, with the convexity upwards. To straighten the canal for the introduction of specula and other instruments, the pinna should be drawn upwards and a little outwards and backwards. The osseous part forms a little more than one-half of the tube, and is narrower than the cartilaginous part.

In the infant at 1 year, a third only of the meatus is formed of bone; the rest is cartilaginous. In a child 5 or 6 years of age the bony and cartilaginous portions of the meatus are about of the same length (Symington). The narrowest portion of the meatus is about its middle. The outer orifice is elliptical, with its greatest diameter directed from above downwards; therefore specula should be elliptical in shape rather than round. The inner end of the tube, on the other hand, is slightly wider in the transverse direction. Owing to the obliquity of the membrana tympani, the floor of the meatus is longer than the roof. The cartilaginous segment of the tube presents many sebaceous glands that may be the seat of minute and very painful abscesses. It also presents numerous ceruminous glands, which secrete the cerumen of the ear, and which, when their secretion is excessive, may produce the plugs of wax that often block the meatus and cause deafness. In the cartilage of the floor of the meatus are certain fissures, fissures of Santorini. They are filled up with fibrous tissue. They permit of easier movement of the cartilaginous meatus. It is through these gaps in the cartilage that a parotid abscess may burst into the meatus. There are neither hairs nor glands in the lining of the bony part of the tube.

The skin of the meatus, when inflamed, may produce an extensive muco-purulent discharge, otitis externa. Polypi are apt to grow from the soft parts of the canal, and exostoses from its bony wall. Foreign bodies are frequently lodged in the meatus, and are often very difficult to extract. It would appear that in many cases more damage is done by the surgeon than by the intruding substance. Mason reports three cases where a piece of slate-pencil, a cherry-stone, and a piece of cedar-wood were lodged in the canal for respectively 40, 60, and 30 years.

The *upper* wall of the meatus is in relation with the cranial cavity, from which it is only separated by a dense layer of bone. Thus, abscess or bone disease in this part may possibly lead to meningitis. A case is reported where an inflammation of the cerebral membrane followed upon the retention of a bean within the meatus. The *anterior* wall of the canal is in relation with the temporomaxillary joint and with part of the parotid gland. This may serve in one way to explain the pain often felt in moving the jaw when the meatus is inflamed, although, at the same time, it must be remembered that movement of the lower maxilla produces a movement in the cartilaginous meatus, and that both the canal and the joint are supplied by the same nerve (the auriculotemporal). From its relation to the condyle of the jaw, it follows that this wall of the meatus may be fractured in falls upon the chin. Tillaux states that abscess in the parotid gland may spread into the meatus through the anterior wall of the passage. The *posterior* wall separates the meatus from the mastoid cells. Directly behind the posterior wall, at a distance of 12 or 15 mm., is the lateral sinus (Fig. 24). The *inferior* wall of the bony meatus is very dense and substantial, and corresponds to the vaginal and styloid processes.

Blood supply.—The pinna and external meatus are well supplied with blood by the temporal and posterior auricular arteries, the meatus receiving also a branch from the internal maxillary. In spite of this supply, the pinna is frequently the seat of gangrene from frost-bite. This is due to the fact that all the vessels are superficial and lie close beneath the surface, that the part is much exposed to cold, and that the pinna lacks the protection of a covering of fat. The same conditions predispose to gangrene of the nose from external cold. Bloody tumours (hæmatomata) are often met with on the pinna, and are common in boxers, football players, and lunatics. They are due to injury, and consist of an extravasation between the perichondrium and the cartilage.

Nerve supply.—The pinna is supplied by the auriculo-temporal, great auricular, and small occipital nerves (*see* Fig. 2, p. 11). The meatus is supplied mainly by the auriculo-temporal, with, in addition, a contribution from the auricular branch of the vagus (Arnold's nerve), which goes to the lower and back part of the canal, not far from its commencement. A sensory branch from the facial also ends in the meatus (Ramsay Hunt). The auricular branch of the vagus has been credited with a good deal in connexion with the nerve relations of the ear. After a heavy dinner, when the rose-water comes round, it is common to see the more experienced of the diners touch the lower part of the back of the ear with the moistened serviette. This is said to be very refreshing, and is supposed to be an unconscious stimulation of Arnold's nerve, a nerve whose main trunk goes to the stomach. Hence, this little branch has been facetiously termed "the alderman's nerve."

Ear coughing, ear sneezing, ear yawning.—It is not uncommon to have a troublesome dry cough associated with some mischief in the meatus. Sometimes the mere introduction of a speculum will make the patient cough. A case is reported in which a troublesome cough persisted for eighteen months, and at once ceased on the removal of a plug of wax from the ear. In such cases the irritation is conveyed to the respiratory and cough centres in the floor of the fourth ventricle by the auricular branch of the vagus. Gaskell has shown that the vagus also contains the dissociated visceral fibres of the fifth nerve. Hence. disturbances may be set up in the vagal nuclei through branches of the fifth nerve, such as the auriculo-temporal. The connexion of the nerves of the external auditory meatus with the vagal nuclei explains, too, the sneezing or vomiting which is sometimes caused by the presence of foreign bodies in the external meatus. The same nerve-connexion also explains the occurrence of repeated yawning, sometimes set up by ear ailments. Irritation conveyed along the inferior dental or lingual nerves may be referred along the auriculo-temporal. Hence the need to examine the tongue and lower teeth in cases of earache. Head has pointed out that disease of the ear, the tonsil, the tongue, or the lower jaw may be associated with an area of tenderness in the skin along and below the jaw.

It is a common practice to introduce ear-rings with the idea of relieving obstinate affections of the eye. The lobule is supplied by the great auricular nerve which springs from the second and third cervical nerves, while the eye is supplied by the ophthalmic division of the fifth. The centres with which these nerves are connected have a definite connexion, for the lower sensory nucleus of the fifth is a direct continuation upwards of the grey matter from which the posterior roots of the cervical nerves arise.

Hilton reports a case of obscure pain in the ear which was found to be due to an enlarged gland in the neck that pressed upon the trunk of the great auricular nerve.

Membrana tympani.—This membrane is very obliquely placed, forming with the horizontal an angle of 45°. At birth it appears to be more nearly horizontal, although it is not really so. Owing to the sloping downwards of the bony wall of the meatus at its inner end, that wall forms with the lower edge of the membrane a kind of sinus in

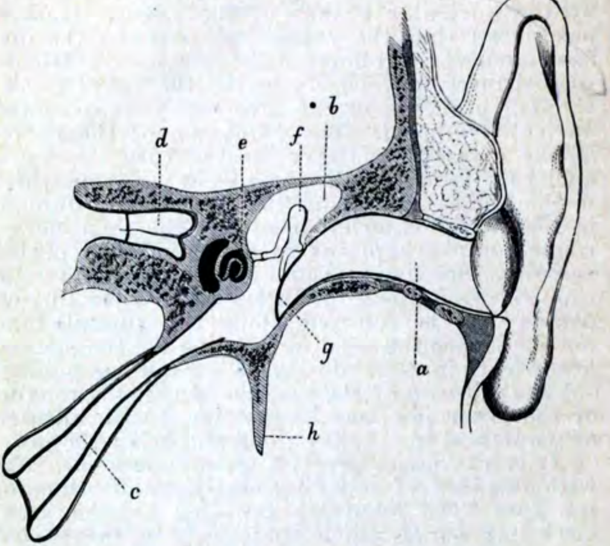

Fig. 22.—Section through the external meatus, middle ear, and Eustachian tube. (*Tillaux.*)

a, External auditory meatus ; *b*, attic of tympanum ; *c*, Eustachian tube ; *d*, internal auditory meatus ; *e*, cochlea ; *f*, ossicles ; *g*, membrana tympani : *h*, styloid process.

which small foreign bodies may readily lodge (Fig. 22). The ring of bone to which the membrane is attached is deficient at its upper and anterior part. The gap so formed is called the tympanic notch or notch of Rivini, and is occupied by loose connective tissue, covered by a continuation of the lining of the meatus, and through it pus may escape from the middle ear into the auditory canal without perforating the membrane. When the membrane gives way owing to a violent concussion transmitted through the air, it often gives way opposite the notch, its attachments here being obviously less secure than elsewhere. The membrane possesses but little elasticity, as shown by the very slight gaping of the part after it has been wounded. It is for this reason, among others, that perforations made in the membrane by the surgeon heal so very rapidly. The membrane has been ruptured during fits of sneezing, coughing, vomiting, etc. The same lesion has followed a box on the ear, and even simple concussions such as that produced by a loud report.

The *umbo*, or deepest point of the depression, is just below the centre of the entire membrane, and corresponds to the attachment of the end of the handle of the malleus. The rest of the handle can be seen through the membrane during life. The head of the malleus is in no connexion with the membrane, being situated in the *attic* of the tympanum above the level of the membrane (Fig. 22). The segment of the membrane above the umbo is very freely supplied by vessels and nerves; it corresponds to the handle of the malleus, and to the chain of ossicles, and is opposite to the promontory and the two fenestræ. The chorda tympani nerve also runs across this supraumbilical portion. The segment below the umbo, on the other hand, corresponds to no very important parts, and is less vascular and less sensitive. Paracentesis of the tympanum through the membrana tympani should therefore always be performed in the subumbilical segment. If performed above the umbo the knife may strike the incus and loosen that bone from its attachments, or the chorda tympani may be cut, which would give rise to a paralytic secretion of saliva. The malleus and stapes are too firmly attached to be readily detached.

The membrane is supplied by the stylo-mastoid artery and the tympanic branch of the internal maxillary, and obtains its nerve supply from the auriculo-temporal, facial, and vagus.

The tympanum.—The width of the tympanic cavity, as measured from its inner to its outer wall, varies from 2 to 4 mm., $\frac{1}{12}$ to $\frac{1}{6}$ of an inch. The narrowest part is that between the umbo of the membrana and the promontory. A fine rod

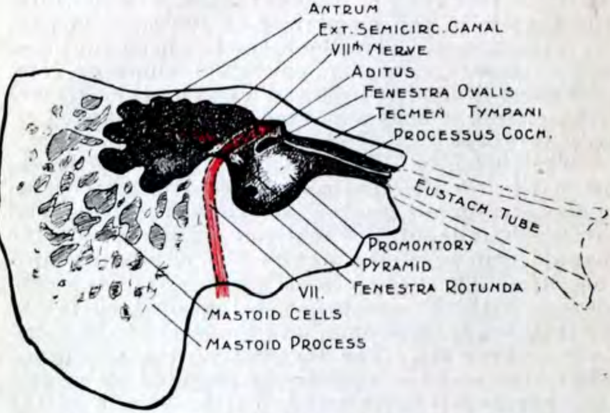

Fig. 23.—Inner wall of tympanum and antrum.
The position of the external semicircular canal and course of the facial nerve (vii.) are shown.

thrust through the centre of the membrana tympani would hit the promontory of the *inner wall* of the cavity. Above the promontory is the fenestra ovalis (fenestra vestibuli), and below and behind it the fenestra rotunda (fenestra cochleæ) (Fig. 23). Skirting the upper and posterior margin of the inner wall of the tympanum is the *facial canal* or aqueduct of Fallopius, containing the facial nerve. The wall of the aqueduct is so thin that inflammatory mischief can readily extend from the middle ear to the facial nerve. The *upper* *wall* or *roof* is very thin, and but little bone separates it from the cranial cavity. The suture between the squamous and petrous bones is found in this wall, and by means of the sutural membrane which separates the bones in the young, inflammatory changes may readily spread from the tympanum to the meninges. The petro-squamous suture unites at the end of the first year and usually contains the petro-squamous vein, a remnant of the primitive jugular. The *floor* is very narrow. Its lowest part is below the level of both the membrana tympani and the orifice of the Eustachian tube, and hence pus may readily collect in this locality (Fig. 23). It is separated by a thin piece of bone from the internal jugular vein behind, and from the internal carotid artery in front. Fatal hæmorrhage from the latter vessel has occurred in connexion with destructive changes in this part of the ear. The *posterior* wall in its upper part presents the opening or aditus of the *tympanic sinus* (antrum of the mastoid). This air sinus opens into the *attic*—that part of the tympanic cavity which is situated above the level of the membrana tympani (Fig. 24).

The **tympanic sinus (antrum of the mastoid)** (Figs. 22 and 24) lies above and behind the external auditory meatus. Implication of this space and of the mastoidal cells, which open into it and surround it, forms one of the most serious complications of middle-ear disease. It is large enough to contain a small bean, and is present at birth (Fig. 25), being developed with the cavity of the tympanum. It is closely surrounded by important structures. Its *roof*, formed by the tegmen tympani, a plate of bone only 2 mm. thick, separates it from the third temporal convolution. Small veins perforate the roof to join the petro-squamous vein, in the remnant of the suture of the same name. In the infant the communication is even more free, for this suture does not close until the end of the first year. The canal for the facial nerve passes downwards on its *inner* wall, where the antrum opens into the attic, and behind the facial nerve, also on the inner wall, is the external semicircular canal (Fig. 23). Facial paralysis or giddiness may follow operations on the antrum if the inner wall is injured. The superior and posterior borders of the meatus indicate the position of the facial nerve (Fig. 24); on the inner wall of the sinus or antrum the nerve is situated 14 to 22 mm. deep

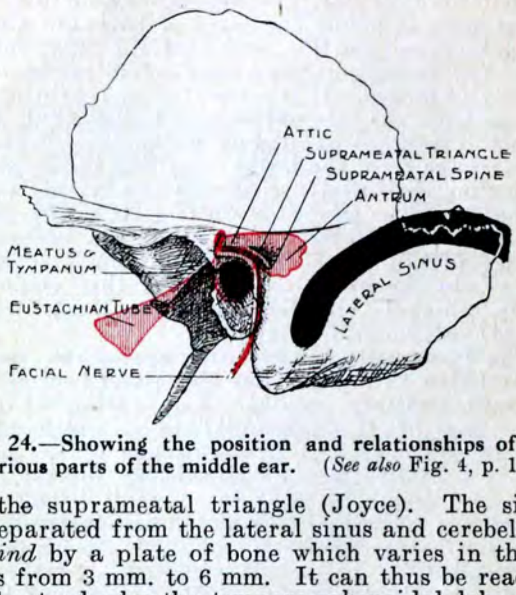

Fig. 24.—Showing the position and relationships of the various parts of the middle ear. (*See also* Fig. 4, p. 15.)

to the suprameatal triangle (Joyce). The sinus is separated from the lateral sinus and cerebellum *behind* by a plate of bone which varies in thickness from 3 mm. to 6 mm. It can thus be readily understood why the temporo-sphenoidal lobe, the lateral sinus, and the cerebellum should be the common seats of secondary infection in cases of middle-ear disease. At the mouth of the tympanic sinus and in the attic of the tympanum are situated the incus, the head of the malleus, and their ligaments, structures which may be diseased and require removal.

At birth the *outer* wall of the sinus is formed by the postmeatal process of the squamosal, a plate of bone 2 mm. thick (Fig. 25). In the child the antrum is comparatively superficial, and pus may easily escape or be evacuated. The suture between the postmeatal part of the squamosal and the petro-mastoid disappears in the second year of life, and so shuts off a possible route that pus may take to reach the surface (Fig. 25). The outer wall of the sinus steadily increases in thickness until

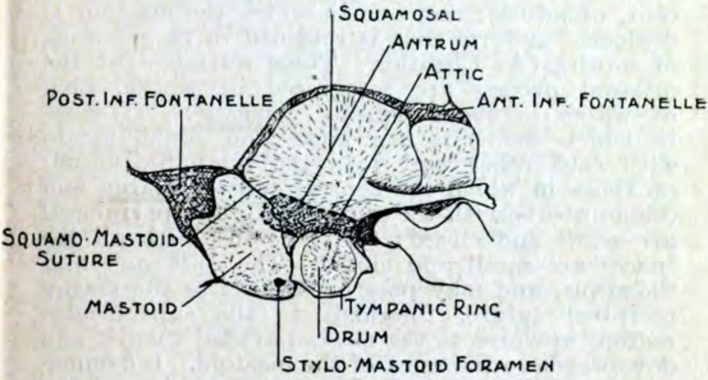

Fig. 25.—Temporal bone at birth.

The positions of the tympanic sinus or antrum and attic are indicated. The squamo-mastoid suture is open and the mastoid process undeveloped.

adult life, when the depth of the cavity from the surface of the bone is found to vary in different individuals from 12 to 22 mm., about 16 mm. being its average depth. A shallow triangle (*see* Fig. 24) above and behind the meatus lies directly over the antrum and serves as a guide to its position. It may also be reached by following the junction of the posterior wall and roof of the external auditory meatus. The drill is entered 5 mm. behind the meatus and on a level with its upper margin. Its roof lies 5 mm. above the level of the meatus. The posterior auricular artery passes upwards behind the meatus, beneath the concha of the auricle, and lies within the field of any operation on the middle ear.

The **mastoid cells** develop with the growth of the mastoid process, which appears as a definitely marked structure in the second year. Besides the sinus there are also some cells present in the outer wall at birth (Young). During infancy there are two types of mastoid: one in which the bone is dense—a form that persists in 1 per cent. of adults; and one in which the mastoid is diploetic—a form that is retained in 20 per cent. of adults (A. Cheatle). Three varieties of the mastoid process are recognized in adults, each of which is about equally common: (1) those in which the cells are large and communicate with each other and with the tympanic sinus; (2) those in which the central cells are large and communicate with the sinus, while the peripheral are small and closed; (3) those in which all the spaces are small and closed. The cells surround the sinus, and may pass backwards to the masto-occipital suture, forwards to the suprameatal region, upwards to the masto-parietal suture, and downwards to the apex of the mastoid. Inflammatory conditions may lead to a thickening of the walls of the mastoidal cells, and the bone may become so dense as almost to resist the chisel. Veins drain into the periosteal veins of the mastoid from the more superficial cells, and by these inflammation may reach the surface and give rise to œdema and swelling behind the ear.

In cases where the outer surface of the mastoid has been spontaneously perforated, a tumour, containing air, has appeared on the skull, and it has been observed that the tumour may be increased in size by forcing air into the ear through the Eustachian tube. Such tumours are known as **pneumatoceles**, and the process that leads originally to the perforation of the bone is of obscure nature. In some cases it seems to have been simply atrophic, and in other instances to have been due to "caries sicca."

On the *anterior* wall of the tympanum is the opening of the **Eustachian tube** (Figs. 22 and 23). This tube, 1¾ inches long, by opening into the pharynx serves to keep a proper supply of air in the tympanum, and so equalize the pressure upon the two sides of the membrane. The floor of the tympanum is below the level of the outer opening of the Eustachian tube. The line of direction of the tube lies almost exactly midway between the transverse and antero-posterior axes of the base of the skull. In the adult it inclines downwards, so as to form an angle of 40° with the horizontal. In the child this angle is only 10° (Symington). In adults three-fourths of the tube is cartilaginous and one-fourth bony (Symington). On the outer side lie the tensor palati, the third division of the fifth nerve, and the middle meningeal artery; on the inner side, the retropharyngeal tissue and (quite posteriorly) the internal carotid artery. The pharyngeal orifice of the tube is usually shut. During swallowing, however, it is opened by the action mainly of the tensor palati muscle. If the nose and mouth be closed and the cheeks blown out, a sense of pressure is produced in both ears. The hearing, at the same time, is dulled, and the change is due to the bulging out of the membrana tympani by the air thus forced into the tympanum. This method of inflating the middle ear is known as **Valsalva's method.**

In **Politzer's method** of passing air into the Eustachian tube, the patient's mouth is closed, while into one nostril the nozzle of a caoutchouc bag filled with air is introduced, and the nostrils are then held firmly closed. The patient is asked to swallow a mouthful of water, while at the same moment the bag is forcibly emptied, and the air, having no other means of escape, is thus driven into the open Eustachian tube. The surgeon listens for the little noise caused by the entrance of the air by means of a tube that passes between the patient's meatus and his own. Prolonged closure of the Eustachian tube leads to deafness, and thus impairment of hearing may follow upon great thickening of the mucous membrane of the tube due to the extension of inflammatory mischief from the pharynx. In the deafness associated with enlarged tonsils and postnasal growths the hypertrophic change extends to the mucous lining of the tube, and in many pharyngeal growths and nasal polypi the orifice of the tube is mechanically obstructed. The near relation of the pharyngeal end of the tube to the posterior nares serves to explain a case where suppuration in the mastoid cells followed upon plugging of the nares for epistaxis. Infection may be carried up to the middle ear by means of the ciliated lining of the Eustachian tube; C. J. Bond found that indigo particles, which had been blown within the nasopharynx, in a case of perforation of the drum, appeared afterwards in a discharge from the external meatus.

The upper edge of the pharyngeal orifice of the tube is about ½ an inch below the basilar process, ½ an inch in front of the posterior wall of the pharynx, ½ an inch behind the posterior end of the inferior turbinate bone, and ½ an inch above the soft palate (Tillaux). In the fœtus the orifice is below the hard palate; at birth, on the same level. The form of the opening is that of a triangle.

Just behind the elevation formed at the orifice of the Eustachian tube there is a depression in the wall of the pharynx, the pharyngeal recess or fossa of Rosenmüller (Fig. 27, p. 111). It may be mistaken for the orifice of the tube, and may readily engage the point of a Eustachian catheter. In cases in which the pharyngeal tonsil (Luschka's tonsil) is enlarged, this fossa on either side may be greatly deepened and made to form a narrow diverticulum. (*See* p. 167.) To pass the Eustachian catheter, the instrument is carried along the floor of the nares with its concavity downwards, "until its point can be felt to drop over the posterior edge of the hard palate into the pharynx. The instrument should now be withdrawn until its point can be felt to rise again on the posterior edge of the hard palate; having arrived at this point, the catheter should be pushed onwards about 1 inch, and during its passage its point should be rotated outwards through a quarter of a circle." This manœuvre should engage it on the orifice of the tube.

Blood supply of the tympanum.—The arteries supplying the tympanum are the tympanic of the internal maxillary and internal carotid, the petrosal of the middle meningeal, and the stylo-mastoid of the posterior auricular. The fact that some of the tympanic veins end in the superior petrosal and lateral sinuses gives another explanation of the frequent recurrence of thromboses of those channels in inflammatory affections of the middle ear. The petro-squamous vein, which crosses the roof of the middle ear, also receives branches from the tympanic sinus and attic, and joins the lateral sinus behind and the meningeal veins in front (Cheatle).

The **lymphatics** of the middle ear follow two routes. The majority pass along the wall of the Eustachian tube and end in the retropharyngeal lymphatic gland. Others reach the postauricular group of glands, situated over the mastoid process, by passing out beneath the lining membrane of the meatus and by other efferent channels which accompany the veins escaping by the superficial openings that are seen on the mastoid part of the temporal.

The **chorda tympani** nerve, from its exposed position in the tympanum, is very likely to be damaged in suppurative disease of the middle ear; and it has been shown that, when this nerve is involved, there may be a disturbance of the sense of taste, which is easily understood when one remembers that some of the nerves of taste reach the tongue by this route.

The **osseous labyrinth** is formed independently of the other bony parts of the ear. Portions of this labyrinth have necrosed and have been expelled in recognizable fragments. In a case recorded by Dr. Barr the whole of the osseous labyrinth (the cochlea, vestibule, and semicircular canals) was removed entire as a necrosed fragment from the auditory meatus. Suppuration of the middle ear may spread to the inner ear by invading the external semicircular canal—the most common route (Scott and West)—and eroding the promontory; by the fenestra ovalis, in which the footplate of the stapes is fixed by the strong annular membrane; or by the fenestra rotunda, which is closed by the membrana secundaria. When inflammatory infections spread to the inner ear, two series of symptoms result: (1) disturbances of hearing and deafness following the spread of inflammation and suppuration to the cochlea, through the perilymph system (scala vestibuli and scala tympani); (2) disturbances of balancing and co-ordination—vertigo and vomiting—from injury and destruction of the saccule, utricle, and ampullæ of the semicircular canals. The perilymph system of the inner ear gives only too easy a means for the spread of inflammation. From the inner ear the suppurative process may extend inwards along the auditory nerve and meatus, thus reaching the large subarachnoid spaces at the base of the brain. It may also reach the cranial contents by the aqueductus vestibuli or aqueductus cochlea, or by a perforation of the superior semicircular canal. Middle-ear disease may lead to the formation of a fistulous opening in the external semicircular canal. In such cases movements of the head may give rise to nystagmus, for reflex movements of the eyes are influenced by stimuli which arise in the maculæ of the semicircular canals (Sydney Scott).

CHAPTER VI

THE NOSE AND NASAL CAVITIES

The Nose

The **skin** over the root, and the greater part of the dorsum, of the nose is thin and lax. Over the alæ, however, it is thick, very adherent to the deeper parts, and plentifully supplied with sebaceous and sweat-glands. Inflammation of the integuments over the cartilaginous portion of the nose is apt to be very painful, and to be associated with much vascular engorgement. The pain depends upon the tenseness of the part, which prevents it from swelling without producing much pressure upon the nerves, while the engorgement depends upon the free blood supply of the region, and the fact that, the edge of the nostril being a free border, the circulation there is terminal, and apt therefore to favour congestion.

The great number of sebaceous glands about the lower part of the nose renders it a favourite spot for acne. It is here that the form of acne termed acne hypertrophica is met with—a condition that produces the appearance known as "grog blossoms." The nose, too, is frequently attacked by lupus, and it is over the dorsum of the nose that lupus erythematosus is most commonly met with. Rodent ulcer also is apt to appear in this region, especially in the fold between the ala of the nose and the cheek.

The integument of the nose is very well supplied with blood, and for this reason the part is well suited for the many plastic operations that are performed upon it. Wounds in this region heal kindly, and even the extensive wound made along the line between the nose and the cheek in removal of the upper jaw leaves very little deformity. In many reported cases portions of the nose have been entirely severed, and have united to the face on being immediately re-applied.

The skin over the root of the nose is supplied by the nasal branch of the first division of the fifth; as is also the skin over the alæ and in the region of the nostril (Fig. 2, p. 11). The greater part of the side of the nose is supplied by the second division of the fifth, and is the seat of pain in neuralgia of that trunk. The fact that the nasal nerve is a branch of the ophthalmic trunk, and has intimate connexions with the eye, serves to explain the lacrimation that often follows painful affections about the nostril, as, for example, when the edge of the nostril is pinched.

The **cartilaginous part** of the nose is often destroyed by lupus, by syphilitic ulceration, and other destructive affections. The parts so lost have been replaced by the various methods included under the head of rhinoplasty. It is well to bear in mind the limits of the cartilaginous segment of the nose, and to remember that in introducing a dilating speculum the instrument should not be passed beyond those limits. In the subjects of inherited syphilis the bridge of the nose is often found to be greatly depressed. This depends upon no actual loss of parts, but rather upon imperfect development from local malnutrition, that malnutrition following upon a severe catarrh of the mucous membrane. The deformity only occurs, therefore, in those who have had "snuffles" in infancy.

The **nasal bones** are often broken by direct violence. The fracture is most common through the lower third of the bones, where they are thinnest and least supported. It is rarest in the upper third, where the bones are thick and firmly held, and where, indeed, considerable force is required to produce a fracture. Since no muscles act upon the ossa nasi, any displacement that occurs is due solely to the direction of the force. Union takes place after these fractures with greater rapidity than perhaps obtains after fracture of any other bone in the body. In one case noted by Hamilton, "the fragments were quite firmly united on the seventh day." If the mucous membrane of the nose be torn, these fractures are apt to be associated with emphysema of the subcutaneous tissue, which is greatly increased on blowing the nose. The air in such cases is derived, of course, from the nasal fossæ. In fractures of the upper third of the ossa nasi the cribriform plate may be broken, but it is questionable whether this complication can occur when the fracture is limited to the lower third of the bones. The root of the nose is a favourite place for meningoceles and encephaloceles, the protrusion escaping through the suture between the nasal and frontal bones. Such protrusions, when occurring in this place, are often covered with a thin and vascular integument, and have been mistaken for nævoid growths.

THE NASAL CAVITIES

The **anterior nares** have somewhat the shape of the heart on a playing-card, and the aperture as a whole measures about 1¼ inches vertically, and a little less than 1¼ inches transversely, at its widest part. The plane of the nostril is a little below that of the floor of the nares. To examine the nasal cavities, therefore, the head should be thrown back and the nose drawn upwards. The anterior nares can be well explored by the finger introduced into the nostril, and the nasal apertures are just so wide on each side of the septum as to allow the finger to be passed far enough back to reach another finger introduced into the posterior nares through the mouth. An effectual way of removing soft polypi in the adult is by tearing them away by two fingers so introduced. The operation is a little rough. By the most gentle introduction of the finger into the nostril it is often possible to feel the end of the inferior turbinated bone. The anterior nares, and front of the nasal cavities, can be well explored by Rouge's operation. In this procedure the upper lip is everted, and a transverse cut made through the mucous membrane into the soft parts that connect the upper lip with the upper jaw. The incision extends between the second bicuspid teeth of either side. The soft parts connecting the upper lip and nose to the bone are divided without damaging the skin, and the flap is dissected up until the nares are sufficiently exposed.

Posterior nares.—If a little mirror, somewhat similar to that used in laryngoscopy, be cautiously introduced behind the soft palate through the mouth, and illumined from the mouth, the following parts may, in favourable circumstances, be seen, viz. the posterior nares, the septum, the middle turbinated bone (middle concha), part of the superior and inferior turbinated bones (conchæ), and part of the inferior meatus. The middle meatus is well seen, and also the Eustachian tube, and the mucous membrane of the upper part of the pharynx.

This mode of examination is very difficult to carry out, and is known as posterior rhinoscopy. The parts just named can all be felt by the finger introduced behind the soft palate through the mouth. The posterior nares are often plugged to arrest severe bleeding from the nose, and in order to cut a proper-sized plug it is desirable to bear in mind the dimensions of the apertures. Each aperture is of regular shape, and measures about $\frac{1}{2}$ an inch transversely by $1\frac{1}{4}$ inches in the vertical direction in a well-developed adult skull.

As regards the nasal cavities generally, it is well to note that the floor is wider at the centre than at either end, that the vertical diameter is greater than the transverse, and is also greatest about the centre of the fossæ Forceps introduced into the nose, therefore, are most conveniently opened if opened vertically. The width of the fossæ increases somewhat from above downwards; thus the superior turbinated bone is only 2 mm. from the septum, while a space of from 4 to 5 mm. intervenes between the inferior turbinated bone and the septum. The nasal cavity is so very narrow above the middle turbinated bone that

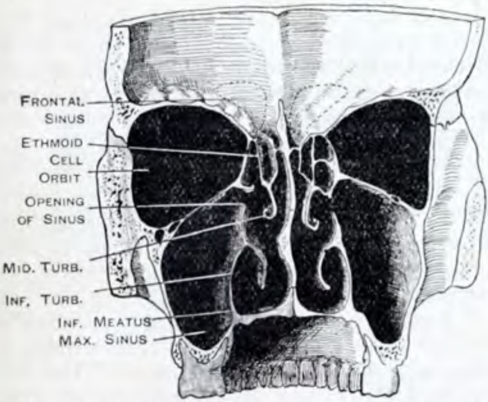

Fig. 26.—Transverse vertical section of the nasal cavities and accessory sinuses.

that bone really forms the surgical roof of the nasal fossæ.

The shape and proportions of the **nasal cavity in the child** are peculiar. In the adult the inferior meatus is large (Fig. 26), and constitutes the chief respiratory passage; in the young child the inferior meatus is relatively very small, the middle meatus affording the main space for the respiratory tide (Lack). The nasal cavities grow rapidly from the sixth to the eighteenth year; during this period the permanent dentition is being formed, necessarily causing an increase in the size of the palate and of the floor of the nose; at the same time the development of the maxillary sinus leads to an increase in the vertical height of the nose, this increase affecting the lower or maxillary much more than the ethmoidal or olfactory part of the cavity. Growth of the nasal cavities and of the face may be arrested or vitiated by any obstruction to the free passage of the breath through the nose; the most common cause of obstruction is the formation of adenoids in the naso-pharynx.

By referring to the relations of the nasal fossæ (Figs. 26, 27) it will be understood that inflammation of the lining membrane (coryza) may extend to the pharynx via the posterior nares; may extend up the Eustachian tube and cause some deafness; may reach the lacrimal sac and conjunctiva through the naso-lacrimal duct; and may extend to the frontal and maxillary sinuses, producing frontal headache and cheekache. These relationships are often demonstrated in a severe "cold in the head." From the nearness of the nasal fossæ to the cranial cavity it happens that meningitis has followed upon purulent inflammations of the nose. Micro-organisms which give rise to inflammation of the meninges of the brain apparently find their way from the mucous lining of the nose to the cranial cavity along minute blood- and lymph-vessels which traverse the cribriform plates with the olfactory nerves. Foreign bodies of various kinds are often lodged in the nose, and may remain there for some years. Thus, Tillaux reports the case of an old woman aged 64 from whose nose he removed a cherry stone that had been there for twenty years.

In washing out the nasal cavities with the "**nasal douche**" the fluid is introduced by means of a siphon. The nozzle of the siphon tube is introduced into one nostril, the mouth is kept open, and the fluid runs through that nostril, passes over the soft palate, and escapes from the other nostril. The latter cavity is therefore washed out from behind forwards. The course of the fluid depends upon the fact that when the mouth is kept open there is such a disposition to breathe through it alone that the soft palate is drawn up and the nares cut off from the pharynx.

The **roof** of each nasal fossa is very narrow, being only about ⅛ of an inch in width (Fig. 26). It is mainly formed by the thin cribriform plate, but its width is such that the danger of the roof being penetrated by so large an object as a pair of polyp forceps has been greatly exaggerated. The cranial cavity has, however, been opened up through the roof of the nose by penetrating bodies introduced by accident or with homicidal intent. Meningitis has followed inflammation of the nasal fossæ, the inflammation extending through the cribriform plate. Through the perineural and perivascular sheaths the lymphatic system of the nose is in continuity with that of the meninges, and by these channels infections may spread from the roof of the nose to the membranes of the brain. Fracture of this part also has been associated with very copious escape of cerebro-spinal fluid through the nostrils. A meningocele may protrude through the nasal roof. In a case reported by Lichtenberg the mass hung from the mouth, having passed through a congenital fissure in the palate. It was mistaken for a polyp, was ligatured, and death resulted from intracranial inflammation.

The **septum** is seldom quite straight in adults; the deviation being more often towards the left. It is, however, straight in children, and remains so up to the seventh year. In adults the septum deviates in 76 per cent. of all persons. The deviation may follow an injury. It has been pointed out that a deviation of the septum may seriously interfere with the singing voice. The nose also is seldom quite straight, and French authors ascribe this to some deviation of the septum, often dependent upon the practice of always blowing the nose with the same hand. If the deviation of the septum be considerable, it may more or less block one nostril, and, until the opposite nostril is examined, be mistaken for a septal tumour encroaching upon the cavity. The flattened nose in acquired syphilis is usually due to destruction of the septum and more or less implication of the adjacent bones.

Outer wall (Fig. 27).—The inferior nasal concha may interfere with the introduction of a Eustachian catheter if the curve of the instrument be too great. The anterior end of the bone is about $\frac{3}{4}$ of an inch behind the orifice of the nostril. The opening of the naso-lacrimal duct is about 1 inch behind the orifice of the nostril, and about $\frac{3}{4}$ of an inch above the nasal floor. This opening is usually slit-like and narrow. The nasal duct pierces the nasal mucous membrane in the same oblique and valvular manner as the ureter enters the bladder; hence the nose can be blown without inflation of the lacrimal sac. The height of the inferior meatus is about $\frac{3}{4}$ of an inch. The superior meatus is a very short and narrow fissure, and into its upper and fore part open the posterior ethmoidal cells. The middle meatus opens widely in front upon a part of the outer wall called the atrium, and, unless care be taken to keep the point of any instrument well towards the floor of the fossa, it is easier to pass the instrument into the middle than into the inferior meatus. Upon the wall of the middle meatus is a deep gutter (the *hiatus semilunaris*), which runs from above downwards and backwards (Fig. 27). Into this groove open the frontal sinus by means of the naso-frontal duct, about $\frac{1}{2}$ an inch long, the anterior ethmoidal cells, and, near its posterior end, the maxillary sinus. The rounded aperture of the frontal sinus is usually situated in the anterior end of the hiatus, but not infrequently it will be found in a recess above and in front of the hiatus. The anterior ethmoidal cells, usually two in number, may open into the hiatus the naso-frontal duct (infundibulum), or directly into the anterior part of the middle meatus. The opening of the maxillary sinus may occur below, instead of within, the posterior part of the hiatus semilunaris (Fig. 27). The upper boundary of the hiatus is formed by the bulla ethmoidalis; its lower sharp prominent margin contains the uncinate process of the ethmoid. The middle ethmoidal cell is seen to open

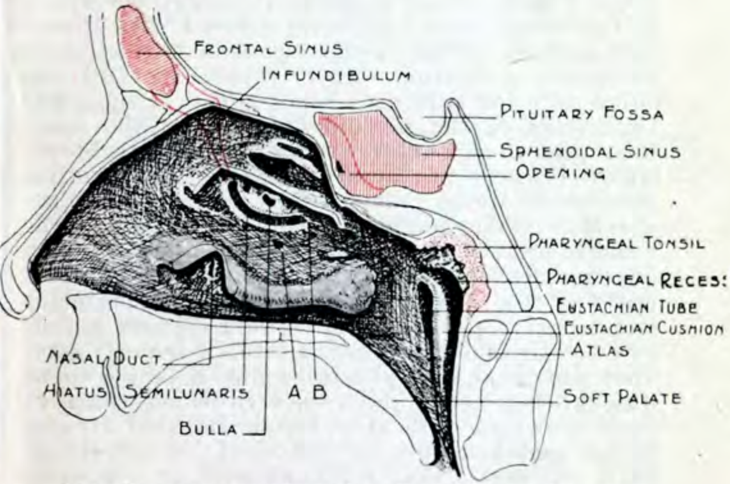

Fig. 27.—Outer or lateral wall of the nasal cavity.

The greater part of the middle turbinate process has been cut away to expose the hiatus, bulla, and opening of the infundibulum or naso-frontal duct and maxillary sinus. A, B, indicate the two positions at which the opening of the antrum may occur.

on the bulla, above the hiatus semilunaris. The level of the hiatus within the nose may be indicated by the position of the internal palpebral ligament. The anterior end or beak of the middle turbinate process can be seen distinctly from the anterior nares, when the interior of the nose is illuminated by reflected light.

The width of the nasal **floor** is about ½ an inch, or a little over. Its smooth surface greatly favours the passage of instruments (Fig. 26). It presents a gentle slope from before backwards. At its anterior part is a depression of mucous membrane over the incisor foramen. This foramen is a vestige of the great communication that once existed between the cavities of nose and mouth.

The **mucous membrane** lining the nasal cavities is covered with ciliated epithelium over the lower two-thirds or respiratory part; the upper third—the olfactory part—is covered with columnar epithelium, while the vestibule is lined with stratified epithelium. It is very thick and vascular over the turbinate bones and over the lower two-thirds of the septum, while over the nasal floor and in the intervals between the turbinate bones it is very much thinner. The mucous membrane lining the various sinuses and the antrum is conspicuously thin and pale. The membrane is provided with many glands, which are most conspicuous over the lower and hinder parts of the outer wall and over the posterior and inferior parts of the septum. These glands may be the subject of considerable hypertrophy. They are capable of providing also a very copious watery secretion, which has in some cases of chronic coryza following injury been so free as to be mistaken for an escape of cerebro-spinal fluid. There is also much adenoid or lymphoid tissue in the nasal mucous membrane, which is the primary seat of the chief scrofulous affections that invade this part. So thick and lax is the normal mucous membrane over the lower border and posterior extremity of the inferior turbinated bones, that it forms a kind of soft cushion, sometimes called the "turbinate body." This condition is mainly due to the presence of a rich submucous venous plexus, the vessels of which run, for the most part, in an antero-posterior direction. When turgid with blood it swells so as to obliterate the interval between the bone and the septum. When the seat of chronic inflammation, the mucous membrane over the inferior bone may appear as a polypoid swelling. The inspired air is heated as it passes over the rich vascular lining membrane of the nose; it is also filtered, the dust and other floating particles being deposited on the moist surface of the conchæ.

Polypi are often met with in the nose. They are of two kinds, the mucous or myxomatous polyp that springs usually from the mucous membrane beneath or over the middle concha, and the fibrous or sarcomatous polyp that usually takes origin from the periosteum of the nasal roof or from that of the base of the skull. Polypi of the latter kind spread in every available direction. They expand the bridge of the nose, close the nasal duct and cause epiphora, depress the hard palate and encroach upon the mouth, invade the antrum and expand the cheek, grow down into the pharynx, pushing forwards the velum palati, and may penetrate even through the inner wall of the orbit. Such tumours may be exposed and removed by separating the posterior and inner attachments of the superior maxilla, turning it forwards, thus exposing the nasal cavity by detaching its outer wall. The bone may be replaced *in situ* after removal of the tumour.

The **blood supply** of the nasal cavity is extensive, and is derived from the internal maxillary, ophthalmic, and facial arteries. With regard to the veins, it may be noted that the ethmoidal veins that come from the nose enter the ophthalmic vein, while it is believed by some authorities that in children a constant communication exists between the nasal veins and the superior longitudinal sinus through the foramen cæcum, and that this communication may be maintained in the adult. These connexions would, in part, explain the occurrence of intracranial mischief as a consequence of certain inflammatory affections of the nasal cavities. Bleeding from the nose, or **epistaxis**, is a common and often a serious circumstance. Its frequency is to a great extent due to the vascularity of the mucous membrane, to its laxity, and to the fact that the veins, especially those over the lowest (maxillary) turbinate bone, form extensive plexuses, and produce a kind of cavernous tissue. The epistaxis is often due, therefore, to interference with the venous circulation, as seen in cases of cervical tumour pressing upon the great veins, in the paroxysms of whooping-cough, and the like. The beneficial effect of raising the arms in epistaxis is supposed to depend upon the extra expansion of the thorax so produced, and the aspiratory effect thus brought to bear upon the cervical veins. The bleeding may be copious and long continued. Thus, Spencer Watson reports a case where the epistaxis continued on and off for twenty months without obvious cause. Martineau mentions an instance in which 12 lb. of blood was lost in sixty hours, and Fraenkel records a case where 75 lb. of blood is said to have escaped from first to last. In several instances the hæmorrhage has proved fatal. The seat of the bleeding is often not easy to detect, even when the examination is post mortem. In many cases the bleeding-point is situated on the septum, ½ an inch above and behind the nasal spine.

The **nerve supply** of these parts is derived from the olfactory nerve, and from the first and second divisions of the fifth nerve. The lacrimation that often follows the introduction of irritants into the nares may be explained by the fact that that part of the cavity is supplied freely by the nasal nerve, a branch of the ophthalmic trunk. As an example of transference of nerve force in the opposite direction may be noted cases where a strong sunlight falling upon the eyes has produced an attack of sneezing. Troubles involving the vagal centres, such as cough and bronchial asthma, have followed affections of the nasal cavities; relief from these troubles has been obtained by cauterization and anæsthetization of the mucous membrane over the inferior concha. The olfactory nerves are situated in the upper third of the cavity, and hence, in smelling intently, one sniffs deeply and dilates the nostril. The inability to dilate the nostril in facial paralysis may explain the partial loss of smell sometimes noted in such cases. Anosmia, or loss of the sense of smell, when following upon an injury to the head, may be due to a rupture of the olfactory nerve fibres as they pass through the cribriform foramina. The olfactory roots cross the edge of the lesser wings of the sphenoid, and in falls on the forehead are liable to injury. The olfactory centre is situated in the hippocampal gyrus.

Most of the **lymphatics** of the nasal fossæ enter the retropharyngeal glands placed behind the pharynx, in front of the rectus capitis anticus major. Hence, as Fraenkel has pointed out, "retropharyngeal abscess may arise in consequence of diseases of the nose." Other lymphatics go to the submaxillary, parotid, and upper deep cervical lymph-glands, and it is common to find these enlarged in nose affections, especially in the scrofulous. The lymphatics of the nose also communicate with those of the meninges through the cribriform plate.

Nasal sinuses.—Of late years a knowledge of the anatomy and relationships of the accessory sinuses of the nose has become of the utmost importance to the surgeon. Over 15 per cent. of the subjects examined in the dissecting room of the London Hospital show disease of one or more of these sinuses; Sir StClair Thomson estimates that the sphenoidal sinus is the seat of disease in 30 per cent. of aged individuals. The collective capacity of the accessory sinuses—the maxillary, frontal, sphenoidal, and ethmoidal—is more than twice that of the nasal cavity (Braune). No satisfactory explanation has yet been found of their use, except to give mass without adding to the weight of the face. They may, as Dr. James Adam has supposed, aid in rendering the inspired air warm and moist.

The **frontal sinus** is extremely variable in size and shape. The surface markings shown in Fig. 28 indicate the average development in the adult; the opening of the fronto-nasal duct or infundibulum is shown in Fig. 27. Large frontal sinuses do not necessarily imply large external prominences

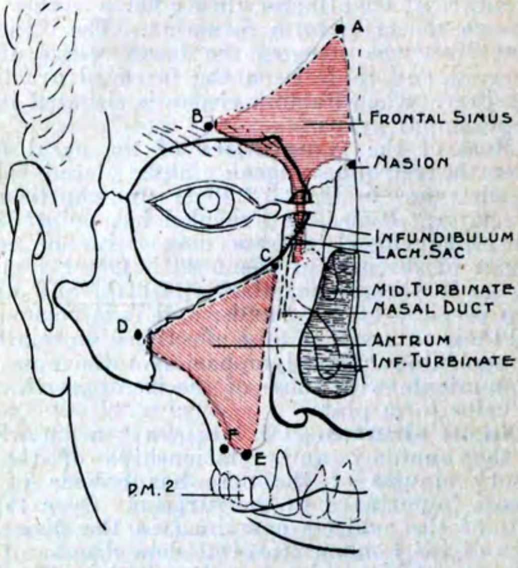

Fig. 28.—Surface markings of the frontal and maxillary sinuses.

A, 1¼″ above the nasion; B, on the supraorbital margin, at the junction of the middle and outer thirds; C, on the infraorbital margin to the outer side of the lacrimal sac; D, on the centre of the cheek-bone in line with the outer margin of the orbit; E, over the second bicuspid; F, over the last molar. The points A, B, and Nasion give the surface position of the frontal sinus; C, D, E, F, that of the maxillary sinus.

over the glabella and superciliary eminences. One sinus may develop at the expense of the other, and the septum may be displaced. They are larger in men than in women. They are absent on one side in 9 per cent. of cases, and on both sides in 7 per cent. (Logan Turner). It is obvious that a depressed fracture may exist over a frontal sinus without the cranial cavity being damaged. In such cases the inspissated contents of the sinus have been mistaken for brain matter escaping. Since the sinuses are in communication with the nose, much emphysema may follow upon the fracture of the sinus wall. Insects have found their way into these cavities. "Centipedes are particularly liable to be found in the frontal sinuses, where they may remain for years, the secretions of these cavities furnishing them with sufficient nourishment" (Fraenkel). Larvæ have also been found here, and maggots that have developed within the nose have managed to make their way to the frontal sinuses.

The frontal sinus is merely a bud or rudiment in early childhood. About the sixth year the bud of mucous membrane grows out from the neighbourhood of the anterior end of the hiatus, and gradually insinuates its growing extremity into the diploë of the frontal bone, separating the inner from the outer osseous table. It reaches its full size about the twenty-fifth year; the stalk of the outgrowth becomes the fronto-nasal duct; it leads from the posterior part of the sinus. The duct is $\frac{3}{4}$ of an inch long, and runs downwards and slightly backwards to open at or near the anterior end of the hiatus semilunaris. Along the hiatus the secretion of the frontal sinus may be conveyed to the antrum, thus converting that cavity into a cesspool in cases of chronic suppuration of the frontal sinus (Fig. 27). The fronto-nasal duct is frequently tortuous, and even after the beak of the middle turbinate process is removed it is not easy to catheterize from below. Hence, in cases of obstruction, the frontal sinus is trephined over the glabella, or at the superior internal angle of the orbit (Tilley), and a probe passed downwards and slightly backwards to drain the sinus into the nose.

The anterior ethmoidal cells commonly open into the fronto-nasal duct, and hence they are usually involved in any disease affecting the frontal sinus. The frontal diploic vein, which joins the frontal vein at the supraorbital notch, receives blood from the frontal sinus. In cases of frontal suppuration, infection may spread rapidly in the frontal bone by means of the veins of the diploë, setting up a destructive form of osteitis and meningitis.

The **sphenoidal sinus** opens on the roof of the nose, behind the superior meatus (Fig. 27); it is developed at the same period of life as the frontal sinus. It is deeply placed, and not very accessible for operation when the seat of disease. It is frequently the seat of chronic suppuration set up by infections from the nose. Its anterior wall, which is comparatively thin, is situated between 7 and 8 cm. from the lower margin of the anterior nares. Tilley recommends the mid-point of the lower border of the middle turbinate as a guide to the opening of the sphenoidal sinus. The nasal septum also serves as a safe guide, for its vomerine part is implanted on the anterior wall of the sinuses. A probe directed to this point from the floor of the anterior nares will, if passed straight onwards, reach the opening of the sinus at the depth mentioned above—7 to 8 cm.

In close contact with the thin lateral wall of this sinus there are certain extremely important structures. Besides the cavernous sinus and internal carotid artery, the optic nerve and second division of the fifth nerve are in the closest contact, and may be affected in sinusitis (Fig. 32, p. 131). On the roof is the pituitary body; tumours of this body may invade the sinus. Its veins join the ethmoidal. The walls of the sinuses are thin and easily perforated, as a case which occurred at the London Hospital will show. A man stumbled forwards on his umbrella as he left a public-house in Whitechapel, the point entering his face above the bicuspid teeth. He walked to the hospital, and died three days afterwards. The ferrule of the umbrella was found embedded in the pons, the point having traversed the maxillary and sphenoidal sinuses.

The **maxillary sinus (antrum of Highmore)** exists at birth, but attains its largest dimensions in old age. The surface markings for indicating its position on the face are given in Fig. 28. The walls of the cavity are thicker in children than in adults. Tumours of various kinds are apt to develop in this cavity, and to distend its walls in various directions. Thus the growth breaks through the thin inner wall and invades the nose, it pushes up the roof of the cavity and invades the orbit (*see* Fig. 26, p. 107), it encroaches upon the mouth through the floor of the sinus, and makes its way also through the somewhat slender anterior wall into the cheek. The densest part of the sinus wall is that in relation to the malar bone, and this part does not yield. There is little inducement for any growth to spread backwards, although it sometimes invades the zygomatic and pterygo-maxillary fossæ. As the infraorbital nerve runs along the roof of the sinus, while the nerves of the upper teeth are connected with its walls, these structures are pressed upon in growths springing from the sinus, and thus neuralgia of the face and teeth is often produced. In individuals who have suffered from adenoids the growth of the sinus is arrested.

In the operation of tapping the antrum a spot is usually selected just above the second bicuspid tooth, since the bone is here thin and is conveniently reached. In some cases it is sufficient to extract one of the molar teeth, since the fangs of these often enter the cavity of the sinus. The tooth usually selected is either the first or the third molar. Not infrequently the sinus communicates at its upper anterior part with the frontal sinus. From Fig. 26 it will be seen that the antra descend below the level of the palate, and cannot be efficiently drained by an opening made above the palatal level.

The opening of the maxillary sinus is shown in Figs. 26, 27; it is on a level with the roof of the cavity: hence if pus be present it drains most freely when the head is turned so that the affected chamber is uppermost. The sphenoidal sinus empties most easily when the head is bent forwards; the frontal, when the head is thrown backwards. The cavity of the antrum is small if the inferior meatus is large or if the canine fossa of the face is well marked. The lymphatics of the sinuses drain into the retropharyngeal glands. As the result of a fall, one of the upper teeth has been entirely driven into the antrum and lost to view. In one case an upper incisor was found lying loose in the antrum three and a half years after the accident that had driven it there.

CHAPTER VII

THE FACE

THE parts of the face, other than those already dealt with, will be considered under the following heads:

1. The face generally.
2. The parotid region.
3. The upper and lower jaws, and parts connected with them.

The lips will be considered with the cavity of the mouth (Chap. VIII.).

1. THE FACE GENERALLY

The **skin** of the face is thin and fine, and is more or less intimately adherent by a delicate subcutaneous tissue to the parts beneath. The skin generally is very freely supplied with sebaceous and sudoriparous glands, and hence the face is frequently the seat of acne, an eruption that especially involves the sebaceous follicles. From the thinness of the skin, and from the absence of dense fasciæ, facial abscesses usually soon point and seldom attain large size.

The **cellular tissue** of the face is lax, and readily lends itself to spreading infiltrations, so that in certain inflammatory affections the cheeks and other parts of the face may become greatly swollen. In general dropsy, also, the face soon becomes "puffy," the change first appearing as a rule in the lax tissue of the lower eyelid. The skin over the chin is peculiarly dense and adherent to the parts beneath, and in most respects closely resembles the integument of the scalp. When such parts of the integuments of the face as cover prominent bones, such as the malar bone, chin, and the supraorbital margin, are struck by a blunt instrument or in a fall, the wound produced has often the appearance of a clean incised wound, just as obtains in contused wounds of the scalp.

The mobility of the facial tissues renders this part very suitable for the performance of plastic operations of various kinds, and their vascularity generally ensures a ready and sound healing. Although there is a large quantity of fat in the subcutaneous tissue of this region, fatty tumours are singularly rare upon the face. They appear, indeed, to avoid this region. Thus, M. Denay reports the case of a man who had no fewer than 215 fatty tumours over different parts of his body, but not one upon his face. The face is peculiarly liable to be the seat of certain ulcers, especially rodent and lupous ulcers, and is the part most often attacked by malignant pustule (anthrax), a disease transmitted to man from cattle afflicted with a malady known in this country as splenic fever, and in France as *charbon*.

Blood supply.—The tissues of the face are very vascular, and are liberally supplied with blood-vessels in all parts. The facial arterioles have a particularly rich supply of vaso-motor nerves, which are derived from the sympathetic system, reaching the facial artery through the superior cervical ganglion. In blushing, the vaso-dilator fibres are stimulated by an emotional disturbance. The finer vessels of the skin often appear permanently injected or varicose in the drunken, or in those who are much exposed to cold, or are the subjects of certain forms of acne. Nævi and the various forms of erectile tumour are common about the face. For a like reason also wounds of the face, while they may bleed readily when inflicted, are apt to heal with singular promptness and accuracy. All wounds, therefore, of this part should have their edges carefully adjusted as soon after the accident as possible. Extensive flaps of skin that have been torn up in lacerated wounds often retain their vitality in almost as marked a manner as do like flaps torn from the scalp. Extensive injuries to the face associated with great loss of substance are often repaired in a remarkable manner, and such injuries may not be immediately fatal, as a case reported by Longmore shows: "An officer of Zouaves, wounded in the Crimea, had his whole face and lower jaw carried away by a ball, the eyes and tongue included, so that there remained only the cranium, supported by the neck and spine." He lived twenty hours.

The pulsations of the facial artery can be best felt at the lower border of the jaw, where the vessel crosses just in front of the anterior border of the masseter muscle. It is here covered only by the integument and the platysma, and can be readily compressed against the bone or ligatured. The anastomoses of the artery upon the face are so free that, when the vessel is divided, both ends, as a rule, require to be secured. The facial vein is only in contact with the artery near the lower border of the jaw; on the face it is separated from it by a considerable interval. The vein is not so flaccid as are most superficial veins; it remains more patent after section, it possesses no valves, and communicates at one end indirectly with the cavernous sinus, and at the other with the internal jugular vein in the neck. This vein has also another, but less direct, communication with the intracranial veins. It is as follows: the facial vein receives the "deep facial vein" from the pterygoid plexus, and this plexus communicates with the cavernous sinus by means of some small veins which pass through the foramen ovale and the fibrous tissue of the foramen lacerum medium. These dispositions of the facial vein may serve to explain the mortality of some inflammatory affections of the part. Thus, carbuncle of the face is not infrequently fatal by inducing thrombosis of the cerebral sinuses, and a like complication may occur in any other diffuse and deeply extending inflammatory condition.

A reference to the development of the face assists to explain the distribution of the fifth nerve and the occurrence of certain abnormalities (Fig. 29). The face is developed from five processes, a mesial, the fronto-nasal, and two lateral —the maxillary and mandibular. The fronto

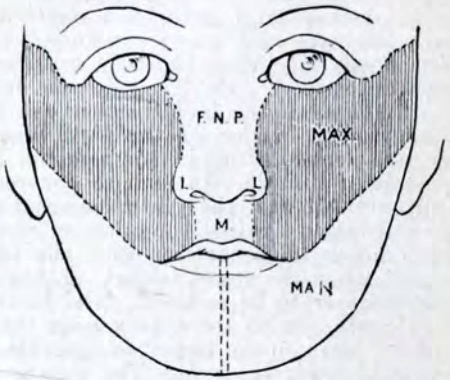

Fig. 29.—Showing the development of the face.

F.N.P., Part formed from the fronto-nasal process ; L., from its lateral, and M., from its mesial parts ; MAX., formed by the maxillary process ; MAN., formed by the mandibular process.

nasal process forms the middle part of the upper lip and the nose. It may fail to develop : thus the condition of cyclops is produced. It springs from the frontal region and carries with it a branch of the first division of the fifth, the nasal nerve. The second division of the fifth is the nerve of the maxillary process, while the third is that of the mandibular.

Nerve supply.—The nerves of the face are very liberally distributed, the fifth being the sensory nerve, the facial the motor (Fig. 2, p. 11). It follows, from the great number of nerve filaments about the part, and the extensive sensory nucleus of the fifth nerve, that severe irritants applied to the face may set up a widespread nerve disturbance (Fig. 31, p. 129). Dr. George Johnson mentions a case where a piece of flint embedded in a scar on the cheek set up facial neuralgia, facial paralysis, and trismus, and induced a return of epileptic attacks.

The positions of the supra- and infraorbital foramina and of the mental foramen and of the exit of the corresponding nerves are indicated as follows: The supraorbital foramen is found at the junction of the inner with the middle third of the upper margin of the orbit. A straight line drawn downwards from this point so as to cross the gap between the two bicuspids in both jaws will cross both the infraorbital and mental foramina. The infraorbital foramen is a little over $\frac{1}{4}$ of an inch below the margin of the orbit. The mental foramen in the adult is midway between the alveolus and the lower border of the jaw, and is a little over $\frac{1}{4}$ of an inch below the cul-de-sac of mucous membrane between the lower lip and jaw. At puberty the foramen is nearer to the lower border of the maxilla, and in old age it is close to the alveolus. The **infraorbital nerve** has been divided for neuralgia at its point of exit, the nerve being reached either by external incision or through the mouth by lifting up the cheek. In other cases the floor of the orbit has been exposed, the infraorbital canal (the anterior half of which has a bony roof) has been opened up, and large portions of the trunk of the nerve have been in this way resected. The **spheno-palatine** (**Meckel's ganglion**) has been repeatedly excised for the relief of neuralgia involving the second division of the fifth nerve. A triangular flap of skin is turned up from the front of the cheek, and the infraorbital foramen is exposed. The anterior wall of the antrum is opened with a trephine, and the bone is cut away from the floor of the infraorbital groove so that the nerve lying in that canal is fully exposed. The nerve is followed back to the posterior wall of the antrum. This wall having been trephined, the spheno-maxillary (pterygopalatine) fossa is opened up and Meckel's ganglion exposed (Fig. 30). Beyond the ganglion the foramen rotundum can be made out. The infraorbital artery runs with the nerve, and that vessel, to-

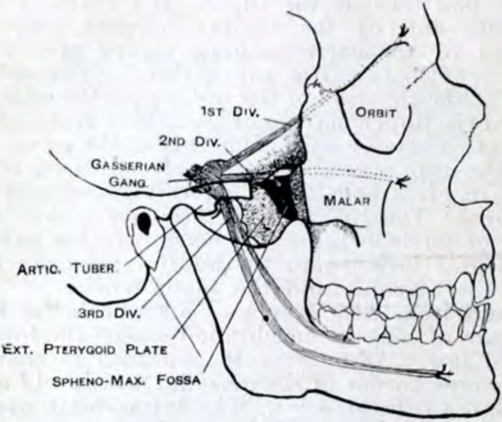

Fig. 30.—Surface markings for the second and third divisions of the fifth nerve.

gether with its anterior dental branch to the incisor and canine teeth, will probably be divided. The infraorbital vein ends in the pterygoid plexus. The ganglion is surrounded by the terminal branches of the internal maxillary artery. It is a triangular body, with a diameter of about ¼ of an inch. It is a little convex on its outer side, and is of reddish colour.

Operations such as that just described serve to recall the relationship of parts, but in practice they are now replaced by the simpler means of *hypodermic injections.* Absolute alcohol, introduced into the trunk of a nerve, produces anæsthesia in the area of its distribution for six months or more. The successful performance of such injections requires a very accurate knowledge of the position and course of the nerves, and also of surrounding structures. The course of the second division of the fifth nerve is shown in Fig. 30. A point on the upper border of the zygoma, 6 mm. (¼ inch) behind the ascending margin of the malar, lies directly over the upper part of the spheno-maxillary fossa which contains the second division of the fifth nerve and Meckel's ganglion. To reach the nerve the needle has to be introduced 37 mm. (1½ inches). An easier and safer route is along the floor of the orbit. The needle is inserted at the mid-point of the lower border of the orbit, and pushed backwards along the floor, parallel to the sagittal plane of the head. The needle is pushed within the spheno-maxillary fossa until it is arrested by coming in contact with the sphenoid at or near the foramen rotundum. By suitable manœuvring the needle can be felt to enter the foramen rotundum. The depth of the foramen rotundum from the margin of the orbit is 43 mm. (1¾ inches). The nerve may also be reached by introducing the needle at the upper border of the zygoma just behind the malar angle, and directing it inwards. The ganglion lies at a depth of 50 mm. (2 inches) from the surface (Symington).

The **inferior dental nerve** has been divided at the mental foramen by an incision made through the buccal mucous membrane opposite to the roots of the two premolar teeth. Through this incision the nerve can be stretched and the cutaneous portion of it excised. The nerve has been divided in the following manner before its entry into the mandibular (inferior dental) foramen: The mouth being held widely open, an incision is made from the last upper molar to the last lower molar just to the inner side of the anterior border of the coronoid process, which can be clearly defined by palpation. The cut passes through the mucous membrane down to the tendon of the temporal muscle. The finger is introduced into the incision, and passed between the ramus of the jaw and the internal pterygoid muscle until the bony point is felt that marks the orifice of the mandibular (inferior dental) canal. The nerve is here picked up with a hook, isolated, and divided.

The **buccal nerve** supplies the mucous membrane and skin of the cheek. It passes forwards on the outer surface of the buccinator muscle.

The **trunk of the third division of the fifth nerve** leaves the middle fossa of the skull by the foramen ovale, the position of which corresponds to the lower border of the zygoma immediately anterior to the eminentia articularis (Fig. 30). To inject the trunk of the nerve, the needle is entered at this point and guided inwards against the under surface of the sphenoid until a depth of 37 mm. ($1\frac{1}{2}$ inches) is reached. Sensations referred along the nerve will tell the operator if the nerve has been reached. It is well to direct the needle a little forwards as well as inwards, for it will be then arrested by the external pterygoid plate; at the posterior border of this plate lies the foramen ovale. It is also possible, by directing the needle in a more upward and backward direction, to enter the foramen ovale and reach the Gasserian (semilunar) ganglion itself (*see* Fig. 32).

When a **sensory nerve is divided,** the area of analgesia which results does not correspond to its anatomical distribution. Thus, when the ophthalmic division of the fifth cranial nerve is cut, only a narrow strip of skin on the forehead is completely deprived of feeling, whereas from the anatomical distribution one would infer that the skin of the forehead and of the anterior half of the scalp would be involved (*see* Fig. 2, p. 11). If the second division is cut, the area of anæsthesia is confined to a narrow space between the orbit and the mouth; on section of the third division, to a strip running downwards in front of the ear and along the course of the lower jaw (Head).

Head has offered an explanation of the varying results which follow section of a sensory nerve. A nerve contains three kinds of sensory nerve fibres: (1) those subserving **deep sensibility**—endowing muscles, bones, ligaments, joints, and deep structures with the power to feel pressure and

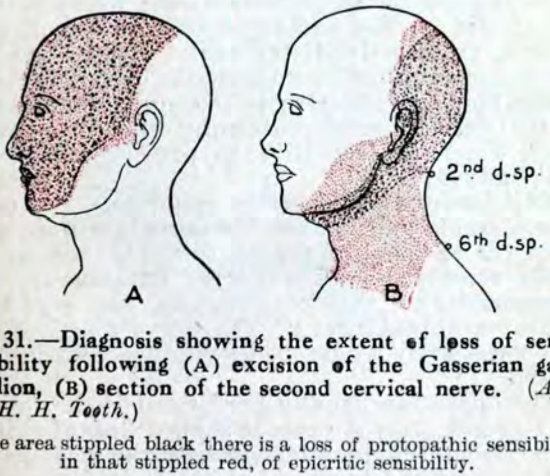

Fig. 31.—Diagnosis showing the extent of loss of sensibility following (A) excision of the Gasserian ganglion, (B) section of the second cervical nerve. (*After H. H. Tooth.*)

In the area stippled black there is a loss of protopathic sensibility: in that stippled red, of epicritic sensibility.

pain; (2) those subserving **protopathic sensibility**—by which the skin is rendered sensitive to prick, and to temperature if it be above 40° or below 22°; (3) those subserving **epicritic sensibility**—by which the skin is endowed with the power of feeling light touch (tested with such a substance as cotton-wool) and finer degrees of temperature. Now, in the majority of instances, when a nerve is divided, the loss of epicritic sensibility corresponds in extent to the anatomical distribution of the nerve; when the semilunar or Gasserian ganglion is removed (*see* Figs. 2 and 31), the loss of epicritic sensibility corresponds to the area of distribution, but the loss of protopathic sensibility is less than the anatomical area. It is evident that protopathic fibres from the second cervical nerve (Fig. 31) invade and supply the area of skin furnished with epicritic sensibility by the fifth nerve. In the lower part of the face there is no overlapping of areas; in the mental branch of the fifth, the epicritic and protopathic fibres are distributed to the same extent of skin. Thus the effects which follow section of a sensory nerve depend on the nature of the fibres in that nerve, and on the extent of skin to which each kind is exclusively distributed. Even after the semilunar ganglion is excised, the deep structures of the face are sensitive to pressure; that is due to the facial nerve containing certain afferent fibres which are sensitive to pressure (Maloney and Kennedy).

Excision of the Gasserian ganglion.—For cases of intolerable and intractable neuralgia Rose proposed the excision of the semilunar ganglion. It is the sensory ganglion of the fifth nerve, and corresponds to the ganglion on the posterior root of a spinal nerve. The nerve fibres of the fifth necessarily undergo degeneration when it is excised.

The operation usually performed is the following (*see* Fig. 32): An omega-shaped flap of skin is raised from the temples, having the zygoma at its base and the temporal ridge at its convexity. The tissues are reflected down to the floor of the temporal fossa. The superficial and deep temporal vessels have to be tied. A wide trephine opening is made in the squamosal and great wing of the sphenoid on a level with the upper border of the zygoma, and the dura mater exposed. This is usually followed by profuse hæmorrhage from the middle meningeal vessels which cross the field of operation. The dura mater and the superimposed temporo-sphenoidal lobe are raised from the bone, when the third and second divisions of the fifth nerve are brought into view as they escape by the foramen ovale and foramen rotundum. They are seen to spring from the ganglion situated over the apex of the petrous bone and on the outer wall of the cavernous sinus. The motor root which supplies the muscles of mastication lies under the ganglion and should not be cut. The ganglion is embedded in the dura mater and surrounded by a prolongation of the subarachnoid

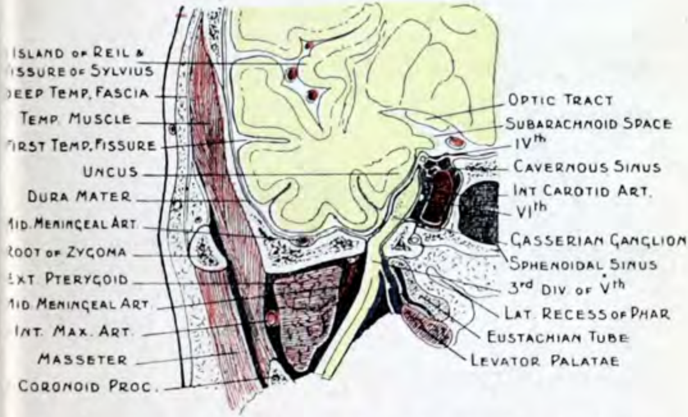

Fig. 32.—Coronal section to show the depth and relationships of the Gasserian or semilunar ganglion.

space (Meckel's space), which is necessarily opened. Only the part of the ganglion connected with the second and third divisions is removed, the part connected with the ophthalmic division being left, as it is firmly embedded in the outer wall of the cavernous sinus and in close proximity to the internal carotid artery and the oculo-motor nerves. The hippocampal convolution containing the olfactory centre lies immediately over the ganglion (Fig. 32). There is always an escape of cerebro-spinal fluid when the dural sheath is opened (Cushing).

The eminentia articularis at the base of the zygoma serves as a useful guide to the position of the ganglion; when the middle fossa is opened and the temporal lobe raised up, the ganglion will be found at a depth of $2\frac{1}{4}$ inches and in the same

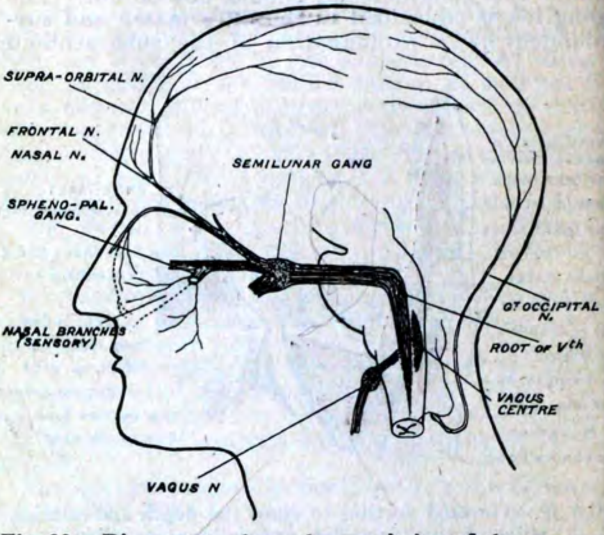

Fig. 33.—Diagram to show the proximity of the sensory nuclei of the fifth and tenth cranial and first and second cervical nerves. (*After Pegler.*)

coronal plane as the articular eminence, but at a higher level.*

To understand the various pains which are so frequently referred to areas supplied by the great fifth nerve—neuralgias, headache, migraine,

* For a full account of the anatomy of this operation *see* "The Surgical Treatment of Facial Neuralgia," by J. Hutchinson, jun. London, 1905.

etc.—it is necessary to realize some of the central connexions of the sensory nucleus in which its afferent fibres terminate. That centre extends (*see* Fig. 33) to the lower part of the medulla oblongata, and is continuous with the posterior horn of the spinal grey matter, in which the sensory fibres of the occipital and other cervical nerves end. Near by is the sensory nucleus of the vagus. Disturbances of the vagal centres can overflow and affect the sensory nuclei of the fifth, the pain being usually referred to the distribution of that nerve to the dura mater. Each division of the fifth nerve sends a branch to the dura mater.

Malar bone.—Such is the firmness of this bone, and so direct is its connexion with the skull, that violent blows upon it are very apt to be associated with concussion. Resting as it does upon comparatively slender bones, it is very rare for the malar bone to be broken alone. It may, indeed, be driven into the superior maxillary bone, fracturing that structure extensively, without being itself in any way damaged. A fracture of the malar bone may lead to an orbital ecchymosis, precisely like that which often attends a fracture of the skull base.

2. The Parotid Region

The deep part of the **parotid gland** is lodged in a definite space behind the ramus of the lower jaw (Fig. 34). This space is increased in size when the head is extended, and when the inferior maxilla is moved forwards, as in protruding the chin. In the latter movement the increase in the antero-posterior direction is equal to about $\frac{3}{8}$ of an inch. It is diminished when the head is flexed. When the mouth is widely opened the space is diminished below, while it is increased above by the gliding forwards of the condyle. These facts should be borne in mind in operating upon and in exploring the parotid space. It will be found also that in inflammation of the parotid much pain is produced by all those movements that tend to narrow the space occupied by the gland. The obliquity of the ramus of the jaw in infancy and old age causes the lower part of the space to be, in the former instance relatively and in the latter instance actually, larger than it is in the adult. The larger part of the gland is superficial and extends over the masseter muscle.

The gland is closely invested by a **fascia** derived from the cervical fascia. The superficial layer of the parotid fascia is very dense, continuous behind with the fibrous

Fig. 34.—Horizontal section through one side of the face and neck just above the level of the lower teeth. (*Braune.*)

a, Facial artery ; *b*, facial vein ; *c*, gustatory nerve ; *d*, inferior dental nerve and artery lying internally to the ascending ramus of jaw ; *e*, styloid process : *f*, internal carotid artery ; *g*, internal jugular vein, with the vagus, spinal accessory, and hypoglossal nerves to its inner side ; *h*, vertebral artery. Externally to the ascending ramus is shown the masseter : internally to it the internal pterygoid : internally to the last-named muscle, the superior constrictor and tonsil.

sheath of the sterno-mastoid, and in front with that of the masseter. Above it is attached to the zygoma, while below it joins the deep layer. The deep layer is slender, is attached to the styloid process, forms the stylo-maxillary ligament, and is connected with the sheaths of the pterygoid muscles and the pterygoid process. The gland is, therefore, encased in a distinct sac of fascia, which is entirely closed below, but is open above. Between the anterior edge of the styloid process and the posterior border of the internal pterygoid muscle there is a gap in the fascia, through which the parotid space communicates with the connective tissue about the pharynx. It is well known that in postpharyngeal abscesses there is very usually a parotid swelling, and in several instances the pus, or at least some portion of it, has been evacuated in the parotid region. In these cases the matter most probably extends from the pharyngeal to the parotid region through the gap just described. From the disposition of the fascia it follows that very great resistance is offered to the progress of a *parotid abscess* directly outwards through the skin. The abscess often advances upwards to the temporal, or zygomatic fossæ, in the direction of least resistance, although progress in that line is resisted by gravity. It frequently makes its way towards the buccal cavity or pharynx, or it may break through the lower limits of the fascia and reach the neck. It must be borne in mind that the gland is in direct contact with the cartilaginous meatus, with the ramus of the jaw and other bony parts, and is closely related to the temporo-maxillary joint. Thus, a parotid abscess has burst into the meatus, has led to periostitis of the bones adjacent to it, and has incited inflammation in the joint of the lower jaw.

In several cases reported by Virchow the pus appears to have found its way into the skull along branches of the fifth nerve, for the environs of the semilunar ganglion were found infiltrated with pus. The auriculo-temporal and great auricular nerves supply the gland with sensation, and the presence of these nerves, together with the unyielding character of the parotid fascia, serves to explain the great pain felt in rapidly growing tumours and acute inflammation of the gland. The pain is often very distinctly referred along the course of the auriculo-temporal nerve. Thus, a patient with parotid growth under my (F. T.'s) care had pain in those parts of the pinna and temple supplied by the nerve, pain deep in the meatus, at a spot that would correspond to the entrance of the meatal branch of the nerve, and pain in the joint of the lower jaw, which is supplied by the auriculo-temporal.

The most important structures in the gland are the external carotid artery, with its two terminal branches, and the facial nerve. The **external carotid artery**, as Tillaux has pointed out, is behind the ramus of the jaw, as high up as the junction of the inferior with the middle third of its posterior border. It then enters the parotid gland, and, passing a little backwards and outwards, comes nearer to the surface, and at the level of the condyle of the jaw breaks into its two terminal branches. The artery, therefore, does not enter the gland at its inferior border, and is not in actual relation with the parotid space at its lowest part. The vessel, moreover, is not parallel with the edge of the ramus, but passes through the parotid gland with some obliquity.

At its point of exit from the base of the skull by the stylo-mastoid foramen, the **facial nerve** lies 1 inch deep to the mid-point of the anterior border of the mastoid process; a line drawn horizontally forwards from that point to the posterior border of the ascending ramus of the mandible marks the position of the main trunk of the nerve (Fig. 35). Within the gland, where the nerve divides into its temporo-facial and cervico-facial divisions, it is superficial to the external carotid artery and the temporo-maxillary vein. The nerve has been stretched close to its point of exit from the stylo-mastoid foramen for the relief of facial tic. It is best found at a spot about $\frac{1}{4}$ of an inch in front of the centre of the anterior border of the mastoid process. It will be found above the posterior belly of the digastric, which serves as a guide to it in the depth of the wound.

Section of the facial nerve causes paralysis of the buccinator and of all the muscles of expression, the mouth being pulled towards the sound side and the eye remaining unclosed. It also contains certain afferent fibres which are

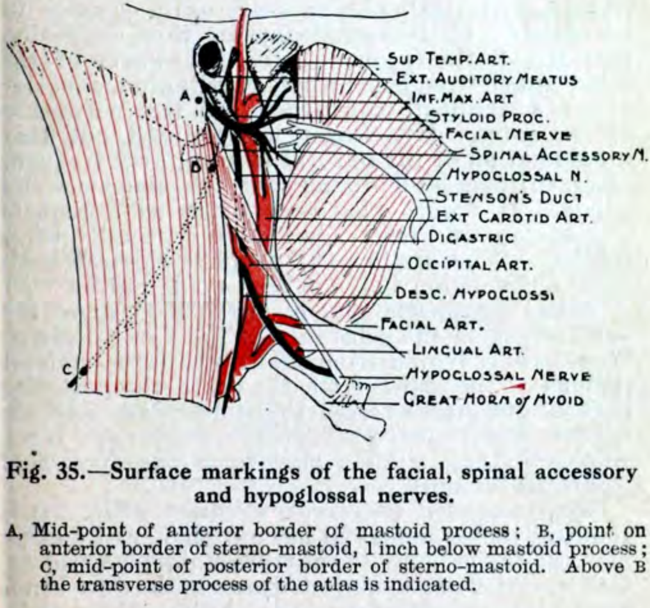

Fig. 35.—Surface markings of the facial, spinal accessory and hypoglossal nerves.

A, Mid-point of anterior border of mastoid process; B, point on anterior border of sterno-mastoid, 1 inch below mastoid process; C, mid-point of posterior border of sterno-mastoid. Above B the transverse process of the atlas is indicated.

sensitive to deep pressure. To restore mobility to the face in cases of palsy, surgeons have, in a number of instances, sutured the facial to the trunk of a neighbouring nerve—the trunks selected being the spinal accessory and hypoglossal (Fig. 35). In the one case the muscles of expression are thrown into action when the trapezius and sterno-mastoid are used; in the other when the tongue is moved. In course of time the patient may become able to dissociate these inconveniently combined movements. At its point of exit the facial nerve gives off its posterior auricular branch to the muscles of the ear and twigs to the posterior belly of the digastric and stylo-hyoid muscles.

Tumours of the parotid are very apt to contain cartilaginous tissue. It is well known that, after mumps, metastatic abscesses are quite common in the testis. It is significant in this connexion that the testis is one of the few parts of the body, apart from bone, where cartilaginous matter forms a frequent constituent of the neoplasms of the part. Mr. Paget has pointed out that inflammation of the parotid is peculiarly frequent after injuries and diseases of the abdomen and pelvis. It occurs also very often as a sequela of some specific fevers, but more especially after typhoid. The anatomical or physiological basis of this connexion has not been made out.

Many lymphatic glands are placed upon the surface and in the substance of the parotid gland. They receive lymph from the frontal and parietal regions of the scalp, from the orbit, the posterior part of the nasal fossæ, the upper jaw, and the hinder and upper part of the pharynx. When enlarged, these glands may form one species of "parotid tumour."

The parotid (Stenson's) duct (Fig. 35) is about 2½ inches long, and has a diameter of ⅛ of an inch, its orifice being the narrowest part. At the anterior border of the masseter muscle the duct bends suddenly inwards to pierce the buccinator muscle. The bend is so abrupt that the buccal segment of the duct may be almost at right angles with the masseteric. This bend should be taken into consideration in passing a probe along the duct from the mouth. The duct opens on the summit of a papilla placed on a level with the second upper molar tooth. The course of the duct across the masseter is represented by a line drawn from the lower margin of the concha to a point midway between the ala of the nose and the red margin of the lip. It lies about a finger-breadth below the zygoma, having the transverse facial artery above it and the infraorbital branches of the facial nerve below. The duct has been ruptured subcutaneously, leading to extravasations of saliva. Wounds of the duct are apt to lead to salivary fistulæ. At least one-half of the buccal part of the duct is embedded in the substance of the buccinator muscle. A salivary fistula over the masseter may involve the parotid gland itself, or that part of it known as the socia parotidis. Inflammatory conditions may spread to the parotid from the mouth along the duct.

3. The Upper and Lower Jaws, and Parts connected with them

Maxilla (for maxillary sinus, *see* p. 119; for hard palate, *see* p. 162).—This bone, on account of its fragility and the manner in which it is hollowed out, is very readily fractured. As the bone is very vascular, serious injuries, involving great loss of substance, are often wonderfully repaired. Its hollowness, and the cavities that it helps to bound, render it possible for large foreign bodies to be retained in the deeper parts of the face. Thus, Longmore reports "the case of Lieutenant Fretz, of the Ceylon Rifles, who was able to do his military duties for nearly eight years with the breech and screw of a burst musket lodged in the nares, part of the tail-pin and screw protruding through the hard palate into the mouth." The bone may undergo extensive necrosis, as in workers in match factories exposed to the fumes of white phosphorus. In one case (*Medical Times and Gazette*, 1862) of necrosis following measles the mischief was limited to the premaxillary, or incisive, bone.

The periosteum of the maxilla is, like the pericranium, not disposed to form new bone. In ordinary cases of necrosis of the upper jaw no reproduction of bone takes place, the gap being left permanent. In the mandible abundant new bone is produced by the periosteum, and extensive losses may be repaired. It is remarkable, however, that in course of years this new bone is liable to be very extensively reabsorbed.

Excision of the maxilla.—The entire bone has been frequently removed when the seat of an extensive tumour, and under certain other conditions. The *bony connexions* to be divided in the operation are the following (*see* Fig. 26, p. 107, and Fig. 30, p. 126): (1) The connexion with the malar bone at the outer side of the orbit; (2) the connexion of the nasal (frontal) process with the frontal, nasal, and lacrimal bones; (3) the connexions of the orbital plate with the ethmoid and palate (the orbital plate is often left behind, or is cut through near the orbital margin); (4) the connexion with the opposite bone and the palate in the roof of the mouth; and (5) the connexion behind with the palate bone, and the fibrous attachments to the pterygoid processes. In the four first-named instances the separation is effected by a cutting instrument; in the last-named, by simply twisting out the bone.

Soft parts divided: These may be considered under three heads: The parts cut (1) in the first incision; (2) in turning back the flap; and (3) in separating the bone.

(1) The following are the parts cut, in order from above downwards, in the usual, or "median," incision, an incision commencing parallel with the lower eyelid, and continued down the side of the nose, round the ala, and through the middle of the upper lip: Skin, superficial fascia, orbicularis oculi, palpebral branches of infraorbital nerve and artery, part of the levator labii superioris, angular artery and vein, lateral nasal artery and vein, nasal branches of infraorbital nerve, compressor naris (musculus nasalis), depressor of the septum and alæ of the nose, attachment of nasal cartilage

to bone, orbicularis oris, superior coronary artery and vein, and mucous membrane of lip. Various branches of the facial nerve to the muscles may be cut. (2) In turning back the flap, the muscles above named will be dissected up, together with the internal palpebral ligament, if the frontal process is removed entire, the levator anguli, the buccinator, a few fibres of the masseter, and, on the orbital plate, the inferior oblique muscles. The infraorbital nerve and artery will be cut as they leave their foramen. In the flap itself will be the trunks of the facial artery and vein, the transverse facial artery, and the facial part of the facial nerve. (3) In separating the frontal process the lacrimal sac and infratrochlear nerve will be damaged, and the naso-lacrimal duct and external branch of the nasal nerve cut across. In separating the bones below, the coverings of the hard palate are divided, and the attachment of the soft palate to the palate bone, unless the removal of that process can be avoided. "Any attempt to dissect off and preserve the soft covering of the hard palate is futile" (Heath). Posteriorly, the trunk of the infraorbital nerve is again divided (this time in front of the spheno-palatine ganglion), together with the posterior dental and infraorbital arteries, and some branches of the spheno-palatine artery. The deep facial vein from the pterygoid plexus will probably be cut, and, lastly, near the palate will also be divided the large palatine nerve and the descending palatine artery.

It will be seen that no large artery is divided in the operation. The inferior turbinated bone (maxillo-turbinal) comes away, of course, with the maxilla.

Mandible.—This bone is to a great extent protected from **fracture** by its horse-shoe shape, which gives it some of the properties of a spring, by its density of structure, by its great mobility, and by the buffer-like interarticular cartilages that protect its attached extremities. The bone is usually broken by direct violence.

and the fracture may be in any part. The symphysis is rarely broken, on account of its great thickness. The ramus is protected by the muscular pads that envelop its two sides, and the coronoid process is still more out of the risk of injury, owing to the depth at which it is placed and the protection it derives from the zygoma. The weakest part of the bone is in front, where its strength is diminished by the mental foramen and by the large socket required for the canine tooth. It is about this part, therefore, that fracture is the most common. The bone may be broken near, or even through, the symphysis by indirect violence, as by a blow or crushing force that tends to approximate the two rami. Thus, the jaw has been broken near the middle line by a blow in the masseteric region. The amount of displacement in fractures of this bone varies greatly, and is much influenced by the nature and direction of the force. In general terms, it may be said that when the body of the bone is broken the anterior fragment is drawn backwards and downwards by the jaw depressors, the digastric, mylo-hyoid, genio-hyoid, and genioglossus; while the hinder fragment is drawn up by the elevators of the jaw, the masseter, internal pterygoid, and temporal. The dense muco-periosteum covering the alveolar part of the mandible is usually also torn through, and thus the fractured surfaces are exposed to the septic conditions which prevail within the mouth. It must be remembered that the mylo-hyoid muscle will be attached to both fragments, and will modify the amount of displacement. Fractures of the ramus are seldom attended with much displacement, muscular tissue being nearly equally attached to both fragments.

In fractures of the body of the bone the dental nerve often marvellously escapes injury, a fact that is explained by the supposition that the bones are not usually sufficiently displaced to tear across the nerve. Weeks after the accident, however, the nerve has become so compressed by the developing callus as to have its function destroyed. One or both condyloid processes have often been broken by falls or blows upon the chin.

The **mandibular (temporo-maxillary) joint** is supported by a capsule which varies greatly in thickness in different parts. By far the thickest part of the capsule is the external part (the temporo-mandibular or lateral ligament). The internal part is next in thickness, while the anterior and posterior portions of the capsule are thin, especially the former, which is very thin. Thus, when this joint suppurates, the pus is least likely to escape on the external aspect of the articulation, and is most likely to find an exit through the anterior part of the capsule, although this part is to a great extent protected by the attachments of the external pterygoid muscle. Immediately behind the condyle of the jaw are the bony meatus and, a little to the inner side, the middle ear. In violent blows upon the front of the jaw these structures may be damaged, and it is interesting to note that the strongest ligament of the joint (the external lateral) has a direction downwards and backwards, so as immediately to resist any movement of the condyle towards the slender wall of bone that bounds the meatus and tympanum. Were it not for this ligament, a blow upon the chin would be a much more serious accident than it is.

The movements of this joint are peculiar. On opening the mouth it will be observed that the condyle moves forwards and downwards upon the articular eminence, while the angle of the jaw moves in a backward and upward direction. The approximate axis of the movement is a transverse line drawn between the inferior dental foramina: thus, it will be seen that the inferior dental nerves (alveolar) enter the mandible at the point of least movement. The external pterygoid muscles, by pulling the condyle upon the articular eminence, take the chief part in opening the mouth; at the same time the chin is depressed by the contraction of the mylo-hyoid and digastric muscles.

Dislocation.—This joint permits of only one form of dislocation, a dislocation forwards. It may be unilateral or bilateral, the latter being the more usual, and it can only occur when the mouth happens to be wide open. Indeed, the dislocation is nearly always due to spasmodic muscular action when the mouth is open, although in some few cases it has been brought about by indirect violence, as by a downward blow upon the lower front teeth, the mouth being widely opened. It has occurred during yawning, violent vomiting, etc. In more than one case the accident happened while a dentist was taking a cast of the mouth. Hamilton quotes a bilateral dislocation in a woman during the violent gesticulations incident to the pursuit of scolding her husband. When the mouth is widely opened, the condyles, together with the interarticular fibro-cartilage, glide forward. The fibro-cartilage extends as far as the anterior edge of the eminentia articularis, which is coated with cartilage to receive it. The condyle never reaches quite so far as the summit of that eminence. All parts of the capsule save the anterior are rendered tense. The coronoid process is much depressed. Now, if the external pterygoid muscle (the muscle mainly answerable for the luxation) contract vigorously, the condyle is soon drawn over the eminence into the zygomatic fossa, the interarticular cartilage remaining behind. On reaching its new position it is immediately drawn up by the temporal, internal pterygoid, and masseter muscles, and is thereby more or less fixed. A specimen in the Musée Dupuytren shows that the fixity of the luxated jaw may sometimes depend upon the catching of the apex of the coronoid process against the malar bone.

Subluxation of the mandible is a name given to a slight and quite incomplete dislocation of the jaw not infrequently met with in delicate women. It is due to a displacement of the interarticular cartilage, and can be cured by exposing the cartilage and attaching it by suture to the fibrous structures around the joint (Annandale).

Excision of the mandible.—Considerable portions of the lower jaw can be excised through the mouth without external wound. In excising one entire half of the maxilla, a cut is made vertically through the lower lip down to the point of the chin, and is then continued back along the inferior border of the jaw, so as to end near the lobule of the ear, after having been carried vertically upwards in the line of the posterior border of the ramus. The soft parts divided may be considered under three heads: Those concerned (1) in the first incision; (2) in clearing the outer surface of the bone; (3) in clearing the inner surface of the bone.

1. (*a*) In the anterior vertical cut: Skin, etc., orbicularis oris, inferior coronary and inferior labial vessels, branches of submental artery, levator menti, mental vessels and nerve, some radicles of anterior jugular vein. (*b*) In the horizontal cut: Skin, etc., platysma, branches of superficial cervical nerve (nervus cutaneus colli) branches of supramandibular part of facial nerve, facial artery and vein at edge of masseter, and inframandibular branch of facial nerve (not necessarily divided). (*c*) The posterior vertical incision would not go down to the bone, and would merely expose the surface of the parotid gland and part of posterior border of masseter muscle.

2. In clearing the outer surface the following parts are dissected back: Levator menti, the two depressor muscles, buccinator, masseter (crossed by part of parotid gland, transverse facial vessels, facial nerve, and Stenson's duct), masseteric vessels and nerve, temporal muscle.

3. In clearing the inner surface: Digastric, genio-hyoid, genio-glossus, and mylo-hyoid muscles, a few fibres of superior constrictor, internal pterygoid muscle, inferior dental (alveolar) artery and nerve, mylo-hyoid vessels and nerve, internal

lateral ligament, rest of insertion of temporal muscle, mucous membrane.

Parts in risk of being damaged.—The facial nerve, if the posterior vertical incision be carried too high up. The internal maxillary artery, temporo-maxillary vein, auriculo-temporal nerve (structures all closely related to the jaw condyle), external carotid artery, lingual nerve, the parotid, submandibular, and sublingual glands. After subperiosteal resection the entire bone has been reproduced.

Deformities.—The lower jaw may be entirely absent, or of dwarfed dimensions, or incompletely formed. These conditions are congenital, and depend upon the defective development of the mandibular or first visceral arch, out of which the lower jaw is formed (Fig. 29, p. 124). They are often associated with branchial fistulæ, supernumerary ears, macrostoma, and like congenital malformations.

Nerves of the jaws.—The upper teeth are supplied by the second division of the fifth, the lower by the third division. Some remarkable manifestations of reflex action have followed irritative lesions of the dental nerves. Thus, cases of strabismus, temporary blindness, and wry-neck have been reported as due to the irritation of carious teeth. Hilton gives the case of a man who was much troubled by a carious tooth in the lower jaw (supplied by the third division of the fifth), and who developed a patch of grey hair over the region supplied by the auriculo-temporal nerve (a branch also of the third division). The roots of the third lower molar are in close proximity to the dental (mandibular) canal, and hence the nerve may be torn if this tooth is roughly extracted. The roots have been seen actually to enclose the nerve.

Caries of the teeth is frequently associated with areas of hyperæsthesia on the side of the face and neck. The explanation of the reflection, to certain areas of skin, of pain set up by dental caries must be sought for in a close association of the central nerve nuclei, in which the cutaneous and dental nerves terminate (*see* Fig. 33, p. 132). Disease of the peridental membrane does not give rise to referred pains (Head).

The **muscles of mastication** are often attacked by spasm. Nowhere else in the body is a group of muscles opposed by so weak a group of opponents as in the mandibular region. The temporal, masseter, and internal pterygoid give the mandible its great biting and grinding power; their opponents, which depress the mandible—the external pterygoid, digastric, mylo-hyoid, genio-hyoid—are able to afford but weak resistance to them. Hence, when in a state of spasm, they at once prevail over their opponents. When the spasm is clonic, chattering of the teeth is produced. When the spasm is tonic the mouth is rigidly closed, and the condition known as trismus, or lockjaw, is produced. Trismus is among the first symptoms of tetanus. It is also very apt to be produced by irritation of any of the sensory branches of the third division of the fifth. Thus, trismus is very common in caries of the *lower* teeth, and during the "cutting" of the *lower* wisdom tooth; it is much less common in affections of the upper set of teeth. If the motor root of the third division of the fifth nerve be cut in excising the Gasserian ganglion, paralysis and atrophy overtake the muscles of mastication of the corresponding side. The muscles of the sound side, however, are still able to carry on the necessary movements of the jaw concerned in speech and mastication.

Teeth.—As a test of age the following periods for the eruption of teeth are given by Mr. C. Tomes: *Temporary teeth:* Lower central incisors, six to nine months; upper incisors, ten months; lower lateral incisors and four first molars, a few months later; then, after a rest of four or five months, the canines; and, lastly, the second molars; the whole being in place by the end of the second year. *Permanent teeth:* First molars, sixth or seventh year; next in order the lower central incisors, then the upper central incisors, and a little later the laterals, the eighth year; first bicuspids, ninth or tenth year; second bicuspids and canines, about the eleventh year, the lower preceding the upper; the second molars, the twelfth or thirteenth year; the wisdom teeth, 18 to 25 or later.

An **alveolar abscess** is formed about the fang of a tooth. In the case of single-fanged teeth the pus may escape along the groove of the fang.

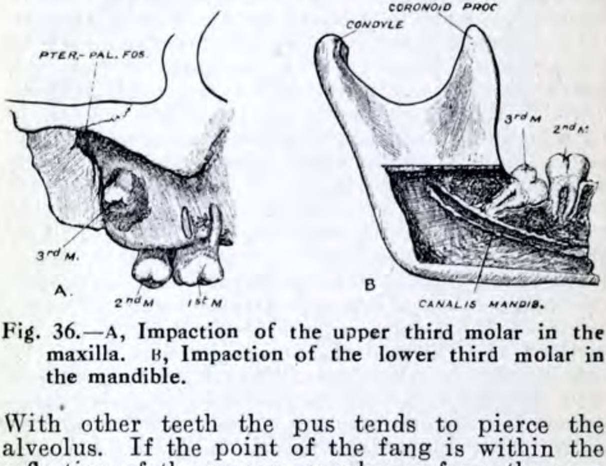

Fig. 36.—A, Impaction of the upper third molar in the maxilla. B, Impaction of the lower third molar in the mandible.

With other teeth the pus tends to pierce the alveolus. If the point of the fang is within the reflection of the mucous membrane from the gum to the cheek the abscess will break into the mouth, but if the point of the fang is without that reflection, or if the pus can gravitate without the line of reflection, then the pus may break through the cheek. Alveolar abscess of the upper incisors and canines never breaks through the cheek. When connected with the upper molars it sometimes does; an abscess forming at the roots of the upper molar or second premolar teeth often breaks into the maxillary sinus. The roots of the incisor, canine, and first premolar teeth are more remote from the sinus; hence abscesses connected with them rarely break into the sinus. When connected with any of the lower teeth the abscess may find its way through the skin of the cheek.

The upper wisdom tooth is developed in the posterior border of the upper jaw, and the lower wisdom on the inner aspect of the ascending ramus. They may fail to come into position, or even remain deeply buried. (Fig. 36.) They may give rise to deeply seated and obscure abscesses which frequently point in the neck, at some distance from the site of origin.

CHAPTER VIII

THE MOUTH, TONGUE, PALATE, AND PHARYNX

The Mouth

The lips.—The principal tissues composing the lips have the following relation to one another, proceeding from without inwards: (1) Skin; (2) superficial fascia; (3) orbicularis oris; (4) labial (coronary) vessels; (5) mucous glands, and (6) mucous membrane. The free border of the lip is very sensitive, many of the nerves having end-bulbs closely resembling tactile corpuscles. The upper lip is supplied with sensation by the second division of the fifth nerve, and the lower lip by the third division. Over these labial nerves a crop of herpes often appears (herpes labialis). The free border of the lower lip is more frequently the seat of epithelioma than is any other part of the body; its lymphatic vessels pass to the submental and submandibular lymphatic glands (Fig. 50, p. 207). The lips contain much connective tissue, and may swell considerably when inflamed, or œdematous. They are very mobile, and are entirely free for a considerable extent from bony attachment of any kind. It follows that destructive inflammations of the lips, and such losses of substance as accompany severe burns, produce much contraction and deformity of the mouth. Contracting cicatrices, also, in the vicinity of the mouth are apt to drag upon the lips, everting them or producing kindred distortions. It is fortunate that the laxity of the tissues around the mouth, and the general vascularity of the part, greatly favour the success of the many plastic operations performed to relieve these deformities.

The **lips** are very vascular, and are often the seat of nævi and other vascular tumours. The labial **arteries** are of large size, and their pulsations can generally be felt when the lip is pinched up. These vessels run beneath the orbicularis oris muscle, and are consequently nearer to the mucous membrane than they are to the skin. When the inner surface of the lip is cut against the teeth, as the result of a blow, these arteries are very apt to be wounded. As such wounds are concealed from view, the consequent hæmorrhage has sometimes given rise to an erroneous diagnosis. Thus, Erichsen quotes the case of a drunken man, the subject of such a wound, who, having swallowed, and then vomited, the blood escaping from a labial artery, was for a while supposed to be suffering from an internal injury. As the anastomoses between the arteries of the lip are very free, it is usually necessary to tie both ends of the vessel when it has been cut across.

The mucous glands in the submucous tissue are large and numerous. From closure of the ducts of these glands, and their subsequent distension, result the "mucous cysts" that are so common about the lips. "Hare-lip" is noticed below in connexion with the subject of cleft palate.

Buccal cavity.—The following points may be noticed in the examination of the interior of the mouth: In the floor of the mouth, on either side of the frenum linguæ, can be observed the sublingual papillæ with the openings of Wharton's ducts. The duct of Bartholin (one of the ducts of the sublingual gland) runs along the last part of the submandibular (Wharton's) duct, and opens either with it or very near it. This duct is singularly indistensible, and hence is partly explained the intense pain usually observed when it becomes obstructed by a calculus. The proximity of this duct to the lingual nerve may serve also to account for the pain in some cases. The submandibular gland can be made out through the mucous membrane at a point a little in front of the angle of the jaw, especially when the gland is pressed up from the outside. On the floor of the mouth. between the alveolus and the anterior part of the tongue, is a well-marked ridge of mucous membrane, directed obliquely forwards and inwards to the sublingual papilla near the frenum. It indicates the position of the sublingual gland (Fig. 37), and also, so far as it goes, the line of the submandibular duct and the lingual nerve. These

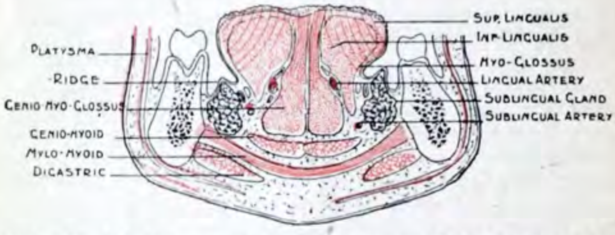

Fig. 37.—Section across tongue and mandible to show the position of the sublingual gland and lingual artery. (*After Poirier.*)

structures, with the sublingual artery, lie beneath the mucous membrane between the gland and the side of the tongue. The ducts of the sublingual gland, some ten to twenty in number, open into the mouth along the ridge of mucous membrane just referred to. **Ranula**, a cystic tumour filled with mucous contents, is often met with over the site of the sublingual gland, and is due to the dilatation of a duct which has become obstructed, or to an occluded mucous follicle. The mucous membrane of the floor of the mouth, as it passes forwards to be reflected on to the gums, is attached near to the upper border of the jaw (Fig. 37). Here also are situated some mucous glands which may become cystic. The genio-glossus is attached near the lower border. Between these two parts (the mucous membrane and the muscle) there is, according to Tillaux, a small space lined with squamous epithelium. To this cavity the name of the sublingual bursa is given. It is constricted is its centre by the frenum linguæ, and is said to be the seat of mischief in "acute ranula."

When the mouth is widely opened the pterygo-mandibular ligament can be readily seen and felt beneath the mucous membrane. It appears as a prominent fold running obliquely downwards behind the last molar teeth. A little below and in front of the attachment of this ligament to the lower jaw, the lingual nerve can be felt as it lies close to the bone just below the last molar. At this point it may be divided, or reached by the needle of a syringe. This nerve, as it lies against the bone, has been crushed by the slipping of the forceps in clumsy extraction of the lower molar teeth.

The coronoid process of the lower jaw can be easily felt through the mouth, and is especially distinct when that bone is dislocated. It may be noted that a fair space may exist between the last molar tooth and the ramus of the mandible, through which a patient may be fed by a tube in cases of trismus or ankylosis of the jaw.

Congenital dermoid and thyroid cysts are sometimes found in the floor of the mouth between the tongue and the lower jaw. Such cysts are supposed to be due to imperfect closure of the first visceral or postmandibular cleft, or to an aberrant bud of the median thyroid outgrowth.

The **gums** are dense, firm, and very vascular. In the bleeding that follows the extraction of teeth much of the blood is supplied by them. The gums are particularly affected in mercurial poisoning, and are also especially involved in scurvy. In chronic lead-poisoning a blue line often appears along their margins. This is due to a deposit of lead sulphide in the gum tissues, which is thus derived: Food débris collected about the teeth in decomposing produces hydrogen sulphide, which, acting upon the lead circulating in the blood, produces the deposit. The blue line, therefore, is said not to occur in those who keep the teeth clean.

The Tongue

On the under surface of the tongue, less than ½ an inch from the frenum, the end of the ranine (comitans hypoglossi) vein can be seen beneath the mucous membrane. Two elevated and fringed lines of mucous membrane may be seen on the under surface of the organ, converging towards its tip. They indicate the position of the ranine (deep lingual) artery, which is more deeply placed than the vein, close to which it lies. It is extremely rare for the tongue to be the seat of congenital defects. The tip may be irregularly cleft or show glandular polypi, probably derived from the glands normally found beneath the tip of the tongue. Fournier gives a case where the tongue was so much longer than usual that the chest could be touched with its tip while the head was held erect.

In rare cases the **frenum linguæ** may be abnormally short, constituting the condition known as "tongue-tie," which is really a very uncommon affection. The genio-glossus, the chief muscle of the tongue, and the genio-hyoid arise from the genial (mental) tubercles of the symphysis. The tongue is kept from falling backwards by its attachments to the symphysis; if these attachments were cut, the tongue could be inverted and swallowed. In complete anæsthesia, as in that produced by chloroform, when all the muscular attachments of the tongue are relaxed, the organ is apt to fall back and to press down the epiglottis, so causing suffocation.

The tongue is firm and dense, but contains, nevertheless, a sufficient amount of connective tissue to cause it to swell greatly when inflamed.

The surface epithelium is thick, and in chronic superficial inflammation of the organ it often becomes heaped up, forming dense opaque layers—ichthyosis linguæ, plaques des fumeurs, leucoma, etc. From the mucous glands, situated chiefly beneath the mucous membrane near the base of the tongue, the mucous cysts are developed that are sometimes met with in this part.

The tongue is very vascular, and is in consequence often the seat of nævoid growths. Its main supply is from the **lingual artery.** This vessel approaches the organ from the under surface, and, as cancer usually shows a tendency to spread towards the best blood supply, it is to be noticed that carcinoma of the tongue nearly always tends to spread towards the deep attachment of the member. At the same time it must be observed that the main lymphatics follow the same course as the main blood-vessels; cancer in spreading tends also to follow the lymph-stream. The vascularity of the tongue is the great bar to its easy removal, hæmorrhage being the complication most to be dreaded in such operations.

The **tongue is well supplied with nerves,** which endue it not only with the special sense of taste, but also with common sensation. According to Weber's experiments, tactile sensibility is more acute on the tip of the tongue than it is on any part of the surface of the body. It should be borne in mind that the lingual nerve, in which the chorda tympani is incorporated, supplies the fore part and sides of the tongue for two-thirds of its surface, while the glosso-pharyngeal nerve supplies the mucous membrane at its base, and especially the papillæ vallatæ. After excision of the semilunar ganglion, taste is unaffected because the fibres subserving that sense reach the lingual nerve in the chorda tympani. The latter nerve must also convey touch fibres, for after excision of the semilunar ganglion a certain sensibility to touch is still retained by the anterior two-thirds of the tongue, although sensibility to pain is completely lost. In painful affections, situated in the area supplied by the lingual nerve, the patient is often troubled with severe pains deep in the region of the meatus of the ear, and an area of skin from the ear along the lower border of the jaw may be tender (Head). The anterior two-thirds of the tongue are a derivative of the mandibular arch, which also forms the anterior

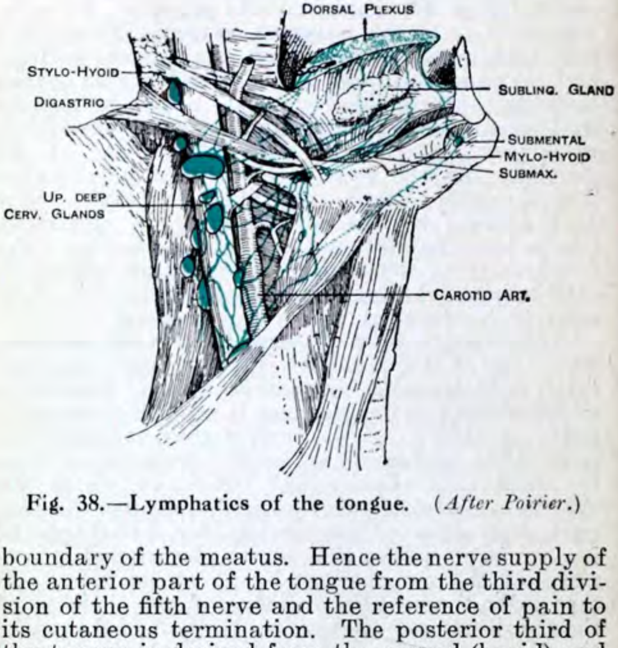

Fig. 38.—Lymphatics of the tongue. (*After Poirier.*)

boundary of the meatus. Hence the nerve supply of the anterior part of the tongue from the third division of the fifth nerve and the reference of pain to its cutaneous termination. The posterior third of the tongue is derived from the second (hyoid) and third visceral arches and is associated with tender areas in the skin over the larynx (Head). Spasmodic contraction of the masticatory muscles is sometimes found to accompany painful lingual ulcers when involving the region of the gustatory nerve. There would seem to be little connexion between an abscess over the occipital region and wasting of one half of the tongue. But Sir James Paget reports the following case:

"A man received an injury to the back of his head that was apparently not severe. In time the right half of the tongue began to waste, and continued to waste until it was less than half the size of the unaltered side. An abscess formed over the occiput, from which fragments of the lower part of the occipital bone were removed. After the removal of all the dead bone the tongue began to recover, and in one month had nearly regained its normal aspect."

Here the atrophy was due to wasting of the lingual muscles produced by pressure upon the hypoglossal nerve, which leaves the skull through the anterior condyloid foramen in the occipital bone. The case illustrates the importance of remembering even small foramina, and the structures they transmit.

The tongue contains much lymphoid tissue, a considerable part of which (the lingual tonsil) is massed under the mucous membrane at the posterior part of the organ. Hypertrophy of this tissue may lead to troublesome symptoms by irritating the sensitive epiglottis. The lingual and pharyngeal adenoid tissue, and the tonsils proper, form a complete ring of lymphoid tissue round the isthmus of the fauces.

The **lingual lymphatics** (Fig. 34) are large and numerous, and offer a free channel for the dissemination of cancerous emboli. They are arranged in two systems: (1) *Superficial*, forming an extremely rich plexus in the submucous tissue on the dorsum and sides of the tongue; (2) *deep*, arranged as a network in the musculature of the tongue. These two systems are in free communication; Cheatle found that the genio-glossus muscle was a common site of secondary deposit in cases of cancer of the tongue. The lymph from these two systems is carried off by the following sets of **efferent vessels**: (1) the *marginal* or lateral vessels, which leave the submucous plexus on the side of the tongue and pass partly to the submandibular group of glands and partly to the upper deep cervical group; (2) the *central* vessels, which form between the two genio-glossus muscles and end in the upper deep cervical glands; (3) the *apical* vessels, which end in the submental gland and in the upper deep cervical; (4) the *basal* vessels from the posterior third of the tongue which terminate in the upper deep cervical group.* The main vessels become blocked by the invasion of cancer cells, so that the lymph has to seek by-paths and circuitous routes, which also in time become occluded. Thus the cancerous invasion may become widely spread and in many directions. The lymphatic glands over the submandibular gland, the lymphoid tissue in that gland and in the sublingual, become the seats of secondary deposit. The submental gland may also be affected.

In the strange congenital affection known as **macroglossia** the tongue becomes much enlarged, and in some cases may attain prodigious dimensions. The enlargement is primarily due to the greatly dilated condition of the lymphatic channels of the organ (hence the name, lymphangioma cavernosum, proposed by Virchow), and to an increased development of lymph tissue throughout the part. The portion most conspicuously affected is the base of the tongue, where the lymphatics are usually the most numerous.

Accessory glands about the tongue.—Accessory glands, belonging to the thyroid body, are frequently found in the vicinity of the hyoid bone. They are also found in the basal part of the tongue, near the foramen cæcum (Makins). Some may be superficial to the mylohyoid muscle, others may be just above the hyoid bone, and others in the hollow of that bone. Cysts lined with ciliated epithelium may

* For a full account of the lymphatics *see* Poirier's "Lymphatics," translated by Cecil Leaf, 1903.

sometimes be found in the same situations. All these structures are the remains of the neck of the central diverticulum which is protruded from the ventral wall of the pharynx in the embryo, and from which the isthmus and adjoining part of the thyroid gland are formed. The *foramen cæcum* on the tongue indicates the spot where this diverticulum arises from the pharynx. Ducts lined with epithelium have been found leading from the foramen cæcum to accessory glands about the hyoid bone. From these glandular and epithelial collections about the hyoid bone certain deep-seated forms of cancer of the neck may be developed. Some of these take the form of malignant cysts described by the author (*Path. Soc. Trans.*, 1886).

Excision.—Many different methods have been adopted for the removal of the entire tongue. It has been removed through the mouth by the écraseur or the scissors, the latter operation being performed with or without previous ligature of the lingual arteries in the neck. It is difficult, however, fully to expose the deeper attachments of the organ through the comparatively small orifice of the mouth. To obtain more room the cheek has been slit up in one procedure, while the lower lip and symphysis of the lower jaw have been divided in another.

In another series of operations the tongue has been reached, or the organ has been fully exposed, by an incision made between the hyoid bone and the mandible. Kocher introduced the method of exposing the tongue from the neck, reaching it by an incision commencing near the ear and following the anterior border of the sterno-mastoid muscle as far as the hyoid bone, whence it turns upwards along the anterior belly of the digastric muscle. This method, besides giving an opportunity of completely controlling hæmorrhage by a preliminary ligature of the lingual artery, allows free removal of the upper deep cervical glands, the lymphatic glands, and the tissue over and in the submandibular and sublingual glands which form the seats of secondary cancerous deposits.

In the removal of the entire organ, the following parts are of necessity divided: The frenum, the mucous membrane along the sides of the tongue, the glosso-epiglottic folds, the genio-glossus, hyo-glossus, stylo-glossus, palato-glossus muscles, the few fibres of the superior and inferior lingual muscles which are attached to the hyoid bone, the terminal branches of the lingual, glosso-pharyngeal, and hypoglossal nerves, the lingual vessels, and, at the side of the tongue near its base, some branches of the ascending pharyngeal artery and of the tonsillar branch of the facial artery.

The Palate

The arch of the hard palate varies in height and shape in different individuals; it is particularly narrow and high in those who have suffered in youth from adenoids. The outline of this arch is of some moment in operations upon the palate.

Cleft palate.—In order to understand the various forms of cleft which occur in the palate and upper lip, it is necessary to review briefly the development of these parts; for all forms of cleft palate and "hare-lip" are due to an incomplete fusion of parts. In Fig. 39, A, the bony palate at birth is shown to be made up of three elements: (1) the premaxillary (os incisivum), carrying the four incisor teeth; (2) the right maxillary; (3) the left maxillary, bearing the right and left canines and milk molars. These three parts are different in origin: the premaxillary part is developed in the mesial nasal process (Fig. 29, p. 124); the maxillary parts from the right and left maxillary processes. Fusion of the various elements to form the palate commences anteriorly and proceeds backwards. In the posterior two-thirds of the palate the maxillary processes fuse with each other in the median line, but in the anterior third they unite with the premaxillary part. Thus the line of fusion is Y-shaped, the premaxillary part occupying the fork. In the majority of cases the cleft occurs in the position of the main stem of the Y, or it may affect only the soft palate; or it may extend forwards to the alveolus on one side or on both, as is shown in Fig. 39, B, C. The lateral incisor is developed in the groove between the premaxillary and maxillary elements; if the condition of cleft

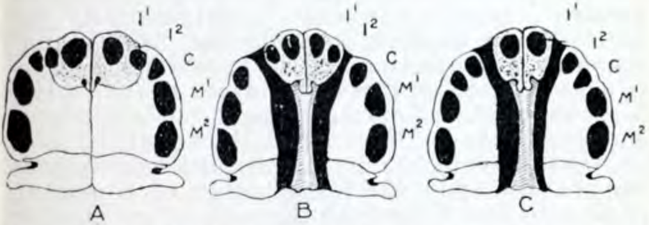

Fig. 39.—Illustrating the relationship of the lateral incisor tooth to the palatal cleft.

A, Normal hard palate. The premaxilla is stippled; the lateral incisor occurs in the suture between it and the maxilla.
B, Double cleft palate, the lateral incisor being situated on the premaxilla to the inner side of the cleft. The septum of the nose is exposed in the cleft between the maxillary bones.
C, Double cleft palate, the lateral incisor being situated on the maxilla to the outer side of the cleft.

palate occurs, the developmental elements separate as growth proceeds; the bud of the lateral incisor may adhere to either side of the cleft thus formed; hence in some cases this incisor is found on the premaxillary process; in others, in the maxillary (Fig. 39, B, C). Each premaxilla may show two centres of ossification, but the cleft is not, as is so often said, the result of the failure of union of two centres of ossification, but is due to the separation of the developmental parts of the palate. As growth goes on during childhood the cleft becomes wider.

The upper lip is developed from the same three elements as the palate (Fig. 29, p. 124); if the palatal cleft extends to the alveolus the lip is also affected, but a cleft on one or both sides of the lip may occur without a cleft of the palate. The premaxillary or median element of the lip is also bilateral in origin, but it is extremely rare to find a persistent separation of its two parts. In cases of double hare-lip one sees occasionally two papillæ on the lower lip, fitting into the clefts in the upper when the lips are in apposition.

The mucous membrane covering the **hard palate** is peculiar in that it is practically one with the periosteum covering the bones; and, therefore, in dissecting up this membrane the bone is bared, as the mucous membrane and the periosteum cannot be separated. The membrane is thin in the middle line, but is much thicker at the sides near the alveoli, the increased thickness depending mainly upon the introduction of a number of mucous glands beneath the surface layers, such glands being absent in the middle line. The density and toughness of the soft covering of the hard palate render it very easy to manipulate when dissected up in the form of flaps, as in the operation for cleft palate.

Sir Rickman Godlee has described a number of cases in which a bony elevation—the *torus palatinus*—is found on the posterior part of the under surface of the hard palate. The elevation or exostosis is commoner in lower races than in Europeans, and begins to form as adult life is reached. It is due to a heaping-up of bone on each side of the median suture of the palate, and in exceptional cases attains noticeable dimensions.

The main **blood supply of the bones of the hard palate** and of its mucous covering is derived from the descending palatine branch of the internal maxillary artery. This vessel, which is practically the only vessel of the hard palate, emerges from the posterior palatine canal near the junction of the hard palate with the soft, and close to the inner side of the last molar tooth. The vessel runs forwards and inwards to end at the anterior palatine canal. Its pulsations on the palate can often be distinctly felt. In dissecting up muco-periosteal flaps from the hard palate by means of a raspatory, it is most important to make the initial incision in the mucous membrane close to the alveolus, so that the flap may include this artery, and its vitality thereby be secured. In dissecting up the flap it should be remembered that the artery runs much nearer to the bone than to the mucous surface.

The **soft palate** is of uniform thickness, its average measurement being estimated at about $\frac{1}{4}$ of an inch. Its thickness is largely due to a stratum of mucous glands on its upper surface. Its central basis is a tendinous expansion, the palatal aponeurosis, in which the tensors of the palate end and by which they are attached to the posterior border of the hard palate. When the soft palate is congenitally cleft, the edges of the fissure are approximated during swallowing by the uppermost fibres of the superior constrictor. This approximation may narrow the cleft by one-half or two-thirds. The muscles that tend to widen the cleft are, in the main, the levator palati and tensor palati. It is necessary that these muscles should be divided in attempting to close the cleft by operation. The levator palati crosses the palate obliquely from above downwards and inwards on its way to the middle line, lying nearer to the upper than the lower surface of the velum. The tensor palati turns round the hamular process, and passes to the middle line in a nearly horizontal direction (Fig. 40). The hamular process can be felt through the soft palate just behind and to the inner side of the last upper molar tooth. When the muco-periosteum, containing the posterior palatine vessels, has been raised from the hard palate on each side of the cleft, so that the hinder border of the horizontal plate of the palate bone is exposed, the operator separates the palatal aponeurosis and the overlying mucous membrane on the nasal aspect from the palate bone, taking care to stop short of the posterior palatine canal and palatine vessels. When the aponeurosis is cut through the tensor palati is partly thrown out of action. The levator palati

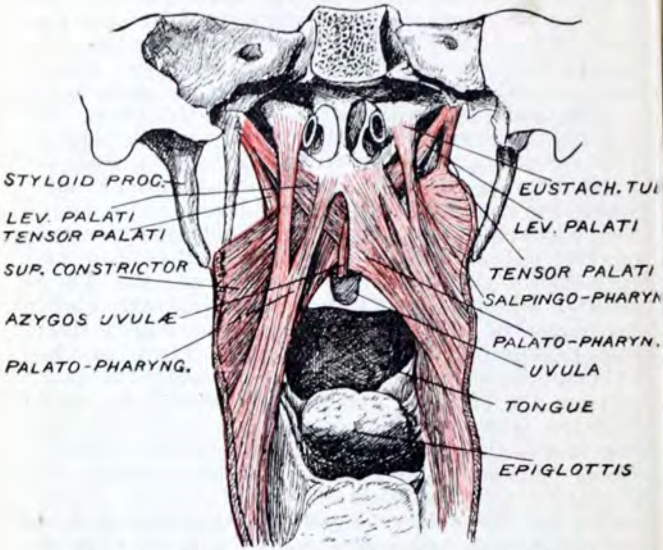

Fig. 40.—Muscles of the soft palate, from behind. (*Blakeway.*)

is best cut as it enters the upper surface of the soft palate within a raised fold of mucous membrane. Its nerve enters the upper end of the muscle, and is thus left undamaged (Berry and Legg).

The **blood supply of the soft palate** is derived from the descending palatine branch of the internal maxillary artery, the ascending pharyngeal artery, and the ascending palatine branch of the facial artery. The latter vessel reaches the velum by following the levator palati muscle, and must be divided in the section made of this muscle in the procedure just described.

The **muscles of the soft palate** are supplied by several nerves. The levator palati, azygos uvulæ, and palato-pharyngeus are innervated with the muscles of the pharynx by the spinal accessory; the palato-glossus with the muscles of the tongue from the hypoglossal, and the tensor palati with the tensor tympani from the third division of the fifth nerve through the otic ganglion.

The Pharynx

The pharynx is about 5 inches in length. It is much wider from side to side than from before backwards. It is widest at the level of the tip of the greater cornua of the hyoid bone, where it measures about 2 inches. It is narrowest where it joins the gullet opposite the cricoid cartilage, its diameter here being less than $\frac{3}{4}$ of an inch. The pharynx is not so large a space as supposed, for it must be remembered that during life it is viewed very obliquely, and erroneous notions are thus formed of its antero-posterior dimensions. The distance from the arch of the teeth to the commencement of the gullet is about 6 to 7 inches, a measurement that should be borne in mind in extracting foreign bodies. **Foreign bodies** passed into the pharynx are most apt to lodge at the level of the cricoid cartilage, a point that, in the adult, is a little beyond the reach of the finger. The history of foreign bodies in the pharynx shows that that cavity is very dilatable, and can accommodate for some time large substances. Thus, in a case reported by Dr. Geoghegan, a man of 60, who for months had had some trouble in his throat for which he could not account, was supposed to have cancer. On examination, however, a plate carrying five false teeth, and presenting niches for five natural ones, was found embedded in the pharynx, where it had been lodged for five months. The plate had been swallowed during sleep (*Med. Press*, 1866). In the *Lancet* for 1868 is an account of a mutton chop that became lodged in the pharynx of a gluttonous individual. The chop presented the ordinary vertebral segment of bone, together with 1½ inches of rib, and was "pretty well covered with meat." Attempts to remove it failed, and it was finally vomited up. Dr. Hicks (*Lancet*, 1884) reports the case of a woman who committed suicide by cramming half a square yard of coarse calico (belonging to her nightdress) into her mouth and throat.

The walls of the pharynx are in relation with the base of the skull, and with the upper six cervical vertebræ. The arch of the atlas is almost exactly on a line with the hard palate. The axis is on a line with the free edge of the upper teeth. The termination of the pharynx corresponds to the sixth cervical vertebra. The upper vertebræ can be examined, as regards their anterior surface, from the mouth. When the bones about the pharynx are diseased, the necrosed parts may be discharged by that cavity. Thus portions of the atlas and axis have been expelled by the mouth, as also have been some fragments of comparatively large size thrown off by the occipital and sphenoid bones.

The mucous membrane of the pharynx is vascular, and readily inflamed; and such inflammations are peculiarly dangerous, in that they may spread to the lining membrane of the larynx. The submucous tissue of the aryteno-epiglottic folds and of the neighbouring part of the pharynx is peculiarly loose, and in œdematous conditions the upper aperture of the larynx may be almost closed.

Much **adenoid tissue** is distributed in the mucous membrane of the pharynx, and it is this tissue that is the primary seat of inflammation in various forms of pharyngitis. A distinct collection of adenoid tissue—the *pharyngeal tonsil*—is found in the roof of the naso-pharynx (*see* Figs. 41 and 27). It is embedded in thick mucous membrane, and extends from the base of the septum of the nose to the mid-point of the basilar process of the skull. The centre of the tonsil is marked by a fissure or depression bounded on each side by two or three folds of mucous membrane laden with adenoid tissue. It reaches its maximum size about the tenth year. It extends laterally towards the recesses behind the Eustachian tubes, and may invade these recesses and thus prevent the free opening of the tubes. This deposit of adenoid tissue may undergo hypertrophic change, and the condition known as "adenoid vegetations" or "postnasal growths" be produced. These growths may cause deafness and may block the posterior nares. They need to be removed by operation. They are supplied by minute arteries derived from the internal maxillary (Vidian and pterygo-palatine) and from the ascending pharyngeal. The veins join the pharyngeal plexus, and the lymphatics drain to the retropharyngeal gland, thence to the deep cervical glands.

Fig. 41.—Tonsil of the naso-pharynx of a boy aged 2 years.
(*From a preparation made by Prof. Symington.*)

The tissue immediately outside the pharyngeal walls is lax, and favours the spread of effusion. Thus, in acute inflammation of the pharynx the effusion has been found to extend along the œsophagus, reaching the posterior mediastinum, and advancing even to the diaphragm. In the lax connective tissue between the pharynx and the spine abscess is not infrequent, due, as a rule, to caries of the vertebræ (postpharyngeal abscess). In this connective tissue, and opposite the axis, is also found a lymphatic gland that receives lymphatics from the nasal cavity and naso-pharynx. This gland may prove the seat of a suppuration. Such collections may so push forward the posterior pharyngeal wall as to depress the soft palate, or may cause severe dyspnœa by interference with the larynx. The matter may discharge itself through the mouth, or may reach the neck by passing behind the great vessels and the parotid gland, presenting ultimately beneath or at one border of the sterno-mastoid muscle.

Many structures of importance are in relation with the lateral walls of the pharynx, the principal being the internal carotid artery, the vagus, glosso-pharyngeal, and hypoglossal nerves (Fig. 34, p. 134). The internal carotid is so close to the pharynx that its pulsations may be felt by the finger introduced through the mouth. These and other deep structures in the neck may be wounded by foreign bodies that, passing in at the mouth, have been thrust through the pharynx into the cervical tissues. The internal jugular vein is at some distance from the pharynx, especially at its upper part (Fig. 34, p. 134). The styloid process, when prominent, and an ossified stylo-hyoid ligament, can also be felt at the side of the pharynx immediately behind the tonsil. In more than one case an ossified stylo-hyoid ligament has been mistaken for a foreign body, and an attempt made to excise it.

The **tonsil** (Figs. 42, 43) is lodged between the anterior and posterior palatine arches. It is in relation externally with the superior constrictor muscle (Fig. 34, p. 134), and it corresponds, as regards the surface, to the angle of the lower jaw. When hypertrophied, the mass tends to develop towards the middle line, where no resistance is encountered, and to effect but little change in its external relations. The mass, often mistaken for the enlarged tonsil in the neck, is formed of enlarged glands, situate near the tip of the great cornu of the hyoid bone, and overlying the internal jugular vein. These glands receive the tonsillar lymphatics, and are almost invariably enlarged in all tonsil affections. The fact that these glands are so frequently the first to enlarge when the cervical glands become tuberculous points to the tonsil as a common site of primary infection. The tonsil is closely enough attached to

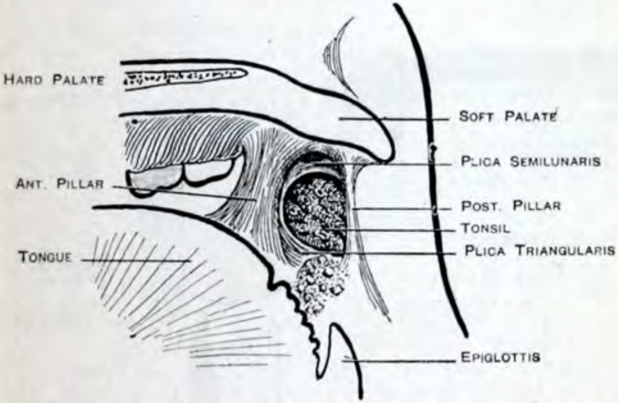

Fig. 42.—Diagram of the pillars of the fauces and of the tonsil.

the pharyngeal wall to be affected by the movements of the pharyngeal muscles (Fig. 43). Thus it is moved inwards by the superior constrictor muscle during the act of swallowing, and may be drawn outwards, on the other hand, by the stylo-pharyngeus muscle. The ease with which a tonsil can be reached depends, other things being equal, upon the extent to which it can be withdrawn by the stylo-pharyngeus, and upon the development of the anterior palatine arch, which, to some extent, hides the tonsil. A child with a prominent anterior palatine arch, containing a well-developed palato-glossus muscle, and with a vigorous stylo-pharyngeus, can for a long time elude the tonsil guillotine. Nevertheless the tonsil can be removed intact and with its capsule still adherent to it. The extent to which a tonsil projects beyond the level of the pillars is no index to its real size (Pybus).

The tonsil is variable in shape; it is frequently divided into three masses, and, besides numerous

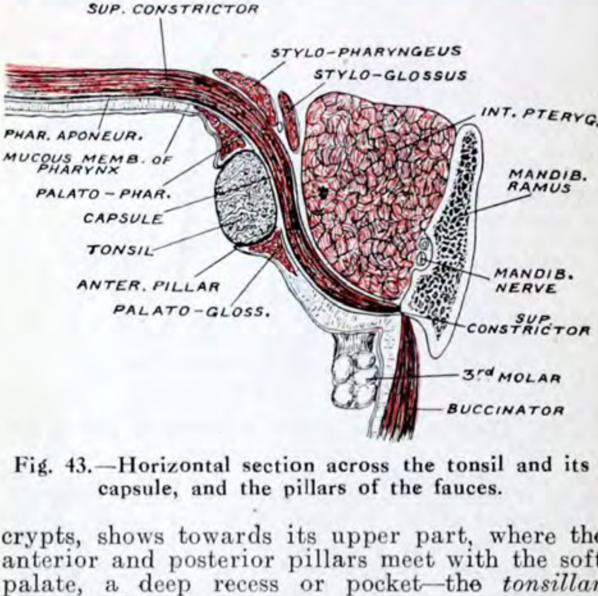

Fig. 43.—Horizontal section across the tonsil and its capsule, and the pillars of the fauces.

crypts, shows towards its upper part, where the anterior and posterior pillars meet with the soft palate, a deep recess or pocket—the *tonsillar recess.* This recess is the remnant of the first visceral cleft in which the tonsil was developed (Seccombe Hett). From the anterior pillar a sharp fold of mucous membrane passes backwards, to end on the tonsil—the *plica triangularis* (Fig. 42)—while another fold may join the pillars over the tonsillar recess (*plica semilunaris*).

The tonsil is separated from the superior constrictor by a fine fibrous capsule (Fig. 43); its lymphatics perforate the constrictor. Two chief forms of tonsil may be recognized: the *embedded*, where the adenoid tissue increases beneath the level of the pillars; and the *projecting*, where the increase affects chiefly the exposed part of the tonsil (S. Hett).

Deafness is often complained of when the tonsil is hypertrophied. This is not due to closure of the Eustachian tube by the direct pressure of the enlarged mass; such pressure is anatomically impossible. The large tonsil may, however, affect the patency of the tube, by disturbing the soft palate, and through it the tensor palati muscle, which is much concerned in keeping open the Eustachian tube. The deafness in these cases is probably due rather to an extension of the hypertrophic process to the lining membrane of the tube than to any pressure effects, since it is usually not improved until some time after the tonsil has been removed. The tonsillar tissue is for the most part collected around a number of crypts (Fig. 43). The decomposition of retained epithelial structures within these recesses produces the fetid breath often noticed in cases of enlarged tonsil, and probably incites the attacks of inflammation to which such tonsils are liable. Calculi may form in these crypts and give rise to a spasmodic cough. In this case the glossopharyngeal nerve conveys the afferent impulse to the respiratory centre.

The tonsil is very vascular, receiving blood from the tonsillar and palatine branches of the facial artery, from the descending palatine branch of the internal maxillary, from the dorsalis linguæ of the lingual, and from the ascending pharyngeal. Hence the operation of removing the tonsil is often associated with free bleeding. The internal carotid artery is close to the pharynx, but some way behind the gland (Fig. 34, p. 134). The vessel is, indeed, about $\frac{4}{5}$ of an inch posterior to that body, and is in comparatively little danger of being wounded when the tonsil is excised. The internal jugular vein is a considerable distance from the tonsil. The facial artery, in its cervical stage, is close to the tonsil. Of important cervical structures, the nearest to the tonsil is the glosso-pharyngeal nerve. The ascending pharyngeal artery is also in close relation with it. Although this vessel is of small size, bleeding from it has proved fatal, as the following interesting case, reported by Mr. Morrant Baker, will show:

A man aged 23 fell when drunk, and grazed his throat with the end of a tobacco-pipe he was smoking at the time. He thought nothing of the accident. In two days he came to the hospital with what appeared to be an acutely inflamed tonsil. The tonsil was punctured, but nothing escaped save a little blood. Several hæmorrhages occurred from the tonsil wound, and on the fourth day after the accident 1 inch of the stem of a clay pipe was discovered deeply embedded in the glandular substance. It was removed, and the common carotid tied. The patient, however, never rallied from the previous severe hæmorrhages, and soon died. The autopsy showed that the stem of the pipe, which had not been missed by the patient, had divided the ascending pharyngeal artery. (*St. Bart.'s Hosp. Reports*, 1876.)

The tonsil is often the seat of *malignant growths.* Such tumours have been removed through the mouth, but are more conveniently dealt with through an incision in the neck along the anterior edge of the sterno-mastoid (Cheevers' operation).

CHAPTER IX

THE NECK

Surface anatomy; bony points.—The hyoid bone is on a level with the fourth cervical vertebra, while the cricoid cartilage is opposite the sixth. The upper margin of the sternum is on a level with the disc between the second and third dorsal vertebræ. (*See* p. 187.) At the back of the neck there is a slight depression in the middle line which descends from the occipital protuberance, and lies between the prominences formed by the trapezius and complexus muscles of the two sides. At the upper part of this depression the spine of the axis can be made out on deep pressure. Below this, the bony ridge formed by the spines of the third, fourth, fifth, and sixth cervical vertebræ can be felt, but the individual spines cannot usually be distinguished. At the root of the neck the spinous process of the vertebra prominens is generally very obvious. The transverse process of the atlas may be felt just below and in front of the tip of the mastoid process. By deep pressure in the upper part of the supraclavicular fossa, the transverse process of the seventh cervical vertebra can be distinguished. If pressure be made over the line of the carotid vessels at the level of the cricoid cartilage, the prominent anterior tubercle of the transverse process of the sixth cervical vertebra can be felt. This is known as the "carotid tubercle." The carotid artery lies directly over it, and in ligaturing that vessel some surgeons make important use of this tubercle as a landmark. If a horizontal section of the neck, in a muscular subject, taken about the level of the sixth cervical vertebra, be viewed, the whole of the body of the vertebra divided will be seen to lie within the anterior half of the section.

Middle line.—In the receding angle below the chin the hyoid bone can be felt and its body and greater cornua well made out. About a finger's-breadth below it is the thyroid cartilage. The details of this latter are readily distinguished, and below it the cricoid cartilage, crico-thyroid space, and trachea can be easily recognized. The separate rings of the trachea cannot be felt. The trachea is less easily made out as it passes down the neck As it descends it takes a deeper position, and at the upper border of the sternum lies nearly 1½ inches from the surface.

The rima glottidis corresponds to the middle of the anterior margin of the thyroid cartilage.

Unless enlarged, the thyroid gland cannot be made out with certainty. According to Holden, the pulse of the superior thyroid artery can be felt at its upper and anterior part.

The anterior jugular veins descend on either side of the middle line upon the sterno-hyoid muscles. They commence in the submandibular region, pierce the fascia just above the inner end of the clavicle, and, passing beneath the origin of the sterno-mastoid muscle, end in the external jugular. The inferior thyroid veins lie in front of the trachea, below the isthmus.

Side of the neck. Muscles.—The sterno-mastoid muscle, especially in thin subjects and when thrown into action, is a prominent feature in the neck. The anterior border of the muscle is very distinct. The posterior border is less prominent, especially at its upper part. A communicating branch from the facial vein generally runs along the anterior border of the muscle to meet the anterior jugular vein at the lower part of the neck. The interval between the sternal and clavicular parts of the muscle is generally well marked. If a needle be thrust through this interval, quite close to the clavicle, it would just touch the bifurcation of the innominate artery on the right side and would pierce the carotid vessel on the left. The posterior belly of the digastric muscle corresponds to a line drawn from the mastoid process to the anterior part of the hyoid bone. The anterior belly of the omo-hyoid follows an oblique line drawn downwards from the fore part of the hyoid bone, so as to cross the line of the carotid artery opposite the cricoid cartilage. The posterior belly can be made out in thin necks, especially when in action, running nearly parallel with and just above the clavicle. Although not taking quite the same direction, yet the posterior borders of the sterno-mastoid and anterior scalene muscles practically correspond to one another.

Vessels.—The common carotid artery is represented by a line drawn from the sterno-clavicular joint to a point midway between the angle of the mandible and the mastoid process. The vessel bifurcates at the upper border of the thyroid cartilage, or not infrequently nearly $\frac{1}{2}$ an inch above that point. The omo-hyoid crosses it opposite the cricoid cartilage, and at about the same level the artery is crossed by the middle thyroid vein. The line of the internal jugular vein is just external to that for the main artery. Both artery and vein lie under the anterior border of the sterno-mastoid. The superior thyroid artery comes off below the great cornu of the hyoid bone, and curves forwards and downwards to the upper edge of the thyroid cartilage. The great cornu of the hyoid serves as an excellent guide to the lingual artery, which invariably forms a loop above the posterior end of that process before proceeding forwards beneath the hyo-glossus (Fig. 35, p. 137). The facial artery is very tortuous, but its general course in the neck is represented by a line drawn from the anterior border of the masseter at the lower border of the mandible to a point just above the tip of the great cornu, while the occipital follows a line that starts from the latter point and runs across the base of the mastoid process.

The external jugular vein follows a line drawn from the mandibular angle to the middle of the clavicle.

The subclavian artery describes a curve at the root of the neck (Fig. 44). One end of the curve corresponds to the sterno-clavicular joint, the other

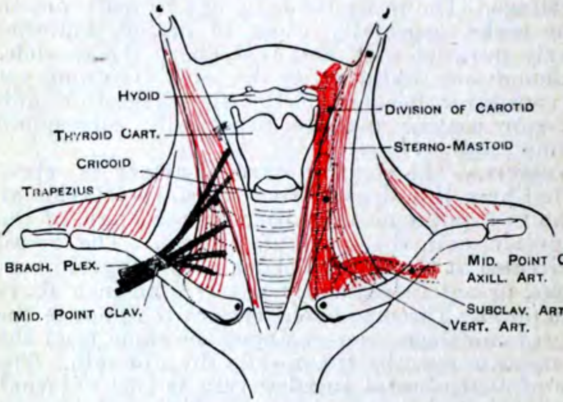

Fig. 44.—Diagram showing the surface markings for the brachial plexus, subclavian and carotid arteries.

end to the centre of the clavicle, the summit of the curve rising to a point about ½ an inch above that bone. In the angle between the posterior edge of the sterno-mastoid and the clavicle the pulsations of the artery may be felt. Just above the clavicle the artery may be compressed against the first rib. The compression is most easily applied when the arm is well drawn down, and the direction of the pressure should be downwards and backwards, for it must not be forgotten that the first rib descends as it passes forwards under the clavicle. The subclavian vein lies below the artery, and is entirely under cover of the clavicle. The suprascapular and transverse cervical arteries run parallel with the clavicle, the former quite behind the bone, the latter just above it. The pulsations of the latter vessel can generally be felt.

Nerves.—The position of the chief superficial nerves of the neck may be fairly indicated by six lines, all drawn from the middle of the posterior border of the sterno-mastoid muscle. A line drawn forwards from this spot so as to cross the sterno-mastoid at right angles to its long axis corresponds to the superficial cervical nerve (nervus cutaneus colli). A second line drawn up across the muscle to the back of the pinna, so as to run parallel with the external jugular vein, corresponds to the great auricular nerve; and a third line, running along the posterior border of the sterno-mastoid muscle to the scalp, marks the course of the small occipital nerve. These lines, continued downwards so as to cross the sternum, the middle of the clavicle, and the acromion, will indicate respectively the anterior, middle, and posterior supraclavicular nerves.

The spinal accessory nerve reaches the anterior border of the sterno-mastoid muscle at a point about 1 inch below the tip of the mastoid process. It emerges from beneath that muscle about the middle of its posterior border, crosses the posterior triangle, and passes beneath the trapezius between the middle and lower thirds of the anterior border of that muscle (Fig. 35, p. 137).

The phrenic nerve commences deeply at the side of the neck, about the level of the mid-point of the thyroid cartilage, and runs downwards to a point behind the sternal end of the clavicle. About the level of the cricoid cartilage it lies beneath the sterno-mastoid (which covers it wholly in the neck) about midway between the anterior and posterior borders of the muscle. The brachial plexus can be felt, and even seen in very thin subjects. Its upper limits may be represented by a line drawn across the side of the neck from a point about opposite to the crico-thyroid space to a spot a little external to the centre of the clavicle (Fig. 44).

The **skin** in the submandibular region is lax and thin, and is often found of considerable value for making flaps in plastic operations about the mouth. The platysma myoides is closely connected with the skin, and to its action is due the turning-in of the edges of such wounds as are athwart the line of direction of the muscle. The amount of subcutaneous fat in the cervical region varies in different parts. In the suprahyoid region it is apt to undergo extensive development, producing the diffused lipoma known as "double-chin."

The skin over the nape of the neck is very dense and adherent, and these two circumstances, in addition to the free nerve supply of the parts, serve to explain the severe pain that often accompanies inflammation in this region. Common carbuncle is very often met with here, at the root of the neck, in the middle line.

When the **sterno-mastoid** muscle of one side is rigidly contracted, either from paralysis of the opposite muscle or from spasmodic contraction, or from some congenital defect, the condition known as **wry-neck** is produced. The position of the head in wry-neck illustrates precisely the effect of the sterno-mastoid when in full action. The head is bent a little forwards, the chin is turned towards the sound side, and the ear on the affected side leans towards the sterno-clavicular joint. In many cases the trapezius and splenius muscles are also affected. Spasmodic contraction of the muscle may be due to reflex irritation. Thus, it has accompanied inflammation of the cervical glands in the posterior triangle. Such inflammation has irritated some branches of the cervical plexus, and the sterno-mastoid muscle, although it is supplied mainly by the spinal accessory nerve, receives a nerve from that plexus (viz. from the second cervical). The course of the reflex disturbance in such cases is therefore not difficult to follow. It is to be remembered, too, that the spinal accessory nerve passes between the upper two or three deep cervical lymph-glands, which may compress it. A like contraction has also been produced by direct irritation of the second cervical nerve in cases of disease of the first two cervical vertebræ. For the relief of some forms of wry-neck, the sterno-mastoid muscle is divided subcutaneously, as in an ordinary tenotomy operation, about ½ an inch above its attachment to the sternum and clavicle. Two structures stand considerable risk of being wounded in this operation, viz. the external jugular vein lying near the posterior border of the muscle, and the anterior jugular which follows its anterior border and passes behind the muscle, just above the clavicle, to terminate in the first-named vein. With common care, there should be no risk of wounding the great vessels at the root of the neck. For spasmodic wry-neck, the spinal accessory nerve and the communicating branches of the second and third cervical nerves have been cut. The spinal accessory nerve, as already stated, is found at the anterior border of the sterno-mastoid, 1 inch below the mastoid process.

There is a curious congenital tumour, or induration, sometimes met with in this muscle in the newly born. It is usually ascribed to syphilis, but, in most cases, is probably due to some tearing of the muscle fibres during the process of delivery.

Cervical fascia.—To the connective tissue which binds together the muscles, vessels, nerves, and glands of the neck the name of cervical fascia is given. It consists of the sheaths of the muscles, vessels, and nerves. These sheaths are united together in such a manner as to allow free movements of the œsophagus, larynx, trachea, and thyroid body, and yet to give a firmness and solidity so that the neck may be moved as a whole. Besides serving as a medium for binding the various structures of the neck together, the cervical fascia forms the supporting tissue in which the extensive lymphatic system of the neck is embedded and conveyed towards the root of the neck.

The deep cervical fascia may be divided into (A) the superficial layer, and (B) the deeper processes (*see* Fig. 45).

(A) The **superficial layer** forms a complete investment for the neck, and covers in all the cervical structures, except the platysma and some superficial veins and nerves, with the completeness of a perfectly fitting cravat. It commences as a thin layer behind at the spinous processes of the vertebræ, and, having invested the trapezius muscle, starts at the anterior border of that muscle, as a single layer, to cross the posterior triangle. Arriving at the posterior border of the sterno-mastoid muscle, it splits to enclose that structure, appearing again as a single layer at the anterior border of the muscle, whence it passes to the middle line of the neck to join the fascia of the opposite side, entirely covering in, on its way, the anterior triangle. The part that occupies the posterior triangle is loose and open in texture, and is continuous with the connective tissue of that triangle. Over the anterior triangle the fascia is attached above to the lower border of the mandible. Behind that bone it passes over the parotid gland to the zygoma, forming the parotid fascia, while a deeper layer passes beneath the gland (between it and the submandibular gland), to be attached to points at the base of the skull. It is from this deeper part that the stylo-mandibular ligament is developed. In front the fascia is attached to the hyoid bone, and just below the thyroid body it divides into two layers again, one to be attached to the front of the sternum and the other to the back. Both of these layers lie in front of the depressors of the hyoid bone, and they form between them a little space (which extends so far laterally as to enclose the sternal head of the sterno-mastoid), the widest part of which is below, and which there corresponds in width to the thickness of the sternum. It will be perceived that, in dividing the sternal head of the sterno-mastoid, the operation is performed within this little chamber formed by the two layers just

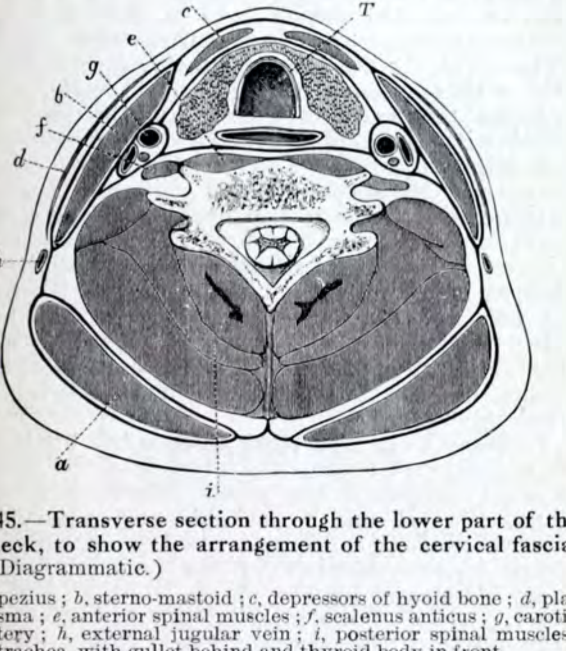

Fig. 45.—Transverse section through the lower part of the neck, to show the arrangement of the cervical fascia. (Diagrammatic.)

a, Trapezius ; *b*, sterno-mastoid ; *c*, depressors of hyoid bone ; *d*, platysma ; *e*, anterior spinal muscles ; *f*, scalenus anticus ; *g*, carotid artery ; *h*, external jugular vein ; *i*, posterior spinal muscles ; T, trachea, with gullet behind and thyroid body in front.

named, and it is well to note that the anterior jugular vein also occupies this chamber on its way to the external jugular trunk.

(B) **The deeper processes.**—(1) From the superficial layer a process comes off near the anterior border of the sterno-mastoid muscles, which, passing beneath the depressors of the hyoid bone, invests the thyroid body and front of the trachea, and runs down, in front of that tube and of the large vessels, to the fibrous layer of the pericardium. (2) The prevertebral fascia is a layer that descends on the prevertebral muscles behind the pharynx and gullet. It is attached above to the base of the skull, and, below, descends into the thorax, behind the œsophagus. Laterally, it joins the carotid sheath, and is then prolonged outwards and downwards over the scalene muscles, the brachial plexus, and the subclavian vessels. It follows these vessels beneath the clavicle, where it forms the axillary sheath and becomes connected with the under surface of the costo-coracoid membrane. (3) The sheath of the carotid artery and its accompanying vein and nerve is continuous with the prevertebral and pretracheal layers and with the sheath of the sterno-mastoid (Fig. 45). The carotid sheath descends with the pretracheal layer, to end in the sheath of the aorta and pericardium. Hence, in a sense, the heart and pericardium are supported from the neck; when the head is thrown back the carotid sheaths become tense and the thoracic structures are lifted upwards.

In many cases a **cervical abscess** has burst into the gullet, or trachea, and even into the pleura. In some instances the great vessels have been opened up. In one remarkable case reported by Savory (*Med.-Chir. Trans.*, 1881), not only was a considerable portion of the common carotid artery destroyed by the abscess, but also a still larger portion of the internal jugular vein and a large part of the vagus nerve. This, and like examples of the destructive action of some cervical abscesses, depend, no doubt, upon the unyielding character of the cervical fascia, which hems in the pus on all sides, and drives it to resort to desperate measures to effect an escape. "It is noteworthy," remarks Jacobson, "that communications between abscesses and deep vessels have usually taken place beneath two of the strongest fasciæ in the body, the deep cervical fascia and the fascia lata" (Hilton's "Rest and Pain").

The **apex of the lung** extends into the neck, and reaches a point from 1 to 2 inches above the inner half of the clavicle. A point between the sternal and clavicular heads of the sterno-mastoid and $1\frac{1}{2}$ inches above the clavicle will, in the majority of adults, mark the highest point of the apex and the position of the neck of the first rib. It lies behind the clavicle, anterior scalene muscle, and subclavian vessels. The right lung commonly extends higher up than the left.

The pleura has been opened in careless operations on the subclavian artery, and has also been torn in dragging deep-seated tumours from the base of the neck. The pleura and lung have been wounded in stabs of the neck and by fragments of bone in severe fractures of the clavicle. Cervical abscesses have opened into the pleura, and, apart from this, pleurisy has followed inflammation of the cellular tissue at the root of the neck. *Sibson's fascia*, which is attached along the inner border of the first rib, strengthens the pleura over the apex of the lung.

Cervical ribs.—These structures have led to many errors in diagnosis, have been mistaken for exostoses, and, where the subclavian artery is carried over them, which is usually the case (Fig. 46), have led to the diagnosis of aneurysm. They are met with in from 1 to 2 per cent. of all individuals, but rarely give rise to symptoms until adult years are reached. They represent the ribs which are normally developed in some lower vertebrates. In most cases a cervical rib is found on either side of the seventh cervical vertebra; sometimes it is movable, sometimes it is ankylosed to the vertebra and its transverse process. A rudiment is always present in the fœtus. It may be very short, and represented only by a head, neck, and tubercle. Such forms have been mistaken for exostoses. It may be long, and may then end free, or be joined to the first rib or the first costal cartilage by ligament, or even by cartilage. In such instances the subclavian artery passes over the cervical rib, its pulsations being very distinctly seen and felt. To the longer form of cervical ribs the scalenus anticus and the scalenus medius

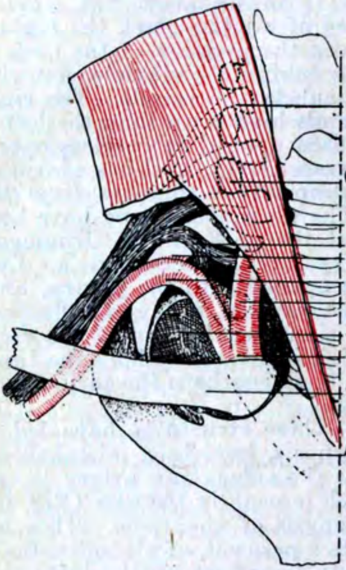

Fig. 46.—Showing the relationship of the subclavian artery and brachial plexus to a cervical rib.

may be attached. Occasionally subjects of this anomaly complain of numbness along the ulnar side of the arm and hand, or of partial paralysis of the muscles of the hand. These symptoms are due to traction on the first dorsal nerve at the point where it crosses above the cervical rib (Thorburn). (*See* Fig. 46.) Cervical ribs with associated pressure symptoms may be traced through several generations of the same family (Theodore Thompson). In thin subjects the rib can be seen as a distinct projection in the neck. Prof. Wood-Jones has pointed out that the **groove on the upper surface of the first rib** is occupied, when the arm hangs by the side, not by the subclavian artery but by the lowest trunk of the brachial plexus formed by the eighth cervical and first dorsal nerves. He has also shown that the groove is deepest, and the pressure between the nerve trunk and rib therefore greatest, in those cases where a considerable part of the second dorsal nerve enters into the formation of the lowest trunk of the brachial plexus.

Cut throat and wounds of the neck.—The skin of the neck is so elastic and mobile that it is readily thrown into folds when a knife, and especially a blunt knife, is drawn across it. Thus in cases of cut throat several distinct skin-cuts may be found that were all produced by one movement of the knife. The wound in cut throat, whether suicidal or homicidal, most frequently involves the thyro-hyoid membrane, next in frequency the trachea, and then the thyroid cartilage. (*See* Fig. 44, p. 176.)

1. If the wound be **above the hyoid bone** the following parts may be cut: Anterior jugular vein; anterior belly of digastric; mylo-hyoid, genio-hyoid, genio-glossus, and hyo-glossus muscles; the lingual artery; branches of the facial artery; the hypoglossal and lingual nerves; the submandibular gland. The substance of the tongue may be cut, and the floor of the mouth freely opened. In any case where the attachments of the tongue are divided the organ is apt to fall back upon the larynx and produce suffocation.

2. If the wound be **across the thyro-hyoid space** the following may be the parts cut: Anterior jugular vein; sterno-hyoid, thyro-hyoid, omo-hyoid muscles; thyro-hyoid membrane; inferior constrictor; superior laryngeal nerve; superior

thyroid artery; and if it be near the hyoid bone the trunk of the lingual artery may be cut. The pharynx would be opened in a deep wound, and the epiglottis divided near its base. Division of the epiglottis in wounds in this situation is always a serious complication.

3. If the wound **involve the trachea** the following may be the parts cut: Anterior jugular vein; sterno-hyoid, sterno-thyroid, and omo-hyoid muscles; part of sterno-mastoid; thyroid gland; superior and inferior thyroid arteries; superior, middle, and inferior thyroid veins; recurrent laryngeal nerves and the gullet.

In wounds of the neck the great vessels often escape in a marvellous manner. They are protected in part by the depth at which they are situated, and in part by their great mobility, lying as they do in an environment of loose connective tissue. Dieffenbach relates a case of cut throat in which both gullet and trachea were divided without any damage to the great vessels. In cut throat the vessels are greatly protected by the projecting thyroid cartilage above and by the contracting of the sterno-mastoid muscles below. Deep gashes made across the crico-thyroid space, or through the upper part of the trachea, reach the great vessels more easily than wounds made with equal force in any other part of the neck.

In some cases of gunshot wound the vessels seem to have been actually pushed aside, and to have owed their safety to their mobility. Thus, in a case reported by Longmore, the bullet passed entirely through the neck from one side to the other. It passed through the gullet, damaged the posterior part of the larynx, but left the great vessels intact. In another recorded case a boy fell upon the point of a walking-stick. The end of the stick passed entirely through the neck from side to side, entering in front of one sterno-mastoid muscle and emerging through the substance of the opposite one. It probably passed between the pharynx and the spine. The boy, who left the hospital well in eighteen days, owed his safety to the laxity of the cervical connective tissue and to the mobility of the main structures in the neck. The structures of the neck are fixed laxly to allow movements of the larynx and tongue.

In connexion with the subject of wounds of the neck, it must be remembered that the most important part of the spinal cord can be reached from behind, through the gap between the atlas and axis. In this situation the cord has been divided by one stab of a knife, the instrument entering between the two bones. Langier gives some ingenious cases of infanticide where the lethal weapon was merely a long needle. The needle was introduced into the spinal canal between the atlas and the axis, and the cord readily cut across.

The **hyoid bone** may be broken by direct violence, as from blows, or in the act of throttling. It is sometimes found broken in those who have been hanged. The fracture may involve the body of the bone, but more usually the greater cornu is found broken off. In the *New York Medical Record* (1882) is published the report of the case of a man who felt something snap under his chin while yawning. On examination the hyoid bone was found to be fractured. The bone was also found broken in a patient who threw her head violently backwards to save herself from falling (Hamilton). The fracture is associated with great difficulty and pain in speaking, in moving the tongue, in opening the mouth, and in swallowing—symptoms that may be readily understood. A bursa lies between the thyro-hyoid membrane and the posterior surface of the hyoid bone. When enlarged, it may form one of the cystic tumours of the neck.

Larynx and trachea.—The position of the larynx in the neck is influenced by age. In the adult the cricoid cartilage reaches to the lower part of the sixth cervical vertebra. In a child of three months it reaches the lower border of the fourth cervical, and in a child of six years the lower border of the fifth vertebra. At puberty it attains the adult position. The upper end of the epiglottis in the adult is opposite the lower border of the third cervical vertebra. With the laryngoscope the following parts may be made out (Fig. 47): The base of the tongue and the glosso-epiglottic folds; the superior aperture of the larynx, presenting in front the epiglottis, the cushion of the epiglottis (Fig. 47, A), at the sides the aryteno-epiglottidean folds (in which are two rounded eminences corresponding to the cornicula and cuneiform cartilages), and at the back the arytenoid commissure of mucous membrane. Deep down can be seen the true and false vocal cords, the ventricle, the anterior wall of the larynx, a little of the cricoid cartilage, and more or less of the anterior wall of the trachea. If the glottis be very fully dilated the openings of the two bronchi may be dimly seen.

The **thyroid** and **cricoid cartilages** and the greater part of the **arytenoid** are in structure hyaline, as are the costal cartilages. Like the last-named, they are liable to become more or less ossified as life advances. Ossification commences in the thyroid and cricoid cartilages at about the age of 20, and in either cartilage the process commences in the vicinity of the crico-thyroid joint. The arytenoid ossifies later. Ossification of the laryngeal cartilages is more marked in males than in females. The larger cartilages are liable to be fractured by violence, as by blows, throttling, etc. The thyroid is the one most frequently broken, and usually in the median line. The posterior superior angle of the thyroid cartilage marks the position of the pyriform fossa, a wide recess, above and external to the aryteno-epiglottic folds (Fig. 47). Foreign bodies may be arrested in this fossa.

The **rima glottidis** is the aperture between the true vocal cords and the vocal process of the arytenoid cartilages, to which the cords are attached posteriorly. The cords are double the length of the processes, and are of a grey-buff colour, owing to the elastic tissue, of which they are mainly composed, being apparent beneath the stratified epithelium. The rima is the narrowest part of the interior of the larynx, and it is well to be familiar with its proportions in reference to the

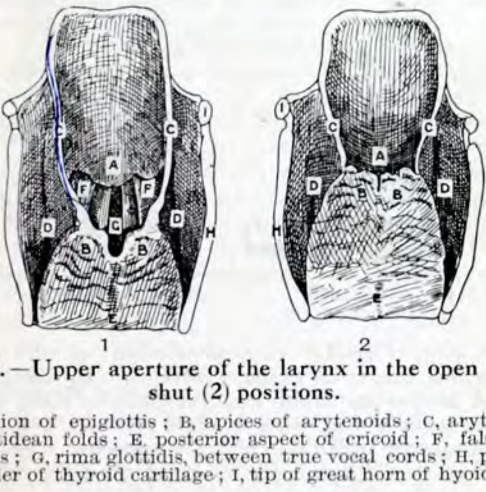

Fig. 47.—Upper aperture of the larynx in the open (1) and shut (2) positions.

A, Cushion of epiglottis; B, apices of arytenoids; C, aryteno-epiglottidean folds; E, posterior aspect of cricoid; F, false vocal cords; G, rima glottidis, between true vocal cords; H, posterior border of thyroid cartilage; I, tip of great horn of hyoid.

entrance of foreign bodies and the introduction of instruments. In the adult male the rima measures nearly 1 inch (23 mm.) from before backwards; from side to side, at its widest part, it measures about one-third of the length; this diameter may be increased to one-half of the length in extreme dilatation. In the female and in the male before puberty the antero-posterior diameter is from 17 mm. The rima is widely opened during inspiration, owing to the action of the crico-arytenoideus posticus, while the vocal cords are approximated in speech under the influence of the crico-arytenoideus lateralis (Fig. 48).

The **mucous membrane** of the larynx varies in thickness in different parts, and in the amount of its submucous tissue. The membrane is thickest, and the submucous tissue most abundant, in the following parts, taken in order of degree: the aryteno-epiglottidean folds, the mucous membrane of the ventricle, the ventricular folds (false vocal cords), and the laryngeal aspect of the epiglottis. These are the parts that become

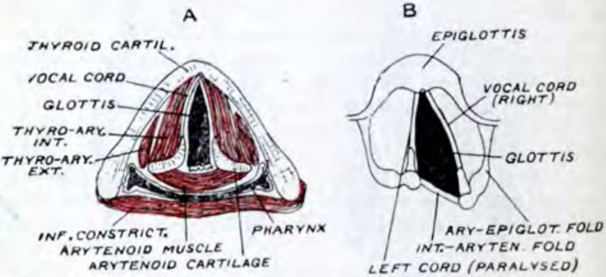

Fig. 48.— A, Coronal vertical section of the larynx, showing the vocal cords, ventricles, ventricular folds, and thyro-arytenoid muscles; B, the rima glottidis seen from above, with the left cord in the position of adductor paralysis, and the muscles which move the arytenoid cartilages indicated on the right.

most congested and swollen in acute laryngitis; and the serious condition known as œdema of the glottis depends mainly upon effusion into the lax submucous tissue in the aryteno-epiglottidean folds. The lax condition of the mucous membrane of the aryteno-epiglottidean folds allows free movements of the arytenoid cartilages and complete closure of the upper aperture of the larynx (Fig. 47). The mucous membrane is firmly bound to the true vocal cords and covered by stratified epithelium, while the rest of the larynx is lined, like the trachea, with ciliated epithelium. Owing to the nature of its covering and exposure to friction, the true vocal cord is not an uncommon site of epithelioma. The affection known as "*clergyman's sore throat*" has an interesting anatomical basis. The mucous membrane of the larynx is well provided with mucous glands, whose function it is to keep moist the parts concerned in phonation. When an individual speaks aloud for a long time the lining of the larynx tends to become dry, on account of the large amount of cold air that is drawn in directly through the mouth. To keep these parts moist the mucous glands have to exhibit increased energy, and in those who speak much in public the glands may in time become so overworked as to inflame. It is the inflammation of these glands that constitutes the present affection. The glands are not distributed equally over all parts of the larynx, but are most numerous in the membrane covering the arytenoid cartilages and parts immediately about them, the base of the epiglottis, and the interior of the ventricle. It is in these parts, therefore, that the changes in chronic glandular laryngitis, or *dysphonia clericorum*, are most marked.

Excision of the larynx.—The entire larynx has been removed for carcinomatous disease, but the operation, although not immediately fatal, has not been followed by very satisfactory results. It is removed through an incision in the middle line. In this incision are divided the platysma, the fascia, and the anterior jugular vein. The larynx is separated from its connexions, the following structures being divided: sterno-thyroid, thyro-hyoid, stylo-pharyngeus, palato-pharyngeus, and inferior constrictor muscles, the laryngeal branches of the superior and inferior thyroid arteries, the superior and inferior laryngeal nerves, the hyo-epiglottic and glosso-epiglottic ligaments. The larynx is then separated from the trachea, and is dissected off from below up. In separating gullet and pharynx there is great risk of "button-holing" the former tube. Growths and foreign bodies may be removed from the larynx by the operation of **thyrotomy**: the two alæ of the thyroid are separated along the middle line and pulled apart, thus exposing the interior of the larynx. In subjects over 45 years of age the cartilage becomes ossified in the middle line, and will require division by a fine saw. It should be remembered that the vocal cords are attached on each side of the median line near the mid-point of the anterior border of the thyroid cartilage, while just above them are fixed the ventricular folds or false vocal cords and stalk of the epiglottis.

The lymphatic vessels of the upper half of the larynx follow the superior laryngeal vessels and pass to the upper deep cervical glands. A small lymphatic gland, the first to become the seat of secondary cancerous deposit, is situated below the horn of the hyoid on the thyro-hyoid membrane (Fig. 50, p. 207). The lymphatics of the lower half of the larynx accompany the inferior thyroid vessels and pass through lymph-glands by the side of the trachea.

Tracheotomy and laryngotomy.—The trachea measures about $4\frac{1}{4}$ inches in length, and from $\frac{3}{4}$ to 1 inch in its extreme width. It is surrounded by an atmosphere of very lax connective tissue, which allows a considerable degree of mobility to the tube. The mobility of the trachea is greater in children than in adults, and adds much to the difficulties of tracheotomy. In this procedure the windpipe is opened in the middle line by cutting two or three of its rings above, below, or through the isthmus of the thyroid gland. Since the trachea, as it descends, lies farther from the surface, and comes in relation with more and more important structures, it is obvious that, other things being equal, the higher in the neck the operation can be done the better. The length of trachea in the neck is not so considerable as might at first appear, and, according to Holden, not more than some seven or eight of the tracheal rings (which number sixteen to twenty in all) are usually to be found above the sternum. The distance between the cricoid cartilage and the sternal notch varies greatly, and depends upon the length of the neck, the age of the patient, and the position of the head. If 2 inches of trachea are exposed above the sternum when the head rests easily upon the spine, then in full extension of the head some $\frac{3}{4}$ of an inch more of the windpipe will, as it were, be drawn up into the neck. According to Tillaux, the average full distance between the cricoid cartilage and the sternum is, in the adult, about $2\frac{3}{4}$ inches (7 cm.). The full distance in a child between 3 and 5 years is about $1\frac{1}{2}$ inches (4 cm.), in a child between 6 and 7 years about 2 inches (5 cm.), and in children between 8 and 10 years about $2\frac{1}{4}$ inches (6 cm.). As may be imagined, the dimensions of the trachea on section vary greatly at different ages, and even in different individuals of the same age. This leads to the question as to the proper diameter of tracheotomy tubes. Guersant, who has paid much attention to this matter, says that the diameter of the tubes should run from 6 mm. to 15 mm.* The tubes with a diameter of from 12 mm. to 15 mm. are for adults. For children under 18 months the diameter of the tube should be about 4 mm.

In performing *tracheotomy* it is most important that the head be thrown as far back as possible, and that the chin be kept strictly in a line with the sternal notch, so that the relations of the middle line of the neck be preserved. Full extension of the head not only gives the surgeon increased room for the operation, but also brings the trachea nearer to the surface, and by stretching the tube renders it much less mobile.

In cutting down upon the trachea in the middle line of the neck from the cricoid cartilage

* The reader may be reminded that 12·5 mm. = about $\frac{1}{2}$ in., and 6 mm. therefore = about $\frac{1}{4}$ in.

to the sternum the following parts are met with: Beneath the integument lie the anterior jugular veins. As a rule these veins lie some little way apart on either side of the median line, and do not communicate except by a large transverse branch which lies in the interfascial space at the upper border of the sternum. Sometimes there are many communicating branches right in front of the tracheotomy district, or the veins may form almost a plexus in front of the trachea, or there may be a single vein which will follow the middle line. Then comes the cervical fascia, enclosing the sterno-hyoid and sterno-thyroid muscles. The gap between the muscles of opposite sides is lozenge-shaped, and is such that the trachea can be exposed without dividing muscle fibres. The isthmus of the thyroid usually crosses the second, third, and fourth rings of the trachea. Above it a transverse communicating branch between the superior thyroid veins is sometimes found. Over the isthmus is a venous plexus, from which the inferior thyroid veins arise, while below the isthmus these veins lie in front of the trachea together with the thyroidea ima artery (when it exists). The inferior thyroid vein may be represented by a single trunk occupying the middle line. In the infant before the age of 2 years the thymus extends up for a variable distance in front of the trachea. At the very root of the neck the trachea is crossed by the innominate and left carotid arteries and by the left innominate vein; and lastly, abnormal branches of the superior thyroid artery may cross the upper rings of the windpipe.

The evil of wounding the thyroid isthmus is exaggerated. I (F. T.) have frequently divided this structure in performing tracheotomy, without any inconvenience resulting. Like other median raphës, the middle line of the thyroid isthmus has but a slight vascularity, and it has been shown that one side of the thyroid gland can only be partially injected from the other (i.e. by injection that crosses the isthmus). The difficulty of tracheotomy in infants depends upon the shortness of the neck, the amount of the subcutaneous fat, the depth at which the trachea lies, its small size, its great mobility, and the ease with which it can be made to collapse on pressure. To the finger, roughly introduced, the infant's trachea offers little resistance. Its mobility is such that we hear of its being held aside unknowingly by retractors while the operator is scoring the œsophagus (Durham). In the child, too, the great vessels often cross the trachea higher up than in the adult, and some inconvenience may also arise from an unduly prominent thymus. In one case, in an infant, the end of a tracheotomy tube pressing on the front of the trachea produced an ulcer that opened the innominate artery (*Brit. Med. Journ.*, 1885). In introducing the cannula, if the tracheal wound be missed, it is easy to thrust the instrument into the lax tissue beneath the cervical fascia and imagine that it is within the windpipe.

In *laryngotomy* the air-passage is opened by a transverse cut through the crico-thyroid membrane. The crico-thyroid space only measures about ½ an inch in vertical height in well-developed adult subjects, while in children it is much too small to allow of a cannula being introduced. The crico-thyroid arteries cross the space, and can hardly escape division. They are, as a rule, of very insignificant size, and give no trouble. Occasionally, however, these vessels are large, and "cases are recorded in which serious and even fatal hæmorrhage has occurred from these vessels" (Durham). In introducing the cannula it may readily slip between the crico-thyroid membrane and the mucous lining instead of entering the trachea.

Foreign bodies often find their way into the air-passages, and they have been represented by articles of food, teeth, pills, buttons, small stones, and the like. They are usually inspired during the act of respiration, and may lodge in the superior aperture of the larynx, or in the rima, or find their way into the ventricle, or lodge in the trachea, or enter a bronchus. If a foreign substance enters a bronchus it usually selects the right, that bronchus having its aperture more immediately under the centre of the trachea than has the left tube. On one occasion, in a dissecting-room subject, I (F. T.) found two threepenny pieces lying side by side, in the right bronchus, so as entirely to block the tube. The danger of inhaled foreign substances depends not so much upon the mechanical obstruction they offer as upon the spasm of the glottis they excite by reflex irritation. A body may, however, lodge in the ventricle for some time without causing much trouble, as in a case reported by Desault, where a cherry-stone lodged for two years in this cavity without much inconvenience to its host. In one strange case a bronchial gland found its way into the trachea by producing ulceration of that tube, was coughed up, and became impacted in the rima glottidis. The patient was saved from immediate suffocation by tracheotomy.

Thyroid body.—Each lobe of this body should measure about 2 inches in length, $1\frac{1}{4}$ inches in breadth, and $\frac{3}{4}$ of an inch in thickness at its largest part. When distinctly beyond these measurements the thyroid may be considered to be enlarged. Its usual weight is between 1 and 2 oz. Of the three surfaces (Fig. 49), the anterior is covered by the infrahyoid muscles, its inner rests on the larynx and trachea, while its outer or posterior covers the carotid sheath. Its prominent posterior border is in contact at its lower part with the recurrent laryngeal nerve and œsophagus. Each lobe extends from about the middle of the thyroid cartilage to the sixth ring of the trachea. It is larger in females than in males, and the right lobe is usually larger than the left. In connexion with these matters it may be noted that thyroid enlargements (bronchocele, goitre) are more common in females than in males, and in any case are more apt to be first noticed on the right side. The body being closely adherent to the trachea and larynx, it follows that it moves up and down during deglutition, and this circumstance is of the utmost value in the diagnosis of bronchocele from other cervical tumours. A strong process of cervical fascia (the suspensory ligament of Berry) binds the gland to each side of the cricoid cartilage, and has to be severed before complete removal is possible. The

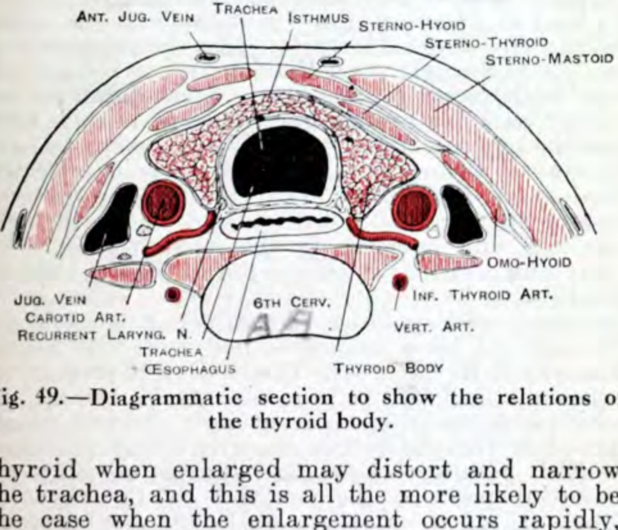

Fig. 49.—Diagrammatic section to show the relations of the thyroid body.

thyroid when enlarged may distort and narrow the trachea, and this is all the more likely to be the case when the enlargement occurs rapidly, since the body is held down by the sterno-hyoïd, sterno-thyroid, and omo-hyoid muscles. The posterior or outer surface of the thyroid body being in contact with the sheath of the great vessels, it follows that the gland when enlarged may readily receive pulsations from those vessels (Fig. 49). It generally touches also the lower part of the pharynx, and the upper part of the gullet behind, and enlargement in this direction may, in connexion with the interference with the movement of the larynx in deglutition, serve to explain the difficulty in swallowing often noticed in bronchocele.

The isthmus of the thyroid gland is developed from a diverticulum which is protruded from the ventral wall of the pharynx in the embryo between the mandibular and hyoid parts of the tongue (Fig. 51, p. 210). The foramen cæcum of the tongue represents the point at which the diverticulum grew out from the pharynx. From this foramen a duct (the thyro-glossal) may be found to lead to accessory gland masses about the hyoid bone. In the vicinity of this bone accessory glands and small cysts lined with epithelium are not infrequently met with. These glands, together with the so-called pyramid or middle lobe, are the remains of the neck of the primitive diverticulum. Below the level of the hyoid bone the median bud divides; hence the pyramidal lobe represents the stalk of the right or of the left division and is never in the median line. The pyramid, which is nearly always connected to the hyoid bone by the levator thyroideæ, exists in 79 per cent. of the subjects examined (Streckeisen). The lateral lobes are developed from the fourth visceral clefts (Fig. 51). The median diverticulum occasionally fails to join one of the lateral, in which case the isthmus is partially absent. Small accessory thyroid bodies are frequently present.

The **parathyroid bodies** appear to play an essential part in the function of the thyroid. They are of the size of small peas, and have a structure similar to that of the medulla of the suprarenal bodies, the cells being grouped in reticulating columns. Two are usually found on each side, one behind the lower pole of the lateral lobe, the other behind the lobe amongst the terminal branches of the inferior thyroid artery. Parathyroid bodies become less numerous as age advances, so that in the aged none may be found (Forsyth). The parathyroid bodies may develop vesicles containing colloid material, and thus become very similar to small accessory thyroids.

Atrophy of the thyroid gland, or its destruction by disease, is apt to lead to a general condition of the body known as **myxœdema.** The condition closely resembles cretinism, especially as met with in goitrous subjects. Myxœdema may follow the entire excision of the thyroid by operation, and has been produced in monkeys by experimental removal of the gland. One prominent feature of myxœdema is the swelling of the subcutaneous tissues from an accumulation therein of a mucinoid substance.

Vaso-motor nerves reach the thyroid through the lower part of the cervical sympathetic chain, and by the same course nerves pass upwards to the eye (*see* p. 64). These nerves appear to be connected centrally, probably in the medulla, for in certain conditions enlargement of the thyroid is accompanied by protrusion of the eye (exophthalmic goitre). The lymphatics of the thyroid gland are numerous, and pass to the deep cervical and superior mediastinal lymph-glands. Asher and Flack found that the internal secretion of the thyroid body could be increased by stimulation of the laryngeal nerves.

The superior thyroid artery reaches the gland at the apex of the lateral lobe; the inferior thyroid artery enters the lower part of the lobe at its posterior aspect. In securing this vessel, and in liberating the lower part of the gland during excision, the recurrent laryngeal nerve is in great danger of being damaged. If it be cut or included in a ligature, all the muscles of the larynx on that side become paralysed, save the crico-thyroid. The thyroidea ima artery, an extra vessel to the thyroid body, which usually arises from the innominate and ascends in front of the trachea, is found in one subject out of every ten.

The **gullet** commences opposite the sixth cervical vertebra, and pierces the diaphragm opposite the tenth dorsal vertebra. The point is marked on the back by the overlapping spine of the ninth dorsal vertebra. By placing the stethoscope a little to the left of this spine, fluid may be heard to enter the stomach. The gullet presents three curves: one is antero-posterior, and corresponds to the curve of the spinal column; the other two are lateral. Commencing at the middle line, it deviates slightly to the left as far as the root of the neck; thence to the fifth dorsal vertebra it gradually returns to the middle line, and finally it turns again to the left, at the same time passing forwards, to pierce the diaphragm. Notwithstanding these natural curvatures, a rigid and straight gastroscope can, in expert hands, be passed from mouth to stomach. Its length is from 9 to 10 inches. There are three narrow parts in the gullet—one at its commencement, one about $2\frac{3}{4}$ inches from that point, and a third where the tube passes through the diaphragm. The narrowing at the commencement and termination of the œsophagus is due to the fact that the musculature at these points is sphincteric in nature, and, except during the passage of food, the lumen in these parts is closed. Under certain conditions the sphincter at the lower end of the œsophagus passes into a state of spasm leading to dilatation of the œsophagus from accumulation of food. In its open state the diameter at each of these points is a little over $\frac{1}{2}$ an inch (14 mm.); the diameter elsewhere is about $\frac{3}{4}$ of an inch (17 mm. to 21 mm.). By forcible distension the two upper narrow parts could be distended to a diameter of 18 to 19 mm., the lower part to 25 mm., and the rest of the gullet to a diameter of nearly $1\frac{1}{2}$ inches (35 mm.). Foreign bodies when swallowed are most apt to lodge above one of the sphincters either at the commencement of the gullet or where it passes through the diaphragm to join the stomach. The same parts also are those most apt to show the effects of corrosives that have been swallowed. A third point of arrest is where the œsophagus passes behind the left bronchus.

Among the relations of the œsophagus, the following may be noted as receiving illustration in surgical practice: The gullet is in nearly all its course in close relation with the front of the vertebral column. In the neck the trachea is immediately in front of it. In the thorax it has the left bronchus, left bronchial glands, pericardium, and left auricle in front of it, while the two vagi form a plexus on it. The left bronchial glands, when enlarged, may press on the gullet, adhere to it, or even cause localized softening and diverticula to spring from it. The thoracic duct passes behind to reach the left side of the gullet in the upper part of the thorax, while in the lower part the aorta, at first to the left of the œsophagus, gradually becomes posterior to it. It is, moreover, partly in contact with both pleuræ, but more especially with the membrane of the right side; and, lastly, the recurrent laryngeal nerve ascends between it and the trachea. (*See* Figs. 57 and 102, pp. 241 and 455.)

Foreign bodies impacted in the gullet are very apt to lead to ulcerations that may open adjacent parts. Thus, in the Musée Dupuytren is a specimen showing a five-franc piece which had stuck in the gullet, and had produced an ulcer that had opened the aorta. In another instance a "smasher" swallowed a counterfeit half-crown piece. Eight months afterwards he died of hæmorrhage. The coin had sloughed into his aorta. In another case (*Lancet*, 1871), a fish-bone, lodged in the gullet opposite the fourth dorsal vertebra, had caused two perforating ulcers; one on the right side had caused plugging of the vena azygos major, while the other on the left had made a hole in the aorta. Less frequently, impacted foreign substances have found their way into the trachea and into the posterior mediastinum. Dr. Ogle reports a case (*Path. Soc. Trans.*, vol. iv.) where a piece of bone impacted in the gullet induced ulceration of an intervertebral disc and subsequent disease of the spinal cord. Carcinoma of the gullet, also, when it spreads, is apt to invade adjacent parts, and especially to open into the trachea or bronchi. If it spreads to the pleura, it will usually involve the right pleura, as being the membrane more in relation with the gullet. Cancer of the gullet has so spread as to invade the thyroid body, the pericardium, and the lung, and has opened up the first intercostal artery in one case and the right subclavian in another.

The sensory nerve supply of the œsophagus comes mainly from the fifth dorsal segment of the cord (Head). In cases of cancer or burns of the gullet, pain is referred to the skin of this segment (*see* Fig. 79, p. 359).

Œsophageal malformations.—In the newly born the upper part of the œsophagus may end blindly, while the lower part commences by an opening in or near the bifurcation of the trachea, so that milk could reach the stomach only by first passing into the larynx and trachea. Death soon follows from suffocation or septic pneumonia. The condition is the result of a maldevelopment of the septum which ultimately separates the trachea and œsophagus. Hernial diverticula of the mucous membrane occasionally occur at the junction of the œsophagus and pharynx, immediately above the upper sphincter of the œsophagus. They are named *pharyngeal pouches*, and protrude between the lower border of the inferior constrictor and the sphincteric fibres which surround the pharyngeal orifice of the œsophagus. The diverticula therefore arise opposite the cricoid cartilage. Since the fundus of the pouch lies between the upper end of the œsophagus and the spine, it necessarily, when filled with food, compresses the commencement of the œsophagus.

The operation of **œsophagotomy** consists in incising the gullet for the purpose of removing an impacted foreign body. The gullet is usually reached from the left side, since it projects more on that aspect. The incision is made between the sterno-mastoid and the trachea, in the same direction as the incision for ligaturing the common carotid. The cut extends from the top of the thyroid cartilage to the sterno-clavicular joint. The omo-hyoid muscle is drawn outwards, or cut. The great vessels, larynx, and thyroid gland are drawn aside, and care must be taken not to wound these structures nor damage the thyroid vessels, thoracic duct, or the recurrent nerve. The gullet, when exposed, is opened by a vertical incision.

Great cervical vessels.—The course, relations, and abnormalities of the great cervical vessels, with the operations whereby they may be ligatured, and the details pertaining to those procedures, are so fully given, not only in works on operative surgery, but also in the chief anatomical text-books, that nothing need be said upon the matter in this place. The main relationships of the carotid and subclavian arteries are shown in Fig. 44, p. 176. In Brasdor's operation a main trunk is ligatured on the distal side of an aneurysm, no branches intervening between the sac and the ligature. The cure by this measure depends upon the fact that blood does not continue to go to parts when once the need for blood in them is diminished. Thus, after amputation at the hip-joint, the femoral artery, having no need to carry to the stump the amount of blood it brought to the limb, often shrinks to a vessel no larger than the radial. When an aneurysm low down in the carotid artery is treated by ligature of the vessel near its bifurcation by Brasdor's method, the blood, having now, as it were, no object in entering the carotid trunk, soon ceases to fill the vessel entirely, and the artery (and in successful cases the aneurysm) shrinks in consequence.

The cervical connective tissue being lax, aneurysms in this part can grow and spread rapidly, and usually soon produce "pressure symptoms"

As examples of these may be noted œdema and lividity of the face and of the upper limb from pressure upon the main veins, laryngeal symptoms from pressure upon the recurrent nerve or trachea, spasm of the diaphragm from pressure upon the phrenic nerve, damage to the sympathetic, and giddiness and impaired vision from anæmia of the brain.

The vertebral artery has been ligatured with doubtful benefit in cases of epilepsy. It is surrounded by vaso-motor nerves derived from the inferior cervical ganglion, which also are necessarily tied. The artery is reached through an incision made along the posterior border of the sterno-mastoid muscle just above the clavicle (*see* Fig. 44, p. 176). The "carotid tubercle" is then sought for, and vertically below it lies the artery, in the gap between the scalenus anticus and longus colli muscles. The procedure is surrounded with considerable difficulties.

Air in veins.—The veins of the neck are under the influence of the respiratory movements. The veins do not collapse owing to attachments to the surrounding fasciæ. During inspiration these vessels become more or less emptied; during expiration they become enlarged and turgid. With greatly impeded breathing they may attain formidable size. Since ether usually causes some respiratory difficulty, it is seldom administered in operations on the neck. The only other veins that are under the influence of the aspiratory power of the thorax are the axillary vein and its larger tributaries. When any one of these vessels is wounded, and the wound is for the moment dry, air may very readily be drawn into it during the inspiratory act, just as air is drawn into the trachea. The air causes embolism of the pulmonary capillaries.

Valves in the veins of the neck.—The subclavian veins and their tributaries are liberally provided with valves, but the internal jugular has only one pair, situated at its termination in the innominate vein. There are no valves in the innominate veins or in the superior vena cava. When the venous pressure within the thorax is greatly raised, as in lifting heavy weights, only the terminal valves of the internal jugular vein prevent the transmission of the pressure to the brain. In accidents which cause sudden compression of the thorax, the head and neck may remain livid for days following the accident. The lividity is probably due to the jugular valves yielding, thus subjecting the capillaries of the head and neck to a higher pressure than they are able to withstand.

Cervical part of the sympathetic cord.—If, in the course of an operation on the neck, the sympathetic cord, which unites the superior, middle, and inferior cervical ganglia, should be cut or included in a ligature, a remarkable series of symptoms results, chiefly noted in the eye and orbit of the same side. It will be remembered that the nerve-fibres which supply the dilator muscle of the iris, the non-striated tarsal muscle of the upper lid, the non-striated muscle of the orbit, the sweat-glands of the face, and give vaso-motor branches to the arteries of the face, tongue, and neck, issue from the spinal cord by the anterior roots of the first and second dorsal nerves. They pass to the cervical cord in the white rami of these two nerves, ascending in the cord which lies behind the carotid sheath. The case of a woman in whom the sympathetic cord had been cut during the removal of tubercular glands from the right side of the neck is recorded by Dr. Purves Stewart. "The right eyelid drooped a little, the right side of the face flushed less than the left; when she chewed, a small patch of excessive perspiration appeared below the right eye. The right pupil was smaller than the left, from paralysis of the dilator pupillæ. Moreover, the affected pupil does not dilate when shaded, yet it contracts briskly to light and on convergence. . . . The *cilio-spinal* *reflex* is abolished; the pupil no longer dilates when the skin on the right side of the neck is pinched."

The **lymphatic glands of the head and neck** are numerous, and arranged in the following sets (Fig. 50):—

(1) Submandibular glands, 10 to 15 in number, situated at the lower border of the jaw beneath the cervical fascia; (2) the suprahyoid, 1 or 2 in number, situated between the chin and hyoid bone near the middle line; (3) parotid or preauricular set, situated in and over the parotid gland; (4) postauricular or mastoid, 2 to 4 in number, situated over the mastoid process; (5) occipital, 3 to 5 in number, over the insertion of the complexus muscle; (6) superficial cervical glands, often absent, situated over the sternomastoid along the external jugular vein; (7) laryngeal, 1 to 3 in number, below the great horn of the hyoid; (8) the upper deep cervical set, 10 to 20 in number, situated over the upper part of the internal jugular vein and bifurcation of the common carotid artery; (9) lower deep cervical set, surrounding the terminal parts of the internal jugular, subclavian, external jugular, and transverse cervical veins. This set becomes continuous with the axillary and mediastinal glands.

These glands are very often enlarged and inflamed, and it is in this part of the lymphatic system that tubercular enlargement of lymph-glands is most commonly met with. The inflammatory affections in glands would appear to be always of a secondary nature, and to follow disturbances in those parts of the periphery whence they respectively receive their lymph. It may be convenient, therefore, to group the relations of certain glands to certain parts of the periphery.

Scalp.—Posterior part = occipital and postauricular glands. Frontal and parietal portions = preauricular glands (Fig. 50).

Vessels from the scalp also enter the superficial cervical set of glands.

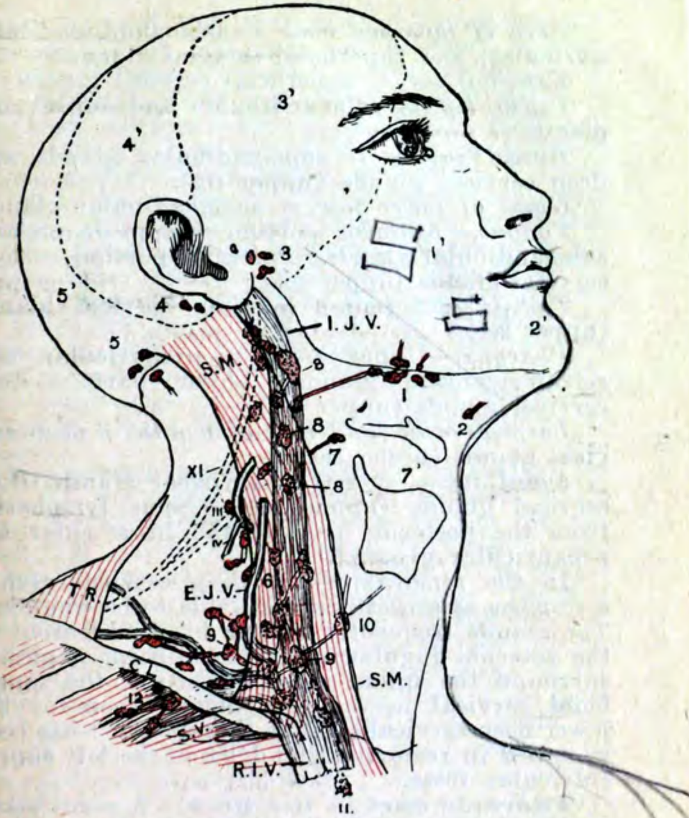

Fig. 50.—Showing the positions of the lymphatic glands of the head and neck. The outlines of the sterno-mastoid (S.M.), trapezius (TR.), internal jugular, subclavian, and right innominate veins are shown.

1, Submandibular glands, 1′ area drained; 2, suprahyoid glands, 2′ area drained; 3, preauricular glands, 3′ area drained; 4, post-auricular glands, 4′ area drained; 5, occipital glands, 5′ area drained; 6, in front of external jugular vein, marking position of the superficial cervical glands; 7, laryngeal gland; 8, 8, 8, upper deep cervical glands; 9, 9, 9, lower deep cervical glands; 10, gland receiving lymph from thyroid; 11, superior mediastinal glands; 12, axillary glands.

Skin of face and neck = submandibular, preauricular, and superficial cervical glands.

External ear = superficial cervical glands.

Lower lip = submandibular and suprahyoid glands.

Buccal cavity = submandibular glands and deep cervical glands (upper set).

Gums of lower jaw = submandibular glands.

Tongue.—Anterior portion = suprahyoid and submandibular glands. Posterior portion = deep cervical glands (upper set).

Tonsils and palate = deep cervical glands (upper set).

Pharynx.—Upper part = preauricular and retropharyngeal glands. Lower part = deep cervical glands (upper set).

Larynx, orbit, and roof of mouth = deep cervical glands (upper set).

Nasal fossæ = retropharyngeal glands, deep cervical glands (upper set). Some lymphatics from the posterior part of the fossæ enter the preauricular glands.*

In the removal of the deep cervical glands a number of structures are liable to be wounded. The glands frequently become firmly adherent to the internal jugular vein; the uppermost glands surround the spinal accessory nerve; the superficial cervical nerves pass among those of the lower deep cervical set; the thoracic duct has been wounded in removing glands from the left supraclavicular fossa.

Thoracic duct in the neck.—A point taken on the upper border of the clavicle, 1 inch from its sternal end, will mark the angle between the internal jugular and subclavian veins at or near which the thoracic duct ends. In 40 bodies investigated by Messrs. F. G. Parsons and P. W. G. Sargent the duct was found to end in the terminal part of the internal jugular vein in 35 instances; in nearly half of these cases the ter-

* From "Scrofula, and its Gland Diseases," by Sir Frederick Treves 1882.

minal part of the duct divided; it frequently has two orifices, and may have as many as four. At its termination the duct curves outwards over the scalenus anticus and phrenic nerve above its point of entrance where it is usually furnished with valves. Ligature of the duct is followed by no untoward symptoms, as a rule, a result which is due to the free anastomosis that exists between it and the lymphatics of the right side of the thorax and to communications with the azygos veins (Leaf). As the duct ascends behind the left common carotid and subclavian arteries to enter the neck, it lies in contact with the pleura and lung. On the right side the thoracic duct is represented by the right lymphatic trunk. The tributaries of these two main lymphatic channels are in free communication within the thorax.

Branchial fistulæ.—Certain congenital fistulæ are sometimes met with in the neck, which are due to partial persistence of one of the branchial clefts. These clefts are placed in the fœtus between the branchial arches. The arches are usually described as five in number. The first lays the foundation for the lower jaw and malleus. From the second are developed the styloid process, the stylo-hyoid ligament, and lesser cornu of the hyoid bone. From the third are formed the body and greater cornu of the hyoid bone, while the fourth and fifth take part in the formation of the cartilages and soft parts of the neck below the hyoid bone. The first cleft is between the first and second arches. "The cervical branchial fistulæ appear as very fine canals opening into minute orifices in one or both sides of the fore part of the neck, and leading backwards and inwards or backwards and upwards towards the pharynx or œsophagus" (Paget). Their length is about $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, and their diameter varies from that of a bristle to that of an ordinary probe. The orifice of a cervical fistula is usually situated just above the sterno-clavicular joint (Fig. 51), and represents the orifice of the *cervical sinus*, a depression or pocket formed during the development of the neck of the fœtus, and serving as a common orifice for the branchial or visceral clefts in which the tonsil, thymus,

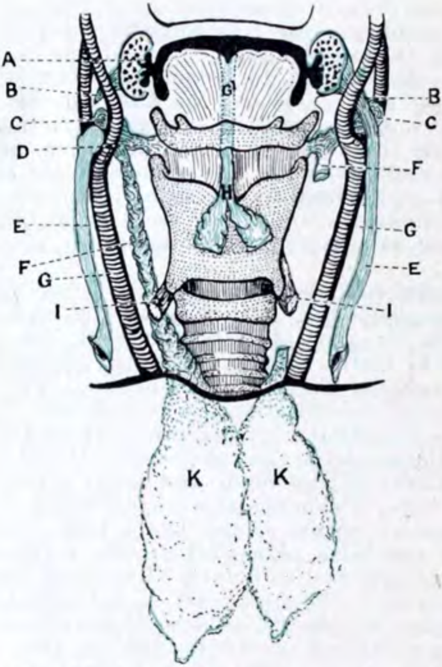

Fig. 51.—Showing the positions and connexions of various embryological remnants in the neck.

A, Tonsil; B, remnant of tonsillar sac (from second cleft recess); C, carotid body between external and internal carotid arteries; D, stalk of thymus (third cleft); E, cervical sinus (united with second cleft recess on left side); F, cervical thymus; G, common carotid; G′, median part of thyroid and thyro-glossal duct; H, infrahyoid part of median thyroid; I, stalk of lateral thyroid from fourth cleft; K K, thymus in thorax.

and lateral thyroids are developed. The fistula, as it ascends, passes towards the bifurcation of the common carotid, where it may come into communication with the carotid body (derived from the third cleft), or with the tonsillar recess (from the second cleft). It can be understood that only parts of these saccular structures and outgrowths may persist, such remnants forming the bases for cervical cysts. Certain dermoid cysts of the neck, and also certain polycystic congenital tumours, occurring as one form of "hydrocele of the neck," also arise from these branchial remnants. At the orifice of the fistulæ, or at the position where they usually occur, tags of skin containing cartilage may appear. They are termed *supernumerary auricles*, because they occupy the same relationship to the fistulæ that the external ear does to the first visceral cleft.

The ventricle of the larynx, as is normally the case in many apes, may become prolonged into a sac which passes through the thyro-hyoid membrane, thus forming a *cervical air-cyst* or *sac* in the laryngeal region of the neck.

Part II.—THE THORAX

CHAPTER X

THE CHEST AND ITS VISCERA

The Thoracic Walls

The two sides of the chest are seldom symmetrical, the circumference of the right side being usually the greater, a fact that is supposed to be explained by the unequal use of the upper limbs. In **Pott's disease,** involving the dorsal region, when the spine is much bent forwards the thorax becomes greatly deformed. Its antero-posterior diameter is increased, the sternum protrudes, and may even be bent by the bending of the spine, the ribs are crushed together, and the body may be so shortened that the lower ribs overlap the iliac crest.

In **pigeon-breast** deformity the sternum and cartilages are rendered protuberant, so that the antero-posterior measurement of the chest is much increased, while a deep sulcus exists on either side along the line of junction of the ribs and their cartilages. It is by the sinking-in of the parietes along the costo-chondral junctions that the protuberance is produced. In children, and especially in rickety children, the thorax is very pliable and elastic, and if a constant impediment exists to the entrance of air, as, for example, from greatly enlarged tonsils, the thoracic walls may yield in time to the suction brought to bear upon them at each inspiration. The weakest part of the thorax is along the costo-chondral line on either side, and it is here that the parietes yield most conspicuously in such cases.

Deformities of the chest result from abnormal curvatures of the dorsal part of the spinal column. The ribs are firmly bound to the vertebræ by the costo-vertebral and costo-transverse ligaments, and hence alteration in the position of vertebræ is attended by changes in the costal series. Thus, when there is *kyphosis* in the dorsal region the upper part of the spine is bent forwards and downwards, carrying with it the upper ribs and the sternum. The antero-posterior diameter of the thorax is thereby increased, but its vertical and transverse measurements are decreased. When *lateral curvature* is produced in the dorsal region, the ribs, on the side towards which the bend occurs, are necessarily compressed, while on the opposite side they are separated. In *scoliosis* of the spine not only is a lateral curvature formed, but the vertebræ undergo a rotation at the same time. The vertebral bodies move towards the convex side of the column, and their spinous processes towards the concavity of the curvature (Fig. 52). The ribs on the concave side are carried forwards on the transverse processes and their angles open out, the side of the chest becoming flattened behind. On the other side (convex) the angles are unduly promi-

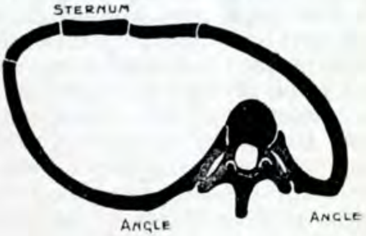

Fig. 52.—Showing the changes in the thorax which follow scoliosis of the spine. (*After Redard.*)

The convexity of the spinal curvature is towards the right: on that side the ribs are sharply bent at their angles. On the concave (left) side the ribs have an open angle.

nent, for the ribs are carried backwards at their vertebral extremities and bent inwards in front. The transverse diameter of the chest thus becomes oblique (Fig. 52). On the concave side the intercostal spaces are diminished in size, the ribs even coming into contact, while on the convex side the spaces are increased in size. The thoracic viscera are necessarily distorted in shape and altered in position.

The sternum.—The upper edge of the sternum corresponds to the disc between the second and third dorsal vertebræ, and the xiphisternal joint to the middle of the tenth dorsal. In the fœtus at full term the upper edge of the sternum is opposite the middle of the first dorsal vertebra (Symington). A transverse ridge or angle may be felt upon its anterior surface that corresponds to the junction of the manubrium and body, and is in a line with the second costal cartilages. The bone is rarely *fractured*, being soft and spongy, and supported by the elastic ribs and their cartilages, as by a series of springs. In the old, when the cartilages are ossified and the chest is more rigid, the tendency to fracture is increased. The sternum is most often found fractured in connexion with injuries to the spine, although it may be broken by simple direct violence. The bone may be fractured by violent bending of the spine backwards, and by abrupt bending of it forwards. In the former instance the lesion is probably due to muscular violence—to the abdominal muscles and the sterno-mastoid pulling one against the other. In the latter instance the lesion is commonly brought about by the violent contact of the chin with the bone. Dislocation may occur at the sterno-manubrial joint (sternal synchondrosis). The manubrium in these injuries generally remains *in situ*, while the body with the ribs is displaced forwards in front of it. A considerable degree of respiratory movement takes place at the sternal synchondrosis; only in very old people does it become obliterated by bony union.

It possesses a distinct synovial cavity surrounded by strong fibrous and fibro-cartilaginous ligaments. Malgaigne cites the case of a youth who, from constant bending at his work as a watchmaker, caused the second piece of the sternum to glide backwards behind the manubrium.

From its exposed position and cancellous structure, the sternum is liable to many affections, such as caries and gummatous periostitis. The comparative softness of the bone is such that it has been penetrated by a knife in homicidal wounds. The shape and position of the bone have also been altered by pressure, as seen sometimes in artisans following employments requiring instruments, etc., to be pressed against the chest.

Certain holes may appear in the middle of the sternum, and through them mediastinal abscesses may escape, and surface abscesses pass deeply into the thorax. These holes result from imperfect union of the right and left sternal bars, out of which the sternum is formed. In the case reported by E. Groux, the bone was separated vertically into two parts. The gap could be opened by muscular effort and the heart exposed, covered only by the soft parts. The sternum has been trephined for mediastinal abscess, and for paracentesis in pericardial effusion, and it has been proposed also to ligature the innominate artery through a trephine hole in the upper part of the bone. The upper part has been divided vertically, each half being turned forwards and outwards with the corresponding ribs in order to gain access to the structures in the superior mediastinum.

The **ribs** are placed so obliquely that the anterior end of one rib is on a level with the posterior end of a rib some way below it in numerical order. Thus the second rib in front corresponds to the fifth rib behind, and the insertion of the seventh to the tenth. If a horizontal line be drawn round the body at the level of the inferior angle of the scapula, while the arms are at the side, the line would cut the sternum in front at the attachment of the sixth cartilage, would cut the fifth rib at the nipple line, and the ninth rib at the vertebral column. The second rib is indicated by the transverse ridge on the sternum already alluded to (angulus Ludovici). The lower border of the pectoralis major leads to the fifth rib, and the first visible serration of the serratus magnus corresponds to the sixth. The longest rib is the seventh, the shortest the first. The most oblique rib is the ninth. As the arm hangs by the side the lower angle of the scapula covers the seventh rib.

The ribs are elastic and much curved, and, being attached by many ligaments behind to the column, and in front to the yielding cartilages, resist with the qualities possessed by a spring such injuries as tend to produce fracture. A rib may be fractured by *indirect violence*, as by a wheel passing over the body when lying prostrate on the back. In such a case the force tends to approximate the two ends of the bone, and to increase its curve. When it breaks, therefore, it breaks at the summit of its principal curve. i.e. about the centre of the bone. The fragments fracture outwards, and the pleura stands no risk of being penetrated. When the rib is broken by *direct violence*, lesion occurs at the spot encountered by the force, the bone fractures inwards, the curve of the rib tends to be diminished rather than increased, and there is much risk of the fragments lacerating the pleura.

The ribs most often broken are the sixth, seventh, and eighth, these being, under ordinary circumstances, the most exposed. The rib least frequently fractured is the first, which lies under cover of the clavicle. In elderly people dying from phthisis the cartilage of the first rib is often found to be calcified and occasionally to be fractured. Indeed, in the majority of people over 45 the cartilage of the first rib is calcified and ossified to a greater or less degree, and there is no doubt that the elasticity and mobility of such ribs are impaired. In cases of emphysema, it has been proposed to divide or even excise the cartilages of the upper ribs in order to increase the respiratory capacity and mobility of the thorax. Fractures are more common in the elderly than in children, owing to the ossification of the cartilages that takes place in advancing life. When a rib is fractured, no shortening occurs, the bone being fixed both in front and behind, while vertical displacement is prevented by the attachments of the intercostal muscles. Thus no obvious deformity is produced unless a number of consecutive ribs are the subjects of fracture. These bones have been broken by *muscular violence*, as during coughing, and in violent expulsive efforts such as are incident to labour. In such instances the ribs are probably weakened by atrophy or disease.

In **rickets** changes take place at the point of junction of the ribs and cartilages which lead to bony elevations, producing, when the ribs on both sides are affected, the condition known as the "rickety rosary." The costo-chondral junctions at which these enlargements occur correspond to the epiphyseal lines of long bones—lines at which growth in length takes place.

The **intercostal spaces** are wider in front than behind, and between the upper than the lower ribs. The widest of the spaces is the third, then the second, then the first. The seventh, eighth, ninth, and tenth interspaces are very narrow in front of the angles of the ribs. The first five spaces are wide enough to admit the whole breadth of the index finger. The spaces are widened in inspiration, narrowed in expiration, and can be increased in width by bending the body over to the opposite side.

Paracentesis is usually performed in the sixth or seventh space, at a point midway between the sternum and the spine, or midway between the anterior and posterior axillary lines. The seventh space can be readily identified by its relationship to the angle of the scapula; when the arm is by the side of the body this space is slightly overlapped by the angle. If a lower space be selected there is danger of wounding the diaphragm, especially upon the right side. If the eighth or ninth space be selected the incision is made just externally to the line of the angle of the scapula. The trocar should be entered during inspiration, the space being widened thereby, and should be kept as near as possible to the lower border of the space, so as to avoid the intercostal vessels. Tapping of the chest through any space posterior to the angles of the ribs is not practicable, owing to the thick covering of muscles upon the thoracic wall in this place, and the fact that the intercostal artery, having a more horizontal course than the corresponding ribs, crosses the middle of this part of the space obliquely. Beyond the angle the intercostal vessels lie in a groove on the inferior border of the rib forming the upper boundary of the space. The vein lies immediately above the artery, and the nerve immediately below it. In the upper four or five spaces, however, the nerve is at first higher than the artery. Paracentesis of the thorax is occasionally followed by syncope or even death. It is difficult to account for such a result; it may be a reflex inhibition of the heart set up during perforation of the parietal pleura, which is richly supplied by the intercostal nerves, or by injury to the lung, which is supplied by the vagus.

Pus may readily be conducted along the loose tissue between the two layers of intercostal muscles. Thus, in suppuration following upon disease of the vertebræ, or of the posterior parts of the ribs, the pus may be conducted along the intercostal spaces to the sternum, and may thus present at a considerable distance from the real seat of the disease.

Removal of ribs.—In order to obtain a free opening into the pleural cavity a portion of one or even of two ribs may be excised.

In some cases of long-standing empyema with an open sinus, all that part of the bony wall of the thorax which corresponds to the outer boundary of the suppurating cavity is removed in order that the cavity may collapse and be in a position to close. This latter measure is known as Estlander's operation, or thoracoplasty. In some instances portions of as many as nine ribs have been excised, and the total length of bone removed has reached 50 to 60 inches.

In removing a rib the bone is entirely bared of periosteum with the rugine, and the excision is extraperiosteal. In this way the intercostal vessels are not exposed, and, if divided subsequently, can be readily secured when the ribs are out of the way.

The **internal mammary artery** runs parallel to the border of the sternum, and about ½ an inch from it. It may give rise to rapidly fatal hæmorrhage if wounded. The vessel may readily be secured in the first three intercostal spaces, and with some difficulty in the fourth or fifth space. It is most easily reached through the second space, and cannot be secured through any space below the fifth.

The **female breast** extends from the second rib above to the sixth below, and from the side of the sternum to the midaxillary line (Stiles). In cases of retained lactation the twelve to fifteen irregular lobes which make up the body of the gland can be felt radiating outwards from the nipple. The lactiferous ducts, which correspond in number to the lobes, open at the apex of the nipple, within which each shows a dilatation or ampulla. Branching processes of adjoining lobes unite and enclose spaces within the body of the gland, containing connective tissue and masses of fat. After the menopause, when the glandular tissue is absorbed in great part, and during the resting condition, fat forms the greater part of the female breast. Besides the main body of the gland, Stiles has drawn attention to numerous peripheral processes which lie in the surrounding connective tissue.

Although the principal part of the breast rests on the pectoralis major, quite one-third of the gland crosses the outer border and rests on the serratus magnus within the axilla (Fig. 53). It also covers the origins of the obliquus abdominis externus and rectus abdominis. In excision or inflammation of the breast it is important to bind the arm by the side to keep the parts from being disturbed by the pectoralis major. Peripheral processes of the gland and many of its deep lymphatics enter the pectoral sheath, hence the removal of this structure with part, or even all, of the pectoral musculature if complete extirpation of cancer is to be assured. The loose retromammary tissue which binds the mamma loosely to the pectoral sheath may be the seat of abscess, or sometimes of a bursal cyst.

The nipple, in the male and in the virgin female, is situated on the fourth intercostal space, about $\frac{3}{4}$ of an inch from the junction of the ribs with their cartilages; after lactation the breast becomes pendent, and the nipple no longer serves as a guide to the intercostal spaces. The nipple contains erectile and muscular tissue, and is richly supplied by cutaneous branches of the third and fourth spinal nerves. It is also furnished with a rich network of lymphatic vessels, which, when the breast is the site of cancer, may become invaded and blocked with cancerous epithelium, giving rise to the condition known as *Paget's disease of the nipple* (Handley). The skin is pigmented, thin, and sensitive, and often the seat of painful fissures and excoriations. In painful diseases of the breast, tender areas occur over the fourth and fifth spinal segments (Fig. 79, p. 359) (Head).

The breast is developed by a solid invagination of epiblast at the point afterwards marked by the nipple. About the sixth month of fœtal life the primitive mammary bud branches out in all directions within the subcutaneous tissue. Thus it comes about that the subcutaneous fascia is condensed around the gland, forming its capsule. The retromammary part of the capsule is connected at the interlobular spaces with the superficial layer, which in turn is fixed to the skin by subcutaneous bands, or skin ligaments.

It is through **lymph channels** that cancer spreads, and those of the breast, which is one of the commonest sites of cancer, are of especial importance if complete eradication of the disease is to be obtained. The lymph-vessels are arranged in the following sets: (1) Perilobular, round the acini and lobules; (2) periductal, round the lactiferous ducts; (3) interlobar, situated in the interlobar septa and joining (4) the retromammary network with (5) the superficial mammary in the anterior part of the capsule. If the interlobar septa are invaded by cancer they contract, and through their cutaneous attachments cause depressions in the skin; if the process invades the periductal vessels, the nipple is retracted. The mammary lymphatic system is connected with the subcutaneous network of vessels, to which cancer may spread, producing that variety of the disease known as *cancer en cuirasse.* Through communications with the lymph channels of the pectoral fascia and muscle, cancer of the breast may spread to these structures. The gland then becomes firmly fixed to the deeply seated structures. The majority of the lymph-vessels pass from the breast to the *pectoral glands*, six to eight in number, situated along the anterior border of the axilla, and to the *central axillary set*, twelve to fifteen in number, situated beneath the axillary tuft of hair and on the inner side of the axillary vein (Fig. 53). From these two sets the lymph-vessels pass to the *deep axillary glands* lying along the front and inner side of the axillary vessels. The deep axillary glands become continuous with the lower deep cervical glands. It is mainly along this path that cancer tends to spread, but vessels leave the inner segment of the breast and pass to the anterior intercostal glands situated in the upper four intercostal spaces and lying on each side of the internal mammary vessels, while occasionally a

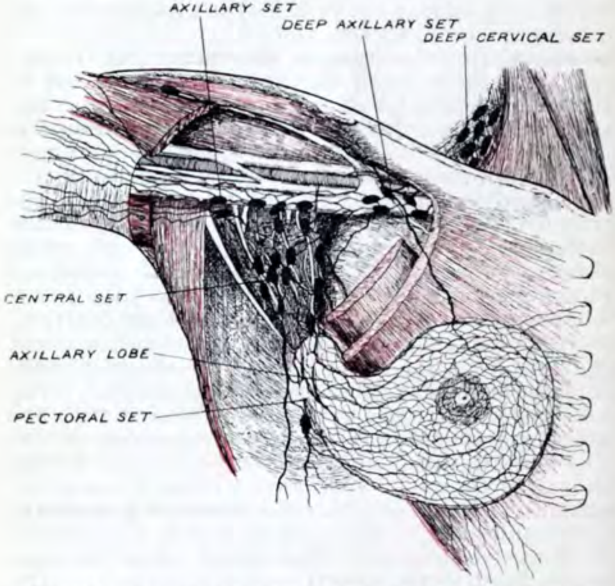

Fig. 53.—Lymphatic vessels and glands of the breast and axilla. (*Modified from Poirier.*)

few vessels pass to the cephalic gland situated in the hiatus between the deltoid and pectoralis major muscles. Handley found a marked tendency for breast cancer to spread downwards in the lymphatics, passing to the epigastric triangle. There the vessels perforate the belly wall to join lymphatics both above and below the diaphragm ; it is probably owing to this communication that the liver is so often the seat of secondary deposit in cases of cancer of the breast. When the normal channels become clogged with cancerous invasion, the lymph passes by circuitous paths. The *subscapular glands*, surrounding the subscapular vessels on the posterior wall of the axilla, may become infiltrated; through the lymphatics of the arm, which end in the central axillary glands, the structures round the shoulder may become the seats of secondary deposit; and through the communication between the lymph system of one breast with that of the other, across the sternum, a secondary deposit may even occur in the opposite breast (Stiles).

The intercosto-humeral nerve pierces the central set of axillary glands. It becomes compressed when these glands are invaded by cancer, and pain is referred to the termination of the nerve over the posterior aspect of the arm above the elbow. Various parts of the brachial plexus may also become involved, or the axillary vein or lymphatics occluded, the arm being swollen and œdematous in consequence.

The following groups of **arteries** supply the gland and are cut in excision of the organ: (1) the lateral (long) thoracic, alar thoracic, thoracic branches of the acromio-thoracic axis; (2) anterior perforating branches from the internal mammary at the second, third, and fourth intercostal spaces; (3) lateral branches from the second, third, and fourth intercostal arteries.

Supernumerary nipples and breasts may occur. They are commonly found in a line between the axilla and the groin. In the embryonic stage of all mammals an epiblastic mammary ridge is found in this position. In man it disappears except at one point, but occasionally some isolated part may persist and proceed to form a breast. Embryology fails to explain the occurrence of breasts on the buttock or back, where they are occasionally found.

The Thoracic Viscera

The lung.—The apex of the lung rises in the neck from 1 to 2 inches above the inner half of the clavicle. Its highest point in the majority of adults lies 1½ inches above the sternal end of the clavicle, in the interval between the sternal and clavicular heads of the sterno-mastoid muscle

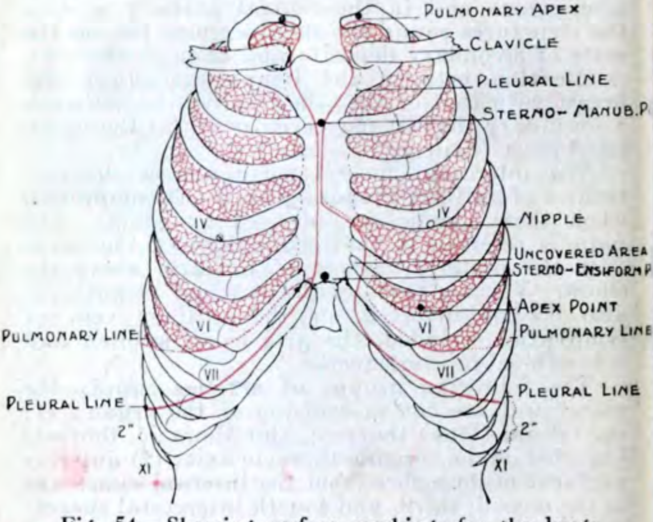

Fig. 54.—Showing surface markings for the lungs and pleura.

(Fig. 54). The anterior edges of the two lungs pass behind the sterno-clavicular articulations, and meet in the middle line at the sternal synchondrosis. The edge of the right lung then continues vertically downwards behind the middle line of the sternum to the sixth chondro-sternal articulation, where it slopes off along the line of the sixth cartilage. The edge of the left lung keeps close to that of the right as far as the fourth chondro-sternal articulation, where it turns off to the left, following a line drawn from the fourth cartilage to near the apex of the heart (Fig. 54). Occasionally it does not diverge, but completely covers the pericardium up to the edge of the sternum. In the child, owing to the thymus, the lungs are more separated in front. The right reaches the middle line, but the left only reaches the left edge of the sternum (Symington). The easiest and also the most accurate method of indicating the *lower border of the lung* is the following (Fig. 54): A line is drawn along the sixth costal cartilage from its sternal end to its heel; from the heel the line is carried horizontally round the body; it will be found to cross the median line behind, at, or near the eleventh dorsal spine (the anticlinal spine). The corresponding border of the *pleura* is not parallel to the lower border of the lung; it is indicated by a line drawn along the seventh costal cartilage from its sternal end to its heel; from there the line is continued to a point 2 inches above the lowest part of the subcostal margin and then prolonged horizontally to the median line behind where it crosses at or near the twelfth dorsal spine. Between the pulmonary line above and the pleural line below, the diaphragm is in contact with the chest wall, separated only by the costo-phrenic reflection of the pleura. On the left side these lines commence at a variable distance from the sternum—1 inch should be allowed for the pleura; $2\frac{1}{2}$ inches for the lung (Fig. 54). The pleura is in relation with the twelfth rib, but occasionally it descends $\frac{1}{2}$ an inch or more below the neck of this rib, and may be wounded in operations on the kidney (Fig. 102, p. 453). It extends lower down in the child than in the adult. The left lung descends to a slightly lower level than the right.

In penetrating wounds involving the pleura, air may enter the pleural cavity, producing pneumothorax, and this air may be subsequently pressed by the respiratory movements into the subcutaneous tissues through the wound in the parietal pleura, and lead to surgical emphysema. In injuries of the lung without external wound, as when that organ is torn by a fractured rib, the air escapes from the lung into the pleura, and may thence pass into the subcutaneous tissues through the pleural wound, thus producing both pneumothorax and emphysema.

Modern bullets of high velocity penetrate the lung without giving rise to a great degree of damage to the pulmonary tissues, or causing much hæmorrhage into the pleural space (hæmothorax). This result is due to the fact that the lungs contain air which is compressible, and lie inside an elastic-walled cavity. The same bullet, entering the medullary cavity of a bone, or the skull, causes an explosive effect because the marrow or brain is incompressible and locked up within a closed chamber.

It is well to note that emphysema may occur about certain **non-penetrating wounds of the thorax** when they are of a valvular nature. In such cases the air is drawn into the subcutaneous tissues during one respiratory movement, and is forced by another into the cellular tissue, the valvular nature of the wound preventing its escape externally. Rupture of an air-vesicle of the lung during violent muscular effort, as in childbirth, may give rise to extensive emphysema of the thorax and neck. When the pleural "cavity" is opened, the lungs, owing to the amount of elastic tissue they contain, undergo some degree of collapse, but there is much misconception regarding the extent to which this takes place. Half the air in the lung, in some cases even two-thirds, is residual and cannot be expelled by the passive collapse of the lung; when the diaphragm is pushed up and the ribs are pulled down by the expiratory efforts of the muscles of the belly-wall the thoracic space may be so reduced in size that the lung still more than fills it; if the glottis be closed a hernia of the lung will occur through the wound in the chest wall. If, however, there is a valvular orifice into the pleural cavity, so that air can be sucked in but not expelled from it, every respiratory effort increases the amount of air in the pleural space; then compression of the lung and suffocation quickly ensue. Air or fluid introduced within the healthy pleural cavity is rapidly absorbed. Air is much more quickly absorbed by the pleura than is a pleural effusion or blood. Hence the practice of replacing the blood or fluid, as it is being withdrawn, by an equal volume of purified air. As the air is absorbed the lung tends to expand to fill the vacuum created. Macewen is of opinion that collapse of the lung is prevented by the capillary attraction which exists between the visceral and parietal layers of the pleura.

In wounds of the lung the blood may escape in three directions: into the tissue of the organ (pulmonary apoplexy), into the bronchi (causing hæmoptysis), and into the pleura (causing hæmothorax). In some instances the lung has been ruptured without wound and without fracture to the ribs.

Owing to the fineness of its capillaries, and to the fact that all venous blood returned to the heart must pass through the lungs before it can reach other parts of the body, it follows that pyæmic and other secondary deposits are more commonly met with in the lung than in any other of the viscera.

Lung cavities resulting from tuberculosis, gangrene, or bronchiectasis have been successfully incised and drained, and the same measure has been applied to hydatid cysts of the lung. Deep incisions in the lung are followed by less hæmorrhage than might be expected from such a vascular organ. In tuberculosis of the lungs pleural adhesions are soon formed, and the lung is thus firmly bound to the chest-wall. In order that the part of the lung which is the site of a large cavity may be allowed to collapse, thus obliterating the cavity and permitting it to heal, the practice of opening the thoracic wall and breaking down the adhesions has been recently introduced. It is too soon to form an estimate of the results of this daring measure.

Nerve supply of the pleura.—In acute inflammation of the pleura, pain may be very intense, and the respiratory movements on the side affected may be greatly diminished. The pain, if in the lower part of the thorax, may be referred to the abdomen. The explanation of these facts must be sought in the nerve supply of the pleura. The costal pleura is supplied by the adjacent intercostal nerves, which also supply the corresponding intercostal muscles. The muscles are inhibited when the underlying parts of the pleura are inflamed. The lower six dorsal nerves also supply the abdominal wall; hence pain arising in the costal pleura may be referred by the patient to the abdomen, and lead to a suspicion of abdominal disease. The diaphragmatic and the mediastinal pleura are supplied by the phrenic nerves, and pain arising in these parts may be referred to the neck or shoulder. The cervical pleura is also supplied by the phrenic nerve (H. M. Johnston).

The **trachea** divides opposite the junction of the sternal synchondrosis in front, and the fourth dorsal vertebra behind. In the fork of the bronchi, and accompanying the bronchi into the roots of the lungs, are chains of lymphatic glands. These become enlarged in all inflammatory conditions of the lungs, giving rise to opacities in radiograms of the thorax and to a dullness on percussion on each side of the upper five dorsal vertebræ (Clive Riviere).

The presence of foreign bodies in the air-passages has already been considered (p. 195); but it may here be pointed out that in some cases they have shown a remarkable facility for escaping through the parietes. Thus, Sir Rickman Godlee records the case of a child, from an abscess in whose back there escaped a head of rye-grass that had found its way into the air-passages forty-three days previously.

Foreign bodies in the trachea and bronchi can now be located and extracted by aid of the *bronchoscope*. The mucous membrane at the bifurcation of the trachea is highly sensitive, and the orifices of the secondary bronchial tubes can be seen to contract and dilate by virtue of the circular musculature in their walls.

The root of the lung and bronchi can be exposed by opening the dorsal wall of the thorax behind the vertebral border of the scapula. Russell and Fox record the case of a boy in whom a pin, 3 inches long, had slipped head downwards within the trachea, and ultimately lodged in the lower division of the left bronchus. They resected part of the eighth rib from the back, pushed the lung forwards to expose the bronchus at the root, and removed the pin. The root of the lung requires to be steadied; through the pericardium it is intimately bound to the diaphragm and follows the movements of that muscle. In the case mentioned above, the boy was able to leave the hospital twelve days after the operation.

The heart and pericardium.—The position and extent of the pericardium may be indicated thus on the surface of the thorax (Fig. 55): Three points are taken: (1) the *apical*, over the apex beat, in the fifth left intercostal space, 3½ inches from the sternum; (2) the *sterno-manubrial*, midway between the insertions of the second costal cartilages; (3) the *inferior caval*, 1 inch to the right of the sterno-ensiform (sterno-xiphoid) point and directly superficial to the termination of the inferior vena cava. When these three points are united by curved lines, as in Fig. 55, the area over the pericardium and its contents is marked out. The lower line crosses ½ an inch or more below the sterno-ensiform point; if a trocar be thrust backwards in the angle between the ensiform process and seventh left costal cartilage, it enters the pericardium just above the diaphragm. Through this angle the pericardium may be drained; by resecting part of the fifth and sixth cartilages its cavity may be explored. The right border of the pericardium is deeply placed and covered by the right lung (Fig. 54); in health it should not project more than 1 inch beyond the right sternal border.

Besides the auricles and ventricles the follow-

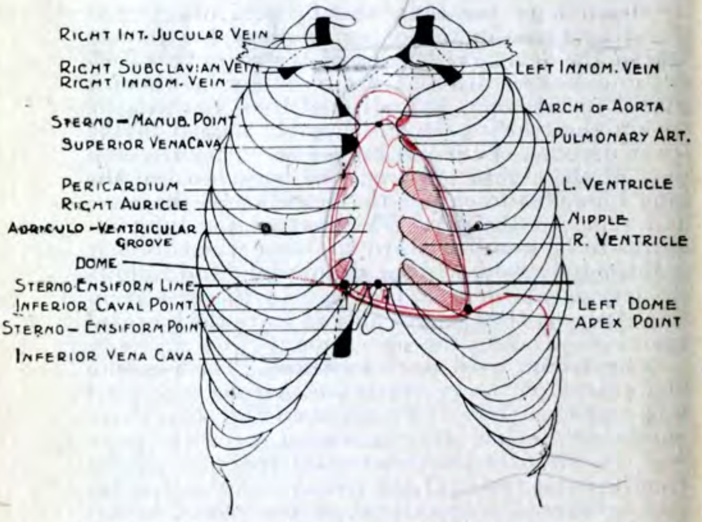

Fig. 55.—Relationship of the pericardium and heart to the sternum and ribs.

ing parts are contained in the pericardium: The terminations of the inferior and superior venæ cavæ; the ascending aorta and pulmonary artery. The position of these parts, and of the arch of the aorta and its branches, is shown in Fig. 55. It will be observed that more than two-thirds of the anterior surface of the heart is made up of right ventricle and auricle; consequently it is these parts which are usually perforated in stabs of the heart.

The heart may be exposed for operative treatment by removal of the terminal inch or more of the fourth and fifth left costal cartilages. The heart may be freely handled and sutured; the surgeon's task is rendered difficult by its rapid motions and the respiratory movements of the pericardium and diaphragm. When the heart is wounded, blood escapes into the pericardium, leading to compression of the auricles and the arrest of the inflow of blood. Hydrops of the pericardium may cause death in a similar manner. Other things being equal, a wound of the ventricle is less rapidly fatal than is a wound of the auricle, owing to the thickness of the ventricular wall, and to its capacity for contracting and preventing the escape of blood. Many instances have been recorded to show that the heart may be very tolerant of foreign bodies in its substance. Thus a man lived for twenty days with a skewer traversing the heart from side to side (Ferrus). In another case a lunatic pushed an iron rod, over 6 inches in length, into his chest, until it disappeared from view, although it could be felt beneath the skin receiving pulsation from the heart. He died a year following, and the metal was found to have pierced not only the lungs but also the ventricular cavities (Tillaux). The heart, too, is tolerant of foreign bodies lying within its chambers. During the Great War a considerable number of soldiers were observed to have a bullet or fragment lying free within the right ventricle, and yet, in such cases, no wound could be found anywhere in the wall of the heart. The bullet in such cases finds its way into one of the great veins, and is swept with the venous blood to the right chambers. In no case had the foreign body been carried into the pulmonary artery. Wounds of the heart have been sutured, the insertion of the stitches causing only momentary disturbance of its action. Travers has sutured a wound of the right ventricle into which he was able to place three fingers to prevent hæmorrhage. Apropos of chest wounds, Velpeau cites the case of a man in whose thorax was found a part of a foil that entirely transfixed the chest from ribs to spine, and that had been introduced fifteen years before death. In the museum of the Royal College of Surgeons is the shaft of a cart that had been forced through the ribs on the left side, had passed entirely through the chest, and had come out through the ribs on the right side. The patient had lived ten years.

Paracentesis of the pericardium.—As already mentioned, the pericardium may be tapped or drained through the left costo-ensiform angle (Fig. 55). The extent to which it is covered by the left pleura and lung is extremely variable, but in the majority of cases it may be tapped in the left fourth and fifth spaces, as far as 1 inch from the sternum, without injuring the pleura. The internal mammary artery descends in these spaces ½ an inch from the sternum, and divides, behind the seventh cartilage, into its superior epigastric and musculo-phrenic branches.

The mediastina.—Abscess in the anterior mediastinum may have developed *in situ*, or may have spread down from the neck. In like manner posterior mediastinal abscesses may arise from diseases of the adjacent spine, or lymphatic glands, or may be due to the spreading downwards of a retropharyngeal or retro-œsophageal collection of matter.

The employment of Röntgen rays in the diagnosis of intrathoracic disease has greatly enlarged our knowledge of the **respiratory movements and relationships of the thoracic viscera.** In Fig. 56 (from a careful drawing given by Dr. Halls Dally) a representation is given of the more important parts seen when the chest is examined in an axis passing from the right nipple to the left scapula of the patient. The heart and liver appear as shadows, moving downwards and forwards in inspiration, upwards and backwards in expiration. As the diaphragm descends, and the heart moves away from the spine, the posterior mediastinum, containing the aorta and œsophagus, appears as a transradiant triangle. With inspiration, too, the lungs clear up and become more transparent. The anterior mediastinum also is seen as a clear space. In the superior mediastinum may be seen the arch of the aorta as it passes backwards from the manu-

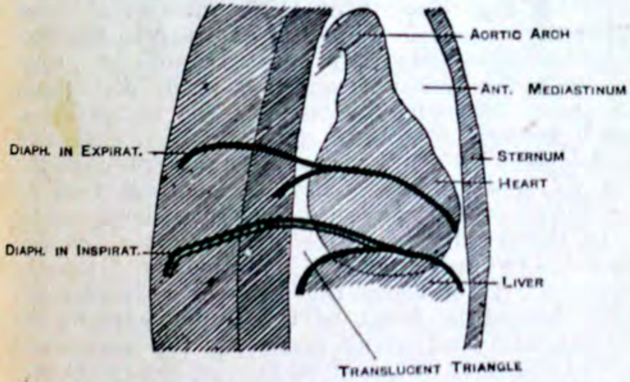

Fig. 56.—Orthodiagram of the thorax. (*After Dr. Halls Dally.*)

The position of parts is shown in extreme inspiration; the position of the diaphragm and liver in expiration is also shown.

brium to the fourth dorsal vertebra. In the individual from whom the diagram was constructed the vertical movement of the diaphragm amounted to 3 inches. In normal respiration the vertical movement varies from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, equal to a movement of a rib-breadth.

The **azygos veins,** commencing as they do below in the lumbar veins, and having more or less direct communications with the common iliac, renal, and other tributaries to the vena cava, are able to a great extent to carry on the venous circulation in cases of obstruction of the terminal part of the superior vena cava. In this they are assisted by the venæ comites of the internal mammary artery and epigastric veins; the intravertebral veins also become greatly enlarged, and serve as anastomotic channels between the superior and inferior caval systems.

These veins are apt to be pressed upon by tumours (such as enlarged gland masses) developed in the posterior mediastinum, and to produce in consequence some œdema of the chest walls by engorgement of those intercostal veins which they receive. Tumours growing in the posterior mediastinum may cause trouble by pressing upon the trachea or gullet, or by disturbing the vagus nerve or the cord of the sympathetic. The numerous lymphatic glands which surround the trachea, bronchi, and œsophagus are often the seat of tuberculosis. They become adherent to these organs and may ulcerate into them.

In the obscure condition named *status lymphaticus* the **thymus gland** is usually found greatly enlarged. It occupies the anterior mediastinum, being placed in front of the upper part of the pericardium and great vessels of the heart, and behind the part of the sternum and the costal cartilages which lie above the level of the third pair of ribs. Its sides are covered by reflections of the mediastinal pleura. When enlarged, it presses on the great vessels and on the treachea and bronchi, causing a certain degree of obstruction, but not enough to account for sudden death in cases of status lymphaticus. The thymus gland, composed of lymphoid tissue, reaches its maximum size (36 grammes = 1¼ oz.) about the eighteenth year; thereafter it becomes gradually reduced in size—more so in men than in women. In a child at birth it should weigh about 12 grm. Its arteries and veins, derived from the internal mammary, inferior thyroid, and innominate vessels, are of small size. The gland is attached by loose connective tissue to surrounding structures. Its partial or even complete removal through a transverse incision made between the ends of the clavicles is feasible (p. 240). Its functions are obscure, but it has a direct effect on the development and growth of bone. For development, *see* Fig. 51, p. 210.

Thoracic duct.—Krabbel reports a case of fracture of the ninth dorsal vertebra associated with rupture of the thoracic duct. The patient died in a few days, and the right pleura was found to contain more than a gallon of pure chyle.

The bodies of the upper lumbar and lower dorsal vertebræ are frequently the site of tuberculosis; so are the apical parts of the lungs. Prof. Wood-Jones has drawn attention to the close relationship of these parts to the thoracic duct, and to the possibility of a tubercular invasion from the alimentary canal being conveyed to these sites of election by the duct. The receptaculum chyli is formed on the bodies of the first and second lumbar vertebræ, from which the duct ascends in the posterior mediastinum in front of the lower dorsal vertebræ. In cases of cancer of the stomach, the cervical glands round the termination of the thoracic duct may become enlarged by secondary growths at an early stage of the disease. The secondary dissemination takes place by means of the thoracic duct.

PART III.—THE UPPER EXTREMITY

CHAPTER XI

THE REGION OF THE SHOULDER

A STUDY of the region of the shoulder comprises the clavicle, the scapula, the upper end of the humerus, and the soft parts that surround them, together with the shoulder-joint and axilla.

Surface anatomy.—The clavicle, acromion process, and scapular spine are all subcutaneous, and can be readily felt. In the upright position, when the arm hangs by the side, the clavicle is, as a rule, not quite horizontal. In well-developed subjects it inclines a little upwards at its outer end.* In the recumbent posture, the weight of the limb being taken off, the outer end rises still higher above the sternal extremity. The degree of the elevation can be best estimated by a study of frozen sections. Thus, in making horizontal sections of the body, layer by layer, from above downwards, Braune found that by the time the sterno-clavicular articulation was reached, the head of the humerus would be cut across in the lateral part of the section (Fig. 57).

The deltoid tubercle of the clavicle may, if large, be felt through the skin, and be mistaken for an exostosis. The acromio-clavicular joint lies in the plane of a vertical line passing up the middle of the front of the arm. A prominence is

* In some women, in the feeble, and in some narrow-shouldered men the clavicle may be horizontal, or its outer end may incline downwards.

sometimes felt about this joint in place of the level surface that it should present. This is due to an enlargement of the end of the clavicle, or to a thickening of the fibro-cartilage sometimes found in the joint. In many cases it has appeared to be due to a trifling luxation upwards of the clavicle, depending upon some stretching of the ligaments. It is certain that the dry bone seldom shows an enlargement such as to account for this very common prominence at the acromial articulation. The sternal end of the clavicle is also, in muscular subjects, often large and unduly prominent, and sufficiently conspicuous to suggest a lesion of the bone or joint when none exists.

The roundness and prominence of the point of the shoulder depend upon the development of the deltoid and the position of the upper end of the humerus. The deltoid hangs like a curtain from the shoulder girdle, and is bulged out, as it were, by the bone that it covers. If the head of the humerus, therefore, be diminished in bulk, as in some impacted fractures about the anatomical neck, or be removed from the glenoid cavity, as in dislocations, the deltoid becomes more or less flattened, and the acromion proportionately prominent. The part of the humerus felt beneath the deltoid is not the head, but the tuberosities, the greater tuberosity externally, the lesser in front. A considerable portion of the head of the bone can be felt by the fingers placed high up in the axilla, the arm being forcibly abducted so as to bring the head in contact with the lower part of the capsule. The head of the humerus faces very much in the direction of the internal or medial epicondyle. As this relation, of course, holds good in every position of the bone, it is of value in examining injuries about the shoulder, and in reducing dislocations by manipulation, the epicondyle being used as an index to the position of the upper end of the bone.

In thin subjects the outline and borders of the scapula can be more or less distinctly made out, but in fat and muscular subjects all parts of the bone, except the spine and acromion, are difficult of access in the ordinary positions of the limb. To bring out the superior (medial) angle and vertebral border of the bone, the hand of the subject should be carried as far as possible over the opposite shoulder. To bring out the inferior angle and axillary border, the forearm should be placed behind the back. The angle formed at the point of junction of the spine of the scapula and the acromion is the best point from which to take measurement of the arm, the tape being carried down to the external condyle of the humerus. The upper border of the scapula lies on the second rib, its lower angle on the seventh.

When the arm hangs at the side with the palm of the hand directed forwards, the acromion, external or lateral epicondyle, and styloid process of the radius all lie in the same line. The groove between the pectoralis major and deltoid muscles can usually be made out. In it run the cephalic vein and a large branch of the acromio-thoracic artery. Near the groove, and a little below the clavicle, the coracoid process may be felt. This process, however, does not actually present in the interval between the two muscles, but is covered by the innermost fibres of the deltoid. The position of the coraco-acromial ligament may be defined, and a knife thrust through the middle of it should strike the biceps tendon and open the shoulder-joint.

When the arm hangs at the side with the palm forwards, the bicipital groove (intertubercular sulcus) may be defined directly below the acromio-clavicular joint.

Just below the clavicle is a depression, the infraclavicular fossa, which varies considerably in depth in different subjects. It is obliterated in subcoracoid dislocations of the humerus, in fractures of the clavicle with displacement, by many axillary growths, and by some inflammations of the upper part of the thoracic wall. In sub-clavicular or infracoracoid dislocation the fossa is replaced by an eminence. In this region, at a spot to the inner (medial) side of the coracoid process, and corresponding nearly to the middle of the clavicle, the pulsations of the axillary artery can be felt against the second rib. Just below the clavicle the interspace between the sternal and clavicular portions of the pectoralis major can often be made out.

The anterior and posterior borders of the axilla are very distinct. The anterior border, formed by the lower edge of the pectoralis major, follows the line of the fifth rib. The depression of the armpit varies, other things being equal, with the position of the upper limb. It is most deep when the arm is raised from the side at an angle of about 45°, and when the muscles forming the borders of the space are in a state of contraction. As the arm is raised above the horizontal line the depression becomes shallower, the head of the bone projecting into the space and more or less obliterating it, while the width of the fossa is encroached upon by the approximation of the anterior and posterior folds. The coraco-brachialis muscle itself forms a distinct projection along the humeral side of the axilla when the arm is raised to a right angle with the body. If the arm be brought nearly close to the side, the surgeon's hand can be thrust well up into the axilla, and the thoracic wall explored as high up as the third rib.

The axillary glands cannot be felt when they are in a normal condition. The central set lies beneath the axillary tuft of hair.

The direction of the axillary artery, when the arm is raised from the side, is represented by a line drawn from the middle of the clavicle to the humerus at the inner (medial) side of the coraco-brachialis. A line drawn from the third rib near its cartilage to the tip of the coracoid process indicates the upper border of the pectoralis minor, and the spot where this line crosses the line of the axillary artery points out the position of the acromio-thoracic artery. A line drawn from the fifth rib near its cartilage to the tip of the coracoid process indicates the lower border of the pectoralis minor, and the position of the lateral or long thoracic artery which runs along that border. The line of the subscapular artery corresponds to the lower or lateral border of the subscapularis muscle along which it runs, but the position of this border can only be approximately indicated on the living or undissected subject.

The circumflex (axillary) nerve and posterior circumflex artery cross the humerus in a horizontal line that is about a finger's breadth above the centre of the vertical axis of the deltoid muscle. This point is of importance in cases of supposed contusion of the nerve. These various indications of the positions of the main branches of the axillary artery are made while the arm hangs in its natural position at the side. The dorsalis scapulæ artery (circumflex scapular) crosses the axillary border at a point corresponding to the centre of the vertical axis of the deltoid.

The clavicle.—The skin over the clavicle is loosely attached, and is easily displaced about the bone. This circumstance may serve to explain why the skin so often escapes actual wound in contusions of the clavicular region, and in part explains the infrequency of penetration of the integument in fractures of the clavicle. The three supraclavicular nerves that cross the clavicle are branches of the third and fourth cervical nerves, and it is well to note that pain over the collar-bone is sometimes a marked feature in disease of the upper cervical spine. This symptom is then due to irritation of these nerves at their points of exit from the spinal canal. A communication between the external jugular and cephalic veins is occasionally seen to cross the clavicle.

Beneath the clavicle the great vessels and the great nerve-cords lie upon the first rib. The vein is the most internal, and occupies the acute angle between the collar-bone and the first rib. It will be seen that growths from the bone may readily press upon these important structures, and that the vein, from its position, as well as from the slighter resistance that it offers, is likely to be the first to be compressed. These structures have also been wounded by fragments of bone in

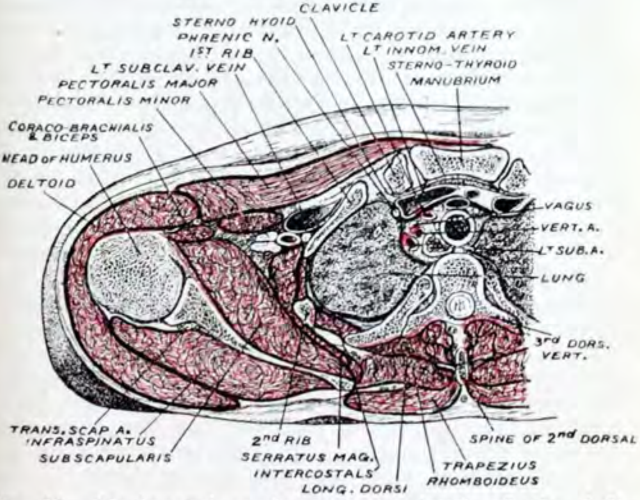

Fig. 57.—Horizontal section at the level of the left shoulder-joint, to show the lie of the parts in the vicinity of the left clavicle. (*After Braune.*)

fracture of the clavicle. Fortunately, between the clavicle and these large nerves and vessels the subclavius muscle is interposed. This muscle is closely attached to the under surface of the bone, is enveloped in a dense fascia, and forms one of the chief protections to the vessels in case of fracture. This interposing pad of muscle is also of great service in resection operations. Behind the clavicle the following structures may be noted (Fig. 57), viz. the innominate, subclavian, and external jugular veins, the subclavian, suprascapular (transverse scapular), and internal mammary arteries, the cords of the brachial plexus, the phrenic nerve and long thoracic nerve (nerve of Bell), the thoracic duct, the omo-hyoid, scalene, sterno-hyoid, and sterno-thyroid muscles, and the apex of the lung. The sternal end of the bone is not far removed from the innominate or left carotid artery, the vagus and recurrent nerves, the trachea, and the œsophagus.

These relations of the clavicle are given to show the dangers in the way of partial or complete resections of the bone. The difficulties and risks of the operation increase as one progresses from the acromial to the sternal end. Resection of the acromial third of the bone is comparatively easy, but resection of the sternal portion is difficult and dangerous. The entire clavicle has been removed with success, and the operation has been followed by less impairment of the arm movements than would be imagined.

The clavicle forms the sole direct bony connexion between the upper limb and the trunk, and in severe accidents, this connexion being broken through, it is possible for the extremity to be torn off entire. Thus Billroth reports the case of a boy aged 14, whose right arm, with the scapula and clavicle, was so torn from the trunk by a machine accident that it was only attached by a strip of skin 2 inches wide. Other similar cases of avulsion of the limb have also been reported.

Fractures of the clavicle.—The clavicle is more frequently broken than is any other single bone in the body. This is due to the fact that it is the only bony connexion between the upper extremity and the trunk, and is often exposed to violence. Force can be brought to bear on it by means of a long lever, the upper extremity. The common fracture, that due to *indirect* violence, is oblique, and very constant in its position, viz.

at the outer end of the middle third of the bone. So closely is the outer third of the clavicle bound by ligaments to the coracoid and acromion processes that it may be regarded as part of the scapula. Hence the impact resulting from a fall on the shoulder is transferred to the clavicle at the junction of its outer and middle thirds. The bone breaks at the point where the force is transferred to the clavicle from the scapula. The position of the coraco-clavicular ligaments is no doubt of the greatest import in localizing the fracture in this position, since a clavicle experimentally subjected to longitudinal compression does not break at this spot (Bennett).

The *displacement* that occurs is as follows. The inner fragment remains unchanged in position, or its outer end is drawn a little upwards by the sterno-mastoid. It will be seen that any action of this muscle would be resisted by the pectoralis major and the costo-clavicular (rhomboid) ligament. The outer fragment undergoes a threefold displacement. (1) It is carried directly *downwards*. This is effected mainly by the weight of the limb aided by the pectoralis minor, the lower fibres of the pectoralis major, and the latissimus dorsi. (2) It is carried directly *inwards* by the muscles that pass from the trunk to the shoulder, viz. the levator scapulæ, the latissimus dorsi, and especially by the pectorals. (3) The fragment is *rotated* in such a way that the outer end projects forwards, the inner end backwards. This rotation is brought about mainly by the two pectorals, assisted prominently by the serratus magnus (anterior). The normal action of this latter muscle is to carry the scapula forwards, and the clavicle, acting as a kind of outrigger to keep the upper limb at a proper distance from the trunk, moves forwards at the same time and keeps the scapula direct. When this outrigger is broken the serratus can no longer carry the scapula directly forwards. The bone tends to turn towards the trunk, and the point of the shoulder is therefore seen to move inwards as well as forwards. The fragments in this fracture must consequently overlap, and as the displacement is difficult to remedy, it follows that in no bone save the femur is shortening so uniformly left as after an oblique fracture of the clavicle. The degree of shortening very seldom exceeds an inch. The deformity associated with this fracture is well corrected when the patient assumes the recumbent position. In this posture, the weight of the limb being taken off, the downward displacement is at once remedied. The point of the shoulder falling back also tends to relieve in part the inward displacement, and the rotation of the outer fragment forwards. It is through the scapula, however, that these two latter displacements are in the main removed. In the recumbent posture the scapula is pressed closely against the thorax, with the result that its outer extremity (and with it, of course, the outer fragment of the clavicle) is dragged outwards and backwards. Some surgeons, recognizing this important action of the scapula in remedying the displacement in these cases, strap the scapula firmly against the trunk, while at the same time they elevate the arm.

Fractures due to *direct* violence are usually transverse, and may be at any part of the bone. When about the middle third they present the displacement just described. When the fracture is between the conoid and trapezoid ligaments no displacement is possible. When beyond these ligaments, the outer end of the outer fragment is carried forwards by the pectorals and serratus, and its inner end is a little drawn up by the trapezius. In this fracture there is no general displacement downwards of the outer fragment, since it cannot move in that direction unless the scapula go with it, and the scapula remains fixed by the coraco-clavicular ligaments to the inner fragment of the clavicle.

The clavicle may be broken by *muscular vio-*

lence alone. Polaillon, from a careful analysis of the reported cases, concludes that the muscles that break the bone are the deltoid and the clavicular part of the great pectoral. In no case does the fracture appear to have been produced by the sterno-mastoid muscle. The commonest movements producing fracture appear to be violent movements of the limb forwards and inwards, or upwards. These fractures are usually about the middle of the bone, and show no displacement other than that of both fragments forwards, i.e. in the direction of the fibres of the two muscles first named. The clavicle is more frequently the seat of *green-stick fracture* than is any other bone in the body; indeed, one-half of the cases of broken collar-bone occur before the age of 5 years.

A reference to the *relations* of the bone will show that important structures may be wounded in severe fractures associated with much displacement and with sharp fragments (*see* Fig. 57). Several cases are reported of paralysis of the upper limb (as a rule incomplete) following upon fracture of this bone. In some cases this symptom was due to actual compression or tearing of some of the great nerve-cords by the displaced fragments. In other cases the nerve injury, while due to the original accident, was yet independent of the broken clavicle. Paralysis of the biceps, brachialis, and brachio-radialis (supinator longus), muscles supplied through the upper (lateral) cord, may result from heavy weights being carried on the shoulder (Fig. 85, p. 392). Cases are reported of wound of the subclavian artery, of the subclavian vein, of the internal jugular vein, and of the acromio-thoracic artery. In several instances the fracture has been associated with wound of the lung, with or without a fracture of the upper ribs.

The clavicle begins to ossify before any bone in the body. At birth the entire shaft is bony, the two ends being still cartilaginous. There is one *epiphysis* for its sternal end, which appears between the eighteenth and twentieth years, and joins the shaft about 25. It is a mere shell, is closely surrounded by the ligaments of the sternal joint, and cannot, therefore, be well separated by accident.* In cases where the clavicle is described as congenitally absent, the membrane-formed part of the bone is represented by a ligamentous cord; the cartilage-formed extremities are represented by bony nodules. Defective ossification of the clavicle is commonly associated with an imperfect ossification of the membrane-formed bones of the skull, the condition being known as *cranio-cleido-dysostosis*, a disease of which D. Fitzwilliams has collected 60 examples. The subjects of this disease, owing to the ligamentous condition of the greater part of the clavicle, are able to approximate their shoulder to a remarkable extent. The defect in the clavicle may be so limited as to resemble a fracture.

Sterno-clavicular joint.—Although this is the only articulation that directly connects the upper limb with the trunk, yet it is possessed of such considerable strength that luxation at the joint is comparatively rare. The amount of movement in the joint depends to a great extent upon the lack of adaptability between the facets on the sternum and the sternal end of the clavicle. The disproportion between these parts is maintained by the interarticular cartilage, which reproduces only the outline of the clavicular surface. The cavity of the joint is V-shaped, since the clavicle only touches the socket at its inferior angle when the arm hangs by the side. When the arm is elevated, however, the two bones are brought in more immediate contact, and the joint cavity becomes a mere slit. Thus, in disease of this articulation it will be found that of all movements of the joint the movement of the limb upwards is

* Mr. Heath (*Lancet*, Nov. 18, 1882) reports a case which is probably unique. It concerns a lad aged 14, who, in the act of bowling at cricket, tore the clavicle away from its epiphyseal cartilage, which remained *in situ*. The muscle producing the accident was apparently the pectoralis major.

the most constant in producing pain. The joint is supplied by the suprasternal branch of the descending cervical nerves.

The movements permitted at this joint are limited, owing to the anterior and posterior sterno-clavicular ligaments being moderately tense in all positions of the clavicle. Movement *forwards* of the clavicle on the sternum is checked by the posterior ligament, and resisted by the anterior ligament. This latter ligament is more lax and less substantial than is the posterior band. Its weakness serves in part to explain the frequency of the dislocation forwards.

Movement of the clavicle *backwards* on the sternum is checked by the anterior ligament, while the passage of the head of the bone is resisted by the powerful posterior band. The movement is also opposed by the costo-clavicular ligament. To produce, therefore, a dislocation backwards considerable force must be used.

Disease of the sterno-clavicular joint.—This articulation is really divided into two joints by the interarticular cartilage, each being provided with a distinct synovial membrane.

These joints are liable to the ordinary maladies of joints, and it would appear that the disease may commence in, and be for some time limited to, only one of the synovial sacs. In time the whole articulation usually becomes involved, but even in advanced cases the mischief is sometimes restricted to the synovial cavity on one side of the cartilage. According to some authors, this joint is more frequently involved in pyæmia than is any other. When effusion has taken place into the sterno-clavicular joint, and especially after suppuration has ensued, the swelling usually makes itself evident in front, owing to the fact that the anterior sterno-clavicular ligament is the thinnest and least resisting of the ligamentous structures about the articulation. For the same reason the pus usually escapes from the anterior surface when it discharges itself spontaneously.

Dislocations of the sterno-clavicular joint.—The clavicle may be dislocated from the sternum in one of three directions, which, given in order of frequency, are: (1) forwards, (2) backwards, (3) upwards. The relative frequency of these dislocations can be understood from what has been already said as to the action of the ligaments in restricting movements.

Acromio-clavicular joint.—This articulation is shallow, and the outlines of the two bones that enter into its formation are such that no obstacle is offered to the displacement of the clavicle from the acromion. The joint, indeed, depends for its strength almost entirely upon its ligaments. The plane of the joint would be represented by a line drawn from above downwards and inwards between the two bones. This inclination of the joint-surfaces serves to explain the fact that the usual luxation of this part takes the form of a displacement of the clavicle upwards on to the acromion.

As the movements permitted in this joint may be impaired by accident or disease, it is well to note the part the articulation takes in the movements of the extremity. The scapula (and with it, of course, the arm), as it glides forwards and backwards upon the thorax, moves in the arc of a circle whose centre is at the sterno-clavicular joint, and whose radius is the clavicle. As the bone moves forwards it is important, for reasons to be immediately given, that the glenoid cavity should also be directed obliquely forwards. This latter desirable condition is brought about by means of the acromio-clavicular joint. Without this joint the whole scapula as it passed forwards with the outer end of the clavicle would precisely follow the line of the circle above mentioned, and the glenoid cavity would look in an increasingly inward direction. It is essential that the surface of the glenoid cavity should be maintained as far as possible at right angles to the long axis of the humerus. When these relations are satisfied, the humerus has the support behind of a stout surface of bone, and it is partly to obtain the value of this support that the boxer strikes out from the side, i.e. with his humerus well backed up by the scapula. If there were no acromio-clavicular joint the glenoid fossa would offer little support to the humerus when the limb was stretched forwards, and a blow given with the limb in that position, or a fall upon the hand under like conditions, would tend to throw the humerus against the capsule of the shoulder-joint, and so produce dislocation. Normally, therefore, as the scapula and arm advance, the angle between the acromion and the adjacent portion of the clavicle becomes more and more acute, and the glenoid fossa is maintained with a sufficiently forward direction to give substantial support to the humerus.* It will thus be seen that rigidity of this little joint may be a cause of insecurity in the articulation of the shoulder, and of weakness in certain movements of the limb. There is also movement in this joint as the arm is lifted towards the head, the angle between the clavicle and axillary border becoming more acute as the shoulder is elevated.

Dislocations of the acromio-clavicular joint.—The clavicle may be displaced *upwards* on to the acromion, or *downwards* beneath it. Polaillon has collected 38 cases of the former luxation, and 6 only of the latter. This disproportion is, in the main, explained by the direction of the articulating surfaces of the joint.

Scapula.—At the posterior or dorsal aspect of the bone the muscles immediately above and below the spine are bound down by the deep fascia. Thus, the supraspinatus muscle is enclosed in a fascia that, being attached to the bone all round the origin of the muscle, forms a cavity open only towards the insertion of the muscle.

The infraspinatus and teres minor muscles are

* For an excellent account of the mechanism of these joints, *see* Morris's "Anatomy of the Joints," p. 202 *et seq.*

also enclosed in a distinct, but much denser, fascia that is attached to the bone beyond these muscles, and blends in front with the deltoid sheath so as to form a second enclosed space. The arrangement of these fasciæ serves to explain the trifling amount of ecchymosis that usually follows upon fractures of the scapular blade. The extravasation of blood about the fracture is bound down by the fasciæ over these muscles, and is unable, therefore, to reach the surface.

Movements of the scapula.—In lifting the arm from the side to a vertical position over the head a double movement takes place—(1) between the scapula and the trunk; (2) between the humerus and the scapula, at the shoulder-joint. The extent of the movement in the first joint is only about 45°, whereas in the second it is about 100°. The one joint is accessory to the other. Hence, in *ankylosis of the shoulder-joint*, we can still attain a certain degree of abduction and adduction of the arm, the whole upper extremity moving with the rotating scapula. To obtain this result the arm *must be abducted from the side* before ankylosis sets in. As the extremity is raised the scapula undergoes a free rotatory movement, its vertebral border passing from an approximately vertical to an approximately horizontal position. At the commencement of the movement, until the arm has ascended 35° from the side, the angle of the scapula is practically stationary; during this stage the scapula is fixed and maintained in position by the trapezius, rhomboids, and serratus magnus. If the *trapezius is paralysed*, as may result from accidental section of the accessory (spinal accessory) nerve in removing glands from the neck, the inferior angle and vertebral border project backwards, under the weight of the raised arm; the acromial region of the shoulder drops downwards and forwards. When the arm passes beyond 35°, the serratus magnus comes into action, and the inferior angle of the scapula moves rapidly forwards. If the nerve to this muscle be paralysed (the long thoracic from 5, 6, 7 c.) or if its antagonists—the rhomboids—which are also then in action, be paralysed (nerve from 5 c.), then the angle and posterior border of the scapula become prominent or "winged"—evidence of the paralysis of these muscles. Thus "winging" of the scapula at the commencement of the movement indicates paralysis of the trapezius; if it occurs after the movement is well begun, then the serratus magnus is affected.

Fractures of the scapula, and especially of the body of the bone, are not common, owing to the mobility of the part and the thick muscles that cover in and protect its thinner portions. It rests also upon a soft muscular pad, and derives, no doubt, additional security from the elasticity of the ribs.

The most common lesion is a fracture of the *acromion process.* This is often but a separation of the epiphysis. There are two, sometimes three, epiphyseal centres for the acromion. Ossification appears in them about puberty, and the entire epiphysis joins with the rest of the bone from the twenty-second to the twenty-fifth year. Several cases of supposed fracture of the acromion united by fibrous tissue are probably but instances of an imperfectly-united epiphysis, and may have been independent of injury. In 5 bodies out of 40 Symington found the acromial epiphysis united to the spine by a fibrous union, and from the statistics of other observers it appears that this is the case in quite 10 per cent. of adults. In fractures of the process much displacement is quite uncommon, owing to the dense fibrous covering the bone derives from the two muscles attached to it. The *coracoid process* may present a genuine fracture, or may be separated as an epiphysis. As an epiphysis, it joins the main bone about the age of 17. The supraglenoid tubercle, from which the long head of the biceps takes its origin, is part of the coracoid epiphysis. In spite of the powerful muscles that are attached to the coracoid, the displacement is usually slight, inasmuch as the coraco-clavicular ligaments are seldom torn. These ligaments, it may be noted, are attached to the base of the process. In some few cases the process has been torn off by muscular violence.

Among the more usual fractures of the *body of the scapula* is a transverse or oblique fracture of its blade below the spine. Owing to the infraspinatus, subscapularis, and other muscles being attached to both fragments, none but a trifling displacement is usual. A fracture may occur through the *surgical neck*. The surgical neck is represented by a narrowed part of the bone behind the glenoid fossa, and in the line of the suprascapular notch (incisura scapularis). The smaller fragment will, therefore, include the coracoid process; the larger, the acromion.

Tumours of the scapula.—Tumours of various kinds grow from the scapula, and mainly from the spongy parts of the bone—viz. the spine, the neck, and the inferior angle. It may be sufficient to excise the scapula alone, but it must be remembered that the main fulcrum on which the upper extremity rotates is then removed. It is therefore more usual in such cases to perform an *interscapulo-thoracic* amputation, which is usually done for malignant tumours involving structures in the neighbourhood of the shoulder-joint. In this operation the upper extremity, including the scapula and the clavicle beyond the origin of the sterno-mastoid, is removed. An elliptical incision is made in front of and behind the shoulder, the upper end of the ellipse lying on the clavicle, the lower at the angle of the scapula. The operation is begun at the clavicle so as to secure the axillary vessels. The artery is tied before the vein so that the limb may continue to empty its blood into the circulation. The main vessels to be noted in connexion with this operation are the suprascapular (transverse scapular) at the superior border of the bone, the posterior scapular (branch of the transverse cervical) about the vertebral border, the subscapular running along the lower border of the subscapularis muscle, the dorsalis scapulæ crossing the axillary edge of the bone, and the acromial branches of the acromio-thoracic artery.

The axilla.—The axilla may be regarded sur-

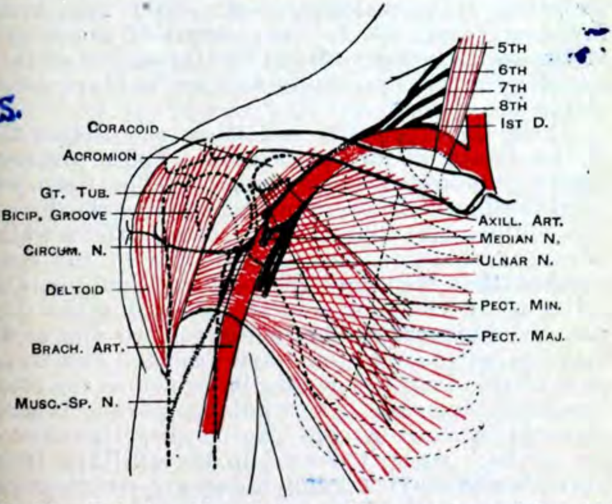

Fig. 58.—Relationship of the axillary artery and brachial plexus to the shoulder-joint and axilla.

gically as a passage between the neck and the upper limb (Fig. 58). Axillary tumours and abscesses may spread up into the neck, and in like manner cervical growths and purulent collections may extend to the armpit. The skin forming the base of the axilla is provided with many short hairs and with numerous sebaceous and sudoriparous glands. In this integument small superficial abscesses are often met with, that arise usually from suppuration of these glandular structures, and that are brought about by the friction of the skin against the clothing. Owing to the tendency of the axillary integument to become chafed and inflamed under friction, the axilla is *not* a good locality to select for the use of the mercurial inunction as applied in syphilis. Beneath the skin and superficial fasciæ is the axillary fascia, and beyond this membrane is the axillary space. The connective tissue with which the axillary space is mainly occupied is very loose, and, while this laxity favours greatly the free movement of the arm, it at the same time permits of the formation of large purulent collections and immense extravasations of blood.

It is important to remember the disposition of the **fasciæ** about this region. There are three layers principally concerned. (1) The deep pectoral fascia which covers in and encloses the pectoralis major. (2) The clavi-pectoral fascia which, adherent above to the clavicle, fills in the space between that bone and the pectoralis minor, then splits to invest this muscle, and joins the deep pectoral layer at the anterior fold of the axilla to form with it the axillary fascia. The upper part of this fascia is generally known as the costo-coracoid membrane. The whole membrane is sometimes known also as the "suspensory ligament of the axilla," since it draws up the axillary fascia towards the clavicle, and is mainly instrumental in producing the "hollow" of the armpit. (3) The axillary fascia which is formed by the union of the two preceding fasciæ, and stretches across the base of the axilla from its anterior to its posterior fold. It is thinnest under the axillary hairs.

Abscess about the axillary region may be formed beneath the pectoralis major, or between the two pectoral muscles, or beneath the pectoralis minor and clavi-pectoral fascia, and therefore in the axillary space. The loose tissue of the axillary space allows the formation of a large abscess cavity. The abscess as it fills the axilla pushes forwards the pectoralis major, more or less obliterates the hollow of the armpit, thrusts back the scapula, and widens the angle between the serratus magnus (anterior) and the subscapularis muscles. There is a great tendency, therefore, for unrelieved abscesses to extend upwards into the neck, that being the direction in which the least amount of resistance is encountered. From the neck the purulent collection may extend into the mediastinum. In one case an axillary abscess, set up by shoulder-joint disease, perforated the first intercostal space and set up fatal pleurisy.

In opening an axillary abscess, and, indeed, in most incisions into this space, the knife should be entered at the centre of the floor of the axilla, i.e. midway between the anterior and posterior margins, and near to the inner or thoracic side of the space. The vessels most likely to be damaged by an indiscreet incision are the subscapular, running along the lower border of the subscapularis muscle; the lateral (long) thoracic, following the lower border of the small pectoral; and the main vessels lying close to the humerus. The knife, if properly entered, should be midway between the two first-named vessels, and quite away from the main trunks. There is an artery that sometimes comes off as the lowest branch of the axillary trunk, and crosses the middle of the axilla, to be distributed to the thorax below the long thoracic. This vessel would probably be wounded in the incision above-named. The artery is, however, very inconstant, is small, and is not far below the surface. It is usually met with in female subjects.

Lymphatic glands of the axilla.—The axillary glands are numerous, and of much surgical importance (*see* Fig. 53, p. 222). They may be arranged in four sets. (1) The greater number are placed to the inner side of the axillary vein beneath the axillary tuft of hair. This *central set* of glands receives the lymph from the upper extremity and breast. Pain in the axilla which follows whitlow or any septic infection of the arm is due to inflammation of this group, which is pierced by the intercosto-humeral nerve. (2) The deep axillary set lies along the axillary vessels. It receives the lymph from the central set and becomes continuous with the lower deep cervical glands in the subclavian triangle. (3) Other glands lie upon the serratus magnus muscle on the thoracic side of the axilla, and just behind the lower border of the pectoral muscles. They receive the lymphatics from the front of the chest, the principal lymph-vessels of the breast, and the superficial lymphatics of the abdomen as low down as the umbilicus. Their efferent vessels for the most part pass on to join the central set of glands. These glands will be the first to be enlarged in certain breast affections, and after blistering and other superficial inflammations, etc., of the chest and upper abdomen. The axillary process of the female breast is in contact with this set. (4) The remaining glands are situated at the back of the axilla, along the subscapular vessels. They are joined by the lymphatics from the scapular and lumbar regions of the back.

It may here be convenient to note that one or two glands are commonly found in the groove between the deltoid and pectoralis major muscles. They receive some vessels from the outer side of the arm and a part of the shoulder and breast. The superficial lymphatics over the upper part of the deltoid go to the cervical glands (Tillaux), over the lower half to the axilla. The lymphatics from the supraspinous fossa follow the suprascapular (transverse scapular) artery, and join the lowest cervical glands. The superficial lymphatics of the back which converge to the axilla are derived from the neck over the trapezius muscle, and from the whole dorsal and lumbar regions as far down as the iliac crest.

The complete removal of axillary glands is an operation frequently undertaken, especially in cases of mammary cancer. Free access to them is obtained by reflecting the pectoral muscles inwards. It will be understood from their position that these bodies, when diseased, are very apt to become adherent to the axillary vessels, and especially to the vein. The latter vessel has frequently been wounded or excised during the removal of gland tumours, and one case at least is recorded in which the artery was accidentally cut (Holmes).

Axillary vessels.—The axillary vein is formed by the union of the basilic with the two venæ comites of the brachial artery. This union commonly takes place at the lower border of the pectoralis minor muscle, and the vein is therefore shorter than the artery. Sometimes the vein does not exist as a single trunk until just below the clavicle. This condition, when present, is very unfavourable to operations upon the artery, as many transverse branches cross that vessel to unite the veins that lie on either side of it. The axillary vein, being comparatively near the heart, is readily influenced as regards its contained blood by the inspiratory movement. Thus it happens that, in many instances of wound of the vessel or of its larger tributaries, air has been drawn into the venous canal and death has ensued. The entrance of air into the main vein is perhaps aided by the circumstance that the costo-coracoid membrane (upper part of the clavi-pectoral fascia) is adherent to the vessel, and thus tends to maintain it in a patent condition when wounded. This connexion with the fascia is supposed by some to account in part for the furious bleeding that occurs from this vein when it is divided.

The vein is more often wounded than is the artery, it being larger, more superficial, and so placed as more or less to overlap the arterial trunk. On the other hand, in injury to the vessel by traction, as, for example, in reducing dislocations, the artery suffers more frequently than the vein. In all positions of the upper limb the artery keeps to the outer angle of the axillary space. The relation of the vein, however, to the first part of the axillary artery, the part above the pectoralis minor, is modified by the position of the limb. Thus, when the arm hangs by the side the vein is to the inner medial side of the artery, and a little in front of it, but when the limb is at a right angle with the trunk the vein is drawn so far in front of the artery as almost entirely to conceal that vessel.

Aneurysm is very frequent in the axillary artery, a fact to be explained by the nearness of the vessel to the heart, by the abrupt curve it presents, by its susceptibility to frequent and extensive movements, and by its liability to share in the many lesions of the upper limb. In violent and extreme movements of the limb the artery may be more or less torn, especially if its walls are already diseased.

In ligaturing the first part of the axillary artery it is well to note that the pectoralis major has sometimes a cellular interval between two planes of muscle fibre, and this may be mistaken for the space beneath it (Heath). If the pectoralis minor has an origin from the second rib, it may more or less entirely cover the artery and require division. The cord of the brachial plexus nearest to the artery may be mistaken for that vessel, or easily included in a ligature intended for it. A ready guide to the axillary vessels in this operation is to follow the cephalic vein. The anterior internal thoracic nerve appears between the vein and artery as it passes to the pectoralis minor; it also may be useful occasionally as a guide.

In applying a ligature to the third part of the artery, it should be borne in mind that a muscular slip sometimes crosses the vessels obliquely, passing from the latissimus dorsi to join the pectoralis major, coraco-brachialis, or biceps muscles. This slip may give rise to confusion during the operation, and may be mistaken for the coraco-brachialis.

Brachial plexus.—When the shoulder is depressed the upper and middle trunks of the brachial plexus, formed by the fifth, sixth, and seventh cervical nerves, can be distinctly felt in the neck, passing from beneath the posterior border of the sterno-mastoid to enter the axilla just externally to the mid-point of the clavicle (Fig. 58). As the trunks of the plexus pass towards the upper surface of the first rib, where they lie above and dorsally to the subclavian artery, the nerve-trunks are surrounded by a lax connective tissue, permitting free movements of the plexus as the shoulder is elevated and depressed. It is at this part of the supraclavicular region where the nerve-cords can be felt above and behind the pulsations of the artery, particularly when the patient is sitting up with the shoulder depressed, that injections are made into the plexus *to produce anæsthesia in the arm.*

The upper trunk, formed by the fifth and sixth nerves, is by far the most exposed to injury, for the reason that it rises higher in the neck than the middle and lower trunks; consequently, if the neck is bent forcibly to the left, as when a burden is borne on the right shoulder, the upper trunk on the right side is subjected to a greater strain than the middle or lower cords (Fig. 59). In cases of shoulder-presentation at birth, or if the neck and shoulder be forced apart by accident, the upper cord is liable to be strained or ruptured, resulting in what is usually described as *Erb's palsy.* It will be recalled that the suprascapular, circumflex (axillary), and musculo-cutaneous nerves are derived from this trunk; so are the nerves to the rhomboids and serratus magnus. The rupture, however, is usually distal to the origin of these nerves, and hence their muscles escape. The muscles affected in Erb's palsy are the supraspinatus, infraspinatus, teres minor, deltoid, coraco-brachialis, biceps, brachialis, and brachio-radialis; occasionally also the supinator (brevis), extensor carpi radialis longior, and pronator (radii) teres. No sensory paralysis is observed in such cases. Curiously enough, section of the fifth cervical gives as wide an area of muscular paralysis as section of the combined fifth and sixth (Wilfred Harris). In complete rupture of the brachial plexus, sensation is completely lost beyond the elbow, but in the arm and shoulder deep sensibility is retained (Sherren). The arm, in such lesions, retains intact

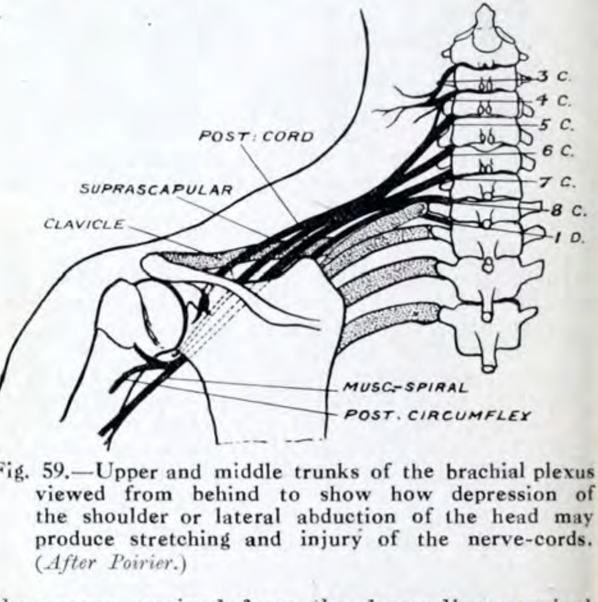

Fig. 59.—Upper and middle trunks of the brachial plexus viewed from behind to show how depression of the shoulder or lateral abduction of the head may produce stretching and injury of the nerve-cords. (*After Poirier.*)

the nerves received from the descending cervical and intercosto-humeral.

Axillary nerves.—Any of the axillary nerves may be injured by a wound, the median being the most frequently damaged, and the musculo-spiral the least frequently. The comparative immunity of the latter is explained by its deep position, its situation at the inner and posterior aspect of the limb, and its large size. The nerves are very seldom torn by a traction on the limb short of more or less complete avulsion. Indeed, if forcibly stretched, they are disposed rather to become torn away from their attachments to the spinal cord than to give way in the axilla. Thus, Flaubert records a case where the last four cervical nerves were torn away from the cord during a violent attempt to reduce a dislocated shoulder.

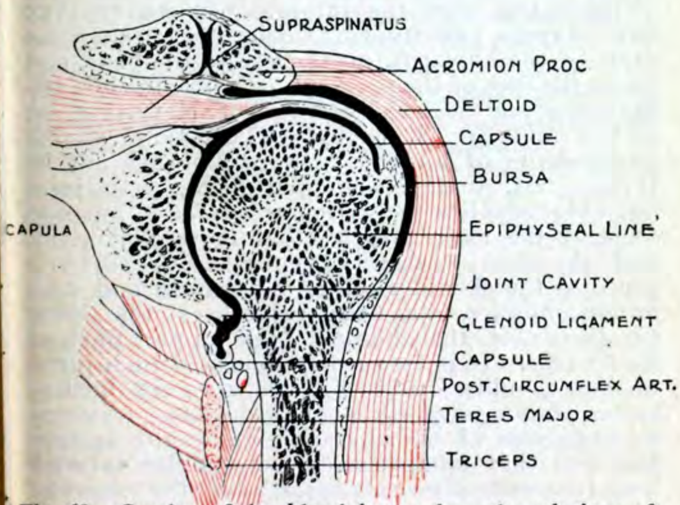

Fig. 60.—Section of shoulder-joint to show the relations of the capsule, epiphyseal line, and bursa. (*After Poirier.*)

The deltoid region.—This region, comprising as it does the "point" of the shoulder, is limited in all parts by the deltoid muscle. The deltoid covers the upper end of the humerus and the shoulder-joint (Fig. 60). Between the joint and the surface, therefore, are only the skin and superficial fascia, the deltoid in its sheath, and some loose connective tissue (the subdeltoid tissue) in which is found the great subdeltoid (subacromial) bursa. This subdeltoid tissue sometimes assumes the form of a distinct thick membrane, and may have an important influence upon the localization of purulent collections proceeding from the joint. The fatty tissue over the deltoid is a favourite seat for lipomata, and it is in this situation that the tendency of these growths to change their position is sometimes seen. Thus, Erichsen records a case where the tumour slid downwards from the shoulder to the breast.

Emerging from the interval between the two teres muscles, and winding horizontally round the shaft of the humerus, quite close to the bone, and about the line of the surgical neck, are the circumflex nerve and posterior circumflex artery (Fig. 58, p. 253, and Fig. 85, p. 392). This nerve affords an example of an arrangement pointed out by Hilton, viz. that a principal nerve to a joint not only supplies the articular surfaces, but also some of the main muscles that move that joint, and the skin over those muscles. This nerve supplies the shoulder-joint, the deltoid and teres minor muscles, and the skin over the lower two-thirds of the shoulder and upper part of the triceps. It is frequently damaged in injuries to the shoulder, and may be severely bruised by a simple contusion of the part, resulting in paralysis of the deltoid. It would appear, however, that damage to the circumflex is much less frequent after contusions of the shoulder than was formerly maintained. It will also be readily understood that the nerve is often torn in fractures of the surgical neck of the humerus, in dislocations of that bone (especially the luxation backwards), and in violent attempts at reducing such dislocations (Figs. 58 and 59).

The shoulder-joint.—From one surgical point of view, joints may be divided into (1) those that depend for their strength mainly upon ligaments; (2) those that are mechanically strong, and that derive their stability to a great extent from the arrangement of their component bones; and (3) those that rely for their support principally upon muscles. As an example of the first kind may be cited the sterno-clavicular joint, of the second form the elbow-joint, and of the third the shoulder-joint. The articulation the least prone to dislocation is the one that derives its strength from tough unyielding ligaments, while the one most often luxated belongs to the third variety, its strength being greatly dependent upon muscles that may be taken by surprise, and that may themselves, from disordered action, prove sources of weakness. These are, of course, not the only features in the etiology of dislocation. A great deal depends upon the amount of movement permitted in a given joint, and the degree of leverage that can be brought to bear upon its parts.

The arch formed by the coracoid and acromion processes and the ligament between them forms an essential support to the head of the humerus, and is an important constituent of the articulation. With this arch the humeral head is in immediate relation, though not in actual contact (Fig. 60). In paralysis of the deltoid the head may be separated by some distance from the coracoid process, and Nannoni records the case of a child with old-standing paralysis of the deltoid between whose humeral head and acromial vault four fingers could be lodged. It is well to note that at least two-thirds of the head of the bone are not in contact with the glenoid cavity when the arm hangs by the side, and Anger points out that in this position three-fourths of the circumference of the humeral head are in front of a vertical line drawn from the anterior border of the acromion process. In this posture, also, the head is wholly to the outer side of the coracoid process. The margin of the glenoid cavity is more prominent on the inner than on the outer side, while the strongest part of the margin and the broadest part of the fossa are below. This is significant, since it points to an attempt to strengthen a part of the joint that practice shows to be the weakest in the articulation, viz. the lower and inner portion of the capsule. It is at this place that the head of the bone leaves the joint in dislocation of the shoulder.

The capsule of the shoulder-joint is very lax, and would lodge a bone-head twice as large as that of the humerus. According to Sir Henry Morris, no one part of the capsule is constantly thicker than the rest, as is the case in the hip-joint.

Of the **bursæ** about the joint, the *subacromial* bursa is the one most frequently the seat of disease. This sac, when distended with fluid, may be mistaken for the results of chronic inflammation of the joint (Fig. 60).

Experiment shows that the walls of this bursa may be actually torn in twists of the arm, especially when either flexed or extended. When the sac is distended, most pain is elicited in the position of abduction, for in this posture the bursal walls are normally folded up, so as to form a sort of collar in advance of the greater tuberosity. In elderly rheumatic people the sac sometimes communicates with the joint. The subscapular bursa may be regarded as an extension of the synovial membrane of the joint between the terminal part of the muscle and the scapula. Pain elicited when the arm is rotated at the shoulder-joint may be due to disease in the joint, or in the subacromial or the subscapular bursa, for a movement then occurs in all three.

The **biceps tendon** strengthens the upper part of the joint, keeps the humerus against the glenoid cavity in the various positions of the limb, and prevents the head of the bone from being pulled too closely upwards under the acromion. The tendon may be ruptured, and in such a case, in addition to the general weakening of the limb, and the peculiar projection formed by the contraction of the muscle, the head of the humerus is usually drawn upwards and forwards until arrested by the coraco-acromial arch. Thus, a kind of slight false dislocation may be produced. In certain violent wrenches of the limb the tendon may rupture the transverse ligament which binds it down, slip from its groove, and be displaced to one or other side, usually to the inner side. The intracapsular part of the tendon may disappear in cases of chronic rheumatic arthritis, owing to the friction against the abraded articular surface of the humerus. In such cases it acquires an attachment to the bicipital groove.

Disease of the shoulder-joint.—This articulation is liable to all forms of joint-disease. The capsule, as just stated, is very lax, the articular surfaces being kept in apposition by the tonus of the surrounding muscles; when chloroform is administered the surfaces may be freely separated and examined. In joint-disease, however, the effusion may effect a considerable separation of the two bones. Braune, having pierced the glenoid cavity through the supraspinous fossa, injected tallow at considerable pressure into the joint. When fully distended the humerus was found to be separated from the scapula by more than ½ an inch, and this may serve to explain the lengthening of the limb often noted in joint-disease of this part with much effusion. When the greatest degree of distension of the capsule was reached the humerus became slightly extended and rotated inwards. It is significant that in shoulder-joint disease it is common for the arm to be found close to the side, the elbow carried a little back (extension), and the limb rotated inwards. This position may also be due to the rigid contraction of the muscles about the joint. When such contractions exist it may be inferred that the powerful latissimus dorsi has a little advantage over its opponents, and may be answerable for the rotation in and slight projection backwards of the arm. The inner part of the epiphyseal line is just within the capsule; the outer, anterior and posterior parts are entirely subperiosteal. It happens, therefore, that the pus in suppurative epiphysitis will find its way into the joint.

There are two diverticula from the synovial membrane: (1) one that runs some way down the bicipital groove (intertubercular sulcus) with the tendon; (2) a cul-de-sac beneath the subscapularis formed by a communication between the synovial cavity and the bursa under that muscle. When the joint is filled with effusion the capsule is evenly distended and the shoulder evenly rounded. Special projections usually occur at the seats of the diverticula. Thus a swelling often appears early in the course of a synovitis in the groove between the pectoralis major and the deltoid muscles, and this swelling may appear bilobed, being cut in two by the unyielding biceps tendon. Fluctuation can best be felt by examining the uncovered part of the capsule in the axilla beyond the subscapular muscle. When the joint suppurates, pus usually escapes at one of the culs-de-sac just mentioned, most often through the one that follows the biceps tendon. Pus may thus extend for some way along the bicipital groove. In one recorded case, pus that had escaped from the shoulder-joint followed the course of the musculo-spiral (radial) nerve, and opened on the outer side of the elbow.

Dislocations.—Dislocations at this joint are more common than at any other joint in the body. This is explained by the shallowness of the glenoid fossa, the large size and globular shape of the head of the humerus, the extensive movements of the arm, the long leverage it affords, and the dependence of the articulation for its strength mainly upon muscles. The upper limb and shoulder are also peculiarly exposed to injury.

The principal forms of luxation of the humerus at the shoulder are: 1 *Subcoracoid*, forwards and a little downwards; the usual form. 2. *Subglenoid*, downwards and a little forwards; rare. 3. *Subspinous*, backwards; rare.

In all complete dislocations the head of the bone leaves the joint-cavity through a rent in the capsule. In so-called "false luxations" the capsule is not torn. For example, in the cadaver, if the deltoid be divided the humeral head can be displaced under the coracoid process without rupture of the capsule; and the same thing may occur during life, in cases where the muscle has long been paralysed.

In all cases of dislocation at this joint the *primary* displacement is always *downwards* into the axilla. It is well known that dislocations at the shoulder are usually due to violence applied to the limb while the arm is abducted, or to severe direct violence forcing the bone downwards. Now, when the limb is abducted the head of the humerus projects below the glenoid fossa, and rests and presses upon the inferior and least protected part of the capsule. The fibres of this portion of the capsule being tightly stretched in this position, it requires the exertion of no extraordinary force to tear the ligament and drive the bone into the axilla.

Thus it happens that in luxations at this joint the rent in the capsule is at its inferior and inner aspect, the humeral head lying beneath the subscapularis, which is always strained and sometimes torn. The head of the bone, being thus driven downwards into the axilla, may, for certain reasons, remain there (subglenoid form), or more usually it will be drawn forwards and inwards by the powerful pectoralis major, aided by other muscles whose action is now less resisted and by the weight of the unsupported limb (subcoracoid form); and lastly, the direction of the violence being applied markedly from in front, the head of the bone may be thrust backwards under the acromion or spinous processes (subspinous form). The overwhelming frequency of the subcoracoid variety is explained by the greater advantage at which those muscles act that draw the bone forwards, in comparison with those that would draw it backwards, and by the very trifling opposition offered to the passage of the head forwards when compared with the substantial obstacles in the way of its passage backwards under the scapular spine.

Features common to all dislocations at the shoulder.—As the roundness of the deltoid depends to a great extent upon the presence beneath it of the humeral head, and as in all these luxations (save perhaps in the slighter grades of the subspinous form) the head is removed practically from its connexion with the deltoid, that muscle is always more or less flattened. This flattening is augmented by the stretching of the muscle which in some degree is constantly present. Stretching of the deltoid involves abduction of the arm, and this symptom is fairly constant in all the luxations. The biceps being also more or less unduly tense, the elbow is found flexed and the forearm supinated. In every form there is some increase in the vertical circumference of the axilla, since the head, having left the glenoid fossa, must occupy some part comprised within that circumference. Again, Dr. Dugas has pointed out that "if the fingers of the injured limb can be placed by the patient, or by the surgeon, upon the sound shoulder while the elbow touches the thorax (a condition that obtains in the normal condition of the joint), there can be no dislocation; and if this cannot be done there *must* be one, for no injury other than a dislocation can induce this physical impossibility." This depends upon the fact that in consequence of the rotundity of the thorax it is impossible for both ends of the humerus to touch it at the same time, and in luxation at the shoulder the upper end of the bone is practically touching the trunk. Lastly, from the position of the great vessels and nerves (Fig. 58) it will be seen that in the subcoracoid and subglenoid luxations the head of the bone may press injuriously upon those structures. Thus may result œdema of the limb and severe pain or loss of muscular power. The artery is usually saved by its greater elasticity; but Bérard reports a case of displacement forwards where the axillary artery was so compressed by the humeral head as to induce gangrene of the limb. The close connexion of the circumflex nerve with the humerus renders it very liable to injury, especially in the subglenoid and subspinous forms of dislocation.

Special anatomy of each form of shoulder dislocation. 1. *Subcoracoid.*—The articular head of the humerus lies on the anterior surface of the neck of the scapula, and the anatomical neck rests on the anterior lip of the glenoid fossa. The head is thus placed immediately below the coracoid process, and is in front of, internal to, and a little below its normal site. The great tuberosity faces the empty glenoid cavity (Fig. 61). The subscapularis muscle is stretched over the head of the humerus, and is usually partly torn. The supraspinatus, infraspinatus, and teres minor are stretched or torn, or the great tuberosity may even be wrenched off. The coraco-brachialis and short head of the biceps are tense, and are immediately in front of the head of the humerus instead of to its inner side. The long tendon of the biceps is deflected downwards and outwards. It is sometimes, although rarely, torn from its groove. The deltoid is put upon the stretch. The prominence

Fig. 61.—Subcoracoid dislocation of the humerus.

formed by the humeral head in the front of the axilla depends to some degree upon the amount of rotation. If the bone be rotated out, the projection is most distinct; but if rotated in, its head sinks into the axilla and is brought more in contact with the scapula than with the skin. The head of the bone being always carried a little downwards, some lengthening must in all cases *really* exist; but with the ordinary method of measuring the limb this lengthening may be replaced by a normal measurement, or even by apparent shortening, if the head of the bone be carried a good deal forwards and inwards, and the limb be abducted. When the head has left the glenoid cavity, abduction tends to bring the external (lateral) condyle nearer to the acromion, and these are the two points between which the measurement is usually taken. Thus the apparent length of the arm depends mainly upon the degree of abduction of the humerus, or the obliquity of the axis of the bone.

2. *Subglenoid.*—The head is below, and a little in front of and internal to, its normal position. It cannot go directly downwards, owing to the situation of the long head of the triceps, but escapes in the interval between that muscle and the subscapularis. The articular surface of the head rests on the anterior aspect of the triangular area just below the glenoid fossa that gives origin to the triceps. The upper border of the great tuberosity is in close relation with the lower margin of the joint. The subscapularis muscle, which binds down the humeral head, is much stretched or torn. The supraspinatus and the infraspinatus are stretched or torn, and the two teres muscles have not been much affected unless there be considerable abduction of the arm. The coraco-brachialis and biceps are stretched, and owing to the amount of abduction usually present, the biceps tendon is but little deflected from a straight line.

3. *Subspinous.*—The head usually rests on the

posterior surface of the neck of the scapula, the groove of the anatomical neck of the humerus corresponding to the posterior lip of the glenoid fossa. The head is thus placed beneath the acromion; but it may be displaced still farther back, and may rest on the dorsum scapulæ, and beneath the scapular spine (Fig. 62). The subscapularis tendon is drawn right across the glenoid fossa, and is often torn from its attachment. The head pushes back the hinder part of the deltoid, the infraspinatous and teres minor muscles. These latter cover the bone, and are stretched over it. The great pectoral is rendered unduly tense, and this serves in part to explain the rotation inwards of the humerus, and the abduction forwards, which are usually observed, those movements being more or less unopposed. The circumflex nerve is often torn.

Fig. 62.—Subspinous dislocation of the humerus.

In reducing dislocations, and especially such as are of long standing, serious damage may be inflicted on the axillary structures. The axillary artery suffers most frequently, the vein rarely, and the nerves still less often. The artery, being placed externally, is apt to contract adhesions to the soft parts covering the head of the displaced bone, and therefore to be torn when those parts are disturbed (Fig. 58).

Fractures of the upper end of the humerus. 1. *Anatomical neck.*—The upper part of the capsule is exactly attached to the anatomical neck, and in this situation the fracture may run beyond the ligament and be partly extracapsular (Fig. 60, p. 261). The lower part of the capsule is inserted some little way below the anatomical neck, and in this position, therefore, the lesion must be intracapsular. From the line of attachment of the lower part of the capsule to the humerus, fibres are reflected upwards to the margin of the articular cartilage on the head of the bone. These fibres, if unruptured, may serve to connect the fragments. It is easy for the small and comparatively dense upper fragment to be driven into the wide extent of cancellous bone exposed on the upper surface of the lower fragment. When impaction occurs, there may be some flattening of the deltoid, since the head is rendered of less dimensions by that impaction, and consequently causes a less projection of the deltoid. The difficulty of obtaining crepitus in non-impacted fractures will be obvious when the small size of the upper fragment is considered, together with its great mobility, and the obstacles in the way of so fixing it that one broken end may be rubbed against the other. The diagnosis of such obscure cases is now cleared up by the aid of the X-rays.

2. *Separation of the upper epiphysis.*—The lower border of this epiphysis is represented by a line crossing the bone at the base of the great tuberosity and placed between the anatomical and surgical necks (*see* Fig. 60, p. 261). It would be fairly indicated by a transverse saw-cut through the widest part of the bone. The three component nuclei of this epiphysis (head, greater and lesser tuberosities) fuse together about the fifth year, and the entire mass joins the shaft about the twentieth year. The upper fragment may be carried and rotated a little outwards by the muscles attached to the great tuberosity, while the lower fragment is drawn inwards and forwards by the muscles inserted into the bicipital groove. Thus, a part of the smooth upper end of

the lower fragment commonly forms a distinct projection below the coracoid process. In such case the axis of the limb would be altered, and the elbow carried a little from the side. Often, however, the displacement is solely in the antero-posterior direction, the lower fragment projecting forwards. So wide are the two bone surfaces at the seat of injury that it is scarcely possible for them to overlap one another.

3. *Surgical neck.*—The surgical neck is situated between the bases of the tuberosities and the insertions of the latissimus dorsi and teres major muscles. A common displacement of parts is the following: The upper fragment is carried out and rotated out by the supra- and infraspinatus and teres minor. The upper end of the lower fragment is drawn upwards by the deltoid, biceps, coraco-brachialis, and triceps, inwards by the muscles attached to the bicipital groove, and forwards by the great pectoral. Thus it forms a projection in the axilla, and the axis of the limb is altered so that the elbow projects from the side. This displacement, however, is by no means constant. Pean, Anger, and others maintain that the usual deformity is a projection of the upper end of the lower fragment forwards, and that this deviation is due to the nature and direction of the violence, and not to muscular action. In some cases there is no displacement, the broken ends being retained *in situ*, probably by the biceps tendon and the long head of the triceps. In at least one instance (Jarjavay) the lower fragment was so drawn upwards and outwards, apparently by the deltoid, as nearly to pierce the skin of the shoulder. Hamilton comes to the general conclusion "that complete or sensible displacement is less common at this fracture than in most other fractures," and in this conclusion many surgeons agree.

Amputation at the shoulder-joint.—The deltoid muscle forms an ideal amputation flap. It has its blood and nerve supply secured for it by the posterior circumflex vessels and circumflex nerve, which require to be avoided as the flap is raised from the posterior aspect of the upper extremity of the humerus prior to division of the capsule. The coracoid process lies under the anterior border of the muscle, and immediately external to the line of the axillary vessels. Thence the preliminary incision, which commences just externally to the coracoid, and is carried down the arm along the anterior border of the muscle, gives access to the axillary vessels so that they may be secured below the origin of the superior profunda (deep artery of arm). The incision is carried backwards above the insertion of the deltoid to the humerus. The insertion of the pectoralis major is cut in the incision along the anterior border of the deltoid; so are the latissimus dorsi and teres major. The insertions of the teres minor, infraspinatus, supraspinatus, and subscapularis are adherent to the capsule and are cut through with it, so as to free the head of the bone. The lower part of the capsule and the long head of the triceps are severed after the head of the humerus has been raised from its socket through the upper wound.

In **excision of the head of the humerus** for disease of the shoulder-joint, an incision is made along the line of the tendon of the supraglenoid head of the biceps, the incision being deepened until the tendon is exposed within the joint. The structures cut through in clearing the humeral head have been enumerated above, in connexion with amputation at the shoulder-joint. It must be remembered, while excising the head, that four-fifths of the growth in length of the humeral shaft takes place at the upper epiphyseal line, and that care must therefore be taken to avoid damage to that line in the young.

CHAPTER XII

THE ARM

THE arm, upper arm, or brachial region is considered to extend from the axilla above to the region of the elbow below.

Surface anatomy.—In women, and in those who are fat, the outline of the arm is rounded and fairly regular. It is less regular in the muscular, in whom it may be represented by a cylinder, somewhat flattened on either side and unduly prominent in front (biceps muscle). The outline of the biceps muscle is distinct, and on either side of it is a groove. The inner of the two grooves is by far the more conspicuous. It runs from the bend of the elbow to the axilla, and indicates generally the position of the basilic vein and brachial artery. The outer groove is shallow, and ends above at the insertion of the deltoid muscle. So far as it goes it marks the position of the cephalic vein.

The insertion of the deltoid is an important landmark, and can be easily distinguished. It indicates very precisely the middle of the shaft of the humerus, is on the same level with the insertion of the coraco-brachialis muscle, and marks the upper limit of the brachialis. It corresponds also to the spot where the cylindrical part of the humeral shaft joins the prismatic portion, to the point of entrance of the nutrient artery, and to the level at which the musculo-spiral nerve and profunda artery of the arm cross the back of the bone.

When the arm is extended and supinated, the brachial artery corresponds to a line drawn along the inner border of the biceps, from the outlet of the axilla (at the junction of its middle and anterior thirds) to the middle of the bend of the elbow. The artery is superficial, and can be felt in its entire extent. In its upper two-thirds it lies on the inner aspect of the shaft of the humerus, and can be compressed against the bone by pressure in a direction outwards and slightly backwards. In its lower third the humerus lies behind it, and compression, to be effectual, should be directed backwards.

The superior ulnar collateral (inferior profunda) would be represented by a line drawn from the inner side of the humeral shaft at its middle to the back part of the internal or medial epicondyle. The nutrient artery enters the bone at its inner aspect opposite the deltoid insertion, and the inferior ulnar collateral (anastomotica magna) vessel comes off about 2 inches above the bend of the elbow.

The ulnar nerve follows first the brachial artery, and then a line drawn from the inner side of that vessel, about the level of the insertion of the coraco-brachialis, to the gap between the inner condyle and the olecranon. The main part of the internal or medial cutaneous nerve of the forearm is beneath the *inner bicipital groove*, while the musculo-cutaneous nerve becomes superficial in the bend of the elbow at the outer margin of the tendon of the biceps in the *outer bicipital groove or sulcus.* Deep in this groove are found two nerves, the musculo-cutaneous and the musculo-spiral (radial), the first emerging from beneath the biceps, the second lying beneath and covered by the proximal part of the brachioradialis.

The **skin** of the arm is thin and smooth, especially in front and at the sides. It is very mobile, being but loosely attached to the deeper parts by a lax subcutaneous fascia. In circular amputations of the arm this looseness of the integument allows it to be sufficiently drawn up by traction with the hand only. It is from the integument covering the anterior surface of the biceps that the flap is fashioned in Tagliacozzi's operation for the restoration of the nose. The fineness of the skin of this part, and its freedom from hairs, render it very suitable for this procedure. The scanty attachments of the skin of the arm allow it to be readily torn or stripped away in lacerated and contused wounds. Sometimes in these lesions large flaps of integument are violently dissected up. The looseness of the subcutaneous tissues favours greatly the spread of inflammatory processes, while its comparative thinness allows of the early manifestation of ecchymoses.

The limb is completely invested with a deep fascia, the **brachial aponeurosis,** as by a sleeve. The fascia is held down at the sides by the two intermuscular septa which are attached along the outer and inner margins of the humerus, running from the deltoid insertion to the outer or lateral epicondyle on the one side, and from the coracobrachialis insertion to the inner epicondyle on the other. By means of this aponeurosis and its septa the arm is divided into two compartments. which can be well seen in transverse sections of the limb (Fig. 63, p. 281). These compartments serve to confine inflammatory and hæmorrhagic effusions. The anterior of the two spaces has the less substantial boundaries, owing to the thinness of the brachial fascia as it covers the biceps. Effusions can readily pass from one compartment to the other by following the course of those structures that, by piercing the intermuscular septa, are common to both spaces: these are the musculo-spiral and ulnar nerves, the profunda artery, the superior and inferior ulnar collaterals. The principal structures that pierce the brachial aponeurosis itself are the basilic vein, a little below the middle of the arm, the internal cutaneous nerve of the forearm, about the middle, and the external cutaneous nerve of the musculo-cutaneous, at the elbow. The two first-named are in the inner bicipital groove, and the last-named is in the outer.

The brachialis is closely adherent to the bone, while the biceps is free. It follows, therefore, that in section of these muscles, as in amputation, the latter muscle retracts more considerably than does the former. It is well, therefore, in performing a circular amputation, to divide the biceps muscle first, and then, after it has retracted, to cut the brachialis anticus.

Brachial artery.—The line of this vessel has already been given (*see* p. 275). It is well to note that in the very muscular the artery may be overlapped to a considerable extent by the biceps muscle. Compression of the brachial, unless performed carefully with the fingers, can hardly avoid at the same time compression of the median nerve. It must also be remembered that the internal cutaneous nerve lies in front of the vessel, or close to its inner side, until it pierces the fascia; that the ulnar nerve lies along the inner side of the artery as far as the coraco-brachialis insertion; and that behind the commencement of the vessel is the musculo-spiral nerve. The venæ comites are placed one on either side of the artery, and communicate frequently with one another by short transverse branches which directly cross the vessel, and which may give trouble in operations upon the artery. If in ligaturing the artery at its middle third the arm rests upon any support, the triceps may be pushed up and mistaken for the biceps. If the incisions be too much to the inner side the basilic vein may be cut, or the ulnar nerve exposed and mistaken for the median. Tillaux states that in the operation a large superior ulnar collateral artery has been taken for the brachial. Inasmuch as the median nerve often derives distinct pulsation from the subjacent vessel, it happens that in the living subject it has been confused with the main artery itself.

Abnormalities in the arrangement of the brachial artery are so frequent (they occur in 12 to 15 per cent. of arms) as to be of surgical importance. It is not unusual to find a collateral branch (vas aberrans) arising from the upper part of the brachial or lower part of the axillary, passing down the arm, *superficially* to the median nerve and ending in the radial or sometimes the ulnar artery. The vas aberrans may replace the brachial, in which case the artery will be found superficial instead of deep to the median nerve, and the profunda or deep artery and the superior ulnar collateral will arise from the remnant of the real brachial artery. This superficial brachial vessel may pass under the *supracondyloid process*, a hooked projection of bone which occasionally springs from the humerus, 2 inches above the internal epicondyle. It is situated among the inner fibres of origin of the brachialis.

The **musculo-spiral (radial) nerve,** from its close contact with the bone, which it crosses at the level of the deltoid insertion, is frequently injured and torn. Thus, it has been damaged in severe contusions, in kicks, in stabs, in bites from horses, and very frequently in fractures of the humeral shaft; or the nerve may be sound at the time of fracture and become subsequently so involved in callus as to lead to paralysis of the parts it supplies. In a case reported by Tillaux, where paralysis followed some time after a fracture, the nerve was found embedded in callus, and on cutting some of the redundant mass away a good recovery followed. In several instances the nerve has been paralysed by the pressure of the head when a man has slept with his head resting on the arm in the position of full supination and abduction. It is said to be often paralysed in Russian coachmen who fall asleep with the reins wound round the upper arm. It has also been frequently damaged by the pressure of badly constructed crutches, especially those that afford no proper support for the hand. Indeed, it is the nerve most often affected in "crutch paralysis," the ulnar being the trunk that suffers next in frequency.

Fracture of the shaft of the humerus is usually due to direct violence. The shaft may, however, be broken by indirect violence, and of all bones the humerus is said to be the one most frequently fractured by muscular action. As examples of the latter may be noted the throwing of a ball, the clutching at a support to prevent a fall, and the so-called trial of strength known as "wrist-turning." Instances of muscular fracture of the humerus occur among soldiers while practising bomb-throwing. When the bone is broken *above* the deltoid insertion the lower fragment may be drawn upwards by the biceps, triceps, and deltoid, and outwards by the last-named muscle; while the upper fragment is drawn inwards by the muscles attached to the bicipital groove. When the fracture is *below* the deltoid insertion, the lower end of the upper fragment may be carried outwards by that muscle, while the lower fragment is drawn upwards to its inner side by the biceps and triceps. The deformity, however, as a rule depends much more upon the nature and direction of the force that breaks the bone than upon any muscular action. The displacements just noted *may* be met with, but usually they are quite independent of the relation of the deltoid insertion to the seat of fracture, and cannot be tabulated. The weight of the arm seldom allows of more than $\frac{3}{4}$ of an inch of shortening.

Fracture of a bone is always attended by a reflex contraction of the muscles surrounding that bone —a reflex set up by injury to the sensory nerves which end in the damaged bone, periosteum, and musculature; hence the overriding of the broken ends. The reflex contraction ceases when the patient is anæsthetized, and the fragments, which could not be set before, can now be brought into apposition with ease.

The humerus is more frequently the seat of

non-union after fracture than is any other bone. This result is quite independent of the position of the fracture in relation to the nutrient artery. Non-union and delayed union are entirely due to the difficulty in obtaining fixation or immobilization of the humeral fragments. Perfect immobilization to secure the rest necessary for repair can only be obtained by preventing all the muscles which act on any part of the humerus from disturbing the site of fracture. Immobilization of the humeral muscles is obtained by fixing all the joints on which they act—the shoulder-joint, the elbow-joint, the wrist- and hand-joints — for muscles with a humeral attachment act on all of these joints. Now, immobilization of the elbow, wrist, and hand is easy, but no means have yet been devised which will keep the shoulder-joint at rest. Another cause would appear to be the entanglement of muscular tissue between the broken ends, for it must be remembered that the shaft of the bone is closely surrounded by adherent muscular fibres. Thus, in an oblique fracture the end of one fragment may be driven into the brachialis, while the other end projects into the substance of the triceps, and immediate contact of the bones may be consequently prevented.

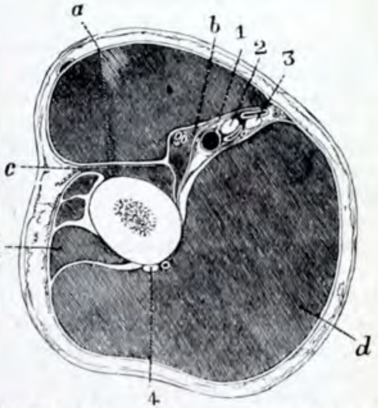

Fig. 63.—Transverse section through the middle of the arm. (*Braune.*)

a, Biceps; *b*, coraco-brachialis; *c*, brachialis (anticus); *d*, triceps; 1, brachial artery; 2, median nerve; 3, ulnar nerve; 4, musculo-spiral (radial) nerve.

Amputation through the middle of the arm.—The parts divided in a circular amputation are fully shown in Fig. 63. In the flap method there is a danger of transfixing the brachial artery. The artery, as may be seen from Fig. 63, may be pushed forwards or backwards by pressure applied to the muscles between which it lies. Before the flaps are shaped, the vessels may be secured at the inner border of the biceps. In the anterior flap are included the biceps, the greater part of the brachialis anticus, with the musculo-cutaneous nerve between them, and a small piece of the triceps from the inner side of the limb. In the posterior flap are the triceps, any small part of the outer portion of the brachialis not included in the anterior flap, the superior profunda artery, and the musculo-spiral nerve.

Growth of the humerus.—About the seventeenth or eighteenth year, growth ceases in the distal epiphyseal line, and the lower or distal epiphysis becomes united to the shaft. Growth ceases much later at the proximal or upper epiphyseal line, the proximal epiphysis joining with the shaft about the twenty-first or twenty-second year. With the closure of the epiphyseal lines, growth in length ceases. Digby has estimated that growth in length takes place four times more rapidly at the proximal than at the distal line. Hence injury to the proximal epiphyseal line in a growing child will give rise to a much greater degree of shortening than a similar injury to the distal line.

CHAPTER XIII

THE REGION OF THE ELBOW

Surface anatomy.—On the anterior aspect of the elbow are seen three muscular elevations. One, above and in the centre, corresponds to the biceps and its tendon; while, of the two below and at the sides, the outer corresponds to the brachio-radialis and the common extensor mass, and the inner to the pronator teres and the common set of flexor muscles. The arrangement of these elevations is such that two grooves are formed, one on either side of the biceps and its tendon. The grooves diverge above, and join the outer and inner bicipital grooves, while below they meet over the most prominent part of the tendon, and thus form together a V-shaped depression (Fig. 64). The distinctness of these details depends upon the thinness and muscular development of the individual. In the inner of the two grooves are to be found the median nerve, the brachial artery and its veins; while deeply placed below the outer groove are the terminations of the musculo-spiral (radial) nerve and profunda artery, with the small radial recurrent vessel. The biceps tendon can generally be felt distinctly. Its outer border is more evident than is its inner edge, owing to the connexion of the bicipital fascia (lacertus fibrosus) with the latter side of the tendon. Extending transversely across the front of this region is a crease in the integument, the "fold of the elbow." This fold is not a straight line, but is convex below. It is placed some little way above the line of the articulation, and its lateral terminations correspond to the tips of the two epicondylar eminences. In backward dislocations of the elbow the lower end of the humerus appears about 1 inch below this fold, whereas in a fracture of the humerus just above the epicondyles the fold is either opposite to the prominence formed by the lower end of the upper fragment, or is below it. This crease is obliterated on extension.

At the apex of the V-shaped depression, about the spot where the biceps tendon ceases to be distinctly felt, and at the outer side of that tendon, the median vein divides into the median basilic and the median cephalic. At the same spot also the deep median vein joins the superficial vessels. The median basilic vein can be seen to cross the biceps tendon, to follow more or less closely the groove along the inner border of the muscle, and to join, a little above the internal (medial) epicondyle with the posterior ulnar vein to form the basilic trunk. The median cephalic, following the groove at the outer margin of the biceps, joins, about the level of the external (lateral) epicondyle, with the radial vein to form the cephalic vein. The brachial artery bifurcates 1 inch below the centre of a line drawn from one epicondyle to the other; the point of division is opposite the neck of the radius. "The coronoid process of the ulna can be indistinctly felt, if firm pressure is made in the triangular space in front of the joint" (Chiene). The points of the two epicondyles can always be felt. The internal epicondyle is the more prominent and the less rounded of the two. The humero-radial articulation is in a horizontal line, but the humero-ulnar joint is oblique, the joint surfaces sloping downwards and inwards. Thus it happens that while the external epicondyle is only $\frac{3}{4}$ of an inch (18 mm.) above the articular line, the point of the internal epicondyle is more than 1 inch (28 mm.) above that part (Paulet). From the obliquity of the joint surfaces between the ulna and humerus, it follows that the forearm, when in extension, is not in a straight line with the upper arm, but forms with it an angle that opens outwards. Thus, when traction is made upon the entire upper limb from the wrist, some of the extending force is necessarily lost, and such traction, therefore, should be applied from the elbow, as is the usual practice in reducing a dislocation of the shoulder by manipulation. A line drawn through the two epicondyles will be at right angles with the axis of the upper arm, while it will form externally a smaller angle with the axis of the forearm. Thus, if we look at the upper arm, the two epicondyles are on the same level, whereas, when viewed from the forearm, the inner epicondyle lies at a higher level than does the external process.

The joint-line of the elbow is equivalent only to about two-thirds of the width of the entire line between the points of the two condyles (Fig. 66, p. 298). The prominence of the condyles forms a capital *point d'appui* for traction by encircling bands applied to the limb above the elbow-joint. At the back of the elbow the prominence of the olecranon is always to be distinctly felt. It lies nearer the internal than the external epicondyle. In extreme extension the summit of the olecranon is a little above the line joining the two condyles. When the forearm is at right angles with the arm, the tip of the process is below the line of the epicondyles, and in extreme flexion it lies wholly in front of that line. Between the olecranon and the inner epicondyle is a depression that lodges the ulnar nerve and the dorsal (posterior) ulnar recurrent artery.

To the outer side of the olecranon, and just below the external epicondyle, there is a depression in the skin which is very obvious when the limb is extended. This pit is to be seen even in those who are fat, and also in young children. In it the head of the radius and *radio-humeral joint* can be felt, and can be well distinguished when the bone is rotated in pronation and supination. The pit corresponds to the hollow between the outer border of the anconeus and the muscular eminence formed by the two radial extensors of the carpus and the brachioradialis. The highest point of the bone that can be felt moving on rotation will correspond to the radius immediately below the line of the elbow-joint, and is a valuable guide to that articulation. The upper limit of the elbow-joint reaches a line drawn between the point of the two epicondyles. The tuberosity of the radius can be felt just below the head of the bone when the limb is in the position of extreme pronation.

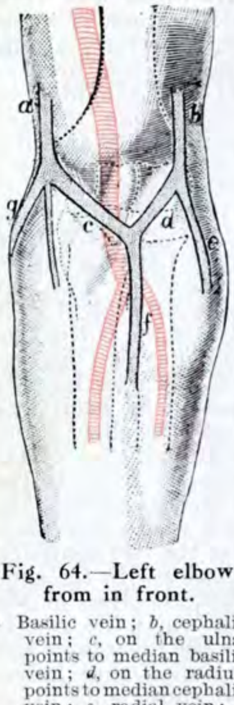

Fig. 64.—Left elbow from in front.

a Basilic vein; *b*, cephalic vein; *c*, on the ulna, points to median basilic vein; *d*, on the radius, points to median cephalic vein; *e*, radial vein; *f*, median vein; *g*, posterior ulnar vein. The brachial artery passes behind the median basilic vein, and divides into its radial and ulnar branches to the inner side of the radial neck.

The **skin** in front of the elbow is thin and fine, and is readily excoriated by tight bandaging and by improperly applied splints. The thinness of the skin allows the subjacent veins to be easily seen through the integuments, but the distinctness with which these veins appear depends mainly upon the amount of subcutaneous fat. In the very stout they may be quite invisible, and it may be difficult or impossible to render them evident by the usual means adopted in venesection.

The arrangement of the **superficial veins** in front of the elbow, so as to form an M-shaped figure, is familiar, but it must be confessed that it is by no means constant (Fig. 64). So far as I (F. T.) have seen, it would appear that the precise **M**-like arrangement figured in most books is only present in about two-thirds, and perhaps in only one-half, of all cases.

The **median vein** breaks up into the median cephalic and median basilic, just to the outer side of the biceps tendon, and, therefore, the latter vein passes in front of the tendon, of the brachial artery and its veins, and of the median nerve. From these structures it is separated by the bicipital fascia. The median basilic vein may cross the brachial artery abruptly, and be comparatively free of it, except at the point of crossing, or it may run for some distance quite in front of the artery, or, crossing it early, may lie parallel with the vessel, although at a different level, for the greater part of its course. As regards size, the median basilic is usually the largest of these veins, the median cephalic coming next, and the median itself third, while the ulnar and radial veins are the smallest of the series. These veins are liable to many abnormalities, some of the most conspicuous being in cases where the main arteries of the part also are abnormal. The deviation is more usual in the veins on the radial than in those on the ulnar side of the limb. Thus it is common for the radial or the median cephalic veins, or both, to be either very defective or entirely absent. In spite of the relation the *median basilic vein* bears to the brachial artery, it is nevertheless the vein usually selected in **venesection** and **transfusion**, and the **intravenous injection of sera and vaccines.** The reasons for its selection are these: it is usually the largest and most prominent of the veins, and the one the nearest to the surface; it is also the least movable vein, and the one the least subject to variation. The bicipital fascia forms an excellent protection to the brachial artery during phlebotomy. The density of that membrane varies, and depends mainly upon the degree of muscular development. In thin subjects the median basilic vein may receive pulsations from the subjacent artery. According to one observer, the walls of this vein are often as thick as those of the popliteal vein. The ulnar, radial, and median veins seldom yield enough blood on venesection, since they are below the point of junction of the deep median vein, and thus do not receive blood from the deep veins of the limb. The brachial artery has, as may be supposed, been frequently injured in bleeding; and at the period when venesection was very commonly practised, arterio-venous aneurysms at the bend of the elbow were not infrequent. Since the principal superficial lymphatic vessels run with these veins, and since some of them can scarcely escape injury in phlebotomy, it follows that an acute lymphangitis is not uncommon after the operation, especially when, the point of the lancet being unclean, septic matter is introduced into the wound.

The *internal cutaneous nerve* (*medial cutaneous of forearm*), which usually runs in front of the median basilic vein, may be wounded in bloodletting from that vessel. The injury to the nerve, according to Tillaux, may lead to "traumatic neuralgia of extreme intensity, and very chronic." A "bent arm" may follow after venesection, and Hilton believes this to be often due to injury to the filaments of the musculo-cutaneous nerve, especially to the inclusion of those filaments in a scar left by the operation. The cutaneous branches of this nerve lie over the median cephalic vein. These peripheral fibres being irritated, the muscles which are supplied from the same segment of the cord (biceps and brachialis) are caused to contract by reflex action. Hence the bent arm. In one case Hilton cured a bent arm following bleeding by resecting the old scar, which on removal was found to have included within its substance some nerve filaments.

There is a **lymphatic (supracubital) gland** situated over the internal intermuscular septum of the arm, and just above the internal epicondyle. It receives some of the surface lymphatics from the inner side of the forearm and two or three inner fingers. In position it is the lowest of the constant glands in the upper limb. In the same position occurs an occasional bony outgrowth of the inner aspect of the humerus—the *supracondyloid process*. The brachial artery, and also the median nerve, may pass beneath and internally (medially) to this process.

Brachial artery.—In forcible flexion of the limb the artery is compressed between the muscular masses in front of the joint, and the radial pulse is much diminished or even checked. The artery may divide in the lower third of the arm, and in such cases the ulnar artery may pass over the bicipital fascia. Aneurysms at the bend of the elbow have been treated by flexion of the limb, that position bringing more or less direct pressure to bear upon the sac. In full extension of the joint the artery becomes flattened out, and the radial pulse diminished. In the over-extension possible with fractured olecranon the pulse may be stopped at the wrist. Forcible extension of an elbow that has become rigid in the bent position has caused rupture of the brachial artery.

The **ulnar nerve** is, from its position at the elbow, very liable to be injured. It passes in a groove behind the internal epicondyle, and is crossed by a bridge of fibrous tissue which prevents its displacement. The nerve may pass in front of the internal epicondyle, and an instance is reported where the nerve slipped forwards over that eminence whenever the elbow was bent (Quain). In exposing the ulnar nerve (for nerve-stretching, etc.) behind the elbow the nerve may be found quite covered by an occasional muscle, the epitrochleo-anconeus.

The elbow-joint.—The strength of this joint depends not so much upon either ligaments or muscles as upon the coaptation of the bony surfaces. The relations of the olecranon and coronoid processes to the humerus are such that in certain positions the strength of the joint is very considerable.

The elbow, being a pure hinge-joint, permits only of flexion and extension. These movements are oblique, so that in flexion the forearm inclines inwards, carrying the hand towards the middle third of the clavicle. If it were not for the obliquity of the joint line it would be possible for the hand to be placed flat upon the shoulder of the same side; but this movement is only possible after some excisions of the joint, for in this operation the oblique direction of the articular surfaces is not reproduced. In extreme extension the ulna is nearly in a straight line with the humerus as regards their lateral planes, while in extreme flexion the two bones form an angle of from 30° to 40°.

Bursæ.—Of the bursæ about the joint the large subcutaneous bursa over the olecranon is very commonly found enlarged and inflamed (Fig. 65), and when inflamed may lead to extensive mischief in the limb. Its enlargement is favoured by certain employments involving pressure on the elbow; thus, the disease known as "miner's elbow" is merely an enlargement of this sac. There is a bursa between the biceps tendon at its insertion and the bone, the relations of which to the nerves of the forearm are worth noting. A case, for instance, is reported where this bursa became chronically enlarged, and by pressing upon the median and dorsal interosseous nerves produced loss of power in the forearm (Agnew). There is a small bursa at the insertion of the triceps (Fig. 65).

Of the **ligaments** of the elbow-joint, the anterior and posterior are comparatively thin, and the latter especially soon yields to the pressure of fluid within the joint in disease of the articulation (Fig. 65). The internal lateral (ulnar collateral) ligament is the strongest and most extensive of the ligaments of the part. From its rigidity, its extended attachment, and the fact that it serves to limit not only flexion and extension, but also any attempt to wrench the forearm laterally from the arm, it happens that it is the ligament that suffers the most often in "sprains" of the elbow. As this ligament is attached to the whole length of the inner border

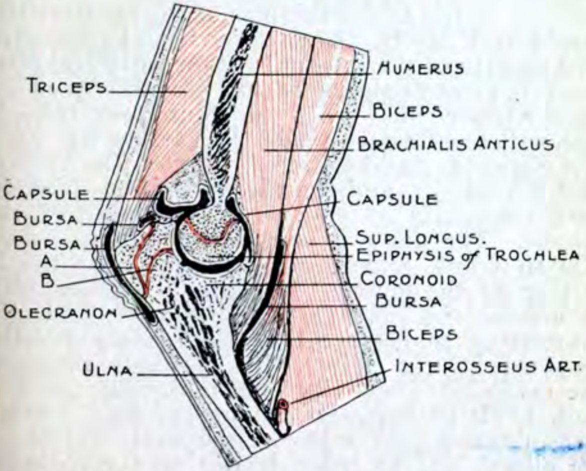

Fig. 65.—Vertical section of the elbow-joint.

The epiphyseal lines of the olecranon and trochlea are shown in red. The joint is semi-extended.

A, Usual cap-like epiphysis of olecranon receiving insertion of triceps; B, occasional epiphysis forming the upper third of the olecranon. Three bursæ are shown—over the olecranon, under the insertion of the triceps, and at the insertion of the biceps. (Supinator longus = brachio-radialis.)

of the olecranon, it may assist in preventing separation of the fragments when that process has been fractured.

Joint-disease.—In disease of this joint the effusion first shows itself by a swelling around the margins of the olecranon. This is explained by the facts that the synovial cavity is here nearest to the surface, and that the posterior ligament is lax and thin (Fig. 65). Some swelling is also soon noticed about the line of the radiohumeral joint, and fluctuation in this situation serves to distinguish joint-effusion from simple enlargement of the bursa beneath the triceps tendon. Deep-seated swelling may be noted about the front of the joint beneath the brachialis anticus, owing to the thinness of the anterior ligament; and, lastly, about the external epicondyle. The density of the internal (ulnar collateral) ligament prevents bulging of the synovial membrane on the inner side. When the joint suppurates the pus will most easily reach the surface by travelling upwards and backwards between the humerus and the triceps, and the abscess points, therefore, very commonly at one or other border of that muscle. The pus may escape beneath the brachialis in front, and discharge itself near the insertion of the muscle. The diseased elbow tends to assume the posture of semiflexion, and it is interesting to observe that that is the position assumed by the joint when forcible injections are made into its cavity (Braune). The joint, in fact, holds the greatest amount of fluid when it is semiflexed. As regards muscular rigidity of the elbow, due to reflex irritation from disease, it is well to note that all the nerves of the articulation, notably the musculo-spiral and musculocutaneous, supply muscles acting upon the joint. The relation of the ulnar nerve to the joint serves to explain cases where severe pain has been felt along the forearm and in the fingers, in parts corresponding to the distribution of that nerve. The upper epiphysis of the radius and the greater part of the lower epiphysis of the humerus are intrasynovial, i.e. come within the capsule of the joint (Fig. 66). The comparatively small upper epiphysis of the ulna is only partly within the capsule (Fig. 65).

Dislocations of the elbow.—These are many, and may be thus arranged. (1) Dislocations of *both radius and ulna* either backwards, outwards, inwards, or forwards (in order of frequency). (2) Dislocations of the *radius alone* either forwards, backwards, or outwards (in order of frequency). (3) Luxation of the *ulna alone* backwards.

As a preliminary it may be convenient to note some general anatomical considerations in connexion with these various displacements.

(*a*) *Antero-posterior luxations are much more common than lateral luxations.*—Displacements in the antero-posterior direction are more common because the movements of the joint take place in that direction, and the width of the articular surface of the humerus from before backwards is comparatively small. On the other hand, there is normally no lateral movement of the elbow, and the width of the articulation from side to side is considerable. The antero-posterior ligaments are feeble, while the lateral (collateral) ligaments are strong.

(*b*) *Both bones of the forearm are more often luxated together than is either the radius alone or the ulna alone.*—This depends upon the powerful ligamentous connexion between the radius and ulna on the one hand, and the absence of such connexion between the humerus and the radius on the other. In the dead subject it is not difficult to dislocate the two bones of the forearm, but it is extremely difficult to separate the radius from the ulna without great breaking and tearing of parts.

(*c*) *The commonest dislocation of the two bones together is backwards, the rarest is forwards.*—In the former instance the movement is resisted by the small coronoid process, in the latter by the large and curved olecranon. For like reasons the luxation outwards is less rare than is the displacement inwards, since the articular surface of the humerus inclines downwards and inwards on the inner side, and thus affords a greater obstacle in that quarter.

(*d*) *If a single bone be dislocated it will usually be the radius.*—This follows from the absence of reliable union between that bone and the humerus, from the greater exposure of the radius ("the handle of the hand") to indirect violence, and from its greater mobility. The luxation is usually forwards, due to the fact that the forms of violence that tend most often to displace the bone tend also to draw it forwards. Paulet asserts that the posterior part of the annular ligament is "much more resistant" than is the anterior part. The luxation of the ulna alone occurs in the backward direction, for reasons that will be obvious.

Dislocations of all kinds may be partial or complete. More usually they are complete when in the antero-posterior direction, and partial when the luxation is lateral.

Some more detailed notice may now be taken of the only two forms of dislocation at the elbow that are at all common.

1. **Displacement of both bones backwards.**—This may be effected during forced extension. Here the point of the olecranon pressed against the humerus acts as the fulcrum of a lever of the second kind, with the result that the sigmoid or semilunar notch is forced away from the trochlea. The addition of violence to the forearm in a backward or upward direction would effect the actual displacement. This condition may be illustrated by a fall, when running, upon the fully extended hand. The lesion may also be produced by certain violent wrenchings of the limb. Malgaigne maintained that the particular kind of wrench most effectual in producing luxation was a twisting inwards of the forearm while the elbow was semiflexed. In this way the internal lateral ligament was ruptured, and the coronoid process twisted inwards and downwards under the humerus, and the bones were thus displaced back-

wards. This lesion would be difficult to effect while the joint was fully flexed. In the complete form the coronoid process is opposite to the olecranon fossa. It can hardly occupy that hollow (as sometimes described), since the connexion of the ulna to the radius, and the projection of the latter bone behind the outer epicondyle, would prevent it from actually falling into the fossa. The anterior and the two lateral ligaments are usually more or less entirely torn, while the posterior and annular ligaments escape. The biceps is drawn over the lower end of the humerus, and is rendered moderately tense. The brachialis is much stretched and often torn. The anconeus is made very tense. Both the median and the ulnar nerve may be severely stretched.

2. **Dislocation of the radius forwards.**—This may be due to direct violence to the bone from behind, or to extreme pronation, or to falls upon the extended and pronated hand. The anterior, external, and annular ligaments are torn.

Sprain of the elbow.—Mr. J. Hutchinson has shown that in young children, under 5 years, forcible traction of the limb in the supinated position may cause the radius to slip downwards, away from the annular ligament, which is displaced upwards. In such cases traction is applied before the muscles of the elbow have had time to undergo their usual reflex contraction, so that when the child is lifted by the hand all the weight falls upon the ligaments at the elbow instead of on the muscles. The only ligaments which resist such a dislocation are (1) the oblique ulno-radial ligament, (2) the lower fibres of the annular ligament which grip the head. Flexion of the elbow in the pronated position restores the ligament to its normal situation. It is clear that this displacement is the anatomical basis of the common sprain of the elbow met with in young children, and usually due to violent traction of the hand.

Fractures of the lower end of the humerus.

—These are: (1) A fracture just above the epicondyles; (2) the "T-shaped fracture," involving the joint; (3) fractures of the internal or medial, and (4) of the external or lateral condylar parts; (5) fracture of the internal epicondyle; and (6) separation of the lower epiphysis. All these fractures are more common in the young.

1. The fracture **"at the base of the epicondyles,"** as it is sometimes called, is usually situate a little above the olecranon fossa, where the humeral shaft begins to expand. It is commonly transverse from side to side, and oblique from behind downwards and forwards. It is generally the result of a blow inflicted upon the extremity of the elbow. Probably the tip of the olecranon driven sharply against the bone acts like the point of a wedge, and takes an important share in the production of the fracture. The lower fragment, together with the bones of the forearm, is generally carried backwards by the triceps, and upwards by that muscle, the biceps, and the brachialis. The median or ulnar nerves, especially the latter, may be severely damaged.

2. The **"T-shaped fracture"** is but a variety of the lesion just noted. In addition to the transverse fracture above the epicondyles, there is also a vertical fracture running between the two epicondyles into the joint. The lower fragment is thus divided into two parts. The displacement is the same. The fracture is usually due to a fall upon the bent elbow, and here possibly the tip of the olecranon again acts as a wedge, producing the transverse fracture, while the prominent ridge along the middle of the semilunar notch of the ulna, acting as a second wedge, produces the vertical fracture into the joint.

For surgical purposes it is convenient to apply the term "condylar part" to each area of the distal articular extremity of the humerus on which the epicondyles are placed. The epicondyles are, strictly speaking, outside the joint capsule; the "condylar parts" descend within it.

3. In fracture of the **internal** or **medial condylar part** the line of separation generally commences about half an inch above the tip of the medial epicondyle (and, therefore, outside the joint), and, running obliquely outwards through the olecranon and coronoid fossæ, enters the articulation through the centre of the trochlear surface (Hamilton). The fragment is often displaced a little upwards, backwards, and inwards, the ulna going with it.

4. In fracture of the **external** or **lateral condylar part** the line of fracture commences also above the external epicondyle and outside the joint, and, running downwards, enters the joint usually between the trochlear surface and the surface for the radius. The displacement is trifling and inconstant.

5. On account of its insignificant size, a fracture of the **external epicondyle** is scarcely possible. Fractures of the **internal** or **medial epicondyle** are, however, quite common, the joint remaining free (Fig. 66). This epicondyle exists as a distinct epiphysis, which unites at the age of 18, and which at any time before that age may be separated from the bone by direct injury or muscular violence. Owing to the dense aponeurotic fibres that cover the part, much displacement of the fragment is uncommon. When displacement exists, it is in the general line of the common flexor muscles that arise from the tip of the process. In such cases the ulnar nerve, which lies behind the process, is often damaged.

6. **The lower epiphysis** (Fig. 66).—In the cartilaginous lower extremity of the humerus four ossific centres appear, one for each of the following parts: capitellum, trochlea, external and internal epicondyles. The three centres named first unite to form the main epiphysis, that for the internal epicondyle remaining separate (Fig. 66). The epiphyseal line is thus divided into two parts, and is irregular in form; it lies both within and without the capsule of the joint (Fig. 66). Its

position may be indicated by a line drawn from the upper border of the external to the lower border of the internal epicondyle. The lower epiphysis joins the shaft at the age of 17. Thus, after 17 the growth of the bone must depend upon the activity of the upper epiphysis, which does not unite until 20. Excision of the elbow, therefore, after the sixteenth or seventeenth year, will not be followed by arrest of development in the limb, even if the epiphyseal line has been transgressed by the saw. Several cases are, however, reported of marked arrest of growth in the limb following upon injuries to the lower epiphysis before the sixteenth year, and to the upper epiphysis before 20. The greater part of the epiphyseal line being within the capsule, but little displacement, other than a slight movement backwards, is consequent upon the separation of the distal mass.

Fig. 66.—Lower epiphysis of the humerus from behind.

A, Centre for internal epicondyle; B, C, D, united centres for the trochlea, capitellum, and external epicondyle; E, E, epiphyseal line: the capsular attachment is indicated by red lines.

Fractures of the olecranon are commonly due to direct violence, and in a few cases to severe indirect violence applied to the lower end of the humerus or upper end of the ulna. Instances of fracture by muscular action are few, and open to some question. The fracture is most commonly met with about the middle of the process, just where it begins to be constricted, and it is usually transverse in direction. The amount of displacement effected by the triceps varies, and depends upon the extent to which the dense periosteum about the process and the ligaments that are attached to it are torn. The olecranon is developed mainly from the shaft of the ulna (Fig. 65). There is a scale-like epiphysis, however, at the summit of the process which joins the rest of the olecranon at the age of 17. Occasionally another epiphyseal centre occurs, giving origin to the upper third of the olecranon (Fig. 65). In young subjects the scale-like epiphysis may be separated by violence, or the cartilaginous olecranon may be dissevered from the rest of the bone. The common fracture of the adult olecranon does not follow the epiphyseal line.

Fracture of the coronoid process is an extremely rare accident, sometimes occurring in dislocation backwards of the ulna. It is impossible to understand how the process can be torn off by the action of the brachialis anticus, since that muscle is inserted rather into the ulna at the base of the projection than into the process itself (Fig. 65). Nor can it be separated as an epiphysis, since it does not exist as such.

Fractures of the head or neck of the radius are rare, and occur usually with dislocation or other severe injury. The head is commonly found split or starred, and the lesion, if limited to the head, could be diagnosed only with the aid of X-rays. The upper epiphysis of the radius is entirely within the limits of the annular ligament, and could scarcely be separated in a simple lesion. It is a mere disc of cartilage joining the shaft at the age of 17. When the neck is broken the upper end of the lower fragment is drawn well forwards by the biceps muscle.

Resection of the elbow may be performed in many ways. In all procedures there is danger of injuring the ulnar nerve, and some little difficulty often in clearing the prominent internal epicondyle. If the knife be kept close to the bone, no vessel of any magnitude should be divided. The muscles most disturbed are the triceps, anconeus, supinator, extensor carpi ulnaris, extensor carpi radialis brevior, and brachialis. It is most important to preserve the periosteum over the olecranon, and the external lateral expansion of the triceps tendon to the deep fascia of the forearm, so that this muscle may still act as an extensor. It is never necessary to divide the insertion of the brachialis, still less of the biceps, although some few fibres of the former muscle may be separated in removing the upper surface of the ulna. By the subperiosteal method the periosteum is carefully peeled off from all the parts to be resected, and is preserved. By this means the triceps retains a hold upon the ulna, and the restoration of the joint is more complete. The functions of the joint may be well restored after resection, especially when performed by the subperiosteal method; but it would appear that after no method are the anatomical details of the joint reproduced. Thus, in a successful case, the new joint will assume the bimalleolar form, and will resemble the ankle- rather than the elbow-joint. The humerus throws out two malleoli on the sites of the normal condyles, and in the concavity between them the ulna and radius are received. Between the ulna and the humerus new ligaments form, and a new annular ligament for the radius is also developed. If, on the other hand, ankylosis is inevitable, then steps must be taken to secure that fixation will occur at the most suitable angle. It has been found by experience that an ankylosed elbow-joint is most useful when the forearm is set to the arm at an angle of about 60°—at such an angle the hand can be brought to the mouth.

Position of the main nerves at the elbow.—The musculo-spiral (radial) is found in front of the external epicondyle, under cover of the brachio-radialis, where it divides into posterior interosseus and radial cutaneous branch. The median is situated at the inner border of the brachial artery; the ulnar lies in a groove behind the internal epicondyle (*see* p. 289).

Chas M Shumway
Nov. 16, 192

CHAPTER XIV

THE FOREARM

Surface anatomy. — At its upper half, and especially in its upper third, the limb is much wider in its transverse than in its antero-posterior diameter. A horizontal section through this part will show a cut surface that is somewhat oval in outline, and is at the same time flattened in front and more convex behind. This outline is best seen in muscular subjects, and depends chiefly upon the development of the lateral masses of muscle that descend from the epicondyles. In the non-muscular, the limb, even in its highest parts, tends to assume a rounded rather than an oval outline. In women and children, also, the limb is round, owing to the comparatively slight development of the lateral muscular masses, and to the accumulation of fat on the front and back of the limb. The posterior surface of the forearm in a vigorous subject presents along its outer border a prominence formed by the brachio-radialis and the two radial extensors, which become tendinous below the centre of that border. On the lower third of this edge is a slight eminence, directed obliquely downwards, outwards, and forwards, and due to the crossing of the extensors of the thumb. In the middle of the posterior surface is another elevation, running down from the outer (lateral) epicondyle, and formed mainly by the extensor communis. To the inner side of this eminence is a groove, well seen in the very muscular, that indicates the posterior dorsal border of the ulna. The ulna is subcutaneous throughout its entire extent, and can be readily examined. The upper half of the radius is too deeply placed to be well made out, but the lower half of the bone can be easily felt beneath the skin. The course of the radial artery is represented by a line drawn from the outer border of the biceps tendon at the bend of the elbow to a point in front of the styloid process of the radius. The pulse is felt between the styloid process and the tendon of the flexor carpi radialis where the artery rests on the distal extremity of the radius. The middle and lower thirds of the ulnar artery follow a line from the inner epicondyle to the radial side of the pisiform bone. The ulnar nerve corresponds to the whole length of this line. The upper third of the artery would be represented by a line drawn from the middle of the bend of the elbow to meet the first line at the junction of the upper and middle thirds of the inner medial border of the forearm. Such a line would be slightly curved, with its concavity outwards. The tendons, etc., that can be demonstrated at the lower extremity of the forearm will be considered in the description of the wrist.

Vessels.—It is well to note the very free anastomoses that exist along the greater part of the limb between the ulnar and radial arteries. This fact was illustrated by a case under my (F. T.'s) care in the London Hospital. A seafaring man had inflicted upon his left forearm three deep transverse wounds across the front of the limb with a sharp knife. The wounds were about 1½ inches apart. The radial artery was divided in each of the wounds, and that vessel, therefore, presented six cut ends. It would appear to be sufficient to ligature the proximal and distal ends of the wounded vessel, and to leave the two isolated portions of the artery, each about 1½ inches in length, alone. Ligatures were applied to five of the divided ends, and the lower end of the upper isolated piece of the artery was left untied, and the effect watched. During the course of the day, when the man had rallied from the profound faintness due to the great loss of blood he had experienced, copious bleeding took place from this single unsecured end of the vessel, and it, of course, had also to be tied.

There is a singular absence of large blood-vessels or nerves along the posterior (dorsal) aspect of the forearm, and it is significant that this is the aspect of the limb most exposed to injury. For a hand's-breadth below the olecranon there is almost an entire absence of superficial veins.

The **median nerve** passes between the humeral and ulnar heads of the pronator teres. At the wrist the median is between the tendons of the flexor carpi radialis and flexor digitorum sublimis; it lies deep to the tendon of the palmaris longus, which serves as a useful guide to its position.

Bones of the forearm.—Transverse sections of the limb at various levels show that the radius and ulna are in all parts nearer to the dorsal than to the volar aspect of the extremity (Figs. 67 and 68). This relation is the more marked the higher up the section. The two bones are nearest to the centre of the limb about the lower or distal end of the middle third. At the upper or proximal part of the forearm the muscles are found mainly at the sides and in front. The more distal the section the less will the bones be covered at the sides, and the more equally will the soft parts be distributed about the volar and dorsal aspects of the limb. It will be noticed that where one bone is the more substantial the other is the more slender, as near the elbow and wrist; and that it is about the centre of the limb that the two are most nearly of equal strength. The proximity of the two bones, and especially of the ulna, to the dorsal aspect of the limb permits them to be easily examined from that surface, while it is from the same aspect that resections and other operations upon the bones are most readily performed. It will be understood, moreover, that in compound fractures, due to penetration of fragments, the wound is more usually on the dorsal aspect of the limb.

The important movements of *pronation* and *supination* take place between these bones, and round an axis corresponding to a line drawn through the head of the radius, the distal end

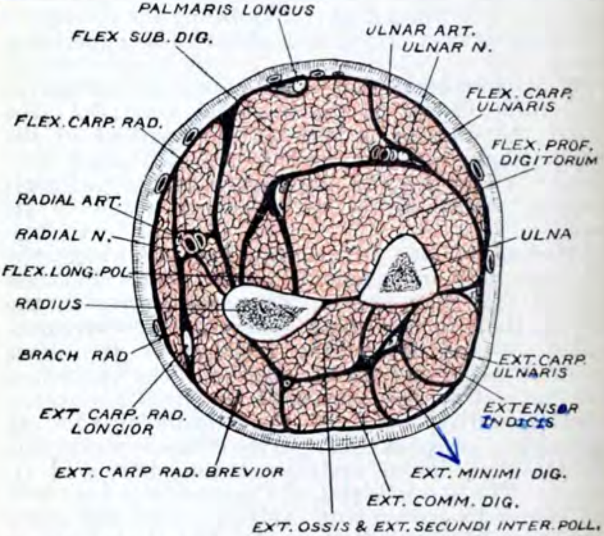

Fig. 67.—Transverse section through the middle of the forearm. (*After Braune.*)

of the ulna, and the metacarpal bone of the ring-finger. In extreme pronation the radius crosses the ulna obliquely; the two bones are almost in contact at the point of crossing; the lower fibres of the interosseus membrane and the dorsal radio-ulnar ligament are tight. "The chief influence in checking supination is not to be found in ligament at all, but in the contact of the posterior edge of the ulnar notch of the radius with the tendon of the extensor carpi ulnaris, as it lies in the groove between the styloid process and the round head of the ulna" (Sir H. Morris). Of the two movements, supination is the more powerful. This is illustrated in many ways. In using a screw-driver or a gimlet the movements of pronation and supination are conspicuously involved, but the main force is applied during supination. It is significant that the thread of a corkscrew is so turned that it shall be inserted by supination rather than by pronation.

The only position in which the two bones are parallel to one another is the mid-position between pronation and supination. It is in this posture only that the interosseous membrane is uncoiled throughout. Hence the selection of this position in the adjustment of most fractures of the forearm. The interosseous space is an irregular ellipse, a little larger below than above. It is narrowest in full pronation, widest in supination, and nearly as wide in the mid-position.

It may be noted that the oblique radio-ulnar ligament tends to resist forces that would drag the radius away from the humerus, and takes the place and the function of a direct ligament, passing from the humerus to the radius, while the interosseous membrane, from the obliquity of its fibres, compels the ulna to share in the strain put upon the radius when that bone is forced upwards, as in resting on, or pushing with, the palm.

Fractures of the forearm.—The two bones are more often broken together than is either the radius or the ulna alone. The radius, when broken alone, is usually fractured by indirect violence, since it receives more or less entirely all shocks transmitted from the hand. The ulna, on the contrary, is more often broken by direct violence, it being the more superficial and exposed of the two bones. For example, in raising the arm to ward off a blow from the head, the ulna becomes uppermost. Among the ancient Egyptians, who were much given to a game of cudgels, fracture in the distal part of the ulna was very common, as we know from the investigations of Elliot Smith and Wood-Jones. When the two bones are broken together, the violence may be direct or indirect. Malgaigne reports a case where both bones in a patient were broken by muscular violence when he was shovelling earth. Here the bones probably were broken between the two opposed forces represented by the biceps and brachialis above and the weight of the loaded shovel in the hand below. When **both bones** are broken and the fractures are oblique, shortening may be produced by the united action of the flexors and extensors. The displacement varies greatly, and depends rather upon the direction of the violence than upon muscular action. Thus Hamilton says: "I have seen the fragments deviate slightly in almost every direction." If union be delayed, the delay is usually in the radius, since it is the more mobile of the bones.

When the **radius alone** is broken (1) between the insertions of the biceps and pronator teres, the upper fragment is flexed by the biceps and fully supinated by that muscle and the supinator. The lower fragment will be pronated by the two pronators, and drawn in towards the ulna by means of these muscles. If such a fracture be put up with the hand midway between the prone and supine positions, the following evils result: the upper fragment is fully supinated by the muscles; the lower fragment is placed in the mid-position by the splints. It follows that the proper axis of the bone is not reproduced, and the use of the biceps and supinator as supinators is entirely lost. Thus patients so treated usually recover with great loss in the power of supination; and, to avoid this ill result, it is advised to put the limb up in full supination, so that the two fragments may unite in their proper axis, the upper fragment being supinated by the muscles, the lower by the splints. (2) When the fracture is between the insertions of the two pronators, the upper fragment may be carried a little forwards by the biceps and pronator teres, and drawn towards the ulna by the latter muscle. The lower fragment will be adducted to the ulna by the pronator quadratus, and its upper end will be still further tilted towards that bone by the action of the brachio-radialis upon the styloid process.

When the **ulna alone** is broken, as, for example, about its middle, the proximal fragment may be drawn a little forwards by the brachialis, while the lower fragment will be carried towards the radius by the pronator quadratus.

The displacement, however, in all cases is influenced as much by the direction of the violence as by the action of muscles. When the fragments, after fracture of one or of both bones, fall in towards one another, so as to meet across the interosseous space, attempts are sometimes made to separate the broken ends and to preserve the integrity of the space by the use of graduated pads. These pads, however, if applied with sufficient force to separate the fragments, will compress one or both of the arteries of the limb, and cause great distress, resulting in a peculiar condition known as **ischæmic contraction**, due, it is believed, to the compression shutting off the blood supply to the muscles. Subsequently the muscles undergo contracture and atrophic changes, thus becoming useless. This condition may be produced in any group of muscles if a severe and continuous pressure be applied to them, such as results from a too tight application of bandages or retention of the elbow or knee in a position of extreme flexion. The fact that the bulk of the venous blood of the forearm is returned by surface veins may explain the ready occurrence of severe œdema in the limb when fractures are treated with improperly applied splints or bandages. Since the arteries also can be readily affected by pressure, it follows that gangrene, as a result of improper treatment, is more common after fracture of the forearm than after fracture in any other part.

Amputation of the forearm.—In amputation of the forearm by double transfixion flaps, at about the upper part of the middle third, the parts would be cut in the following manner (Fig. 67): On the face of the anterior or volar flap would be seen from without inwards the brachio-radialis (cut the whole length of the flap), then the flexor sublimis (cut to a like extent), and, lastly, the flexor carpi ulnaris. Between the brachio-radialis and the flexor sublimis the divided end of the pronator teres is seen; and between the flexor sublimis and the skin would lie the flexor carpi radialis and the palmaris longus. The latter would appear as a tendon at the inner border of the flap. In the angle between the two flaps would be found, in front of the radius, a little of the flexor longus pollicis, and in front of the ulna, the flexor profundus, the latter cut much the longer. Quite close to the radius, and for the most part behind it, would be the lowest part of the supinator, while behind the ulna would be the cut fibres of the proximal end of the abductor longus pollicis (extensor ossis metacarpi pollicis). On the face of the posterior flap would be seen from without inwards the extensor carpi radialis longus and brevis, the extensor communis, the extensor of the little finger, and the extensor carpi ulnaris. The radial artery will run the whole length of the anterior or volar flap, and be cut near its outer or lateral border to the inner or medial side of the brachio-radialis. The ulnar artery will be cut shorter, in front of the bone, and between the flexor sublimis and flexor profundus. The volar interosseous vessels will be divided immediately in front of the interosseous membrane. The dorsal interosseous vessels will be cut long, and will be found between the superficial and deep muscles.

Fig. 68 shows the relation of the parts as they would be cut in a circular amputation of the forearm in its distal third.

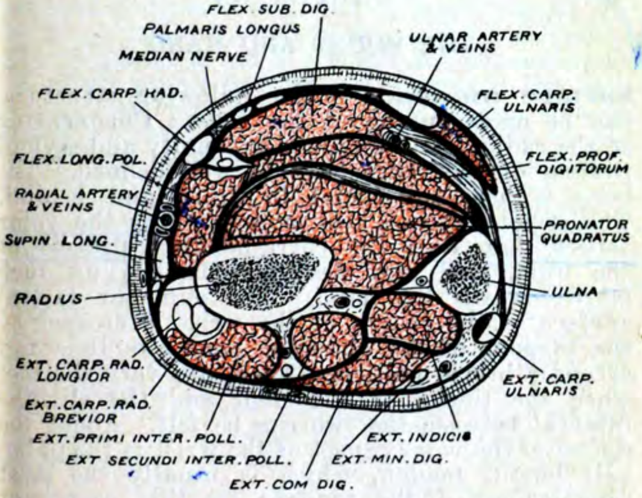

Fig. 68.—Transverse section through the lower third of the forearm. (*After Braune.*)

CHAPTER XV

THE WRIST AND HAND

Surface anatomy. — The following structures can be made out about the **wrist**: Commencing at the radial side, the lower extremity and styloid process of the radius can be well defined. The bone is here superficial in front and behind. The styloid process lies more towards the volar aspect than does the corresponding process of the ulna, and also descends about ½ an inch more towards the hand. The outer or lateral surface of the radius at the wrist is crossed by the tendons of the abductor longus pollicis and extensor brevis pollicis. These are very distinct when the thumb is abducted, and the slit-like interval between the two can be felt. About the centre of the volar aspect of the wrist is the palmaris longus tendon, which is usually the most conspicuous of the tendons on this aspect of the joint. It will be found absent in quite 10 per cent. of wrists examined. It is rendered most prominent when the wrist is a little flexed, the fingers and thumbs extended, and the thenar and hypothenar eminences as much approximated as possible. A little to its outer side is the larger but less prominent tendon of the flexor carpi radialis. In the narrow groove between these two tendons lies the median nerve, and on the radial side of the flexor carpi radialis is the radial artery.* The venæ comites surround the artery, and when

* Sometimes the superficial volar arises higher and is larger than usual. It then runs by the side of the radial in front of the wrist, and, giving additional volume to the pulse, has been the foundation of the so-called "double pulse."

distended alter the character of the pulse (Hill). Towards the ulnar border of the wrist the flexor carpi ulnaris tendon is evident, descending to the pisiform bone. It is rendered most distinct when the wrist is slightly flexed and the little finger pressed forcibly into the palm. In the hollow which this posture produces between the last-named tendon and the palmaris longus lie the flexor sublimis tendons, and just to the radial side of the flexor carpi ulnaris the pulsations of the ulnar artery can be felt. Beneath the thin skin on the volar aspect of the wrist can be seen a part of the plexus of veins which end in the median and volar ulnar trunks. The ulnar nerve grooves the radial side of the pisiform bone.

On the dorsum of the wrist the following tendons can be readily distinguished from without inwards (Fig. 70): the extensor longus pollicis (extensor secundi internodii), the extensor communis, and the extensor carpi ulnaris. Of these, the most prominent is the first-named. It is rendered most distinct when the thumb is forcibly abducted and extended. The tendon leads up to a small but prominent bony elevation on the back of the radius, that marks the outer border of the osseous groove for its reception. This tendon, when it reaches the radius, points to the centre of the dorsal surface of that bone, and also indicates roughly the position of the interval between the scaphoid (navicular) and semilunar (lunate) bones. The lower end of the ulna is very distinct. When the hand is supine, its styloid process is exposed at the medio-dorsal aspect of the wrist to the medial side of the extensor carpi ulnaris. In pronation, however, the process is rendered less distinct, while the head projects prominently on the dorsum of the wrist, and is found to lie between the tendons of the extensor carpi ulnaris and extensor digiti quinti.

Radio-carpal joint (wrist-joint).—The tip of the styloid process of the ulna corresponds to the line of the wrist-joint, and a knife entered below that point would enter the articulation. A knife entered horizontally just distal to the tip of the styloid process of the radius would hit the scaphoid bone. A line drawn between the two styloid processes would slope downwards and outwards; its two extremities would represent the extreme inferior limits of the radio-carpal joint, and would fairly correspond to the chord of the arc formed by the line of that joint. The line between the styloid processes would be nearly ½ an inch beyond the summit of the arch of the wrist-joint.

There are several folds in the skin on the volar aspect of the wrist; of these, the distal is the most distinct. It is a little convex downwards, precisely crosses the neck of the os magnum (capitate bone) in the line of the third metacarpal bone (Tillaux), and is not quite ¾ of an inch distal to the arch of the wrist-joint. It is about ½ an inch proximal to the carpo-metacarpal joint, and indicates very fairly the upper border of the transverse carpal (anterior annular) ligament (Fig. 73).

Palmar surface of the hand.—The palm is concave in the centre, where the skin is adherent to the palmar aponeurosis or fascia. This "hollow of the hand" is of somewhat triangular outline, with the apex upwards. On either side are the thenar and hypothenar eminences. At the proximal end of the former eminence a bony projection is felt, just distal and medial to the radial styloid process, which is formed by the tubercle of the scaphoid and ridge on the trapezium (multiangulum majus) (Fig. 73). The interval separating these two processes of bone cannot always be made out. At the proximal extremity of the hypothenar eminence is the projection of the pisiform bone, and just below it the unciform (hamate) process can be identified. Distal to the hollow of the palm, and opposite the clefts between the four fingers, three little elevations are seen, especially when the proximal phalanges are extended, and the middle and distal are flexed. These correspond to the fatty tissue between the flexor tendons and the digital slips of the palmar aponeurosis. The grooves which separate the elevations correspond to those slips.

As the hand is closed, certain definite **creases or folds** become apparent in the palm. In the palm of the extended hand these creases are represented by lines which have been much exploited by the unscrupulous at the expense of the credulous, but for the surgeon they are mere surface guides to deeper structures. Two of them (*see* Fig. 69) are transverse in direction—the *proximal transverse* and *distal transverse*—both becoming thrown into folds as the fingers are flexed on the palm. The two oblique folds, the *radial oblique* and *ulnar oblique* (often interrupted), are apparent when the thumb is opposed or flexed towards the fingers. The proximal transverse fold as it crosses the middle of the palm marks the convexity of the superficial volar (palmar) arch. The distal transverse fold crosses the necks of the fifth, fourth, and third metacarpals, and marks approximately the beginnings of the mucous or synovial sheaths of the three digits on the ulnar side of the hand. It is at a level corresponding to the distal transverse line that the *palmar aponeurosis* (*fascia*) breaks up into its four slips, and midway between this fold and the webs of the fingers lie the metacarpo-phalangeal joints. Of the three transverse lines on the flexor aspect of the fingers, one, the proximal, is placed $\frac{3}{4}$ of an inch beyond (distal to) the metacarpo-phalangeal joint, being single for the index and little fingers, but double for the middle and ring. The middle and distal lines of the fingers are interphalangeal folds. The intermediate lines are double for all the fingers, and are exactly opposite the proximal interphalangeal joints (Fig. 69). The distal creases are single, and are placed somewhat proximal to the corresponding joints. There are two single creases on the thumb, corresponding to the two

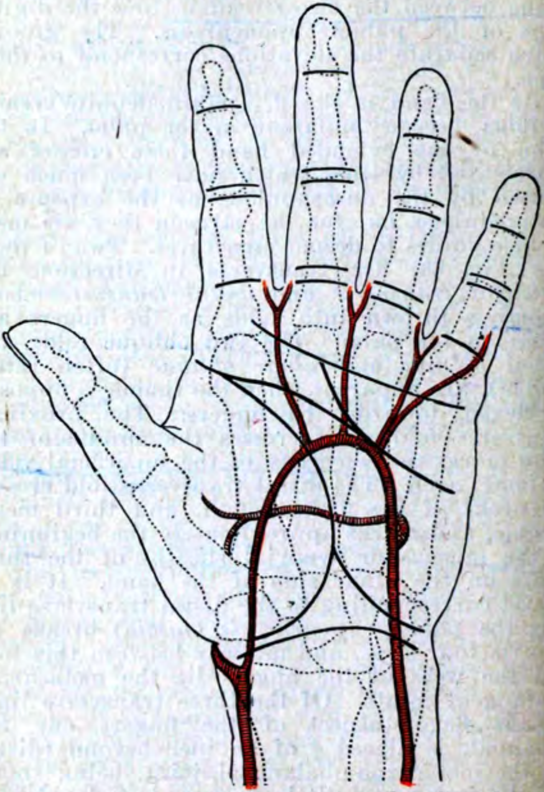

Fig. 69.—Surface markings on the palm of the hand.
The thick black lines represent the palmar lines. The termination of the radial and ulnar arteries in the superficial and deep volar (palmar) arches is shown.

joints, the proximal crossing the metacarpo-phalangeal articulation obliquely. The superficial volar arch may be represented by a curved line across the palm, starting from the pisiform bone and running in a line with the palmar border of the thumb when outstretched at right angles with the index finger. The deep arch is $\frac{1}{4}$–$\frac{1}{2}$ an inch nearer the wrist, and its position may be accurately marked by a line drawn from the base of the fifth metacarpal to the base of the second, two easily distinguished points. The volar digital arteries bifurcate about $\frac{1}{2}$ an inch proximal to the clefts between the fingers (Fig. 69).

Dorsal surface of the hand.—On the radial side of the wrist, when the thumb is extended, a hollow is obvious between the abductor longus pollicis and extensor brevis pollicis and the extensor longus pollicis. French writers have termed this hollow "tabatière anatomique" (Fig. 70). Across this hollow and beneath the tendons just named runs the radial artery. Under the skin over the space can usually be seen a large vein, the cephalic vein of the thumb. Across the space also runs the lateral division of the terminal branch of the cutaneous radial nerve. In the floor of the "snuff-box" are the scaphoid bone and the trapezium. The extensor longus pollicis crosses the apex of the first interosseous space. The sesamoid bones of the thumb and the joint between the trapezium and the first metacarpal bone can all be well made out. The latter articulation is situated in the floor of the "tabatière." On the back of the hand the various tendons and the surface veins, too, can all be clearly distinguished. Between the first and second metacarpal bones is the first dorsal interosseous muscle, which forms a conspicuous prominence when the thumb is pressed against the side of the index finger. The three rows of knuckles are formed by the proximal bones of the several joints.

The **skin** of the palm and of the front of the fingers is thick and dense, while that on the back of the hand is much finer. The palm, the fronts and sides of the fingers, and the dorsal aspects of the last phalanges, all show an entire absence of hair and of sebaceous glands. These parts are, therefore, exempt from the maladies that attack hair-follicles and their gland appendages. On the dorsum of the hand, and of the proximal and middle rows of phalanges, there are numerous hairs and sebaceous follicles.

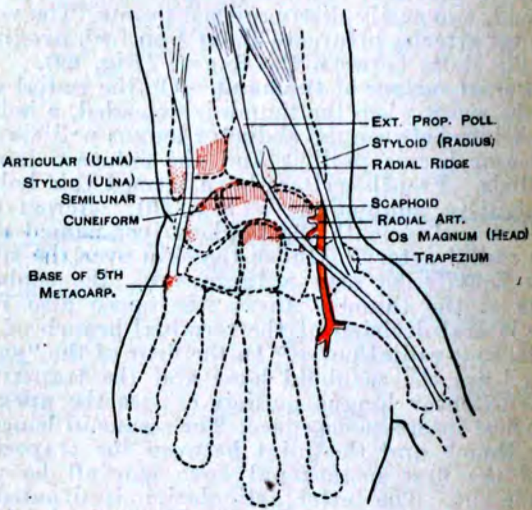

Fig. 70.—Chief surface markings on the dorsal aspect of the wrist.

Ext. prop. poll. = extensor longus pollicis; scaphoid = navicular os magnum = os capitatum; semilunar = os lunatum; cuneiform = os triquetrum.

Sweat-glands are more numerous in the skin of the palm than in any other part. According to Sappey they are four times more numerous here than they are elsewhere. Krause has estimated that nearly 2,800 of these glands open upon a square inch of the palm. Only about half the number are found upon the dorsum of the hand

The profuseness with which the palm may perspire is well known, and is very marked in certain conditions. The cutaneous nerve-supply of the hand is very free. The nerves present Pacinian bodies, which are far more numerous in the hand than in any other part. With the exception of the tip of the tongue, a more acute degree of tactile sensibility is met with in the hand than elsewhere in the body. The most sensitive district is the palmar surface of the distal or ungual phalanx of the index finger, while the least sensitive to tactile impressions is the dorsum of the hand. It may be said that the tips of the fingers are about thirty times more acute to the sense of touch than is the skin of the middle of the forearm, which is among the least sensitive portions of the integument as regards tactile influences.

The **subcutaneous tissue** of the front of the hand, and especially of the palm, is scanty and dense, and somewhat resembles the subcutaneous tissue of the scalp in that the skin is closely adherent to it, and the fat it contains is arranged in minute lobules lodged in lacunæ. Cutaneous ligaments bind the skin down at the creases of the palm and fingers. The subcutaneous tissue on the dorsum, however, is lax, and has but a frail association with the skin. Thus it follows that subcutaneous extravasations of blood are practically impossible in the palm and on the anterior aspect of the fingers, while they may be very extensive on the dorsum. In like manner œdema of the extremity is conspicuously marked upon the dorsal surface, while the palm remains comparatively free even in severe cases. The denseness of the integuments of the palm renders inflammation of the part extremely painful, owing to the tension that is so readily produced, whereas inflammation in the lax tissues of the dorsum may reach some magnitude without causing great pain. The palm of the hand is well adapted to meet the effects of pressure and friction. The cuticle is thick, the skin is adherent, and immediately beneath it lies the dense palmar aponeurosis, which efficiently protects the palmar nerves and the main vessels; while it must be noted that the front of the hand, and especially the palm, is singularly free from surface veins. Indeed, the great bulk of the blood from the hand is returned by the superficial veins on the dorsa of the fingers and hand. In like manner, the lymphatics of the palm, which form a rich subcutaneous plexus, join the large efferent lymphatics on the dorsum of the hand.

The form of the **nail** varies somewhat in different individuals, and, according to certain authors, there are special types of nail to be met with in some constitutional diseases. By the Hippocratic hand is meant a hand the tips of the fingers of which are clubbed while the nails are much curved. This condition would appear to be due to impeded circulation by retardation in the return of venous blood, and perhaps also to imperfect oxygenation of that blood. It is most often met with in congenital heart disease, in phthisis, empyema, chronic lung affections, and certain thoracic aneurysms. There are several forms of inflammation affecting the matrix of the nail and the soft parts immediately around it (onychia, paronychia). Such inflammations lead to great deformity of the structure itself. When a nail is thrown off by suppuration or violence a new nail is produced, provided any of the deeper epithelial cells are left. During convalescence from certain illnesses (e.g. scarlet fever), a transverse groove will appear across all the nails. This groove indicates the portion of nail formed during the illness, and by watching its movement the rate of growth of the nail can be estimated. The nail grows at the average rate of $\frac{1}{32}$nd of an inch per week; if the hand is immobilized by splints the rate of growth is retarded. (Head). It may be noted that each digital nerve gives a special branch of large size to the pulp beneath the nail, and this abundant nerve supply, combined with the inexpansibility of the part, explains the intense pain felt when a foreign body is thrust under the nail.

Beneath the skin of the palm is the dense **palmar fascia** or **aponeurosis.** This fascia gives almost as much strength to the hand as would so much bone, while its unyielding character, its comparative freedom from vessels and nerves, render it well suited to withstand the effects of pressure. The fascia gives slips to each finger; each slip sends fibres to join the digital sheaths of the tendons, the skin, and the superficial transverse ligament. In the disease known as **Dupuytren's contraction** the palmar fascia, and especially its digital slips, become contracted. One or more or all of the fingers may be involved in the contraction. The proximal phalanx is drawn or flexed towards the palm, and later the second phalanx becomes bent, even causing dislocation of the proximal interphalangeal joint (Hutchinson). The skin is drawn in towards the fascia, since the two structures are normally connected with one another. Experiment shows that by dragging upon the fascia the proximal phalanx can be readily bent, and also, but with less ease, the middle phalanx. The middle part of the palmar fascia represents the tendon of the palmaris longus in the hand.

The structures of the palm are divided into three spaces by the fascia (Fig. 71). Thus the muscles of the thenar and hypothenar eminences are both enclosed in a thin fascia proper to each. The two spaces formed by these membranes are enclosed in all directions, and are capable, though only in a feeble way, of limiting suppuration when it commences in them. Between these two spaces is a third space, which is roofed in by the palmar fascia. This cavity is closed in at the sides, but is open above and below. Above there is a free opening beneath the annular ligament and along the flexor tendons into the forearm, while below there are the seven passages provided for by the division of the palmar fascia. Of these seven passages, four, situate at the roots of the several fingers, give passage to the flexor tendons, while the remaining three correspond to the webs between the fingers, and give passage to the lumbricales and the digital vessels and nerves. When pus, therefore, forms on the palm, beneath the palmar fascia, it cannot come forward through

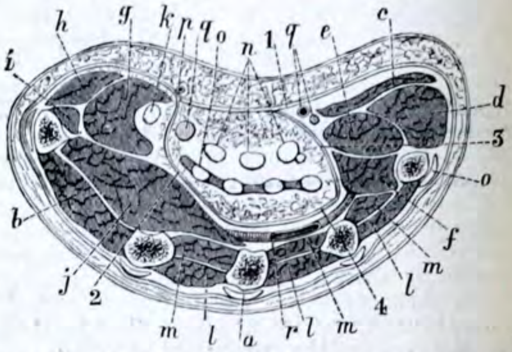

Fig. 71.—Horizontal section of the hand through the middle of the thenar and hypothenar eminences. (*Tillaux.*)

a, Metacarpal bone; *b*, first dorsal interosseous; *c*, palmaris brevis; *d*, abductor quinti digiti; *e*, flexor brevis min. dig.; *f*, opponens min. dig.; *g*, flexor brevis poll.; *h*, abductor brevis poll.; *i*, opponens poll.; *j*, adductor poll.; *k*, flexor long. poll.; *l*, dorsal interossei; *m*, palmar interossei; *n*, flexor sublimis; *o*, flexor profundus; *p*, superfic. volæ; *q*, median nerve, and (on inner side) ulnar artery and nerve; *r*, deep volar arch; 1, palmar fascia; 2, outer septum; 3, inner septum; 4, deep fascia of palm.

that dense membrane, but escapes rather along the fingers or makes its way up into the forearm. So rigid is the resistance offered by the palmar fascia, that pent-up pus will make its way through the interosseous spaces and appear on the dorsum of the hand, rather than come through the coverings of the palm.

In opening a **palmar abscess**, when it points above the wrist, the incision should be in the long axis of the forearm, should be above the transverse carpal (anterior annular) ligament, and is most conveniently made a little to the ulnar side of the palmaris longus, for a cut in this position would escape both the ulnar and radial arteries and also the median nerve.

The **tendons** about the wrist are bound down and held in place by the transverse carpal and dorsal carpal (annular) ligaments. So dense is the transverse carpal ligament, that even in extensive abscess of the palm reaching into the forearm, and in severe distension of the synovial sheaths beneath the ligament, it remains firm and will not yield. The lower border of the dorsal carpal ligament corresponds to the upper edge of the transverse carpal, and these structures together act the part of the leather bracelet which the labourer sometimes wears around his wrist, and which, in fact, takes the function of an additional ligament.

The **fibrous sheaths** for the flexor tendons extend from the metacarpo-phalangeal joints to the proximal ends of the distal phalanges. The pulp of the distal or ungual phalanx, therefore, rests practically upon the periosteum. Opposite the finger-joints the sheaths are lax and thin, and spaces may occur between the decussating fibres of the sheaths, through which the synovial membrane lining the sheath may protrude. It is, I believe, through this less protected part of the sheath that external suppuration often finds its way into the interior of the sheath. The sheaths in the rest of their course are dense and rigid, and when cut across remain wide open (Fig. 72). Thus, after the division of the sheath, as in amputation, an open channel is left leading into the palm of the hand, and offering the greatest facility for the spread of pus into that part. It is this rigidly open fibrous sheath that probably may explain the frequency of suppuration in the palm after amputation of a part of a finger.

The tendons accurately fill the fibrous sheaths.

A gangliform growth on the tendon as it enters the sheath, or a constriction of the sheath with an inequality in the tendon, gives rise to the condition known as "snap" finger. Such a digit cannot be extended by will, but when pushed a little way "springs back with a snap like the blade of a pocket knife" (Abbe). "Congenital contraction" of the little finger is very common

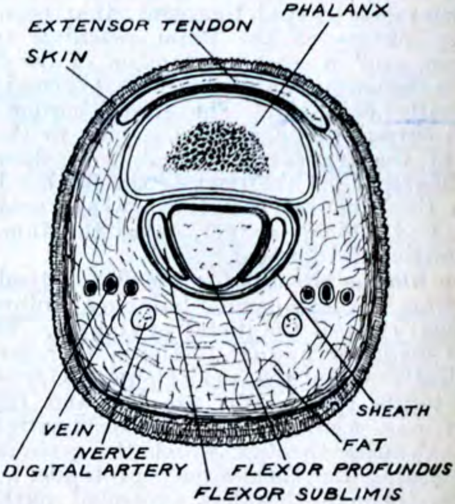

Fig. 72.—Horizontal section through the middle of the first phalanx. (*After Tillaux.*)

in a slight degree. In pronounced cases the proximal phalanx is hyperextended and the middle flexed. Lockwood found in such a case that the condition was due to a contraction in the fibrous sheath in front of the joint. Contracted finger following whitlow is due to an adhesion of the tendons to their sheath. Paralytic contraction of the flexor muscles also brings about permanent contracture of the fingers.

Synovial sacs and sheaths.—There are two synovial sacs beneath the transverse carpal ligament for the flexor tendons, one for the flexor longus pollicis, the other for the flexor sublimis and profundus tendons (Fig. 73). The former extends up into the forearm for about 1¼ inches above the ligament, and follows its tendon to its insertion in the last phalanx of the thumb. The latter rises

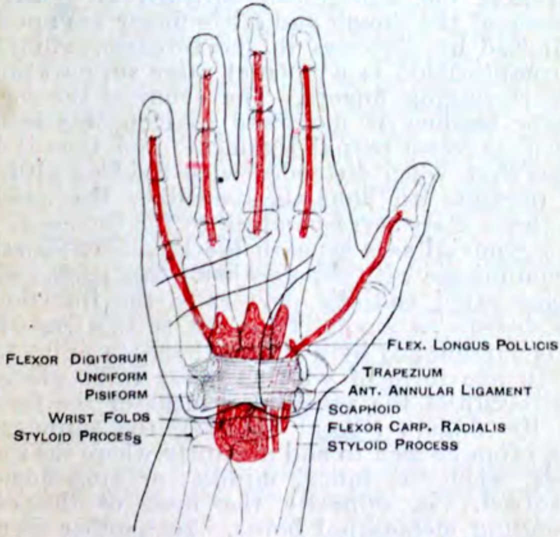

Fig. 73.—Anterior annular ligament of the wrist, and synovial sheaths of the wrist and hand.

The creases of the hand are indicated by black lines; the synovial sheaths are shown in red. Ant. annular ligament = transverse carpal; unciform = os hamatum.

about 1½ inches above the transverse ligament, and ends in diverticula for the four fingers. The process for the little finger usually extends to the insertion of the flexor profundus tendon in the ungual phalanx. The remaining three diverticula end about the middle of the corresponding metacarpal bones. The synovial sheaths for the digital part of the tendons to the index, middle, and ring fingers end above about the neck of the metacarpal bones, and are thus separated by about $\frac{1}{4}$–$\frac{1}{2}$ an inch from the great synovial (mucous) sac beneath the transverse carpal ligament. Thus there is an open channel from the ends of the thumb and little finger to a point in the forearm some $1\frac{1}{2}$ inches above the wrist. The arrangement explains the well-known surgical fact that abscesses of the thumb and little finger are apt to be followed by abscesses in the forearm, while such a complication is not usual after suppuration in the remaining fingers. The synovial sac for the flexor tendons is narrowed as it passes beneath the transverse carpal ligament, and thus it happens that, when distended with fluid or with pus, it presents an hour-glass outline, the waist of the hour-glass corresponding to the ligament. The two synovial sacs beneath the ligament sometimes communicate with one another. The tendon of the flexor carpi radialis perforates the insertion of the transverse carpal ligament to the trapezium; it is surrounded by a synovial sheath (Fig. 73).

In one form of **whitlow**, that form where the pus occupies the synovial sheaths of the tendons on the fingers (thecal abscess), the suppuration can often be seen to end abruptly where the sheath ends, when the index, middle, or ring finger is involved, viz. opposite the neck of the corresponding metacarpal bones. In another form of whitlow (the abscess in the pulp at the end of the finger) the periosteum of the third phalanx is readily attacked, there being no intervening tendon sheath over that bone. In this affection the bone often necroses and comes away, but it is significant to note that it is very seldom that the whole of the phalanx perishes. The upper part, or base, of the bone usually remains sound, and is probably preserved by the insertion of the flexor profundus tendon. The base of the bone is an epiphysis that does not unite to the shaft until the eighteenth or twentieth year.

The tendons do not lie free within the sac, but are bound to it by folds of synovial (mucous) membrane in much the same way as the bowel is bound to the abdominal parietes by its mesentery. These folds may be ruptured in severe sprains, when the nutrient vessels for the tendon, which are contained in them, may be torn. Rupture is followed by effusion into the sac. These folds are almost absent within the digital sheaths, the slight ligamenta longa and brevia, near the phalangeal insertions of the tendons, being their sole representatives. Synovial sacs are lined by a squamous epithelium, and have extremely free communication with the lymphatic vessels of the part. Hence the free absorption of infective matter from such cavities. Hence, too, the ease with which inflammatory processes can spread along the sheaths, leading to the formation of adhesions between them and the contained tendons. When such adhesions are formed and organized, the tendons become fixed and the fingers grow stiff and worse than useless. The importance of early movements, after the inflammation has subsided, will be apparent, for only by active and passive movements of the wrist and fingers can the tendons be prevented from becoming closely adherent to their sheaths.

Beneath the dorsal carpal ligament there are six synovial sheaths for tendons, corresponding to the six canals formed by that ligament. The sheath most frequently inflamed is that for the abductor longus pollicis and extensor brevis pollicis. It runs from a point about $\frac{3}{4}$ of an inch above the radial styloid process to the first carpo-metacarpal joint. The other sheaths reach *above* to the upper border of the dorsal carpal ligament, that for the two radial extensors, however, beginning about $\frac{1}{2}$ an inch above the ligament. The sheaths for the extensor communis and the extensor minimi digiti extend distally to the middle of the metacarpus; that for the extensor indicis barely reaches the metacarpus. The other sheaths follow the tendons to their insertions. The synovial lining and folds of these sheaths are injured in Colles's fracture of the radius. The tendons become adherent and fixed to their sheaths unless this be prevented by passive movements of the tendons.

Blood-vessels and lymphatics.—The hand is very well supplied with blood, and indeed the finger pulp is one of the most vascular parts in the body. Cases are recorded where the tip of the finger has been accidentally cut off, and has grown again to the limb on being immediately reapplied. The position of the palmar arches has been pointed out. It is well known that hæmorrhage from either of the palmar arches cannot be checked by ligature of the radial or ulnar artery alone, on account of the connexion of the arches with those vessels; and it is also known that simultaneous ligation of the two vessels may have no better effect, owing to the anastomoses between the palmar arches and the interosseous vessels. The anastomosis between the two palmar arches is freely established both by the main vessels themselves and by the communion that exists between the digital arteries from the superficial arch and the palmar interosseous branches from the deeper vessels. In bleeding from the palm, the simultaneous ligature of the radial and ulnar arteries may also entirely fail in those cases where the arches are freely joined, or are more or less replaced by large and abnormal interosseous vessels, or by a large "median artery." When either the radial or the ulnar part of the arches is defective, the lack is usually supplied by the other vessel; and it is well to note that the deficiency is most common in the superficial or ulnar arch. Pressure applied to the palm to arrest bleeding is apt to cause gangrene, owing to the rigidity of the parts and the ease with which considerable pressure can be applied.

The radial artery, as it curves round the back of the hand to reach the deeper part of the palm, is in close contact with the carpo-metacarpal joint of the thumb (Fig. 70). This fact must be borne in mind in amputation of the entire thumb, and also in resection of the first metacarpal bone. The superficial volar, if large, may bleed seriously. It adheres to the surface of the transverse carpal ligament, and may therefore be difficult to pick up when wounded.

From the larger size and great number of the lymphatics about the fingers and on the dorsum of the hand, it follows that lymphangitis is more common after wounds of those parts than after wounds of the palm.

Bones and joints.—The distal radio-ulnar joint is supported by the powerful triangular fibro-cartilage (articular disc), which forms the strongest and most important of all the ligamentous connexions between the two bones. The synovial sheath of the extensor quinti digiti sometimes communicates with this joint, and may therefore be involved when that articulation is diseased.

The strength of the wrist-joint depends not so much upon its mechanical outline or its ligaments as upon the numerous strong tendons that surround it, and that are so closely bound down to the bones about the articulation. Moreover, in the case of the wrist the long lever does not exist on the distal side of the joint. The volar radio-carpal is the strongest ligament of the joint, while the dorsal is the weakest. The former structure limits extension, and the latter flexion; and in connexion with this arrangement it is interesting to note that injury from forced extension is more common than from forced flexion. Thus, when a man falls upon the hand, he more usually falls upon the palm (forced extension) than upon the dorsum (forced flexion). Owing to the thinness of the dorsal ligament, together with the more superficial position of the hinder part of the joint, it follows that the effusion in wrist-joint disease is first noticed at the back of the hand.

Movements at the wrist take place as freely in the intercarpal joint (between the first and second row of carpal bones) as in the radio-carpal joint (Fig. 70). The axis of the *radio-carpal* joint is such that in flexion the palm turns towards the ulnar side of the forearm; while in flexion at the *mid-carpal* joint the palm moves towards the radial side. When movement takes place at both joints these tendencies are balanced and pure flexion is produced. The tendon of the extensor carpi ulnaris is placed anteriorly to the axis of the mid-carpal joint, but behind the radio-carpal, and therefore produces flexion in one joint and extension in the other (Ashdowne). The muscles which act on the wrist exemplify the various parts that muscles play in producing a purposeful movement. A muscle may act as (1) a *prime mover*, (2) an *antagonist*, (3) a *synergic muscle*, (4) a *fixation muscle*. For instance, when the fingers are flexed: the deep and superficial flexors are the prime movers; the antagonists in action are the extensors of the fingers; the flexors of the fingers would also produce flexion at the wrist were not the extensors of the wrist thrown into action as synergic muscles; when the extensors of the fingers act, the flexors of the wrist contract; in flexing and extending the fingers the wrist can be rendered immovable by the flexors and extensors of the carpus, which then act as *muscles of fixation*. Thus a movement which appears simple results from the action of groups of muscles, and it is this complexity which makes the diagnosis of nerve lesions from a study of the action of muscles so difficult. What has been said of the muscles of the wrist applies equally to all the muscles of the body. (*See* Beevor's Croonian Lectures, 1903.)

It is a well-known fact that the wrist-joint has to be in an extended position before the flexors of the fingers can act with power; if the wrist is flexed they lose the power to grasp.

This must be remembered in all cases where the wrist-joint is likely to become stiff or ankylosed; it must be set in an extended (dorsiflexed) position.

But little movement is allowed in the *carpo-metacarpal* joints of the index, middle, and ring fingers, but in the like joints of the thumb and little finger movements are free, and their preservation is of great importance to the general usefulness of the hand. The glenoid (volar meta-carpo-phalangeal) ligaments in front of the three finger-joints are firmly attached to the distal bone, and but loosely to the proximal. Thus it happens that in dislocation of the distal bone backwards, the glenoid ligament is carried with it, and offers a great obstacle to reduction. In flexing the middle and distal phalanges alone, it will be seen that the proximal phalanx is steadied by the extensor tendon as a preliminary measure; and in paralysis of the extensors, flexion of these two joints alone is not possible.

Very few persons have the power of flexing the distal finger-joint without at the same time bending the adjoining middle phalangeal; but in certain inflammatory affections about the last phalanges the terminal joint is sometimes seen to be fixed in a flexed posture while the other finger-joints are straight. In "mallet" finger the distal phalanx is fixed in a flexed position. The condition is due to a partial or complete rupture of the extensor tendon of the finger, commonly the result of a blow over the terminal knuckles.

Colles's fracture.—This name is given to a transverse fracture through the lower end of the radius, from ½ to 1 inch above the wrist-joint (Fig. 74). It is associated with a certain definite deformity, and is always the result of indirect violence, a fall upon the outstretched hand. There are good reasons why the bone should break in this situation. The lower end of the radius is very cancellous, while the shaft contains a good deal of compact bone. At about ¾ of an inch from the articular surface these two parts of the bone meet, and their very unequal density greatly tends to localize the fracture in this situation. As to the mechanism of this lesion, many different opinions are still held, and a vast deal has been written on the subject. Prof. Chiene's account of this lesion is subjoined, as representing with admirable clearness the views most generally accepted

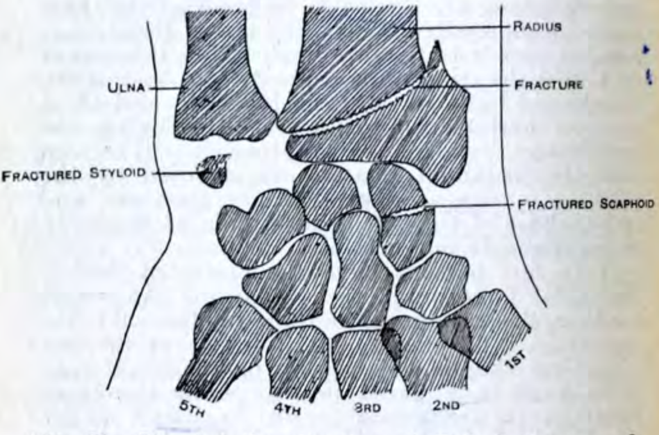

Fig. 74.—Showing the situation of Colles's fracture of the radius, with fracture of the styloid of the ulna. The usual position of a fracture of the scaphoid is also indicated.

as to the nature of the injury. The deformity in Colles's fracture is entirely due to the displacement of the lower fragment.

"The displacement is a triple one: (*a*) backwards, as regards the antero-posterior diameter of the forearm; (*b*) rotation backwards of the carpal surface on the transverse diameter of the forearm; (*c*) rotation through the arc of a circle, the centre of which is situated at the ulnar attachment of the triangular ligament, the radius of the circle being a line from the ulnar attachment of the triangular ligament to the tip of the styloid process of the radius."

In over 50 per cent. of cases the styloid process of the ulna is also broken by the force transmitted to it through the triangular fibro-cartilage (Morton). By means of this rotatory displacement, the tips of the two styloid processes come to occupy the same level, or the radial process may even mount above the ulnar. In nearly every case there is some penetration of the fragments, the compact tissue on the dorsal aspect of the upper fragment being driven (by a continuation of the force that broke the bone) into the cancellous tissue on the palmar aspect of the lower fragment. It is only in very rare instances that the fragments are so separated as to ride the one over the other. In such cases the radio-ulnar ligaments are probably ruptured, and the wrist ceases to present the typical deformity of a Colles fracture. In studying the radiographs of 170 cases diagnosed as Colles's fracture, Dr. R. Morton found there was dislocation as well as fracture in 3 and separation of the lower radial epiphysis in 11 cases. This epiphysis is often separated by accidental violence. It joins the shaft about the twentieth year. Its junction with the shaft is represented by a nearly horizontal line, and the epiphysis includes the facet for the ulna and the insertion of the brachio-radialis.

Since the introduction of radiographic methods of examination, it has been found that many injuries, formerly regarded as mere sprains, are really due to fracture or displacement of carpal bones or fracture of a metacarpal.

Fracture of the scaphoid (navicular) occurs as the result of falls on the outstretched palm, or by direct violence. It lies in the floor of the "snuff-box," and may be palpated there. The semilunar (os lunatum) is most frequently displaced, and of the metacarpal bones the fifth is most frequently fractured.

Dislocations. 1. **At the wrist-joint.**—So strong is this articulation, for the reasons above given, that carpo-radial luxations are extremely rare. For the same reasons, when they do occur they are usually complicated, and are associated with tearing of the skin, rupture of tendons, injury to the synovial sheath, or fractures of the adjacent bones. The luxations of the carpus may be either backwards or forwards, the latter being extremely rare.

There are five articular synovial cavities connected with the carpus. They occur in the following situations: (*a*) Between the carpus and forearm bones: it may communicate with the lower radio-ulnar cavity through the triangular fibro-cartilage (articular disc); (*b*) between the unciform and the fourth and fifth metacarpals; (*c*) between the metacarpal of the thumb and trapezium; (*d*) between all the carpal bones and extending to the carpo-metacarpal joints of the second and third digits; (*e*) between the pisiform and cuneiform bones. Hernial protrusions and gangliform growths from these synovial membranes are frequently seen on the dorsum of the carpus.

2. **Dislocation of the os magnum (os capitatum).**—In forcible flexion of the hand, the os magnum naturally glides backwards and projects upon the dorsum. In very extreme flexion (as in falls upon the knuckles and dorsum of the metacarpus), this movement of the bone backwards may be such as to lead to its partial dislocation, the luxation being associated with some rupture of ligaments. In one recorded case this luxation was produced by muscular force. The patient, while in labour, "seized violently the edge of her mattress, and squeezed it forcibly." Something was felt to give way in the hand, and the head of the os magnum was found to be dislocated backwards.

3. **Dislocations at the metacarpo-phalangeal joint of the thumb.**—In this luxation the proximal phalanx is usually displaced backwards, and

the lesion is of interest on account of the great difficulty often experienced in reducing the bone. Mr. Jonathan Hutchinson has investigated several cases and found that reduction is prevented by the fibro-cartilaginous plate on the palmar aspect of the joint. The plate is firmly attached to the phalanx and is dislocated with it. When subcutaneously divided from the extensor aspect of the thumb, the dislocation may be reduced with ease. Another factor is that the head of the metacarpal becomes button-holed between the two heads of the flexor brevis pollicis and held there, because the injury caused by the dislocation sets up in these muscles a strong reflex contraction. Such contraction disappears with the establishment of a general or local anæsthesia.

Avulsion of one or more fingers may be effected by severe violence. In such cases the finger torn off usually takes with it some or all of its tendons. These tendons are practically drawn out of the forearm, and may be of considerable length. Billroth figures a case where the middle finger was torn out, taking with it the two flexor and extensor tendons in their entire length. When one tendon only is torn away with the finger, it is usually that of the flexor profundus.

Amputation at the wrist-joint by the circular method.—In the *dorsal wound* will be cut the following tendons: the extensores longus, indicis, communis, quinti digiti, and ulnaris, the cutaneous branches of the radial nerve, and the dorsal branch of the ulnar nerve. The two radial extensors will be cut short in the radial angle of the wound, as will also be the abductor and extensor longus pollicis. The radial artery will be divided close to the radius. In the *palmar wound* will be found the ulnar artery, the superficialis volæ, the ulnar and median nerves, the opponens, flexor brevis, and abductor pollicis in part, the flexor brevis, opponens, and abductor minimi digiti in part (the bulk of the opponens being left behind on the hand), and the tendons of the flexor sublimis and flexor carpi radialis. The tendons of the flexor profundus and flexor longus pollicis are usually cut short close to the bones.

Amputation of the thumb at the carpometacarpal joint by flaps.—In the *palmar* flap will be cut the abductor, the short and long flexor, the opponens, and the adductor pollicis. The extensores ossis and brevis will be cut short in the posterior angle of the flap. The extensor longus and a considerable portion of the abductor indicis will be found in the *dorsal* flap. The vessels divided will be the two dorsal arteries of the thumb and the princeps pollicis. There is great danger, in this operation, of wounding the radialis indicis, and the radial artery itself where it begins to dip into the palm.

Epiphyses of the upper limb.—The epiphyses about the elbow join the shafts of their respective bones at 17 years (except the tip of the internal condyle, which joins at 18). The epiphyses at the shoulder and wrist extremities of the bones join at 20. The nutrient canals of the three bones run towards the elbow. The nutrient artery of the humerus comes from the brachial or inferior profunda, those of the radius and ulna from the anterior interosseous.

CHAPTER XVI

THE NERVE SUPPLY OF THE UPPER EXTREMITY

At various points in the preceding chapters we have touched on the surgical relations of individual nerve-trunks of the arm. It will now be of great advantage to survey the nerve supply to the upper extremity as a whole, in order to establish the general anatomical principles which guide the surgeon to a rational diagnosis and treatment of nerve lesions. Primarily the human body is arranged segmentally, one anatomical segment following another along the axis of the skull and spine; and each segment has its own primary nerve supply. Seeing that the limbs are outgrowths from the trunk, we are prepared to find that each limb-bearing segment will contribute to the nerve supply of the limb. That is so. The upper extremity arises in the embryo from the fifth, sixth, seventh, and eighth cervical and first dorsal segments; hence it is the spinal nerves of these segments which contribute to the formation of the **brachial plexus** (Fig. 75). To recognize the orderly distribution of those segmental nerves we must place the limb in primitive or embryonic position, with the extensor or dorsal aspect uppermost, the radius and thumb on the anterior or *preaxial* border of the limb, and the ulna and little finger on the *postaxial* border. When a limb is placed in this position (*see* Fig. 77, B), the fifth, sixth, seventh, and eighth cervical and first dorsal nerves will be seen to be distributed in an orderly manner from the preaxial and postaxial border of the limb. The central nerve of the plexus (the seventh) supplies the central digits of the hand; the sixth supplies

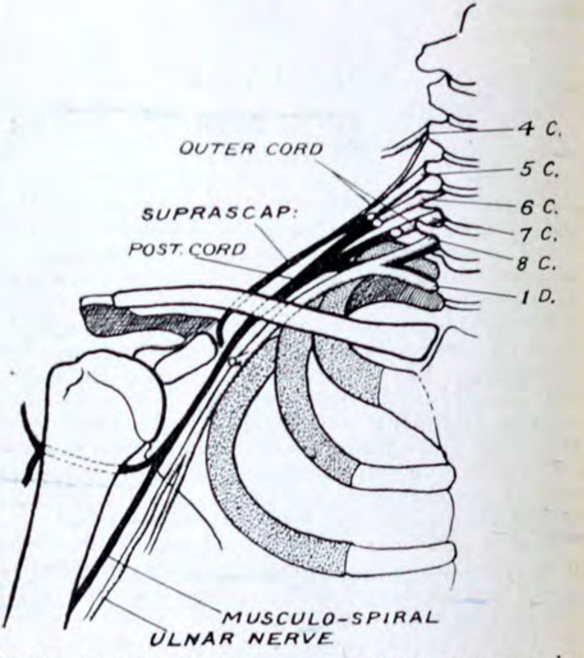

Fig. 75.—Showing the dorsal preaxial origin of the musculo-spiral (radial) nerve, and the ventral post-axial origin of the ulnar nerve from the brachial plexus.

the preaxial and the eighth the postaxial borders of the hand. The fifth cervical and first dorsal supply respectively the preaxial and postaxial borders of the upper arm and forearm. These are the chief segmental nerves, but, as will be seen from Fig. 75, the fourth cervical and second dorsal spinal nerves also contribute strands of varying size. In a brachial plexus of the *prefixed type* the fourth cervical makes a relatively large contribution, the second dorsal takes no share; in the *postfixed* type the opposite is the case. There is a degree of individual variation in the spinal distribution of half a nerve segment or more. Further, it must be remembered that the segmental distribution is not confined to the skin, but affects all the deep structures of the limbs, particularly the muscles.

In Fig. 75 are represented the origins of the ulnar and musculo-spiral (radial) nerves in order to emphasize another primary differentiation of nerves. As they issue from the intervertebral foramina, the spinal nerves which go to the limb become divided into ventral and dorsal divisions, the ventral for distribution in the flexor aspect of the limb, the dorsal in the extensor aspect. It will be seen that the ulnar nerve arises from the ventral division of the eighth cervical and first dorsal, while the musculo-spiral arises from the dorsal division of all five; but the contribution from the first dorsal is usually a very slight one. It will be seen also that the extensor nerves tend to be preaxial in origin, the flexor nerves postaxial.

Further, it is important to remember that *a muscle is never dependent on a single spinal nerve;* a muscular branch always contains fibres from two or more spinal nerves. Hence, section of a single spinal nerve will produce only a partial, never a complete, paralysis of any single muscle. The cell centres in the spinal cord with which the nerve fibres of the brachial plexus are connected are arranged in functional groups. Most muscles are complex in action, are concerned in different acts or movements, and must therefore receive fibres from several cell centres, and hence these fibres will issue from the cord by several spinal nerves. To produce complete paralysis in a muscle, all the spinal nerves contributing to its nerve supply must be divided. A muscle may be paralysed as regards one function and still remain active to another (Colin Mackenzie). It must also be kept in mind that a muscle is not only supplied with motor or efferent fibres, but has a most abundant supply of sensory or afferent fibres. By these latter fibres we recognize **deep pressure** and **degree of contraction or pain.** Afferent fibres, which arise in tendons, ligaments, joints, and bone, are also contained in the muscular branches of nerves. The nerves arising in all of these structures subserve the function of **deep sensibility.** Under certain disordered conditions the afferent stimuli conveyed by these nerves give rise to the **sensation of pain.**

The nerves of **superficial or cutaneous sensibility** commence in the skin. The fibres of the cutaneous nerves fall into two groups: (1) fibres which serve the function of what Head and Sherren term *protopathic sensibility*—fibres which convey painful stimuli: stimuli resulting from injury, such as pin-prick, etc., or stimuli caused by bodies which are much above or below the normal temperature of the skin; (2) fibres which serve the function to which the same observers have given the name of *epicritic sensibility*.* These latter are of at least three kinds: (*a*) those which convey stimuli resulting from touch by a light substance, such as cotton-wool; (*b*) those which convey stimuli from objects heated moderately above body-temperature; (*c*) those which convey stimuli from objects of a temperature moderately below that of the skin. When a cutaneous nerve to the hand or to a distal part of the arm is cut, it is found that the area losing its sensitiveness to pin-prick is much less than the anatomical distribution of the nerve, while the loss to light touch approximately corresponds to the area of anatomical distribution

* See *post*, p. 345.

(*see* Fig. 78, p. 345). In other words, in the distal parts of the limb there is a great degree of overlapping in the distribution of adjoining protopathic systems, whilst in the proximal and basal parts of a limb the case is the reverse, the epicritic system having the greater overlap. It is well known that if a nerve is in process of repair after suture, protopathic sensibility returns before epicritic in the area of normal distribution. Further, it has been observed that in the case of a nerve which is being compressed against a cervical rib, or within a healing scar, the area of protopathic distribution is more reduced or contracted than that of epicritic sensibility (Stopford).

In compression and other lesions of limb nerves, **disturbance of the vaso-motor system** is often observed. The vaso-motor supply to the arteries of the limbs has been re-investigated by Prof. Wingate Todd and his pupils. There is a special branch from the sympathetic cord of the neck, given off to the subclavian artery before that vessel reaches the first rib. The median and ulnar in their course down the arm send off numerous branches to the brachial and other arteries. These vaso-motor fibres run in the trunks, cords, and nerves of the brachial plexus, and are particularly liable to injury when subjected to pressure. Further, it must be remembered that the *sheaths of nerves* are strong and protect the contained nerve fibres from all ordinary degrees of violence. The *sweat-glands*, so numerous on the fingers and palm of the hand, have also a special *nerve supply* from the sympathetic system. Those for the sweat-glands of the palm are conveyed in the median nerve, for it is only on section or paralysis of this nerve that the glands of the hand are disturbed. Under those conditions they produce a profuse paralytic secretion.

The **symptoms which follow a lesion to the nerves of the upper limb** depend on the point injured. If the fifth spinal nerve be crushed between its origin in the spinal cord and its exit from the intervertebral foramen, either from fracture or caries of the cervical vertebræ, the injury is followed by paralysis, partial or complete, of the rhomboids, spinati, deltoid, biceps, brachialis, and brachio-radialis, but strangely enough the lesion is not accompanied by loss of sensation. Perhaps the fact that the posterior root of the fifth cervical nerve is very small may assist to explain this fact (W. Harris). Injury to the spinal cord just above the origin of the eighth cervical vertebra will leave the skin of the ulnar half of the arm anæsthetic, while the muscles of the fingers, hand, and wrist, and some of those at the elbow and shoulder, will be paralysed. The fibres for the innervation of the various groups of arm muscles pass out, as we have just seen, in quite an orderly manner by the fifth cervical to the first dorsal nerve from corresponding segments of the cord. Those for the abductors of the shoulder pass out by the fifth; for the adductors, by the sixth and seventh; for the flexors of the elbow, by the fifth and sixth; for the extensors, by the seventh and eighth; for the extensors of the wrist and fingers, by the sixth and seventh; and for the flexors, by the eighth and first dorsal. It is important to remember that a cervical spinal nerve makes its exit from the canal opposite the origin of the next spinal nerve.

The following is Dr. Herringham's account of the usual **spinal origin** of the fibres in the nerves of the upper limb, and of the usual supply of the chief muscles:

Nerves

Long thoracic, 5, 6, 7.
Suprascapular, 5, or 5, 6.
External (lateral) cutaneous, 5, 6, 7.
Internal (medial) cutaneous, 1, or 8, 1.
Lesser internal (medial) cutaneous, 1.
Circumflex (axillary), 5, 6.
Median, 6, 7, 8, 1.
Ulnar, 8, 1.
Musculo-spiral (radial), 6, 7, 8, or 5, 6, 7, 8.

Muscles

3, 4, 5, Lev. scap.
5, Rhomboids.
5, or 5, 6, Biceps, brachialis ant., supra- and infraspinatus, teres minor.
5, 6, Deltoid, subscapularis.
6, Teres major, pronator teres, flexor carpi rad., brachio-radialis and supinator, superficial thenar muscles.
5, 6, 7, Serratus magnus.
6 or 7, Extensores carpi rad.
7, Coraco-brachialis, latiss. dorsi, extensors at back of forearm, outer head of triceps.
7, 8, Inner head of triceps.
7, 8, 1, Flexor sublimis, flexores profund., carpi uln., long. poll., pronator quad.
8, Long head of triceps, hypothenar muscles, interossei, deep thenar muscles.

In the **cutaneous nerve supply of the fingers,** it must be remembered that on the palmar aspect the thumb, the two outer fingers. and the radial side of the ring finger are supplied by the median, the remaining one and a half fingers by the ulnar (Fig. 76). On the dorsal aspect the thumb is supplied by the lateral radial cutaneous, the index and middle fingers are supplied (as far as the base of the second phalanx) by the radial, and over the second and third phalanges by the median.* The little finger and the ulnar side of the ring finger are supplied by the ulnar. The radial side of the ring finger, as far as the base of the second phalanx, is supplied by the radial, and the rest of this side of the digit by the median (Fig. 77). The cleft between the middle and ring fingers is occasionally supplied by the ulnar, or partly by the ulnar and partly by the radial. (The roots and spinal segments to which these nerves belong may be ascertained from Figs. 76 and 77.) The hand is mainly supplied by the seventh. The neighbouring spinal nerves, as is also the case with ordinary terminal branches, overlap widely in their distribution. The area of anæsthesia is always less than the area of anatomical distribution. The nerves along the ulnar side of

* It will be noticed that the extension of a *ventral* nerve to the *dorsal* aspect of the two distal phalanges is a departure from the general rule.

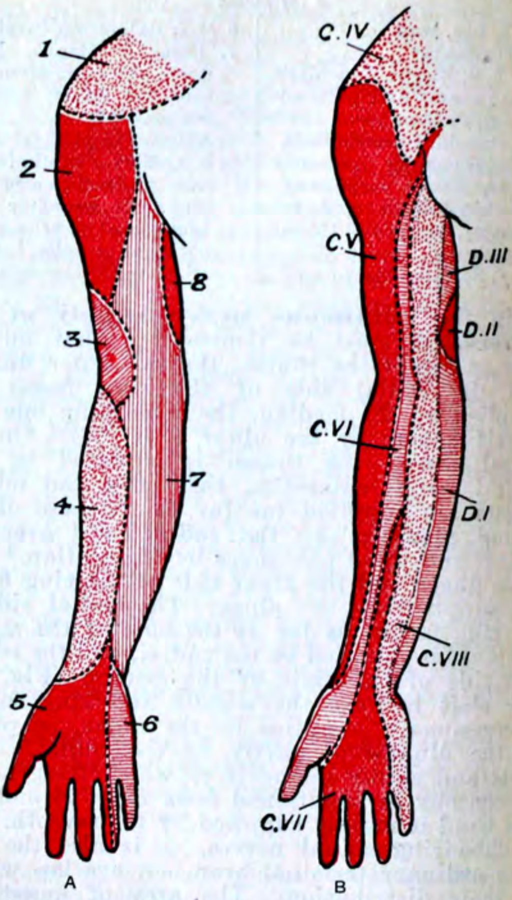

Fig. 76.—A, Distribution of the individual cutaneous nerves to the skin on the flexor (volar) aspect of the arm. B, Distribution of the spinal (segmental) nerves on the same aspect.

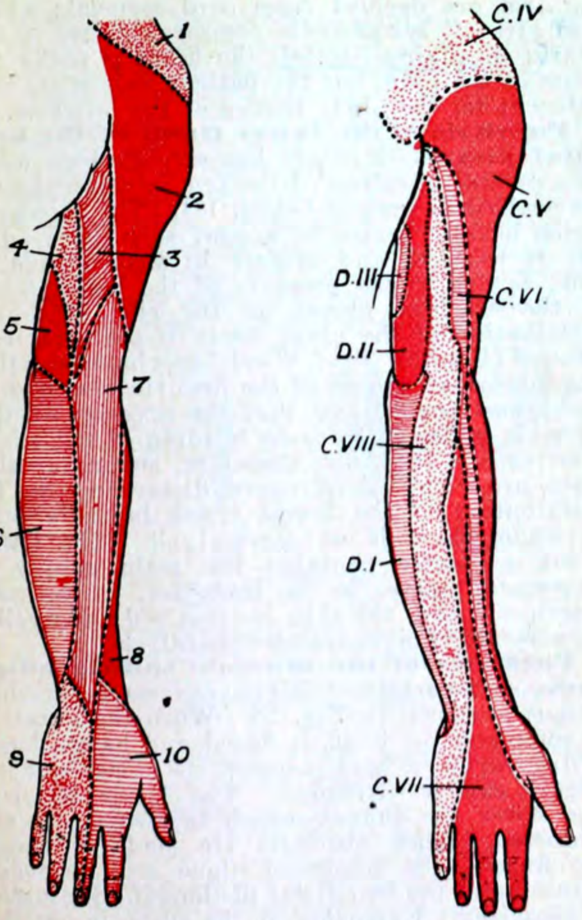

Fig. 77.—A, Distribution of the individual cutaneous nerves on the extensor or dorsal aspect of the arm. B, Distribution of the spinal (segmental) nerves on the same aspect.

the arm are derived from cord segments which also give off sympathetic (sensory) nerves to the heart; in angina pectoris the heart is really the cause of the pain, but the patient feels it on, and *refers* it to, the ulnar border of the left arm.

Paralysis of the lower trunk of the brachial plexus.—Mention has already been made of a partial paralysis of the arm in cases where a cervical rib is present (*see* p. 184). The paralysis, which usually begins to appear soon after adult life is reached, and oftener in women than in men, is due to the pressure of the lowest trunk of the brachial plexus on the rib; hence the distribution of the ulnar nerve is the area most affected (Fig. 75). Prof. Wood-Jones has shown that the subclavian groove of the first rib is caused by the lowest trunk, and that the pressure of this nerve is sufficient to cause bending of the rib in some cases. It is not, therefore, surprising that cases are recorded of nerve disturbance in the distribution of the lowest trunk in individuals in whom there is no cervical rib. The lowest trunk evidently contains the main supply of vaso-motor nerves to the limb, for, in the cases just mentioned, the skin is often red and swollen as a result of a vaso-motor paralysis.

Paralysis of the musculo-spiral (radial) nerve.—The origin of this nerve from the brachial plexus is shown in Fig. 75. When the paralysis is complete, the hand is flexed and hangs flaccid ("drop-wrist"), and neither the wrist nor the fingers can be extended. The latter are bent and cover the thumb, which is also flexed and adducted. When attempts are made to extend the fingers, the interossei alone act, producing extension of the two distal phalanges. Supination is impaired. Extension at the elbow is lost, but there is practically no loss of sensation unless the nerve is cut above the origin of its cutaneous branches. Section of the *radial cutaneous nerve* in the upper part of the forearm gives no loss of sensation (Head and Sherren).

Paralysis of the median nerve.—Flexion of the middle phalanx is impossible in every finger, as is also a like movement of the distal joint of the index and middle fingers. Flexion of the distal phalanges of the two inner digits is possible, the inner part of the flexor profundus being supplied by the ulnar nerve. Flexion of the proximal phalanx of the ring and of the little finger and extension of the second and third phalanges of all the fingers can still be performed by the inner lumbricales and interossei. The thumb is extended and adducted, and can neither be flexed nor opposed. Bending of the wrist is only

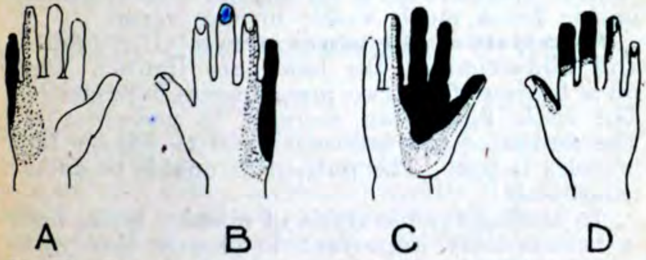

Fig. 78.—**Results of section of the ulnar nerve (A, B), and of the median nerve (C, D).** (*Head and Sherren.*)

Black: Area in which epicritic and protopathic sensibilities are lost.
Stippled: Area in which only epicritic sensibility is lost.

possible when the hand is forcibly adducted by means of the flexor carpi ulnaris, which is not paralysed. Pronation is lost.

Section of the median or ulnar nerves at the wrist does not give rise to the results which one would expect from their anatomical distribution. Such lesions have been investigated by Head and Sherren. After section of the ulnar nerve in the forearm—taking this nerve as an example to explain their observations on nerves generally—they found that *epicritic sensibility* is lost over the area of anatomical distribution (Fig. 78). Over this area the patient is unable to distinguish light touch (tested by cotton-wool) and degrees of temperature between 22°–40° C. In a small area of the fifth digit (*see* Fig. 78) neither pricks nor very cold or very hot things can be felt; in this area, besides epicritic sensibility, there is also lost the form known as *protopathic*. But everywhere over the area of the ulnar nerve deep pressure is felt; *deep sensibility* remains because the nerves which subserve it arise in the forearm and reach the fingers by the tendons. If the tendons are cut, deep sensibility also is lost. The effect of cutting any nerve depends on the nature of the fibres it contains; a nerve may contain epicritic fibres for a small area and protopathic for a much wider, or vice versa.

Paralysis of the ulnar nerve.—Ulnar flexion and adduction of the hand are limited. Complete flexion of the two inner fingers is impossible. The little finger can scarcely be moved at all. The action of the interossei and two inner lumbricales is lost. The patient is unable to adduct the thumb.

In testing for paralysis of muscles in the hand it is extremely important to observe closely the **muscles which flex, extend, abduct, and adduct the thumb.** The ulnar border of the metacarpal of the thumb can be approximated to the radial border of the corresponding bone of the index finger by only two muscles—the adductor pollicis and first dorsal interosseous. These are paralysed when the ulnar nerve is cut. Their action may be simulated by the flexor longus pollicis, brevis pollicis, or opponens pollicis, but in such cases it will be observed that it is not the ulnar border but the flexor surface of the thumb which is moved towards the metacarpal bone of the index finger.

The nerve supplying the humerus is the musculo-cutaneous. The radius and ulna are supplied by the anterior interosseous of the median. It may be taken as a general law that *the nerve supply of a bone* is the same as that of the muscles which are attached to it.

PART IV.—THE ABDOMEN AND THE PELVIS

CHAPTER XVII

THE ABDOMEN

THE ABDOMINAL PARIETES

Surface anatomy.—The degree of prominence of the abdomen varies greatly. The protuberance of the belly in young children is mainly due to the relatively large size of the liver, which occupies a considerable part of the cavity in early life. It also depends upon the small size of the pelvis, which is not only unable to accommodate any abdominal structure (strictly so called), but can scarcely provide room for the pelvic organs themselves. Thus in infancy the bladder and a great part of the rectum are virtually abdominal viscera. After long-continued distension, as, for example, after pregnancy, ascites, etc., the abdomen usually remains unduly prominent and pendulous.

In cases of great emaciation it becomes much sunken, and its anterior wall appears to have collapsed. This change is most conspicuous about the upper part of the region. Here the anterior parietes immediately below the line of the costal cartilages, instead of being in the same plane with the anterior thoracic wall, may so sink in as to be almost at right angles with that wall on the one hand, and with the lower part of the abdominal parietes on the other. In such cases the abdominal walls just below the thoracic line may appear to be almost vertical when the patient is in the recumbent posture. This change of surface is of importance in gastrostomy, since the subjects for that operation are usually much emaciated, and the incision has to be made close below the costal line.

The position of the **linea alba** above the umbilicus is indicated by a slight median groove, but no such indication exists below the navel. The **linea semilunaris,** which corresponds to the lateral or outer border of the rectus abdominis, may be represented by a slightly curved line drawn from about the tip of the ninth costal cartilage to the pubic spine (tubercle). Above the umbilicus the line is indicated on the surface by a shallow depression. The outline of the **rectus** can be well seen when the muscle is in action. It presents three "lineæ transversæ"—one usually opposite the xiphoid process, one opposite the umbilicus, and a third between the two. The two upper of these lines are obvious in well-developed subjects.

The site of the **umbilicus** varies with the obesity of the individual and the laxity of the abdomen. It is always about 2 cm. ($\frac{4}{5}$ of an inch) below the centre of the line between the xiphoid process and the pubes. In the adult it is some way above the centre of the body, as measured from head to foot, while in the fœtus at birth it is below that point. It corresponds in front to the disc between the third and fourth lumbar vertebræ, and behind to the tip of the third lumbar spinous process. It is situated about $\frac{3}{4}$ of an inch above a line drawn between the highest points of the two iliac crests.

The anterior superior spine, the pubic spine, and the inguinal (Poupart's) ligament are all conspicuous and important landmarks. The **pubic spine** is nearly in the same horizontal line as the upper edge of the great trochanter. It is very distinct in thin subjects. In the obese it is entirely lost beneath the pubic fat. In such individuals, however, it can be detected, when the subject is a male, by invaginating the scrotum so as to pass the finger beneath the subcutaneous fat. In the female the position of the process may be made out by abducting the thigh and thus making prominent the tendon of origin of the adductor longus muscle. This muscle arises from the body of the pubes immediately below the spine, and by running the finger along the muscle the bony prominence may be reached. If the finger be placed upon the pubic spine it may be said that a hernia descending to the inner side of the finger will be inguinal, while one presenting to the outer side will be femoral. In the erect position of the body the **anterior superior spine** is a little below the level of the promontory of the sacrum, while a point taken over the junction of sternum and ensiform process—the *sterno-ensiform point*—is opposite the upper part of the tenth dorsal vertebra. This point can be readily recognized in even fat subjects by the depression below the sternal insertions of the seventh pair of costal cartilages, and, as will be seen presently, forms a valuable landmark. A point taken midway between the umbilicus and sterno-ensiform—the **mid-epigastric point**—lies opposite the disc between the first and second lumbar vertebræ and is a surface-marking of great clinical utility (Addison).

In that part of the back which corresponds to the abdominal region, the right and left masses of the erector spinæ are distinct, and in any but fat subjects their outer edges can be well defined. Between these masses is the spinal furrow, which ends below in an angle formed by the two great gluteal muscles. Immediately behind the middle of the crest of the ilium is the supra-iliac (Petit's) triangle, or the gap between the external oblique and latissimus dorsi muscles. The fourth lumbar spine is about on a level with the highest part of the iliac crest. In counting the ribs it is well to commence from above, since the last rib may not project beyond the outer edge of the erector spinæ, and may consequently be overlooked.

The aorta bifurcates opposite the middle of the body of the fourth lumbar vertebra, just to the left of the middle line, about ¾ of an inch below and to the left of the umbilicus. A line drawn on either side from the point of bifurcation to the middle of Poupart's ligament will correspond to the course of the **common** and **external iliac** arteries. The first two inches of this line would cover the common iliac, and the remainder the external.

The cœliac axis comes off opposite the lower part of the twelfth dorsal vertebra, at a spot about 1½ inches above the mid-epigastric point, corresponding behind to the twelfth dorsal spine. The **superior mesenteric** and **suprarenal** arteries are just below the axis. The **renal vessels** arise about ½ an inch below the superior mesenteric, opposite the mid-epigastric point. The **inferior mesenteric** artery comes off from the aorta about 1 inch above the umbilicus. The **deep epigastric** artery follows a line drawn from the middle of the inguinal ligament to the umbilicus. Along the same line may sometimes be seen the superficial epigastric vein.

The abdominal "rings" will be referred to under Hernia (p. 365 *et seq.*).

Anterior Abdominal Parietes

The **skin** over the front of the abdomen is loosely attached in the region of the groin. It is more adherent to the deeper parts in the middle line than elsewhere, but not so adherent as to hinder the spread of inflammation from one side of the abdomen to the other. In cases of great obesity two transverse creases form across the belly, one crossing the umbilicus and the other passing just above the pubes. In the former of the two creases the navel is usually hidden from sight. In cases of ankylosed hip-joint transverse creases are often noted running across the middle of the belly. They are produced by the freer bending of the spine that is usually required in such cases, some of the simpler movements of the hip-joint being transferred to the column when the articulation is rendered useless.

After the skin has been stretched, from any gross distension of the abdomen, certain silvery streaks appear in the integument over its lower part. They are due to an atrophy of the skin produced by the stretching, and their position serves to indicate the parts of the parietes upon which distending forces within the abdomen act most vigorously. They are well seen after pregnancy, ascites, ovarian tumours, etc.

Beneath the skin is the **superficial fascia,** which over the lower half of the abdomen can be readily divided into two layers. The great bulk of the subcutaneous fat of this region is lodged in the more superficial of the two layers. In cases of great obesity the accumulation of fat is perhaps more marked beneath the skin of the abdomen than it is elsewhere. A layer of fat 6 inches in depth has been found in this region in cases of great corpulence. The superficial vessels and nerves lie for the most part between the two layers of the fascia, so that in obese subjects incisions may be made over the abdomen to the depth of an inch or so without encountering blood-vessels of any magnitude.

The **deep layer** of the superficial fascia contains elastic fibres, and corresponds to the tunica abdominalis or "abdominal belt" of animals. It is attached to the deeper parts along the middle line as far as the symphysis, and to the fascia lata just beyond the inguinal ligament. In the interval between the symphysis and the pubic spine it has no attachment, but passes down into the scrotum and becomes the dartos tissue. Extravasated urine that has reached the scrotum may mount up on to the abdomen through this interval, and will then be limited by the deeper layer of the fascia. It will not be able to pass down into the thigh on account of the attachments of the fascia, nor, for a like reason, will it tend to pass over the middle line. In the same way emphysematous collections following injuries to the chest, when beneath the deeper layer of the fascia, receive a check at the groin, and lipomata also that grow beneath the membrane tend to be limited by the middle line and that of Poupart's ligament.

The anterior abdominal parietes vary in **thickness** in different subjects. In cases of great emaciation the outlines of some of the viscera may be readily made out or even seen through the thinned wall. In some cases of chronic intestinal obstruction the outlines of the distended intestine are visible, and their movements can be watched; in instances of obstruction of the pylorus the movements of the dilated and hypertrophied stomach can often be seen. The relative thickness of the abdominal wall in various subjects depends rather upon the amount of the subcutaneous fat than upon the thickness of the muscles. This muscular boundary affords an admirable protection to the viscera within. By contracting the abdominal muscles the front of the belly can be made as hard as a board, and in acute peritonitis this contraction can sometimes be seen to produce a remarkable degree of rigidity. A **blow upon the abdomen** when the muscles are firmly contracted will probably do no injury to the viscera, unless the violence be extreme. The rigid muscular wall acts with the efficacy of a dense indiarubber plate. It may be bruised or torn, but it will itself receive the main shock of the contusion.

The probable effect on the contained viscera of a blow upon the abdomen will depend upon many factors; but, so far as the walls themselves are concerned, the effect greatly depends upon whether the blow was anticipated or not, and upon the extent of the padding of fat that is furnished to the parietes. If the blow be anticipated the muscles of the belly will be instinctively contracted, and the viscera at once provided with a firm but elastic shield. Thus the abdominal muscles have been found bruised and torn while the viscera were intact; and, on the other hand, in cases probably where the muscles were inert or taken unawares, a viscus has been found to be damaged without there being any conspicuous lesion in the belly-wall. In the Great War several cases were recorded of gunshot injury to abdominal viscera and yet the track of the bullet which caused the visceral injury was confined to the muscular parietes. Besides protecting the viscera, the muscular wall serves as the chief means of **visceral support.** The moment the upright posture is assumed, the muscles of the abdominal wall pass reflexly into a state of contraction, thus bearing the weight of the abdominal contents.

Along the **linea alba** the abdominal wall is thin, dense, and free from visible blood-vessels. Hence in many operations upon the abdominal cavity the incision is made in the middle line. Along the outer border of the rectus muscle (i.e. about and just beyond the linea semilunaris) the parietes also are thin and lacking in vessels, and consequently that situation is well suited for an incision. About 1 inch below the navel the two recti muscles are almost in contact, and here the linea alba can scarcely be said to exist, while above the muscles remain apart, the linea alba being normally $\frac{3}{4}$ of an inch wide. In pregnancy, obesity, and ascites the supra-umbilical part may become 2 or more inches wide, but the narrow infra-umbilical part is unaffected; when this part of the linea alba widens the condition is known as *divarication of the recti.*

In this case the contents of the abdomen bulge out between the recti when these two muscles are thrown into action, as when a patient attempts to assume the sitting from a supine posture unaided by the arms. Pellets of subperitoneal fat may grow through interstices in the linea alba and give rise to what are called "fatty herniæ."

The fibrous ring of the **umbilicus** is derived from the linea alba. To this ring the adjacent structures—skin, fascia, and peritoneum—are all closely adherent. The adhesion is such, and the amount of tissue between the skin and peritoneum is so scanty, that in operating upon an umbilical hernia it is scarcely possible to avoid opening the sac.

The umbilicus represents the point where the lateral abdominal walls finally close. At the sixth week the opening is funnel-shaped and contains the yolk-sac and a fold of the bowel to which it is attached. This condition may persist and give rise to a congenital umbilical hernia. In the fœtus three vessels enter at the navel, and immediately separate on reaching the abdominal cavity, the vein passing directly upwards and the arteries obliquely downwards. Running down from the umbilicus in the middle line is also the remains of the urachus. In the fœtus the spot where the three vessels part company is about the centre of the navel, and it thus happens that in a congenital umbilical hernia the gut as it escapes separates the three vessels, which become to some extent spread over it. The congenital hernia, indeed, works its way in among the structures of the cord and receives its main coverings from them. These herniæ are fortunately rare, for in certain instances they extend some way into the cord, and in at least two reported cases the gut was cut across by the accoucheur in dividing the cord at birth.* As the abdomen increases in

* The congenital hernia must be distinguished from the infantile umbilical hernia so commonly met with after separation of the cord. For an account of these congenital herniæ, *see* paper by the Author in the *Lancet*, 1881, i. 323.

height the contraction of the two obliterated arteries and of the urachus drags upon the cicatrix and pulls it backwards and downwards.

In some cases there is found at the navel a fistula from which urine is discharged. This is due to a **patent urachus.** The urinary bladder is formed from the allantois; and the part of the allantois between the bladder and the navel forms the urachus, in which the lumen is usually obliterated, although it may remain patent. In one instance of patent urachus the abnormal opening was 1 inch in diameter. The patient, a man aged 40, had a stone, which was extracted by passing the finger into the bladder through the opening at the umbilicus.

Sometimes a fistula discharging fæces is met with at the navel. This depends upon the persistence of the vitello-intestinal duct, a passage that at one time connects the intestine of the early fœtus with the yolk-sac, which, as development proceeds, comes to be situated at the placental end of the umbilical cord. In 99 per cent. of fœtuses this communication disappears, but in 1 per cent. it remains as a duct, cord, or diverticulum. When the intestinal end persists it is known as **Meckel's diverticulum**, and springs from the ileum some 2 or more feet above the ileo-cæcal orifice. This fœtal relationship also explains the presence of a fibrous cord which is sometimes seen connecting Meckel's diverticulum with the umbilicus. The fibrous cord may cause strangulation of the bowel (Fig. 90, p. 412).

The position of the transverse intersections of the **rectus muscle** should be borne in mind. They adhere to the anterior layer of the rectus sheath, but not to the posterior. They are able therefore to some extent to limit suppurative collections and hæmorrhages beneath the sheath on its anterior aspect. This muscle is often the seat of one form of "**phantom tumour.**" These tumours are mostly met with in the hysterical and hypochondriacal, and when associated with some vague abdominal symptoms are apt to mislead. They are due to a partial contraction of the muscle, usually to a part between two intersections, and are said to be more common in the upper part of the rectus. When the fibres of the muscle are contracted the "tumour" is obvious, but when they relax it disappears. The phantom tumour, however, is not always a matter of little moment. It may be associated with grave disease within the abdomen, and be due to **reflex muscular contraction,** the starting-point of such reflex act being in the viscera. These localized contractions may provide a clue to the seat of visceral disease. Thus, the stomach derives its chief sensory nerve supply from the eighth dorsal segment of the cord; the section of the rectus between the upper and middle inscriptions is also supplied from this segment through the eighth dorsal nerve; hence contraction of this section may be associated with disease of the stomach. The rectus receives nerves from the lower six dorsal nerves; the section at the umbilicus is supplied by the tenth. I (F. T.) have, for example, seen a conspicuous phantom tumour in the upper part of the right rectus associated with cancer of the stomach, with ulcer of the duodenum, and with malignant disease of the peritoneum.

Other vanishing tumours depend upon distension of the intestines by flatus or by fæcal matter. In great distension of the abdomen the fibres of the rectus may be much stretched, since they bear the brunt of the distending force. The direction of the fibres also renders them liable to be torn in opisthotonos, or extreme arching of the back, or tetanus. Portions of the muscle have also been ruptured by muscular violence, as in vaulting.

The **lateral muscles** of the front abdominal wall are separated from one another by layers of loose connective tissue. In the tissue between the internal oblique and transversalis are found the chief nerves and arteries.

Everywhere the peritoneum is bound to the abdominal wall by **subperitoneal connective tissue.** In the pelvis this tissue is lax, to allow the viscera of the pelvis—the bladder, rectum, and uterus—to expand; so, too, over the iliac fossæ and on the anterior abdominal wall for 2 inches above the inguinal ligament and the symphysis pubis; but above this level and on the under surface of the diaphragm it binds the peritoneum down closely. The looseness of this layer greatly favours the spread of abscess, to the progress of which it offers little resistance. Such an abscess may spread from the viscera, especially from those that have an imperfect peritoneal covering, as, for example, the kidney, the vertical parts of the colon, etc. The laxity of this tissue has been of service in certain surgical procedures. Thus the external and common iliac arteries can be reached by an incision made some way to the outer side of the vessels and without opening the peritoneum.

Wounds of the abdomen may give trouble in their treatment, since, when inflicted, they may open up several layers of fascia and so lead to bagging of pus and to the spread of suppuration should an abscess follow the lesion. The constant respiratory movements of the belly-walls do not favour that rest which is so essential to the healing of wounds. In penetrating wounds the contraction of the muscles may encourage the protrusion of the viscera, especially when the incision is transverse to the direction of the muscular fibres. In reducing small portions of protruded viscera it is quite possible to push them into one of the connective-tissue spaces between the muscles, or into the subserous tissue, instead of into the peritoneal cavity. In applying sutures to wounds involving the whole thickness of the parietes it is necessary that the threads should include the peritoneum, so that early healing of that membrane may be brought about. Without such precaution a gap may be left in the surface of the peritoneum which would favour the formation of a hernia in the site of the old wound.

Blood-vessels.—The only **arteries** of any magnitude in the abdominal walls are the inferior or deep epigastric arteries, some branches of the deep circumflex iliac, the last two intercostal vessels, the superior epigastric, a branch of the internal mammary, and the abdominal divisions of the lumbar arteries. The superficial vessels are of small size.

The superficial **veins** on the front of the abdomen are numerous, and are very distinct when varicose. A lateral vein, extending from the axilla to the groin, uniting the axillary and femoral veins, is often rendered in this way very prominent. The surface abdominal veins may take no part as alternative blood channels in cases of obstruction of the inferior vena cava. Clinical experience shows that these veins may be also enormously varicose in instances where the inferior cava is quite patent. In one case under my (F. T.'s) care there was extensive varicosity of the surface veins, from the pectoral region to the groin, which involved one side of the body only. It has been shown, moreover, that the valves of these vessels are so arranged that the blood in the surface veins above the navel goes to the axilla, while that in the veins of the subumbilical region runs to the groin. In the neighbourhood of the umbilicus these veins are connected with the portal vein in the liver through anastomotic venous channels in the falciform ligament of the liver (Sappey). Hence, in cases where the portal circulation is obstructed by disease of the liver or partial obliteration of the portal vein, some of the portal blood makes its way to the superficial epigastric veins through the umbilical communication. In such cases the blood is found to flow away from the umbilicus.

As regards the surface **lymphatics** of the front of the abdomen, it may be said in general terms that those above the umbilicus go to the axillary glands, and those below to the glands of the groin.

Nerves. — The abdominal wall is supplied by the lowest six dorsal or intercostal nerves, and by the first lumbar nerve (Fig. 79). They run

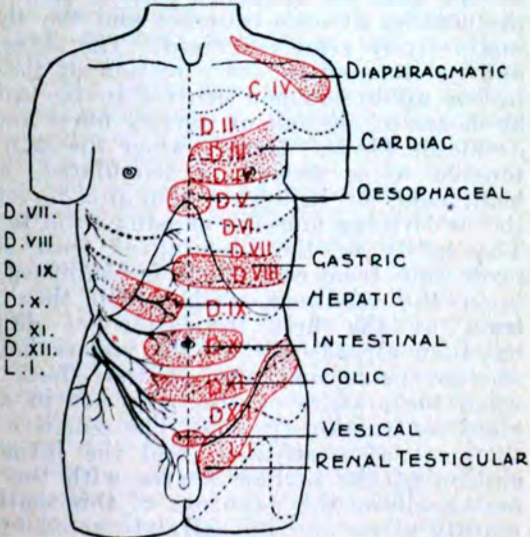

Fig. 79.—Showing approximately the areas of skin supplied by spinal nerves on the anterior surface of the trunk.

The areas are marked on the left side by dotted lines, and the number of the spinal nerve by which each is supplied is stated. The nerves are shown on the right side. The red stippled areas show the regions to which pain is commonly referred in connexion with visceral disease—according to the observations of Sir James Mackenzie. The pain radiates towards the unenclosed part of each area.

obliquely to the long axis of the abdomen downwards and inwards from the sides to the middle line, and hence are damaged more extensively in vertical than in oblique incisions. Their direction is represented by a continuation of the lines of the ribs: they are placed parallel to one another and at fairly equal distances apart. It is important to note that they supply not only the abdominal integument and the peritoneal lining, but also the muscles, viz. the rectus, the two oblique muscles, and the transversalis. If a cold hand be suddenly placed upon the belly the muscles at once contract and the abdomen is instinctively rendered rigid. The skin, muscles, and peritoneum in every section of the wall are linked up to common centres in the spinal cord by means of afferent or sensory fibres and efferent or motor fibres. Hence, when the skin or peritoneum of a section is stimulated, by touch, heat, cold, or injury, a stimulus is reflected to the underlying muscles, causing them to contract. The safety of the viscera, at least so far as protection from contusions is concerned, depends upon the readiness with which they can contract at the first indication of danger. As has been already stated, the viscera have a very efficient protection against the effects of blows when the muscles of the belly are in a state of rigid contraction (p. 352). The sensitive skin acts the part of a sentinel, and the intimate association of the surface nerves with the muscular nerves allows the warnings of this sentinel to be readily given and immediately acted upon. The rigidity of the muscles in certain painful affections of the skin over the abdomen is often very conspicuous. The case of a man with a burn over the belly might be instanced. While the burn is protected by the dressings the abdominal muscles are lax and the parietes move with the respiratory act. The moment the dressings are removed, the surface becoming painful, its spinal centre is excited and the muscles at once contract and the belly becomes rigid.

It will be noticed that six of the abdominal nerves supply intercostal muscles, and are thus intimately associated with the movements of respiration. The abdominal muscles are of course concerned in the same movements. These associations are illustrated when cold water is suddenly dashed over the belly. The subject of the experiment at once experiences a violent respiratory movement in the form of a deep gasp.

There are other practical points about these nerves. In caries of the spine, and in certain injuries to the column, the spinal nerves may suffer injury as they issue from the vertebral canal. This injury may show itself by modified sensation in the parts supplied by such nerves. Thus in Pott's disease the patient often complains of a sense of tightness about the abdomen, as if a cord were tied around it. This sense of constriction depends upon an impaired sensation in the parts supplied by a certain pair of nerves; or, if the sense of constriction be wider spread, by two or more pairs of nerves. In other cases a sense of pain may take the place of that of constriction. It would hardly be believed that spinal disease has been mistaken for "belly-ache." But many such cases have been recorded. A child complains of pain over the pit of the stomach or about the umbilicus, and this feature may quite absorb for a while the surgeon's attention. The abdomen is carefully poulticed, while the only mischief is in the vertebral column. A case came under my (F. T.'s) notice in which a man complained of intense and abiding pain over the stomach. The pain was made worse by food, and, as all means used failed to relieve it, the abdomen was opened by an exploratory incision. Nothing abnormal was discovered. A little later it became evident that the pain was due to a malignant tumour situated in the bodies of the dorsal vertebræ. There had never, before the operation, been any suspicion of spinal disease. The site of the painful part depends, of course, upon the position of the spinal ailment, and so the cutaneous symptoms may serve to localize the caries in the vertebræ.

Thus the skin over the "pit of the stomach" is supplied by the sixth and seventh dorsal nerves, and the tenth nerve is nearly in a line with the umbilicus. The position of the areas supplied by each spinal nerve on the trunk is shown in Fig. 79. The umbilicus may be at the upper or lower border of the area of the tenth, according to the individual. A spinal root may be cut and yet scarcely a trace of anæsthesia may result owing to the overlapping of the nerve distributions.

Not only may a lesion at the origin of a spinal nerve give rise to a pain referred by the patient to the abdomen, but, as may be readily understood from the fact that the nerves of the abdominal wall also supply the lower half of the thorax, thoracic lesions may give rise to symptoms which are referred to the abdomen. Pain or tender areas in the upper part of the abdomen may be actually due to a pleurisy in the lower part of the thorax.

Although the course of the spinal nerves in the body-wall is oblique—following the axes of the ribs—yet in their final distribution they supply zones of skin which approximately pass horizontally round the body. This is due to the fact that the posterior primary divisions and lateral cutaneous branches, before they reach their areas of skin, descend to the same level as the anterior cutaneous nerves—the terminal branches of the anterior divisions. Indeed, the lateral cutaneous nerves of the lower segments, as the lower limb is approached, actually descend farther than the anterior cutaneous nerves (Fig. 79). The horizontal arrangement of the skin areas is demonstrated by the distribution of the cutaneous lesions in *herpes zoster*—a disease which is now ascribed to a lesion of the ganglia of the posterior roots.

The nerves of the body-wall have still more important associations, viz. **visceral associations.** The cord-centres with which the body-wall nerves are connected are also in communication with the viscera of the abdomen and thorax through the sympathetic system. The *visceral spinal centres* are in close communication with corresponding *somatic spinal centres*. Hence diseased conditions in the abdominal viscera give rise to disturbance in the corresponding cord-centres, and the brain, being accustomed to localize pain only along the somatic nerves, makes a mistake and refers the pain along the spinal nerve of the segment disturbed. Not only is pain referred, but the skin supplied from the disturbed spinal centres becomes tender; and through a study of these areas of tenderness Head has been able to localize the visceral centres in the spinal cord, thus affording the surgeon a means for increased accuracy of diagnosis. The abdominal viscera are supplied from the sixth dorsal to the first lumbar spinal segments, the nerves passing to their destinations through the rami communicantes, splanchnic nerves, and sympathetic plexuses of the abdomen. No visceral nerves escape by the second, third, or fourth lumbar nerve roots, hence these are never the seats of visceral referred pains. The pelvic viscera are supplied from the fifth lumbar to the third or sometimes fourth sacral nerve through the nervi erigentes.

It is important to remember, too, that there are three systems of nerves in the belly-wall: (1) the nerves to the skin; (2) the nerves to the muscles (motor and sensory); (3) the nerves to the parietal peritoneum. Any one or all of these three sets may be the seat of referred pain, the most common being the muscular nerves. The pain elicited by pressure on the muscles or by movements is usually, but erroneously, regarded as situated in the diseased viscus. The tonus and condition of the muscles of the abdominal parietes are influenced by the condition of the viscera through the interconnexion of their nerve-centres in the spinal cord.

canal for the whole or part of its entire length. This canal runs obliquely from the internal, deep, or abdominal, to the external, superficial, or inguinal ring, and is about 1½ inches in length. It represents the track followed by the testis in its descent to the groin. It is, in a sense, a passage right through the abdominal wall, and is occupied by the spermatic cord. It is not a free canal, however, in the same sense as one would speak of an open tube, but is rather a potential one, a tract of tissue so arranged as to permit of a body being thrust along it. It is a breach in the abdominal wall, not a doorway; a breach that is forcibly opened up and widened in the acquired forms of hernia. When a hernia occupies the inguinal canal it is covered in front by the integuments, the external oblique aponeurosis, and the lower fibres of the internal oblique and transversalis muscles. It rests behind upon the transversalis fascia, the conjoined tendon, and the triangular fascia (reflected inguinal ligament); over it arch the transverse and internal oblique muscles, while below it is the angle formed by the union of the inguinal (Poupart's) ligament with the transversalis fascia. The herniated bowel is contained within a "sac," which is always formed of peritoneum. In congenital hernia the sac exists already formed as an abnormally patent "processus vaginalis." In acquired hernia the sac consists of that part of the parietal peritoneum which the gut pushes before it in its descent.

The *external or superficial ring*, ½ an inch external to and above the pubic spine, is readily felt by invaginating the scrotum with the point of the finger and then passing the digit up in front of the cord (Fig. 81). If the nail be kept against the cord the pulp of the finger can readily recognize the triangular slit-like opening. Under ordinary circumstances in adults it will just admit the tip of the little finger. The *internal ring* is situated about ½ an inch above Poupart's ligament, midway between the symphysis pubis and anterior superior iliac spine. This is the *femoral point*; it lies directly over the femoral artery as that vessel escapes from the abdomen beneath Poupart's ligament (Fig. 81).

There are two principal forms of inguinal hernia, which can be best understood by a view of the

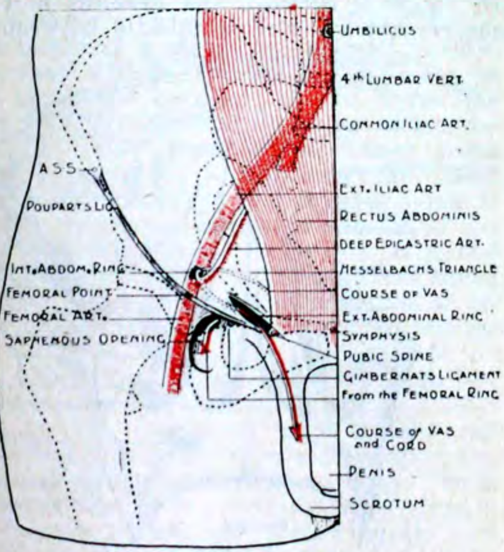

Fig 81.—Surface markings for the inguinal and femoral canals.

A S.S. = anterior superior spine of ilium. Int. abdom. ring = deep or abdominal ring. Ext. abdom. ring = superficial or inguinal ring.

anterior abdominal parietes from within (Fig. 82). From such an aspect it will be seen that the peritoneum is marked by three linear ridges that run, broadly speaking, from the umbilicus to the pelvic brim. One of these ridges follows the middle line from the navel to the symphysis and represents the urachus; a second, which may be indicated by a line drawn from the femoral point to the navel, represents the inferior or deep epigastric artery; while between these two, and much nearer to the epigastric vessel than to the middle line, is the line formed by the obliterated hypogastric artery (Fig. 82). By means of these ridges the peritoneum is made to present three fossæ—an external to the outer side of the epigastric artery, an internal between the urachus and the hypogastric artery, and a middle between the track

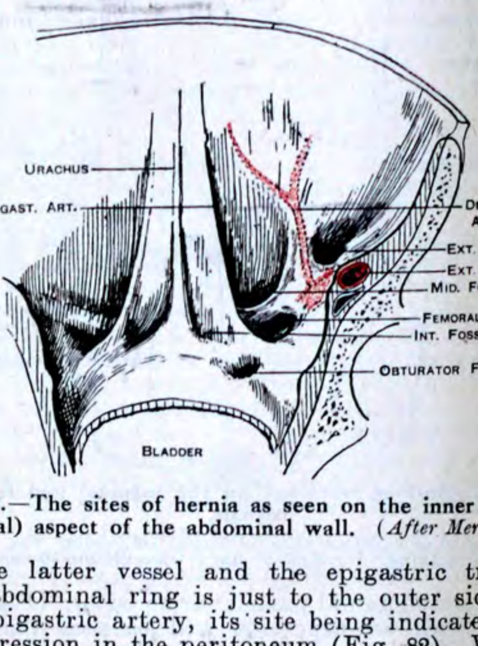

Fig. 82.—The sites of hernia as seen on the inner (peritoneal) aspect of the abdominal wall. (*After Merkel.*)

of the latter vessel and the epigastric trunk. The abdominal ring is just to the outer side of the epigastric artery, its site being indicated by a depression in the peritoneum (Fig. 82). When a hernia follows the inguinal canal throughout its entire length, it is called **oblique, indirect,** or **external**; "oblique" or "indirect" from its taking the oblique direction of the canal, "external" from the position of its neck with reference to the epigastric vessel. The coverings of such a hernia would be the same as those of the cord, viz. the skin, the superficial, external spermatic (intercolumnar), cremasteric, and internal spermatic (infundibuliform) layers of fascia, the subperitoneal tissue, and the peritoneum. When the hernia escapes to the medial side of the inferior epigastric artery, through the space known as the recto-epigastric (Hesselbach's) triangle, it is called a **direct or internal** hernia, for reasons that will be obvious. There may be two forms of direct hernia: in one form the gut escapes through the middle fossa above described, in the other through the inner fossa between the hypogastric artery and the outer edge of the rectus muscle. The middle fossa is nearly opposite to the apical or outer part of the inguinal or external ring. A hernia escaping through that fossa would enter the inguinal canal some little way below the point of entrance of an oblique hernia, and would have the same coverings as that hernia. The inner fossa corresponds, or is opposite to, the inner part of the inguinal ring. A hernia escaping through this fossa would be resisted by the conjoined tendon and the reflected inguinal ligament. These structures are either stretched over the hernia so as to form one of its coverings, or the conjoined tendon is perforated by the hernia, or thrust aside. In any case the hernia is forced almost directly into the inguinal ring.

Direct versus indirect inguinal hernia.—The oblique hernia which enters the abdominal ring may occupy a remnant of the *processus vaginalis*, and be therefore developmental in origin, but the direct is never congenital. In the congenital oblique hernia the outline of the inguinal canal and the relations of the various parts concerned are but little disturbed, and the differences between this form of rupture and the direct variety are conspicuous. The acquired oblique hernia however, does not present such a contrast to the direct form as might be expected. In the first-named rupture, from constant dragging upon the parts, the abdominal ring becomes more or less approximated to the inguinal ring, and the length of the canal, and consequently the obliquity of the hernia, is considerably reduced. Thus the axes of the two forms of rupture do not present such differences as to make their nature at once obvious. The direct hernia, however, on reduction, will pass directly back into the belly, while the indirect will, even in old cases, take a slight but appreciable direction outwards. After the reduction of the direct hernia, the edge of the rectus muscle may be readily felt to the inner side of the aperture. The direct hernia is usually small and globular, while the oblique rupture may attain large size, and tends to assume a pyriform outline.

Forms of oblique hernia depending upon congenital defects in the "vaginal process." *The descent of the testis.*—It is well known that the testis in the fœtus descends from the region of the kidney into the scrotum by a way through the abdominal wall that is afterwards known as the inguinal canal.

Its descent is preceded by the passage into the scrotum of a process of the peritoneum, the vaginal process. The testicle usually enters the abdominal ring about the seventh month of fœtal life, and by the eighth month is in the scrotum. The process of descent, which was investigated and made clear by John Hunter some 150 years ago, is often misunderstood. The gubernaculum (Fig. 83) is a solid, bullet-like plug of growing tissue which, by a pure process of growth, burrows its way through the abdominal wall into the scrotum, carrying with it a saccular or tubular process of peritoneum—the processus vaginalis—with the testicle and epididymis enclosed within the process. The lower or growing end of the gubernaculum is composed of rapidly proliferating cells; its upper part, which is attached to the globus minor and mesentery of the testicle, is composed of non-striated muscular tissue. It can be understood that the growing end of the gubernaculum may, in abnormal circumstances, be diverted from its course and carry the testicle towards the root of the penis, or outwards in the groin, or backwards into the perineum, thus giving the testicle an eccentric, extrascrotal position. It was Hunter's opinion — and the evidence now accumulated goes to support him—that the process of descent is regulated by the full development of the testicle, probably by an internal secretion. Hence, if the testicle is imperfect, the process of descent is arrested, the testicle being left in the abdomen or stranded in the inguinal canal.

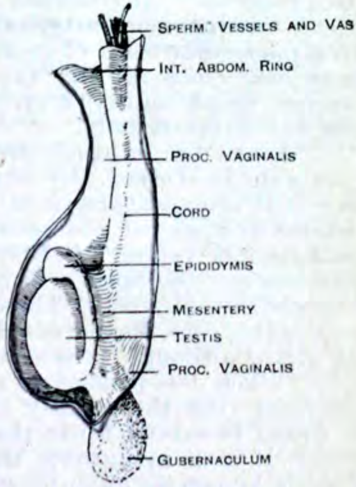

Fig. 83.—Relationship of the processus vaginalis, gubernaculum, and plica vascularis to the testicle of the human fœtus.

The vaginal process is often found open at birth; even in children three or four months old, the communication remains open in 30 to 40 per cent. of cases. The part of the processus vaginalis which surrounds the testicle becomes the *tunica vaginalis*, while the elongated tubular part between it and the abdominal ring is known as the *processus funicularis*. The manner in which the processus vaginalis is cut off is as follows: It becomes obliterated in two places, at the deep or abdominal ring and at a spot just above the epididymis, the obliteration usually beginning at the higher point first. Supposing obliteration to have taken place at these two points, the vaginal process between them will be represented by an isolated tube. This soon shrinks, closes, and dwindles to an insignificant fibrous cord. It may, however, remain patent in part, and if fluid accumulates in this patent portion an "encysted hydrocele of the cord" is produced. As regards the mode of closure, three contingencies may happen, each giving rise to a particular form of hernia: (1) the "process" may not close at all; (2) it may close at the upper point only; and (3) it may close at the lower point only.

1. When the vaginal process is entirely open, gut can be forced, by compression of the abdominal musculature, into the scrotum. Such a condition is called a *congenital hernia.* Here the intestine is found to occupy a large sac of the peritoneum, the open orifice of which is placed at the abdominal ring. The term "congenital" is misleading, as the hernia is very rarely present at birth, although it is common in early life.

2. When the process is closed only at the abdominal ring the unduly large tunica vaginalis is found to extend up to that orifice. If a hernia forms it may invaginate the processus vaginalis. This is known as an *infantile* or *encysted hernia.* In such a case the tunica vaginalis lies in front of the sac, and therefore three layers of peritoneum would have to be cut through before the gut could be reached. The term "infantile" was given to this rupture because the first cases reported were met with in infants; the term "encysted," because the hernial sac was considered to be enclosed by the sac of the tunica vaginalis.

3. The funicular process may remain open from the abdominal ring to the top of the testicle, and there end, the normal tunica vaginalis being beyond. Hernia into this process is called a *hernia into the funicular process.*

If, in the dead subject, the inguinal canal be opened up, and an attempt made to draw a piece of gut down from the abdomen into the scrotum, it will be found that this cannot be done, owing to the shortness of the mesentery. In any case of scrotal hernia, therefore, the mesentery must become lengthened, and all the evidence at our disposal points to this elongation as having been acquired as the hernia was formed.

Another factor which must be considered in the production of hernia is the *tension* or *pressure within the abdomen*. When a labourer lifts a heavy weight from the ground, the musculature of the abdomen is thrown into vigorous action, compressing the viscera and raising the pressure within the abdomen to 100 mm. of mercury or more. When a child cries, coughs, or strains at stool there is a sudden rise of intra-abdominal pressure. The compressed viscera seek out the weakest points in the abdominal wall, which are represented by the abdominal and other rings. The escape of viscera at the abdominal ring is prevented by the conjoined parts of the internal oblique and transversalis. Mr. George Chiene observed that when a patient was asked to strain, this muscle contracted vigorously, so that a finger inserted into the inguinal canal was gripped between the conjoined tendon and Poupart's ligament. Herniæ are notoriously frequent in men who have to lift and carry heavy burdens.

The *inguinal canal in the female* is much smaller and narrower, although a trifle longer, than it is in the male. It is occupied by the round ligament, and offers such resistance that acquired inguinal hernia is as rare among females as it is common among men. In the female fœtus a process of peritoneum descends for a little way along the round ligament. It corresponds to the processus vaginalis of males, and is known as the canal of Nuck. If this process remains patent, as it not infrequently does, it may lead to a rupture that corresponds to the congenital hernia of males. Indeed, in quite early life the inguinal rupture is about the only form met with in female children, if exception be made of umbilical hernia. Not uncommonly the ovary is found as one of the contents of the hernial sac—for in the newly-born child the ovary lies above the level of the pelvic brim and relatively near the internal abdominal ring. In all such instances of early inguinal hernia the gut has travelled down a patent *processus vaginalis*.

It only remains to be said that in endeavouring to reduce an inguinal hernia by taxis the thigh should be flexed and adducted, for in this position the abdominal parietes that bound the inguinal canal are the most relaxed. This position of the thigh affects the inguinal region mainly through the attachments of the fascia lata to the inguinal (Poupart's) ligament.

In **herniotomy** an incision is made along the middle of the tumour and in its long axis, being so arranged that its centre shall correspond to the inguinal ring. The superficial external pudic artery is usually divided in the operation. It is impossible to distinguish the various layers of tissue that cover the hernia, the only one, as a rule, that is recognizable being the layer from the cremaster. In dividing the constriction it is usually recommended to cut upwards in all forms of inguinal hernia. The only vessel in risk of being damaged is the inferior or deep epigastric. In the oblique form of rupture an incision directly upwards would quite avoid this artery; but in a direct hernia, where there is reason to suppose that the vessel is in close connexion with the neck of the sac, it is well that the incision be directed a little inwards as well as upwards. It should be remembered that the incision required to relieve a constriction is, if properly applied, of the most insignificant character.

Radical cure of hernia.—In all operations to mend the breach in the abdominal wall caused by the extrusion of a hernia, the first desideratum is the removal of the peritoneal sac. Its removal is followed by a cicatricial contraction of the tissues which surround its ligatured neck. The second aim is to repair the sphincter mechanism, represented chiefly by the conjoined muscle and its tendon. Its origin or insertion may be shortened; its nerve supply from the ilio-inguinal must be secured and protected; the gap between the inguinal ligament and the inguinal border of the conjoined muscle may be diminished. Attempts have been made by Bloodgood to transplant the outer fibres of the rectus abdominis from the outer part of the pubic crest to the inner part of the inguinal ligament, but it is difficult to maintain such transplanted parts in health and thus secure the canalicular region.

2. **Femoral hernia.**—In this form of rupture the gut leaves the abdomen through the femoral ring (Fig. 84) and passes down into the thigh along the femoral canal. The name *femoral ring and canal* is given to the narrow interval between the femoral vein and the inner wall of the femoral sheath. Like the inguinal canal, it is a potential rather than an actual canal, and exists only when the sheath has been separated from the vein by dissection or by a hernial protrusion of some kind. The femoral canal is funnel-shaped, about $\frac{1}{2}$ an inch in length, and ends opposite the saphenous opening (fossa ovalis). A point taken on the inguinal ligament midway between the pubic spine and femoral point lies directly over the femoral ring; the centre of the saphenous opening is situated $\frac{3}{4}$ of an inch below this point (Fig. 81). Femoral herniæ are always acquired, and possess a sac, made by themselves out of the parietal peritoneum covering the femoral ring and its vicinity. The ring is much larger in women than in men, and thus it happens that this species of rupture is much more common in the former sex. As the gut is repeatedly pressed —by coughing, lifting heavy weights, straining—

against an unnaturally capacious ring, it pushes in front of it a sac of peritoneum and the septum crurale (the name given to the subperitoneal tissue that covers in the femoral ring) and enters the femoral sheath. The adhesions of the sheath limit its downward progress when it has travelled about ½ an inch, and it therefore passes forwards through the saphenous opening, pushing before it the cribriform fascia covering that opening. It then receives a covering from

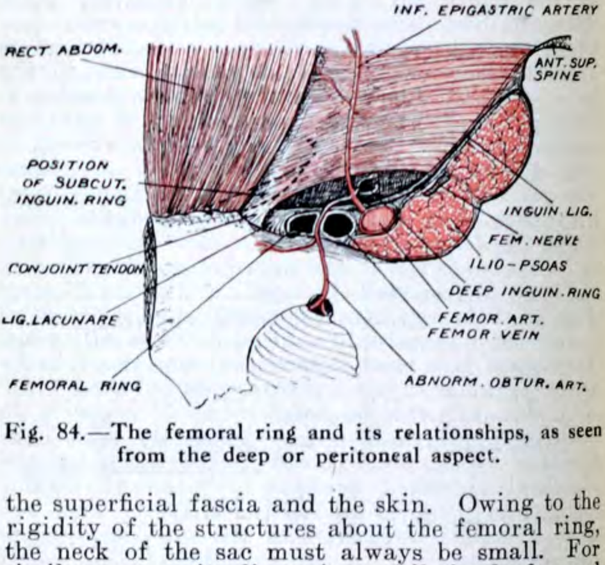

Fig. 84.—The femoral ring and its relationships, as seen from the deep or peritoneal aspect.

the superficial fascia and the skin. Owing to the rigidity of the structures about the femoral ring, the neck of the sac must always be small. For similar reasons its dimensions while in the femoral canal must of necessity be insignificant, but when once it has escaped through the saphenous opening the loose subcutaneous fasciæ of the groin afford it ample opportunity for increase. When the hernia has passed through the saphenous opening it tends to mount upwards over the inguinal ligament, in the direction of the anterior superior iliac spine. Even when it overlaps the ligament considerably it can hardly be mistaken for an inguinal hernia, since it must always lie to the outer side of the pubic spine. The hernial sac is superficial to the deep layers of the inguinal fascia (Scarpa's fascia).

Relations.—When a hernia occupies the femoral canal there are in front of it the skin and superficial fasciæ, the iliac part of the fascia lata, the fascia cribrosa, and the anterior wall of the femoral sheath. Behind are the posterior wall of the femoral sheath and pubic portion of the fascia lata, the pectineus muscle, and the bone. The boundaries of the femoral ring are, in front, the inguinal ligament and the femoral sheath; behind, the bone covered by the fascia lata and the pectineus; on the inner side, the conjoined tendon, Gimbernat's ligament (ligamentum lacunare), and the inner part of the deep crural arch; on the outer side, the femoral vein in its sheath (Fig. 84). The spermatic cord lies (in the male) just above the femoral ring, and the epigastric artery skirts its upper and outer part (Fig. 84). The little pubic branch of this artery passes round the ring to ramify over Gimbernat's ligament. In two cases out of seven the obturator artery arises from the epigastric. In 10 per cent. of cases the abnormal obturator passes on the inner side of the femoral ring and is in danger of being wounded in operations for strangulation (Fig. 84); in other cases the artery descends to the outer side of the ring or may cross it (R. Quain). In one instance where the vessel was placed internally to the femoral ring the pulsations of the abnormal artery were felt before the parts were divided. In addition to the vessels about the ring there is also a pubic vein, which, ascending from the obturator vein in the thyroid foramen, enters the external iliac vein.

The size of the femoral canal and the degree of tension at its orifices vary greatly with the position of the limb. If the thigh be extended, abducted, and rotated outwards, these parts are made very tense, while they are the most lax when the limb is flexed, adducted, and rotated inwards. It is consequently in the latter position that the thigh should be placed when taxis is being attempted.

In **herniotomy** the incision is made along the inner side of the tumour, and is so arranged that its centre corresponds to about the upper part of the saphenous opening. The constriction is usually at the neck of the sac, and caused by Gimbernat's ligament. It is divided by an incision directed upwards and inwards. In repairing the breach caused by a femoral hernia several of the surrounding structures are utilized. On the surface of the pubes, just above the ring is the *ileo-pectineal periosteal ligament* (*Cooper's ligament*). That has been raised and sutured to the inguinal ligament, or the inner part of the inguinal ligament may be sutured to the pubes. Fibres of the pectineus which arise from the pubic aspect of the femoral ring (Fig. 84) have been brought forwards and sutured to the inguinal ligament, or the outer fibres of the rectus abdominis may be transplanted and fixed to the ileo-pectineal periosteal ligament. Mere ligature of the neck of the sac leads to a cicatricial adhesion of parts within the ring, often sufficient to prevent recurrence of a hernia.

3. **Obturator hernia.**—In this form the gut, pushing before it the peritoneum, the subperitoneal fat, and the pelvic fascia, escapes through the obturator canal (Fig. 82, p. 368). The direction of this canal is, from behind, downwards, forwards, and inwards. The inguinal is separated from the femoral canal by the inner part of Poupart's ligament; the femoral is separated from the obturator by the horizontal ramus of the pubis.

Beyond the canal the hernia may pass between the obturator membrane and the obturator externus muscle and remain deeply placed, or it may make its way through the muscle or emerge above it and be then covered by the pectineus and adductor brevis. The obturator artery is, as a rule, at the outer and posterior part of the sac; it is very rarely in front of it. The obturator nerve is generally found to the outer side of the sac; less commonly it is in front of it. The proximity of the nerve renders it very liable to be pressed upon, and pain along the nerve is often a marked feature of the rupture. The hernia presents beneath the pectineus muscle, to the inner side of the capsule of the hip, behind and to the inner side of the femoral vessels, and to the outer side of the adductor longus tendon. Pain on moving the hip is generally a conspicuous symptom. The obturator externus may be made tense by rotation inwards of the slightly abducted thigh. This hernia is much more common in females; and it is worthy of note that the orifice of the obturator canal can be examined, to some extent, through the vagina.

4. **Rare forms of hernia.** — In **perineal hernia** the sac, covered by the fascia of the abdominal aspect of the pelvic diaphragm (*recto-vesical fascia*), escapes through the anterior fibres of the levator ani muscle, between the prostate and the rectum. In **ischio-rectal hernia** the protrusion takes place into the ischio-rectal fossa. In **pudendal hernia** the sac lies in the posterior inferior half of the labium pudendi, escaping between the ascending ramus of the ischium and the vagina; it has been mistaken for a cyst. In **sciatic hernia** the gut escapes through the great sacro-sciatic notch in front of the internal iliac vessels, above or below the pyriformis, and presses under the gluteus maximus muscle. As regards **umbilical hernia,** nothing remains to be added to what has been already said (p. 354), save that the sac from its position nearly always contains omentum, and may contain stomach. In **lumbar hernia** the gut escapes in front of the quadratus lumborum muscle, and appears on the surface through the triangle of Petit

(the gap between the latissimus dorsi and the external oblique muscles), and therefore just above the highest point of the iliac crest. The sac must either force before it or (in cases of injury) come through the fascia lumborum and internal oblique muscles, since these structures form the floor of the triangle. A hernia may escape through the "upper lumbar triangle"—a gap near the last rib where the aponeurosis of the transversalis is covered only by the latissimus dorsi. Macready (*Lancet*, November 8, 1890) collected twenty-five examples of this hernia. **Diaphragmatic hernia*** may be congenital or acquired. The former variety is by far the more common, and is due to simple arrest in the development of the diaphragm and persistence of the original connexion between the thorax and abdomen; the position of this connexion is marked by the fibrous interval between the muscular fibres arising from the last rib and those springing from the external arcuate ligament (lateral lumbo-costal arch). The congenital form very rarely occurs on the right side, the development of the liver securing the closure of the pleuro-peritoneal opening on that side. In the acquired form, which is usually the result of a crushing accident, the diaphragm may be lacerated at any point, but in the majority of instances the lesion is situated in the left dome over the stomach. In an adult subject dissected by Dr. N. Paterson the abdominal contents of the left hypochondrium occupied the left pleural cavity; there was a large aperture in the left dome; the condition had not been recognized during life and apparently had given rise to no marked symptoms. Such cases of unrecognized diaphragmatic hernia are not uncommon; but symptoms of obstruction are apt to occur ultimately. Of the organs, the stomach is the most frequently dislodged, then the transverse colon, omentum, small gut, spleen, liver, pancreas, and kidneys, in the order named.

* For a description of the various forms, see Keith, *Brit. Med. Journ.* Oct. 29, 1910.

The hernia may escape through the *foramen for the gullet*, but never through that for the vena cava, nor through the hiatus aorticus. A partial hernia of the stomach through the œsophageal orifice is not uncommon. Mr. W. A. E. Waller has recorded the case of a young man aged 19 who died with obscure symptoms of obstruction. The stomach was found incarcerated in the œsophageal orifice, the greater part having passed into the left pleural cavity. The parts commonly selected are the connective-tissue intervals between the sternal and costal origins of the diaphragm in front and its vertebral and costal origins behind. These herniæ are more common in males.

Femoral and inguinal diverticula.—Recently Mr. R. W. Murray has called attention to the frequency with which diverticula of peritoneum are found over the openings of the femoral and inguinal canals (*see* Fig. 82, p. 368). In 200 post-mortem examinations he found 52 femoral and 13 inguinal diverticula and yet no hernia. In some cases the inguinal sacs may be formed from the processus vaginalis, but all the femoral forms and probably the majority of the inguinal are caused by yielding of the fibrous tissue of the parietes over the femoral and internal abdominal rings. In these regions the peritoneum is elastic and so loosely bound to the abdominal wall that it may be evaginated by even a low degree of intra-abdominal pressure. In all forms of treatment, measures should be taken to secure a firm adhesion of the peritoneum in the region of the abdominal and femoral rings.

Posterior Abdominal Parietes

The lateral and posterior walls of the abdomen are lined inside with two **fasciæ**, the transversalis and iliac. The **transversalis fascia** lines the whole of the transversalis muscle, and is much thicker below than above. Above, it joins the fascia covering the diaphragm, while below it is attached to the iliac crest and to the whole of the inguinal ligament, save at that spot where it passes into the thigh to form the anterior layer of the femoral sheath. The **iliac fascia** encloses the ilio-psoas muscle, the part over the psoas being the thinner. This part is attached on the inner side to the sacrum, and to the spine at the points corresponding to the psoas origin. Above, it is attached to the ligamentum arcuatum internum (lateral lumbo-costal arch), and on the outer side to the anterior layer of the lumbar fascia along the outer edge of the psoas. Below, the fascia encloses the iliacus, and is attached to the iliac crest, to the pelvic brim, and to the inguinal ligament, save at that part where the membrane passes beneath the ligament to form the posterior wall of the femoral sheath. It follows the ilio-psoas muscle to its insertion, and ends by blending with the fascia lata.

The arrangement of these fasciæ greatly influences the progress and direction of **abscess.** Thus an abscess placed beneath the transversalis fascia will point either just above the iliac crest or the inguinal ligament, or run down along the spermatic cord and distend the inguinal canal.

The iliac fascia encloses the ilio-psoas in a very distinct osseo-aponeurotic space. Between the fascia and the muscle (especially its iliac division) there is a good deal of loose connective tissue, and thus every facility is offered for the progress of subfascial abscesses in this region. The osseo-aponeurotic space is practically closed on all sides within the abdomen, and is only open below where the fascia passes with its muscle into the thigh. This opening being at the most dependent part of the space, it follows that the psoas or iliac abscess very commonly points on the upper part of the thigh, just to the outer side of the femoral vessels. An **abscess in the iliac fossa,** although most likely to reach the thigh, might mount up to the superior attachments of the fascia, and point at the iliac crest or at the outer part of Poupart's ligament. Or it might disregard the inner attachments of the fascia and gravitate into the pelvis. If the patient should occupy for long the recumbent posture, there is no reason why it should not extend upwards along the psoas muscle.

The term *iliac abscess*, however, is often applied to collections that are not within the space formed by the iliac fascia, but that are situated rather in the subperitoneal connective tissue. This tissue is very extensive and lax in the iliac fossa in order to allow the expansion of the peritoneum which necessarily attends the filling and emptying of the cæcum, colon, bladder, uterus, and rectum. Large collections of purulent matter may form in it or may spread into it from the pelvis. Some distance above Poupart's ligament (1½ to 2 inches) the subserous tissue becomes dense and the peritoneum closely bound down. Hence such abscesses remain in the iliac fossa, bulging out the abdominal wall just above the inguinal ligament, and occupying the angle formed by the union of the iliac and transversalis fasciæ. In some cases they are disposed to extend into the pelvis.

The abscess, when in the subserous tissue, is brought into close contact with certain of the viscera, especially with the cæcum and the iliac colon, and into these portions of the colon it may open. Thus, I (F. T.) have seen a case of iliac abscess due to pelvic necrosis which opened into the iliac colon, and at the same time discharged through sinuses about the groin. In this case some pus passed by the anus, while on the other hand some fæcal matter escaped by the groin. Retroperitoneal abscesses in the pelvis (pelvic cellulitis) may mount up into the iliac fossæ, may appear as "iliac abscesses," and may ultimately discharge themselves by many openings in the lower parts of the anterior abdominal wall.

It may be well to note that the common and external iliac vessels, the lymphatics, and the ureters are *outside* the iliac fascia, and rest upon its abdominal surface, while the anterior crural nerves and abdominal parts of the lumbar nerves are *within* the osseo-aponeurotic space. Thus the intrafascial abscess may, with little difficulty, reach the thigh by following the iliac vessels; while the extrafascial collection would pursue the anterior crural nerve.

A psoas abscess, or abscess within the fascial sheath of the psoas muscle, is usually due to spinal caries, although it may appear independently of that disease. If the lumbar spine be involved the matter can pass directly into the substance of the muscle, which it will more or less entirely destroy. If the mischief be in the dorsal spine, the matter gravitates along the front of the column until it reaches the diaphragm, which it pierces by an inflammatory process. It is now brought into relation with the heads of the psoas, and has to pass through a narrow strait. The pus, following the muscle, at last reaches the thigh, and usually points, just below the groin, to the outer side of the femoral vessels. The substance of the psoas may be completely replaced by an abscess cavity.

Lumbar region.—The muscles which form the lateral and posterior walls of the abdomen, and fill in the interval between the iliac crest and the lowest rib, are the external oblique and latissimus dorsi, the internal oblique, the transversalis muscle with its fascia lumborum, the erector spinæ, and quadratus lumborum. The distance from the iliac crest to the tip of the nearest rib (usually the eleventh) varies from 3 to 7 cm., the average being 4·8 cm., a little less than 2 inches (Addison).

The external oblique and latissimus dorsi muscles are separated by a small triangular interval below (the triangle of Petit), but above they overlap. The interval is most pronounced in women. The outer border of the erector spinæ (sacro-spinalis) affords a useful landmark in the lumbar region. At the crest of the ilium the outer border of the quadratus lumborum extends an inch beyond the erector spinæ, but at the twelfth rib it lies an inch internally to that muscle (Fig. 100, p. 447). The triangle of Petit is $1\frac{1}{2}$ to 2 inches beyond the erector spinæ, or just behind the mid-point of the iliac crest.

Between the last rib and the iliac crest is stretched the dense fascia lumborum, the posterior aponeurosis of the transversalis muscle. It is pierced near the rib by the last intercostal artery and nerve, and near the ilium by the ilio-hypogastric nerve and its accompanying artery. It is along these structures that an abscess may possibly find its way through the fascia in certain cases. The fascia divides behind into three layers, to enclose in definite spaces the quadratus and erector spinæ muscles, the middle layer passing between these two muscles to the tips of the transverse processes. Within these spaces or compartments suppuration may be for some time limited. A lumbar abscess commencing in some adjacent part, as in the spine or in the loose tissue around the kidneys, usually spreads backwards by piercing the fascia lumborum or the quadratus muscle.

Treves's operation for caries of the lumbar vertebræ.—The lumbar vertebræ, and, possibly, the last dorsal, may be reached by an incision through the loin. A vertical cut is made along the outer edge of the erector spinæ muscle. The fibres of that muscle having been drawn aside, the middle layer of the fascia lumborum is incised, and the quadratus lumborum is exposed. This muscle is divided vertically, and then the front of the vertebræ may be reached by introducing the finger under the psoas muscle. Through such an incision a sequestrum representing the whole of the body of the first lumbar vertebra has been removed. The lumbar arteries are avoided by keeping close to the transverse processes of the vertebræ. Through this incision a psoas abscess may be most conveniently opened.

CHAPTER XVIII

THE PERITONEUM AND ALIMENTARY TRACT

The peritoneum.—Certain of the viscera, as for example the stomach, spleen, and small intestine, are so closely invested with peritoneum that they could not be wounded without that membrane being wounded also. Inflammatory affections of such viscera are also very apt to involve the peritoneum. Other organs, such as the kidney, descending colon, pancreas, etc., are so imperfectly covered with the serous membrane that a wound of those organs need not involve it, nor need it be implicated in even extensive inflammatory changes. Large abscesses may, for instance, form about the kidney and discharge themselves through the skin without any peritonitis being induced. Spontaneous perforation of the small intestine must involve the peritoneum,. while, on the other hand, the duodenum and ascending colon may become perforated, and the matter escape into the subserous tissue without the serous membrane being in any way involved. It is noteworthy in connexion with bacterial infection that it is singularly easy to set up inflammation of the peritoneum if the membrane be approached from its inner surface, but comparatively difficult if it be approached from without. Thus a small puncture of the membrane may, on the one hand, lead to fatal peritonitis, while, on the other, it may be extensively torn from its attachments (as in ligaturing the common iliac artery from the side) without any peritonitis following. Or, again, a little pus escaping on the inner surface of the membrane may lead to inflammation, while the outer surface may be bathed with pus for a long while (as in large perirenal abscesses) without any peritonitis being produced. To understand these effects one must remember that septic matter, on the free surface of the peritoneum, has open to it an enormous area over which it may spread unrestrainedly and from which it may be readily absorbed. Indeed, we know that fluid substances pass quickly from the peritoneal cavity into the lymphatic system. Carmine particles suspended in fluid are found within the thoracic duct seven minutes from their injection within the cavity; absorption takes place most rapidly in the subdiaphragmatic area (Dunbar and Remy). Inflammation of the peritoneum may lead to the formation of a great variety of bands and adhesions, beneath which pieces of intestine may be caught and strangulated.

The peritoneum will allow of very considerable stretching if only that stretching be effected gradually. This is frequently seen in cases of gradual distension of the bowel, in the formation of the sac in hernia, and in the growth of retroperitoneal tumours. Abrupt stretching of the membrane leads to certain rupture of it. The parietal peritoneum may be ruptured by violence without damage to any of the viscera.

The **great omentum** is, from its position, very apt to be wounded. In small wounds of the front of the belly it very often protrudes and acts as an excellent plug to prevent the escape of other and more important structures. It is often found in hernia, especially in umbilical hernia, where it is almost constant. Its limits vary, and it has an inclination to the left side. This depends upon the fact that the omentum is developed from the mesogaster, and accounts for the fact that herniæ containing omentum are much more common on the left side. The omentum, like the other parts of the peritoneum, is apt to inflame, and to contract adhesions to the neighbouring parts. These adhesions are often of the greatest service in limiting inflammatory and hæmorrhagic extravasations, by matting the bowels together and forming spaces between them. In perforation of the bowel or appendix from disease, an opportune adhesion of the omentum over the aperture may prevent escape of the intestinal contents.

Large masses of tissue may be nourished through an adherent omentum. Thus, when the proper blood supply of an ovarian tumour has been cut off by twisting of its pedicle, the growth may be nourished through the omentum, if that structure is adherent to it. Rutherford Morrison proposes to relieve congestion of the portal circulation by setting up an anastomosis between the omental vessels and the systemic circulation. When an adhesion between the omentum and parietal peritoneum is produced artificially, large anastomotic vessels open up and communicate with the vascular network beneath the parietal peritoneum, thus possibly relieving tension in cases of obstructed portal circulation. In cases of obesity fat collects conspicuously in the great omentum. In herniæ the omentum generally contracts adhesions to the sac, and becomes irreducible, or it may form a kind of second sac about the gut itself ("omental sac"). The end of the omentum, by becoming adherent to distant parts, as to the pelvic viscera, may form itself into a firmly attached band, beneath which the bowel may be fatally strangled. In like manner the intestine has been strangulated through slits and holes that have developed in the omentum, usually as a result of inflammatory adhesions. The functional meaning of the great omentum is by no means definitely established, but it undoubtedly increases the absorptive area of the peritoneum, and evidence is not lacking to show that it takes an active part in repelling bacterial invasions of the peritoneal cavity. Thus, Dr. B. H. Buxton found that the mononuclear white corpuscles of the omentum of rabbits were soon laden with typhoid bacilli in cases where artificial cultures had been introduced within the peritoneal cavity.

The mesentery.—The parietal attachment of the mesentery is liable to some variation. The point at which this attachment commences above is practically constant. It corresponds with the ending of the duodenum, is about on a level with the lower border of the pancreas, and is just to the left of the second lumbar vertebra. (*See* p. 394.) From this point the insertion of the mesentery follows an oblique line that runs downwards and to the right, crossing the great vessels, and then ending in a somewhat uncertain manner on the right iliac fossa (Fig. 85, p. 392). The parietal attachment of the mesentery measures, as a rule, about 6 inches. From its oblique attachment it follows that, when hæmorrhage takes place in the abdomen on the right side of the mesentery, the blood first is conducted into the right iliac fossa; when on the left side, into the pelvis. This may explain the circumstance that collections of blood are more common in the right than in the left iliac fossa.

The length of the mesentery from the spine to the bowel varies in different parts of the canal; its average length is 8 inches. The longest part is that which goes to the coils of intestine lying between a point 6 feet from the duodenum and a point 11 feet from the same part of the gut (Treves).* Such coils will, therefore, include 5 feet of the intestine, and the mesentery here may reach the length of 10 inches. These coils are habitual occupants of the pelvis, and may be easily herniated. If the fresh body of an adult be opened, and the condition of the viscera and peritoneum be normal, it will be found that it is impossible to drag a loop of small intestine through the femoral canal (artificially

* *See* "The Anatomy of the Intestinal Canal and Peritoneum in Man." London, 1885.

enlarged) on to the thigh, or down the inguinal canal into the scrotum. In fact, no coil can, in any part, be drawn out of the abdomen below a horizontal line on a level with the spine of the pubes. It is evident, therefore, that in femoral or scrotal hernia the mesentery must be elongated or its attachments lowered.

Certain holes are sometimes found in the mesentery, through which intestine has been strangulated. Some of these holes, especially those that are slit-like, are due to injury, others are due to absorption from pressure or congenital defect of the mesentery.

Cases of *imperfect attachments of the mesentery* have been frequently recorded of late years. The primary attachment is at the origin of the superior mesenteric artery, from which point a process of peritoneal adhesion or fixation extends during the fœtal life towards the right iliac fossa. If this process is completely arrested then, the whole intestine may become rotated round the superior mesenteric artery, causing obstruction of the bowel, or, if only the lower part of the mesentery remains unattached, the loop formed by the lower part of the ileum and commencement of the great bowel may undergo a rotation and cause obstruction. It is important to remember that there are *two kinds of peritoneal adhesions* or *bands*, those formed during fœtal life when the mesentery and bowel are being fixed to the posterior wall of the abdomen (developmental adhesions), and those formed in later life as the result of disease (pathological adhesions).

Peritoneal spaces and communications.—Owing to the arrangement of the peritoneum the cavity of the abdomen is divided into a number of *potential spaces* which are connected together by certain definite communications or routes. Alimentary contents, pus, or blood escaping within the peritoneal cavity tend to collect in certain of these spaces and overflow into neighbouring spaces in well-defined directions. Some writers see in this arrangement of the peritoneum a resemblance to the watersheds of a country, and hence the potential spaces and routes are sometimes spoken of as the "watersheds of the peritoneum." The chief of these spaces are: (1) The *lesser sac*. This communicates with (2) the *subhepatic space* by the foramen of Winslow; the space is bounded above by the under-surface of the liver and below by the duodenum, hepatic flexure of colon, transverse mesocolon, right kidney, and right costo-colic ligament (Fig. 85). (3) The *right subphrenic space* between the diaphragm and liver; it is bounded towards the middle line by the falciform and coronary ligaments; below it opens into the subhepatic space. (4) The *left subphrenic space*, between the diaphragm above and left lobe of liver and stomach below; it is separated from the corresponding right space by the falciform ligament; below it communicates with (5) the *perisplenic space;* this space is bounded below by the splenic flexure and its mesocolon, the left costo-colic ligament, and left kidney. These five spaces lie in the *supra-omental region* of the abdomen—above the transverse mesocolon. Below the transverse mesocolon there are two spaces, normally occupied by small intestine; they are (6) the *right infra-omental*, bounded above by the transverse mesocolon, below and to the left by the duodeno-jejunal junction and root of the mesentery; (7) the *left infra-omental*, bounded above by the transverse mesocolon; it is separated from the right space by the duodeno-jejunal junction and mesentery of the small bowel. The remaining space—the eighth—lies in the pelvis, the recto-uterine in the female, the recto-vesical in the male. Communications between the supra- and infra-omental spaces exist only at the two extremities of the transverse mesocolon. Overflow from the subhepatic spaces tends to pass down the groove external to the ascending colon (right external paracolic groove); by that groove it reaches the iliac fossa; from the iliac fossa, the pelvic space; from the pelvis it may mount to the left infra-omental pouch, and from there the fluid matter may make its way to the left external paracolic groove and thence to the perisplenic space. In this description the writings of Barnard, Wallace, Box, Jenkins, and Maynard Smith have been followed.

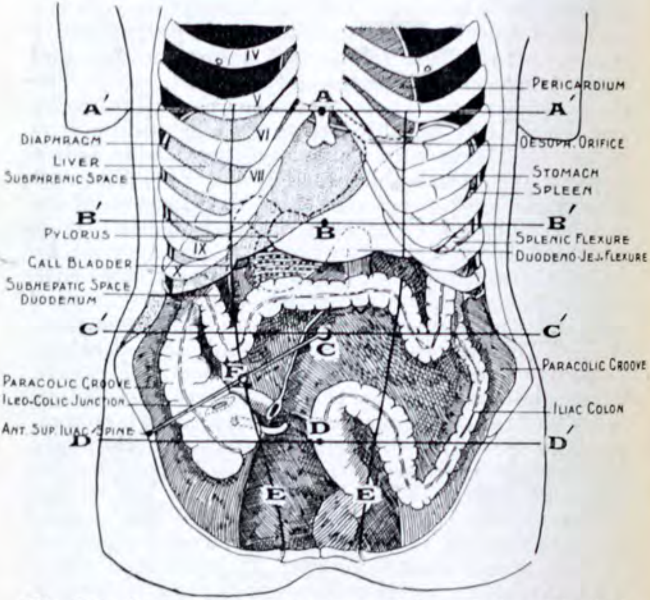

Fig. 85.—Showing the average position of the abdominal viscera with their surface markings. (*After Addison.*)

A, Sterno-ensiform point; A′A′, sterno-ensiform line; B, mid-epigastric point; B′B′, mid-epigastric or transpyloric line; C, umbilical point; C′C′, umbilical line; D, mid-hypogastric point; D′D′, mid-hypogastric line; E E, outer border of the right and left rectus abdominis; F, Monro's point—on the right spino-umbilical line at the outer border of the rectus abdominis.

Surface markings of the abdominal viscera.—In Fig. 85 is shown the position of the abdominal viscera in an average individual, while in Fig. 86 is represented the position assumed by these viscera in a well-marked case of **visceroptosis (Glénard's disease).** Study of such cases, especially with the aid of X-rays, shows the need of an accurate and simple method of indicating the normal position of the abdominal contents. The

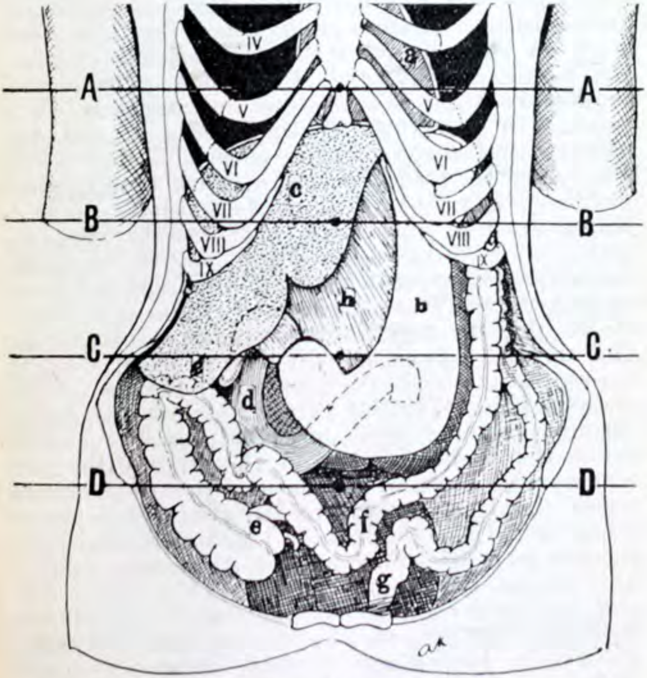

Fig. 86.—Showing the position of the viscera in the condition of visceroptosis.

A A, Sterno-ensiform line: it crosses above the fifth costal cartilage; B B, mid-epigastric line; C C, umbilical line; D D, mid-hypogastric line; *a*, pericardium; *b*, stomach (greatly elongated and dilated); *c*, liver; *c'*, the lingual or Riedel's process; *d*, duodenum; *e*, cæcum; *f*, transverse colon; *g*, rectum; *h*, elongated gastro-hepatic omentum.

N*

upper limit of the viscera is best indicated by the sterno-ensiform (sterno-xiphoid) point and line. The position of the *sterno-ensiform point* is indicated by a distinct depression under the insertion of the seventh pair of costal cartilages; the *sterno-ensiform line* is drawn transversely on the body through this point and should cross the fifth pair of costal cartilages if the thorax is of normal shape. The right dome of the diaphragm, in the standing posture, reaches this line; the left dome is ½ an inch below it; in the supine position the domes rise upwards ½ an inch. The central tendon is ½ an inch below the sterno-ensiform point. In visceroptosis the domes of the diaphragm and viscera within them sink downwards until they lie 1 inch or more below their normal position (Fig. 86). The *mid-epigastric point* is taken on the linea alba half-way between the umbilical and sterno-ensiform points; the *mid-epigastric line* (transpyloric plane of Addison) crosses the body at this point; it marks the level of the pylorus and pancreas, with the beginning and termination of the duodenum (Fig. 85). In visceroptosis the parts sink until they reach the umbilical line (Fig. 86). The *umbilical line*, drawn through the umbilicus, usually crosses somewhat below the highest point on the iliac crests; the transverse colon and duodenum cross the abdomen above the line, the bifurcation of the aorta is below it. In visceroptosis the transverse colon, pyloric part of stomach, and duodenum descend well below the umbilical line (Fig. 86). The *mid-hypogastric point* is taken on the linea alba half-way between the umbilicus and symphysis pubis; it lies about 1 inch below the promontory of the sacrum. The *mid-hypogastric line* crosses the iliac colon in the left groin and the fundus of the cæcum in the right. The outer border of the rectus abdominis (linea semilunaris) also serves as a useful guide; at the point where it crosses the costal margin on the right side (*right costo-rectal point*) is situated the gall-bladder; on the left side the greater curvature of the stomach emerges from the hypogastrium at this point (Fig. 85). A line drawn from the umbilicus to the right anterior superior iliac spine (*spino-umbilical line*) provides a useful guide to the ileo-cæcal region. *Monro's point* is situated on this line at the outer border of the rectus abdominis; the ileo-cæcal orifice lies to the right of Monro's point immediately below the spino-umbilical line. In certain common pathological states of the great bowel, and in nearly all cases of partial or complete visceroptosis, the ileo-cæcal junction is displaced towards the pelvic brim.

The viscera are maintained in position by the action of several structures, but by far the chief are the muscles of the abdominal wall—the external and internal oblique, transversalis, rectus abdominis, diaphragm, and levator ani. By their contraction or tonus they maintain the viscera firmly pressed together; in the upright posture the weight of the upper viscera rests on the lower viscera. In rising from the supine to the upright posture the upper viscera and diaphragm are seen in the living body (by aid of X-rays) to descend about ½ an inch or more. When the muscles and belly-walls are cut away, and the dead body raised to the upright position, all the viscera drop downwards to the extent of 2 inches or more. The peritoneal ligaments, reflections, omenta, and mesenteries merely limit the degree of movement; the viscera are freely movable to allow the extensive respiratory action of the diaphragm. Besides the peritoneal, there are other visceral supports formed by vessels and their sheaths of connective tissue, such as the attachment of the liver to the diaphragm by the inferior vena cava, the kidneys and small intestine to the posterior abdominal wall by their vessels. It is only when the muscles of the belly-wall are thrown out of action that any strain or weight falls on the peritoneal and vascular supports.

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The transport mechanism of the alimentary tract.—It must never be forgotten that the living alimentary tract—and it is with the living tract we have to deal in all clinical cases—represents a mechanism for the transport of food from the mouth to the anus, through a circuitous route, some 29 feet in length in the average adult. From the time the food enters the tract until the residue is expelled, it is handled, controlled, and propelled by the muscular system—the longitudinal and circular coats—of the tract; it is urged by a complex series of timed operations from section to section of the tract, in each of which certain processes of digestion and absorption are carried on. It is quite clear that, for orderly transport along such a busy road, there must be an elaborate signal-block system such as railway transport has made us familiar with in everyday life. When we look at such a diagram of the alimentary tract as appears below (Fig. 87), we see that the tract is divided into sections. Each section is separated from the next by a sphincteric point or tract. There is, in the first place, the œsophageal section, some 10 inches in length; it is separated from the pharyngeal tract by the *lower pharyngeal* or *upper œsophageal sphincter;* it is separated from the gastric section by the *lower œsophageal* or *cardiac sphincter.* At each of these sphincteric points food is temporarily delayed and regulated in its transit. The gastric section extends from the cardiac to the *pyloric sphincter*, a distance which is ever varying but may be stated as being on the average from 4 to 6 inches. The pyloric sphincter delays and regulates the passage of the food. Then follows the duodenal section, some 10 or 12 inches long; X-ray observations show a *duodenal sphincteric mechanism* in its third or terminal part, especially active under certain pathological conditions. Now comes the long ileo-jejunal tract, which in a relaxed state may measure 25 feet, and a short time after-

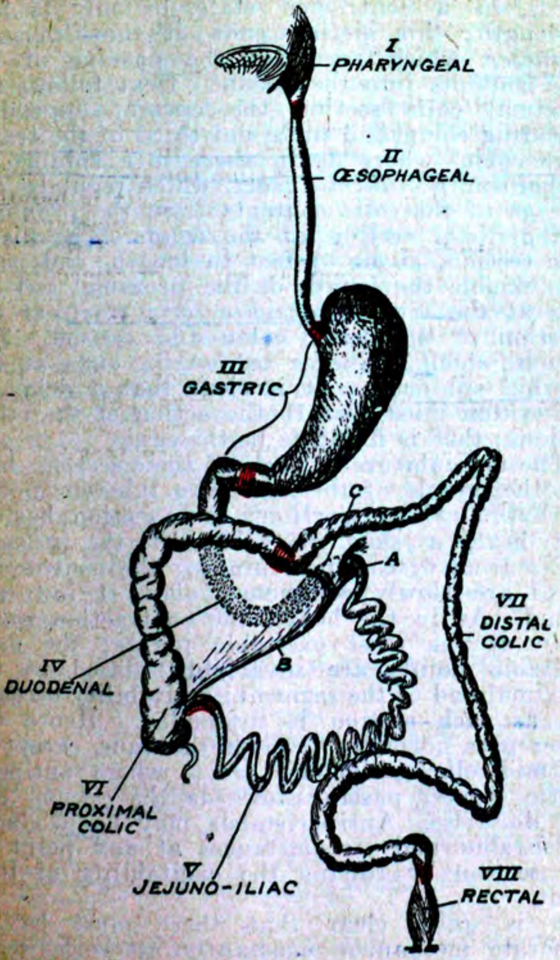

Fig. 87.—Diagram to show the sections and sphincteric points in the alimentary tract.

A, B, C, Peritoneal folds by which the vagal and splanchnic nerve fibres pass to important points in the alimentary tract.

wards, in a contracted state, be only 15 feet in length; this section ends at the *ileo-cæcal sphincter*, which regulates the passage of the iliac contents into the cæcum. Next follows the proximal colic section—the cæcum, appendix, ascending colon, and proximal third of the transverse colon—where again there is a sphincteric mechanism, a *mid-colic tract*, which regulates the passage of the colic contents from the proximal to the distal section of the colon. The distal colic section, about 3½ feet in length, and more than double the length of the proximal section, ends at the *recto-colic sphincteric tract*, at the junction of the pelvic colon and rectum. The rectum, about 8 inches in length, ends at the internal sphincter. It is clear that a delay in one section must disturb the action of the other sections; that is found to be the case.

The musculature of each of these sections has, like the muscle of the heart, an inherent power of rhythmical contraction; each section has its own beat, a slow one—that of the stomach varies from 6 to 8 per minute; the contraction waves are slowly conducted, about 1 inch per second. As in the heart, the contraction waves begin at the most excitable points; the most excitable points are invariably placed at the proximal end of the segment; excitability becomes less as each section is descended. Hence the waves pass normally towards the anus, except at the mid-colic sphincteric tract, where antiperistaltic waves, passing towards the cæcum, can and do arise. Antiperistalsis may be produced under abnormal circumstances at any point in any section by raising the excitability of that point.

It is quite clear that there must be an elaborate mechanism constantly at work, regulating and harmonizing the action of the various segments. We know, for example, that when the gastric section passes into action on taking food, a simultaneous action is set up in the distal ileum. We know, too, that when disease of the cæcum, appendix, or proximal colon is present, there is a stasis in the lower ileum due to the contraction of the ileo-cæcal sphincter, and there is a disturbed or retarded action in the gastric and duodenal sections. Such results can be produced experimentally when all nerves issuing from the medulla and spinal cord—the vagi, dorsal sympathetic, and pelvic nerves—are cut. These reactions are not brought about by a central but by a peripheral mechanism, resident in peripheral nerve plexuses and connected ganglia, particularly in the *myenteric* (Auerbach's) *plexus*, which is situated between the outer or longitudinal and inner or circular coats of the tract. We know that the central nervous system can and does affect the motor system of the tract through the vagal, sympathetic, and pelvic efferent nerves, but they exercise that power not directly but through the mediation of the peripheral system lying within the walls of the tract. With these general principles constantly kept in mind, we may now take up more profitably the consideration of the various structures in a more strictly anatomical manner.

The stomach.—The relationships of this organ are—

	Above. Liver, small omentum, diaphragm.	
In front. (From left to right) diaphragm, abdominal wall, liver.	**Stomach.**	*Behind.* Transverse mesocolon, lesser sac, pancreas, crura, solar plexus, great vessels, spleen, left kidney, and suprarenal.
	Below. Great omentum, small intestines, transverse colon, gastro-splenic omentum.	

The œsophagus perforates the diaphragm slightly to the left of the middle line and ends at the *cardiac orifice* of the stomach, 3 to 4 inches deep to the terminal inch of the seventh left costal cartilage. The *pyloric orifice*, permanently closed by its sphincter except when the contents of the stomach are passing to the duodenum, is situated on the mid-epigastric plane and about 1 inch to the right of the linea alba in the dead body, but in the living, especially in the upright posture, its position is lower, being slightly to the right of the linea alba and about 2 inches above the umbilicus (*see* Fig. 85). Being situated under the quadrate lobe of the liver and bound to the transverse fissure (porta) by the gastro-hepatic omentum, the pylorus is necessarily displaced by enlargement or displacement of the liver; in cases of visceroptosis it may drop to the umbilical line (Fig. 86). Normally the *lesser curvature* is overlapped by the liver, and the gastro-hepatic omentum is hidden (Fig. 85), but when the stomach becomes dilated, elongated, or falls down, the lesser curvature and gastro-hepatic omentum are exposed (Fig. 86). A curved line drawn from the position of the cardiac orifice (on the seventh left costal cartilage, 1 inch from the sternum) to the position of the pylorus (midway between the epigastric point and right costal margin) indicates the normal position of the lesser curvature. While the lesser curvature is comparatively fixed, owing to the attachment of the gastro-hepatic omentum, the greater curvature is freely movable; its position alters as the stomach is full or empty, contracted or relaxed. The variable position of the great curvature as seen in the living is represented in Fig. 88 from observations made by Dr. A. F. Hurst. When the patient is standing, the great curvature descends to the umbilicus or below it; when lying down, the great curvature is an inch or more above the umbilicus. Simple *dilatation of the stomach* leads to a low position of the greater curvature without altering the position of the lesser curvature; in ptosis of the stomach both curvatures descend, but the greater descends more owing to dilatation being always present (Fig. 86). In ptosis the curvatures become more vertical in position (Fig. 86).

It must be remembered that even in healthy people the stomach varies both in shape and in position. In 60 young people, all apparently in good health, Dr. Alan Newton found that in 19 the great curvature was opposite to or above the umbilicus, while in 41 it lay below, in some cases far below, the umbilicus. In healthy people the stomach may be mainly confined to the epigastric region as in children, or extend to the hypogastric region as is common in the aged.

The **shape** of the stomach depends on many conditions: on its state of physiological activity,

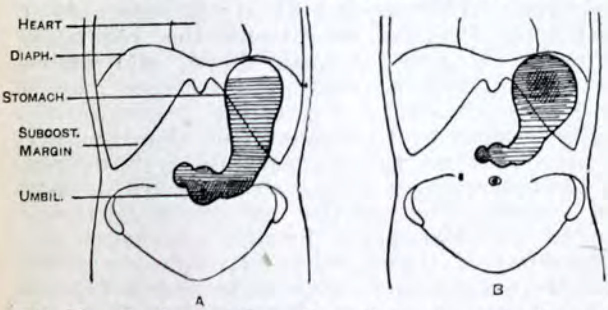

Fig. 88.—Radiographic outline of the stomach of a patient who has taken a bismuth-laden diet. (*After Dr. A. F. Hurst.*)

A, Standing position ; B, horizontal position.

on the pressure of surrounding organs, and on its degree of fullness. In life, its cardiac and pyloric parts react differently during digestion; the cardiac part, which is vertical in position and constitutes about two-thirds of the organ, undergoes mainly a *tonic*, not a *peristaltic*, contraction. The pyloric part, tubular in shape and horizontal in position, is the seat of constant peristaltic waves during digestion. These waves sweep towards the duodenum along the pyloric division. The point at which they begin is often found contracted after death, and this observation has given rise to the opinion that the cardiac and pyloric divisions are separated by a mid-gastric sphincter. When food is swallowed, it passes at once into the pyloric division, and, as more food is taken, both divisions of the stomach fill (Dr. A. F. Hurst and Dr. A. E. Barclay). The fundus of the stomach, lying in the left dome of the diaphragm, always contains air both in the resting and in the active organ. The gastric cushion of air distends the left dome of the diaphragm just as the right dome is cushioned by the convexity of the liver. A gastric cushion of air is necessary for the normal action of the diaphragm. The amount of air is regulated in health; in diseased conditions the regulating mechanism is apt to break down, and distension results. When empty the stomach may be found to be diastolic or systolic; if systolic it is usually covered by the transverse colon, and does not present when the epigastrium is laid open. The two extremities of the stomach are its most fixed points. The cardiac extremity is loosely fixed to the diaphragm by the œsophagus, lax periœsophageal tissue, and gastro-phrenic reflections of peritoneum; the pyloric end is fixed to the liver and posterior abdominal wall by the gastro-hepatic omentum, by the hepatic branch of the cœliac axis and the tissue surrounding that vessel. The close relations of the stomach to the diaphragm and thoracic viscera serve in part to explain the shortness of breath and possible palpitation of the heart, etc., that may follow upon distension of the organ (Fig. 85). The near proximity of the heart to the stomach is illustrated by a case where a thorn (of the *Prunus spinosa*), ½ an inch long, had been swallowed and had then found its way through the diaphragm and pericardium into the wall and cavity of the right ventricle.

The viscus is susceptible of enormous dilatation when the pylorus is obstructed. The distended organ may reach as low as the pubes.

The stomach rests behind on the lesser sac of the peritoneum, which plays the part of a bursa to it. Gastric ulcers rarely perforate into the lesser sac, but when they do the contents can only escape by the foramen of Winslow, and may not be seen when the abdomen is opened. The sac is opened by incising the great omentum at the greater curvature of the stomach.

Wounds of the stomach.—In most cases a fatal result rapidly follows upon injuries to the stomach, for the contents of the organ escape into the peritoneal cavity and set up an acute peritonitis. The most certainly and rapidly fatal cases, therefore, are those in which the stomach was full of food at the time of the accident. A small punctured wound of the stomach need not be followed by escape of contents, since the loosely attached mucous membrane may escape from the wound and effectually plug it. This was illustrated many times in the Boer War and in the Great War, the viscus having been perforated by a Mauser bullet. In a few cases the belly-wall in front of the stomach has been wounded, the viscus has protruded, its anterior wall has been wounded by the same injury that penetrated the parietes, and a fistulous opening leading into the stomach cavity has resulted. The best example of such cases is afforded by the well-known instance of Alexis St. Martin, the subject of so many physiological experiments. In this man the abdominal parietes in front of the stomach were torn away by a gunshot wound, a part of the anterior wall of the stomach sloughed, and a permanent fistula resulted. Dr. Murchison reports the case of a woman in whom a gastric fistula was produced by the continued pressure of a copper coin worn over the epigastric region. This coin was deliberately worn by the patient in order to excite a lesion that would arouse the sympathy of her friends. The pressure led to an ulceration that finally opened up the stomach.

Some remarkable cases have been recorded where **foreign bodies** have been swallowed and have lodged in the stomach. Certain of these cases serve to illustrate the capacity of the stomach, and among the most striking is an instance where the viscus at death was found to contain 31 entire spoon-handles, each about 5 inches long, 4 half-handles, 9 nails, half an iron shoe-heel, a screw, a button, and 4 pebbles. The whole mass weighed 2 lb. 8 oz. The patient was a lunatic.

Lymphatics of the stomach.—The stomach is abundantly supplied with lymphatics, which commence in the mucous coat and form plexuses in the submucous and muscular strata, from which efferent vessels pass to glands along the lesser and greater curvatures. By these vessels primary cancers of the stomach spread, and hence their connexions become of surgical importance. The distribution of the glands connected with the stomach is shown in Fig. 89. The chief group —the *coronary*—is situated near the œsophageal orifice and along the upper part of the lesser curvature. The afferent vessels of this group are shown in Fig. 89; the efferent vessels pass with the coronary artery to the suprapancreatic group behind the lesser sac and near the origin of the cœliac axis from the aorta. The *subpyloric group* is situated below and behind the pylorus. It receives afferent vessels from glands along the greater curvature (right gastro-epiploic), and from the pylorus and duodenum; its efferent vessels pass with the hepatic artery to the *suprapancreatic group*, and some also end in the superior mesenteric group at the origin of the superior mesenteric artery. The efferent vessels of the subpyloric group are joined by the lymphatics from the liver (Fig. 89). (Jamieson and Dobson.)

Gastrotomy and **gastrostomy.**—Gastrotomy consists in opening the stomach through the anterior abdominal wall for the purpose of removing a foreign body, for making an examination, or for dealing with a simple or malignant ulcer;

gastrostomy, in opening the stomach in a like situation with the object of establishing a gastric fistula through which the patient may be fed in cases where the gullet is occluded by disease. The uncovered part of the stomach, accessible in these operations, is represented by a triangular area, bounded on the right by the edge of the liver, on

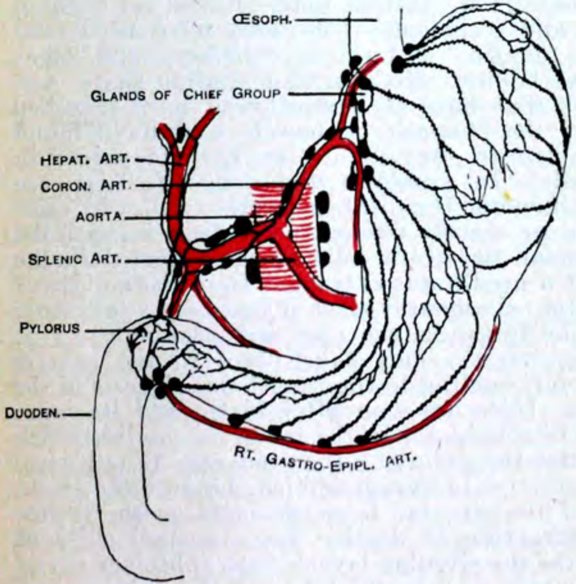

Fig. 89.—The groups of lymphatic glands connected with the stomach. (*Prof. J. K. Jamieson and Mr. J. F. Dobson.*)

the left by the cartilages of the eighth and ninth ribs, and below by a horizontal line passing between the tips of the tenth costal cartilages (Fig. 85). The incision in these operations must be situated in this triangle, and may be made either parallel to and about two fingers' breadth from the free border of the costæ, or along the left semilunar line. In the former incision the three flat muscles of the abdomen are cut through.

The **pylorus** is normally in a closed state, and should, when open, be capable of taking the forefinger. In spite of the narrowness of the pylorus, large substances that have been swallowed have been passed by the anus without trouble. Among these may be noted a metal pencil-case, 4¼ inches long, 10 oz. of garden nails, and fragments of crockery-ware, swallowed by a lunatic; a fork, a door-key, and other strange bodies. Needles and similar sharp substances that have been swallowed have travelled out of the stomach or bowels and have found their way to the surface at various points in the body. In a patient under my (F. T.'s) care at the London Hospital, a needle swallowed some months previously was extracted from beneath the skin, near the groin. In a case reported in the *Lancet* a needle was extracted from the middle of the thigh, six months after it had been swallowed; and like instances are recorded elsewhere.

Hypertrophy may take place in the pyloric sphincter, leading to the functional stenosis of the orifice. It occurs soon after birth, and its cause has to be sought for in the reflex mechanism which regulates the pylorus. It is not easy to tell when the sphincter is hypertrophied, because the thickness of the circular layer depends on the degree of contraction at death. In a normal child of 3 months the circular layer of the sphincter varies from 1 to 2 mm in thickness at the pylorus, and extends along the pyloric canal for 25 mm. (1 inch): if the thickness is over 3 mm. the sphincter may be regarded as hypertrophied (L. Mackey). Relaxation of the sphincter normally follows when the chyme expelled from the stomach has been neutralized in the duodenum. An acid condition of the duodenal contents inhibits sphincteric relaxation.

Resection of the pylorus.—The pylorus is frequently the seat of cancer. As a means of relieving the patient, the whole of the diseased pyloric region has been removed, and the divided ends of the stomach and duodenum united by sutures. The situation of the cancerous pylorus within the abdomen varies considerably, as the diseased part is very apt to shift its position. It is often found to have sunk down by its weight to a point below the umbilicus, and to have contracted adhesions to adjacent organs. The diseased part has to be isolated and the omental connexions of the right end of the stomach freely divided. The vessels that are almost certainly divided are the pyloric, the gastro-epiploica dextra, and the gastro-duodenal.

Gastrectomy.—Considerable portions of the stomach have been excited in cases of cancer, and the entire organ has been removed (total gastrectomy) for the same cause. Up to the time of writing, some fifteen examples of this operation have been recorded, with more or less immediate death in five. In Schlatter's first case of gastrectomy, performed in 1897, the patient died in fourteen months from secondary deposits. In a case operated on by Sir Berkeley Moynihan the patient survived the operation for six years and was able to lead a normal life. Ricord published a case in which he removed the whole stomach, the first piece of the duodenum, and part of the pancreas. The patient was alive and well eleven months after the operation (*Gaz. des Hôpitaux*, March 22nd, 1900). There is difficulty in uniting the gullet to the small intestine; both vagi nerves are divided as they emerge through the diaphragm, and the solar plexus is apt to be roughly handled.

Other operations on the stomach.—Many other operations are performed upon the stomach which call merely for mention in this place. One of the most useful and the most frequently performed is *gastro-jejunostomy*, where an opening (or stoma) is made between the stomach and the upper part of the jejunum. In this operation the transverse mesocolon is opened in order that the bowel may be applied to the posterior aspect of the stomach. In making the opening the middle colic artery and its larger branches are to be avoided. The operation is performed in cases of stenosis of the pylorus, in cases of dilatation of the stomach without much stenosis, in certain examples of ulcer, and in many other conditions. In the operation of *pyloroplasty* a non-malignant stricture of the pylorus is divided and the pyloric passage thus made free. In *gastroplication* certain conditions of dilated stomach are dealt with by taking in a fold or pleat in the stomach wall and thus lessening its capacity.

Small intestine.* — The average **length** of the small intestine in the adult is 22½ feet, the extremes being 30 feet and 15 feet, the length, to a considerable extent, depending on the degree of contraction of the longitudinal muscular coat. In the fœtus, at full term, the lesser bowel measures about 9½ feet. It is roughly reckoned that the first 8 or 9 feet of the adult bowel belong to the jejunum, and the remaining 12 or 13 feet to the ileum. The division into jejunum and ileum is quite arbitrary. There is no one point where it can be said that the jejunum ends and the ileum commences. When the small intestines are exposed by accident or operation, it is often difficult, especially when there is abdominal disease, to recognize the upper from the lower part of the gut. It may be noted, however, that the jejunum is wider than the ileum (its diameter being ¼ of an inch greater than that of the ileum), and that its coats are thicker and more vascular. If the gut be empty, and can be rendered translucent by being held against a light, the lines of the valvulæ conniventes can be well seen. These folds are large and numerous in the jejunum, but become small and scanty in the upper ileum, and are wanting in the lower third of that bowel.

* The account of the intestines is based upon the author's work "On the Intestinal Canal and Peritoneum in Man." London, 1885.

The coils of small intestine occupy no certain **position** in the abdomen. In the fœtus, and during the earliest part of extra-uterine life, the bulk of the small intestine is placed to the left of the middle line. This is on account of the relatively large size of the liver, to the weight of which the lesser bowel no doubt acts as a counterpoise. In the majority of adult bodies the small intestine is disposed in an irregularly curved manner from left to right. The gut, starting from the duodenum, will first occupy the contiguous parts of the left side of the epigastric and umbilical regions; the coils then fill some part of the left hypochondriac and lumbar regions; they now commonly descend into the pelvis, reappear in the left iliac quarter, and then occupy in order the hypogastric, lower umbilical, right lumbar, and right iliac regions. Before reaching the right iliac region they commonly descend again into the pelvis.

Much interest attaches to the coils of small intestine that are **found in the pelvis.** These are the coils that are apt to become involved and adherent in cases of pelvic peritonitis, and that would probably form the protrusion in most cases of obturator, sciatic, and pudendal hernia. No small intestine occupies the fœtal pelvis. The amount found in the adult pelvis depends mainly upon the state of distension of the bladder and rectum, and upon the position of the pelvic colon. The coils that are most usually found in this position belong to the terminal part of the ileum, and to that part of the intestine that has been already alluded to as possessing the longest mesentery (p. 389). The ileum is the part of the intestine that is most frequently found in inguinal and femoral herniæ. It is also the part most usually involved in cases of strangulation by internal bands, by holes in the mesentery, etc.

Of all the viscera, the small intestines are the most exposed to **injury**, and at the same time it must be noted that by their elasticity, and by the ease with which their coils slide over one another and so elude the effects of pressure, they are the best adapted to meet such injuries as contusions and the like. A minute punctured wound of the small gut does not lead to extravasation of contents. The muscular coat contracts and closes the little opening. Thus, in excessive tympanites the bowels are often freely punctured in many places with a fine capillary trocar, to allow the gas to escape, without any evil resulting. A case of intestinal obstruction of sixteen weeks' duration is reported, in which the abdomen was punctured 150 times (*Boston Med. Journ.*). If the wound be a little larger the loose mucous membrane becomes everted or protruded through the wound and effectually plugs it. Gross observed that a longitudinal cut in the small bowel 2½ lines in length was immediately reduced to a wound 1¾ lines in length by muscular contraction, and that the eversion of the mucous membrane in addition to this contraction entirely sealed the opening. Even the opening made in the intestine—for example, in the jejunum—by the penetration of a Mauser bullet may be attended by no escape of contents. A contracted empty piece of bowel becomes nearly twice as long when distended.

Owing to the greater power of the circular layer of muscle a longitudinal wound gapes more than a transverse wound, and, in consequence of the greater muscular development of the jejunum, wounds of that part gape more than do those of the ileum. Transverse wounds gape most when inflicted across the free border of the gut, since in that place the longitudinal muscular fibres are thickest.

In one remarkable case a man was stabbed in the belly. It was subsequently found that there was a small puncture in the ileum, which had been plugged by the mucous membrane and further secured by recent lymph. The man did well until the fourth day, when he died somewhat suddenly. It was then found that an intestinal worm (*Ascaris lumbricoides*) had worked its way through the wound, breaking down the adhesions, and had escaped into the peritoneal cavity. Extravasation followed, and thus the worm was the cause of the man's death.

The calibre of any portion of the small intestine depends mainly upon the condition of its muscular wall. The tube may become much contracted when empty. On the other hand, the muscular coats of a loop, or part of a loop, of bowel may pass into a state of permanent contraction or *intestinal spasm*, giving rise to symptoms of *intestinal obstruction*. Or a similar result may arise from an opposite condition—that of *paralysis*. If a piece of bowel is injured or cut (as may be necessary) in resection of the intestine, or is involved in a localized inflammation or peritonitis, it passes into a state of paralysis (*paralytic ileus* of Handley) and hence is unable to pass on the alimentary contents, which, therefore, collect and distend the segment of bowel proximal to the seat of injury or peritonitis.

Meckel's diverticulum.—From 1 to 4 feet from the end of the ileum is sometimes seen a diverticulum (Meckel's) (Fig. 90) which represents the remains of the vitello-intestinal duct (p. 355). It may be expected in 2 per cent. of the bodies examined. This diverticulum usually exists as a tube of the same structure as the intestine. Its length varies. It may sometimes extend as a patent tube as far as the umbilicus. It is more often but a few inches long, and may then end in a free conical or globular extremity, or in a fibrous cord. This diverticulum may cause intestinal obstruction in many ways. Its end may contract adhesions, and beneath the bridge thus formed a loop of bowel may be strangled. It may twist itself about a piece of intestine so as to form a knot round it. In more than one case it has been found in an external hernia. It may become invaginated and start an intussusception of the bowel. The lumen of the gut is often considerably diminished at or near the site of the diverticulum, and at this narrowing intussusception of the bowel may commence.

A loop of bowel may be strangulated over the remains of a patent vitello-intestinal duct (Fig. 90). The duct, if complete, ends at the umbilicus. The artery of the yolk-sac may also persist, and form a cord between the mesentery of the ileum and the umbilicus, and over this a loop of bowel may become strangulated. A

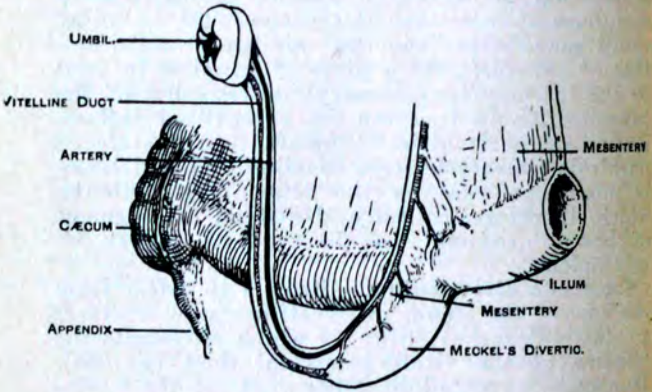

Fig. 90.—To show Meckel's diverticulum, the remains of the vitello-intestinal duct, and of the artery to the yolk-sac.

short cord may pass from the mesentery of the ileum to the fundus of the diverticulum, and between this and the diverticulum a knuckle of bowel may become incarcerated. Such a cord may arise in three ways: (1) from the proximal part of the artery of the yolk-sac, (2) from the free border of a mesentery with which the diverticulum may be provided, and (3) by the elongation of an inflammatory adhesion between the apex of the diverticulum and the mesentery (Fig. 90).

Duodenum and fossa duodeno-jejunalis.—The first portion of the duodenum is nearly horizontal. It measures about 2 inches in length and passes backwards from the pylorus to near the upper end of the right kidney. The second portion, about 3 inches in length, descends vertically in front of the inner border of the right kidney to the level of the third lumbar vertebra. The third portion, some 5 inches in length, crosses from right to left in front of the third vertebra, and then ascends for a short distance on the surface of the left psoas muscle, to end in the jejunum to the left of the second lumbar vertebra (Fig. 85, p. 392). The first portion, which is movable, is invested by peritoneum in the same manner as the stomach. The second part is covered by peritoneum in front only, except at the spot where it is crossed by the transverse colon. The third part is also covered by peritoneum on its anterior aspect only, this membrane being, however, free of the gut where the superior mesenteric vessels cross it. A sphincteric constriction is usually found near the termination of the third stage.

The end of the duodenum, the duodeno-jejunal bend, is very firmly held in place by a band of fibro-muscular tissue which descends upon it from the right crus of the diaphragm and the tissue about the cœliac axis. This band is called the suspensory muscle of the duodenum (Treitz). It serves also to support the mesentery. In ptosis of the viscera the neck of the pancreas and duodeno-jejunal bend are the least displaced parts because of their attachment to the posterior wall by the fibrous tissue round the cœliac axis and origin of the superior mesenteric artery. All sections of the duodenum have been ruptured by violence. Owing to its large non-peritoneal surface, the bowel, if approached from behind, may be wounded without opening the peritoneum.

Brunner's glands occur in the first stage of the duodenum; their secretion probably protects this part of the gut against the acid chyme which is only neutralized as it reaches the second stage. It is probably because of the nature of its contents that the first stage of the duodenum is so frequently the site of ulceration; over 90 per cent. of duodenal ulcers occur in the first stage (Collin). The ulcer may perforate and the contents escape into the subhepatic space, or adhesions may form to surrounding organs—the gall-bladder, the liver, the head of the pancreas, the right kidney, or the hepatic flexure of the colon.

Very frequently small **diverticula of the mucous membrane** are formed at the point where the common bile-duct perforates the muscle coat of the duodenum. They are often large enough to take the first joint of the forefinger, and occur especially in cases of ptosis of the viscera. In the newly born a complete *occlusion of the duodenum* may be found just above the entrance of the common bile-duct.

On the *left side* of the terminal part of the duodenum is the **duodeno-jejunal fossa.** Normally it is occupied or filled by the convexity of the terminal part of the duodenum, to which it serves as a bursa. The suspensory ligament or fold forms its upper crescent or border, its lower crescent being formed by another fold, the duodenal (Fig. 91). The fossa is only apparent when the duodenum is artificially displaced. The inferior mesenteric vein ascends near the left margin of the pocket (Fig. 91). This fossa is the anatomical cause of *mesenteric*, *mesocolic*, *mesogastric*, or *retroperitoneal hernia*. The commencement of the jejunum presses into the fossa, enlarges its cavity, and ultimately separates the peritoneum from its posterior attachments. It may spread in one or in all of three directions: to the right, behind the duodenum; to the left, behind the inferior mesenteric vein; or upwards, behind the suspensory ligament and root of the transverse mesocolon. More and more of the small intestine passes into the increasing pouch, until at last, as in the case reported by Sir Astley Cooper and in many others, nearly the whole of the small intestine may be found lodged in an enormous median retroperitoneal sac, the mouth of which is the orifice of the fossa duodeno-jejunalis. The duodenum can be seen to enter the sac and the end of the ileum to leave it. The sac usually extends downwards on the left

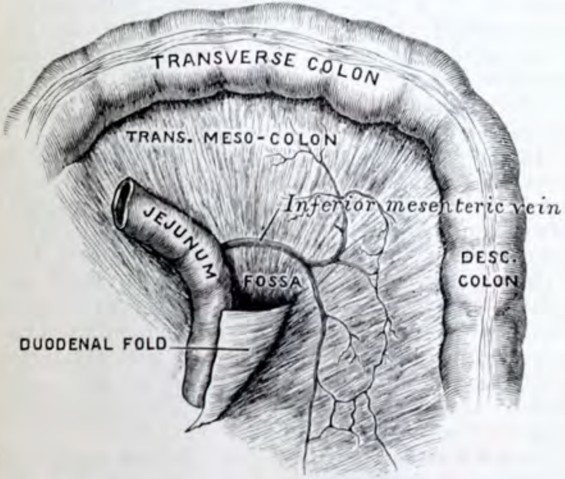

Fig. 91.—The fossa duodeno-jejunalis.

side, and may reach the promontory of the sacrum. In such hernia obstruction is apt to occur.

Operations on the small intestine.—*Enterotomy* is the operation of opening the small intestine above some obstruction that threatens to be fatal or insuperable. A knuckle of bowel, above the obstruction, is secured to the wound in the abdominal wall, and opened. The small intestine has also been opened to remove impacted foreign bodies and large gall-stones. In such cases the intestinal wound is closed immediately.

Enterectomy.—Parts of the small intestine have been resected with success for various diseased conditions. In one case more than two yards of the small intestine were cut away on account of multiple stricture. The patient, a young woman, made an excellent recovery. Resections have also been successfully performed in cases of bullet wound or stab involving the lesser bowel, and in other injuries. Tumours of the gut have been removed by a partial resection. Non-malignant strictures of the bowel have been treated by incision and dilatation. The bowel above an obstruction has been connected to the bowel below an obstruction by the operation called *intestinal anastomosis* or *short-circuiting*.

Experience shows that if leakage occurs after resection or suture of intestine it will most likely occur along the attachment of the mesentery. This circumstance is thus explained by Mr. Anderson: The two layers of the mesentery diverge as they approach the bowel, and so leave a triangular space, the base of which, averaging about $\frac{5}{16}$ths of an inch in width, is formed by the uncovered muscular tissue. It is the existence of this bare piece of intestine that renders adjustment of the serous coat at the attachment of the mesentery a matter of some difficulty.

Ileo-cæcal region.—The **cæcum** reaches only a moderate development in man, as also in the carnivora. In herbivorous animals it is of great size, and appears to serve as a reservoir for the elaboration and absorption of food. The appendix, which represents a specialized part of the cæcum, is as well developed in the newly born child as in the young of anthropoid apes. In the human fœtus it can be seen to be but the narrowed extremity of the cæcum. The fœtal type of cæcum, which is very characteristic, may persist throughout life. In a large proportion of people the appendix tends to become smaller or atrophied as adult years are reached, probably because our modern diet makes only a slight call on its activity. It is very frequently the seat of disease, and it is worthy of note that such disease tends to cause the entire obliteration of the part (as after many forms of so-called appendicitis).

It must be understood that the term *cæcum* is applied to that part of the colon which lies below the entrance of the ileum. The average breadth of the adult cæcum is 3 inches, its average length (vertical measurement) $2\frac{1}{4}$ inches. These measurements apply to the organ as seen in the cadaver; in the living it is constantly changing its shape according to its state of physiological activity. The cæcum normally contains gas, and gives a high, tympanitic note on percussion; Glénard found that in cases of ptosis of the viscera it was often contracted, and when palpated had the consistency of a sausage.

The cæcum is usually lodged in the right iliac fossa, and is so placed that its apex corresponds with a point a little to the inner side of the middle of the inguinal ligament. When distended with gas or fæcal contents it occupies the whole of the right iliac fossa. The ileo-cæcal orifice is situated immediately below the spino-umbilical line and externally to Monro's point (*see* Fig. 85, p. 392).

A slightly distended cæcum so located may be emptied by flexing the thigh upon the abdomen. The cæcum is entirely invested by peritoneum, although a portion of its posterior surface is occasionally in connexion with the areolar tissue of the iliac fossa. The peritoneum is usually reflected from the commencement of the ascending colon on to the posterior parietes below the level of the iliac crest. A mobile cæcum may hang over the pelvic brim, or occupy the pelvis, or even find its way into an inguinal hernia of the left side. The mobility of the cæcum can be tested by deep palpation when it is laden with a bismuth meal and examined by the aid of X-rays. The cæcum is not infrequently found in an inguinal or femoral hernia of the right side (cæcal hernia). Such herniæ are, except in a few rare instances, provided with a proper and complete peritoneal sac. Foreign bodies that have been swallowed are very apt to lodge in the cæcum, and in that situation may cause ulceration and even perforation of the bowel, producing one form of typhlitis. In cases of fæcal retention, also, the largest accumulation of fæcal matter is very usually met with in the cæcum, and upon that part of the bowel when distension is extreme the greatest strain usually comes. Solitary follicles are numerous in the mucous membrane of the cæcum, especially near the ileo-cæcal orifice. Intestinal concretions also are not uncommon in this part.

Three kinds of movement occur in the cæcum: (1) a churning movement, which has been observed to commence within an hour of taking food; (2) antiperistaltic movements, which begin in the colon and end in the cæcum (*see* p. 398); (3) propulsive or emptying movements. Water is absorbed and the fæces commence to assume a solid consistency as they reach the transverse colon. The ileo-cæcal orifice is guarded by a muscular sphincter (*ileo-cæcal sphincter*); it is innervated by the sympathetic system and regulates the escape of chyme from the ileum (Elliot and B. Smith); Sir William Macewen has seen it in action in the case of a soldier in whom a wide cæcal fistula resulted from a gunshot injury. The same observer has also seen a secretion escaping from the mouth of the appendix, which is situated about 1 inch below the ileo-cæcal orifice. In certain conditions, as Dr. James Case was the first to observe, the reflexes which regulate the ileo-cæcal sphincter no longer act, and the orifice then becomes incompetent, allowing the contents of the cæcum to regurgitate into the ileum.

The **appendix** varies in length. Its average measurement in the adult is 4 inches, the extremes being 1 inch and 6 inches. Its position is continually varying, although, as a rule, it is seen to lie behind the end of the ileum and its mesentery, and to point in the direction of the spleen. It frequently also lies behind the cæcum; it may be found embedded in the ascending mesocolon. In such cases the appendix has been pushed behind the cæcum and caught in the mesocolon during the later months of fœtal life, when the cæcum migrates from the neighbourhood of the liver to the right iliac fossa. The appendix may hang within the pelvis and, in inflammatory conditions, contract adhesions to the ovary or other

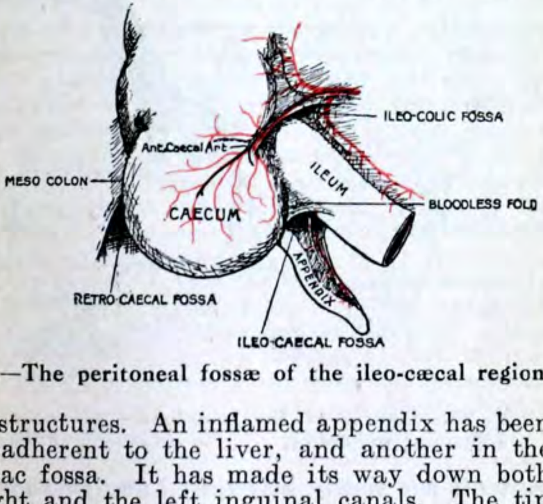

Fig. 92.—The peritoneal fossæ of the ileo-cæcal region.

pelvic structures. An inflamed appendix has been found adherent to the liver, and another in the left iliac fossa. It has made its way down both the right and the left inguinal canals. The tip of the process may adhere to a neighbouring peritoneal surface, and thus form a "band," beneath which a piece of small intestine may be strangulated.

The mesentery of the appendix (Fig. 93), which contains an artery derived from the ileo-colic, may be so short as to produce kinks in the appendix. The mucous lining is so crowded with solitary lymphoid follicles as almost to occlude its lumen. Like other lymphoid structures, these follicles begin to atrophy soon after adult life is reached. In some forms of appendicitis these follicles are involved. In patients fed with a bismuth meal the shadow of the appendix can usually be distinguished (40 per cent. of individuals, Barclay; 80 per cent., Case). As with the rest of the alimentary tract, its musculature undergoes a slow rhythmical peristaltic movement by which, if the lumen be still patent, the cæcal

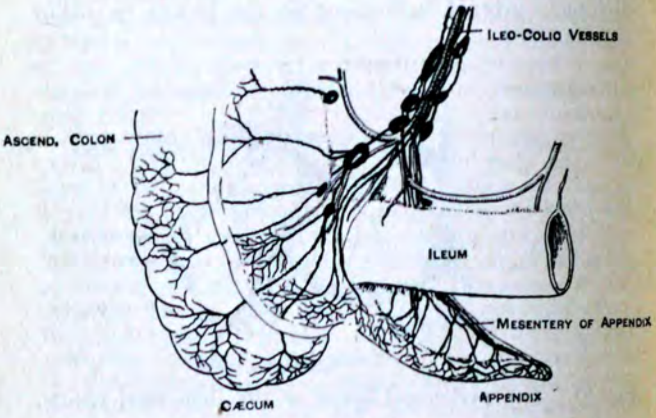

Fig. 93.—Course of the lymphatics of the cæcum, appendix, and colon. (*After Jamieson and Dobson.*)

contents are slowly introduced and extruded. Its function remains unknown. It may be necessary to palpate and displace the cæcum before the shadow of the appendix is seen.

Lymphatics of the cæcum and appendix (Fig. 93).—Since in inflammation of the appendix infection spreads chiefly by its lymphatics, the arrangement of this system is of surgical importance. As in other parts of the alimentary canal, there are three plexuses of lymphatics: (1) a submucous, which receives the lymph from the mucous membrane; (2) an intermuscular plexus; (3) a subserous plexus. All three are in the freest communication. The lymphoid follicles are situated in submucous lymph-spaces; at breaks in the muscular coat the submucous and subserous plexuses are in direct continuity; hence infection may readily spread to the peritoneal coat, setting up peritonitis. The efferent vessels pass chiefly into the meso-appendix, where one or more glands may occur, but most of the efferent vessels pass to the ileo-colic group of glands situated in the ileo-colic angle (Fig. 93). This group also receives lymphatics from the anterior part of the cæcum and base of the appendix by vessels which pass through the anterior colic fold. Vessels from the posterior aspect of the cæcum also join the ileo-colic group. These vessels do not communicate with the lymphatics of the iliac or lumbar regions (Jamieson and Dobson). The vessels which issue from the ileo-colic group of glands join the efferent vessels of the small intestine and of the ascending colon, and enter glands situated along the superior mesenteric artery.

It is in the ileo-cæcal region that **intussusception** most frequently occurs. In this condition one part of the intestine is prolapsed or "telescoped" into the lumen of an immediately adjoining part. In the ileo-cæcal variety (the commonest form) the narrow ileum, and subsequently the cæcum, are prolapsed into the colon. The ileo-cæcal orifice forms the summit of the protrusion or intussusceptum. In the ileo-colic variety (the rare form) the end of the ileum is prolapsed through the valve. The orifice and the cæcum remain in their normal situations, and the summit of the intussusceptum is formed only by the ileum. In another variety, which is also common, the apex of the intussusceptum is formed by the fundus of the invaginated cæcum.

There are three fairly constant peritoneal fossæ, which are sometimes the seat of hernia, in the ileo-cæcal region (Fig. 92). They are: (1) the ileo-colic, situated between the ascending colon and termination of the ileum—a fold containing the anterior cæcal artery bounds it above; (2) the ileo-cæcal fossa, between the termination of the ileum and the cæcum—it is bounded in front by the bloodless (ileo-cæcal) fold and behind by the mesentery of the appendix; (3) the retrocæcal fossa, behind the cæcum—it is bounded on the right by the lower termination of the ascending mesocolon.

Rate at which the contents of the alimentary canal progress.—A study of the movements of a bismuth-laden diet along the alimentary canal of the living materially modifies the conception one forms of the bowel from an examination of this part in the dead. The account given here is founded chiefly on the observations of Dr. A. F. Hurst. The contents of the stomach begin to pass into the duodenum very soon after food is taken; in 4½ hours the food begins to enter the cæcum, which gradually fills. In 6½ hours the bismuth-laden contents have reached the hepatic flexure, and in 9 hours the splenic flexure. In the ascending colon and first part of the transverse colon the fluid part of the fæces is absorbed. The progress along the descending iliac and pelvic colon is slow. In 30 hours the bismuth diet is lodged in the iliac and pelvic colons. The colon must be regarded not as a passive tube, but as an active muscular organ concerned in propulsion as well as absorption.

Large intestine.—From the cæcum to the pelvi-rectal junction this portion of the bowel is accessible to pressure except at the hepatic and splenic flexures, which are deeply placed. The hepatic flexure is under the shadow of the liver, and the splenic curve, which reaches a higher level, is behind the stomach (Fig. 85, p. 392). The transverse colon crosses the belly transversely, so that its lower border is nearly on a level with the umbilicus (Fig. 85). In cases of fæcal accumulation the outline of the colon, with the exception of the two flexures above named, may be distinctly defined. In distensions of the small intestine the belly tends to present the greatest degree of swelling in front, and about and below the navel. In distension of the larger gut the front of the abdomen may remain (for a while at least) comparatively flat, while the distension will be most obvious in the two flanks and in the region just above the umbilicus. Tumours of the transverse colon, and of the lower two-thirds of the ascending and descending colon, can be well defined, even when of moderate size, and in cases of intussusception the progress of the mass along the colon can often be traced with great ease, and the effects of enemata and other methods of reduction carefully watched. The diameter of the large intestine (excluding the rectum) gradually diminishes from the cæcum to the iliac colon, that of the former being about $2\frac{1}{2}$ inches, and of the latter $1\frac{1}{2}$ inches. The narrowest part of this segment of the bowel is at the point of junction of the pelvic colon with the rectum, and it is significant that this is the point at which stricture is the most common. At this point, too, is situated the pelvic rectal sphincteric tract.

The tendency to stricture increases as one proceeds from the cæcum to the anus. A stricture is frequent in the descending colon, less frequent in the transverse colon, while in the ascending colon it is comparatively rare. Strictures are not uncommon about the flexures of the bowels.*

The **ascending** and the **descending colon** are placed vertically. The average length of the ascending colon in the adult (as measured from the tip of the cæcum to the hepatic flexure) is 8 inches. The average length of the descending colon, measured from the splenic flexure to the iliac crest, is rather less. The descending colon is very little liable to variation, and is always found in a semi-contracted condition. That part of the colon

* *See* "Intestinal Obstruction," by Sir Frederick Treves, London, 1899.

which lies in the left iliac fossa, from the iliac crest to the left psoas muscle, is distinguished as the **iliac colon.** In cases of non-descent of the cæcum the ascending colon may be apparently absent. Sir Frederick Treves has pointed out that in 52 per cent. of adult bodies there is neither an ascending nor a descending mesocolon, and that a mesocolon may be expected on the left side in 36 per cent. of all cases, and on the right side in 26 per cent. These points are of importance in connexion with the somewhat uncommon operation of lumbar colotomy. The breadth of the mesocolon, when it exists, varies from 1 to 3 inches. The line of attachment of the left mesocolon is usually along the outer border of the kidney, and is vertical. That of the right mesocolon is, as a rule, less vertical, runs along the outer border of the kidney, and crosses its lower end obliquely from right to left.

The **transverse colon** has an average measurement of 20 inches. It is not quite horizontal, since the splenic flexure is on a higher level than the hepatic flexure, as well as posterior to it, and always shows a number of bends, one occurring near its commencement and another near its end (Fig. 85, p. 392). Fæcal masses lodged in the transverse colon have given rise to many errors in diagnosis. In some instances this part of the colon is displaced towards the pelvis, so that V- or U-shaped bends are produced. In such cases the point of the V or the U may reach the symphysis pubis, while the two colic flexures occupy their proper situations. The sagging and elongation of the transverse colon indicate a loss of tone and of contraction in its muscular coat, especially of the longitudinal tæniæ. There is a corresponding relaxation in the muscular walls of the abdomen, so that the normal support is withdrawn from the abdominal viscera. The peritoneal supports of the hepatic and splenic flexure become stretched and appear to compress and obstruct the free passage of the colic contents.

The constipation in such cases appears to be due, not to the kinking and compression of the colon, but to the primary relaxation of the colic musculature, the cause of which is still obscure.

The right-hand part of the transverse **colon** is in intimate relation with the gall-bladder, and is commonly found to be bile-stained after death. In some cases where gall-stones have been lodged within the gall-bladder, the walls of that structure have ulcerated from pressure, the ulceration has involved the subjacent transverse colon, and thus a fistula has been established between the gall-bladder and the gut, through which large stones have been passed. Hepatic abscesses also have discharged themselves through the transverse colon. The transverse colon often finds its way into an umbilical hernia, and is concerned in many of the cases of hernia into the foramen of Winslow (epiploicum).

The **pelvic colon** commences as the colon crosses the left psoas, and ends in the pelvis, usually opposite the third piece of the sacrum. Its termination is marked by three features: (1) There is a contraction in the diameter—the pelvi-rectal sphincteric tract; (2) the peritoneum ceases to enclose the colon completely and form a true mesentery; (3) the three longitudinal tæniæ become spread out to form a continuous longitudinal muscular coat. Sir Frederick Treves was the first to distinguish the pelvic colon as a separate segment of the colic tract, applying to it the term "omega loop," because it resembles the capital omega, Ω. Although termed "pelvic colon," it should be remembered that in the fœtus and in the child it is not pelvic but suprapelvic in position. Frequently it is spoken of as the "sigmoid loop." The average length of the loop in the adult is 17½ inches. The two extremities of the loop are about 3 or 4 inches apart. If they are approximated to one another, as by contracting peritonitis at the root of the sigmoid mesocolon, a kind of pedicle is established, about which the loop may readily become twisted. Such a twist of the bowel constitutes a volvulus of the pelvic colon or loop; and it may be here said that volvulus of the intestine is more commonly met with in this loop than in any other part of the canal.

The line of attachment of the mesentery of the pelvic colon crosses the left psoas muscle and the

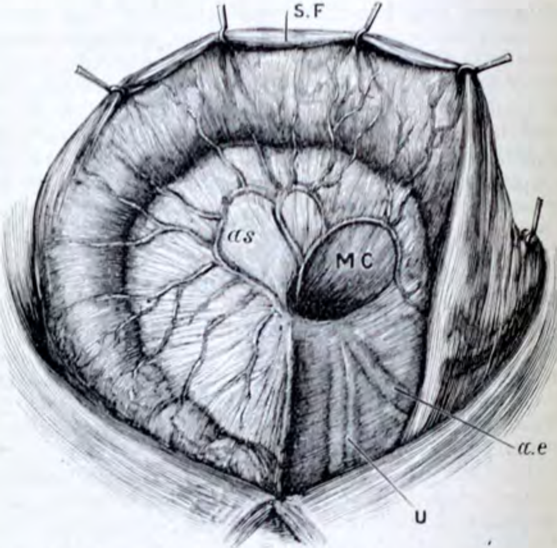

Fig. 94.—Sigmoid flexure (pelvic colon) turned upwards to show the intersigmoid fossa. (*Jonnesco.*)

S.F, Sigmoid flexure; *a s*, sigmoid artery; M C, intersigmoid fossa; *a.e*, external iliac artery; U, ureter in front of internal iliac vessels.

iliac vessels near their bifurcation; it then turns abruptly down, and, running nearly vertical, terminates at the middle line. In the left wall of this mesocolon, close to the point where it lies over the iliac vessels, a fossa is sometimes to be found (Fig. 94, M C); it is produced by the sigmoid artery, and is about $1\frac{1}{2}$ inches in depth. It is called the intersigmoid fossa, and is the seat of *sigmoid hernia*. Cases of strangulated hernia in this fossa have been recorded.

The pelvic colon, when empty, normally occupies the pelvis. When distended this piece of bowel may become so enormously dilated as to reach the liver. The chief examples of extraordinary dilatation of the colon concern this loop, as in *megacolon* or *Hirschsprung's disease*, where there is apparently an extraordinary degree of dilatation and hypertrophy of the muscular coat, and yet such coats have no power of contraction. Fæcal masses are very frequently lodged in the distal part of the pelvic colon, and certain intestinal concretions have been met with in the same situation.

Sir Frederick Treves demonstrated by experiment that the "long tube," when introduced through the anus, could not be passed beyond the sigmoid flexure in ordinary cases and with a normal disposition of the bowel.

In cases of congenital absence or deficiency of the rectum, the pelvic colon—in some cases the iliac colon—is opened in the groin and an artificial anus established there. One difficulty has been said to depend upon the uncertain position of the pelvic colon in cases of congenital deformity, it being sometimes on the right side and sometimes in the pelvis at the middle line. It is rarely, however, found in these positions. Out of 100 post-mortem examinations on young infants, Curling found the loop on the left side in 85 cases. Out of 10 children who were operated on for imperforate anus, the loop was found in the left fossa in only 1 case (Montgomery).

The iliac and pelvic colons are often the seat of **multiple diverticula of the mucous coat.** These diverticula occur at points where vessels enter or emerge from the bowel, thus giving rise to weak points in the muscular coat through which the mucous coat forms small herniæ or diverticula. They protrude within the appendices epiploicæ and root of the mesentery. This part of the colon serves as a receptaculum for the fæces, and is always tonically contracted, and this is probably the reason why the pelvic colon is more frequently the seat of these diverticula than any other part of the bowel.

The section of the body shown in Fig. 95 gives the immediate **relations of the descending colon,** and the structures to be cut through if the surgeon wishes to expose this structure in the loins. The position of the descending colon in the loin may be represented by a line drawn vertically upwards from a point on the iliac crest 1 inch external to the outer border of the erector spinæ. An incision is made across the centre of this line parallel to the last rib, and so planned that the centre of the incision corresponds to the centre of the line. The superficial tissues having been incised, the following structures are divided in layers in the order here given (Fig. 95): (1) The latissimus dorsi and external oblique muscles to an equal extent; (2) the internal oblique in the entire length of the incision; (3) the lumbar (lumbo-dorsal) fascia, with a few of the most posterior fibres of the transversalis muscle; (4) the transversalis fascia. The quadratus lumborum will be exposed in the posterior inch or so of the incision, and usually does not need to be cut. At the seat of the operation the descending colon occupies the angle between the psoas and quadratus lumborum muscles, and the non-peritoneal surface is exactly represented by that part of the bowel that faces this angle (Fig. 95). Thus, if during the operation the curved finger be placed in this angle, and the patient be rolled over to the left side, the bowel that falls into the finger cannot well be other than the descending colon. The width of the non-peritoneal surface varies from $\frac{4}{5}$ of an inch to 1 inch in the empty state, and may attain to 2 inches or more in the distended condition (Braune).

Iliac or inguinal colotomy. — In this very common, excellent, and simple operation the pelvic colon is exposed and opened in the left iliac region. A line is drawn from the anterior superior iliac spine to the umbilicus, and an in-

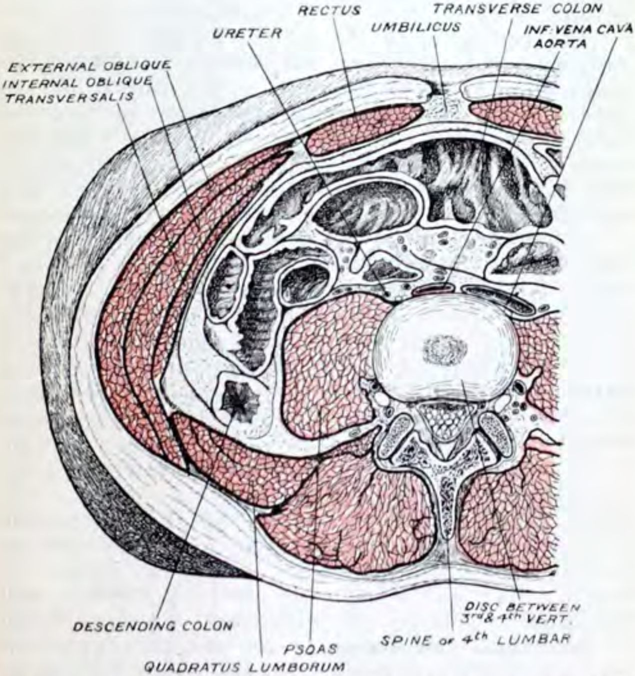

Fig. 95.—Horizontal section through the body at the level of the umbilicus. (*After Braune.*)

cision some 2 inches in length is made at right angles to this line and at a distance of about 1½ inches from the point of the bone. The three muscles of the abdomen and the peritoneum having been divided, the loop of the pelvic flexure is brought into the wound, is secured, and is (at once or at a later period) opened. The ascending branch of the deep circumflex iliac artery crosses the line of the incision. The iliac colon is bound by a very short mesentery to the iliac fossa, but, owing to the mobility of the peritoneum in this region, the bowel is easily brought into the wound.

The cæcum may be opened on the right side, and as a rule the most convenient incision is an oblique one placed externally to the deep epigastric artery. The appendix has also been opened and sutured to the incision in the groin (*appendicostomy*). Through the opening in the appendix the cæcum and colon may be irrigated and washed out.

Colectomy consists in excising a portion, or the whole, of the colon. The cæcum has been removed, and considerable segments of the rest of the large intestine. The treatment of cancer of the colon by excision is attended with considerable success. Portions of the ascending and descending parts of the colon have been excised through an incision in the loin, but colectomy is much more readily carried out through an anterior wound. In the case of a young girl, Sir Frederick Treves excised the whole rectum and anus, the sigmoid flexure, and the whole of the descending colon. The divided transverse colon was brought out at the anus. The child made a perfect recovery. The parts removed are in the museum of the Royal College of Surgeons. The operation of **intestinal anastomosis** or **short-circuiting** is very frequently practised on the colon. Thus, in an obstruction of the descending colon impossible of removal, the transverse colon may be united to the sigmoid flexure.

In more recent years Sir W. Arbuthnot Lane has applied **excision of the great bowel** to cases of obstinate constipation and toxæmia which are unrelieved by all known medical measures, especially to those cases where the transverse colon is greatly elongated and kinked (*see* p. 424). In many cases the operation is attended with marked success. In cases of obstinate colitis the great bowel may be "rested" by uniting the lower part of the ileum to the pelvic colon, thus short-circuiting the food passage. The results of such operations are often favourable, and have been cited in support of the theory, promulgated by Metchnikoff, that the great bowel is a useless and dangerous structure in man. The evidence, so far as it goes, indicates that no colon is better than a diseased colon, but it certainly does not signify that no colon is better than a healthy one. In cases of ileo-sigmoid anastomosis the iliac contents are often carried backwards into the colon by a process of antiperistalsis, leading even to a loading of the colon.

Congenital malformations of the colon.—These are of moment with regard to operative procedures. It may be very briefly said that in the fœtus the small bowel occupies at one time the right side of the abdomen, while the large gut is represented by a straight tube that passes on the left side vertically from the region of the umbilicus to the pelvis. The cæcum is at first situated within the umbilicus, and then ascends in the abdomen towards the left hypochondrium. It next passes transversely to the right hypochondrium, and then descends into the corresponding iliac fossa. It may be permanently arrested at any part of its course. Thus the cæcum may be found about the umbilicus, or in a congenital umbilical hernia, or in the left hypochondriac region (the ascending and transverse parts of the colon being absent), or it may be found in the right hypochondrium, the ascending colon only being unrepresented.

The whole of the large intestine has at one time an extensive mesentery, and in some rare cases this condition may persist throughout life. When it does persist, it may lead to one form of volvulus of the bowel.

CHAPTER XIX

THE OTHER ABDOMINAL VISCERA

The liver.—The liver is moulded to the arch of the diaphragm, and lies over a part of the stomach (Fig. 96). Properly speaking, it has only two surfaces—a *visceral surface*, which in the upright posture rests on the stomach, duodenum, gastro-hepatic omentum, neck of the pancreas, hepatic flexure of colon, right kidney, and right suprarenal body; and a *parietal surface*, in contact with the diaphragm and anterior belly-wall in the subcostal angle. As seen from the front it is triangular in outline, with its apex near the apex of the heart (Fig. 96); its upper border is best indicated by a line commencing at the apex beat (Fig. 96) and passing across the mid-line ½ an inch below the sterno-ensiform point; it ascends as it reaches the nipple line to the level of the sterno-ensiform plane. The lower border commences at the apex beat, crosses the mid-line about 1 inch above the mid-epigastric point, reaches the costal margin at the outer border of the rectus, and the remainder of its lower border corresponds to the costal margin as far as the tip of the eleventh rib. The liver is in contact with the right kidney along the lower margin of that rib (Fig. 97). For surgical purposes the liver in the right hypochondrium may be regarded as made up of three zones—an upper or pulmonary, a middle or pleural, and a lower or diaphragmatic (Figs. 96, 97). In the lower zone, which is 1½ to 2 inches wide in the mid-axillary line, the liver may be incised or explored; in the middle zone, which is of equal width, the pleural reflection is encountered. In the erect posture the lower edge on the right side is about $\frac{1}{3}$ or $\frac{1}{4}$ of an inch below the margins of the costal cartilages. In the recumbent position the liver ascends about an inch, and is entirely covered by the costæ, except at the subcostal angle. It ascends also in expiration and descends in inspiration.

The fundus of the gall-bladder approaches the surface behind the ninth costal cartilage, close to

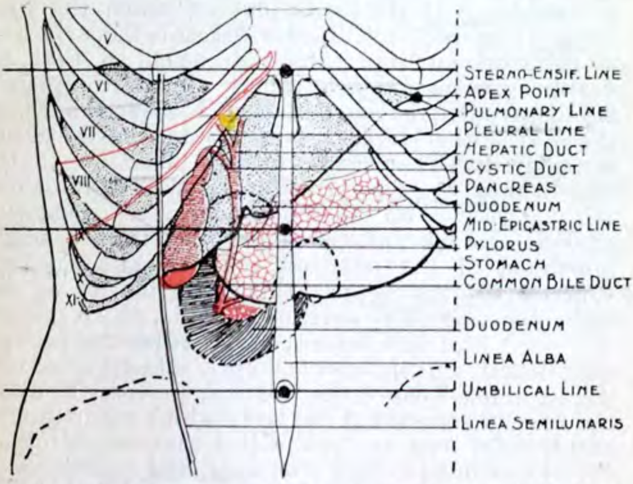

Fig. 96.—Showing the position of the liver, gall-bladder, bile-ducts, and pancreas.

The lower limits of the pleura and lung are indicated.

the outer border of the right rectus muscle (Fig. 96). Its position is extremely variable; it frequently occupies a position considerably below and external to the one mentioned.

The liver is retained in shape by, and moulded upon, the diaphragm above and the abdominal organs below. When removed from the body the shape which it possesses clinically is lost. It presents many variations in form. One of the commonest is a *linguiform process* (often referred to as Riedel's lobe), which projects from the margin of the right lobe under the tenth costal cartilage (Fig. 86, p. 393). It is found more frequently in women than in men, and may be mistaken for a floating kidney or an abdominal tumour.

In the condition known as **ptosis of the liver** the upper surface slides forwards in the dome of the diaphragm, and its lower border may descend to the level of the umbilicus or reach the iliac fossa (Fig. 86). With the descent there is also a rotation on its transverse axis, so that its diaphragmatic surface comes almost completely to the front. In such a case the factors which maintain the liver in position have to be considered. They are: (1) Its fixation to the diaphragm by the inferior vena cava and the fibrous tissue on the non-peritoneal posterior (dorsal) surface of the right lobe in the neighbourhood of the inferior vena cava; it is convenient to distinguish this attachment as the *mesohepar*. (2) The peritoneal folds, which include the right and left lateral (triangular), coronary, and falciform ligaments, also attach it to the diaphragm. These folds are lax, in order to allow the free movements of the liver which occur during respiration and in the filling and emptying of the stomach. (3) The muscular abdominal walls, which keep the other abdominal viscera constantly pressed against the lower surface of the liver. The muscles constitute the chief means of maintaining the liver in position. In many women over 40 the right lobe of the liver projects quite 2 inches below the eleventh rib, and, as in the child, the extremity of the left lobe frequently comes in contact with, or even overlaps, the upper part of the spleen.

The liver is more often **ruptured** from contusion than is any other abdominal viscus. This is explained by its large size, its comparatively fixed position, its great friability of structure, and the large quantity of blood contained in its vessels. A normal liver will take its own weight of blood if its veins be injected at ventricular pressure (Salaman). Death in such injuries usually ensues from hæmorrhage, since the walls of the portal and hepatic veins, being incorporated with the liver substance, are unable to retract or to collapse. The hepatic veins also open direct into the vena cava, and, being unprovided with valves, could allow of the escape of an immense quantity of blood if any retrograde current were established. The hepatic vessels are thin-walled, and it is almost impossible to ligature them, except by buried sutures. It is possible for the liver to be ruptured without the peritoneal coat being damaged; and such injuries may be readily recovered from. The liver presents, behind, a fairly extensive non-peritoneal surface, at which rupture or wound may occur without extravasation into the abdominal cavity. From the relation of the liver to the right lower ribs, it follows that this viscus may be damaged when the ribs are fractured, and in some cases the broken ends of the bones have been driven through the diaphragm into the liver substance. **Stabs** through the sixth or seventh right intercostal space, over the liver region, would wound both the lung and the liver, would involve the diaphragm, and open up both the pleural and peritoneal cavities.

The intimate relation of the liver to the transverse colon is illustrated by a case where a toothpick, 4 inches in length, was found in the substance of the liver. It had worked its way there, from the colon, along an abscess cavity which connected the two viscera. The relation of the liver to the heart may be illustrated by a case still more remarkable. In this instance a loose piece of liver, weighing one drachm, was found in the pulmonary artery. The patient had been crushed between two wagons, the liver was ruptured and the diaphragm torn, a common result of crushing accidents and a prolific source of diaphragmatic hernia. A piece of the liver had been squeezed along the vena cava into the right auricle, whence it had passed into the right ventricle, and so into the pulmonary artery. The heart itself was quite uninjured. Bullets lodging in the liver may ultimately be carried to the cavity of the right ventricle. Considerable portions of the liver have been removed with success. It is remarkable from what grave injuries of the liver recovery is possible. Thus, Dr. Gann (*Lancet*, June, 1894) reports the case of a man of 28 who had a harpoon driven through the whole thickness of the right lobe of the liver, so that it projected at the posterior border. The blade was 7 inches long, and had two barbs. It was removed by operation twenty-eight hours after the accident, and the patient made a good recovery.

From a reference to the relations of the liver it will be readily understood that an **hepatic abscess** may open into the pleura, and in some cases, indeed, the pus from the liver has been discharged from the trachea. Thus, it has been possible for a patient to cough up some portion of his liver, although, of course, in a very disintegrated and minute form. Hepatic abscess may burst in one or other of the following directions, placed in order of their frequency: (1) into the right lung; (2) into the bowel; (3) upon the surface of the body. Such abscesses have, in rare cases, opened into the stomach. The liver is very frequently the seat of the secondary abscess of pyæmia, and, according to Mr. Bryant's statistics, abscesses in this viscus are more common after injuries to the head than after injuries elsewhere. They are rare in pyæmia following affections of the urinary organs, and are equally rare in the pyæmia after burns. Secondary deposits of tumours and abscesses are frequently limited to the right or to the left of a line drawn from the fundus of the gall-bladder to the inferior vena cava. This remarkable limitation is to be explained by the fact that the liver to the right of this line is supplied only by the right terminal division of the portal vein, while the part to the left receives blood only from the left division (Cantlie).

The **gall-bladder** may be absent, as is the case in some animals, or reduced to a cicatrix from disease. It is often removed by operation, and no disturbance in the biliary function is apparent (Moynihan). Its mucous membrane has a peculiar reticulated, honeycomb appearance, and is made up of columnar epithelium, which secretes mucus and has a power of absorption. When inflamed the cells pour out a morbid amount of secretion, in which the cholesterin of the bile may become deposited if the outflow is obstructed, and may form the nuclei of **gall-stones.** These are composed mostly of cholesterin, a normal constituent of bile, and vary in size from a hemp-seed to a hen's egg. The escape of gall-stones is rendered more difficult by the presence of a spiral fold of mucous membrane in the neck and duct of the gall-bladder. The gall-bladder, at its neck, forms an acute angle with the *cystic duct*, the spiral fold serving, as in a rubber pipe, to keep the passage open. In the erect position the long axis of the gall-bladder is directed upwards and backwards, and the cystic duct downwards and forwards (Fig. 96). The cystic duct lies in the gastro-hepatic omentum (hepato-duodenal part), where it joins the hepatic to form the common bile-duct. It is accompanied by the cystic artery. The cystic veins pass directly to the liver and end in the portal capillary system. In cases of cystitis the part of the liver receiving the cystic veins is seen to be contracted or atrophied.

A gall-stone may be arrested in, and require removal from, any part of the cystic or the common bile-duct. The *common bile-duct* is 3 inches long, and its lumen $\frac{1}{5}$ of an inch wide, but by the passage of gall-stones it may become three times its normal diameter. The upper half of the common bile-duct lies in the gastro-hepatic omentum, in front of the epiploic foramen (Winslow's), with the portal vein behind it and to the right. The hepatic artery lies close on its left, and its branch, the superior pancreatico-duodenal, crosses the common bile-duct as it passes to its second or deeper stage. A stone arrested in the lower half of the duct is difficult of access. The duct lies buried between the head of the pancreas behind and the duodenum in front and to the outer side. It may be necessary in such a case to open the duodenum and extract the stone through its posterior and inner wall, or the duodenum and head of the pancreas may be turned forwards from the inner border of the right kidney, thus exposing the lower half (post-duodenal stage) of the common bile-duct in the groove between the duodenum and pancreas. The terminal half-inch is embedded in the wall of the duodenum and ends in the ampulla of Vater. At its termination, where the duct is narrowest, it is surrounded by a *sphincter* (supra-ampullary sphincter) which regulates the flow of bile. The lumen of the lower half of the duct is less than that of the upper half. Two lymphatic glands lie in the gastro-hepatic omentum by the side of the bile-duct, and have been mistaken for gall-stones when calcified. In its ampullary part there are submucous glands, which are liable to infection and inflammation.

The gall-bladder receives its **nerve supply** from the eighth and ninth segments of the cord (Head), through the great splanchnic and cœliac plexus. The intense colic caused by gall-stones, believed to be due to spasm of the non-striated muscular coat of the bile-ducts, is reflected along the ninth dorsal nerve to the anterior abdominal wall. Stimulation of the sympathetic nerves causes the muscle of the cystic duct to contract, but relaxes that of the gall-bladder (T. R. Elliot). The contractions of the musculature of the biliary system are correlated with the movements of the stomach, and hence are liable to occur soon after taking food (Lynn Thomas).

The gall-bladder and the bile-duct have been ruptured alone without rupture of the liver. The injury is rapidly fatal, owing to the escape of bile into the peritoneal cavity. Large gall-stones may be passed direct into the bowel through a fistulous track which has been established between the gall-bladder and the intestine. Gall-stones have suppurated out through the anterior belly-wall, and have been removed from abscesses in the parietes. Thus, Burney Yeo reported a case where more than one hundred gall-stones were discharged through a spontaneous fistula in the hypogastric region, 5 inches below the umbilicus. In cases where the bile-duct is occluded by gall-stones, or by other causes, the gall-bladder may become enormously distended, and may form a tumour extending some way beyond the umbilicus. So large a tumour has been formed that the mass has been mistaken for an ovarian cyst. The gall-bladder as it enlarges tends to follow a line extending from the tip of the right tenth cartilage across the median line of the abdomen below the umbilicus. For the relief of this condition, **cholecystotomy**, or incision into the gall-bladder, has been performed. In this operation the incision or puncture is made over the most prominent part of the tumour. Impacted gall-stones have been removed entire from the bile-duct through an incision so made, or the stone has been crushed *in situ* and extracted in fragments.

In **cholecystectomy** the whole of the gall-bladder is excised and the cystic duct closed. The bile finds its way into the intestine direct through the common duct.

In **cholecystenterostomy** a fistula is established between the gall-bladder and the intestine. The operation is carried out in cases in which there is an insuperable obstruction in the common duct. The gall-bladder thus takes the place of the common duct.

The spleen.—The spleen is deeply situated in the left hypochondriac region, and in the normal condition cannot be palpated, being quite covered in front by the cardiac end of the stomach (Fig. 98). It most closely approaches the surface in the parts covered by the tenth and eleventh ribs. Above this it is entirely overlapped by the edge

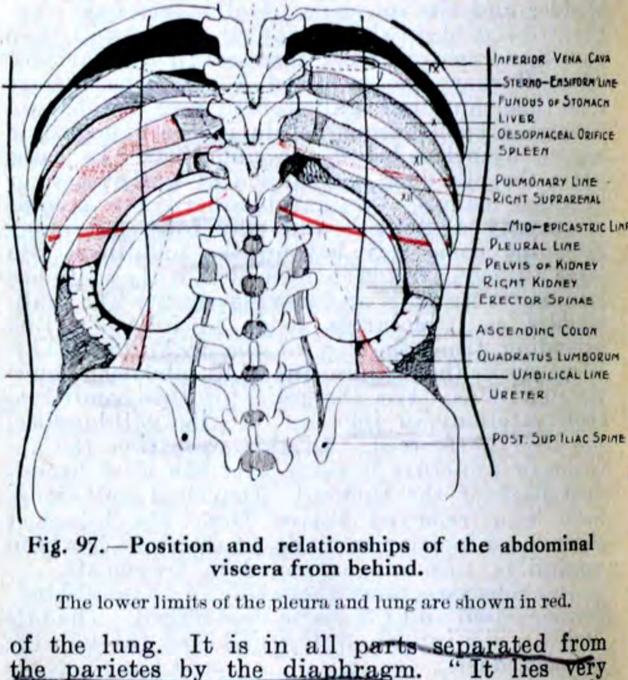

Fig. 97.—Position and relationships of the abdominal viscera from behind.

The lower limits of the pleura and lung are shown in red.

of the lung. It is in all parts separated from the parietes by the diaphragm. "It lies very obliquely, its long axis coinciding almost exactly with the line of the tenth rib. Its highest and lowest points are on a level, respectively, with the ninth dorsal and first lumbar spines; its inner end is distant about 1½ inches from the median plane of the body, and its outer end about reaches the mid-axillary line" (Quain) (Fig. 97). It possesses three surfaces, gastric, renal, and phrenic, well shown in Fig. 98.

A dislocated or floating condition of the spleen is rare. Its hilus is attached to the stomach by the gastro-splenic fold of peritoneum. Its renal surface is closely applied to the upper half of the left kidney; its gastric surface is kept in apposition to the stomach; its upper pole is attached near

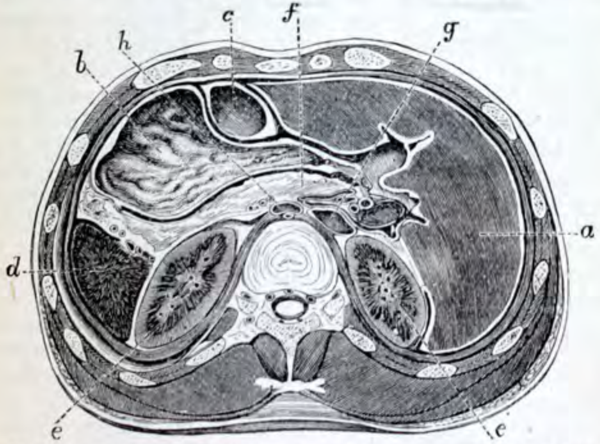

Fig. 98.—Horizontal section through upper part of abdomen. (*Rüdinger.*)

a, Liver; *b*, stomach; *c*, transverse colon; *d*, spleen; *e*, *e*, kidneys; *f*, pancreas, *g*, inferior vena cava; *h*, aorta with thoracic duct behind it.

the cardiac orifice of the stomach by the lienophrenic fold of peritoneum, while its lower rests on the costo-colic peritoneal fold, and has the tail of the pancreas and colon in contact with it. The tension of the abdominal walls exerts a general pressure on it through the other abdominal organs. When the spleen enlarges, as in ague, its crenated anterior border may be felt beneath the tenth costal cartilage. The movable or floating spleen is met with only in adults. The organ may be so displaced as to reach the iliac fossa.

Injuries.—Although extremely friable in structure, the normal spleen is not very frequently ruptured. Its connexions, indeed, tend to minimize the effects of concussions and contusions. When the spleen, however, is enlarged, it is very readily ruptured, and often by quite insignificant violence. Thus, several cases have been recorded of rupture of an enlarged spleen by muscular violence. For instance, a woman ruptured her spleen in an attempt to save herself from falling, and another in springing aside to avoid a blow. The patients in each instance were natives of India, and the latter case gave rise to a charge of homicide. The spleen being extremely vascular, it follows that ruptures of the viscus are usually, but not necessarily, fatal from hæmorrhage. It is well to note, in connexion with this matter, that the spleen contains most blood during digestion. A case is reported, however, of a boy who met with an accident just after dinner, and who managed to walk some distance, although his spleen, as the autopsy revealed, was separated into three portions. He lived some days. In severe fractures of the ninth, tenth, and eleventh ribs the spleen may be damaged and lacerated.

The *capsule* of the spleen contains muscular tissue, and possesses a power of rhythmical contraction. This fact may serve to explain cases of recovery from limited wounds of the organ, such as small gunshot wounds. In such lesions the capsule may contract and greatly narrow the hole in the viscus, while the track of the bullet or knife may become filled with blood-clot, and the bleeding thus be stayed.

The spleen may be greatly enlarged in certain diseased conditions. The hypertrophied spleen may attain such dimensions as to fill nearly the whole abdomen; in one case a cystic tumour so completely occupied both iliac fossæ that it was mistaken for an ovarian cyst, and the operation for ovariotomy was commenced.

Extirpation of the spleen has been successful in cases of abdominal wounds with protrusion of the viscus. It has also been performed with fair results in many cases of hypertrophied spleen and of wandering spleen. The operation is not justifiable in cases of leukæmic enlargement of the organ, it having proved invariably fatal in such instances. The splenic artery, with its large accompanying vein, lies in the lieno-renal ligament, in contact with the tail of the pancreas below.

The **pancreas** lies behind the stomach, in front of the first and second lumbar vertebræ (Fig. 96). It crosses the middle line behind the mid-epigastric line. In emaciated subjects, and when the stomach and colon are empty, it may sometimes be felt on deep pressure, especially in those who are the subjects of visceroptosis; prolapse of the stomach leaves the pancreas exposed above the lesser curvature. It is in relation with many most important structures. So closely is it mixed up with the solar plexus that this structure is necessarily involved in inflammatory conditions, and must be disturbed in any operative procedures on its head and neck. The pancreatic duct (duct of Wirsung) usually ends with the common bile-duct in the terminal (Vaterian) ampulla (Fig. 99, A), so that a gall-stone arrested at this point may occlude both ducts or possibly cause a reflux of the bile within the pancreatic duct. Not uncommonly (in 30 per cent. of cases) the ampulla is partly (Fig. 99, B) or completely divided (Fig. 99, C), so that the orifices of the two ducts are separated; in such cases occlusion of the termination of the bile-passage leaves the pancreatic duct free. An accessory duct (the duct of Santorini) is present in a more or less developed condition in 50 per cent. of subjects. It may form a connexion with the main duct, as in Fig. 99, A, or be merely a minute ductule, as in

Fig. 99, B. The accessory duct opens nearer the pylorus, being ¾ of an inch above the ampulla of Vater. The ampulla usually extends into a papilla which projects within the duodenum, but this papillated condition is not always present. Septic conditions may spread from the duodenum to the pancreas or gall-bladder by means of their ducts.

The common bile-duct in its second stage lies between the head of the pancreas and the duodenum. It thus happens that in carcinoma of this part of the gland the duct may became en-

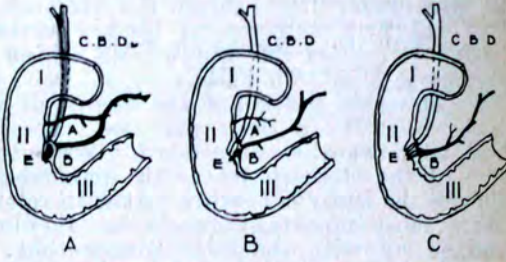

Fig. 99.—Showing the variations in the manner of termination of the pancreatic and bile-ducts.

A, Form in which the common bile-duct (C, B, D) and main pancreatic duct (B) end in an ampulla (E). A, Accessory duct: i. ii., iii., first, second, and third stages of the duodenum.
B, Form in which the ampulla is partly divided. The accessory duct is shown in its reduced form.
C, Form in which the common bile-duct and pancreatic duct have separate openings into the duodenum. The accessory is absent.

tirely occluded and jaundice result. Or the duodenum and even the colon may be more or less obstructed by pressure, or the neighbouring vessels be closed. Cancer of the pylorus may spread to the head of the pancreas by direct extension. The lymphatics of the two parts also freely communicate.

The pancreas lies behind the lesser sac of the peritoneum (bursa omentalis), its anterior surface being covered by the posterior wall of the sac; it is in front of the aorta, in the fork between the cœliac axis above and the superior mesenteric artery below. The portal vein passes upwards behind the neck of the gland.

Islets of Langerhans.—When microscopic sections of the pancreas are examined, numerous small groups of cells are observed among the normal acini of the gland. These islets of Langerhans are acini of the gland which have become modified to form an internal secretion (Swale Vincent). They vary in number from 300 to 400 (M. A. Lane). The pathological proof is now definite that destruction of these islets gives rise to diabetes (Mayo Robson).

The kidney.—The relations of this organ are as follows (*see* Figs. 98, 100):—

In front.

Right.	*Left.*
Visceral surface of liver.	Fundus of stomach.
Second part of duodenum.	Descending colon.
Commencement of transverse colon.	Pancreas.
Ascending colon.	Spleen.

Externally.		*Externally.*
Liver.	**Kidney.**	Spleen.

Behind.

Lower part of arch of diaphragm.
Quadratus lumborum. Psoas. Transversalis.
Last rib and transverse processes of upper two lumbar vertebræ.

The kidneys are deeply placed, and cannot be felt or distinctly identified when normal. They are most accessible to pressure at the outer edge of the erector spinæ, just below the last rib (Figs. 97 and 100). The dullness of the right kidney merges above in that of the liver, while on the left side it is impossible to distinguish between the dullness of the kidney and of spleen. The right kidney usually lies lower down than does the left; but even the lower pole of the right kidney is an inch above the crest of the ilium, or—what for practical purposes is the same level—above the umbilical line (Fig. 85, p. 392). The simplest manner of indicating the position of a kidney is to mark out the position of the upper and lower pole and between those two points delineate the well-known form of the kidney. The lower pole of the right organ lies about ½ an inch outside the prominent lateral border of the erector spinæ and 1 inch above the iliac crest (Fig. 100); since the kidney is about 4 inches long and is situated obliquely—its long axis corresponding to that of the twelfth rib—its upper pole is sufficiently indicated by taking a point 4 inches above and 1½ inches internal to the position of the lower pole. The spine of the eleventh dorsal vertebra—which may be identified when the patient bends by its anticlinal direction and semilumbar form—is just below the level of the upper pole. On an average the left kidney lies ½ an inch higher than the right (Addison). In many instances in the female the lower pole reaches the iliac crest, and may even go below it. Such positions are much less common in the male. The hilus lies about 2 inches from the middle line, and is opposite to the first lumbar spine and usually in the gap between the transverse processes of the first and second lumbar vertebræ (Fig. 97). In radiograms of the injected ureter the shadow of the pelvis of the kidney is seen to fall across those of the transverse processes just mentioned, and also that of the last rib (Fig. 103).

The anterior surface is but slightly covered by peritoneum, being only in contact with that membrane in such parts as are not in relation with the cellular tissue at the back of the colon and at the back of the duodenum or pancreas (Fig. 98). The external border is more closely in connexion with the peritoneum, while the posterior surface is quite devoid of that membrane (Figs. 97, 98, 100). Crossing the posterior surface of the kidney obliquely from above downwards and outwards are branches of the last dorsal nerve and of the first lumbar artery, together with the ilio-hypogastric and ilio-inguinal nerves (Fig. 100).

Rupture of the kidney is more often recovered from than is a like lesion of any other of the more commonly injured abdominal viscera. This

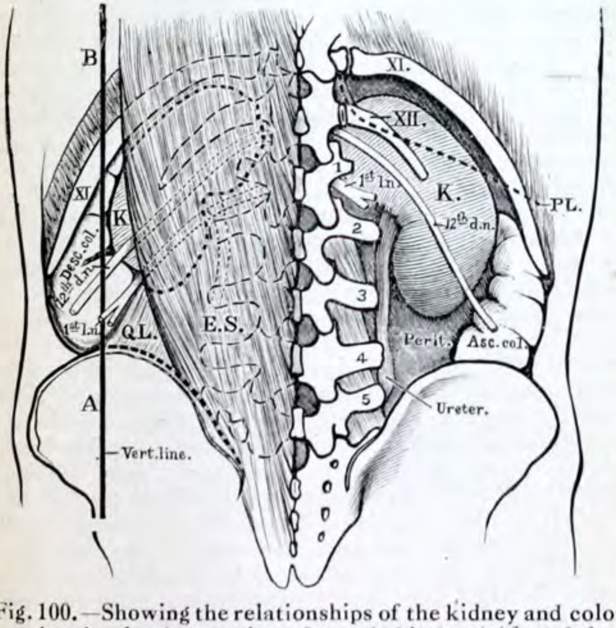

Fig. 100.—Showing the relationships of the kidney and colon in the lumbar region from behind. (*Adapted from Merkel.*)*

PL., Lower line of pleura ; XI., eleventh rib ; XII., twelfth rib ; 12th d.n., twelfth dorsal nerve ; 1st l.n., ilio-inguinal and ilio-hypogastric nerves ; A B, vertical line representing position of descending colon (desc. c.) ; Q.L., quadratus lumborum ; E.S., erector spinæ ; peritoneum (perit.) is shown reflected from the front of the kidney to the colon on the right side.

* The kidneys are represented in the position they assume when the body is turned on its face ; in the supine position they fall inwards and backwards into the position described in the text. In the subject figured above, the twelfth rib is shorter than is common.

depends upon its extensive non-peritoneal surface, whereby the extravasation of blood and urine that follows the accident is very often entirely extraperitoneal. The gland may be readily wounded from behind or from the loin, without the peritoneum being injured. When the spinal column is much bent forwards, the kidney lies in the angle of the bend, at a part where the flexion of the column is the most acute. In extreme flexion, therefore, of the spine, it may be squeezed between the ilium and the lower ribs. Thus, hæmaturia is not uncommon after injuries to the back associated with extreme bending of the spine forwards, as when a heavy weight falls upon the bowed shoulders.

The kidney is embedded in a large quantity of loose fatty tissue constituting the perirenal capsule, and suppuration extending in this tissue constitutes a **perinephritic abscess.** Such an abscess may be due to disease of the kidney itself, to affections of the adjacent parts (spine, colon, etc.), or to injuries. The pus is at first in front of the quadratus lumborum, and then usually makes its way through that muscle or through the lumbar fascia. It then presents itself at the outer edge of the erector spinæ, having passed between the adjacent borders of the external oblique and latissimus dorsi muscles. It may, however, spread into the iliac fossa, or extend into the pelvis along the loose connective tissue behind the descending colon and rectum, or open into the colon or bladder, or even into the lung. Most rarely of all does it perforate the peritoneum. **Renal abscess** usually opens upon the non-peritoneal surface of the gland. It may open into the adjacent colon. In one case a renal abscess, due to stone, made its way from the right kidney into the pyloric end of the stomach, so that a communication was established between those two organs. The **perirenal fat** is of much surgical importance, as its laxity permits of a ready enucleation of the organ. It is more abundant behind than in front. The fat is of a peculiar oleaginous nature, forming an elastic, mobile supporting cushion in which the kidney can respond to the respiratory movements of the diaphragm. When this tissue has been destroyed or modified by inflammation, the kidney becomes fixed, and its removal a matter of great difficulty. This is illustrated by the removal of a large tuberculous kidney which has been long diseased. Besides the perirenal capsule, the kidney also possesses its proper capsule, which can be easily stripped from the normal organ. The blood pressure in the renal vessels renders the capsule tense; in inflammatory conditions the tension may become so great as to interfere with the free passage of blood through the kidney. Incision of the capsule has been proposed to relieve such congested conditions.

Movable kidney. — The kidneys, being closely applied to the diaphragm, necessarily follow its respiratory movements; in normal breathing the up-and-down excursion of the kidney is about ½ an inch in extent. The *perirenal capsule* in which the kidney is loosely embedded is merely a specialized part of the subperitoneal connective tissue. The parts of the perirenal capsule have been artificially separated into *prenephric* and *postnephric fasciæ.* Above, the perirenal capsule is continuous with the dense subperitoneal tissue on the diaphragm, externally with the equally dense layer over the transversalis, internally it fuses with the sheaths of the inferior vena cava and aorta, while below it is continued downwards, as the lax subperitoneal tissue surrounding the ureter, to become continuous with the corresponding tissue in the pelvis. Hence only downward renal displacements are possible. The perirenal capsule and the renal vessels, while they restrict and determine the direction of the renal movements, only come into action when the normal respiratory limits have been exceeded. The force which retains the kidneys in position is the intra-abdominal tension maintained by the musculature of the abdominal wall, by which the other viscera are compressed against the kidneys. With the absorption of fat from the capsule the tissue of the perirenal capsule becomes more lax and the renal movements more unrestrained. Hence movable kidney is often met with in the badly nourished. It is far more common in women than in men. In the former sex the influence of pregnancy appears to have especial effect, acting, probably, by dragging upon the peritoneum, and by loosening its connexions, as well as by inducing, after delivery, a general laxity of the abdominal walls. The right kidney is far more often movable than is the left, owing probably to the displacing influence of the liver. It is not uncommon to find cases in which a movable kidney has pressed against the neck of the gall-bladder and obstructed the flow of bile. The movable kidney can, of course, only be displaced within a segment of a circle whose radius corresponds to the length of the renal vessels, and yet this displacement may be considerable.

The dragging pains which are felt with a movable kidney are due to a stretching of the renal plexus, which is connected with the solar plexus and enters the kidney with the arteries. The kidney receives its nerve supply from the tenth, eleventh, twelfth dorsal, and first lumbar segments of the spinal cord through the small and lesser splanchnics (Head). Pain is referred to the wall of the abdomen along the sensory nerves derived from these segments.

Abnormalities of the kidneys.—One, or less frequently both kidneys, may be developed in an abnormal position. The left is more often out of place than the right, and may be found over the sacro-iliac synchondrosis, or the promontory of the sacrum, or be discovered in the iliac fossa or pelvis. The irregularly placed kidney is often misshapen. The kidney may exhibit a more or less extreme degree of lobulation, a condition present in the newly born. The *ureter may be double* in its upper part or throughout its whole extent, there being two ureteral orifices in the bladder. *Supernumerary arteries* are frequently present; cases have been recorded where such vessels, passing to the lower pole of the kidney, have caused constriction or *kinking of the ureter*, and hydronephrosis. In

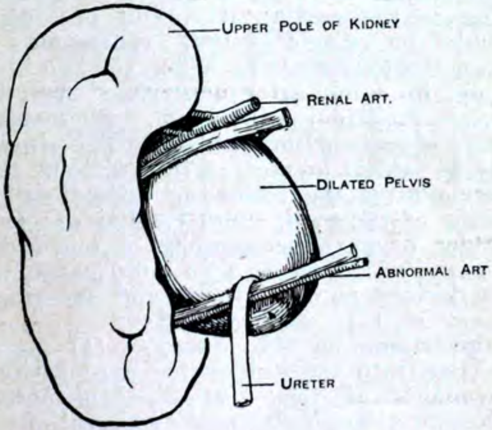

Fig. 101.—An abnormal renal artery causing kinking at the uretero-pelvic junction, and hydronephrosis. (*After Hurry Fenwick.*)

a series of cases of hydronephrosis, Mr. Hurry Fenwick found that the kinking of the ureter was due to an abnormal vessel in 16 per cent. of cases (Fig. 101).

The kidneys are developed in the pelvic region, and ascend in the early months of fœtal life to a lumbar position. New renal vessels are formed as the ascent takes place. The "sacral" kidney is one which has been arrested in its ascent, and the blood supply is drawn from the common iliac arteries. Double ureter is due to a division of the primary renal bud.

The two kidneys may be fused. "The lowest degree of fusion is seen in the *horse-shoe kidney*. The two kidneys are united at their inferior portions by a flat, riband-like, or rounded bridge of tissue, which crosses the vertebral column. In the higher degrees the two lateral portions approach one another more and more until they reach the highest degree, in which a single disc-like kidney lying in the median line, and provided with a double or single calyx, represents complete fusion" (Rokitansky). When the two kidneys are united by a web of connective tissue, the condition is no bar to operation. There may be an entire absence of one kidney. The single kidney may be lateral or median in position. Sir Henry Morris gives the following estimate of the frequency of these abnormal conditions: Congenital absence or extreme atrophy of one kidney may be expected in about 1 in 4,000 cases, the horse-shoe kidney in 1 in 1,600, and the single fused kidney in 1 in 8,000 cases.*

Operations on the kidney.—(1) *Nephrotomy.* Incision into the kidney for exploration, or the evacuation of pus. (2) *Nephrolithotomy.* Incision into the gland for the removal of a calculus. (3) *Nephrectomy.* Removal of the entire organ. (4) *Nephrorrhaphy.* The operation of securing a movable kidney in its normal position. In the first, second, and fourth operations the kidney is reached through the loin. In nephrectomy the incision is carried backwards about 1 inch over the erector spinæ, and a part of the quadratus lumborum will be divided (*see* Fig. 100). The *costo-vertebral ligament*, a specialized part of the middle layer of the lumbar fascia which binds the last rib to the tips of the upper two lumbar transverse processes, also falls in the line of the incision. The perirenal capsule

* For fuller details regarding abnormalities of kidneys, *see* "Urinary Surgery," by F. S. Kidd.

is opened up, and the gland enucleated from the capsule of fat in which it lies. In some instances the last rib has been resected to obtain more space for the operation. The pleura reaches the neck of the twelfth rib and occasionally it descends as far as the transverse process of the first lumbar vertebra (Figs. 97 and 100). Not uncommonly the *twelfth rib* is so short that it is completely hidden by the erector spinæ, and the eleventh rib appears to be the last. The pleura may be deliberately opened if necessary, and then sutured. If the patient be in a semi-prone position there is no risk of collapse of the lung.

When the kidney is free from its fatty capsule, the vessels at the hilus are secured separately by ligatures. The numerous nerves to the kidney are no doubt included with the vessels. They constitute a surgical pedicle of the kidney. At the hilus the vein lies in front, the artery and its branches next, and the ureter behind and towards the lower part. The artery is about the size of the brachial, and usually divides into four, five, or six branches before it reaches the kidney. This fact must be borne in mind if the structures at the hilus are separately secured. One-third of these branches constantly enter behind the ureter and are liable to injury in exploration of the pelvis of the kidney. The vein is also represented at the hilus by three or four branches. Accessory renal arteries may be present. Some may enter the upper end of the kidney or its anterior surface. In removing large renal tumours an abdominal incision is advised, the cut being made either along the corresponding semilunar line, and on a level with the diseased mass, or in the linea alba. The abdominal operation is the more usual one; it has the advantages of greater ease and rapidity in performance, and gives an opportunity for examining the condition of both kidneys. In chronically inflamed conditions of the kidney—as, for example, in long-standing tuberculous disease—the kidney becomes adherent, and on the right side is apt to become closely bound down to the vena cava. Much care is needed in clearing the great vein when so adherent. In removing a very adherent kidney the diaphragm has been torn.

The **suprarenal bodies** are situated at the upper poles of the kidneys, but are more closely united to the diaphragm than to these organs, as is seen from the fact that they are not displaced with the kidneys. The right body lies behind the right lobe of the liver, and so close to the inferior vena cava that the two may become bound by inflammatory adhesions. They are glands which form an internal secretion (adrenalin) that is evidently concerned in regulating the tonus of non-striated muscle. When applied directly, it causes constriction of arteries and a narrowing of the bowel. The functional activity of the gland is regulated through its relatively large supply of nerves (Canon); after violent exertions, severe injuries, or prolonged operations its adrenalin content is greatly reduced or exhausted. The cortex of the body is developed from epithelium covering the Wolffian body, and when that body descends with the genital glands, detached parts may accompany these organs and form **suprarenal tumours.** Parts may also become embedded in the kidneys and give rise to peculiar renal tumours. The medulla, which arises with the sympathetic system, receives a large nerve supply from the solar plexus. Disease of the suprarenals may cause bronzing of the skin, and hence it is believed that they are concerned in the formation of body pigment.

The **ureters** are strong tubes about 15 inches long, with thick muscular walls, and are placed entirely behind the peritoneum. The average width is that of a goose-quill. The ureter rests from above downwards upon (1) the psoas muscle and the genito-crural (genito-femoral) nerve; (2) the common iliac vessels on the left side, and

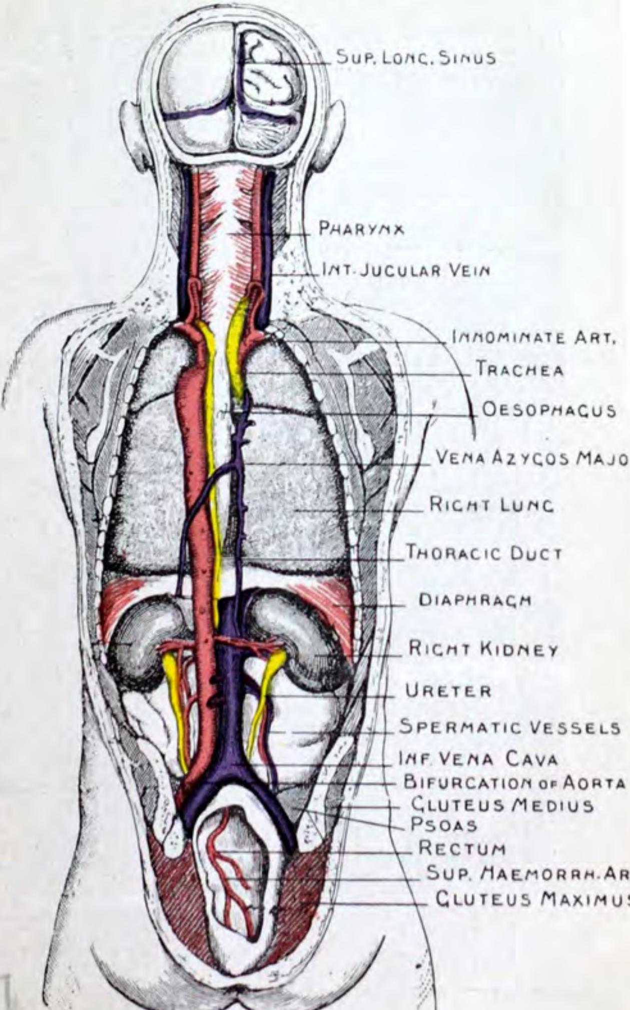

Fig. 102.—View of the kidneys, etc., from behind. (*After Rüdinger.*)

the external iliac vessels on the right side; (3) after passing downwards on the internal iliac artery it enters the posterior false ligament of the bladder, and so reaches the bladder wall. In the female it passes through the base of the broad ligament, where the uterine artery loops over it ¾ of an inch from the neck of the uterus. It rests on the roof of the upper part of the vagina before entering the bladder, and a calculus arrested in that stage may be distinctly felt. The narrowest part of the tube is the portion within the bladder walls (intramural part), and when renal calculi pass along the ureter they are often arrested at this point. There are two other narrow points at which the calculi may be stopped: at the junction of the tube with the pelvis of the kidney, and where it crosses the pelvic brim. The ureters permit of great distension, and in certain cases of gradual dilatation they have attained a width equal to that of the thumb and even of the small intestine. Several cases are recorded of rupture of the ureter from external violence. When such an accident occurs a large urinary collection usually forms behind the peritoneum, which, leading to suppuration, will produce a fluctuating tumour beneath the parietes.

The ureter expands in the sinus of the kidney into a funnel-shaped cavity—the renal pelvis. This in turn divides into the calyces. In the pelvis or calyces, calculi are frequently lodged. The calyces are too narrow to admit an exploring finger. The ureter has been successfully resected and sutured. It is supplied by nerves from the renal plexus and by vessels from the renal, inferior vesical, and subperitoneal plexus. The muscular coats have a definite contractile rhythm, the point of greatest excitability being at the pelvi-ureteral junction. Hence, it is at this point that peristaltic waves commence and sweep the urine droplets towards the bladder. In some cases hydronephrosis is the result not of kinking but of disordered condition of the rhythm-centre.

The malformations of the ureter have been already mentioned (p. 451).

In the search for impacted calculi by the aid of X-rays the following method will be found useful for indicating the course of the ureter: The pelvis of the kidney lies between the transverse processes of the two upper lumbar vertebræ

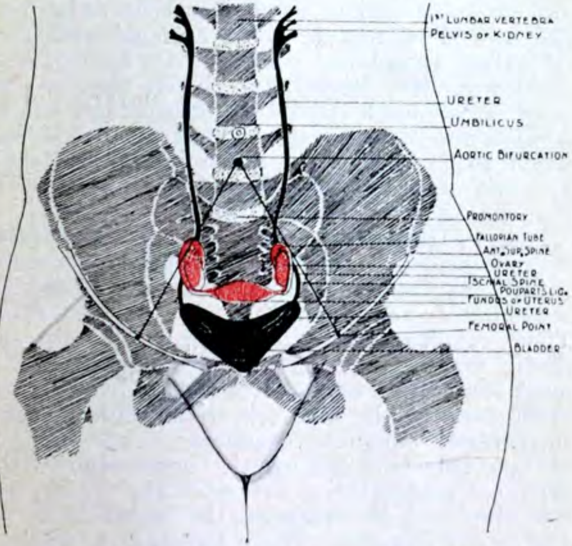

Fig. 103.—Diagram to show the course of the ureters and position of the bladder,

As they appear in a skiagram when they have been injected with a bismuth solution. The positions of the fundus of the uterus, Fallopian tubes, and ovaries are also indicated.

(Fig. 103); its position on the surface of the body may be indicated by taking a point just internal to that used for the gall-bladder (p. 433). At the brim of the pelvis the ureter crosses at or near the bifurcation of the common iliac artery, a point which lies at the junction of the upper obturator nerve, which lies beneath the sigmoid flexure and could be readily pressed upon by the gut when diseased. Pain arising from the small intestine is usually referred to the neighbourhood of the umbilicus—the distribution of the tenth dorsal nerve (Fig. 79, p. 359). It seems remarkable that such pains should be restricted to so narrow an area, but a full explanation of this is to be found in the fact that the whole of the small intestine arises from an extremely small part of the embryonic alimentary tract. Pains along the groin (along the twelfth dorsal and first lumbar nerves) arise from many sources—from disease of the kidney, ureter, ovary, testicles, Fallopian tubes, uterus, appendix, hip-joint, and from herniæ. Hence a pain referred to this region requires that all these parts should be investigated as to the source of the disease.

Blood-vessels of the abdomen.—Some of the visceral branches of the abdominal aorta are of large size, and would bleed very copiously if wounded. Thus, the cœliac axis and the superior mesenteric artery are as large as the common carotid; the splenic, hepatic, and renal vessels are about the size of the brachial; while the largest part of the inferior mesenteric trunk has dimensions equal to those of the ulnar artery. Aneurysms of the aorta are especially apt to occur at the cœliac axis, that being a point where a number of large branches are abruptly given off, and where the course of the circulation undergoes in consequence a sudden deviation. Although two, or in some places three, anastomotic arches occur between the branches of the superior mesenteric artery before they form a final network in the bowel, yet embolism of a comparatively small branch may lead to gangrene of the gut (Lockwood).

When it is remembered that the lumbar glands lie about the vena cava and iliac veins, it will be understood that great enlargement of those bodies may cause œdema from pressure. Gangrene of the whole of the small intestine may result from an embolism of the portal vein. In a case reported by Mr. Barnard the embolism was caused by an inflammatory constriction at the point where the vein passes behind the neck of the pancreas. The inferior vena cava has been ligatured successfully; amongst the collateral veins which enlarge, the chief are the azygos, epigastric, and intravertebral veins. Recently Prof. Shattock has reported a remarkable case of **complete occlusion of the inferior vena cava**—the case of the late Dr. W. Rivers Pollock. As a young man Dr. Pollock won the inter-university 120 yards hurdle race in 16 seconds, making a record. He held his breath throughout the race, and collapsed when the tape was passed. Holding the breath dams the blood back in the great veins; the heart and pulsating muscles, in such a race, must force the blood onwards into the great venous trunks, with the result that the inferior vena cava becomes overdistended, damaged, perhaps thrombosed, and then finally occluded. Gradually the veins leading from the groin to the axilla and breast become distended and varicosed, thus taking the place of the inferior vena cava. All his life long Dr. Pollock remained an invalid and had to wear elastic supports. The renal veins were also occluded, but communications between the renal and subperitoneal veins opened up, the kidneys, however, never working as in health.

A number of minute but most important anastomoses exist between some of the visceral branches of the abdominal aorta and certain of the vessels supplied to the abdominal parietes. These anastomoses are situated in the subperitoneal tissue and mostly concern such viscera as have a fair surface uncovered by that membrane. The **viscera** branches that join the anastomoses are derived from the hepatic, renal, and suprarenal arteries, and from the vessels supplying the lower part of the duodenum, the pancreas, the cæcum, and the ascending and descending segments of the colon. The **parietal** vessels joining with the above are derived from the phrenic, lumbar, ilio-lumbar, lower intercostal, epigastric, and circumflex iliac trunks. In a case detailed by Prof. Chiene the cœliac axis and mesenteric vessels were plugged, but blood in sufficient amount to supply the viscera had reached branches of these arteries through their parietal communications.

In **obstruction of the portal circulation** that is owing to disease of the liver, blood from the portal vein may pass into the systemic veins at the following points (Fig. 104): (1) Lower part of the rectum, from the superior to the inferior and middle hæmorrhoidal veins; (2) at the œsophagus, from the coronary to the œsophageal veins; (3) in the falciform and round ligaments, from the portal vein to tributaries of the epigastric; (4) in the subperitoneal tissue of the posterior wall of the abdomen, whereby the renal, phrenic, lumbar, and intercostal veins receive blood from mesenteric, pancreatic, and other veins. By bringing about adhesions between the omentum or visceral peritoneum and the parietal peritoneum, as is done in the *Talma-Morrison operation*, new and large communications are formed between the portal and systemic venous circulations. Cases have been recorded of communications between the external iliac vein and the portal vein. These have generally been effected by the deep epigastric vein joining with a pervious umbilical vein in the vicinity of the navel.

Thoracic duct.—The thoracic duct may be wounded in the course of removing tubercular glands from beneath the lower part of the left sterno-mastoid; or, as in some reported cases, may be severed by a stab in the neck. In each case lymph and chyle in large quantities escaped from the wound. The duct has been found to have been obliterated, and that, too, without producing any marked symptoms during life. It has been cut and ligatured during removal of glands from the supraclavicular triangle, with no bad result. Mr. Leaf has shown that the thoracic

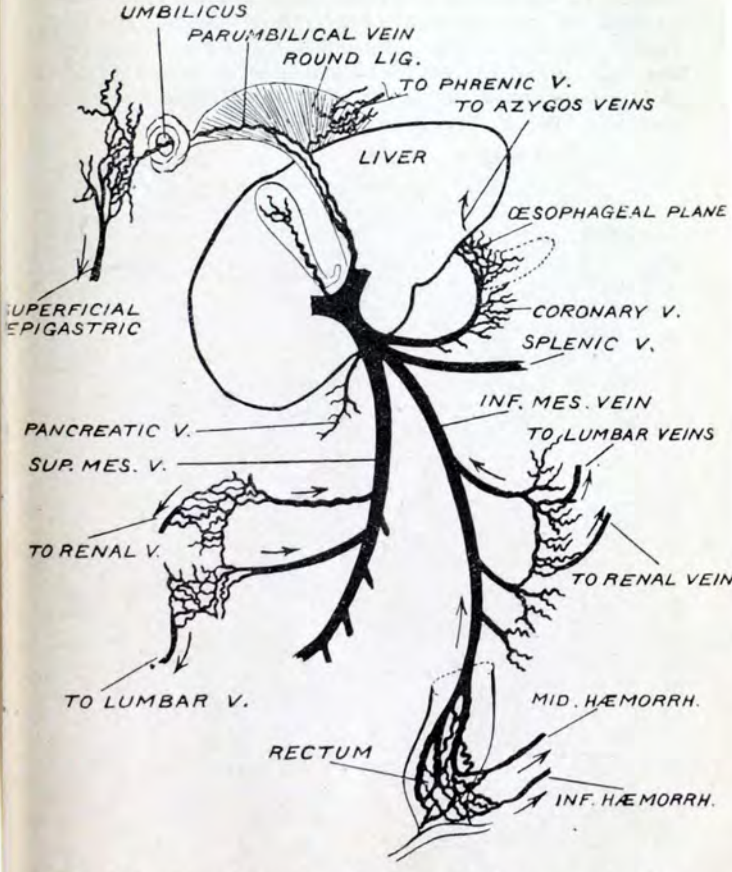

Fig. 104.—To show the sites at which communications occur between the portal and systemic circulations. (*After J. S. B. Stopford*)

duct communicates freely with the azygos veins in the posterior mediastinum and with the lymphatic vessels of the right side of the thorax and neck. It frequently serves as a channel for the spread of malignant tumours situated in the upper part of the abdomen. Enlargement of the inferior deep cervical glands in the left side of the neck may be the first sign of cancer of the stomach (W. M. Stevens).

CHAPTER XX

THE PELVIS AND PELVIC VISCERA

Mechanism of the pelvis.—Besides forming a cavity for certain viscera, a support for some abdominal organs, and a point for the attachment of the lower limb and of many muscles, the pelvis serves to transmit the weight of the body both in the standing and sitting postures. The transmission is effected through two arches, one available for the erect position, the other for the posture when sitting. In the standing posture, the arch is represented by the sacrum, the sacro-iliac joints, the acetabula, and the masses of bone extending between the two last-named points. If all other parts of the pelvis were to be cut away but these, the portions left would still be able to support the weight of the body, and would represent in its simplicity the arch through which that weight is transmitted. In the sitting position, the arch is represented by the sacrum, the sacro-iliac joints, the tubera ischiorum, and the strong masses of bone that extend between the two last-named parts. Sir Henry Morris terms these two arches the femoro-sacral and the ischio-sacral. On examining the innominate bone it will be seen that its thickest and strongest parts are such as are situate in the line of these. "When very considerable strength is requisite in an arch, it is continued into a ring so as to form a counter-arch, or what is called a *tie* is made to connect together the ends of the arch, and thus to prevent them from starting outwards. . . . The body and horizontal rami of the pubes form the tie or counter-arch of the femoro-sacral, and the united rami of the pubes and ischium the tie of the ischio-sacral arch. . . . This explains how it is that so much strain is made upon the symphysis when any increased weight has to be supported by the pelvis, as in pregnancy; why there is such powerlessness, with inability to stand or sit, in cases in which this joint is weakened or diseased; and why the anterior portion of the pelvis yields under the weight of the body and becomes deformed in rickets and mollities ossium." * The pelvic deformity in rickets, it may be here observed, varies greatly according to the age at which the disease sets in, and the usual attitude of the child when it becomes affected. In the common form of rickety pelvis the two acetabula approach one another, the anterior part of the pelvis yields, so that the symphysis is pushed forward, and the cavity becomes greatly narrowed in its transverse diameter. In severe cases the pubic arch may practically collapse, and the horizontal rami become almost parallel to one another.

In the erect attitude the pelvis is so inclined that the plane of the brim of the true pelvis forms with the horizon an angle of from 60° to 65°; the base of the sacrum is about 3¾ inches above the upper border of the symphysis, while the tip of the coccyx is a little higher than its lower border. The centre of gravity of the whole body (adult) is at a spot just above the lumbo-sacral angle, and exactly over the mid-point of a line drawn between the heads of the femora.

Fractures of the pelvis.—From what has been already said, it may be surmised that the weakest parts of the pelvis are at the symphysis and the sacro-iliac joints. The bones of these parts, however, are so very firmly knit together by powerful ligaments that it is very rare for these articulations to give way, fracture of the adjacent bones being more common. The commonest fracture of the pelvis is in the weak

* Sir Henry Morris, "The Joints," p. 116, where a most valuable account of the mechanism of the pelvis will be found.

counter-arch, and involves the rami of both the pubes and the ischium. The fracture is often associated with some tearing of ligaments about the sacro-iliac joint, and is met with in accidents due to the most varied forms of violence. This last remarkable circumstance is thus explained by Tillaux. If (*a*) the pelvis be compressed in an antero-posterior direction, the main brunt of the force comes upon the weak counter-arch, which fractures from *direct* violence. The force, continuing, tends to push asunder the two iliac bones, and so cause rupture of the *anterior* ligaments at the sacro-iliac joint. If (*b*) the force be applied transversely, the two acetabula tend to be pressed towards one another, the counter-arch becomes more bent, and ultimately gives way by *indirect* violence. The violence, continuing, forces the two ilia towards one another; the strain then falls upon the sacro-iliac joint, and the *posterior* ligaments of that joint are apt to yield, or portions of the bone adjacent to the joint are torn away. In cases of falls, when the patient alights upon the feet or ischial tuberosities, it can be understood how in many instances the main arches will escape injury owing to their great strength, while the counter-arch becomes fractured. Any part of the pelvis, including the sacrum, may be broken by well-localized direct violence. More or less of the iliac crest, the anterior superior and posterior superior spines, have been knocked off. The first-named part may be separated as an epiphysis. It joins the bone at about the twenty-fourth year. In one case the anterior inferior spinous process was torn off by the rectus muscle during the act of running a race. The os innominatum has been broken into its three anatomical portions. This accident cannot take place after about the seventeenth year, since by that time the Y-shaped cartilage is usually fully ossified, and the three elementary bones are fully united in the acetabulum. Before such consolidation occurs, abscess in the hip-joint not infrequently makes its way through the cartilage into the pelvis. The acetabulum has been fractured, and the head of the femur driven through its thinnest part into the pelvis. In fractures of the pubes and ischium the bladder has been torn by the sharp fragments. In one case a loose piece of bone that had been driven into the bladder became the nucleus for a stone. The urethra and vagina also have been lacerated or seriously compressed by the displaced bones. In fractures of the sacrum the rectum has been torn, or has been so compressed by the lower fragment (which is almost always carried forwards) as to be nearly closed.

Symphysis pubis.—Separation of the bones at the symphysis without fracture has occurred from severe violence. Malgaigne reports three cases where the separation was brought about by muscular violence only, by extreme action of the adductor muscles of the two sides. The symphysis pubis may be divided in cases of contracted pelvis, with the object of obtaining more room during labour, and of so avoiding Cæsarean section. The union consists of fibro-cartilage and transverse peripheral fibrous bands. It varies in depth from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches, and may be divided subcutaneously, when the bones gape quite $\frac{1}{2}$ an inch. It has been shown, however, that to gain $\frac{1}{2}$ an inch in the antero-posterior diameter the bones must be separated to the extent of 2 inches. Such a separation involves laceration of the sacro-iliac ligaments, and damage to the attachments of the pelvic viscera.

The **sacro-iliac joint** may be the seat of disease. Normally, there are a synovial space and a slight degree of movement in this joint. As the articulation lies in the line of the great arches of the pelvis, it follows that, when inflamed, much pain is felt, both when the patient is standing and when sitting, and particularly when an attempt is made to turn the body on the pelvis. When **abscess** forms it tends to come forwards, owing to the anterior ligament being slight while the posterior ligament is dense, thick, and of great strength. Having reached the pelvic aspect of the joint, the pus may occupy the iliac fossa, or gain the ilio-psoas sheath. Or it may follow the lumbo-sacral cord and great sciatic nerve and point in the thigh behind the great trochanter; or it may be guided by the obturator vessels to the inner side of the thyroid foramen, and ultimately appear at the inner side of the thigh. The abscess may, however, proceed backwards, and point over the posterior aspect of the joint. The joint cannot be approached from behind because of its depth and the strength and thickness of its posterior ligaments. It is best exposed from the gluteal region by an incision which runs nearly parallel to, but some 2 inches below, the posterior half of the iliac crest. The gluteal muscles and fascia are cut through until the ilium is exposed and the upper margin of the sciatic notch made out by the surgeon's finger. The joint is exposed (*see* Fig. 115, p. 525) by trephining the ilium at the mid-point of a line drawn from the anterior border of the sciatic notch to a point at the junction of the posterior and middle thirds of the iliac crest (Wheeler).

The nerve relations of this joint are important. It is supplied by the superior gluteal, by the lumbo-sacral cord and the first sacral nerve, and by the first and second posterior sacral nerves (Morris). The lumbo-sacral cord and the obturator nerve pass over the front of the joint, the former being very closely connected with the articulation. It will be understood from these relations that in sacro-iliac disease pain is felt over the sacral region (upper sacral nerves) and in the buttock (gluteal nerve). Much pain is also often complained of in the hip- or knee-joint, and along the inner part of the thigh (obturator nerve). In one or two reported cases there has been severe pain in the calf and back of the thigh, with painful twitchings in the muscles of those parts (lumbo-sacral cord and connexion with the great sciatic nerve). **Dislocation of the sacrum** at this joint is prevented by the remarkable double wedge-shaped outline of the bone, and by the very dense ligaments that bind it in its place. The bone is set very obliquely, so that the weight of the body tends to force its base into the pelvis and tilt its apex upwards. The strong posterior sacro-iliac ligaments prevent the first movement, the great sacro-sciatic the second.

Sacro - coccygeal tumours. — The sacro-coccygeal region is very often the seat of congenital tumours. To this part of the pelvis has also been found attached a third lower limb, leading to the condition known as "tripodism." Parasitic fœtuses have also frequently been found attached to this segment of the spine. In many of the instances of attached fœtuses the two individuals have been joined together at this part of the column. Some of the sacro-coccygeal tumours contain epithelial cysts and fragments of skin, muscle, nerve, bone, cartilage, and mucous membrane. These strange masses spring from the anterior part of the coccyx, between it and the rectum. By some they are supposed to arise from the coccygeal body, by others (Bland-Sutton) from the structures known to embryologists as the postanal gut and the neurenteric passage.

The **sacro-coccygeal joint** may be dislocated or diseased. In either affection great pain is kept up from the frequent movement of the part by the muscles attached to the coccyx (the gluteus maximus, coccygeus, levator ani, and sphincter). In the luxation the bone may project into the rectum, and thus give trouble. The joint and the parts about it may be the seat of such severe neuralgia ("coccygodynia") as to require excision of the coccyx, or a free division of the structures that cover it behind. The joint and the fibrous tissue about it are supplied by the following nerves: the posterior divisions of the second, third, and fourth sacral, and the anterior and posterior divisions of the fifth sacral and coccygeal. In old age the coccyx becomes ossified to the sacrum.

Floor of the pelvis and the pelvic fascia.—The outlet of the bony pelvis is occupied in the recent state by the following structures, from behind forwards: the pyriformis, the sacro-sciatic ligaments, the coccygeus, the levator ani (by far the most important element), and the triangular ligament of the perineum. These form the floor or diaphragm of the pelvis. The three structures last named separate the pelvic cavity from the perineum and provide a muscular hammock for the support of the pelvic viscera.

Apertures in the pelvic floor.—The pubo-coccygeal fibres of the right and left levator ani are separated by a narrow cleft which extends from the symphysis pubis to the ano-coccygeal body. Through this cleft or raphë pass the apertures of the pelvic floor, the anal canal, the vagina, and the urethra. The length of the cleft is about $1\frac{3}{4}$ inches; in defæcation the fibres of the levator ani are relaxed and the anal canal moves backwards and downwards so that the cleft is elongated about $\frac{1}{2}$ an inch (R. H. Paramore). In parturition the vaginal aperture becomes greatly distended by the passage of the fœtal head. In muscular efforts, when the musculature of the abdominal wall is also contracted, the cleft or raphë is shortened by the contraction of the pubo-coccygeal fibres, the anal canal being pulled towards the symphysis. The cleft is also filled, between the anal canal and the uro-genital passage, by the perineal body. Between the adjacent borders of the right and left pubo-coccygeal muscles the intervening tissue contains much non-striated muscle. Anteriorly the cleft is strengthened by the triangular ligament; the mesial pubo-coccygeal fibres lie on this ligament.

Pelvic fascia.—The pelvic fascia is a complex structure made up of the following parts: (1) muscular sheaths; (2) visceral sheaths or capsules; (3) vascular sheaths; (4) arcuate ligament of the levator ani. The *muscular sheaths* are the following: (1) The obturator fascia, which covers the pelvic aspect of the obturator internus and is attached to the interior of the pelvis round the origin of the muscle; (2) the fibrous sheet on the pelvic aspect of the pyriformis, in which are embedded the internal iliac vessels and sacral nerves; (3) the sheath of the levator ani—the layer on its perineal aspect is known as the *anal fascia*, the stratum on its pelvic aspect as the *visceral* layer of fascia; (4) the triangular ligament, which is the fibrous tissue enclosing the constrictor urethræ and affording a firm attachment to the bulb of the penis (Elliot Smith). The *visceral sheaths* are: (1) the sheath of the prostate; (2) the sheath of the vagina; (3) the sheath of the rectum. These fibrous coverings of the organs which rest on the muscular floor of the pelvis fuse with the visceral layer on the upper surface of the levator ani and with the perivascular sheaths. The *perivascular sheaths* are: (1) the fibrous tissue surrounding the visceral branches of the internal iliac artery—the uterine, vesical, prostatic, and hæmorrhoidal—and round the pelvic plexus of nerves (part of this tissue has been described under the name of the *suspensory ligament* of the pelvic viscera—A. M. Paterson); (2) the fibrous sheath surrounding the internal pudic vessels, of which Alcock's canal is a part. The *arcuate tendon* of the levator ani is the structure formerly described as the white line. It is a strong band of fibrous tissue passing backwards from the posterior aspect of the pubis, near the lower border of the symphysis, to the inner aspect of the pelvis, near the ischial spine on the inner surface of the obturator fascia. From this tendinous band many fibres of the levator ani arise; the suspensory or perivascular ligament is also supported from it. Its middle part is often free, so that one can slip a finger downwards between the arcuate ligament and the obturator fascia; a hernia may occur here. The muscular and vascular sheaths unite at their points of contact; thus the pelvic diaphragm and viscera are welded into a united complex structure.

Fixation and movements of the pelvic viscera.—The pelvic viscera are liable to displacement; a knowledge of how they are fixed and kept in position affords the only basis of a sound treatment. The bladder, rectum, and uterus must be so lodged that they can fill and empty; they must be so supported that they can withstand the violent movements and pressures to which all the abdominal viscera are subject during active muscular and respiratory efforts. To allow a free visceral movement, the parietal pelvic peritoneum is loosely attached, but over the bladder, uterus, and rectum this membrane is firmly bound down. Thus, when these viscera are distended, the reflections of the parietal peritoneum, being attached by an extremely lax layer of subserous tissue, readily allow the viscera to expand and mount up from the pelvis. When their contents are being expelled, the visceral musculature requires a fixed point from which to act. The musculature of the bladder is fixed to the back of the pubis and triangular ligament by the pubo-prostatic ligament and capsule of the prostate; it is also attached to the anterior parts of the arcuate ligaments of the levator ani by the lateral true vesical ligaments. The vagina, which is also attached to the arcuate and triangular ligaments, affords an indirect attachment of the uterus to the pelvis during parturition. The anal canal is fixed in the posterior part of the aperture of the pelvic floor. The rectum becomes continuous with the anal canal; anterior bands of its longitudinal muscular coat end in the perineal body. The rectum is further fixed by its sheath becoming continuous with the upper layer of visceral fascia on the levator ani, and to the sacrum and coccyx. The visceral fascia, which covers the upper or pelvic surface of the levatores ani and thus forms part of their sheath, and the stout perivascular sheaths (named suspensory ligaments), help to support the pelvic viscera in the following manner: Above, they are attached to the lateral pelvic wall by the fibrous ligament of the levator ani; below, they blend with the sheaths of the prostate, vagina, and rectum. When the viscera are in their normal position and the levatores ani are in action, these ligamentous supports are slack; it is only when the muscular supports of the pelvic diaphragm are relaxed or damaged and the viscera are displaced that these ligamentous supports come into action. In violent movements of the pelvic viscera their nerves and vessels would be subjected to strain were they not protected by strong sheaths. As at the shoulder-joint the muscles retain the bones in their normal position; the ligaments act only when the limit of muscle action is exceeded.

Subserous tissue of the pelvis.—The loose subserous tissue which attaches the peritoneum to the pelvic fascia is often the seat of inflammatory processes, especially in the female. Between the broad ligaments, round the neck of the uterus and by the sides of the vagina it is particularly abundant, and forms the perimetric and parametric tissue. It allows a free mobility to the vagina and uterus. Inflammatory processes and abscesses may spread rapidly up the sides of the pelvis and into the iliac fossæ, through the subserous stratum of connective tissue. In this stratum, too, lie the ureter and the iliac vessels, surrounded by their fibrous sheaths. In this layer are also the fibro-muscular bands which form the utero-sacral and round ligaments. The **utero-sacral ligaments** encircle the pouch of Douglas and bind the upper part of the vagina to the loose tissue of the sacrum. The fold of peritoneum at the bottom of the recto-vesical or recto-vaginal pouch is fixed to the sheath of the prostate or vagina and to the perineal body by a septum of fibrous tissue which separates the rectum from the structures anterior to it.

CHAPTER XXI

THE PERINEUM

Male perineum (Fig. 105).—This is a lozenge-shaped space bounded by the symphysis, the rami of the pubes and the ischia, the ischial tuberosities, the great sacro-sciatic ligaments, the edges of the two great gluteal muscles, and the coccyx. A transverse line drawn across the space between the anterior extremities of the tubera ischiorum, and just in front of the anus, divides the perineum into two parts. The anterior part forms nearly an equilateral triangle, measuring about $3\frac{1}{4}$ inches on all sides; it is called the *urethral triangle.* The posterior part is also somewhat triangular, contains the rectum and ischio-rectal fossæ, and is called the *anal triangle.*

The bony framework of the perineum can be felt more or less distinctly all round, and in thin subjects the great sacro-sciatic ligaments can be made out beneath the great gluteal muscle. The anus is in the middle line between the ischial tuberosities, its centre being about $1\frac{1}{2}$ inches from the tip of the coccyx. The raphë, a lineal ridge in the skin, can be followed from the anus along the middle line of the perineum, scrotum, and penis. No vessels cross this line, and, therefore, in making incisions into the perineum the line is always chosen when possible. In the middle line, midway between the centre of the anus and the spot where the scrotum joins the perineum, is the central point of the perineum. The two transverse perineal muscles, the bulbo-cavernosus and the sphincter ani, meet at this point, which also corresponds to the centre of the inferior edge of the triangular ligament. The bulb is just in front of it, as is also the artery to the bulb, and in lithotomy, therefore, the incision should never commence in front of this spot.

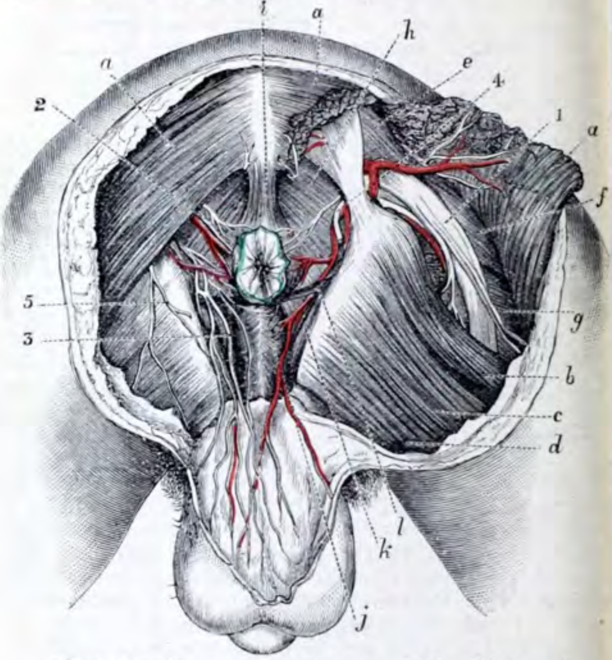

Fig. 105.—The male perineum. (*After Rüdinger.*)

a, Gluteus maximus; *b*, semi-tendinosus and biceps; *c*, adductor magnus; *d*, gracilis; *e*, pyriformis; *f*, obturator internus; *g*, quadratus femoris; *h*, levator ani; *i*, external sphincter; *j*, bulbo-cavernosus; *k*, ischio-cavernosus; *l*, transversus perinei; 1, sciatic nerve; 2, inferior hæmorrhoidal vessels and nerve; 3, superficial perineal vessels and nerves; 4, pudic (internal pudendal) nerve (cut) and pudic artery; 5, perineal branch of posterior cutaneous of thigh.

The perineal space is separated from the pelvic cavity by the levator ani muscles and the fascial structures connected with them. The *depth* of the perineum means the distance between the skin and the pelvic floor. This depth depends, to a great extent, upon the amount of fat under the integument. It varies considerably in different parts, measuring from 2 to 3 inches in the hinder and outer parts of the perineum, and less than 1 inch in the anterior parts of the space.

The **ischio-rectal fossa** is of pyramidal shape, its apex being at the lower border of the levator ani (*see* Fig. 106), and its base being formed by the skin between the anus and the ischial tuberosity. The fossa is shut in at its apex by the fusion of the fibrous layers covering its outer and inner wall. It becomes shallower as it passes forwards, and ceases opposite the base of the triangular ligament. It measures about 2 inches from before back, 1 inch from side to side, and is between 2 and 3 inches in depth. Its boundaries are: on the *outer* side, the obturator internus muscle, covered by its fascia and the fibrous sheath of the internal pudic vessels and nerves (Fig. 106); on the *inner* side, the levator ani, covered by the anal fascia; in *front*, the base of the triangular ligament and the transversus perinei muscle; and *behind*, the gluteus maximus, great sacro-sciatic ligament, and coccygeus. The pudic vessels and nerves (internal pudendal) are placed about 1½ inches above the lower border of the tuber ischii. The fossa is occupied by a mass of fat which affords to the anal canal the support of an elastic cushion. This fatty tissue is badly supplied with blood, and this fact, in addition to the dependent situation of the part, and its exposure when the patient sits upon damp, cold seats, etc., leads to abscess being very frequent in the space (**ischio-rectal abscess**). These abscesses are hemmed in on all sides, soon fill the fossa, and then tend to discharge themselves in the two directions where the resistance is least, viz. through the skin and through the wall of the anal canal. When this double discharge of the abscess has taken place, a complete **fistula in ano** is established. It is well to note that in fistulæ in ano the opening into the anal canal is nearly always within ½ an inch of the anus. An opening into the bowel high up is resisted by the union of the fibrous covering of its outer and inner wall (Fig. 106).

Crossing the space obliquely from its hinder part to the anus are the inferior hæmorrhoidal vessels and nerves (Fig. 105); crossing the an-

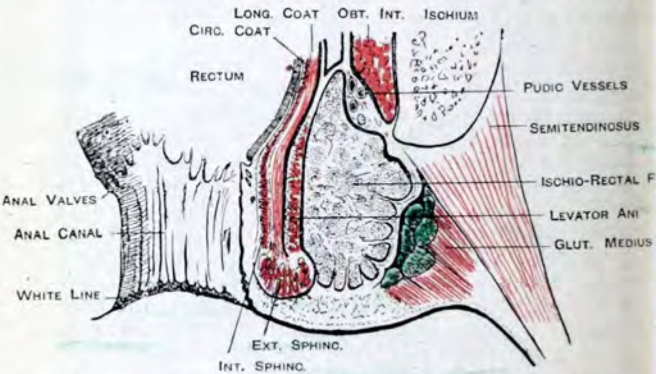

Fig. 106.—Section of the anal canal and of the ischio-rectal space. (*Modified from figures by Prof. Elliot Smith and Sir Charles Ball.*)

terior and outer corner of the fossa are the perineal vessels and nerves, and about the posterior border of the space are the fourth sacral nerve and some branches of the small sciatic nerve (posterior femoral cutaneous). It will be readily understood, therefore, that ischio-rectal abscesses are associated usually with extreme suffering until they are relieved. The severe pain is probably due to the rich nerve supply of the skin and mucous membrane of the anus, and also to the stretching of the external hæmorrhoidal nerve by the abscess as it progresses towards the surface. In opening an abscess in the fossa the main structures to avoid are the rectum, the pudic and inferior hæmorrhoidal vessels.

Anus. (*See* p. 518.)

Urethral triangle. — The skin of the perineum between the anus and the scrotum is thin, and shows very readily any extravasations of blood that may form beneath it. The superficial fascia is divided into two layers, of which the more superficial is quite unimportant, and contains what little subcutaneous fat exists in this part.

The deep layer, known as the **perineal fascia** (fascia of Colles), is attached on either side to the rami of the pubes and ischium, and behind to the base of the triangular ligament. In front it becomes continuous with the dartos coat of the scrotum. This fascia, therefore, by its attachments forms with the triangular ligament a well-isolated aponeurotic space, containing the bulb with all that part of the spongy (cavernous) urethra between the triangular ligament and the attachment of the scrotum, the penile muscles, the transverse perineal muscles, vessels, and nerves, and the perineal vessels and nerves. When extravasation of urine follows upon a rupture of the part of the urethra above named, the course of the escaping fluid is directed by the attachments of this pocket-shaped fascia. The urine fills the pocket. It is unable to gain the ischio-rectal fossa on account of the attachment of the fascia to the triangular ligament. The lateral attachments of this membrane prevent the urine from passing into the thighs. It is therefore guided into the scrotum, and there finds itself beneath the dartos tunic. It distends the scrotal tissues, and then mounts up on to the abdomen through the gap left between the symphysis pubis and pubic spine. It must be remembered that the perineal fascia, the dartos coat, and the deeper layer of the superficial fascia of the abdomen are continuous, and merely represent different parts of the same structure. Pus or blood within this aponeurotic space would follow the same course if the effusion were extensive enough. The pain occasioned by such effusion can be understood when it is noted that the three chief sensory nerves of this region (the two superficial perineal from the pudic, and the perineal branch of the posterior femoral cutaneous) are included within the space (Fig. 105).

The **triangular ligament** has a depth of about 1½ inches in the middle line, and is formed of two layers, of which the posterior is thin, ill defined, and formed by the sheath on the lower surface of the pubic fibres of the levator ani. The membranous urethra, surrounded by the sphincter (constrictor) urethræ, lies between the two layers, and runs about 1 inch below the symphysis, and about ¾ of an inch above the central point of the perineum (Fig. 107). The artery to the bulb passes inwards between the two layers about ½ an inch above the base of the ligament and 1½ inches in front of the anus. The terminal part of the pudic artery pierces the anterior layer of the ligament about ½ an inch below the symphysis. The dorsal vein of the penis enters the pelvis between the subpubic ligament and the apical part (transverse part) of the triangular ligament; the dorsal nerve accompanies it (Elliot Smith). In uncomplicated rupture of the membranous urethra the urine extravasated would be limited to the space between the layers of the ligament until subsequent suppuration had made a way for it to escape. When extravasation occurs behind the triangular ligament, the effusion may collect in the retropubic space if the capsule of the prostate is ruptured (Deanesley), or it may pass backwards by the side of the rectum into the cellular tissue of the pelvis.

On the deep or pelvic aspect of the triangular ligament is the prostate, surrounded by its capsule and the prostatic venous plexus (Figs. 107 and 108). In dissecting down from the surface to the prostate, we meet, as Cunningham has well

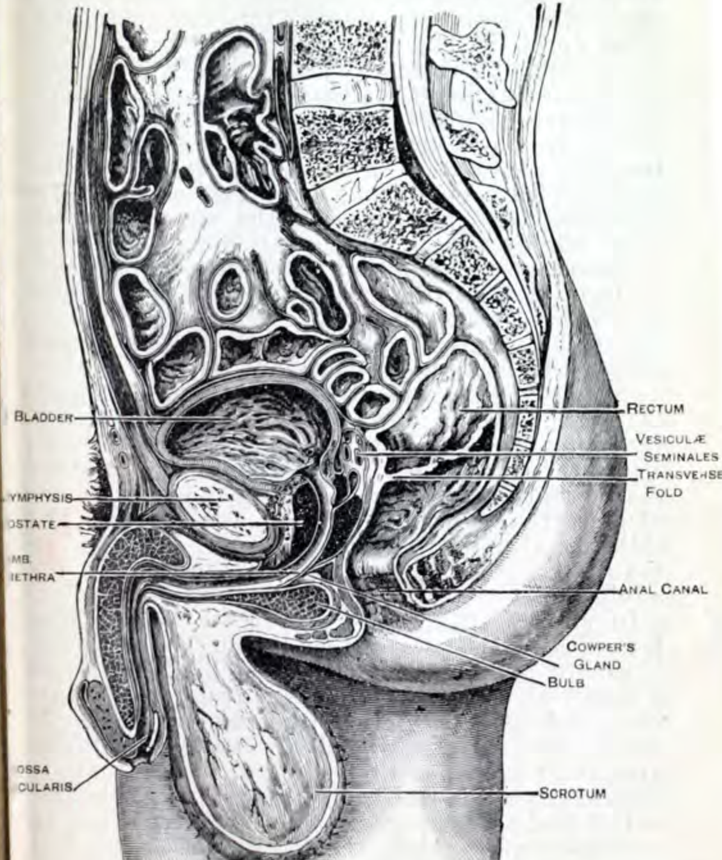

Fig. 107.—Vertical antero-posterior section of the male pelvis. (*Braune.*)

ectlop lithotopy

pointed out, alternate strata of fascial and muscular tissue, forming seven layers in all, viz.: (1) superficial fascia; (2) superficial perineal *muscles;* (3) triangular ligament (anterior layer); (4) sphincter urethræ *muscle;* (5) triangular ligament (posterior layer); (6) levator ani *muscle;* (7) sheath of prostate.

Stone in the bladder.—Stones in the bladder, which were formerly removed by a perineal incision, are now commonly crushed and washed out through the urethra by the operation of *litholapaxy.* This operation is carried out readily even in male children. If the stones are too large for crushing, the suprapubic operation is performed to give sufficient room for extraction.

In operations for the removal of vesical calculi in *children* it must be kept in mind that in them the pelvis is relatively narrower than in the adult, the bladder is more an abdominal than a pelvic organ, and the neck of the bladder, therefore, is high up. The viscus, moreover, is very movable, and has less substantial attachments than has the adult's bladder. In children the prostate is slightly developed, and thus more of the actual neck of the bladder is exposed. In children also the peritoneum descends lower on the posterior surface of the bladder than in the adult (*see* p. 491).

In **perineal lithotomy**, and in other operations for reaching the neck of the bladder by this route, it should be remembered that the bladder lies at a depth of from 2½ to 3 inches from the surface when the body is in the lithotomy position. If the bladder is empty and the rectum full, the prostate, trigone, and reflection of peritoneum are carried upwards and forwards; if the bladder is full and the rectum empty, the movement is in an opposite direction. In fat people the bladder and peritoneum are carried away from the perineum; in lean people the opposite is the case.

Suprapubic lithotomy.—This operation has been revived of late years, and, in cases in which litholapaxy is contraindicated, has supplanted perineal operations. In order to bring the summit of the bladder well above the symphysis, both bladder and rectum may be dilated. Into the former viscus, tepid water or boric lotion is injected. It is found that in the adult 8 to 10 oz. is sufficient to ensure the desired distension. In the case of a male child aged 5, the injection of 8 oz. of water into the bladder caused the reflection of peritoneum to mount to more than 1 inch above the symphysis. An incision, some 3 inches in length, is made immediately above the symphysis in the median line. The bladder is exposed below the peritoneum, is drawn forwards by a hook, and opened.

The bladder.—During micturition the muscular coats of the bladder contract until the organ becomes a firmly contracted cone-shaped body, its lining membrane being thrown into folds and its lumen completely obliterated by the end of the act. All parts contract, the trigone as well as the dome. When the act is finished the bladder relaxes and becomes triangular in outline, flattened against the anterior half of the pelvic floor or diaphragm, the apical part resting against the posterior aspect of the symphysis. Then it begins to fill; at very short intervals of time, tiny jets of urine are forced in at the two ureteric orifices, situated at the lateral angles of the trigone, by the peristaltic waves which sweep slowly down the ureters. The ureters act as hydraulic pumps in the filling of the bladder; the ureteric orifices are valvular, and the vesical musculature at their orifices acts so as to produce a sphincteric effect, thus preventing reflux. As the bladder fills, its muscular coats pass into a state of passive contraction or tonus; as in all involuntary muscle, the tone of the bladder is rhythmical, waxing and waning. The muscular coats yield reflexly and adapt themselves to the increasing content until a certain point is reached—a point which gives the sensation of fullness and discomfort. The escape of urine is prevented (1) by the involuntary or reflex-acting *vesical sphincter* (internal sphincter), which surrounds the neck of the bladder and commencement of the urethra (Fig. 108, A, A); (2) by the voluntary urethral sphincter, placed between the layers of the triangular ligament (Fig. 108, E, E). The act of micturition is initiated by a voluntary compression of the bladder (by the abdominal and pelvic musculature) which is sufficient to overcome the vesical sphincter and force urine into the upper part of the urethra. Urine in the urethra produces a reflex inhibition of the sphincters, and at the same time stimulates the contraction of the expelling vesical musculature. Thus in life the shape of the bladder and its relationships are constantly changing. At death we may find the bladder in every stage of contraction (systole) or of relaxation (diastole).

When moderately distended with an opaque solution and examined by the aid of X-rays, the bladder is seen to be conical in form, with its apex behind the symphysis and its base or upper surface indented by the pressure of the abdominal viscera (Fig. 103, p. 457). As *distension of the bladder* increases, the summit of the viscus is brought more and more in contact with the anterior abdominal wall, the organ becoming also more convex on its posterior than on its anterior surface. This tendency for the summit of the distended bladder to press itself against the anterior parietes is of good service in tapping the organ above the pubes, and also in suprapubic lithotomy. When greatly distended it may reach the umbilicus, and may even touch the diaphragm. The usual capacity of the organ is about one pint, but when quite full it may hold some quarts. When both bladder and rectum are quite empty the apex of the bladder and the prevesical reflection of the peritoneum are a little below the upper margin of the symphysis pubis. As the distended bladder ascends above the pubes it dissects the serous membrane from the parietes, and the layer so lifted off forms a cul-de-sac or fold of peritoneum between the upper part of the anterior surface of the bladder and the parietes. When the apex of the bladder is 2 inches above the pubes the peritoneal reflection is probably not more than $\frac{3}{4}$ of an inch above the same point of bone. When the apex of the bladder is midway between the umbilicus and the pubes there may be 2 inches (vertical) of the anterior abdominal wall in the middle line and immediately above the symphysis devoid of peritoneal lining. Thus it happens that the distended viscus may be tapped above the pubes without the peritoneum being wounded, but this is not always the case (R. Thompson). As the bladder becomes distended, not only does it rise into the abdomen, but it extends also towards the perineum, diminishing the length of the prostatic and membranous urethra.

Between the anterior surface of the bladder and the symphysis, and shut in by the peritoneum above, is the *retropubic or prevesical space*, containing lax connective tissue (Fig. 108). The looseness of this connective tissue permits the bladder readily to ascend as it fills. In injuries to the pelvis and to the front of the bladder a diffuse inflammation may be set up in this tissue and assume serious proportions. Extension of a retropubic abscess into the perineum is limited by the fascial reflections formed by the pubo-prostatic and lateral vesical ligaments.

The bladder, although fairly fixed, has been found in inguinal, femoral, and vaginal herniæ. In the erect position its neck (in the male) lies on a horizontal line drawn from before backwards through a point a little below the middle of the symphysis, and is placed about $1\frac{1}{4}$ inches (3 cm.) behind that articulation, but its position varies with the fullness of the bladder and the state of the rectum.

Relations of the bladder to the peritoneum.—The pubic surface is entirely devoid of peritoneum, while the superior surface is entirely covered by that membrane. At the sides there is no peritoneum in front of, or below, the obliterated hypogastric arteries. On the posterior aspect of the bladder the serous membrane extends down as far as a transverse line uniting the upper parts of the two seminal vesicles, so that the upper ends of the vesicles are covered by peritoneum. This recto-vesical pouch of peritoneum in the adult extends to within about 3 inches of the anus, and does not reach below a line 1 inch above the base of the prostate. Harrison Cripps gives the distance of the pouch from the anus as 2½ inches when the bladder and rectum are both empty, and as 3½ inches when those viscera are distended. (*See* Bladder in the Child, p. 490.)

Puncture of the bladder per rectum.—The base of the bladder is applied to the lower part of the rectum, but they are separated by a thin fibrous septum—the recto-vesical. The area in contact with the rectum is triangular in shape, the apex being formed by the prostate, the sides by the diverging seminal vesicles, and the base by the recto-vesical fold of peritoneum. This triangle is equilateral, and in the dissected specimen measures about 1½ inches on all sides. It corresponds to the trigone on the inner surface of the viscus. It is through this triangle, and as near as possible to the prostate, that the bladder is tapped when the operation is performed per rectum. The recto-vesical fold of peritoneum is raised, and is carried still farther from the anus when the organ is distended.

Rupture of bladder.—The bladder may be ruptured by violence applied to the anterior abdominal wall apart from pelvic fracture or external evidence of injury. Such a rupture can, however, hardly happen to the empty bladder; it must be full or distended at the time of the accident. It is very rare for the rupture to be on the anterior surface only. As a rule, the tear involves the superior or abdominal surface, and implicates the peritoneum. The injury, therefore, is very fatal (5 recoveries out of 78 cases). In some cases of vesical rupture the surgeon has opened the abdomen and has stitched up the rent in the viscus with perfect success. The bladder may be torn by fragments of bone in fractures of the pelvis, or by violence applied through the rectum or vagina. A case, for example, is reported (Holmes's "System of Surgery") of a man who fell upon a pointed stake fixed in the earth. The stake passed through the anus, pierced the rectum, and entered the bladder near the prostate. The patient recovered, the wound having been made in the triangular area on the fundus of the bladder alluded to above, and therefore outside the peritoneum. The viscus may be ruptured by an accumulation of urine, as seen in cases of congenital closure of the urethra in some infants. In the museum of the Royal College of Surgeons is a preparation of "the bladder of a woman which burst near the entrance of the ureter in consequence of neglected retention of urine." In neglected cases of stricture in the male the urethra gives way rather than the bladder, and an extravasation of urine into the perineum follows. A small puncture of the bladder, as, for example, that made by a fine trocar, is at once closed by the muscular contraction of its wall.

The **mucous membrane** of the bladder is very lax, to allow of its accommodating itself to the varying changes in the size of the viscus. Over the trigone, however, it is closely adherent, and were it not so the loose mucous membrane would be constantly so prolapsed into the urethral orifice during micturition as to block up the neck of the bladder. When examined by the cystoscope, the mucous membrane is seen to be red and congested when the bladder is empty, pale and anæmic when the bladder is full (Newman). The trigone is bounded by three orifices, for the urethra and the two ureters, and forms an equilateral triangle, measuring about $1\frac{1}{2}$ inches on all sides. It is here that the effects of cystitis are most evident, and the unyielding character of the mucous membrane over the trigone serves in part to explain the severe symptoms that follow acute inflammation of that structure. Since the orifice of the urethra forms the lowest part of the bladder in the erect posture, it follows that calculi gravitate towards the trigone, and are very apt to irritate that part of the interior. The same remark applies to foreign bodies in the viscus. The mucous membrane about the trigone and neck is very sensitive, whereas the interior of the remainder of the bladder appears to be singularly defective in common sensation. This can be well noted in using sounds and catheters.

The **sensory nerves** for the bladder are derived mainly from two parts of the spinal cord, namely, the twelfth dorsal and first lumbar segments, and the second, third, and fourth sacral segments. From the first source (through the hypogastric plexus) come the sensory nerves to the upper part of the bladder, and the motor nerves which stimulate the internal sphincter to contract and inhibit the expelling musculature; and from the second source (through the nervi erigentes) the motor fibres which stimulate the expelling musculature and inhibit the sphincter. The trigone, having the same nerve supply as the penis and scrotum, gives rise, when injured, to pains which are referred along the perineal nerves. The co-ordination of the various structures concerned in the act of micturition is a function of a nerve centre (micturition centre) in the lumbar part of the spinal cord.

In the **muscular coat** of the bladder the fibres are collected in bundles which interlace in all directions. When the viscus becomes hypertrophied these bundles are rendered very distinct, and produce the appearance known as "fasciculated bladder." This simply means that the muscle of the bladder, having been unduly exercised to overcome some obstruction to the escape of urine, increases in size, as do other much-exercised muscles, and that increase serves to demonstrate the arrangement of the individual bundles. From distension the mucous membrane becomes bulged out between the unyielding muscle bundles, so that sacculi are formed, and the appearance known as "sacculated bladder" is produced. In some cases the parietes yield especially at one part, and one large saccule is produced. In this way a sacculus may be formed which in time may become almost as large as the bladder itself, and give rise to the erroneous description of "double bladder," etc.

The **ureters** run for $\frac{3}{4}$ of an inch in the muscular wall of the viscus, and their oblique course, together with the action of the neighbouring vesical musculature, prevents the regurgitation of urine from the bladder. No circular muscular fibres surround the termination of the ureter; there is nothing in the nature of a sphincter to safeguard the orifice (T. B. C. Benians). On cystoscopic examination it is seen that once or twice a minute each ureter contracts and expels a spurt of urine into the bladder; between these spurts the ureteric orifices are closed by the intravesical pressure. If the ureter becomes shortened, as is the case if it is the seat of a tubercular ulceration, the vesical orifice of the ureter is drawn outwards (Fenwick). The mucous membrane is laxly attached and may be prolapsed within the bladder as a pedunculated body. In cases of retention the ureters become distended; but this is due rather to accumulation of urine within them than to its reflux from the bladder. In cases of great distension of the bladder the neck of the viscus is opened up by the pressure from within, and the patient exhibits the feature of overflow of urine. A band of muscle passes from the sheath of the ureter towards the internal urinary meatus along each side of the trigone (Bell's muscle), while another (Mercier's bar) unites the orifices across the base. These bands maintain the ureteral orifices in position when the bladder is full, and safeguard their valvular mechanism (Wright and Benians). Infections spread readily from the bladder to the ureter and from the ureter to the pelvis of the kidney; the valvular orifice of the ureter offers no hindrance to them.

The **female bladder** is less capacious than that of the male. Its neck is situated a trifle nearer to the symphysis than it is in the male, and lies in a horizontal line continued back from the lower border of the symphysis. There being no prostate, the neck of the bladder is very distensible, and this fact, taken in connexion with the shortness and dilatability of the urethra, allows of most stones being extracted by forceps without cutting. By simple dilatation, stones of a diameter of $\frac{3}{4}$ of an inch have been removed. Through the dilated urethra the orifices of the ureters can be seen and examined. The intimate relation of the bladder to the vagina allows it to be examined well from the latter passage, and the comparative thinness of the dividing wall serves to explain the frequency of vesico-vaginal fistulæ. Strange foreign bodies have been introduced into the female bladder, such as hair-pins, crochet-hooks, sealing-wax, penholders, and the like.

The orifice of the ureter is 3 cm. from the cervix uteri, and 4 cm. from the vesical opening of the urethra. The close relation of the ureter to the cervix renders it liable to injury in supravaginal amputation of that part, and in certain operations on the uterus.

The **bladder in the child** is egg-shaped, and its vertical axis is relatively much greater than in the adult. The larger end of the egg-shaped cavity (the base or fundus) is directed downwards and backwards. The base is developed and the pelvic position assumed about the fourth year

(Birmingham). The viscus is situated mainly in the abdomen, the pelvis being small and very shallow. At birth the orifice of the urethra is on a level with the upper edge of the symphysis. Although the bladder projects so freely into the abdomen, its pubic wall is still entirely uncovered by peritoneum. On the posterior wall the serous membrane extends lower down than in the adult, reaching the level of the urethral orifice at the time of birth, and the level of the prostate in young male children. The prostate is exceedingly small in children. Thompson states that at the age of 7 years it only weighs 30 gr., whereas in subjects between 18 and 20 it weighs 250 gr. The bladder wall in the child is so thin that in sounding for stone it is said that a "click" may be elicited by striking the pelvis through the parietes of the viscus.

The prostate.—The prostate is situated about ¾ of an inch below the symphysis pubis, and rests upon the rectum above the anal canal (Fig. 107). It is, therefore, placed within 1½ to 2 inches of the anus, and can be readily examined from the bowel. The prostate is made up of two lateral lobes which fuse together in front of the urethra by a *pubic commissure* (Fig. 108) and behind by two commissures, one above the common ejaculatory ducts—the *median commissure*—and one below those ducts—the *rectal commissure* (*see* Fig. 108, B, D). The part here named median commissure was formerly known as the *median lobe*—a name which is apt to mislead, for it is not a separate lobe, but, as already explained, merely a fusion of the two lateral lobes. Each gland is made up of numerous branching tubular glands which are embedded in and surrounded by non-striated muscle and fibrous tissue. The glands end in the urethra—chiefly in the prostatic sinuses—but the use of their secretion is unknown. The secretion is discharged through the long and very narrow ducts. In certain forms of prostatic irritation, little white opaque threads, very much like short pieces of cotton, are found in the urine, and are actual casts of the prostatic ducts.

Capsule of the prostate.—Owing to the success which has attended enucleation as a means of treatment for enlarged prostate, much discussion has recently taken place concerning its ensheathing structures. The term *capsule* has

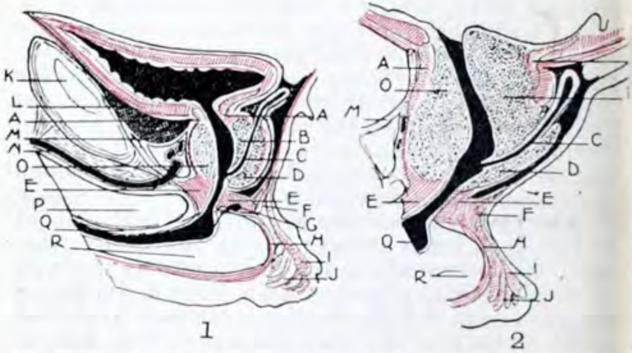

Fig. 108.—1, Median section of the normal prostate; 2, similar section of enlarged prostate.

A, A, Sphincter vesicæ; B, median commissure; C, common ejaculatory duct; D, rectal commissure; E, E, sphincter urethræ; F, recto-urethral muscle; G, Cowper's gland; H, bulbo-cavernosus; I, internal sphincter of anus; J, external sphincter of anus; K, symphysis pubis; L, retropubic space; M, pubo-prostatic ligaments and sheath of prostate; N, dorsal vein of penis; O, pubic commissure; P, corpus cavernosum; Q, urethra: R, bulb.

been proposed for the superficial fibro-muscular stratum of the gland, while the term *sheath* has been applied to the enveloping fibrous structure derived from the pelvic fascia. In enucleating the gland everything within the sheath is removed. At only one part is the sheath intimately adherent to the capsule, and that is along the anterior or pubic surface; elsewhere it is free of it. Since the base of the prostate is applied to the bladder and uncovered by the sheath, while elsewhere it is enclosed, it follows that the sheath is most easily entered and the gland enucleated from the bladder (Fig. 108, B). The apex of the prostate rests on the sphincter urethræ; its sides are applied to the pubo-rectal (pubo-coccygeal) fibres of the levator ani; hence the sheath of the prostate fuses with the adjacent sheaths of these two muscles. The prostatic plexus of veins, which receives the vesical veins, tributaries and communications of the dorsal vein of the penis, internal pudic (pudendal) and obturator veins, lies in the fibrous tissue between the prostate and levator ani. The tissue to the outer side of the veins is counted sheath; that to the inner, capsule. The sheath of the prostate on the posterior or rectal aspect is formed by the *recto-vesical septum.*

The prostatic abscess usually bursts into the urethra, that being the direction in which least resistance is encountered. If it does not enter the urethra, it will probably open into the rectum, there being only the recto-vesical septum of fascia between the two organs. This encasement of the gland in an unyielding membrane will serve, in part, to explain the severe pain felt in acute prostatic abscess. In acute prostatitis pains are referred over the tip of the last rib (tenth dorsal nerve), over the posterior iliac spine (eleventh dorsal nerve), or even to the soles of the feet (third sacral nerve). The prostate derives its nerve supply from the lower three dorsal and upper three sacral segments; hence the widely distributed character of the referred pains (Head).

Hypertrophy of the prostate.—The average measurements of the normal prostate are $1\frac{1}{2}$ inches across at its widest part, and $1\frac{1}{4}$ inches from before backwards, or from apex to base. After the age of 53 the organ is very apt to become hypertrophied; and, according to Sir Henry Thompson, this hypertrophy may be considered to exist when the gland measures 2 inches from side to side, or when it weighs 1 oz. or more. The usual weight of the prostate is ¾ oz. If the enlargement mainly affect the lateral parts, it will be understood that the hypertrophy may attain considerable dimensions without retention of urine being produced. On the other hand, a comparatively trifling enlargement of the median commissure (third lobe) may almost entirely block the orifice of the urethra. As this part enlarges it pushes its way into the bladder through the urethral orifice, dilating and destroying the sphincter vesicæ and forming a mechanical obstruction to the free passage of urine (Fig. 108, 2). If the affection be general, the prostatic urethra is lengthened, and if one lateral lobe be more enlarged than the other, the canal deviates to one side. When the enlargement particularly affects the median commissure, the prostatic urethra, which is normally almost straight, becomes considerably curved, the curve being sometimes very abrupt. It is important to note that enlargement of the median commissure alone can hardly be made out by rectal examination. The projecting middle commissure, when viewed from the interior of the bladder, may appear as a distinct, well-rounded, pedunculated or sessile growth.

In the operation of *prostatectomy* this projecting and most troublesome mass is removed through a suprapubic incision. Everything within the sheath of the prostate—gland, urethra, common ejaculatory ducts—is enucleated by the surgeon's finger through the base of the bladder; the sheath then encloses a space which at first is filled with blood and urine, but afterwards contracts to form a new urethra. In spite of the destruction of the prostatic part of the urethra, the patient soon attains control of the act of micturition. The sphincter urethræ is undamaged. The prostate is a sexual organ, and its size and development depend on the presence and activity of the testes. In early life castration prevents its development or causes atrophy if already developed; but this is only partially true when the operation is performed after the full development of sexual life. Removal of one testicle causes a partial atrophy, but section of the vasa deferentia has usually no effect (C. Wallace). The lymphatics of the prostate, which are numerous, pass to a group of glands on the wall of the pelvis, between the external and internal iliac arteries.

The **male urethra** is about 8½ inches in length (21 cm.), 1¼ inches being devoted to the prostatic urethra, ¾ of an inch to the membranous, and 6½ inches to the penile or spongy (cavernous) portion. Between the ages of 4 and 6 years its length is 8 to 9 cm., and between 10 and 13 years 10 to 11 cm. The canal may be divided into a pelvic and relatively fixed and a perineal, penile or movable part. The pelvic part extends from the neck of the bladder to the anterior layer of the triangular ligament. The sphincter urethræ makes a functional demarcation of the two parts. This pelvic part describes an even curve, fairly represented by a line parallel with the axis of the outlet of the pelvis. The "short curve" of a metallic catheter is designed to accommodate the axis of the pelvic urethra. This part of the urethra lies about 1 inch behind and below the pubic arch. The movable portion of the urethra forms, when the penis is dependent, a curve in the opposite direction, so that the whole canal follows somewhat the outline of the letter **S**.

In **introducing a catheter** it must be noted that while the instrument passes along the movable urethra the canal accommodates itself to the catheter, but while traversing the fixed or pelvic segment the instrument must accommodate itself to the unyielding canal. In introducing a catheter in the recumbent posture the penis is held vertically upwards, and in this way the curve formed by the movable urethra is obliterated. The instrument is best kept close to the surface of the groin, and over and parallel to Poupart's ligament. When the fixed urethra is reached, the handle of the catheter is brought to the middle line, and then, being kept strictly in the median plane of the body, is depressed between the legs, so that the front of the instrument may follow the natural curve of the canal. The greatest difficulty in the introduction is generally experienced at the point where the movable and fixed parts of the urethra meet, at the anterior layer of the triangular ligament (Fig. 108). This difficulty is due to three circumstances: (1) The wide bulbous urethra is suddenly contracted to the narrow membranous part; (2) the entrance to the membranous part is protected and closed by the sphincter urethræ; if there is urethritis the sphincter is thrown into a state of reflex spasm at the approach of the catheter, and only yields to gentle and continuous pressure; (3) at its sphincteric orifice the axis of the urethra changes its direction. In passing a catheter, even in the normal urethra, all those difficulties have to be negotiated. When a false passage has been made by a catheter in a case where no stricture exists to offer a definite obstruction, the instrument is usually found to have left the canal just in front of the triangular ligament.

The **urethral canal** must not be regarded as forming an open tube like a gas-pipe. Except when urine or an instrument is passing along it, the tube appears on section as a transverse slit, the superior and inferior walls being in contact. This fact should be remembered in amputation of the penis by the écraseur. In the fossa navicularis the tube appears as a vertical slit. The mucous lining is kept in apposition by the flaccidity of the parts, and the spongy tissue and non-striated muscle-fibres which form a substratum to it.

The *prostatic* part of the canal is the widest and most dilatable portion of the whole urethra.

It is widest at its centre, having here a diameter of nearly ½ an inch; at the bladder end its diameter is about ⅓ of an inch, while at the anterior extremity of this part of the urethra the measurement is a little less than ⅓ of an inch. The ejaculatory ducts, guarded by sphincteric muscles (F. S. Kidd), open into the prostatic urethra, and thus it happens that inflammation of this part of the canal may spread back along those ducts to the seminal vesicles, and thence along the vas deferens to the epididymis (Fig. 108). It is by spreading along these parts that inflammation of the testicle is set up when gonorrhœa involves the prostatic urethra, and it will be understood that a similar inflammation may follow impacted stone in the prostatic urethra, prostatic abscess, and the like. Stricture never occurs in this part.

The *membranous urethra* is, with the exception of the meatus, the narrowest part of the entire tube. Its diameter is about ⅓ of an inch. It is fixed between the two layers of the triangular ligament, and is surrounded by the reflex-acting sphincter urethræ. It is at this spot, therefore, that what is known as "spasmodic stricture" usually occurs. In any case, the contraction of the sphincter (constrictor) urethræ often offers an appreciable amount of resistance to the passage of a catheter or sound.

The *penile urethra* is dilated at either end, viz. at the parts occupying the bulb and the glans penis respectively. The diameter of the bulbous urethra is midway between those of the prostatic and membranous segments of the canal, while that of the greater part of the penile urethra is midway between those of the bulbous and membranous portions. It is in the bulbous urethra that organic stricture is the most commonly met with. The *meatus* measures from ⅕ to ¼ of an inch, and therefore if a catheter will pass the meatus it will pass along any part of the normal canal. Its aperture is very resisting, and has often to be incised to allow the larger instruments to pass.

The *narrowest parts* of the urethra, therefore, are (1) at the meatus, and (2) in the membranous segment, especially at its anterior end. It is at these points that calculi passed from the bladder are most apt to lodge. The widest portions of the canal, on the other hand, are at (1) the fossa navicularis, (2) the bulbous part of the urethra, and (3) the centre of the prostatic portion.

The **mucous membrane** may be examined from end to end by means of the *urethroscope*. The penile urethra is furnished with numerous mucous glands, for the greater part arranged along the upper or dorsal wall. These glands supply a lubricant which is necessary for the easy passage of urine and the protection of the lining membrane. When, however, the lining membrane becomes the site of infective inflammation, these glands and crypts become particularly affected, just as is the case in other inflamed mucous membranes, such as the tracheal and bronchial; their secretion becomes enormously increased in amount and purulent in character. They become harbouring nests for the gonococcus. With the urethroscope their swollen condition can be made out, and the lacuna magna in the roof of the navicular part distinguished, as can be the colour of the various parts of the urethra. The openings of the ducts of Cowper in the floor of the bulbous urethra cannot be seen (F. S. Kidd), but the puckering of the mucous membrane at the entrance to the membranous urethra and its closure by the sphincter are readily made out. The parts in the floor of the deep urethra can also be examined—the orifice of the *prostatic utricle* (*uterus masculinus*) and orifices of the *ejaculatory ducts*. The deep part of the urethra is sensitive, and it is extremely important to remember that the lining membrane of this part has a remarkable power to absorb innocuous as well as noxious substances.

The urethra may be **ruptured** by the patient falling astride of some hard substance. In such an injury it is crushed between the hard substance and the pubic arch. The part of the canal, therefore, that is most often damaged is the membranous segment, and the posterior part of the penile division. The more the body is bent forwards at the time the perineum is struck, the greater is the length of penile urethra that may be crushed against the pubes.

The **female urethra** is about $1\frac{1}{2}$ inches in length, and has a diameter of from $\frac{1}{4}$ to $\frac{1}{3}$ of an inch. It is capable, however, of great distension. In the erect position the canal is nearly vertical, and in the recumbent posture almost horizontal.

The penis.—The skin covering the bulk of the organ is thin and fine, and the subcutaneous tissue is scanty and lax. It follows, from the looseness of this tissue, that the skin is very distensible and movable. The latter fact should be borne in mind in circumcision, for in performing that operation the skin of the penis can be so readily drawn forwards over and beyond the glans, that if it is excised as far back as possible the greater part of the organ may be left bare. This applies, of course, mainly to children. The laxity of the submucous tissue permits the organ to become enormously swollen when œdematous, or when extravasated urine finds its way into the part. Over the glans penis the mucous membrane is so adherent that there is practically no subcutaneous tissue. It happens, therefore, that when Hunterian chancres appear on this part they can never be associated with other than the most trifling induration, there being no tissue in which the thickening can develop. At the corona, on the other hand, the submucous tissue is lax and plentiful, so that the induration can readily form, and it is about this spot, therefore, that the syphilitic sore often attains its most characteristic development. The vascularity of the penis, and the rapid engorgement that ensues when the return of its venous blood is impeded, serve to explain the ready and extensive swelling of the organ that follows when any constricting band is placed about it. This should be borne in mind in tying in a catheter by securing it by tapes around the penis. The blood spaces in the corpus spongiosum may be rendered indistensible from gonorrhœal inflammation while those of the corpora cavernosa remain free. The corpus spongiosum then acts like the string of a bow during the erection of the penis. Through the superficial lymphatics disease may spread from the skin and meatal region of the penis to the inner of the inguinal glands. Deeper vessels pass with the

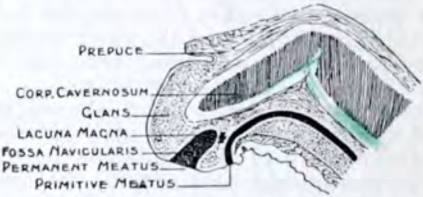

Fig. 109.—Section of penis, showing a common form of hypospadias.

The cross marks the point where the tissue breaks down between the cloacal urethra and meatal ingrowth.

prostatic veins to the internal iliac group of glands on the lateral wall of the pelvis. Some vessels pass directly to the external iliac glands through the femoral ring.

The penis is frequently the seat of arrests of development, presenting a variety of appearances. Among them may be mentioned **hypospadias,** where the inferior wall of the urethra and corresponding part of the corpus spongiosum are wanting, and **epispadias,** where the superior wall of the canal and corresponding part of the corpora cavernosa are more or less entirely deficient. In the condition of hypospadias two meati are present—one situated on the glans opening into a cul-de-sac which represents the fossa navicularis, and another just behind leading into the urethra (Fig. 109). Here is seen the double origin of the male urethra—the part within the glans is formed by an ingrowth of epithelium from the surface of the glans, while the rest of the penile urethra is derived from the cloaca. At first the cloacal urethra opens by its own orifice (primitive meatus, Fig. 109), but in the course of development the ingrowth from the glans takes place to form the permanent meatus and fossa navicularis; when this ingrowth opens into the cloacal urethra the primitive meatus becomes closed. The frenum preputii is formed over it. The condition thus represented is one of arrested development. On the prepuce of such cases sebaceous glands are arranged in two pigmented oval groups—*preputial ocelli* (Shillitoe).

The scrotum.—The **skin** of the scrotum is thin and transparent, so that in bruising of the parts the discoloration due to the extravasation of blood beneath the surface is readily and distinctly seen. It is also very elastic, and allows of great distension, as is seen in large scrotal herniæ and testicular tumours. The integument of the part is indeed redundant, and the excision of a portion of it will hardly be missed. Even in gangrene of the scrotum, when both testicles have been exposed, the parts have been entirely restored without any inconvenient shrinking or contraction. The *rugæ* on the surface of the scrotum favour the accumulation of dirt, and the irritation set up by such accumulation may be the exciting cause of the epitheliomata that are not uncommon in this part. When the surface is sweating, the rugæ tend to favour a retention of the moisture between their folds: from this and other circumstances it happens that the scrotum is liable to eczema and to those syphilitic skin disorders that are often localized by irritation. The rugæ are a sign of health, since they depend upon the vigorous contraction of the muscle fibres in the dartos tissue. In the enfeebled, or under the relaxing effects of heat, the scrotum becomes smooth and pendulous. In a simple incised wound, as in castration, the dartos is apt to turn in the edges of the skin and cause some difficulty in applying the sutures. This difficulty may be avoided by inducing the relaxation of that tissue for a while by the application of a warm sponge to the wound.

The **subcutaneous tissue** is lax and very extensive, and permits of considerable extravasations of blood forming beneath the surface. The scrotum, from its dependent position, and from the looseness and extent of its cellular tissue, is often the first part of the body to become œdematous in dropsy, and is apt to show that œdema in a marked degree. The scrotum also is the part most frequently the seat of elephantiasis, which is due essentially to a distension of the lymphatic vessels and spaces of the connective tissue. The vitality of the scrotum is not considerable, and it therefore not infrequently sloughs in parts when severely inflamed. For this reason strapping should be applied with some care over the enlarged testis, for against the hard mass of the affected gland the integument of the scrotum can be subjected to considerable pressure when the strapping is tightly applied. In such a case the whole of one side of the scrotum has been seen to slough from an indiscreet use of this familiar method of treatment.

The **testicle** may be retained within the abdominal cavity, or may lodge for varying periods of time, or for life, in the inguinal canal. It may, on the other hand, pass beyond the scrotum into the perineum, or may miss the inguinal canal altogether and escape through the femoral canal and saphenous opening on to the thigh (*see* p. 370). The testis proper is entirely invested by the visceral layer of the tunica vaginalis, except over a small part of its posterior border where the vessels enter. The epididymis is entirely covered by the serous membrane at its sides, is more or less so covered in front, but is free or uncovered along the greater part of its posterior border (*see* Fig. 83, p. 371). It is about the posterior border of the epididymis that the visceral layer of the tunica vaginalis joins the parietal layer. The posterior border of the testicle and of the epididymis—from globus major to globus minor—is bound by a reflection of serous membrane—the mesentery of the testicle. Instead of binding the whole of the posterior border, the mesentery may be attached merely to the lower pole of the testicle and globus minor; on such a pedunculated attachment the testicle is apt to become strangulated by a twisting of its narrow mesentery. A narrow, elongated mesentery is found only in glands which are late in descending or have been arrested in their descent; *torsion of the testicle* is, therefore, only possible in imperfectly developed organs. The more intimate and extensive connexion of the serous tunic with the testis or gland proper serves in part to explain the greater frequency with which *hydrocele* appears in inflammation of this part of the organ, as compared with its occurrence when the epididymis is alone inflamed. It is owing to the reflections of the tunica vaginalis that in cases of common hydrocele the testicle remains firmly set at the lower and posterior part of the swelling, and yet so extensively is the organ surrounded by that membrane that the position of the gland in the larger hydroceles is often difficult to determine. In some cases the testicle occupies the front of the scrotum, the epididymis being placed anteriorly, and the body of the gland being located behind it. The vas deferens descends also along the front of the cord. In these cases the testicle is just in the position it would occupy if it had been turned round upon its vertical axis. The condition is known as *inversion of the testicle*, and should be sought for in cases of hydrocele, as in several instances the testis has been pierced by the trocar when tapping collections in cases where the inversion existed.

The proper gland tissue is invested by a very dense membrane, the **tunica albuginea**. The epididymis, on the other hand, lacks any such firm fibrous investment. The unyielding character of the tunica albuginea serves in great part to explain the intense pain felt in acute affections of the testis proper, a degree of pain which is not reached when the less tightly girt epididymis is alone involved. It will be understood also that in inflammation of the epididymis the part swells rapidly and extensively, while in a like affection of the body of the gland the swelling is comparatively slow to appear.

It should be borne in mind that the lymphatics of the scrotum go to the inguinal glands, those of the testicle to the lumbar; in malignant disease of the testicle the secondary deposits are to be expected deep within the abdomen by the side of the aorta. The testicle is developed in front of the tenth dorsal vertebra, and receives its nerve supply from the tenth dorsal segment. Its nerves pass by the small splanchnics, solar and aortic plexuses, to the spermatic artery, on which they reach the gland. The epididymis receives its nerve supply from the pelvic plexus, along the vas deferens.

Spermatic cord.—The structures in the cord are (1) the vas deferens, (2) the cremaster muscle, (3) the spermatic and (4) cremasteric arteries, (5) the artery to the vas deferens, (6) the pampiniform plexus of veins, (7) the genito-crural nerve, (8) sympathetic nerve fibres, and (9) lymphatics. The **vas deferens** (**ductus deferens**) lies along the posterior aspect of the cord (Fig. 110), and can be detected by the firm, cord-like sensation which it gives when pinched between the thumb and finger. Mr. Birkett (Holmes's "System") gives three cases of rupture of the vas deferens during severe and sudden exertion. The duct appears to have in each case given way within the abdomen at some point between the internal ring and the spot where it approaches the ureter. Resection of part of the vas has been practised to bring about atrophy of enlarged prostate, but has not proved successful. The size of the **cremaster muscle** depends mainly upon the weight it has to suspend. In atrophy of the testicle it almost entirely disappears, while in cases of large slow-growing

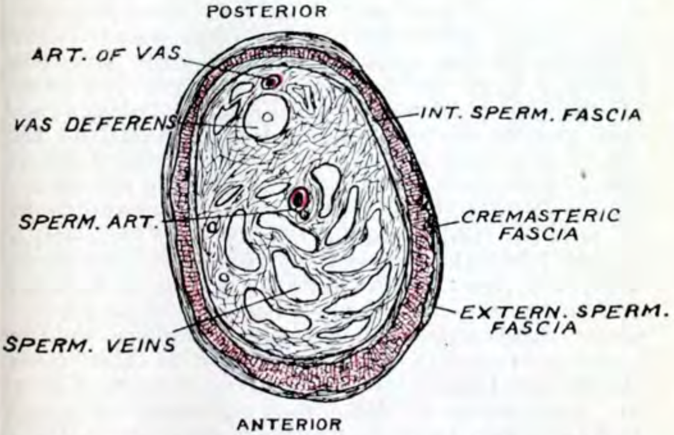

Fig. 110.—Section of the left spermatic cord of an adult, at the level of the external abdominal ring, viewed from above.

tumours of the gland it attains considerable proportions. Of the **arteries**, the spermatic comes from the aorta and lies in front of the vas, the cremasteric arises from the deep epigastric and lies among the superficial layers of the cord in its outer segment, while the deferential artery from the superior or inferior vesical lies by the side of the vas (Fig. 110). The first-named vessel is the size of the posterior auricular, and the two latter the size of the supraorbital. The spermatic artery divides into a number of branches as it reaches the testicle; these branches pass to the inner side of the epididymis, which may be removed without interfering with the blood supply of the testicle. The three arteries of the cord are divided in castration, and may all require ligature. It is advisable to secure the vessels in sections, rather than adopt the clumsy plan of involving the whole cord in one common ligature. The **veins** are divided roughly into two sets. The anterior is by far the larger set, runs with the spermatic artery, and forms the *pampiniform plexus*. The posterior set is small and surrounds the vas, running with the deferential artery. The veins of the spermatic and pampiniform plexus are very frequently varicose, and then constitute the affection known as *varicocele.* Many anatomical causes render these veins liable to this affection: they occupy a dependent position, and the main vein is of considerable length, and follows a nearly vertical course; the vessels are very large when compared with the corresponding artery, and so the *vis a tergo* must be reduced to a minimum; they occupy a loose tissue, and are lacking in support and in the aid afforded to other veins (as in the limbs) by muscular contraction; they are very tortuous, form many anastomoses, and have few and imperfect valves; they are exposed to pressure in their passage through the inguinal canal. The left veins are more frequently affected than the right. Mr. Spencer has shown that the veins of the left cord are always much larger than those of the right. It may also be pointed out that the left testicle hangs lower than the right; that the left spermatic vein enters the left renal at a right angle, while the right spermatic vein passes obliquely into the vena cava; and that the left vein passes beneath the sigmoid colon, and is thus exposed to pressure from the contents of that bowel.

The **female generative organs** require but little notice in the present volume. The

labia majora have the same pathological tendencies as has the scrotum, to which, indeed, they anatomically correspond. They are liable to present large extravasations of blood, are greatly swollen when œdematous, are prone to slough when acutely inflamed, and are the usual seats of elephantiasis in the female. A hernia may present in one or other labium (pudendal hernia), the neck of the sac being between the vagina and the pubic ramus. Of such a hernia the ovary is frequently a content.

"On everting one of the labia minora and pressing the hymen inwards, a small red depression may generally be seen on the vulva, somewhat posteriorly. It leads to the orifice for Bartholin's gland" (Doran). This gland, an oval body about ½ an inch in length, lies against the posterior part of the vaginal orifice, under the superficial perineal fascia, and covered by the fibres of the sphincter vaginæ. It wastes after 30. It corresponds to the gland of Cowper in the male (Fig. 108, p. 492). Both are apt to become the sites of chronic gonorrhœal inflammation. Abscess of the gland and cystic dilatation of its duct are not uncommon.

The **vagina** is lodged between the bladder and rectum, while the upper fourth of its posterior surface is covered with peritoneum, and is therefore in relation to the abdominal cavity. Thus it happens that the bladder, the rectum, or the small intestines may protrude into the vagina by a yielding of some parts of its walls and thus produce a vaginal cystocele, rectocele, or enterocele.

The anterior wall of the vagina measures a little over 2 inches, the posterior wall about 3 inches. The long axis of the canal forms an angle of 60° with the horizon, and is therefore almost parallel to the pelvic brim. The loose areolar tissue at the base of the broad ligament lies on each side of the upper extremity of the vagina. The ureter terminates in the bladder, on the upper part of the vaginal roof. (For structures concerned in supporting the contents of the female pelvis, *see* p. 473.)

The abdominal cavity may be opened through a wound of the vagina. In one or two instances of such injuries several feet of intestine have protruded through the vulva. In one reported case an old woman, the subject of a brutal rape, walked nearly a mile with several coils of the small bowel hanging from her genitals.

From the comparative thinness of the walls that separate the vagina from the bladder and rectum, it happens that vesico-vaginal and recto-vaginal fistulæ are of frequent occurrence. The vagina is very vascular, and wounds of its walls have led to fatal hæmorrhage. It is very dilatable, as can be shown when the canal is plugged to arrest hæmorrhage from the uterus.

The **uterus** weighs about 1 oz. The uterine cavity and the cervical canal together measure about $2\frac{1}{2}$ inches. This must be borne in mind when a uterine sound is being passed. The blood-vessels run transversely to the length of the uterus, so that a ligature may be placed completely around the organ without affecting the circulation above or below. Ligature of the *uterine artery* has been practised to arrest the growth of uterine tumours. The artery rises from the internal iliac $\frac{1}{2}$ an inch below the pelvic brim, and passes to the neck of the uterus in the broad ligament; it is $2\frac{1}{2}$ inches long and loops over the ureter midway in its course. It is reached by incising the broad ligament between the Fallopian tube behind and the round ligament in front; it is found in the loose areolar tissue under the wound.

The *lymphatics* from the fundus of the uterus and appendages pass to the lumbar glands, a few also pass along the round ligament to the inguinal glands. The lymphatics of the cervix, which is frequently the seat of cancer, pass to the internal iliac glands on the lateral wall of the pelvis.

The unimpregnated uterus is very rarely wounded, owing its immunity to the denseness of its walls, to its small size, to its great mobility, and to its position within the bony pelvis.

The **ovary** is so placed that the outer part of the Fallopian tube turns downwards externally to it. The more common position of the ovary may be indicated on the surface of the body by the line employed to mark out the course of the common and external iliac arteries—a line drawn from the aortic bifurcation to the femoral point (Fig. 81, p. 367). The ovary lies internally to the mid-point of this line (Fig. 103, p. 457), near the angle between the external and internal iliac arteries; it may be indistinctly palpated through the vagina. Its nerves come from the tenth dorsal segment of the cord. The sensory nerves for the cervix are derived from the lower sacral segments. The lymphatics of the ovary pass to the lumbar glands, which lie by the side of the lower part of the aorta and vena cava in the retroperitoneal tissue. The ovaries exert a very marked trophic influence on the breast; the hypertrophy of the mammæ at puberty and in pregnancy depends on an internal secretion of the ovary (Starling). By their removal it was hoped that cancer of the breast might be arrested, but the procedure has not been followed by much success. At the brim of the pelvis the ovarian vessels lie within a fold of peritoneum, named the *ovario-* or *infundibulo-pelvic ligament*, for it is attached both to the ovary and to the infundibulum of the Fallopian tube. This ligament forms the outer part of the pedicle in ovariotomy.

The various **vestigial structures connected with the ovary**—structures which may become dilated into cysts—are shown in Fig. 111. Such vestiges correspond to structures which are fully developed in the male and form part of the elaborate system of ducts that convey semen from the tubules of the testicle to the urethra. Thus the ductus (vas) deferens is represented by the Wolffian duct, lying between the layers of the broad ligament; the Wolffian tubules, passing towards the hilus of the ovary, correspond to the vasa efferentia of the male; the rete testis, which lies in the mediastinum of the testicle and serves to convey the semen from the seminiferous tubules to the vasa efferentia, is represented at the hilus of the ovary and along the ovarian fimbria of the tube by isolated structural elements. Two of these elements, the efferent ducts and rete channels, are developed as independent structures, and only

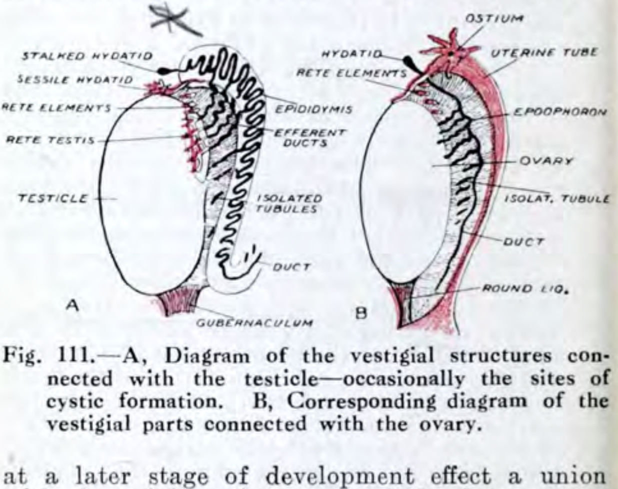

Fig. 111.—A, Diagram of the vestigial structures connected with the testicle—occasionally the sites of cystic formation. B, Corresponding diagram of the vestigial parts connected with the ovary.

at a later stage of development effect a union with the neighbouring parts of the duct system. In the female a considerable number, and in the male a few, of these structural elements persist as isolated rudiments of tubules, and thus may become the site of cyst formations.

The **rectum** commences in front of the third sacral vertebra, and is about 5 inches in length (Fig. 112). It is continuous at the pelvi-rectal constriction with the pelvic colon, which is invested by peritoneum and supported by a mesentery. The **serous membrane** gradually leaves the posterior surface of the rectum, then its sides, and lastly its anterior surface. Anteriorly, the peritoneum, in the form of the recto-vesical pouch, extends in the male to within 3 inches of the anus, while on the posterior aspect of the gut there is no peritoneum below a spot 5 inches from the anus. Thus, in excision of the rectum, more of

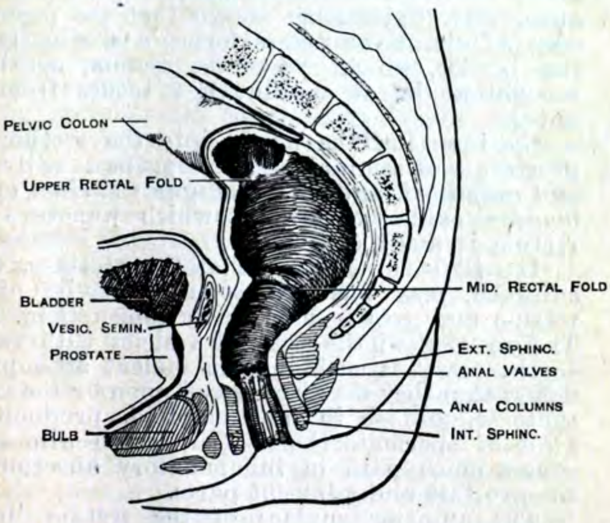

Fig. 112.—The stages of the rectum and the anal canal on mesial section. (*Prof. A. M. Paterson.*)

the bowel can be removed in the posterior than in the anterior part of the tube without opening the peritoneal cavity. It will be seen, also, that carcinomatous and other spreading ulcers are more apt to invade the peritoneal cavity when they are situated in the anterior wall of the intestine. The lowest part of the rectum, distinguished as the **anal canal**, is surrounded by the internal sphincter—an involuntary muscle that is continuous with the circular coat. In a state of rest the anal canal, which is directed downwards and backwards, measures $1\frac{1}{2}$ inches, but during defæcation and when the patient bears down it assumes a shallow annular form. The canal is firmly fixed to the levatores ani and perineal body, hence in prolapse it is the rectum above the canal which is extruded through the anus. Mr. Cripps has shown that the posterior edge of the levator ani forms a distinctly-felt free border, which crosses the rectum, nearly at a right angle, at a point $1\frac{1}{2}$–2 inches from the anus.

By inserting the finger into the rectum the prostate and seminal vesicles can be readily felt and examined, and that triangular surface of the bladder explored through which puncture per rectum is made (p. 486).

It will be understood that the prostate, when enlarged, may encroach upon the cavity of the rectum and greatly narrow its lumen (Fig. 108). The position of the seminal vesicles with regard to the bowel is such that in violent attempts at defæcation they may be pressed upon by the rectal contents, and so in part emptied, producing a kind of spermatorrhœa. Defæcation also often causes much pain in inflammatory affections of the prostate and adjacent parts.

The anterior surface of the rectum in the female is in relation, so far as the finger can reach, with the vagina, and, in examining the lower part of the rectum, it is convenient to protrude its mucous membrane through the anus by means of the finger introduced into the genital passage.

From a functional as well as a morphological point of view the *rectum is divided into two parts*—an upper, in relationship with the peritoneum and the recto-vesical pouch, dilatable, and, before defæcation, laden with fæces; and a lower, which is beyond the peritoneum and serves merely for the passage, not the storage, of fæces (Wood-Jones). Advantage of this circumstance is taken in operations for the cure of ectopia vesicæ where the ureters are removed from the exposed bladder and implanted in the rectum. It is the distension of the upper rectum which gives a sense of fullness and sets in train the voluntary and involuntary efforts of defæcation.

Fæces may become impacted in the rectum. Strange bodies, too, are frequently found misplaced within it. Among the latter may be mentioned a bullock's horn, an iron match-box, and a glass tumbler. By antiperistaltic movements of the rectum and colon, such bodies may be carried towards the cæcum. Thus a case has been reported by Alexander in which the handle of an umbrella, accidentally lodged in the rectum, was removed by a surgeon, two weeks later, from the hepatic flexure of the colon. Experiment has shown that when the rectum is distended in the male, the recto-vesical fold of peritoneum is raised, and the bladder is elevated and pushed forwards. In the female the fundus uteri is raised and pushed towards the symphysis. The rectum is artificially distended in suprapubic lithotomy, in order to bring the bladder into better position (p. 483).

If the sphincters of the anus be very gradually dilated, the *entire hand*, if small, may be introduced into the rectum in both males and females; but in several cases, when so dilated, it has been found that the sphincter never regains its normal action. The circumference of the hand should not exceed 8 inches. By a semi-rotary movement, and by alternately flexing and extending the fingers, the hand can be insinuated into the commencement of the pelvic colon. Owing to the mobility of this part of the bowel a large extent of the abdomen may be explored through the bowel wall. The structures that can be readily felt are the kidneys, the aorta, the iliac vessels, the uterus and ovaries, the bladder and its surroundings, the pelvic brim, the sacro-sciatic foramina, the ischial spine, the sacrum, etc. In some subjects even a small hand cannot be passed beyond the reflection of the peritoneum over the second part of the gut. In such instances the peritoneum offers a resistance like a tight garter, and prevents the farther advance of the hand without great risk of laceration of the parts (Walsham). Owing to the constrained position of the hand and the cramping of the fingers, this method of examination has proved to be of but limited service.

The **attachments of the rectum** by means of its sheath to the pelvic fascia are not very firm; fibrous prolongations from the perivascular sheath accompany the middle hæmorrhoidal vessels, and fibrous bands from the sacrum also join its sheath and have to be severed in the operation of excision. The laxity of its attachment is shown in some cases where the gut has been protruded at the anus. In excision of the rectum, also, advantage is taken of this mobility.

The **mucous membrane** is thick, vascular, and but loosely attached to the muscular coat beneath. This laxity, which is more marked in children, favours prolapse, an affection in which the mucous membrane of the lower part of the rectum is protruded at the anus. At the junction of the rectum and pelvic colon there is a circular fold or valve, and often the musculature here is constricted and acts functionally as a sphincter (Fig. 112). Above the base of the prostate (Fig. 112) the anterior wall of the rectum, at the junction of its upper and lower parts, is folded within the lumen of the gut to form a *transverse fold*, often named after Houston who described it. These *rectal folds* or *valves*, especially when the gut is empty, may offer considerable resistance to the introduction of a bougie or long enema tube, and their position should be therefore borne in mind.

The **vessels**, and especially the veins, at the lower part of the rectum are apt to become varicose and dilated, and form piles. The tendency to piles can in part be explained by the dependent position of the rectum, by the pressure effects of hardened fæces upon the returning veins, and by the fact that part of the venous blood returns through the systemic system (internal iliac vein) and part through the portal system (inferior mesenteric vein). This connexion with the portal trunk, which is not an extensive one, may cause the rectum to participate in the many forms of congestion incident to that vein. The veins of the rectum can also be affected by violent expiratory efforts. In the lower part of the rectum—the extraperitoneal part, which is some 3–4 inches in length—the arrangement of the vessels is peculiar, and is such as to favour varicosity. The arteries, "having penetrated the muscular coats at different heights, assume, in this segment, a longitudinal direction, passing in parallel lines towards the edge of the bowel within the submucous coat. In their progress downwards they communicate with one another at intervals, and they are very freely connected near the orifice, where all the arteries join, by transverse branches of considerable size." (Quain.) The branches of the superior hæmorrhoidal arteries terminate in the submucous tissue of the anal canal, forming vascular columns which extend to the anus. The veins form a plexus with a precisely similar arrangement. The veins beneath the mucous membrane of the anal canal perforate the muscular coat of the rectum about an inch above the anal canal. At the point of perforation they are liable to be compressed.

The **lymphatics** of the rectum perforate the muscular coat and ascend in its sheath, where, on the posterior aspect, there may be one or more glands. They join the efferent vessels of the colon in the mesentery of the pelvic colon. They also pass to the internal iliac group of lymphatic glands on the lateral wall of the pelvis and to the lumbar glands. Hence, in cancer of the lower part of the rectum these glands and the vessels leading to them are the earliest seats of secondary infections. The lymphatics of the pelvic colon pass to the glands in front of the sacrum and to others between the layers of the meso-rectum.

The rectum may be most freely exposed from behind (Figs. 102, p. 455, 105, p. 476, and 112). In **Kraske's operation** for the extirpation of cancer of the rectum an incision is made along the sacrum in the middle line, from the level of the posterior inferior iliac spine to the anus. A flap is turned out on the left side, including the skin and origin of the gluteus maximus. The attachments of the left sacro-sciatic ligaments, coccygeus, and levator ani to the sacrum and coccyx are divided and turned outwards. The lateral and median sacral arteries and a plexus of veins are raised with the fibrous tissue from the anterior surface of the sacrum by a periosteal elevator. The left halves of the fourth and fifth sacral vertebræ, with the left half of the coccyx, are removed. The fourth and fifth sacral and coccygeal nerves are necessarily cut, but an attempt should be made to save the third sacral nerve, owing to the importance of its function. The rectum is then exposed, with the hæmorrhoidal vessels and reflection of peritoneum. By opening the peritoneal cavity part of the pelvic colon may be brought into the wound. As will be seen from Fig. 113, there is a risk, when removing the rectum, of injuring the blood supply of the pelvic colon. If the superior hæmorrhoidal artery be tied at the base of the mesentery of the pelvic colon, the arteries to the distal part are very liable to be included in the ligature (J. W. Smith). After the diseased part is removed, with the presacral and internal iliac lymphatic glands, the lower end of the pelvic colon is brought down and sutured to the anal part. An attempt should be made to save the levator ani as well as the third sacral nerve, in order that the integrity of the pelvic diaphragm may be maintained. For a complete removal of secondary deposits in the lymphatic system of the rectum, the sacral operation is usually combined with an abdominal section.

The rectum is supplied with sensory and motor

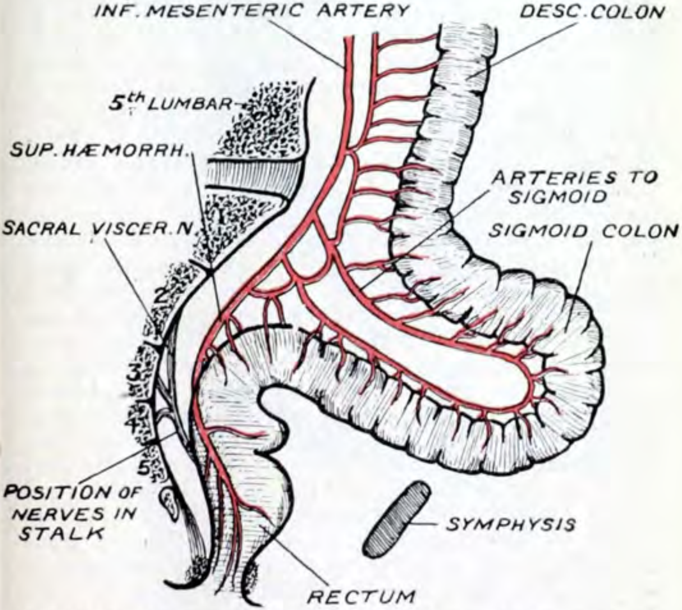

Fig. 113.—Diagrammatic representation of the arterial supply of the pelvic colon and rectum. (*Wingate Todd.*)

nerves from the second, third, and fourth sacral segments, through the corresponding nerves. Motor nerves are also derived from the lower two dorsal and upper lumbar segments; they reach the rectum through the hypogastric and pelvic plexuses. The reflex act of defæcation depends not only on these nerves being intact, but also on the functional activity of the defæcation centre in the lumbar part of the spinal cord.

The anus.—The skin about the anus is thrown into numerous folds, and in these ulcer or fissure of the anus forms. Within the anal canal the mucous membrane of the lower rectum is thrown into vertical folds—the columns of Morgagni. When the canal is dilated they are obliterated, and as age advances they become less well marked. As is shown in Figs. 106 and 112, the columns end at a ring of minute transverse folds or valves, the *anal valves*, situated opposite the lower border of the internal sphincter. When the anus is closed, the mucous membrane lining it, covered by stratified epithelium, is also thrown into folds, which ascend to the anal valves; at the anal valves the columnar epithelium of the lowest part of the rectum, the anal canal, meets the stratified epithelium of the anal mucous membrane. The valves mark the point where the termination of the rectum opened into the proctodæal depression in the course of development.

When the anal canal is closed, the columns and valves come together and so make the anal orifice competent. The valves may be torn by the passage of scybalous masses, and from the rent thus caused a fissure of the anus may be produced (Ball). The extreme painfulness of these ulcers is due to the exposure of a nerve fibre at their base, and to the constant contraction of the sphincter muscle which they excite. In 90 per cent. of cases of **pruritus ani** there is a small ulcer in the posterior wall of the anal canal, near the anal valves (F. C. Wallis). Relief is given by excising the base of the ulcer, so as to divide some part of the sphincter; or by violently dilating the anus, so as to tear up the base of the ulcer and paralyse for a while the action of the disturbing muscle.

The anus may be torn during defæcation when the stools are hard. A case is reported of a woman who, during violent efforts at defæcation, felt something give way, and discovered fæces in her vagina. The recto-vaginal wall had ruptured 2 inches from the anus. During labour the child's head has passed into the rectum, and has been delivered per anum.

An **imperforate anus** is the most common congenital defect of the rectum. This condition

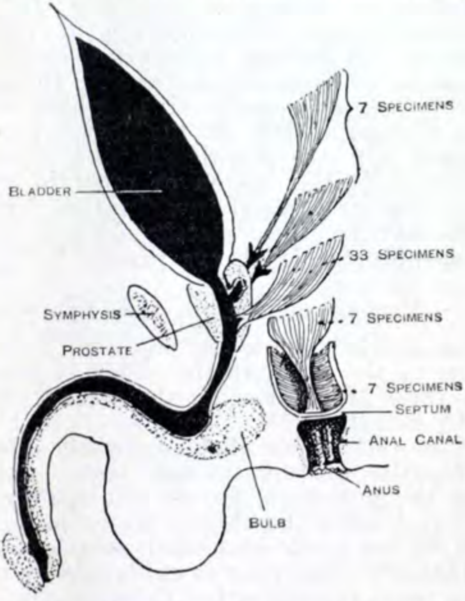

Fig. 114.—Diagram to show the manner in which the rectum terminated in 54 cases of imperforate anus in the male.

represents an arrest of development. The formation of the anus is a double process: first there is an ingrowth from the perineum, and secondly a downgrowth from the bowel, these two elements meeting and communicating at the upper end of the anal depression. In many cases of imperforate anus, only a thin anal membrane requires to be broken down to allow the free passage of fæces; but in other cases the defect is much greater, the anal canal, and even the rectum, being completely wanting. Not infrequently in such cases the rectum may communicate with the urethra in the male or with the vulval cleft in the female. This communication is due to the persistence of an embryonic condition. In Fig. 114 is given a diagrammatic representation of the manner in which the rectum terminated in 54 museum specimens of imperforate anus. In more than half of these specimens—all of which were males—the rectum ended at the lower part of the prostate. In the female it may terminate at any point of the vagina or open in the vulval cleft. The proctodæal invagination for the anal canal may be incompletely formed or absent, but a sphincter is always present.*

Nerves of Pelvis and Perineum

The pelvic viscera are supplied by the pelvic plexus of the sympathetic. This is joined by at least three spinal nerves, the second, third, and fourth sacral.

It is well known that in certain affections of the bladder, rectum, prostate, etc., pain is felt along the perineum, in the penis, over the buttock, and down the thigh. These parts are supplied by the pudic and small sciatic nerves, and the reason for the pain is explained by the origin of the sensory nerves for those organs from the same and adjoining segments and nerve centres of the spinal cord. The upper part of the rectum is provided with but little sensation, as illustrated by the passage of instruments, by the comparative painlessness of malignant and other growths high up in the bowel, and by the little inconvenience felt when the gut is distended with hardened fæces. From this apathy it has probably happened that, in the self-administration of

* *See* Keith, *Brit. Med. Journ.*, Dec., 1908.

enemata, patients have thrust the tube through the rectum into the peritoneal cavity. The anal canal, on the other hand, is extremely sensitive. Normally, as stated above, fullness of the rectum excites the sensation leading to defæcation. If there is obstruction or distension, combined with spasm of the muscular coat, severe ill-defined pains are occasioned.

The nerve relations between the anus and the neck of the bladder are very intimate. Painful affections of the anus often cause bladder troubles, and retention of urine is very common after operations upon piles. Maladies, on the other hand, which involve the bladder neck are often associated with tenesmus and anal discomfort. Their relationship to common functional centres in the spinal cord is maintained by the pelvic plexus, but mainly by the fourth sacral nerve. This nerve gives special branches direct to the neck of the bladder, and then goes to supply the muscles of the anus (the sphincter and levator) and the integument between the anus and the coccyx.

The mucous membrane of the urethra, the muscles of the penis, and the greater part of the skin of the penis, scrotum, perineum, and anus, are supplied, from the second, third, and fourth sacral segments, by the pudic nerve. Thus, it will be understood that irritation applied to the urethra may cause erection of the penis (as illustrated by chordee in gonorrhœa), or may produce contraction of the urethral muscles (as seen in some forms of spasmodic stricture). The disturbance caused by accumulated secretion beneath the prepuce in young children may provoke great irritability of the organ, and it is well known that painful affections of the perineum and anus may be associated with priapism. The distribution of the third sacral segment in the perineum by means of the perineal branch of the small sciatic will explain the pain about the buttock and down the back of the thigh that is often complained of during the growth of perineal abscess and in painful affections of the scrotum. This nerve crosses just in front of the tuber ischii, and may be so pressed upon by using a hard seat as to cause one-sided neuralgia of the penis and scrotum. It is also in close connexion with the ischial bursa, and neuralgia of the same parts has been met with in cases of inflammation involving that structure.

The *testicle* is supplied mainly from the tenth dorsal segment by the spermatic plexus. The kidney is also partly supplied from the same segment. This is illustrated by the *pain felt in the renal region* during neuralgia of the testicle, and by the pain felt in the testicle and the vigorous retraction of that organ observed in certain affections of the kidney, such as in acute nephritis, and in the passage of renal calculi. By means of the renal plexus the testicle is brought into direct communication with the semilunar ganglia and the solar plexus, which receives some of the terminal fibres of the vagus. This communication may serve to explain the great collapse often noticed in sudden injuries to the testicle, and especially the marked tendency to vomit so often observed in such lesions. So far as its nerves are concerned, the testicle is nearly in as intimate relation with the great nerve-centre of the abdomen as is a great part of the small intestine, and one would expect a sudden crush of the testis to be associated with as severe general symptoms as would accompany a sudden nipping of the ileum in a rupture. Such a resemblance in symptoms is actually to be observed in practice.

PART V.—THE LOWER EXTREMITY

CHAPTER XXII

THE REGION OF THE HIP

THIS region will be considered under the following heads:—

1. The buttocks.
2. The region of the femoral (Scarpa's) triangle.
3. The hip-joint, with the upper third of the femur.

1. THE BUTTOCKS

Surface anatomy.—The bony points about the gluteal region can be well made out. The crest of the ilium is distinct, as is also the anterior superior spine. The posterior superior spine is less evident, but can be readily felt by following the crest to its posterior termination. This spine is on a level with the second sacral spine, and is placed just behind the centre of the sacro-iliac articulation (Fig. 115). The great trochanter is a conspicuous landmark. It is covered by the fascial insertion of the gluteus maximus. Its upper border is on a level with the centre of the hip-joint, and is somewhat obscured by the tendon of the gluteus medius which passes over it. The comparatively slight prominence of the trochanter in the living subject, as compared with the great projection it forms in the skeleton, depends upon the completeness with which the gluteus medius and minimus fill up the hollow between the trochanter and the ilium. When these muscles are atrophied the process becomes very conspicuous. In fat individuals its position is indicated by a slight but distinct depression over the hip.

If a line be drawn from the anterior superior spine to the most prominent part of the tuber ischii, it will cross the centre of the acetabulum, and will hit the top of the trochanter. This line, known as Nélaton's line, is frequently made use of in the diagnosis of certain injuries about the hip (Fig. 115). McCurdy prefers a line drawn from the pubic spine at a right angle to the median line of the body; if the femur is normal in position the *pubic line* should cross at or just above the great trochanter (Fig. 116). The mid-point of this line lies in front of the lower part of the femoral head. The anterior superior spine or crest of the ilium may be used as a fixed point from which to estimate the degree of displacement of the great trochanter.

The ischial tuberosities are readily felt. They are covered by the fleshy fibres of the gluteus maximus when the hip is extended. But when the hip is flexed, the processes become to a great extent uncovered by that muscle. The muscular mass of the buttock is formed by the gluteus maximus behind and by the gluteus medius and minimus and tensor fasciæ femoris in front. The last-named muscle can be seen when in action, i.e. when the thigh is abducted and rotated in.

The fold of the buttock crosses the obliquely-placed lower border of the gluteus maximus. When the hip is fully extended, as in the erect posture, the buttocks are round and prominent, the gluteal fold is transverse and very distinct. When the hip is a little flexed, the buttocks become flattened, the gluteal fold becomes oblique and then disappears. Among the early signs of hip disease are flattening of the buttock and loss of the gluteal fold. These signs depend upon the flexion of the hip, which is practically

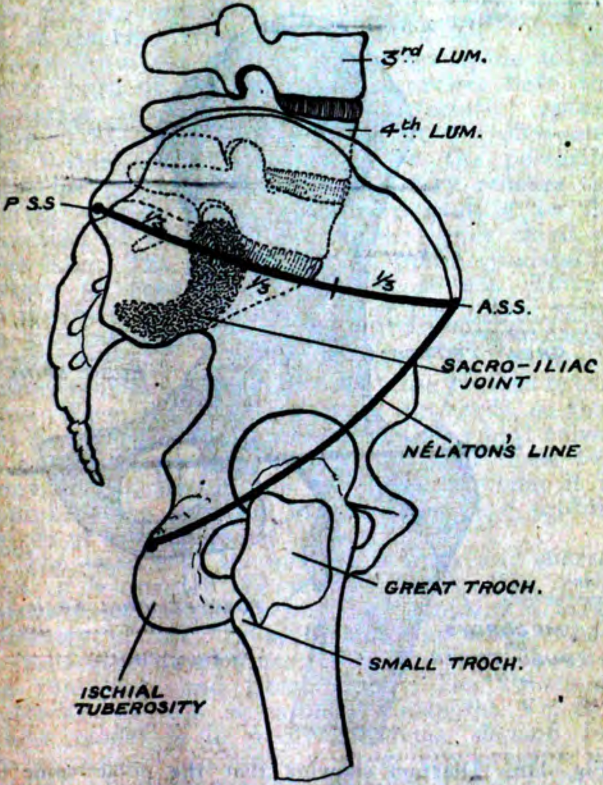

Fig. 115.—Diagram showing the line used by Nélaton to test upward displacement of the femur, and another which serves to indicate the position for trephining the sacro-iliac joint.

A.S.S., Anterior superior spine of ilium; P.S.S., posterior superior spine of ilium.

constant in every case of the malady before treatment. Very soon, however, in all cases of disease of the hip-joint, and also in many cases of true sciatica, reflex wasting of the gluteal musculature sets in.

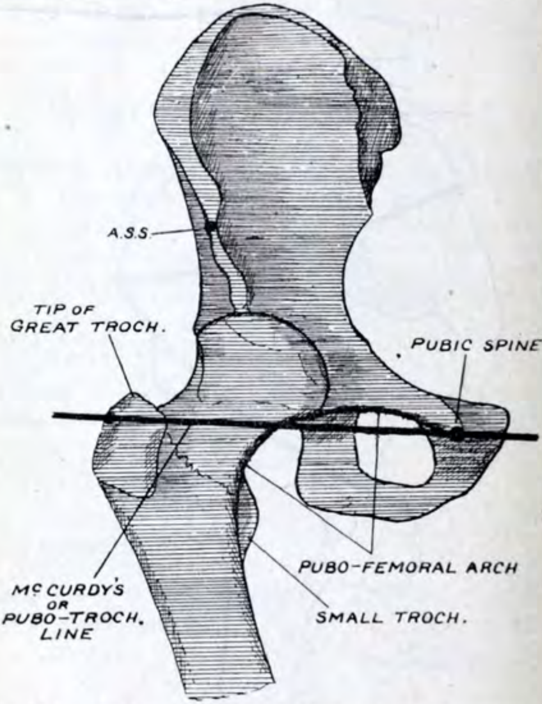

Fig. 116.—Diagram showing that the pubic spine (tubercle) and the tip of the great trochanter are on the same horizontal plane (McCurdy's line), and that the lower border of the neck of the femur and the inner border of the obturator foramen form a continuous arch (Shenton's) when the femur has its normal relationships.

With regard to the vessels and nerves of the buttock, if a line be drawn from the posterior superior spine to the top of the great trochanter when the thigh is rotated in, a point at the junction of the inner with the middle third of that line will correspond to the superior gluteal artery as it emerges from the sciatic notch. A line drawn from the posterior superior spine to the outer part of the tuber ischii crosses both the posterior inferior and ischial (sciatic) spines (Fig. 117). The former is about 2 inches and the latter about 4 inches below the posterior superior process. The sciatic artery reaches the gluteal region at a spot corresponding to the junction of the middle with the lower third of this line. The position of the pudic (pudendal) artery as regards the buttock is not difficult to indicate, since it crosses over the ischial spine in passing from the great to the small sacro-sciatic foramen. The *sciatic nerve* is most easily found as it escapes from beneath the gluteus maximus. When the thigh is rotated outwards, so that the great trochanter approaches the ischial tuberosity, the nerve lies midway between these two bony points, but in the unrotated position it is found at the junction of the inner and middle thirds of a line joining them.

The **skin** over the buttock is thick and coarse, and is frequently the seat of boils. The **subcutaneous fascia** is lax, and contains a large quantity of fat. It is to this fat rather than to muscular development that the buttock owes its roundness and prominence. The enormous buttocks of the so-called "Hottentot Venus," whose model is in many museums, depend for their unusual dimensions upon the greatly increased subcutaneous fat. The amount of adipose tissue normally in the part renders the buttock a favourite place for lipomata. The laxity of the superficial fascia permits large effusions, both of blood and pus, to take place in the gluteal region, and ecchymoses of the buttock can probably reach a greater magnitude in this district than is possible elsewhere.

The **deep fascia** of the buttock, a part of the fascia lata of the thigh, is a structure of much importance. This dense membrane is attached above to the iliac crest, and to the sacrum and coccyx. Descending in front over the gluteus medius, it splits on reaching the interior edge of the gluteus maximus into two layers, one of which passes superficially and the other deeply to the muscle. The gluteus maximus is thus enclosed, like the meat in a sandwich, between two layers of fascia, and the two lesser gluteal muscles are bound down within an osseo-aponeurotic space, which is firmly closed above, and only open below towards the thigh and internally at the sciatic foramina. Extravasations of blood may take place beneath this fascia without any discoloration of the skin to indicate the fact, the blood being unable to reach the surface through the dense membrane. Such extravasations may be long pent up, and, as they fluctuate, may be mistaken for abscess.

Deep inflammations beneath this fascia, and especially when beneath the gluteus medius, may be associated with much pain, owing to the circumstance that the inflammatory effusions will be pent up between a wall of bone on one side and a wall of dense fascia and stout muscle on the other. Abscesses so pent up may travel for a considerable distance down the thigh before they reach the surface, and Farabeuf relates a case where a gluteal abscess travelled to the ankle before it broke. In other circumstances the gluteal abscess may make its way into the pelvis through the sciatic foramina, or a pelvic abscess may escape through one of these foramina and appear as a deep abscess of the buttock.

The thickened part of the fascia lata that runs down on the outer side of the limb, between the crest of the ilium above and the outer tuberosity of the tibia and head of the fibula below, is known as the ilio-tibial band. This band is tightly stretched across the gap between the iliac crest and the great trochanter, and, if pressure be made with the fingers between these two points, the resistance of this part of the fascia can be appreciated. It is obvious that in fracture of the neck of the femur, when the great trochanter is made to approach nearer to the crest, this band will become relaxed—an observation which may be of value in the diagnosis of fractures of the femoral neck.

The lower free edge of the **gluteus maximus** is oblique, and ends some way below the transverse line of the fold of the buttock (Fig. 117). It would appear that even this great muscle may be ruptured by violence. Thus a case has been reported of a robust man aged 63, who, while trying to lift a heavy cart when in a crouching position, felt something give way in his buttock, and heard a snap. He fell, and was carried home, when it was found that the great gluteal muscle was ruptured near the junction of the muscle with its tendon.

At least three **bursæ** exist over the great trochanter, separating that process from the three gluteal muscles respectively. The most extensive is that between the insertion of the gluteus maximus into the ilio-tibial band and the outer surface of the great trochanter. The bursa allows the great trochanter to move freely beneath the muscle during rotation of the thigh. When this sac is inflamed, much difficulty is experienced in moving the limb, and the thigh is generally kept flexed and adducted. This position means absolute rest from movement on the part of the gluteal muscles, which, when acting, would extend and abduct the limb, and bring pressure to bear upon the tender bursa.

There is a bursa over the ischial tuberosity that is often inflamed in those whose employments involve much sitting, the bursa being directly pressed upon in that position. This sac is the anatomical basis of the disease known in older text-books as "weaver's bottom" or "lighterman's bottom." When enlarged this bursa may press upon the inferior pudendal nerve (perineal branch of the posterior femoral cutaneous).

Arteries and nerves of the buttock.—The superior gluteal artery is about the same size as the ulnar, and the sciatic (inferior gluteal) as the lingual. The former vessel may sometimes be of much greater magnitude, and has led, when wounded, to rapid death from hæmorrhage. Wounds of the gluteal vessels will probably involve only the branches of the artery, since the greater part of the main trunk is situate within the pelvis. Gluteal aneurysms are not very uncommon, and with regard to the treatment of these tumours it may be noted that the gluteal artery, or, better, the internal iliac (hypogastric) trunk, can be compressed through the rectum. Both the gluteal and sciatic arteries have been ligatured in the buttock, through incisions made directly over the course of the vessels. In rare cases the companion artery of the sciatic nerve may assume the size and functions of the femoral artery.

The **sciatic nerve** is a continuation downwards of the main part of the sacral plexus (Fig. 117). It is in this nerve that the form of neuralgia known as sciatica is located. A reference to the immediate relations of the nerve will show that it may readily be exposed to many external influences. Thus, in the pelvis it may be pressed upon by various forms of pelvic tumour, and sciatica be produced in consequence. Accumulation of fæces within the rectum may press on this nerve and thus cause neuralgia. It is said to have been injured also by the pressure of the fœtal head during tedious labours, and to be affected by violent movements of the hip, a circumstance readily understood if the close relation of the nerve to the hip-joint be borne in mind. The nerve is also near enough to the surface to be influenced by external cold, and to this influence many forms of sciatica are ascribed.

Nerve stretching and injecting.—The *sciatic nerve* has been frequently cut down upon and stretched for the relief of certain nervous affections of the limb. In connexion with this

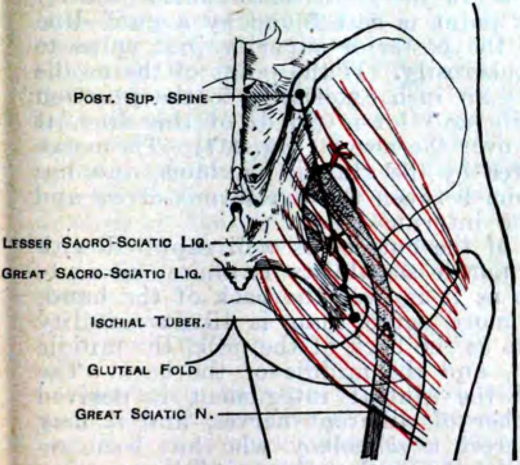

Fig. 117.—Formation and relationships of the upper part of the sciatic nerve.

procedure it is important to know how great an amount of traction may be brought to bear upon this and other nerves without the cord giving way. Trombetta, who has paid much attention to the *breaking-point of nerves*, gives the following weights as those required to break the undermentioned nerves:—

Great sciatic, 183 lb.
Internal popliteal (tibial), 114 lb.
Anterior crural (femoral), 83 lb.
Median, 83 lb.
Ulnar and radial, 59 lb.
Brachial plexus in the neck, 48–63 lb.
Brachial plexus in the axilla, 35–81 lb.

The sciatic nerve may be stretched by flexing the extended lower extremity of the belly. This measure has served to cure certain cases of sciatica. For the *hypodermic injection* of the sciatic nerve to relieve sciatica, the needle is inserted so as to penetrate the nerve as it lies on the bone below the great sacro-sciatic (sciatic) notch. This point is best found by a guide-line drawn from the posterior superior iliac spine to the ischial tuberosity. If the point of the needle be inserted ½ an inch externally to the junction of the middle and lower thirds of this line, it lies directly over the nerve (Fig. 117). The nerve is here covered by the gluteus maximus, and lies on the ischium between the pyriformis above and the obturator internus below.

The skin of the buttock is well supplied with nerves, and tactile sensibility is almost as acute in this part as it is over the back of the hand, while it is more acute than is like sensibility in such parts as the back of the neck, the middle of the thigh, and the middle of the back. The sensation of the gluteal integument is derived from a number of different nerves, and it may possibly interest a schoolboy who has been recently birched to know that the painful sensations reached his sensorium through some or all of the following nerves: Offsets of the posterior branches of the lumbar nerves, some branches of the sacral nerves, the lateral cutaneous branch of the last dorsal nerve, the iliac (lateral) branch of the ilio-hypogastric nerve, offsets of the external (lateral) cutaneous nerve, and large branches of the small sciatic. These nerves are derived from four spinal segments—the twelfth dorsal, first lumbar, second and third sacral (Fig. 149, p. 643). The second and third sacral also supply the sexual organs, hence the physiological effects which may follow application of punishment to this part, as in the celebrated case of J. J. Rousseau.

It should be remembered that the pelvic viscera can be readily reached through the sciatic foramina from the buttock. A case was admitted to the London Hospital of a man who had an apparently insignificant stab of the buttock. He died in a few days of acute peritonitis, and the autopsy showed that the dagger had passed through the great sacro-sciatic foramen, had entered the bladder and allowed urine to escape into the peritoneal cavity. In the Great War many of the worst abdominal injuries were those in which the wounds of entry were situated in the region of the buttock. The rectum, too, has been damaged in injuries to the buttock; and Anger records a case of an artificial anus situate upon the buttock which had followed a gunshot wound that, after involving the buttock, had opened up the cæcum. It is by this route that Kraske's operation for resection of the rectum is performed, and also Rigby's operation on the ureter.

2. The Region of the Femoral (Scarpa's) Triangle

Surface anatomy.—The most important landmarks in the region of the groin, the anterior superior iliac spine, the spine (tubercle) of the pubes, and the inguinal (Poupart's) ligament, are readily made out. To the two spines reference has already been made (p. 524). The *inguinal ligament* follows a curved line, with its convexity downwards, drawn between these two projections. It can be felt in even stout persons, its inner half more distinctly than its outer, and even in very fat individuals its position is indicated by a slight furrow. Owing to its attachment to the fascia lata the ligament is relaxed and rendered less distinct when the thigh is flexed and adducted, or when it is rotated in. The mid-point of a line joining the pubic with the anterior superior spine lies over the head of the femur and hip-joint. In this position a crease is often to be seen crossing the groin.

The sartorius muscle is brought into view when the leg is raised across the opposite knee, and the adductor longus is rendered distinct when the thigh is abducted and the subject's attempts to adduct the limb are resisted. Even in the obese the edge of this muscle can be felt when it is in vigorous action, and the fingers can follow its border up to the very origin of the muscle, just below the pubic spine.

The lymphatic glands in this region can sometimes be felt beneath the skin, especially in thin children. The femoral ring lies behind the inguinal ligament 1 inch externally to the pubic spine (Fig. 81, p. 367). The position of the saphenous opening (fossa ovalis) is sometimes indicated by a slight depression in the integuments. It lies just below the inguinal ligament, and its centre is about 1½ inches below and external to the pubic spine. In thin subjects the long saphenous vein can often be made out, passing to the saphenous opening.

If a line be drawn from the femoral point (Fig. 81, p. 367) to the tubercle for the adductor magnus, on the inner (medial) condyle of the femur, when the thigh is slightly flexed and abducted, it will correspond in the upper two-thirds of its extent to the position of the *femoral artery*. Just below the inguinal ligament the femoral vein lies to the inner side of the artery, while the anterior crural (femoral) nerve runs about ¼ of an inch to its outer side. The profunda femoris arises about 1½ inches below the inguinal ligament, and the internal and external circumflex vessels come off about 2 inches below that structure.

The **skin** over the femoral (Scarpa's) triangle is, unlike that of the buttock, comparatively thin and fine. The looseness of its attachment, also, to the parts immediately beneath permits it to be greatly stretched, as is seen in cases of large femoral herniæ, and in certain inguinal tumours of large size. It may even give way under severe traction, as occurred in a case reported by Berne. The patient in this case was a child aged 11, the subject of hip disease. The thighs were flexed upon the abdomen, and, forcible extension being applied to relieve the deformity, the skin gave way just below the groin, and separated to the extent of some 2½ inches. Contracting scars in the region of the groin may produce a permanent flexing of the hip, and this result is not uncommon after deep and severe burns in this neighbourhood. It may at the same time be noted that horizontal wounds about the groin can be well adjusted by a slight flexion of the thigh.

Instances are recorded where a supernumerary mammary gland, provided with a proper nipple, has been found located in the groin. Jessieu relates the case of a female who had a breast so placed, and who suckled her child from this part (*see* p. 223). In a few cases the testicle, instead of descending into the scrotum, has escaped through the femoral canal, and made its appearance in the femoral triangle. It has even mounted up over the inguinal ligament after the manner of a femoral hernia, being probably urged in that direction by the movements of the limb.

The **superficial fascia** in this region is not very dense, and has little or no influence upon the progress of a superficial abscess. This fact receives extensive illustration, since the glands in Scarpa's triangle frequently suppurate, and yet the pus in the great majority of cases readily reaches the surface in spite of the circumstance that the denser layer of the superficial fascia (for in this region it is divided into two layers) covers in those glands, and should hinder the progress of pus towards the surface. Although the subcutaneous fat is not peculiarly plentiful in this region, yet the femoral triangle is a favourite spot for lipomata.

The **fascia lata** completely invests the limb, being, so far as the front of the thigh is concerned, attached above to the inguinal ligament, to the body and ramus of the pubes, and the ramus of the ischium. Its integrity is interrupted only by the saphenous opening. This fascia exercises some influence upon deep abscesses and deep growths. Thus a psoas abscess reaches the thigh by following the substance of the psoas muscle, and finds itself, when it arrives at the femoral triangle, under the fascia lata. In a great number of cases it points where the psoas muscle ends, but in other and less frequent instances its progress is decidedly influenced by the fascia lata, and it moves down the limb. Thus guided, a psoas abscess has pointed low down in the thigh, and even at the knee, and Erichsen reports a case where such an abscess (commencing, as it did, in the dorsal spine) was ultimately opened by the side of the tendo Achillis (calcaneus).

Muscles.—The **ilio-psoas** muscle, which is stretched, as it were, over the front of the hip-joint, and participates in many of the movements of that joint, is peculiarly liable to be sprained in violent exercises. Between this muscle and the thinnest part of the hip capsule is a bursa, which not infrequently communicates with the joint. When chronically inflamed, this bursa may form a large tumour on the front of the thigh that may, according to Nancrede, attain the size of a child's head. To relieve this bursa from pressure when inflamed, the thigh always becomes flexed, and a train of symptoms is produced not unlike those of hip disease. The ilio-psoas muscles also act on the intervertebral joints of the lumbar region of the spine and on the sacro-iliac joints. Hence, disease of any of these joints will throw the ilio-psoas into an irritable and contracted condition. Indeed, no muscles in the body have more extensive or more important clinical relations than have the ilio-psoas; if the kidneys, ureters, cæcum, appendix, sigmoid colon, pancreas, iliac chain of lymphatic glands, or nerves of the lumbar plexus suffer from diseased conditions, then movements in which the ilio-psoas muscles are involved will be accompanied by pain.

The **sartorius** is a muscle which, from its length, peculiar action, etc., one would hardly expect to find ruptured from violence, yet in the Musée Dupuytren there is a specimen of such a rupture, about the middle of the muscle, united by fibrous tissue. The **adductor** muscles, and especially the adductor longus, are frequently sprained, or even partially ruptured, during horse exercise, the grip of the saddle being for the most part maintained by them. "Rider's sprains," as such accidents are called, usually involve the muscles close to their pelvic attachments. Much blood is often effused when the fibres are ruptured, and such effusion may become so dense and fibrinous as to form a mass that has been mistaken for a detached piece of the pubes (Sir Henry Morris). The term "rider's bone" refers to an ossification of the upper tendon of the adductor longus or magnus, following a sprain or partial rupture. Cases are reported where the piece of bone in the tendon was ½ an inch, 2 inches, and even 3 inches long. It occasionally happens in strains and sudden exertions that the insertion of a muscle, or of part of a muscle, to the femur is partly torn away, bringing with it a piece of periosteum. The result is that new bone is thrown out at the site of the rupture, forming a tumour-like mass (Godlee).

Blood-vessels.—The **femoral artery** occupies so superficial a position in the femoral triangle that it is not infrequently wounded. The vessel also has been opened up by cancerous and phagedænic ulcerations of this part, the occurrence leading to fatal hæmorrhage. Pressure is most conveniently applied to the artery at a spot immediately below the inguinal ligament, and should be directed backwards, so as to compress the vessel against the pubes and adjacent parts of the hip capsule. Lower down, compression should be applied in a direction backwards and outwards, so as to bring the artery against the shaft of the femur, which lies at some distance to its outer side. Pressure rudely applied by a tourniquet may cause phlebitis by damaging the vein, or neuralgia by contusing the anterior crural (femoral) nerve.

From the proximity of the artery and vein, it happens that arterio-venous aneurysms following wounds have been met with in this situation. Aneurysm is frequent in the common femoral, and many reasons can be given why that vessel should be attacked. It is just about to bifurcate into two large trunks, its superficial position exposes it to injury, it is greatly influenced by the movements of the hip, and its coat may, if diseased, be damaged by those movements, if excessive.

Phlebitis of the **femoral vein** has in many cases followed contusion of the vessel in its upper or more superficial part, and a like result has even followed from violent flexion of the thigh. The long (great) saphenous vein is often varicose. The **saphenous veins** lie outside the fascia lata, and therefore derive no support from it. In muscular exertions the pressure in the veins may be greatly raised, and then the muscular coats of the saphenous veins have to bear unaided a considerable burden. If that burden is long continued the muscular coats give way and a varicose condition results.

Nerves.—The **anterior crural** or **femoral** nerve lies on the ilio-psoas muscle, and it is said that neuralgia, and even paralysis of the nerve, may follow upon inflammation of that muscle and upon psoas abscess. The superficial position of the trunk exposes it to injury. The **genito-crural** nerve (the nerve that supplies the cremaster muscle) gives a sensory filament to the integument of the thigh in the femoral triangle. Irritation of the skin over the seat of this nerve, which is placed just to the outer side of the femoral artery, will cause, in children, a sudden retraction of the testicle. The same result is often seen in adults, also, on more severe stimulation. In this manner the condition of the second lumbar segment of the spinal cord may be tested.

The **lymphatic glands** in this region are numerous, and, as they are frequently the seat of abscess, it is important to know whence they derive their afferent vessels. They are divided into a superficial and a deep set. The superficial set, averaging from ten to fifteen glands, is arranged in two groups, one parallel and close to the inguinal ligament (the horizontal series), the other parallel and close to the long saphenous vein (the vertical series). The deep set, about four in number, are placed along the femoral vein, and reach the femoral canal.

The inguinal glands receive the following lymphatics :—

Superficial vessels of lower limb = vertical set of superficial glands.

Superficial vessels of lower half of abdomen = middle glands of horizontal set.

Superficial vessels from outer surface of buttock = external glands of horizontal set.

From inner surface of buttock = internal glands of horizontal set. (A few of these vessels go to the vertical glands.)

Superficial vessels from external genitals = horizontal glands (some few going to vertical set).

Superficial vessels of perineum and anus = vertical set.

Deep lymphatics of lower limb = deep set of glands.

The lymphatics which accompany the obturator, gluteal, and sciatic arteries and the deep vessels of the penis pass to the pelvis and have no connexion with the inguinal glands. The only superficial lymphatics of the lower extremity which do not pass direct to the inguinal glands are those that drain the outer side of the ankle and posterior aspect of the leg. The vessels from these areas accompany the short (small) saphenous vein and end in the popliteal glands; the efferent vessels from these glands pass to the deep inguinal set.

One of the deep glands lies in the femoral canal and upon the septum femorale. Being surrounded by dense structures, it is apt to cause great distress when inflamed and great pain when the hip is moved. In some cases, by reflex disturbance, it has produced symptoms akin to those of strangulated hernia. Some branches of the anterior crural (femoral) nerve lie over the inguinal lymph-glands, and Sir B. Brodie reports a case in which these branches were stretched over two enlarged glands, like strings of a violin over its bridge, so that violent pains and convulsive movements were set up in the limb.

The efferent vessels from the inguinal glands pass through a chain of lymphatic glands stretching along the course of the external and common iliac vessels. Three of these glands lie immediately above the inguinal ligament. The efferent vessels of the internal iliac group of glands, into which the pelvic lymphatics drain, join the chain along the common iliac vessels. The lumbar glands receive the lymph from the iliac groups and pass it on by the right and left lumbar trunks to the cisterna chyli.

Elephantiasis Arabum is more common in the lower limb than in any other part, and leads to an enormous increase in the size of the extremity (Cochin or Barbadoes leg). Its pathology is intimately concerned with the inguinal lymphatics. The lymphatics are obstructed by the larvæ of a small threadworm, *Filaria sanguinis hominis*. The lymph-vessels and lymph-spaces in the connective tissue become greatly distended, and the elements of the connective tissue hypertrophied.

3. The Hip-Joint

The hip-joint is of considerable strength (Fig. 118), not only on account of the shape of the articulating bones, which permits of a good ball-and-socket joint being formed, but also because of the powerful ligaments that connect them and the muscular bands that directly support the capsule. These advantages, however, are to some extent counterbalanced by the immense leverage that can be brought to bear upon the femur, and the numerous strains and injuries to which the joint is subjected, as the sole connecting link between the trunk and the lower limb.

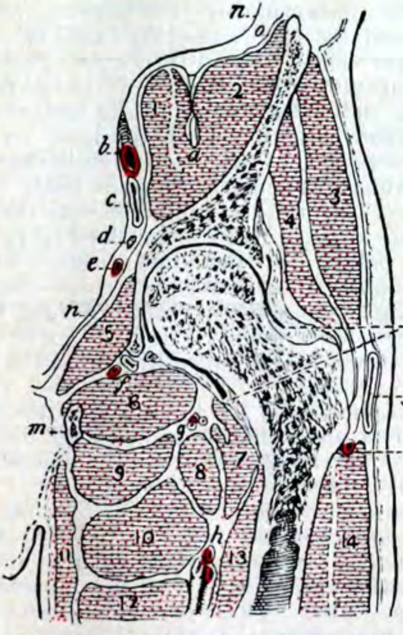

Fig. 118.—Vertical section of the upper third of the thigh, showing the structures in relationship with the hip-joint. (*After Braune.*)

Muscles.—1, Psoas; 2, iliacus; 3, gluteus medius; 4, gluteus minimus; 5, obturator internus; 6, obturator externus; 7, ilio-psoas; 8, pectineus; 9, adductor magnus; 10, adductor brevis; 11, gracilis; 12, adductor longus; 13, vastus internus; 14, vastus externus. *a*, Anterior crural nerve; *b*, external iliac artery; *c*, external iliac vein; *d*, obturator nerve; *e*, obturator artery; *f*, branches of obturator vessels to hip-joint; *g*, internal circumflex vessels; *h*, deep femoral vessels; *i*, branch of external circumflex: *j*, bursa over great trochanter; *k*, reflections of capsule to neck of femur; *m*, ascending ramus of pubes; *n*, peritoneum; *o* iliac fascia.

The **acetabulum** is divided into an articular and a non-articular part. The former is of horseshoe shape, and varies from 1 inch to ½ an inch in width. The bone immediately above the articular area is very dense, and through it is transmitted the superincumbent weight of the trunk. The non-articular part corresponds to the area enclosed by the horseshoe, and is made up of very thin bone. It is, however, rarely fractured by any violence that may drive the femur up against the pelvic bones, since no ordinary force can bring the head of the thigh-bone in contact with this segment of the os innominatum.

Pelvic abscesses sometimes make their way into the hip-joint through the non-articular part of the acetabulum, and an abscess in the hip-joint may reach the pelvis by the same route. But both such circumstances are rare. In some cases of destructive hip disease the acetabulum may separate into its three component parts. Up to the age of puberty these three bones are separated by the Y-shaped cartilage. At puberty the cartilage begins to ossify, and by the eighteenth year the acetabulum is one continuous mass of bone. The breaking-up of the acetabulum by disease, therefore, is only possible before that year.

The manner in which the various movements at the hip are limited may be briefly expressed as follows: The limit of every natural movement is fixed by the extensibility of the muscles which surround a joint. That is readily seen at the hip-joint, for when the knee is extended, and the hamstring muscles thus tightened, flexion at the hip is limited long before the ligaments become tense. Ligaments only come into play when the muscular defence of the joint breaks down. *Flexion*, when the knee is bent, is limited by the contact of the soft parts of the groin. *Extension*, by the ilio-psoas, rectus femoris, and the ilio-femoral or Y-ligament. *Abduction*, by the adductor mass of muscles and the pubo-capsular ligament. *Adduction* of the flexed limb, by the gluteal musculature, the ligamentum teres and ischio-capsular ligament. *Rotation outwards* is resisted by the tensor fasciæ femoris, the anterior parts of the glutei medius and minimus, and the ilio-femoral ligament. The ligamentum teres, which is not a strong ligament, becomes taut when the thigh is flexed and rotated outwards. It is ruptured in all cases of complete dislocation. The structures which take the chief part in maintaining the integrity of the joint, however, are not the ligaments but the strong muscles which surround and act on the joint. Atmospheric pressure bears no part, for the fat at the transverse notch is readily drawn into the acetabulum to make good any space vacated by the femoral head in all normal movements of the hip-joint. All joints are provided with yielding pads of fat to obviate alterations of atmospheric pressure interfering with movements in the joint.

Hip-joint disease.—Owing to its deep position and its thick covering of soft parts (Fig. 118), this articulation is able to escape, to a great extent, those severer injuries that are capable of producing acute inflammation in other joints. Acute synovitis is indeed quite rare in the hip, and the ordinary disease of the part is of a distinctly chronic character. It follows, also, from the deep position of the articulation that pus, when it is formed in connexion with disease, remains pent up, and is long before it reaches the surface. Suppuration in this region, therefore, is often very destructive. When effusion takes place into the joint, the swelling incident thereto will first show itself in those parts where the hip capsule is the most thin. The thinnest parts of the capsule are in front and behind—in front, in the triangular interval between the inner edge of the Y-ligament and the pubo-capsular ligament; behind, at the posterior and lower part of the capsule. It is over these two districts that the swelling first declares itself in cases of effusion into the joint, and, as these parts are readily accessible to pressure, it follows that they correspond also to the regions where tenderness is most marked and is earliest detected. Consequently it is over these two weak spaces that abscesses form and work a passage to the surface of the hip.

In chronic hip-disease certain false positions are assumed by the affected limb, the meaning of which it is important to appreciate. These positions may be arranged as follows, according, as

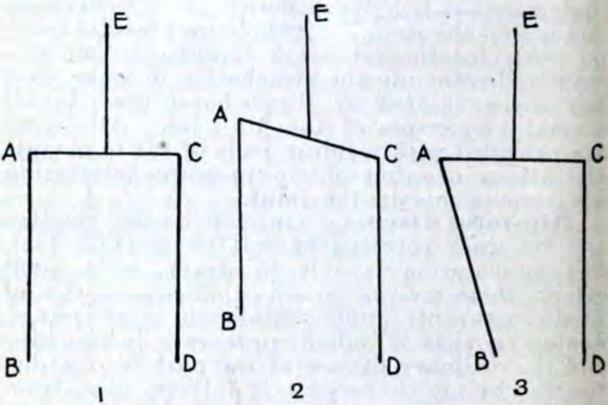

Fig. 119.—Diagrams of positions of pelvis and limbs. 1, Parts in normal position. 2, Adduction corrected by tilting up the pelvis. 3, Femur adducted.

AC, Line of pelvis: AB, limb on diseased side; CD, limb on sound side; E, the spine. It will be found that in diagrams 2 and 3 the angle at A is the same in both.

nearly as possible, to their order of appearing: (1) The thigh is flexed, abducted, and a little everted; associated with this there is (2) *apparent* lengthening of the limb and (3) lordosis of the spine; (4) the thigh is adducted and inverted, and incident to this there is (5) apparent shortening of the limb.

(1) The first position is simply the posture of

rest for the surrounding muscles—the posture in which they exert the least pressure on the joint-surfaces. Flexion is the most marked feature in this position. Its effect is pronounced. It relaxes the main part of the Y-ligament, which, when the limb is straight, is drawn as an unyielding band across the front of the joint. The attachments of the psoas muscle are approximated and its pressure over the joint is relaxed in the flexed position.

(2) The apparent lengthening is due to the tilting down of the pelvis on the diseased side when the patient attempts to bring his limbs and trunk into a straight line as he lies on his back (Fig. 119). Actually, when measured from anterior superior iliac spine to internal malleolus, the limb is not lengthened. The pelvis is tilted downwards on the diseased side, to accommodate the abducted position of the disabled limb.

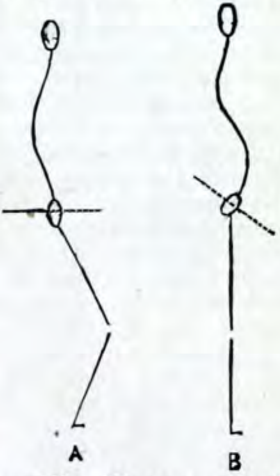

Fig. 120.—Diagram to show the mode of production of lordosis in hip disease.

A, Femur flexed at hip, pelvis (represented by the dotted line) straight and spine normal. B, The flexion concealed or overcome by lordosis of the spine; the pelvis rendered oblique.

(3) The lordosis, or curving forwards, of the spine occurs in the dorso-lumbar region. It depends upon the flexion of the limb, and is the result of an attempt to conceal that false position, or at least to minimize its inconveniences (Fig. 120). When the thigh is flexed at the hip by disease, the lower limb can be made to appear

straight by simply increasing the forward convexity of the lumbar curvature of the spine. We have to keep constantly in mind that the spinal movements of the loin are correlated with those at the hip-joints, and that the psoas muscles act on both; we can compensate a limitation at the hip-joint by overdoing the lumbar movement, thus producing the lordosis we see in cases of hip-joint disease. A patient with a flexed hip as the result of disease can lie on his back in bed, with both limbs apparently perfectly straight, he having concealed the flexion, as it were, by producing a lordosis of the spine. But, as Thomas was the first to show, if the lordosis be undone by flexing the sound thigh on the belly, then the flexed position of the thigh on the diseased side at once becomes apparent. This lordosis generally appears a little late in the disease, and after the limb has become more or less fixed in the false position by contraction of the surrounding muscles.

(4) Sooner or later, if disease progresses, the thigh becomes adducted and inverted, while it still remains flexed. Destruction of the articular surfaces—particularly of the hinder part of the acetabulum—disorganization of the capsule, and altered action of the surrounding musculature produce a partial or complete dislocation.

(5) The apparent shortening, which may appear at a late stage, is produced by reversing the tilting which appeared in the earlier stage when the diseased limb was abducted. The manner in which the pelvis may be tilted upwards to produce apparent shortening of the *adducted* limb is illustrated in Fig. 119, 2, 3. In some cases of simultaneous disease in both hip-joints that has been indifferently treated, both thighs may remain adducted. The limbs are unable, of course, to remedy their position by the usual means, when the disease is double, and consequently one limb is crossed in front of the other,

and the peculiar mode of locomotion known as "cross-legged progression" is produced.

When hip-disease commences in the bone it usually involves the epiphyseal line which unites the head of the femur to the neck. This line is wholly within the joint, and the epiphysis forming the head unites with the rest of the bone about the eighteenth or nineteenth year. (Fig. 118.)

It is well known that patients with hip-disease often complain of pain in the knee. This referred pain may be so marked as entirely to withdraw attention from the true seat of disease. Thus, I (F. T.) once had a child sent to me with a sound knee carefully secured in splints, but without any appliance to the hip, which was the seat of a somewhat active inflammation. This referred pain is easy to understand, since the two joints are supplied from the same segments of the spinal cord. In the hip, branches from (1) the anterior crural (femoral) enter at the front of the capsule; (2) branches from the obturator, at the lower and inner part of the capsule; and (3) branches from the sacral plexus and sciatic nerve, at the posterior part of the joint. In the knee, branches from (1) the anterior crural (nerves to vasti) enter at the front of the capsule; (2) branches from the obturator, at the posterior part of the capsule; and (3) branches from the internal and external popliteal divisions of the great sciatic nerve, at the lateral and hinder aspects of the joint.

Pain, therefore, in the front of the knee, on one or both sides of the patella, has probably been referred along the anterior crural curve; and pain at the back of the joint, along the obturator or sciatic nerves.

In *hysterical individuals* joint-disease may be imitated by certain local nervous phenomena, the articulation itself being quite free from structural change. This affection most commonly shows itself in the hip or knee, and the "hysterical hip," or "hysterical knee," takes a prominent place in the symptomatology of hysteria. It is not quite easy to understand why these two large joints should be so frequently selected for the mimicry of disease. Hilton has endeavoured to explain the fact upon anatomical grounds, having reference to the nerve supply of these joints in relation to the nerve supply of the uterus. The uterus is mainly supplied by an offshoot from the hypogastric plexus, and by the third and fourth sacral nerves. Now, the hypogastric plexus contains filaments derived from the lower lumbar nerves; and from the same trunks two nerves to the hip and knee (the anterior crural and obturator) are in great part derived. The sciatic also contains a large portion of the third sacral nerve. The common origin of the joint and uterine nerves forms the basis of Hilton's explanation of the relative frequency of hysterical disease in the large articulations of the lower limb. The explanation, however, is unsatisfactory, since the uterus receives many of its nerves from the ovarian plexus, and the theory is founded upon the unwarranted supposition that all hysterical disorders are associated with some affection of the uterus or its appendages. More recently Head has revived Hilton's theory in modified form. He explains the connexion not through an anatomical association of nerves, but through an association of the centres from which nerves arise in the spinal cord. The spinal segments from which the obturator nerve arises, the second, third, and fourth, contain no visceral nerves, and, therefore, cannot be associated with visceral conditions. On the other hand, the sacral segments from which the great sciatic nerve arises are those which supply the pelvic viscera.

Fractures of the upper end of the femur may be divided into (1) fractures of the neck wholly within the capsule; (2) fractures of the base of the neck not wholly within the capsule; (3) fractures of the base of the neck involving the great trochanter; (4) separations of epiphyses. It can be scarcely possible, apart from gunshot injuries, to fracture the neck of the femur by direct violence, owing to the depth at which the bone is placed, and the manner in which it is protected by the surrounding muscles. The violence, therefore, that causes the lesion is nearly always indirect, as by a fall upon the feet or great trochanter, or by a sudden wrench of the lower limb.

(1) The true **intracapsular fracture** may involve any part of the cervix within the joint, but is most usually found near the line of junction of the head with the neck (Fig. 118, p. 541). This fracture is more common in the old, in whom it may be produced by very slight degrees of violence. The liability of the aged to this lesion is explained by atrophy of the supporting and strengthening trabeculæ and by a lessened protective reflex on the part of the muscles. The neck of the femur becomes set more transversely as old age comes on. In youth the neck forms an angle of 140° with the shaft of the femur; in the aged the angle decreases to 120°, and is thus more liable to fracture when a false step is taken. These fractures are but rarely impacted; but when impacted, the lower fragment, represented by the relatively small and compact neck, is driven into the larger and more cancellous fragment made up of the head of the bone. The fracture may be subperiosteal, or the fragments may be held together by the reflected portion of the capsule. These reflected fibres pass along the neck of the bone from the attachment of the capsule at the femur to a point on the cervix much nearer to the head. Fractures of this part very often fail to unite, because there is no part of the body which is so difficult to immobilize as the top of the femur. The pelvis as well as the femur must be secured in a fixed position if the fragments are to be kept at rest; that can only be attained by immobilizing

the lower limbs and trunk. Blood is brought to the head of the femur by vessels in the neck of the bone and in the reflected parts of the capsule, but only an insignificant supply is carried by the ligamentum teres (Walmsley). A deficiency in the blood supply to the fragments has been often put forward to explain failures of union, but there is no real evidence to support this contention.

(2) In connexion with **fractures at the base of the neck,** it must be remembered that a wholly extracapsular fracture of the neck of the femur is an anatomical impossibility. If the fracture is wholly without the capsule, then it must involve a part of the femoral shaft, and cannot be entirely through the cervix. In the front of the bone the capsule is attached to the femur along the intertrochanteric line, and strictly follows the line of junction between the cervix and the shaft. Behind, the capsule is inserted into the neck about ½ an inch above the posterior intertrochanteric line or crest. When fractures at the junction of the neck and shaft are impacted, the upper fragment, represented by the compact and relatively small cervix, is driven into the cancellous tissue about the great trochanter and upper end of the shaft (Fig. 121). As a result of this impaction the trochanter may be split up, and the bones may become free again through the extent of this splintering. The impacted end of the cervical fragment is shaped like a chisel; the calcar femorale forming its cutting edge (R. Thompson).

With regard to the *symptoms of a fracture of the neck of the femur,* the following may be noticed: (*a*) The swelling often observed in the front of the limb, just below the inguinal ligament, is due either to effusion of blood into the joint or to projection of the fragments against the front of the capsule; (*b*) the shortening is brought about by the glutei, the hamstrings, the tensor fasciæ femoris, the rectus, sartorius, and ilio-psoas, the adductors, gracilis, and pectineus;

(*c*) the eversion, or rotation outwards of the limb, is mainly due to two causes: (i) the weight of the limb, which causes it to roll outwards, as is seen in persons insensible or asleep, the line of gravity passing through the outer part of the thigh; (ii) the fact that the compact tissue on the posterior aspect of the neck is much more fragile than that on the anterior aspect. Thus the cervix is often more extensively fractured behind than in front, or the fracture may be impacted behind

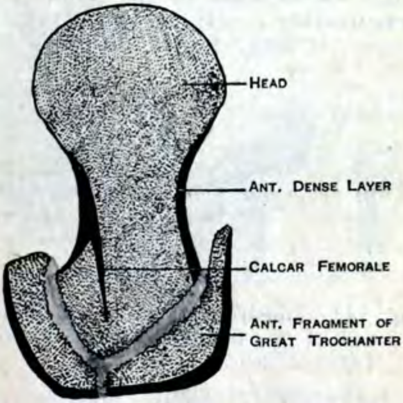

Fig. 121.—The calcar femorale and its relationship to impacted fractures of the neck of the femur. (*Ralph Thompson.*)

but not in front, and in either case the limb will tend to become everted. As a third cause may be mentioned the action of the ilio-psoas, of the adductor and pectineus muscles, and of the small rotator muscles, all of which will tend to roll the femur outwards.

(3) **Fracture of the base of the neck involving the great trochanter.**—In this lesion the head, the cervix, and a part of the great trochanter are separated from the shaft and the rest of the trochanter.

(4) **Separation of epiphyses.**—There are three epiphyses in the upper end of the femur—one for the head, which unites between 18 and 19 years of age; one for the lesser trochanter, which unites about 17; and one for the greater trochanter, which unites about 18. The neck is formed by an extension of ossification from the shaft (Fig. 122). The epiphysis for the head is secured against separation by being shaped like a cap, by its epiphyseal line being arranged transversely to the axis of the femur, and also by its intracapsular position (Fig. 118). The epiphysis, however, is subject to a peculiar form of disloca-

Fig. 122.—Illustrating the ossification of the upper end of the femur and the condition of coxa vara. (*After Elmslie.*)

A, The upper end at birth.
B, " " at second year.
C, " " at fourth year.
D, " " of a femur from a subject of coxa vara.

tion which gives rise to the condition of *coxa vara.* The epiphysis gradually tilts downwards so that the neck of the femur appears to sink under the weight of the body, coming to form an angle of 90° or less with the shaft of the femur. It occurs in adolescents. Owing to the prominence of the trochanter and shortening of the limb which necessarily result, the condition may be mistaken for a fracture of the neck of the femur or a congenital dislocation of the hip-joint. In paralytic limbs the opposite condition, *coxa valga*, is found. The angle may measure 145° or more. The great trochanter may be separated. The epiphyseal lines of the head and great trochanter are continuous until the neck is ossified (*see* Fig. 122).

Dislocations of the hip.—These injuries are comparatively rare, on account of the great strength of the articulation, and when they occur in a healthy joint are always the result of a considerable degree of violence. A dislocation of the hip may be congenital, or may be spontaneously

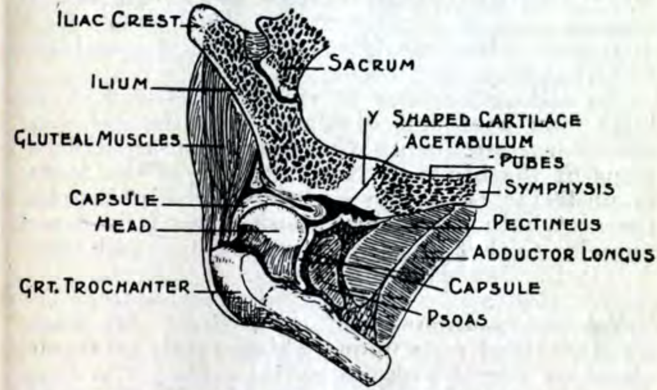

Fig. 123.—Congenital dislocation of the hip.

From a specimen presented to the London Hospital Medical College Museum by Mr. Openshaw. It was obtained from a child aged 4 years.

produced by muscular efforts, as shown in a few rare cases, or may be the result of disease of the articulation. **Congenital dislocation** of the hip-joint is due in most instances to a failure in the development of the acetabulum. In such cases the acetabulum retains the shallow character seen during the second month of fœtal life. The outgrowth of the acetabular rim fails, especially in the iliac part. The acetabular cavity becomes filled up by the duplication of the capsule, which is unduly lax (Fig. 123). The round ligament may be intact or deficient. The head of the femur becomes flat and the neck short, and the bone slips backwards on the dorsum ilii when the child learns to walk. The weight of the body is supported by the muscles and ligaments round the hip-joint, and the gait of the patient resembles the waddle of a duck. If replaced the head again slips from the shallow cavity. In time osteophytic outgrowths from the ilium lead to the formation of a new cavity. The deformity is evidently correlated with the development of the female sexual organs, for it occurs nearly nine times more frequently in female than in male children (Fairbanks).

In **dislocations due to violence** the head of the bone may be found displaced in either of four directions, producing the four regular dislocations of the hip. In two the head of the femur is posterior to a line drawn vertically through the acetabulum, and in the other two it is found anterior to that line (*see* Figs. 124, 125, and 126).

(1) Backwards and upwards. Head rests upon ilium, just above and behind acetabulum. The "*dislocation upon the dorsum ilii.*" (2) Backwards. Head rests upon ischium, and, as a rule, about on a level with the ischial spine. The "*dislocation into the sciatic notch.*" (3) Forwards and downwards. Head rests on thyroid foramen. The "*obturator or thyroid dislocation.*" (4) Forwards and upwards. Head rests upon the body of the pubes, close to its junction with the ilium. The "*dislocation upon the pubes.*"

The above arrangement represents also the order of frequency of these luxations, No. 1 being the most common dislocation of this part, and No. 4 the most rare.

General facts.—In all these dislocations of the hip, (*a*) the luxation occurs when the limb is in the position of abduction; (*b*) the rent in the capsule is always at its posterior and lower part; (*c*) the head of the bone always passes at first more or less directly downwards; (*d*) the

Y-ligament is untorn, while the ligamentum teres is ruptured.

(*a*) It is maintained that, in all luxations at the hip, the pelvis and femur are in the mutual position of abduction of the latter at the time of the accident. The lower and inner part of the acetabulum is very shallow, and the lower and posterior part of the capsule is very thin. In abduction the head of the bone is brought to the shallow part of the acetabulum; it moves more than half out of that cavity; it is supported only by the thin weak part of the capsule, and its further movement in the direction of abduction is limited only by the pubo-capsular ligament, a somewhat feeble band. In abduction the round ligament is slack, and in abduction with flexion both the Y-ligament and the ischio-capsular ligaments are also relaxed. In the position of abduction, therefore, no great degree of force may be required to thrust the head of the bone through the lower and posterior part of the capsule and displace it downwards.

(*b*) The above being allowed, it will be understood that the rent in the capsule is always at its posterior and lower parts. "Generally the rupture is jagged and irregular, but will be found to extend more or less directly from near the shallow rim of the acetabulum, across the thin portion of the capsule to the femur near the small trochanter, and then to run along the back of the ligament close to its attachment to the neck of the bone" (Sir Henry Morris).

(*c*) If the position of the limb at the time of the accident be considered, it will be seen that the femur will in *every* case be displaced downwards. There is, indeed, but one primary dislocation of the hip—a luxation downwards. The four forms given above are all secondary, the bone having in each instance first passed downwards before it moved to any of the positions indicated.

(*d*) The ilio-femoral ligament is never torn in any regular dislocation. It is saved by its great density and the circumstance that it is probably more or less relaxed at the time of the luxation. The method of reducing these dislocations by manipulation depends for its success mainly upon the integrity of the ilio-femoral or Y-ligament, which acts as the fulcrum to a lever of which the shaft of the femur is the long arm and the neck the short. In the backward luxations the head is behind the Y-ligament, and in the forward displacements in front of it.

Fig. 124.—Dislocation upon the dorsum ilii. (*Bigelow.*)

The anatomy of each form of hip dislocation. Nos. 1 and 2: *The dislocations backwards* (Fig. 124).—The femoral head, having been displaced in the way indicated, is carried towards the dorsum or sciatic notch by the glutei, hamstring, and adductor muscles. The bone having taken a general direction backwards, the height to which it ascends depends mainly upon the nature of the dislocating force, and also upon the extent of the rupture in the capsule and the laceration of the obturator internus tendon and other small external rotators. The dorsal dislocation is, therefore, a more advanced grade of the sciatic. The more extreme the flexion and inward rotation at the time of the accident, the more likely is the dislocation to be sciatic. More moderate flexion and inward rotation will produce a luxation upon the dorsum. In the dorsal luxation the head is above the obturator internus tendon, while in the sciatic form it is below it (Bigelow). In these backward dislocations the ilio-psoas muscle is greatly stretched. The quadratus femoris, the obturators, the gemelli, and the pyriformis are more or less lacerated. The pectineus is often torn, and the glutei muscles even may be ruptured in part. The sciatic nerve may be compressed between the femoral neck and the rotator muscles, or between the head of the bone and the tuber ischii. In both of the backward luxations there is shortening due to the circumstance that the line between the anterior superior spine and the femoral condyles is lessened by the displacement upwards and backwards of the bone. The adduction and inversion in the main depend upon the position of the head and cervix, which must follow the plane of the bone upon which they lie. This position is maintained by the tense Y-ligament. The damage done to the chief external rotators places them also *hors de combat*. The flexion is due to the tension of the Y-ligament and of the ilio-psoas muscle.

Fig. 125.—Obturator or thyroid dislocation. (*Bigelow.*)

Nos. 3 and 4: *The dislocation forwards.*—If the head after leaving the acetabulum simply moves a little forwards along the inner edge of the socket, the thyroid luxation is produced (Fig. 125). If it goes farther and moves upwards, the pubic displacement will result (Fig. 126). The latter dislocation is therefore but an advanced form of the former. Whether the head will remain in the thyroid foramen or ascend on to the pubes depends on whether extension and rotation outwards accompany the displacement. If these occur the pubic form is produced. In these injuries the pectineus, gracilis, and adductors will be more or less torn, while the ilio-psoas, glutei, and pyriform muscles are much stretched. The obturator nerve may be stretched or torn, and in the pubic luxation the anterior crural nerve may be involved. The abduction and eversion of the limb noticed in these luxations depend partly upon the position of the head of the bone, fixed more or less by the Y-ligament, and partly upon the action of the gluteal muscles and some of the small external rotators, which are tightly stretched. The flexion of the limb is mainly due to the stretching of the ilio-psoas muscle.

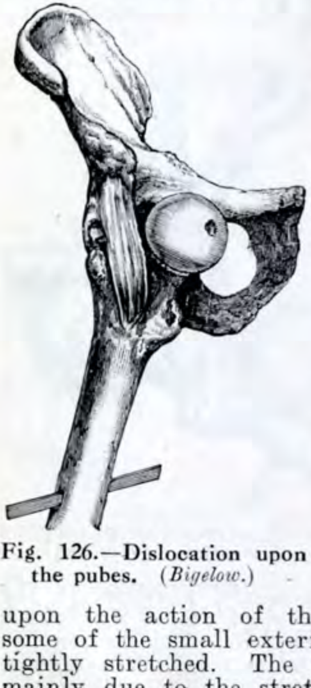

Fig. 126.—Dislocation upon the pubes. (*Bigelow.*)

In the thyroid luxation the extremity is said to be lengthened. This lengthening is, however, only apparent, and is due to the tilting down of the pelvis on the injured side. In the pubic dislocation there is shortening, the head being carried above the acetabular level.

Of the modes of **reducing these dislocations** by manipulation little can be said here. The more usual proceedings may be briefly summarized as follows:

First.	Flex the thigh in the adducted position in luxations Nos. 1 and 2. Flex the thigh in the abducted position in luxations Nos. 3 and 4.	To relax the ilio-femoral or Y-shaped ligament.
Secondly.	Circumduct out, in Nos. 1 and 2. Circumduct in, in Nos. 3 and 4.	To bring back the head to the rent in the capsule by the route by which it has escaped.
Thirdly.	Extend in all cases.	To induce the head to enter the acetabulum again.

In reducing dislocations of the hip it may be noted that the internal condyle of the femur faces in nearly the same direction as the head of the bone.

In **amputation of the thigh at the hip-joint** many methods may be employed, but there is a consensus of opinion that it is wise to design the operation so that the femoral vessels may be secured in the preliminary incision. In disarticulation by a racquet-shaped incision, the part representing the handle is placed over the upper 3 inches of the femoral artery, commencing above at the inguinal ligament, and the elliptical part is carried round the inner side of the limb, 4 inches below the pubic spine, and brought up on the outer side, below the great trochanter. The surface markings for the femoral artery are given at p. 512; the origin of the deep femoral artery and its circumflex branches lie about $1\frac{1}{2}$ inches below the inguinal ligament, but it is frequently $\frac{1}{2}$ an inch higher or lower. The common femoral is separated from the capsule of the hip-joint by the psoas muscle; the femoral vein lies close to its inner side, and the anterior crural nerve $\frac{1}{2}$ an inch to its outer side, on the psoas muscle (*see* Fig. 118, p. 541). Branches of the sciatic and obturator arteries also enter the thigh and require to be secured. The *nerves* divided are: the external, middle, and internal cutaneous, the internal saphenous, the deep muscular branches of the anterior crural, the obturator, the great and small sciatic. The *muscles* divided are: the sartorius, quadriceps extensor cruris, adductors magnus and longus, gracilis, and hamstrings. The capsule of the joint is divided, the head of the femur thrust from its socket, and the ligamentum teres cut. The attachments of the following structures to the upper third of the femur have to be separated: the gluteus maximus, medius, minimus, pyriformis, gemelli, obturator internus and externus, quadratus femoris, adductor magnus, brevis, pectineus, psoas, and iliacus, with the capsular ligament.

CHAPTER XXIII

THE THIGH

UNDER the term "the thigh" it will be convenient to describe that part of the lower limb that extends between the regions just described and the districts of the knee and popliteal space.

Surface anatomy.—In muscular subjects the outline of the thigh is irregular, but in the less muscularly developed, who are provided with a good share of subcutaneous fat, the limb, in this section of it, is more or less evenly rounded. The prominence of the rectus muscle is noticeable on the front of the thigh, especially when the muscle is in action. To the inner side of this structure, and conspicuous along the lower half of the thigh, is the eminence formed by the vastus internus (medialis). The mass to the outer side of the rectus is composed of the vastus externus (lateralis) muscle, and occupies the greater part of the limb in this region, being, however, more conspicuous below.

Running down the anterior and inner aspect of the thigh, from the apex of the femoral (Scarpa's) triangle, is a depression which indicates the interval between the quadriceps muscle and the adductors. Along this groove the sartorius lies. Over the surface of the vastus externus a longitudinal depression is often to be observed, formed by the pressure exercised by the superimposed ilio-tibial band of the fascia lata. The hamstring muscles cannot generally be distinguished the one from the other above the popliteal space, nor is their separation from the adductors indicated. The separation, however, between them and the vastus externus is distinct, and corresponds to the position of the external intermuscular septum. The line of the femoral vessels has already been given (p. 534). The long saphenous vein follows in the thigh the course of the sartorius muscle, and may be represented on the surface by a line drawn from the region of the saphenous opening (p. 534) to the posterior border of the sartorius muscle at the level of the inner (medial) condyle of the femur. The long saphenous nerve follows the course of the femoral artery, lying first to the outer side of that vessel and then gradually crossing it. In the lower fourth of the thigh the nerve passes under cover of the sartorius muscle to the inner side of the knee, and is accompanied by the superficial (saphenous) branch of the anastomotic artery. A line drawn down the back of the limb from a point midway between the great trochanter and tuber ischii to the middle of the ham will correspond to the great sciatic nerve and one of its continuations, the internal popliteal or tibial. The great trunk usually bifurcates a little below the middle of the thigh.

The **skin** of the thigh is coarse on the outer side of the limb, but internally it is thin and fine, and is apt to be readily excoriated by ill-applied bandages or splints. It is but loosely attached to the subjacent parts, a circumstance that greatly favours the performance of circular amputations in this region. At one place, however, it is a little more adherent, viz. along the groove that separates the vastus externus from the hamstring muscles, and that corresponds to the outer intermuscular septum. The laxity of the subcutaneous tissue favours extensive extravasations beneath the skin, and permits of large flaps of integument being torn up in cases of injury to this part of the extremity.

The **fascia lata** invests the limb at all parts like a tightly fitting sleeve. It is thickest at its outer side, where it forms the dense ilio-tibial band. It is thinnest at the upper and inner aspect of the thigh, where it covers the adductor muscles. It increases considerably in strength as it approaches the front of the knee, and attaches itself to the tibia and lateral margins of the patella. This fascia resists, especially at its outer part, the growth of tumours and abscesses, and limits deep extravasations of blood. It has occasionally been ruptured in part by violence, and through the rent so formed the subjacent muscle has bulged, forming what is known as a hernia of the muscle. This condition has been met with in the case of the quadriceps muscle, and also of the adductor longus. Such "herniæ" are probably associated with some rupture of the fibres of the muscles implicated. Two deep processes of the fascia are attached to the femur, and form the outer and inner intermuscular septa. The outer septum separates the vastus externus from the biceps, and the inner the vastus internus from the adductors. Together with the fascia lata, these septa divide the thigh into two aponeurotic spaces, which can be displayed in a transverse section of the limb (Fig. 127). These divisions, however, are of little surgical moment, and the inner septum is often so thin and feeble that it could have but little effect in directing the course of an abscess.

In circular amputations of the thigh the **muscles** are apt to retract unevenly, since some are attached to the femoral shaft while others are free. The muscles so attached are the adductors, vasti, and crureus (vastus intermedius), while the free muscles are the sartorius, rectus, hamstrings, and gracilis. Indeed, the retractility of tissues must be kept in mind in all amputations. The bone, which has to be covered, is non-retractile. Nerves retract very little, and are apt to swell into bulbous and sensitive ends unless cut very short. Arteries, on the other hand, are highly retractile; veins are less elastic and tend to retract less.

In spite of its great strength the tendon of the quadriceps may be ruptured by muscular violence. A good example of such an accident is recorded by Mr. Bryant (*Med. Times and Gaz.*, 1878). A man aged 42 stumbled and fell down a pit 10 feet deep. On examination the tendon was found to be torn across, and the gap above the patella produced by the rupture occupied no less extent than the lower third of the thigh. A somewhat more remarkable accident is reported to have happened to the sartorius muscle. This muscle, just before its insertion into the tibia, gives off an aponeurotic expansion from its anterior border to the capsule of the knee-joint. In the case alluded to (*Lancet*, 1873), this expansion is said to have been ruptured, and the muscle itself to have been found dislocated backwards in consequence. The accident befell a man aged 40, who was squatting, in the position assumed by tailors, upon the floor of a wagon, when his companion tripped over him and fell across his bent knees. Something was felt to have given way near the ham, and on examination the above lesion was diagnosed.

The femoral artery may be ligatured at any part of its course in the thigh, and the comparatively superficial position of the vessel renders it very liable to be injured. In the middle third of the thigh it lies beneath the sartorius in the adductor (Hunter's) canal. The thigh affords many instances of the remarkable way in which isolated branches of a main artery are often alone damaged. Thus, Langier relates the case of a man-cook who, in running round a table, struck the upper and outer side of his thigh against the corner of it. This led to a subcutaneous rupture of the external circumflex artery. Unfortunately the extravasation was cut into, and the patient, after being subjected to many modes of treatment, died from the effects of repeated hæmorrhage. Dr. Butcher (*Dublin Journ. Med. Sci.*, 1874) gives the case of a man who was stabbed in the thigh over the femoral vessels during a scuffle. Profuse bleeding followed, and it was found that the only vessel wounded was the internal circumflex artery, just at its point of origin from the profunda. The case was treated promptly, and the man did well. On the other hand, cases have been recorded during the Great War in which the femoral artery and vein were completely severed by a bullet wound, and yet only slight hæmorrhage resulted. In these cases it was found that the ruptured ends had become widely separated, and that the edges had become in-turned within the lumina of the vessels.

Fractures of the shaft of the femur.—The shaft may be broken at any part, but the lesion is most common at the middle third of the bone, and least frequent at its upper third. If it is broken by direct violence the fracture is usually transverse, and if by indirect violence it is usually oblique. The probability of a fracture being due to direct violence diminishes in the bone from below upwards, while the probability of a lesion from indirect violence increases in the same direction. Thus it happens that the fractures of the upper third of the bone are usually oblique, while those of the lower third are more commonly transverse. The femur has often been broken by muscular violence, but it is doubtful if this has ever occurred in other than a diseased bone. In many of these cases the amount of force that breaks the bone is most insignificant. Thus, Vallin reports the case of a girl aged 18, described as robust, who broke the femur about its middle while in the act of mounting a table for the purpose of undergoing a vaginal examination. In oblique fractures in the upper third of the bone the line of fracture usually runs downwards and inwards; while in oblique fractures of the middle third the direction is more commonly downwards and forwards, with a slight lateral inclination that is sometimes inwards and sometimes outwards. Fractures of the lower third of the bone are discussed in connexion with the region of the knee (Chap. XXIV.).

With regard to fractures of the upper and middle thirds, the displacements of the fragments depend greatly upon the obliquity of the fracture. As a rule the lower fragment is drawn up behind the upper one by the hamstrings, aided by the rectus, gracilis, sartorius, tensor fasciæ, and adductors, and is carried a little to its inner side under the influence of the last-named muscles. The lower end of the upper fragment usually projects forwards and a little outwards. This is due to the agency of the lower fragment, which tilts the upper piece of bone in the direction named. In the fracture of the upper third of the shaft the projection forwards of the upper fragment is aided by the ilio-psoas muscle. Thus the deformity produced in fractures of the femoral shaft is usually angular in character. The eversion of the foot noted in fractures of the femur is due to the weight of the limb, which causes the helpless member to roll outwards.

Certain spiral or helicoidal fractures may be produced in the lower part of the shaft as the result of torsion. M. Féré found by experiment that if the limb be carried forwards in front of the opposite knee, and the foot rotated outwards, a spiral fracture can be produced at the junction of the lower and middle thirds of the femur. A like fracture at the same level, but with the direction of the spiral reversed, can be caused by carrying the limb outwards and then rotating it inwards.

Shortening of the limb after fracture.—The chief difficulty in setting the broken ends and maintaining them in position lies in the action of the surrounding muscles. From the moment of fracture onwards all the muscles of the neighbourhood pass into a state of reflex contraction. That contraction can be overcome by a general or local anæsthesia, and the parts can then be set in their proper position. To maintain the parts in position two principles must be kept in mind: (1) impulses which produce reflex contraction must be prevented by complete immobilization of the joints, and therefore of the muscles, of the limb; (2) the retractility of the muscles must be gradually overcome by applying a continuously-acting extending

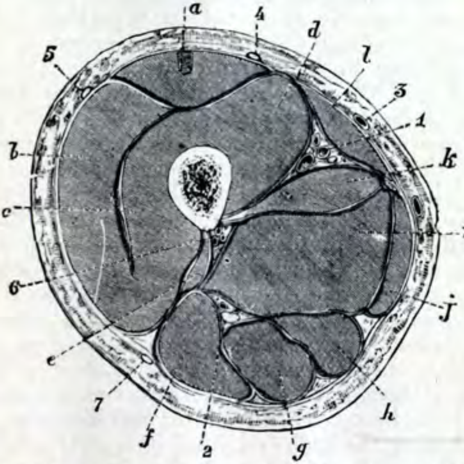

Fig. 127.—Transverse section through the middle of the thigh. (*Braune.*)

a, Rectus femoris; *b*, vastus externus; *c*, crureus; *d*, vastus internus; *e*, short head of biceps; *f*, long head of biceps; *g*, semitendinosus; *h*, semimembranosus; *i*, adductor magnus; *j*, gracilis; *k*, adductor longus; *l*, sartorius. 1, femoral artery; 2, great sciatic nerve; 3, great saphenous vein; 4, middle cutaneous nerve; 5, external cutaneous nerve; 6, perforating branches from profunda; 7, small sciatic nerve.

force to the limb with a properly graduated system of weights and pulleys. It is doubtful if a fracture of the shaft of the femur can, after any treatment, become united without some shortening resulting, save in a few exceptional cases. It is important, in connexion with this subject, to remember that the lower limbs may be normally of unequal length. Dr. Garson, as a result of the careful examination of some 70 skeletons, states that both the lower limbs are of equal length in only about 10 per cent. of all cases. He also found that the femur was more frequently the seat of variation than the tibia.

Amputation of the thigh.—As already mentioned, the unequal contraction of the muscles renders a circular amputation unsuitable for the thigh. Hence the operation preferred is one in which a large flap is formed from the tissues in front of the thigh, and a shorter flap from the structures on the posterior aspect. The various structures which are involved and the relationship of the one to the other are best understood by examining a section of the thigh, such as is shown in Fig. 127. The parts cut are the following: the quadriceps, sartorius, gracilis, long and great adductors, and the three hamstring muscles; the superficial and deep femoral vessels, the descending branches of the external circumflex artery, the lower perforating vessels, and the long saphenous vein; the main branches of the femoral nerve (middle cutaneous, internal cutaneous, and muscular, together with the long saphenous nerve), the anterior branch of the external cutaneous nerve, the obturator, and the great and small sciatic nerves.

CHAPTER XXIV

THE REGION OF THE KNEE

In this chapter will be considered the articulation of the knee, the soft parts about the joint, the popliteal space, the lower end of the femur, the patella, and the upper ends of the tibia and fibula.

Surface anatomy.—In the front of the knee the patella can be distinctly felt and seen. Its inner border is a little more prominent than the outer. When the limb lies in the extended posture, with the quadriceps relaxed, the patella can be moved to and fro, and appears to be but loosely attached. When the quadriceps is contracted the bone is drawn upwards, and becomes firmly fixed against the femur. In flexion of the joint the patella sinks into the hollow between the tibia and the intercondyloid notch, and is very firmly fixed. In this position some part of the trochlear surface of the femur can be made out above the patella. On each side of the knee-cap a hollow exists which may be completely filled up with fat in the obese.

When the limb lies in the extended posture the ligamentum patellæ is not to be very distinctly made out. It becomes a little more conspicuous in the flexed position, and is most prominent when the quadriceps muscle is vigorously contracted. The subpatellar pad of fat bulges outwards on each side of the ligament and may be mistaken by the inexperienced for fluid in the joint.

On the inner side of the knee the following parts can be felt from above downwards (Fig. 128): the tubercle for the adductor magnus, and the tendon of insertion of that muscle; the inner condyle of the femur, which is very prominent, and forms the chief part of the rounded eminence on this aspect of the joint; and below this the inner tuberosity (condyle) of the tibia. Between the two latter processes of bone, the interarticular line and semilunar cartilage (medial meniscus) are easily felt (Fig. 128). On the outer side of the joint is the external condyle of the femur,

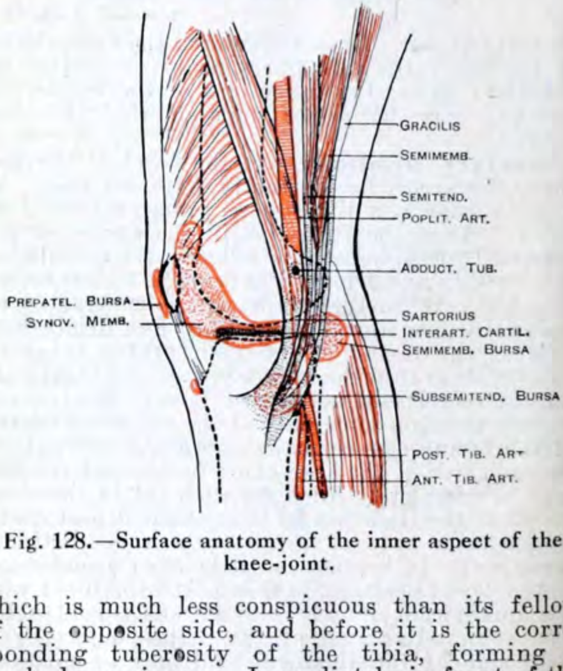

Fig. 128.—Surface anatomy of the inner aspect of the knee-joint.

which is much less conspicuous than its fellow of the opposite side, and before it is the corresponding tuberosity of the tibia, forming a marked prominence. Immediately in front of the biceps tendon the upper part of the external lateral ligament can be felt when the joint is a little flexed. Between the tendon and the patella the lower part of the ilio-tibial band can be detected as a prominent rounded band, descending to the external tuberosity (condyle) of the tibia. It is most distinct when the knee-joint is forcibly extended by muscular action, and often stands out conspicuously beneath the skin. The tubercle of the tibia and the head of the fibula are both readily felt, and are nearly on the same level.

The popliteal space only appears as a hollow when the knee is bent. In the extended limb the hollow is replaced by an evenly rounded eminence. The crease in the skin that passes transversely across the ham is some way above the line of the knee-joint. On the outer side of the space the biceps tendon can be very readily felt, especially when the muscle is in action. Just behind it, and along its inner border, lies the common peroneal nerve. It can be rolled under the finger as it crosses the head of the fibula to pass beneath the peroneus longus muscle. On the inner side of the ham three tendons can be felt. Nearest to the middle of the space is the long, prominent tendon of the semitendinosus. Internal to it is the larger and less distinct semimembranosus tendon, and still more to the inner side the gracilis may be made out.

The popliteal vessels enter the ham obliquely at its upper and inner part, and under cover of the semimembranosus muscle. The outer border of this muscle is the guide to the upper portion of the artery (Fig. 128). The vessels in their descent reach a point behind the middle of the knee-joint, and then pass vertically downwards. The termination of the popliteal artery is on a level with the lower part of the tubercle of the tibia. When the limb is flexed, the pulsations of the artery can be felt and the vessel compressed against the femur a little below its point of entry into the popliteal space. The upper articular arteries run transversely inwards and outwards just above the femoral condyles. The lower articular arteries are also placed transversely, the inner vessels running just below the internal tuberosity of the tibia, and the outer just above the head of the fibula. The deep branch of the anastomotica magna descends to the inner condyle of the femur in the substance of the vastus internus, and along the front of the adductor magnus tendon. The internal saphenous vein passes up along the back part of the internal condyle of the femur, and then follows the sartorius muscle to the thigh. It is just below the interarticular line that the long saphenous nerve usually joins the vein. The short saphenous vein follows the middle line of the calf just below the ham, and pierces the deep fascia at the lower part of the popliteal space. This vessel is much less conspicuous than is the long saphenous vein, and is, indeed, not often to be seen unless varicose.

The internal popliteal (tibial) nerve descends in the middle line, and continues the line that marks the course of the great sciatic trunk.

Front of the knee.—The skin over the front of the knee is dense, and very movable. This mobility affords considerable protection to the knee-joint, especially in stabs with bluntish instruments, and in any injury where the gliding movement of the skin may direct the violence away from the articulation. In flexion, the skin is drawn tightly over the patella, and, as is the case elsewhere, where the integument lies more or less directly upon the bone, a contusion over the knee-cap may produce a lesion precisely like an incised wound. In the *Lancet* for 1877 is recorded the case of a very stout woman aged 57, who, stumbling on a hard road, fell upon her bent knee. The skin was burst across the front of the knee, and a wound produced that was 7 inches in length, and as cleanly cut as if made by a scalpel.

There is but little subcutaneous fat in front of the articulation, and thus it happens that in amputations through the knee-joint the anterior flap is very thin, and is composed of little other than the simple integument.

As blisters, and various forms of counter-irritant, are often applied to the front of the knee in cases of disease, it may be well to take note of the blood supply of this part, and of the relations between the surface vessels and nerves and those of the joint. The vessels that give branches to the front of the knee, and are concerned in the supply of the part to which blisters are usually applied, are the anastomotic, the four articular branches of the popliteal, and the anterior tibial recurrent. In some reflex manner, not well understood, a counter-irritant applied to the skin over the joint alters the nutrition and blood supply of the joint itself. The skin over the front of the knee, the anterior parts of the joint, and the quadriceps are supplied from the third and fourth lumbar segments through branches of the anterior crural (femoral) and obturator nerves.

The superficial lymphatics in the region of the knee lie for the most part on the inner aspect of the joint, and follow the course of the long saphenous vein. Ulcers, and other inflammatory affections of the skin over the articulation, are more apt to be associated with lymphangitis and with enlargement of the inguinal glands when situate on the inner aspect of the joint than when placed in front or to the outer side of it.

The **bursæ** over the front of the knee are: (1) The patellar bursa, a large sac placed in front of the patella and upper part of the patellar ligament, separating those structures from the skin (Fig. 128). It is frequently divided by septa into superficial and deep compartments. It is very often found enlarged in those who kneel much—in housemaids, stonemasons, *religieuses*, etc. The parts about are well supplied with nerves, and hence much pain is usually associated with acute inflammation of this sac. It is in close contact with the patella, and, in one case reported by Erichsen, suppuration of the bursa led to caries of that bone. (2) There is a bursa between the patellar ligament and the tubercle of the tibia (Fig. 129). When inflamed, this causes more pain than is observed in affections of the previous bursa, since it is firmly compressed between two rigid structures, the ligament and the bone. It is separated from the synovial cavity by the pad of fat that lies behind the patella. (3) The bursa between the quadriceps tendon and the femur will be considered in connexion with the synovial cavity.

Popliteal space.—The **skin** over the space is not so movable as is that over the front of the knee. When destroyed by injury, by burns, or by extensive ulceration, the contraction of the resulting cicatrix may lead to a rigidly bent knee. The skin in this place has also been ruptured by forcible extension applied to the limb in cases of contracted knee. Beneath the skin and superficial tissue is the **popliteal fascia**, a dense membrane that covers in the space. It is but a continuation of the fascia lata of the thigh, and is continuous below with the fascia of the leg. It passes without bony attachment over the hamstring muscles that bound the ham. This fascia limits, often in a very marked manner, the progress of popliteal abscesses and growths towards the surface. Its unyielding character is a prime cause in the production of the severe pain with which such collections and tumours are often associated. The popliteal abscess, unable to reach the surface, is encouraged to extend either up into the thigh or down the leg. The ham may hold a very considerable quantity of pus. Velpeau saw a case where a litre ($1\frac{3}{4}$ pints) of pus was evacuated from this region in a patient who presented before the operation but an insignificant swelling in the site of the collection. Duplay records two cases of ulceration of an abscess into the popliteal artery, and Ollivier an instance where the abscess, unable to find a way to escape, ultimately entered the knee-joint.

Pus may reach the ham from the buttock or pelvis by following the great sciatic nerve, or may extend from the thigh through the opening in the great adductor for the femoral vessels.

The **hamstring muscles** and fascial structures are frequently found permanently shortened in neglected cases of knee-joint disease, and produce thereby more or less rigid flexion of the leg upon the thigh. Irritation from disease of the knee-joint may lead to contracture of the hamstring muscles. These muscles are supplied through the great sciatic nerve from the fifth lumbar segment, from which the knee-joint derives in part its nerve supply. Contraction of these muscles in knee-joint disease tends not only to flex the knee but also to draw the tibia backwards and produce, in some cases, a partial luxation.

The hamstring tendons may be ruptured by violence, the tendon most frequently torn being that of the biceps. The muscles are greatly stretched when the trunk is bent forcibly forwards at the hip-joint, the knee remaining extended. Extreme movement in this position has ruptured some of the fibres of this muscle. The difficulty experienced in touching the toes with the fingers while the knees are kept stiff depends upon the resistance offered by the stretched hamstrings. In tenotomy of the biceps tendon the common peroneal nerve is in great risk of being wounded. It may be noted that contraction of the muscle tends to increase the distance between the tendon and the nerve, and to render the former more superficial. The peroneal nerve may be compressed by bandages, garters, or "putties" applied too tightly over the head or neck of the fibula. In such cases there is a tendency to trail the foot in walking, owing to a partial paralysis of the extensor muscles of the leg, which are supplied by the two branches of the common peroneal nerve.

Vessels of the ham.—The popliteal vessels are, from their depth, but seldom wounded. It must be borne in mind that the lower part of the *popliteal artery* may be reached from the anterior aspect of the leg by an instrument passing between the tibia and fibula. Thus, Spence reports the case of a farmer who received a wound in front of the leg, just below the knee, from the slipping of his knife while cutting a stick. It was discovered subsequently that the knife had entered the interosseous space and had wounded the popliteal artery at its bifurcation. It had indeed nearly severed the anterior tibial artery from the main trunk.

The popliteal artery has been ruptured by external violence, as when a wheel has passed over the region of the vessel. This artery is more frequently the seat of aneurysm than is any other artery in the body, save only the thoracic aorta. In 551 cases of spontaneous aneurysm, collected by Crisp, the popliteal vessel was the seat of the disease in 137 instances, the thoracic aorta having been affected in 175 of the cases. This marked disposition to aneurysm depends upon many factors. The vessel is subjected to a great deal of movement, which may readily injure a popliteal artery that has lost its elasticity owing to age or disease. Experiments upon the dead body show that the inner and middle coats of the vessel may be ruptured by extreme flexion of the knee, and that a like rupture may in a smaller percentage of cases be brought about by forcible extension. Moreover, except when the limb is in the position of extension, the popliteal artery is, like the thoracic aorta, much curved. Then, again, the vessel breaks up into two large vessels, and it is well known that the point of bifurcation of an artery is a favourite spot for aneurysm. Lastly, the artery is supported only by the lax tissue of the popliteal space, and the support of strong muscles given elsewhere to so many large vessels is practically absent. Some popliteal aneurysms have been successfully treated by flexing the knee and retaining the limb for some time in that position. That flexion can have a direct effect upon the lumen of the vessel is shown by the diminished pulse at the inner ankle produced by forcibly bending the leg upon the thigh. The artery and vein are so adherent that it is difficult to separate the two when applying a ligature to the arterial trunk. This adhesion must have been appreciated by any who have taken pains to "clean" the artery in a dissection of the ham.

The *popliteal vein* is a remarkably substantial vessel, and has walls so dense and thick that on section they often look more like the tunics of an artery. On the ground of this peculiarity, and of its close adhesion to its companion vessel, Tillaux asserts that "it is unlike any other vein in the economy." It is worthy of note that the vein, although more superficial than the artery, is very rarely ruptured by violence. As a rule, the artery alone is torn.

From the relations of the artery to the vein and nerve it will be understood that the popliteal aneurysm may soon lead to œdema of the leg and to nerve symptoms depending upon pressure on the internal popliteal trunk. It has more than once also made its way into the knee-joint, with the posterior ligament of which the artery is in such close relation.

The *short* or *small saphenous vein* lies almost in the middle line, and, not being usually apparent through the skin, may be divided in an incision made into the lower part of the popliteal space.

The **lymphatic glands** in the ham are from four to five in number and are deeply placed about the great vessels. When enlarged they have been mistaken for aneurysm and other popliteal tumours. They receive the deep lymphatics of the outer and posterior aspects of the foot and leg. A small gland is often met with beneath the fascia, close to the point of entry of the short saphenous vein. It receives some lymphatics that follow that vessel.

The **bursæ about the ham** are usually seven in number, four on the inner side of the space and three on the outer. *Inner side.*—(1) A large bursa beneath the semimembranosus and over the internal condyle of the femur and the inner head of the gastrocnemius (Fig. 128). This is the largest bursa in the space, and after adult life it usually communicates with the joint. It is, of all the bursæ in this region, the one most often enlarged, and when affected may attain great size. In one reported case the sac measured 5 by 3½ inches. In the extended position of the limb the enlarged bursa feels firm and resistant, but on flexion it becomes flaccid and can often be made entirely to disappear. Probably the slit-like communication between the bursa and the joint is closed when the posterior ligament is tightened by extension, and is opened when it is relaxed on bending the knee. In the latter posture the contents of the bursa can be reduced into the cavity of the knee-joint, and so the tumour disappears. (2) A little bursa between the semimembranosus tendon and the internal tuberosity of the tibia. Rather below the level of the knee there are two further bursæ—(3) one beneath the insertion of the sartorius, and (4) another beneath the insertions of the gracilis and semitendinosus. *Outer side.*—(1) A large diverticulum of the synovial membrane of the joint between the popliteus tendon and the external tuberosity of the tibia. This diverticulum serves the purpose of a bursa, and may open into the tibio-fibular articulation, and so bring that cavity into connexion with the knee-joint. (2) A bursa between the outer head of the gastrocnemius and the outer femoral condyle. It is not constant and is not connected with the articulation. (3) A bursa between the biceps tendon and the external lateral ligament. The peroneal nerve runs across this sac—a circumstance that may explain some of the pain experienced when the bursa is enlarged.

It is not improbable that wounds in this region of bursæ containing fluid have been mistaken for wounds of the joint, and the escaping serum for synovia.

The knee-joint (Fig. 129).—This articulation is the largest in the body. It owes its great strength to the powerful ligaments that unite the two component bones, and especially to the muscles and fasciæ that surround it. It derives no strength from the shape of the articular surfaces, since they are merely placed in contact with one another. In spite of its frequent exposure to injury, dislocations at the knee are extremely rare. The **lateral ligaments** are comparatively feeble, are tense in extension and relaxed in flexion. The laxity of these ligaments is such that partial luxations of the tibia are possible without rupture of these bands, especially in cases where the joint is found slightly flexed after the accident. The **crucial ligaments** are very powerful, and are more or less tense in all extreme positions of the joint. The anterior of these ligaments especially resists extension, forward displacement of the tibia, and rotation inwards of the leg. The posterior ligament resists extreme flexion and displacement backwards of the tibia. In the movement of extension the tibia slides a little forwards and is rotated a little outwards. In flexion that bone glides backwards and rolls a little inwards. Extension generally is limited by the crucial and posterior ligaments; flexion by the ligamentum patellæ and anterior part of the capsule, in addition to the crucial ligaments. Rotation is possible only in the flexed position. The thinnest part of the posterior ligament is the portion below the oblique fibres derived from the semimembranosus. If pus should find its way from the joint into the ham, it will probably escape through this part of the ligament.

In the contracted knee associated with fibrous ankylosis the chief contraction, so far as the joint-tissues are concerned, is in the posterior ligament, in the lateral ligaments, and in the fibrous and fatty tissue between the former ligament and the posterior crucial band. But it must be kept in mind that all structures are affected—the skin, the aponeuroses, and particularly the muscles.

The **synovial membrane** of the knee-joint extends upwards as a large cul-de-sac above the patella and beneath the extensor tendon. This cul-de-sac reaches a point an inch or more above the upper margin of the trochlear surface of the femur, and is rendered very distinct when the joint is distended with fluid (Fig. 129). When the knee is bent the cul-de-sac is drawn down, and therefore this position of the limb is advised when operations are about to be performed upon the lower end of the femur. Above the synovial pouch is a bursa that separates the quadriceps tendon from the femur, and is usually over an inch in its vertical measurement (Fig. 129). From the examination of 260 knee-joints in both infants and adults, Schwartz found that this bursa communicated with the synovial cavity in 7 cases out of 10 in young children, and in 8 cases out of 10 in adults. It will thus be seen that, when this communication exists, a stab over the femur, about 2 inches above the trochlear surface of the bone, or about the same distance above the top of the patella, when the limb is extended, will practically open the knee-joint.

The complexity of the synovial membrane in the knee-joint is due to the fact that there are really three subcompartments or joint-cavities. These are—(1) the trochlear, for movements of the patella; (2) the external tibio-femoral; (3) the internal tibio-femoral. The two latter are subdivided by the semilunar cartilages (articular menisci) into upper and lower compartments. In the upper compartments the rolling condylar movements occur; in the lower, the gliding movements between the menisci and the tibia. In walking, movements occur in all five compartments. The ligamentum mucosum lies between the trochlear and condylar joints; the crucial ligaments between the tibio-femoral joints.

The crucial ligaments, although more or less completely invested by the synovial membrane, are yet entirely outside the synovial cavity. The posterior crucial ligament is continuous with the posterior part of the capsule.

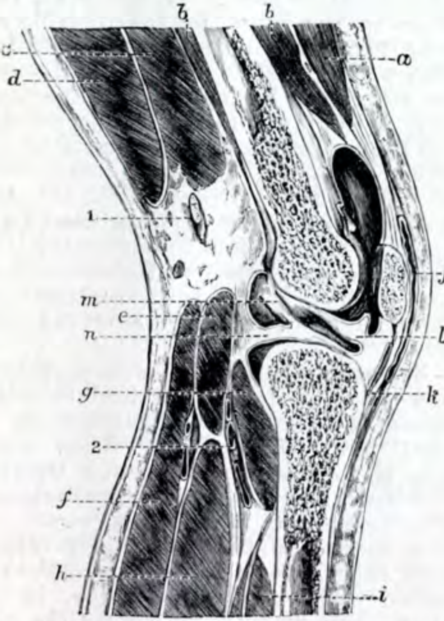

Fig. 129.—Vertical section of knee-joint distended with fluid. (*Braune.*)

a, Vastus externus; *b*, crureus; *c*, short head, and *d*, long head, of biceps; *e*, plantaris; *f*, gastrocnemius; *g*, popliteus; *h*, soleus; *i*, tibialis posticus; *j*, bursa patellæ; *k*, ligamentum patellæ; *l*, ligamentum mucosum; *m*, anterior crucial ligament; *n*, external semilunar cartilage. 1, external popliteal nerve; 2, popliteal artery

The upper third of the patellar ligament is in relation to the synovial membrane of the patellar joint, from which, however, it is separated by a pad of fat. The lower two-thirds of the ligament are in relation to the bursa and fatty tissue that intervene between the band and the tibia. A knife passed horizontally backwards at the apex of the patella would, when the limb is extended, just miss the joint-line between the femur and tibia, and would hit the latter bone. If, however, there be any effusion in the joint, or the limb be a little flexed, a knife so introduced would pass between the two bones (Fig. 129). Fringes of the synovial membrane (the alar ligaments) fill the intervals between the articular surfaces of the patella and femur. Villous processes may grow out from them, become detached, and form loose bodies in the joint. That such processes should undergo chondrification and form cartilaginous bodies is not surprising, seeing that the synovial lining is derived from the same tissue as forms the articular surfaces of the bones and is in reality merely a finely spread layer of cartilage covering a fibrous membrane

Joint - disease.—Owing to its superficial position the knee-joint is the articulation that is most frequently the seat of inflammation due to injury and exposure to cold. When distended with fluid, the effusion soon shows itself above and at the sides of the patella, by bulging forward the synovial sac, which is here more nearly in relation to the surface than it is elsewhere. Fluctuation is soon to be detected, and the patella, being pushed away from the femur, is said to "float" upon the distending fluid (Fig. 129).

The inflamed knee-joint, if left to itself, almost invariably assumes the flexed position. This is the *position of rest;* the muscles are here relaxed and do not press the joint-surfaces together; the ligaments are no longer tense, and the fluid-capacity of the joint is increased.

Dislocation of the semilunar cartilages or menisci.—One or other of these cartilages may be displaced from its attachments to the tibia, and become nipped or locked between that bone and the femur. The accident is particularly common in miners who work in a crouched posture, and in all who take part in vigorous games and exercises. The result is a sudden pain in the limb, often associated with a fixing of the knee in a flexed position. The accident is usually brought about by a twist given to the leg when the knee-joint is more or less bent, but it may occur, as Walton maintains, even in extreme extension. The effective cause is a twisting of the joint so that the condyles of the femur and tuberosities of the tibia rotate in opposite directions. In 200 cases of internal derangement of the knee-joint, Bennett found that the internal cartilage was affected in 155 cases and the external in only 45. The left knee was the seat of derangement nearly three times as often as the right, and the lesion occurred nine times more frequently in men than in women. The anterior extremity of the internal semilunar cartilage is usually found bruised and torn from its tibial attachment. To understand the liability to injury of the anterior part of the internal semilunar cartilage, it is necessary to examine the manner in which it is maintained in position, the movements which it undergoes, and the strains to which it is subjected in active athletes. In the extended position of the knee, displacement is less easy, for the cartilages are immovably fixed by the coaptation of the articular surfaces, brought about by the tension of the ligaments and active contraction of the muscles surrounding the joint. When the joint is partly flexed the internal cartilage is fixed (1) by its anterior horn attached to the tibia, above and behind the attachment of the ligamentum patellæ and outside the joint-cavity (Fig. 130); (2) by the transverse ligament to the anterior part of the external cartilage (Fig. 130); (3) by the coronary ligament to the capsule of the joint and internal lateral ligament: the anterior fibres of this ligament are the longest (Fig. 130). As the joint is flexed the cartilages, especially the internal, glide backwards; if in this position the biceps brings about a sudden rotation outwards of the tibia, the anterior horn is carried forwards and outwards with that bone, while the posterior is firmly fixed to the internal condyle of the femur by the internal lateral ligament, and thus a severe strain is thrown on the anterior part of the internal cartilage, which is brought into the position shown in Fig. 130. The same strain occurs when the foot and tibia are fixed and there takes place an inward rotation of the femur, such

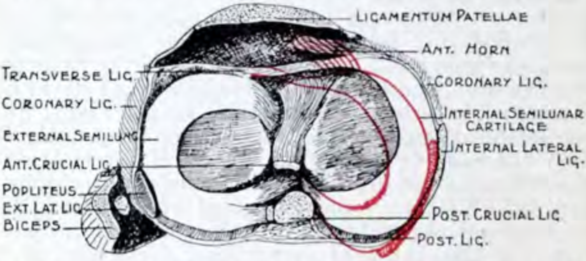

Fig. 130.—Illustrating the fixation and movements of the semilunar cartilages.

The position of the internal semilunar cartilage, when the tibia is rotated outwards or femur inwards, is shown in red.

as occurs at the completion of extension. The weakest point in the internal semilunar cartilage is in the thin inner crescentic margin of its anterior third, and it is here that partial rupture usually occurs. The intense pain is due to the rupture and to the fact that the strain wedges the cartilage between the tibia and femur, thus forcing them apart and causing an instant and severe hyperextension of the unyielding ligaments of the joint. The external cartilage is smaller than the internal, is rounder, is more movable, and possibly on these accounts is less likely to be "nipped" between the bones. It is attached in part to the femur through the posterior crucial ligament and is grooved by the tendon of the popliteus, two factors which add to its security (Fig. 130). It is a remarkable fact that such damaged cartilages may be excised and yet the joint may regain its full security of movement.

Genu valgum, or knock-knee.—The appearances produced by this affection are familiar. When a person stands erect with the feet together, the tibiæ are practically vertical, and the femora meet them at a certain angle, the *tibio-femoral angle.* The degree of this angle depends, in normal subjects, to a great extent upon the relative width of the pelvis. In genu valgum this angle becomes more marked; the tibiæ cease to be vertical in the erect position; their lower ends deviate more and more from the middle line, until the distance between the two malleoli becomes considerable when the individual stands upright and when he is not concealing any of the deformity by rotating the limb.

To understand the production of the condition of genu valgum we must first clearly appreciate the action of the muscles which descend on the inner or medial aspect of the knee-joint—the semimembranosus, semitendinosus, gracilis, and sartorius. The moment that the erect posture is assumed these muscles pass into a state of tonus or contraction, while the quadriceps extensor becomes lax. These medial knee-supporting muscles suspend the tibia from the pelvis, so that, in standing, the knees are braced and the weight of the body is partly supported by these muscular straps. The first step in the production of genu valgum lies in a defective action—an exhaustion—of the general postural muscles. with the result that (1) a strain is thrown on the internal lateral ligament; (2) there is a tendency to the production of a gap between the internal femoral condyle and the tibial tuberosity. The pressures on the joint-surfaces are altered, and with that alteration results a change in the growth of the bones in the neighbourhood of the joint, for the growth of every bone is regulated, according to *Wolff's law*, by the pressures falling on that bone. Hence the overgrowth of the inner femoral condyle and tibial tuberosity when the pressure is taken away from them by the failure of the internal supporting muscles. In the young the overgrowth takes place at the adjoining parts of the epiphyseal lines, which assume an oblique position. The overgrowth is on

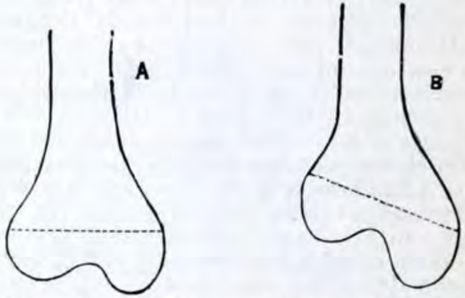

Fig. 131.—A, Normal femur. B, Femur in an advanced state of knock-knee, showing the enlargement of the internal condyle.

The dotted line in each case represents the line of the epiphysis.

the shaft side, not the condylar side, of the epiphyseal lines (Fig. 131). There is no alteration in the front-to-back length of the condyles; hence, when the knee is flexed the deformity disappears.

Fractures of the patella.—This bone is more often broken by muscular violence than is any other in the body. Although the patella may be fractured both by muscular and by direct violence, it would appear that the former is the agent that the more often produces the lesion. Thus, in 127 cases of simple transverse fracture collected by Hamilton, he considers that muscular action was the cause of the injury in 106 instances. The form of fracture due to muscular violence is very uniform. It is nearly always transverse, simple, and through the centre of the bone, or just above that point or just below it. The position of the knee that most favours fracture by muscular action is that of flexion. When the knee is bent, the patella rests upon the femoral condyles along its transverse axis only. Nearly the whole of its upper half is unsupported behind, and the extensor muscle acts in a line nearly at right angles to the vertical axis of the bone. Thus, by violent contraction of the quadriceps, the patella may be snapped across the condyle as a stick is snapped across the knee (Fig. 132). As the fracture usually causes the patient to fall, it has been supposed that the contact with the ground, rather than any previous muscular action, may have caused the lesion. But, as Hamilton has pointed out, if a person falls upon the bent knee when the limb also is flexed upon the trunk, the part that comes in contact with the ground is not the patella, but the tubercle of the tibia.

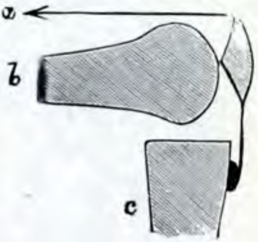

Fig. 132.—Diagram to show mechanism of fracture of the patella by muscular action.

a, Line of action of quadriceps muscle; *b*, femur; *c*, tibia.

In the great majority of cases the lesion not only involves the bone but also the cartilage and fibrous structures that cover it respectively behind and in front; the synovial membrane also is torn, and the patella bursa opened up. Thus the synovial contents may come in actual contact with the skin. In all cases where there is much separation of the fragments, the fibrous expansion attached to either side of the patella must be torn through. Indeed, none but a slight separation of the parts is possible until that expansion is ruptured.

Braune has demonstrated this by experiment, by sawing through the patella without damage to the lateral ligamentous structures, and noting that but trifling separation of the fragments was possible until these structures had been divided. In stellate fractures, due to direct violence, these fibrous expansions from the extensor tendon may be uninjured, and no separation of any magnitude be permitted between the portions of the broken bone.

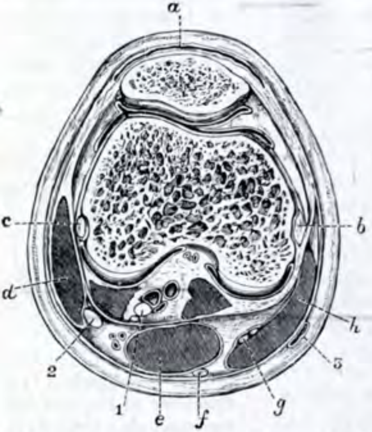

Fig. 133.—Transverse section of left knee-joint through the centre of the patella. (*Braune.*)

a, Bursa patellæ ; *b*, internal lateral ligament and inner condyle ; *c*, external lateral ligament and outer condyle ; *d*, biceps ; *e*, semimembranosus ; *f*, semitendinosus ; *g*, gracilis tendon ; *h*, sartorius. 1, internal popliteal nerve ; 2, external popliteal nerve ; 3. internal saphenous vein.

The patella is more readily broken by muscular violence than is either the extensor tendon or the ligamentum patellæ. In the flexed position it will be seen (Fig. 132) that the bone is placed at a considerable disadvantage when compared with the two other structures. Richet reports a case where violent contraction of the quadriceps caused the tubercle of the tibia to be torn away from the bone without any other lesion of the parts immediately concerned being produced.

The patella may be congenitally absent. It is developed in the tendon of the quadriceps, remaining cartilaginous until the end of the second year. Its sesamoid nature is seen in the tendency to unite by fibrous rather than by bony union after fracture. It receives its blood supply from nearly all the arteries round the knee-joint.

Dislocation of the patella.—This bone may be dislocated outwards or inwards, or turned upon its edge so that its anterior and posterior surfaces are placed laterally. The luxation outwards is by far the most common. This depends upon the fact that the quadriceps, the patella, and the ligamentum patellæ do not, when the muscle is contracted, follow the lines of the femur and tibia. They are more nearly in a straight line, that passes to the outer side of the angle formed by the femur with the leg at the knee-joint. Muscular contraction, therefore, tends to draw the knee-cap outwards, a tendency that is in all normal circumstances corrected by the increased prominence of the external condyle. The vastus externus also is said to be more powerful than the internus, or the vastus internus may be partially paralysed (D. Greig). The tensor fasciæ femoris has an attachment to the patella through the ilio-tibial band. By the sudden action of this muscle a patient of Mr. Rigby's was able to produce a voluntary outward dislocation of the patella. Dislocations usually occur in the extended position of the joint, and are commonly due to muscular action.

In **dislocations of the knee,** which are very rare, the tibia may be displaced outwards, inwards, forwards, or backwards. The two lateral luxations appear to be more common than the antero-posterior. X-ray examination of such dislocated joints shows that the *tibial spine* may be broken, or detached with the tibial insertion of a crucial ligament. The projection of the spine of the tibia between the femoral condyles offers an obstacle to lateral dislocation. The former are nearly always partial, the latter usually complete. Considerable violence is required to produce these luxations, owing to the great strength of the ligaments and muscles and the great width of the bones involved. Direct violence to the tibia or femur, associated often with a twisting of the former bone, is the common cause of the lesion. It is probable that in all luxations of the knee the crucial ligaments are torn. The lateral ligaments also are usually ruptured, but in the partial luxations they may be sometimes found to be intact. The tendinous expansion of the vasti in front of the knee seldom escapes some laceration, even in the partial dislocations. Dr. F. S. Mackenzie found by experiment on the dead body that division of the crucial ligaments did not materially influence the force necessary to produce a dislocation at the knee-joint. He found, too, that in seven out of eight experiments dislocation was produced and not fracture—whereas in life fracture is by far the commoner result. He concludes, therefore, that the strength of the joint depends on the surrounding muscles rather than on the surrounding ligaments. The popliteal vessels and nerves are much compressed, and appear to be more severely injured by the femur in the forward dislocation than by the tibia in the backward displacement.

Lower end of the femur.—The condylar part of the femur is composed almost wholly of cancellous bone, with but a slight layer of compact tissue. It is so spongy that it may be pierced by a bullet, as pointed out by Legouest, without any splintering of the bone being produced and without damage to the articulation. The *fractures* that may be met with in the lower end of the bone are the following: (1) a fracture of the shaft above the condyles; (2) a separation of the lower epiphysis; (3) a fracture separating either the outer or inner condyle; (4) a T-shaped fracture, i.e. a transverse fracture above the condyles with a vertical one between those processes. These lesions are, as a rule, due to well-localized direct violence. Fractures Nos. 1 and 4 may be produced by indirect violence, as by a fall upon the feet from a height. Sir Henry Morris states that lateral flexion, or force applied in a lateral direction, is best calculated to produce a separation of the epiphysis. Hamilton reports a strange case in a man aged 21, whose outer condyle was fractured by a twist of the leg which happened while he was undressing himself to bathe. The only fracture that requires special notice in this place is the fracture of the shaft just above the condyles. The lesion is situated generally about 2 inches above the line of the epiphysis, and corresponds to the spot where the compact shaft joins the softer and more cancellous tissue of the lower end of the bone. It is near the place, also, where the femoral artery crosses the bone to reach the ham, and it has thus happened that the vessel has been wounded by splinters in this particular injury. The fracture is usually oblique, from behind downwards and forwards. The lower fragment will be drawn upwards by the same muscles that produce shortening in other fractures of the shaft (p. 550), and its sharp upper end is very apt to be pulled forcibly into the popliteal space by the gastrocnemius muscle. This latter displacement is difficult to remedy. If the limb be extended, the fragment is only drawn the more into the ham, and it is therefore possible for the limb to appear straight and yet have the knee-joint much bent. The contraction of the gastrocnemius tends to maintain the lower femoral fragment in the popliteal space, and therefore division of the tendo Achillis (calcaneus) has been proposed. The reflex contraction of the opposing muscles may be overcome by the application of a continuous traction to the limb. The lower fragment of the femur may be replaced by completely flexing the leg on the thigh. (Hutchinson and Barnard.)

The **upper end of the tibia** is sometimes the seat of *fracture*, although of all parts of this bone the upper third is the part least often broken. One or other of the tuberosities may be broken off, or there may be a transverse or oblique fracture of the upper end of the shaft associated with a vertical one running up into the joint between the two tuberosities. Such accidents are the result, in nearly every instance, of great direct violence. Mr. Makins reports three cases of separation of the anterior tubercle in adolescents, and many other cases have been reported more recently. It is usually ossified by an extension from the epiphyseal centre for the upper extremity of the tibia, but may have a separate centre (Schlatter).

The spongy tissue in the head of this bone and in the lower end of the femur is, *par excellence*, the favourite seat for myeloid sarcoma.

In **exploring the knee-joint** Sir Robert Jones first flexes the joint over the end of the operating-table, and as far as possible maintains it so, for, if moved, air is sucked into the joint and may bring infection with it. He opens the joint by a vertical incision which divides the patella and ligamentum patellæ into right and left halves. This is the transpatellar route to the joint-cavity.

In **excising the knee-joint** through a horseshoe incision commencing at the back of one condyle, and continued across the joint, above the insertion of the ligamentum patellæ, to the back of the other condyle, the following structures are divided: Skin, fascia, patellar plexus of nerves (formed by the middle and internal cutaneous and the patellar branch of the long saphenous), bursa patellæ, anterior part of the capsule, ligamentum patellæ, synovial membrane, lateral and crucial ligaments, the superior and inferior articular arteries, the anastomotica magna, and the anterior tibial recurrent vessels.

The incision over the inner condyle need not be made so far back as to divide the internal saphenous vein and nerve. In sawing the femur it is most important that the exact inclination of the joint-surface of the bone be reproduced. If it were improperly sawn, the patient would be bow-legged or knock-kneed. The rule, therefore, is that the saw be applied parallel to the articular surface and perpendicular to the shaft.

In young subjects care must be taken that the

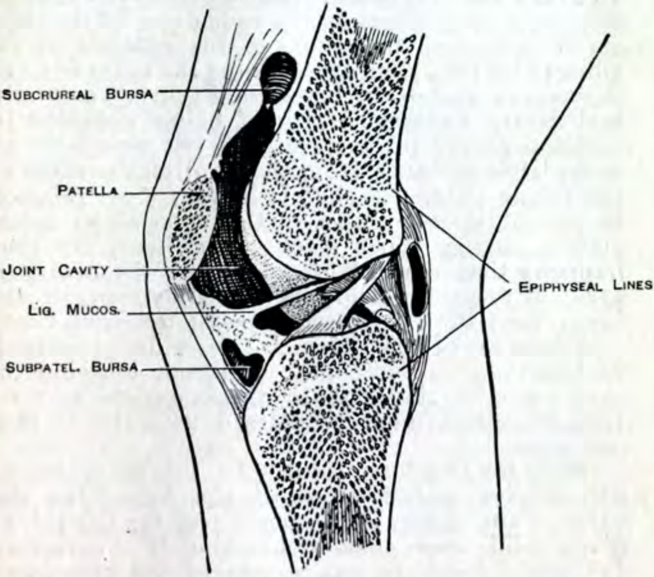

Fig. 134.—**Epiphyseal lines in the neighbourhood of the knee-joint and their relationship to the synovial membrane.** (*After Allen Thomson.*)

saw-cuts do not pass beyond the epiphyseal line. The upper limit of the *femoral epiphysis* will be represented by a horizontal line drawn across the bone at the level of the tubercle for the adductor magnus (Fig. 134). If the whole of the trochlear surface be removed in the excision the whole of the epiphysis will have been taken away. A single nucleus appears in this epiphysis shortly before birth, and joins the shaft about the age of 20–21. The limits to the *tibial epiphysis* are represented behind and at the sides by a horizontal line that just marks off the tuberosities. It includes, therefore, the depression for the insertion of the semimembranosus, and also the facet for the fibula. In front the epiphyseal line slopes downwards on either side to a point on the upper end of the shin, so as to enclose the whole of the tubercle of the tibia (Fig. 134). The centre joins the main bone at the twenty-first or twenty-second year. The popliteal artery runs some risk of being wounded in excision of the joint. The vessel is separated by some little distance from the popliteal surface of the femur (Fig. 133), but is in very close relation to the tibia, the posterior ligament alone intervening at the upper level of the bone. It thus happens that the risk of wounding the artery is greater when the tibia is sawn than when the lower part of the femur is being removed.

Excision of the knee is, to a large extent, replaced by arthrectomy. Indeed, excision of this joint carried out in the complete manner just described must be classed as quite a rare operation.

Rest for the knee-joint.—In the early stages of injuries and diseases of the knee-joint the surgeon's first aim is to secure rest for the joint; his second and subsequent aim is to restore function. Now, to secure rest of the knee-joint it is necessary to rest also the hip- and ankle-joints, because many of the muscles which act on the knee act also on the hip or ankle. It is manifest that such double-joint muscles cannot be thrown out of action until all the joints on which they act are immobilized. So soon as the acute stage is over, it is necessary gradually to restore the functions of the rested muscles; that can be done by passive and active movements, which must include all the joints of the lower limb.

Amputation through the knee-joint.—To illustrate the anatomy of the part an amputation by a single anterior flap may be selected. The parts involved are shown in Fig. 133. In fashioning the anterior flap (composed only of integument), and in opening the joint, the patellar plexus of nerves, the superficial branches of the plexus of arteries, the ligamentum patellæ, and the anterior part of the capsule will be cut. Nearer the condyles of the femur the anastomotic and the two superior articular arteries will be divided. The long saphenous vein and nerve will be divided at the inner angle of the flap. On the cut surface made by the posterior incision will be found divided the sartorius, gracilis, and semitendinosus, the semimembranosus, both heads of the gastrocnemius, the popliteus, plantaris, and biceps. The popliteal vessels, the sural arteries, the short saphenous vein, the internal and external popliteal nerves (tibial and common peroneal), the external saphenous and the small sciatic nerves will also be found divided in the same incision.

The most convenient amputation at the knee-joint is by equal lateral flaps (Stephen Smith's operation). This operation has been attended by excellent results, and in actual practice the method of amputation by a single anterior flap is but very rarely employed.

CHAPTER XXV

THE LEG

Surface anatomy.—The anterior border of the tibia can be felt in its entire length, forming, as it does, the prominence of the shin. It should be remembered that this border presents a somewhat flexuous course, being curved outwards above and inwards below. The broad internal surface of the bone is subcutaneous, and the internal border can be followed from the tuberosity (medial tibial condyle) to the malleolus. The head of the fibula can be distinctly made out, but the upper half of the shaft of the bone is lost beneath the mass of muscle on the outer side of the limb. The lower half of the fibular shaft can be felt, and the bone just above the malleolus becomes subcutaneous in the interval between the peroneus tertius and the two other peroneal tendons. The fibula is situated so far behind the line of the tibia that a knife thrust transversely through the leg from the inner side behind the tibia will appear in front of the fibula on the outer side (Fig. 136). Between the tibia and fibula the outline of the tibialis anticus muscle can be well defined when it is in action. To its outer side is the less conspicuous and narrower eminence formed by the extensor communis digitorum. In well-developed limbs the groove that separates these two muscles is very distinct, and forms the best guide to the anterior tibial artery. In the lower third of the leg these muscles become tendinous, and between them the extensor longus hallucis can be felt as it comes to the surface. The long and short peroneal muscles can be defined, and their tendons followed behind the malleolus. When in active contraction the interval between the two muscles is often well marked. The gastrocnemius muscle and the more superficial parts of the soleus are brought well into view when the body is raised upon the toes. The two heads of the former muscle are then quite conspicuous, and it can be seen that the inner head is the larger and descends lower in the leg.

The popliteal artery bifurcates on a level with the lower part of the tubercle of the tibia (Fig. 128, p. 570). The course of the posterior tibial vessel is represented by a line drawn from a point midway between the inner and outer borders of the limb at the lower part of the ham to a spot midway between the inner malleolus and the prominence of the heel. The artery becomes superficial in the lower fourth of the leg, where it may be felt pulsating between the tendo Achillis (calcaneus) and the tibia. The peroneal artery arises about 3 inches below the knee, follows the posterior surface of the fibula, and ends behind the outer malleolus. The position of the anterior tibial artery may be indicated by a line drawn from a point midway between the outer tuberosity of the tibia and the head of the fibula to the centre of the front of the ankle-joint. Both the saphenous veins can often be made out in the leg. The inner or larger vein passes in front of the malleolus and ascends just behind the internal border of the tibia. With it runs the long saphenous nerve. The short saphenous vein lies behind the outer malleolus, and, passing up the middle of the calf, ends at the ham. It is accompanied by the external saphenous nerve.

The **skin** is somewhat more adherent to the deeper parts in the leg than it is in the thigh. The difference in the degree of this adhesion is obvious when skin-flaps are dissected up from the two parts in cases of amputation. Over the internal surface of the tibia and the greater part of the shin the integument lies directly upon the periosteum and bone, nothing intervening save a scanty amount of subcutaneous fascia. Thus blows and kicks over these parts of the leg are apt to be associated not only with much pain but also with much bruising or tearing of the integument. A "graze on the shin" is one of the commonest of lesions, and is produced by a degree of violence that upon a well-covered part would have little or no effect. It will be understood that ulcers over these feebly protected parts may, if they spread in depth, readily expose the bone and lead to some disease of its substance, or at least to some inflammation of its periosteum. Scars left by deep ulcers or burns are also often found to be quite adherent to the bone.

The **aponeurosis** of the leg invests it like a tightly drawn buskin, being lacking only over the subcutaneous surface of the bones. (Fig. 136.) It is attached to the head and the anterior and inner borders of the tibia, the head of the fibula, and the two malleoli. It is continuous above with the fascia lata, and below with the fascia of the foot and the annular ligaments. It is thicker in front than behind, and is especially thick at the upper part of the leg just below the knee. Here the fascia offers great resistance to the growth of tumours springing from the head of the tibia. From the deep surface of the aponeurosis two septa pass inwards to be attached to the anterior and external borders of the fibula. They serve to isolate the two larger peroneal muscles from the other muscles of the limb, and form a closed space which might become a definite and well-localized cavity for pus. Beneath the gastrocnemius and soleus a layer of fascia extends between the two bones and covers in the deep layer of muscles. It is thin above but denser below, and would have some influence in directing the progress of a deep abscess. In paralytic conditions of the limb the fascial expansions and sheaths undergo contracture, and offer resistance when the surgeon seeks to restore the limb to its normal form (Colin Mackenzie).

In the upper third of the leg there is a septum between the tibialis anticus and extensor communis digitorum, which must be found in the operation for ligaturing the upper part of the anterior tibial artery.

In the substance of the soleus muscle there is a tendinous expansion connected with the inner border of the tibia. In cutting through the soleus to apply a ligature to the posterior tibial artery, it is possible that this intersection may be mistaken for the aponeurosis on the deep surface of the muscle.

Several cases are reported of rupture of some part of the gastrocnemius muscle during violent exertion. The tendo Achillis has been ruptured in like circumstances. This accident befell the celebrated John Hunter when dancing. It is said that the plantaris tendon is also not infrequently torn across, producing a sudden sharp pain in the calf during exertion, to which the French give the name *"coup de fouet."*

Vessels.—The large arteries of the leg, being all in close proximity to the bones, are apt to be injured by sharp fragments in fractures of the limb. This especially applies to the peroneal artery, which runs along the fibula in a fibrous canal, and is in considerable risk of being wounded in fractures about the middle of that bone. It is at the point of bifurcation of the popliteal artery that emboli are peculiarly apt to lodge. They plug the vessel and practically block the three main arteries of the leg. Gangrene, therefore, not infrequently follows the occurrence. It is a remarkable fact that gangrene is less likely to occur when the vein as well as the artery is ligatured (Makins).

Varicose veins are more commonly met with in the leg than in any other part of the body, save, perhaps, in the hæmorrhoidal and spermatic veins. This depends upon the great length of the veins of the lower limb, the large columns of blood their valves have to support, their vertical position, the liability of the great trunks (iliac), into which they ultimately enter, to be compressed, and upon the fact that the superficial veins, being outside the fascia, lose that assistance to the circulation derived from muscular contraction. From a physical point of view the vascular system must be regarded as a vertical column of fluid. The lower the level the greater is the pressure on the containing walls. The saphenous veins are thin-walled, distensible tubes situated outside the rigid-walled cylinder formed by the deep fascia of the leg and thigh, low in the body, where the pressure from gravity is greatest (Hill). The use of garters especially affects the long saphenous vein, which lies close to the bone at the spot about which these contracting bands are usually applied. Between the two layers of the muscles of the calf Verneuil describes a venous plexus, which he believes to be more often the seat of varices than are the vessels of the surface. A varicose condition of these deeply placed veins may explain the "aching legs" complained of by those who stand a great deal. The intramuscular veins are very large. Callender showed that six chief veins which pass from the soleus muscle to enter into the posterior tibial and peroneal trunks have a united diameter of not less than 1 inch. Varix would appear to commence most often at points where the deep veins join the superficial vessels. There is good reason for this, for at these points three forces meet, the general directions of which are shown in the annexed diagram (Fig. 135). There is the weight of the superincumbent column of blood (*a*) acting from above, the resistance offered by the next valve below the point of entry of the deep vein acting from below (*b*), and the force with which the blood is driven by the contracting muscles out of the deep vein into the superficial trunk acting at an angle to both these

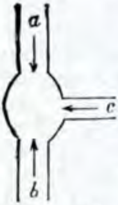

Fig. 135.

lines of force (*c*). Unfortunately for the subjects of varices, the two principal veins (the saphenous) are accompanied by sensory nerves, and there is no doubt that much of the pain incident to varicose veins in the leg depends upon pressure on these nerves.

With reference to **pain in the leg,** it must be remembered that the nerves that bring sensation to the part arise at a considerable distance from their points of termination, and that the causes of pain in the limb may be situated far away from the seat of trouble. Thus, Sir B. Brodie mentions the case of a gentleman who suffered from severe pain in the left leg, from the foot to the knee, in the course of the peroneal nerve. No cause could be found for it. After the patient's death, however, a large tumour was found attached to the lumbar spine, which had evidently compressed the left great sciatic nerve. It is more difficult to offer an explanation, based on anatomical grounds, for cases such as those reported by Sir William Bennett, where the removal of a corn from the sole of the foot in one instance, and a tumour from the leg in another, was followed by the disappearance of a pain which had been felt in the groin.

There would appear to be little connexion between disease in the rectum and a pain in the leg, yet in one case at least that connexion was marked. "Only recently," writes Hilton, "I saw a gentleman from South Wales, who was the subject of stricture of the rectum from malignant disease. He suffered pain in the knee-joint and in the back part of the leg. This led me to suspect —what really turned out, upon careful examination, to be the case—that a large mass of cancer was involving the nerves on the anterior part of the sacrum, and also, no doubt, the obturator nerve." Dr. Ralfe mentions cases of renal calculus attended by severe pain in the side of the foot. I (F. T.) have met with many such instances, the pain being most commonly in the heel.

Fractures of the leg.—The tibia and fibula are more often broken together than singly, and when either is broken alone it is more often the fibula than the larger bone.

1. **The tibia and fibula.**—As regards the resistance it offers to violence the fibula presents about the same degree of strength in all its parts, save at the malleolus and at its upper extremity. Its great length and the manner of its attachment to the tibia (its two ends being fixed and its main part being unsupported) render it a slender bone, and but for the efficient protection it derives from the thick pad of muscles that surrounds it, it would no doubt be very frequently broken. This is all the more likely to be the case, since the bone is placed upon the more exposed aspect of the limb.

The shaft of the tibia presents various degrees of strength, according as we regard its upper, middle, or lower third. According to Dr. Leriche, the average transverse diameter of the adult tibia just below the tuberosities is a little over $1\frac{3}{4}$ inches. The transverse diameter at the base of the malleolus is a little less than $1\frac{3}{4}$ inches, and that of the narrowest part of the bone is a little more than 1 inch. This narrow part is at the junction of the lower with the middle third of the shaft, and is the weakest point in the bone. Thus it happens that the most common spot for a fracture of the tibia is at the junction of the middle with the lower third of the shaft. It is here that the bone yields when broken by indirect violence, while the lesions depending upon direct violence may be at any part of the shaft. Owing to the thin covering of soft parts, and the slight barrier interposed between the fracturing force and the bone, it comes to pass that fractures of the leg are more often compound and comminuted than are those of any other bones of the extremities. If the fracture be oblique, as is commonly the case when the violence is indirectly applied, the line of breakage usually extends from behind, downwards, forwards, and a little inwards. The lower fragment, with the foot, is drawn up behind the rest of the bone by the muscles of the calf, and is usually displaced also outwards by the obliquity of the fracture line. Often the lower fragment is slightly rotated outwards by the rolling over of the foot, a rotation produced by the simple weight of the limb. If the fracture be transverse there may be little or no displacement. The fibula is usually broken at a higher level than the tibia, and its lower fragment follows, of course, with absolute precision the corresponding fragment of the larger bone. A remarkable spiral fracture (*fracture hélicoïde*), involving the lower third of the tibia, has been described by French surgeons. It is associated with a more or less vertical fissure that involves the ankle-joint, and with a fracture of the fibula high up. MM. Leriche and Tillaux have shown that this injury is due to torsion, especially to some twisting of the leg while the foot is fixed.

2. **The fibula alone.**—Fractures of this bone in its lower fourth are usually due to indirect violence, and will be dealt with in connexion with the ankle-joint. When it is broken in any other part the fracturing force is usually directly applied, the lesion transverse, and the displacement insignificant or scarcely obvious. The tibia acts as an efficient splint.

3. **The tibia alone.** — The malleolus may be broken by a blow, or the lower epiphysis separated. The latter comprises the whole of the inner malleolus and the facet with which the fibula articulates. It joins the shaft during the eighteenth or nineteenth year. Fractures of the tibia alone are nearly always due to direct violence; whilst most common in the lower third of the bone, they become more rare as the knee is approached. When transverse there may be no visible displacement, the fibula acting as a splint. Thus, Sir Henry Morris mentions the case of a woman who walked into and out of a hospital with a transverse

fracture of the tibia that was not detected on examination, and was not, indeed, discovered until two days after the accident. When the fracture is just above the ankle the lower fragment may be moved in whatever direction the foot is forced, such displacement being resisted and limited by the inferior tibio-fibular ligaments.

In **rickets** the tibia is, of all the bones of the extremities, the one that most frequently becomes

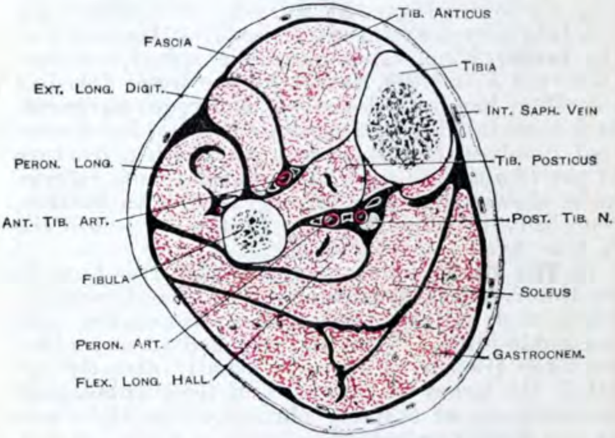

Fig. 136.—Section across the leg at the junction of the upper and middle thirds. (*After Braune.*)

bent. It yields at its weakest part (the junction of the middle and lower third), and there the bone will be found to have developed a curve forwards and a little outwards.

The **fibula is occasionally absent**, a circumstance usually associated with a deformity of the foot and absence of two or more of the outer toes. The subcutaneous position of the tibia makes it the favourite site from which to obtain *bone-grafts*.

Amputation at the junction of the upper with the middle third by unequal antero-posterior flaps may be taken as an example of amputations of the leg (*see* Fig. 136). In the anterior flap the following structures would be cut: Skin, cutaneous nerves, fascia, tibialis anticus, extensor communis digitorum and a little of the extensor proprius hallucis, the peroneus longus and a

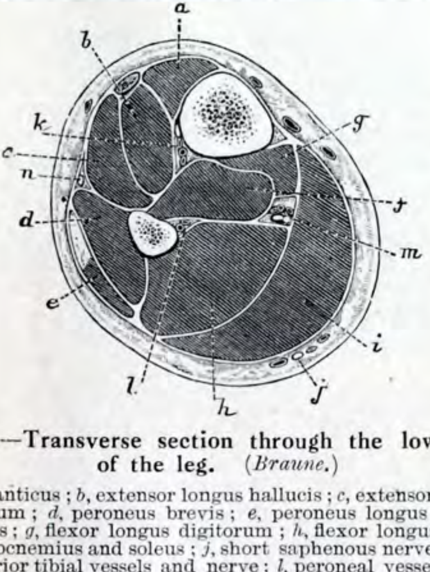

Fig. 137.—Transverse section through the lower third of the leg. (*Braune.*)

a, Tibialis anticus ; *b*, extensor longus hallucis ; *c*, extensor communis digitorum ; *d*, peroneus brevis ; *e*, peroneus longus ; *f*, tibialis posticus ; *g*, flexor longus digitorum ; *h*, flexor longus hallucis ; *i*, gastrocnemius and soleus ; *j*, short saphenous nerve and vein ; *k*, anterior tibial vessels and nerve ; *l*, peroneal vessels ; *m*, posterior tibial vessels and nerve ; *n*, musculo-cutaneous nerve.

small part of the upper extremity of the peroneus brevis, the anterior tibial vessels and nerve, and the musculo-cutaneous nerve. In the posterior flap the following would be the parts divided: Skin, external and internal saphenous veins and nerves, fascia, gastrocnemius, plantaris, soleus, tibialis posticus, flexor longus digitorum, a little of the upper end of the flexor longus hallucis, the posterior tibial vessels and nerve, and the peroneal vessels.

In Fig. 137 is shown a transverse section of the leg at the lower third, from which can be gathered an idea of the number and position of the parts cut in amputations through that part.

An excellent method of amputation at the upper part of the leg is by a single external flap containing the anterior tibial artery in its entire length.

CHAPTER XXVI

THE ANKLE AND THE FOOT

Surface anatomy. Bony points.—The outlines of the two malleoli can be very distinctly defined. The external is somewhat the less prominent, descends lower, and lies farther back than the internal process. The tip of the outer malleolus is about ½ an inch behind and below the tip of the corresponding bony prominence. The antero-posterior diameter, however, of the internal malleolus is such that its posterior border is on a level with that of the outer process behind.

On the *dorsum* of the foot the individual tarsal bones are not to be distinguished, although the astragalus forms a distinct projection upon that surface when the foot is inverted.

On the *inner side* of the foot the tuberosity of the os calcis (calcaneus) may be felt most posteriorly. In front of it, and about 1 inch vertically below the inner malleolus, is the projection of the sustentaculum tali. About 1¼ inches in front of the malleolus the tuberosity of the scaphoid (navicular) can be distinctly made out (Fig. 140, p. 625). In the interval between it and the last-named process lie the inferior calcaneo-scaphoid ligament, and the tendon of the tibialis posticus. Farther towards the front of the foot can be felt the ridge formed by the base of the first metatarsal bone, and between it and the scaphoid tubercle (process) lies the inner cuneiform bone. Lastly, the shaft of the first metatarsal bone, its expanded head, and the sesamoid bones that lie on the plantar aspect of the metatarsal phalangeal joint can be more or less distinctly defined. On the *outer side* of the foot the external surface of the os calcis is subcutaneous in nearly the whole of its extent. Less than 1 inch below and in front of the malleolus is the peroneal tubercle, with the short peroneal tendon above it and the long one below it. Some $2\frac{1}{2}$ inches from the outer malleolus the tuberosity of the fifth metatarsal bone is very evident, and extending for an inch or so behind it lies the cuboid bone.

Joint-lines.—The ankle-joint lies about on a level with a point $\frac{1}{2}$ an inch above the tip of the inner malleolus. Immediately behind the tubercle of the scaphoid is the astragalo-scaphoid articulation, and a line drawn transversely across the dorsum of the foot, just behind the process, very fairly corresponds to the mid-tarsal joint (the joint compounded of the astragalo-scaphoid and calcaneo-cuboid articulations).

If the latter articulation be approached from the outer side it will lie opposite a point midway between the outer malleolus and the tuberosity of the fifth metatarsal bone.

The lines of the articulations between the first and fifth metatarsal bones and the inner cuneiform and the cuboid respectively are easily indicated, being placed just behind the bases of the former bones. The metatarso-phalangeal articulations are situated about 1 inch behind the webs of the corresponding toes. The proximal phalanx and part of the middle are buried in the web.

Tendons.—The tendo Achillis (calcaneus) stands out very conspicuously at the back of the ankle, and between it and the malleoli are two hollows which are evident in even obese individuals. Over the front of the ankle the tendons of the extensor muscles are readily to be distinguished, especially when the joint is flexed. From within outwards they are: the tendons of the tibialis anticus, extensor longus hallucis, extensor longus digitorum, and peroneus tertius. Beneath the tendons of the extensor of the toes, and on the outer part of the dorsum of the foot, the prominent fleshy mass formed by the extensor brevis digitorum can be felt and, when in action, seen. Above and behind the inner malleolus the tendons of the tibialis posticus and flexor longus digitorum can be discerned, the former lying nearer to the bone. Nearer to the middle line runs the flexor longus hallucis. Behind the outer malleolus the long and short peroneal tendons can be felt, lying close to the edge of the fibula, the tendon of the smaller muscle being the closer to it.

In the middle of the sole of the foot the resisting plantar fascia (aponeurosis) can be felt, and some of its processes made out when the toes are drawn up by the extensors. The fleshy mass on the inner margin of the foot is formed by the abductor and flexor brevis hallucis; that on the outer side by the abductor and flexor brevis minimi digiti.

Vessels.—The anterior tibial artery and (deep peroneal) nerve are placed opposite the ankle-joint, between the tendons of the extensor proprius hallucis and longus digitorum. The dorsal artery runs from the middle of the ankle to the interval between the bases of the first and second metatarsal bones. It may be felt pulsating against the bones along the outer side of the extensor proprius hallucis tendon, which is the readiest guide to it. The plantar arteries start from a point midway between the tip of the malleolus internus and the centre of the convexity of the heel. The internal vessel follows a line drawn from this point to the middle of the under surface of the great toe. The external vessel crosses the sole obliquely to within a thumb's-breadth of the base of the fifth metatarsal bone. From thence it turns more transversely across the foot, running inwards over the bases of the metatarsal bones to inosculate with the dorsalis pedis artery at the back of the first interosseous space. On the dorsum of the foot the subcutaneous veins may be seen forming an arch, convex towards the toes, and from the ends of the arch vessels may be followed into the internal and external saphenous veins.

The **skin** about the ankle and over the dorsum of the foot is thin and but loosely attached to the subjacent parts. It becomes readily excoriated, as is frequently the case where splints or instruments have been improperly applied. Since the skin over the malleoli lies directly upon the bone, while that covering the dorsum of the foot is but slightly separated from the bones of the tarsus, it follows that the integuments in this region are readily contused, and may suffer gangrene from an amount of pressure that would cause but little trouble in other parts. Over the sole the integument is dense and thick in all those parts that come in contact with the ground. In the normal foot, the heel, the outer margin of the foot, and the line of metatarso-phalangeal joints are in contact with the ground when the sole is placed flat upon it (Fig. 142, p. 633).

The **subcutaneous tissue** about the ankle and foot varies greatly both in quantity and character. Over the front of the ankle and dorsum of the foot it is very lax, free from fat, and is the first part to be infiltrated in general dropsy of the body. On the sole the subcutaneous tissue is dense, firm, and studded with pellets of fat. It is $\frac{3}{4}$ of an inch thick over the heel.

The integuments of the foot are well supplied with **nerves**, being furnished with branches from no less than six nerve trunks—the musculo-cutaneous (superficial peroneal), the anterior tibial (deep peroneal), the two saphenous, and the external and internal plantar. Many Pacinian bodies are found upon these cutaneous branches, and end-bulbs are met with in the skin on the sole. The integuments of the foot respond acutely to sensations of pain, of pressure, of temperature, and to certain unwonted forms of tactile impression, such as tickling. Many *postural reflexes* arise from the skin of the sole, as well as from the joints of the foot; the clinician uses these reflexes to test the state of the lumbar part of the spinal cord. Tactile insensibility, however, as measured by the æsthesiometer, is not acute, the dorsum of the foot showing, in regard to this matter, no more sensitiveness than does the skin of the buttock.

Over the "tread of the foot," and especially under the ball of the great toe, the peculiar affection known as "perforating ulcer" is most commonly met with. This ulcer occurs as an occasional symptom in certain nerve maladies, and particularly in locomotor ataxy.

Fasciæ of the foot and the tendons about the ankle.—The **dorsal fasciæ** occur in two layers, a superficial one that is continued from the upper anterior annular ligament (transverse ligament of the leg), and a deeper placed over the extensor brevis and interossei muscles. These membranes are both thin and insignificant, and exercise no influence from a surgical point of view. The **plantar fascia** is divided into three parts, a central or main portion which is extremely dense and powerful, and an inner and an outer expansion which are thin and surgically insignificant. The outer of the two lateral portions is, however, of some substance, and forms a very thick band between the os calcis and the tuberosity of the fifth metatarsal bone, that may become rigidly contracted in some forms of talipes. The central expansion accommodates itself to the abnormal conditions of the foot: if the arch of the foot collapses, as in *flat-foot*, it becomes stretched and elongated; if, on the other hand, the arch becomes bent, as in *pes cavus*, resulting from paralysis of extensors of the foot, the fascia becomes contracted and taut.

The best place in which to divide this membrane is at a spot about 1 inch in front of its attachment to the os calcis. This is its narrowest part, and the knife (which should be introduced from the inner side) will be behind the external plantar artery which runs beneath the expansion.

An abscess situated beneath the membrane will be very closely bound down, and will advance in any direction other than through the membrane itself. Such deep collections cause intense pain, and often much destruction, before they are discharged. They may open upon the dorsum, or may extend up along the tendons to the region of the ankle. There are certain foramina or spaces in the substance of this layer occupied usually by fat; through one or more of these an abscess will, in exceptional cases, extend, and then spread out beneath the integuments. Such an abscess will have, therefore, two cavities united by a small hole, and will form the *abcès en bissac* or *en bouton de chemise* of the French. The plantar fascia divides into slips near the roots of the toes, and forms a series of arches, beneath which pass the tendons, vessels, and nerves bound for the digits. Two intermuscular septa connected with the membrane separate the flexor brevis digitorum from the abductor hallucis on the one side and the abductor minimi digiti on the other. They are, however, membranes of too feeble a structure to affect much the progress of a deep plantar abscess.

The anterior **annular ligament** is divided into two parts—an upper band (transverse ligament) in front of the tibia and fibula, and a lower band (cruciate ligament) in front of the upper limits of the tarsus (Fig. 138). Beneath the former there is only one synovial sheath, that for the tibialis anticus; beneath the latter are three sheaths—one for the peroneus tertius and extensor communis, one for the extensor proprius pollicis, and a third for the tibialis anticus.

There is often a large irregular bursa between the tendons of the extensor longus digitorum and the projecting head of the astragalus. This bursa sometimes communicates with the joint at the head of the astragalus.

Beneath the internal annular ligament (ligamentum laciniatum) are three *synovial sheaths* for the tendons of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis. Inflammation involving the sheath for the tibialis

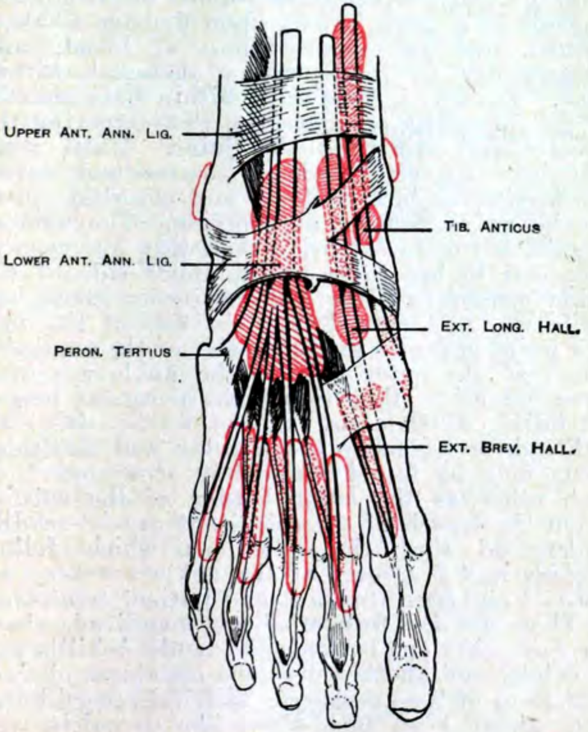

Fig. 138.—Synovial sheaths on the extensor surface of foot and ankle. (*Lovell and Tanner.*)

posticus may spread to the ankle-joint, with which the tendon is in close relation. Beneath the outer annular ligament (peroneal retinaculum) is the single synovial sheath for the long and short peroneal tendons.

In *severe sprains of the ankle* not only are the ligaments about the joint more or less ruptured, but the various synovial sheaths just named are apt to be torn and filled with blood. The long-abiding trouble which often follows severe sprains depends to a great extent upon damage to these sheaths, and to extravasations of blood, and subsequently of inflammatory material, within them. Tendons become fixed within their sheaths by the *formation of adhesions*, thus tethering the muscles and stiffening the joint. Until these adhesions are elongated by passive and active movements, or broken down and absorbed, there can be no restoration of function. The tendon-sheaths are more extensive than they are usually supposed to be; those at the inner side of the ankle commence from 1 to 2 inches above the malleolus, and extend into the sole of the foot to a point opposite the tuberosity of the scaphoid. Those at the outer side of the ankle are even more extensive, that round the peroneus longus extending to the base of the first metatarsal, although occasionally the plantar and malleolar parts may be found completely separated from each other at the outer border of the cuboid. From the length of the sheaths it can be readily understood that the adhesions which follow sprains and fractures at the ankle are very extensive, and need constant and patient treatment.

There are few **bursæ** of any magnitude about the foot, save one between the tendo Achillis and os calcis, and another over the metatarso-phalangeal joint of the great toe. The first-named bursa rises about ½ an inch above the os calcis, and bulges out on either side of the tendon. When inflamed it may produce symptoms like those of ankle-joint disease, and when suppurating may lead to caries of the os calcis. The enlargement of the bursa over the metatarso-phalangeal joint of the great toe constitutes a **bunion.** It lies in the subcutaneous tissue between the internal sesamoid and the skin, and comes into existence with the production of the common condition known as **hallux valgus.** The great toe becomes abducted, bent towards the middle line of the foot. This condition, like genu valgum and flat-foot, is the result of a disordered action of the muscles which regulate the position of the proximal phalanx of the great toe. When, at the end of a step, the heel is raised, the proximal phalanx and its sesamoids form a socket in which the head of the metatarsal bone of the great toe rotates (Fig. 140, p. 625). During this act the proximal phalanx is balanced by two muscles: the abductor prevents its rotation outwards; the adductor, inwards. The chief strain falls on the abductor, often handicapped and confined by ill-fitting or too tightly fitting boots. The adductor is thus left unbalanced, and it draws the toe gradually into an abducted position. The cartilage over the inner part of the head of the metatarsal bone disappears, and a communication between the bursa and joint may be set up. The result of this deformity is a great weakening of the toe and adjacent part of the foot, a lengthening of the internal lateral ligament of the joint, and a displacement outwards of the tendon of the extensor proprius hallucis. Bursæ are often developed over the malleoli in tailors, and especially over the external process, the part most pressed upon when sitting cross-legged. In club-foot, bursæ are found over any points that are exposed to undue pressure.

The **tendons** about the ankle are not infrequently ruptured by violence. Those that most often are so injured are the tendo Achillis and the tendons of the tibialis posticus and the long and short peroneal muscles. The tendo Achillis usually breaks at a point about 1½ inches above its insertion, where it becomes narrowed and its fibres collected into a very definite bundle.

In some forms of violence the synovial and fibrous sheaths that bind down a tendon may be ruptured and *the tendons thus become dislocated.*

This has happened to the tibialis posticus and peroneal muscles. In each instance the dislocated structure comes forward upon or in front of the malleolus. No tendon in the body is so frequently displaced as is that of the peroneus longus.

The tendons about the ankle are frequently divided by operation, in nearly all cases the open operation being preferred to a subcutaneous tenotomy. The tendo Achillis is usually cut about 1 inch above its insertion, the knife being entered from the inner side to avoid the posterior tibial vessels. The tibialis posticus tendon is, as a rule, divided just above the base of the inner malleolus. There is, however, enough room between the annular ligament and the scaphoid bone to cut it on the side of the foot (Fig. 141, p. 631). The anterior tibial tendon may be divided readily either in front of the ankle or at its insertion into the internal cuneiform bone, and one or both peronei just above the external malleolus. On section of a tendon a gap is felt, owing to retraction by the muscle. The cut ends are still united by the fibrous tissue in which they lie, and from which they derive their blood supply. If cut within a sheath the synovial membrane forms a loose binding between the cut ends. A fibrous band between the cut ends is ultimately formed from the effusion which fills the gap. The new band is firmly adherent to the sheath in which it lies, and at first will limit the movements of the tendon.

Part of the tendon of a sound muscle may be yoked to that of one which has become paralysed, thus restoring certain movements to the foot.

Blood-vessels.—The lines of the various arteries have been already indicated (p. 609). Wounds of the plantar arch are serious, on account of the depth at which the external plantar artery lies, and the impossibility of reaching the vessel without making a large wound in the sole that would open up important districts of connective tissue and do damage to tendons and nerves. The arch is formed by the junction of the external plantar artery with the dorsal artery of the foot, a continuation of the anterior tibial vessel. In cases, however, of bleeding from the arch, ligature of both the posterior and anterior tibial vessels at or just above the ankle would not necessarily arrest the hæmorrhage. After ligature of these vessels blood would still be brought indirectly to the arch by means of the peroneal artery. By its anterior peroneal branch this vessel communicates with the external malleolar branch of the anterior tibial artery, and with the tarsal branch of the dorsalis pedis. By its terminal branch it communicates with the two last-named vessels, and also with the internal calcaneal branches of the external plantar artery.

As a matter of practice, however, elevation of the limb, together with pressure upon the wounded point and compression of the main artery, is sufficient to check most hæmorrhages from the plantar arch.

The dorsalis pedis artery, from its superficial position and its close contact with the bones of the foot, is frequently divided in wounds and ruptured in severe contusions. The posterior tibial artery at the ankle is well protected by the projecting malleolus, the dense annular ligament, and the tendons that run by its side.

The superficial veins of the foot, like those of the hand, are found mainly upon the dorsum of the member. The sole, as a part exposed to pressure, is singularly free from them. About the malleoli, and especially about the inner process, these veins form a considerable plexus. Hence it is that appliances which fit tightly around the ankle are apt to produce œdema and pain in the parts beyond.

The **lymphatics** form a very fine and elaborate plexus in the coverings of the sole, from which vessels arise that reach the borders and dorsum of the foot, and principally the inner border.

The main lymph-vessels of the part are found upon the dorsum, about the radicles of the two saphenous veins. Those on the inner side of the foot are by far the more numerous; they follow pretty generally the course of the internal saphenous vein, and end in the inguinal glands. The external vessels pass up along the outer ankle and outer side of the leg. The bulk of them pass obliquely across the ham to join the inner set above the knee; others reach the inner set by crossing the front of the tibia, while a few follow the short saphenous vein and end in the popliteal glands (*see* p. 577).

The **ankle-joint** is a very powerful articulation, its strength being derived not only from the shape of its component bones, but also from the unyielding ligaments and many tendons that are bound about it like straps. Of the ligaments, the two lateral are very strong, and have an extensive hold upon the foot. The anterior and posterior are extremely thin and insignificant, although the latter is supported by the tendon of the flexor longus hallucis, which crosses it. When effusion takes place into the joint, it first shows itself in front, beneath the extensor tendons, and just in front of the lateral ligaments. This is due to the feebleness of the anterior ligament and the extent and looseness of the synovial sac in relation with that structure. More extensive effusions cause a bulging behind through yielding of the thin posterior part of the capsule, and fluctuation can then be obtained on either side of the tendo Achillis. In no ordinary case can fluctuation be detected distinctly beneath the unyielding lateral ligaments. Moreover, the loose synovial sac of the ankle-joint extends both in front and behind beyond the limits of the articulation, while at the sides it is strictly limited to the joint-surfaces.

The ankle is a perfect hinge-joint, and permits only of flexion (plantar-flexion) and extension (dorsiflexion). The very slightest amount of lateral movement is allowed in extreme extension, when the narrower, or hinder, part of the astragalus is brought into contact with the widest, or anterior, part of the tibio-fibular arch. When obvious lateral movement exists at the ankle, the joint must be the seat of either injury or disease; and it is important not to mistake the lateral movements permitted between certain of the tarsal bones for movements at the ankle-joint. Movements are limited chiefly by the muscles crossing the joint, the ligaments becoming taut only in extreme positions, when the natural resistance of the muscles has been overcome. Muscles are the sentinels of joints (Colin Mackenzie).

Owing to its exposed position, this joint is very liable to become inflamed from injury or other external causes. When inflamed, no distortion is, as a rule, produced, the foot remaining at right angles with the leg. It would appear that this position is due to the circumstance that the flexor and extensor muscles about balance one another, and it does not seem that the capacity of the joint is affected by the posture of the foot. The synovial cavity of the ankle is in communication with the inferior tibio-fibular articulation.

In connexion with the subject of "referred pains," it should be remembered that the nerves supplying the ankle-joint bring that articulation into relation with the lumbar segments of the spinal cord through the internal saphenous, and the sacral segments through the anterior tibial (deep peroneal) nerve.

Dislocations at the ankle-joint.—The foot may be dislocated at the ankle in five directions, which, placed in order of frequency, are: outwards, inwards, backwards, forwards, and upwards between the tibia and fibula. These dislocations, which are never purely in one direction, are nearly always associated with fracture of either the tibia or the fibula, or of both bones.

1. **The lateral dislocations: outwards; in-**

wards. — These luxations differ somewhat from those met with in other joints. In the great majority of cases they consist of a lateral twisting of the foot, of such a kind that the astragalus is rotated beneath the tibio-fibular arch. There is no great removal of the upper surface of the astragalus from that of the tibia, one or other edge of the former bone being brought in contact with the horizontal articular surface of the latter. Although much deformity is produced, the actual separation of the foot from the leg is not considerable. In some rare cases a true lateral dislocation in the horizontal direction has been met with.

These injuries are due to sudden and violent twistings of the foot. The luxation outwards is due to forcible eversion of the foot; the luxation inwards, to violent inversion.

It is of interest, in the first place, to note the relation of the *fibula* to injuries at the ankle-joint, especially as a fracture of the lower end of the shaft of that bone may follow alike upon both inversion and eversion of the foot. The lower 3 or 4 inches of the fibula may be considered to form a lever of the first order (Fig. 139, A). The fulcrum is at the inferior tibio-fibular articulation, one arm of the lever is the malleolus below that joint, while the other arm may be regarded as formed by the lower 2 or 3 inches of the shaft of the bone. Now, the lower ends of the tibia and fibula are bound together by very powerful ligaments, viz. the anterior and posterior tibio-fibular, the transverse, and the inferior interosseous. In no ordinary lesion about the ankle, whether fracture or dislocation, do these ligaments give way. If they should yield, then an anomalous form of fracture or luxation would be produced. In forcible eversion of the foot, the internal lateral ligament becomes stretched and tears, the astragalus is rotated laterally beneath the tibio-fibular arch and is brought into violent contact with the end of the outer malleolus. This process is pushed outwards, and acts as one end of a lever. The fulcrum is secured by the unyielding tibio-fibular ligaments, and the fibula breaks at the other end of the lever, a point some 2 or 3 inches above the end of the bone (Fig. 139, B). In forcible inversion of the foot, the astragalus undergoes a

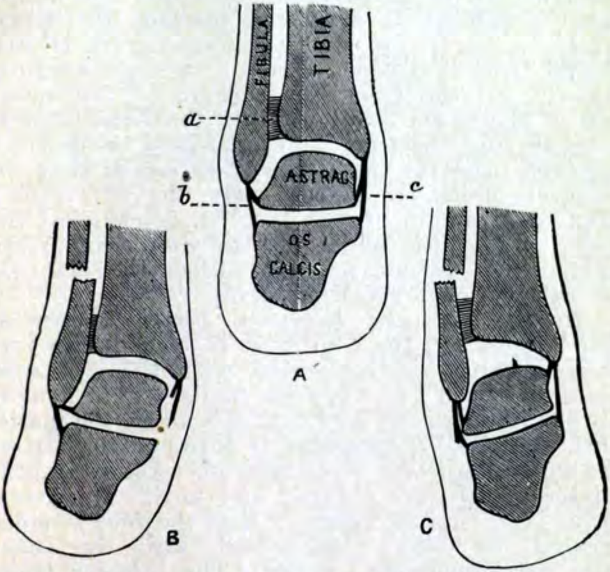

Fig. 139.—Diagrams to illustrate the mechanism involved in fractures of the lower end of the fibula.

A, Parts in normal position: *a*, tibio-fibular ligaments; *b*, external lateral ligament; *c*, internal lateral ligament. B, Fracture of fibula due to eversion of foot. C, Fracture of fibula due to inversion of foot.

little lateral rotation in the opposite direction; the external lateral ligament is greatly stretched, and tends to drag the end of the outer malleolus inwards. If the ligament yields, the case will probably end as a sprained ankle, or pass on to a dislocation inwards of the foot. But if it remains firm, the end of the fibular lever (the tip of the malleolus) is drawn towards the middle line, the fulcrum is secured by the tibio-fibular ligaments, and the shaft breaks at the other end of the lever, some few inches above the end of the bone (Fig. 123, C). It will be seen that in the fracture due to eversion the upper end of the lower fragment is displaced towards the tibia, while in the lesion due to inversion it is displaced from that bone. From a careful examination of all the cases of fracture of the lower end of the fibula admitted into the London Hospital during the time I (F. T.) held the post of surgical registrar there, I was convinced that the lesion is much more frequently due to eversion than to inversion of the foot. A fracture of the lower end of the fibula due to simple inversion of the foot is not possible unless the external lateral ligament remains entire.

In the *outward luxation*, better known as *Pott's fracture*, the condition is such as has just been described in connexion with the effects of eversion of the foot upon the fibula. That bone is always broken some 2 or 3 inches above the malleolus, the deltoid ligament is torn, or the tip of the inner malleolus wrenched off. Above all, the tendon-sheaths are injured and torn. The astragalus is so rotated laterally that the foot is much everted, its outer edge raised, while its inner edge rests upon the ground. The inferior tibio-fibular ligaments remain intact. If they yield, an unusual form of fracture or dislocation is produced, as already stated. Boyer relates a case, considered to be unique, where the foot was luxated outwards, but without any fracture of the fibula. That bone, however, had been forced upwards entire, and its head dislocated from the articular facet of the tibia. A horizontal dislocation outwards, without rotation of the foot and without fracture of the fibula, is possible if the inferior tibio-fibular ligaments are entirely torn.

In *Dupuytren's fracture* (a rare injury) the fibula is fractured from 1 to 3 inches above the malleolus, the inferior tibio-fibular ligaments are entirely lacerated, or the portion of the tibia to which they are attached is torn away, and remains connected with the lower fragments of the fibula. The foot is dislocated horizontally outwards, and is drawn upwards, the extent of the upward displacement depending upon the height at which the fibula breaks.

In the *inward luxation* the external lateral ligament is torn or the tip of the outer malleolus dragged away, the deltoid ligament is intact, but the internal malleolus is commonly broken by the violence with which the astragalus is brought into contact with it. That bone itself may be broken, and is in any case rotated laterally, so that the foot is inverted and its inner border much raised. In all forms of this dislocation, whether simple or complicated, the inferior tibio-fibular ligament remains intact.

2. **The antero-posterior dislocations: backwards; forwards.**—These injuries are brought about by great force applied to the foot while the leg is fixed, or more commonly by sudden arrest of the foot during some violent impulse given to the body, as on jumping from a carriage which is in motion. In the luxation backwards the astragalus is displaced behind the tibia, while the articular surface of the latter bone rests upon the scaphoid and cuneiform bones. The anterior and posterior ligaments are entirely torn, and a great part also of the two lateral bands. The fibula is broken some 2 or 3 inches above the malleolus, and there is usually a fracture also of the inner malleolus.

The dislocation upwards.—In this rare accident the inferior tibio-fibular ligaments are ruptured, the two bones are widely separated at their lower ends, and the astragalus is driven up between them. The anterior and posterior ligaments are entirely ruptured, but the lateral ligaments usually escape with but some slight laceration.

The accident appears to be generally caused by a fall, the patient alighting flat upon the soles of the feet.

Dislocation of the astragalus (talus).—This bone is sometimes luxated alone, being separated from its connexions with the os calcis, the tibia, the fibula, and the scaphoid bone. The displacement may be either forwards, backwards, or lateral. The luxation forwards is by far the most common lesion, the next in frequency being a luxation outwards and forwards. In these injuries the interosseous ligament between the os calcis and astragalus is entirely torn, as are also the greater part of the lateral ligaments of the ankle, and the various bands that connect the astragalus with the os calcis and scaphoid. In all instances the malleoli are brought nearer to the sole. Radiography has shown that fracture not infrequently accompanies dislocation of the astragalus. When it is remembered that the astragalus is the keystone of the plantar arch, and must receive the chief impact in all accidents which force the weight on the feet, the fracture of its neck or of its body becomes intelligible. In such cases the astragalus has been excised and a fair degree of movement regained in the new ankle-joint.

Subastragaloid dislocations of the foot.—In these lesions, which are not very uncommon, the astragalus remains in position between the tibia and fibula, while the rest of the foot is dislocated below that bone. The luxation, therefore, concerns the anterior and posterior subastragaloid joints. The foot may be displaced either forwards, backwards, or laterally. The forward dislocation is extremely rare, and the lateral luxations are nearly always oblique. In the most usual displacements the foot is dislocated outwards or inwards, and is at the same time carried backwards.

The **mediotarsal joint** is situated between the head of the astragalus and scaphoid on the inner side of the foot, and the os calcis and cuboid on the outer. The inner is part of the anterior subastragaloid joint (*see* p. 627), while the outer has a separate synovial cavity. It should be noted that the movements of turning the toes either in or out take place mainly at the hip-joint; while the turning of one edge of the foot either up or down is a movement that mostly concerns the subastragaloid joints.

The foot.—There are two arches in the foot, an antero-posterior and a transverse.

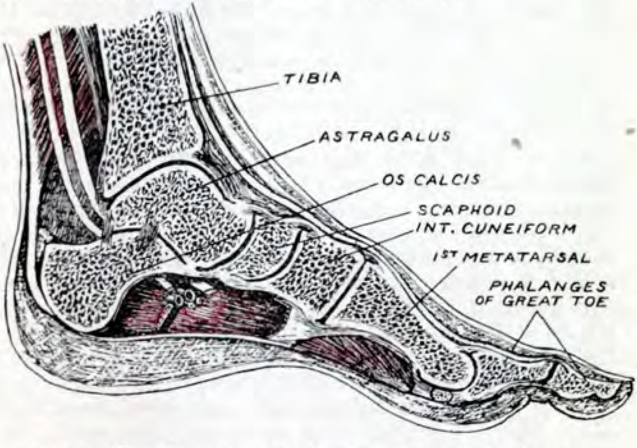

Fig. 140.—Antero-posterior section of the foot. (*After Rüdinger.*)

1. The **antero-posterior arch** has its summit at the astragalus. It may be considered as composed of two piers. The hinder pier consists of the os calcis, the anterior pier of the scaphoid, cuneiform, and metatarsal bones. The astragalus forms the keystone of the arch, the head of the bone especially performing that function (Fig. 140).

The foot rests upon the heel, the heads of the metatarsal bones, and the outer margin of the foot (Fig. 142). The hinder pier is solid, is made up of a strong bone, and contains only one joint. It serves to support the main part of the weight of the body, and gives a firm basis of attachment to the muscles of the calf. The anterior part of the arch, on the other hand, contains many small bones and a number of complicated joints. It serves to give elasticity to the foot, and to diminish the effect of shocks received upon the sole of the foot. The comparative value of the two piers of the arch in this latter respect can be estimated by jumping from a height and alighting first upon the heels and then upon the balls of the toes. The inner part of the arch is much more curved than the outer, and forms the instep.

2. The **transverse arch** is most marked across the cuneiform bones. It gives much elasticity to the foot and affords protection to the vessels of the sole. According to Sir Robert Jones, the transverse arch may be strained or flattened, the condition being accompanied by pain *at the metatarso-phalangeal joints* (metatarsalgia) when the patient brings his weight to bear on the retrodigital pad of the sole. When the patient compresses the metatarsals together the pain is relieved, and it is for this reason that the fault is supposed to lie in a breakdown of the transverse arch. A bar across the sole of the shoe throws the weight of the body more on the heel, thus relieving the strain on the transverse arch.

Maintenance of the plantar arch.—Although the various bones are so shaped as to fit into their respective positions in the arch, and are bound together by ligaments, yet the maintenance of the arch depends neither on the shapes of the bones nor on their ligamentous attachments, but on the living muscles which spring into action the moment the weight of the body rests on the feet. Three groups of muscles are concerned: (1) the flexor group, rising from the posterior aspect of the tibia, fibula, and interosseous membrane; (2) the extensor group, rising from the anterior surfaces of these structures; (3) the plantar group, in the sole of the foot. It is only when the muscles are damaged or exhausted that a strain falls on the ligaments. Ligaments cannot be exposed to a continuous strain without elongating. As they elongate, the bones accommodate themselves to the new form of arch, which is thus rendered permanent.

The movements of **inversion** and **eversion**, whereby the foot is adapted to the ground on which it treads, occur at the subastragaloid joints. These are two in number: (1) the anterior subastragaloid joint between the head of the astragalus and three other parts—(*a*) sustentaculum tali; (*b*) inferior calcaneo-scaphoid ligament; (*c*) scaphoid (Fig. 140); (2) posterior subastragaloid between the body of the astragalus and os calcis. The posterior is separated from the anterior joint by the interosseous ligament. A third joint is also concerned in these important movements, viz. that between the os calcis and cuboid. The muscles which produce inversion are (1) tibialis posticus, (2) tibialis anticus. The first produces inversion with plantar flexion, the others with dorsal flexion. The flexor muscles of the toes assist the first, the extensor of the great toe the second. Eversion is produced by (1) peroneus longus, (2) peroneus brevis, (3) peroneus tertius, (4) extensor longus digitorum. The first produces eversion with plantar flexion, the other with dorsal flexion. Thus there are four groups of muscles acting on the subastragaloid articulations which balance and determine the movements of the foot, and four positions in which they may fix the foot: (1) inversion with plantar flexion (talipes equino-varus); (2) eversion with plantar flexion (talipes equino-valgus); (3) inversion with dorsiflexion (talipes calcaneo-varus); (4) eversion with dorsiflexion (talipes calcaneo-valgus). The position assumed will depend on the group or groups of muscles which are paralysed or weakened. Eversion is limited by the structures along the inner side of the sole of the foot—the abductor hallucis, plantar fascia, the tibial muscles, and the inferior calcaneo-scaphoid ligament. Inversion is limited by the peroneal muscles, the ligaments along the outer border of the foot, and, ultimately, by the tuberosity of the scaphoid coming in contact with the sustentaculum tali. The movements of inversion and eversion correspond to supination and pronation, but in the upper extremity these are produced between radius and ulna, whereas in the lower extremity they occur almost entirely between the astragalus and the rest of the foot.

Club-foot.—It is usual to divide the various forms of talipes, or club-foot, into four main groups, viz.: (1) T. equinus; (2) T. calcaneus; (3) T. varus; and (4) T. valgus. Four secondary forms result from combinations of these principal varieties, viz.: T. equino-varus, T. equino-valgus, T. calcaneo-varus, and T. calcaneo-valgus.

1. *Talipes equinus.* In this deformity the heel is drawn up, and the patient walks upon the balls of the toes. The contracting muscles are those of the calf, attached to the tendo Achillis. The paralysed muscles are the extensors of the foot. There is plantar flexion and marked inversion of the foot. In a well-marked case the os calcis is much raised, and may even be brought in contact with the tibia. The astragalus is displaced downwards and projects upon the dorsum. The foot tends to become more and more inverted, until at last the scaphoid may even touch the sustentaculum. The ligaments of the sole are usually much contracted.

2. *Talipes calcaneus.* In this form of club-foot the toes are drawn up and the patient walks upon the heel. The contracting muscles are the extensors on the anterior aspect of the limb. The os calcis is rendered more vertical, and the astragalus becomes so obliquely placed that part of its upper articular surface may project beyond the tibia in a backward direction.

3. *Talipes varus.* This is the commonest form,

but it is never pure, being usually associated with inversion of the foot. Certain features of the fœtal foot are retained in an exaggerated degree. In a well-marked congenital case there is a threefold deformity: (1) The heel is drawn upwards by the muscles attached to the tendo Achillis; (2) the foot is inverted by the contraction of the tibialis anticus and posticus; (3) the sole is contracted by the flexor longus digitorum muscle and the shrinking of the plantar fascia and ligaments. The neck of the astragalus is elongated and deflected downwards and inwards to a greater extent than in the normal foot. In the adult the neck of the astragalus is deflected inwards to the axis of its body at an angle of 10°; in the newly born at an angle of 25°; and in talipes varus at an angle of 50°. The scaphoid is displaced upwards and inwards, until its inner border often touches the internal malleolus. The three cuneiform bones follow the scaphoid, and the cuboid becomes the lowest bone in the tarsus. The outer border of the cuboid forms an angle with the os calcis, and the tendons of the peroneus longus slip backwards from the groove in the cuboid to lie on the os calcis. The anterior border of the internal lateral ligament is contracted and unduly prominent. There is thus a marked degree of inversion.

4. In *talipes valgus* the foot assumes permanently the position of eversion. The contracting muscles are the two peronei. In a well-marked congenital case the os calcis is found a little raised and the astragalus is displaced forwards and downwards. The scaphoid is so rotated that its inner part is depressed and its outer raised. The internal portion of the bone forms one of the two projections obvious on the inner side of the foot, the other prominence being formed by the head of the astragalus. The cuboid is found to be a little rotated outwards. The arch of the foot is lost, and all those ligaments are stretched that serve to support and maintain that arch.

Of the mixed, or secondary, forms of talipes nothing need be said. They are the results merely of a combination of the primary varieties.

As trouble is often caused in talipes by pressure being brought to bear upon an unusual part of the foot, it is well to note upon what portion of the member the patient treads in the different varieties of the deformity. In varus the "tread" is mainly upon the outer side of the fifth metatarsal bone; in valgus, upon the internal malleolus and scaphoid; in equinus, upon the bases of all the toes; in equino-varus, upon the base of the little toe; in equino-valgus, upon the base of the great toe; in all forms of calcaneus, upon the heel. In cases of extreme and obstinate club-foot of the congenital variety, wedges of bone are sometimes removed by the operation known as *tarsectomy*. Thus, in talipes equino-varus the base of the wedge will be on the outer side of the foot, and will be mainly represented by the cuboid; the apex will be at the scaphoid.

Flat-foot and **splay-foot** are the names given to a deformity due probably to the yielding of certain ligaments, whereby the arch of the foot is lost and the sole becomes more or less perfectly flat. The foot, at the same time, is abducted, and the outer border is often a little raised, so that the patient walks mainly upon the inner side of the foot. This deformity is met with in those who stand a great deal, and is the direct result of yielding of the muscles which maintain the foot in a position of inversion—especially the tibialis anticus and posticus. It is only when these muscles become exhausted and yield that the ligaments are strained and elongated, for it may be accepted as a law that the normal strain at a joint falls on the muscles, the ligaments only coming into action in limiting the extent of movements. The inferior calcaneo-scaphoid ligament is normally lax in the standing posture; the weight of the head of the astragalus is then supported by the tibialis posticus (Fig. 141).

As is well known, the muscles of the leg and foot become more quickly exhausted when standing than when walking, for in the standing posture the muscles which invert the foot are maintained in a condition of tonus, whereas in walking they have alternate periods of action and rest. Hence, in those whose occupations entail prolonged periods of standing, the muscles which maintain the inversion of the foot become exhausted—especially the tibialis posticus; they gradually yield, and the superincumbent weight of the body then falls on the structures which

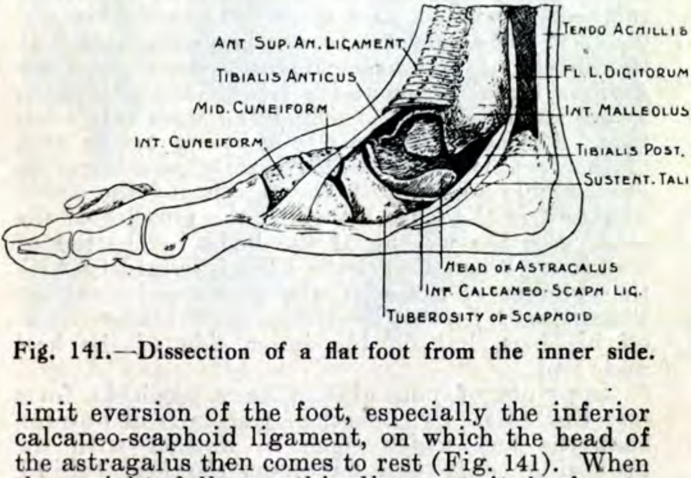

Fig. 141.—Dissection of a flat foot from the inner side.

limit eversion of the foot, especially the inferior calcaneo-scaphoid ligament, on which the head of the astragalus then comes to rest (Fig. 141). When the weight falls on this ligament it begins to yield; the head of the astragalus is pressed forwards, downwards, and inwards by the superincumbent weight, and the foot beyond becomes, as a consequence, over-extended and turned out (Fig. 141). The os calcis slants inwards, and its anterior end is depressed. The sustentaculum tali, the head of the astragalus, and the scaphoid tubercle form prominences on the inner side of the foot, and may rest on the ground (Fig. 141). The long and short plantar ligaments also, which contribute so much to the maintenance of the arch of the foot, in time yield, and allow of a still greater degree of deformity. There is a stretching also of the deltoid ligament. In neglected cases the distortion is rendered more or less permanent by alterations in the shape of the tarsal bones, and by a contraction of such ligaments as have been relaxed by the deformity. The scaphoid and internal cuneiform become markedly wedge-shaped, with the apices directed to the dorsum of the foot (Fig. 141). The foot being abducted, and its outer border a little raised, the peronei muscles become relaxed, shortened, and contribute to the permanency of the disorder. It will be understood that the abnormal pressure brought to bear upon the various tarsal bones and articulations will cause severe pain to be often associated with this affection. The calf muscles waste, owing to the arch of the foot having lost its rigidity and being no longer able to support the weight of the body. The *foot is the lever* by which the muscles of the calf raise the weight of the body in the act of walking. When that lever loses its rigidity with the collapse of the arch, the calf muscles can no longer act; hence the patient no longer steps off his toes, but off the inner side of the heel and foot.

Imprints of normal feet vary much in form (*see* Fig. 142). Dr. Lovett of Boston is of opinion that the feet which come in contact with the ground at only two parts—at the heel behind, and along the pad of the foot in front—are those which are most prone to break down (Fig. 142, A). In flat-foot the inner border of the foot also comes in contact with the ground, so that the area between the heel, the plantar pad, and the outer margin of the foot, left blank in the normal imprint, become partially or completely filled up (Fig. 142, D).

It may be noted that the mediotarsal joint, which is so conspicuously involved in the distortion, is supplied by the anterior tibial, musculo-cutaneous, and external plantar nerves.

In the condition known as **pes cavus** (**claw-foot**) the foot is flexed at the midtarsal joint, the plantar arch is increased, the heel is drawn up, and the proximal phalanges, especially of the great toe, are dorsiflexed. The condition develops gradually, and ultimately gives rise to great disability; its cause is obscure. There is usually

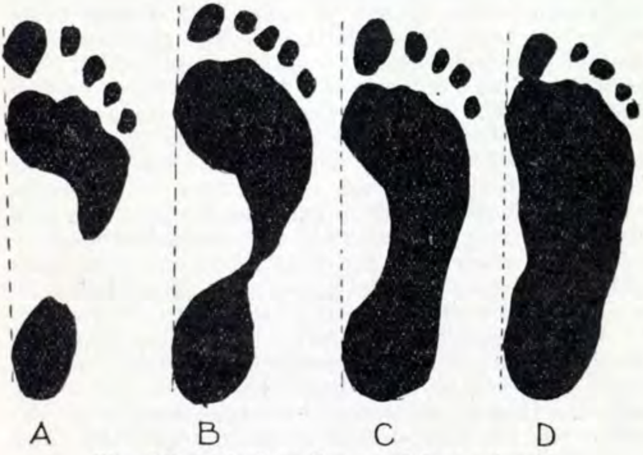

Fig. 142.—Various forms of foot-prints.

A, Of normal foot with high arch.
B, „ „ „ also with high arch.
C. „ „ „ with low arch.
D, „ flat foot.

some degree of weakness of the extensors of the toes and foot.

The **tarsal bones,** owing to their spongy character, are readily broken by direct violence, as in severe crushes. The soft parts that cover these bones being scanty upon the dorsal aspect of the foot, it follows that these accidents are often compound and associated with much laceration of the integuments.

The tarsal bone the most frequently fractured is the *os calcis*. This bone may be broken by a fall upon the heel, and in many instances has been the only one fractured by such an accident. A few cases have been recorded of fracture of the calcaneus by muscular violence, the muscles producing the lesion being those attached to the tendo Achillis. Thus, Sir A. Cooper reports the case of a woman aged 42, in whom a large fragment of the posterior part of the os calcis was torn away by the muscles and drawn some 2½ inches away from the heel. The accident was caused by her taking a false step. Abel has collected three cases of fracture of the *sustentaculum tali*. He believes that this injury may be produced by falls upon the sole or by extreme inversion of the foot, whereby the astragalus is forced violently against the process. Skiagrams of the heel often show a *calcanean spur*, running forwards from the internal or external tuberosity of the os calcis into the plantar fascia. In some cases the presence of such a spur is connected with a persistent pain felt at the inner side of the heel.

The *astragalus* alone may be broken by a fall upon the feet, and such accidents are often associated with fractures of both that bone and the os calcis. It must be noted, however, that in a fall, when the patient alights upon the feet, the tibia and fibula are much more likely to be broken than are the tarsal bones, since the bones of the leg transmit the weight of the body directly, whereas that weight is much diffused and broken up when passing through the foot with its many bones and joints. Skiagrams of the tarsal bones bring out the lines or bony trabeculæ along which such forces are transmitted. When examining such skiagrams, particularly in cases of injury, the posterior process of the astragalus may be seen as if separated or fractured. It must be remembered that this process is developed as a separate bone (*os trigonum*), and in some cases it fails to fuse with the astragalus.

The **metatarsal bones** and **phalanges** are nearly always broken by direct violence. I (F. T.) had, however, under my care at the London Hospital a man who had broken the shafts of the three outer metatarsal bones by simply slipping off the edge of the curb. Since the introduction of X-rays as a means of diagnosis, fractures of the metatarsal bones, especially of the fifth, and of the phalanges are found to occur not infrequently, and often as the result of a movement or accident which seems totally insufficient to produce such lesions.

One or more of the metatarsal bones may be luxated, or the entire series may be displaced upwards, downwards, inwards, or outwards, the first-named lesion being the most common. This is particularly the form of lesion seen in the feet of those who have been thrown from horseback and dragged by a foot caught in the stirrup.

Ossification of the tarsus.—At birth the tarsus is mainly cartilaginous. Ossification begins in the os calcis in the sixth month and in the astragalus in the seventh month of fœtal life. The centre for the cuboid appears at birth, and in the scaphoid, the last to ossify, in the third year. It is not until puberty that the cartilage of the tarsal bones is completely ossified. Like the epiphyses of long bones, the tarsal bones are entirely formed in cartilage, there being no periosteal formation. Hence it is possible, as Ogston has shown, to enucleate the ossific centres from the tarsal bones of children who are the subjects of club-foot and, by remodelling the cartilaginous capsules left behind, obtain new ossifications of a more normal form.

Dislocation of the proximal phalanx of the great toe is often very difficult to reduce, as is also the case in the corresponding luxation of the thumb. When the displacement is dorsal, the difficulty is probably due to the sesamoid bones, which are embedded in the glenoid ligament or fibro-cartilaginous plate, and the reflex contrac-

Fig. 143. — Oblique antero-posterior section of foot, to show the synovial cavities of the tarsus. (*Rüdinger.*)

1, Tibia; 2, fibula; 3, astragalus; 4, os calcis; 5, external lateral ligament; 6, internal lateral ligament; 7, interosseous ligament between astragalus and os calcis; 8, head of astragalus; 9, scaphoid; 10, 11, and 12, the three cuneiform bones; 13, cuboid.

tion of the groups of muscles which find an insertion on these sesamoids. The outward dislocation of the proximal phalanx, constituting the condition of hallux valgus, has been already mentioned (*see* p. 615). The inner lateral ligament of the joint is elongated, while the outer is contracted. In *hallux rigidus* this joint is slightly flexed and rigid, due probably to a reflex contraction of the short muscles which act on the great toe, the cause being usually some lesion of the articular surfaces of the joint. Obscure pains are often associated with the lesion—a form of metatarsalgia. The second toe is commonly longer than the others, and is more liable to assume the form known as "*hammer-toe.*" The proximal phalanx in such a form is extended, while the middle is strongly flexed. The condition is commonly inherited, and is due to contracture of the interossei and lumbrical muscles.

There are six **synovial cavities** in the foot, excluding that of the ankle-joint, viz. one for the posterior subastragaloid joint, a second for the anterior subastragaloid, a third between the os calcis and cuboid, a fourth between the latter bone and the two outer metatarsals, a fifth for the joint between the inner cuneiform and first metatarsal bones, and a sixth for the remaining articulations (Fig. 143). These synovial cavities tend greatly to diffuse disease among the various bones of the foot when once a bone has become inflamed. The best position, therefore, for bone disease, with reference to the question of extension, would be in the hinder parts of either the os calcis or astragalus, and one of the worst positions would be assumed by disease involving the scaphoid bone.

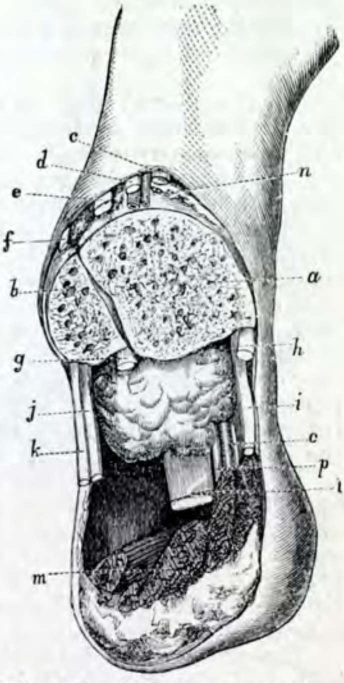

Fig. 144.—Syme's amputation. (*Agatz.*)

a, Tibia; *b*, fibula; *c*, tibialis anticus; *d*, extensor proprius hallucis; *e*, extensor communis digitorum; *f*, peroneus tertius; *g*, flexor longus hallucis; *h*, tibialis posticus; *i*, flexor longus digitorum; *j*, peroneus brevis; *k*, peroneus longus; *l*, tendo Achillis; *m*, some muscles of the sole that are not usually left in this operation; *n*, anterior tibial vessels; *o*, posterior tibial vessels; *p*, posterior tibial nerve.

Syme's amputation at the ankle (Fig. 144).—In the heel-flap are cut the integuments, the external saphenous nerve and vein, the peroneus longus, peroneus brevis, tibialis posticus, flexor longus digitorum, flexor longus hallucis, tendo Achillis, points of origin of the flexor brevis digitorum and of the two abductor muscles, and the internal and external plantar arteries and nerves.

In the dorsal flap are cut the integuments, tibialis anticus, extensor communis digitorum, extensor proprius hallucis, peroneus tertius, anterior tibial vessels and nerve, musculo-cutaneous nerve, and internal saphenous nerve and vein. The position of the principal structures divided is shown in Fig. 144. It is not usual to dissect up any of the muscular tissue of the sole, as shown in Agatz's illustration. It should be noted that the integuments of the heel derive their blood supply, which is very free, mainly from the external calcaneal branch of the posterior peroneal artery on the outer side, and the internal calcaneal from the external plantar on the inner.

If the heel incision is carried sufficiently far back to divide the trunk of the posterior tibial artery, the heel-flap is deprived of the last-named source of blood supply. The posterior tibial artery bifurcates upon a line drawn from the tip of the inner malleolus to the centre of the convexity of the heel.

The nerves supplying the integuments of the heel are the calcaneal branch of the external saphenous and the calcaneal and plantar cutaneous twigs from the posterior tibial.

In **Pirogoff's amputation** the os calcis is retained, but the parts divided in the anterior flap are the same as in Syme's operation. In the heel or sole flap the same structures also are cut as in the corresponding flap in a Syme, with the exception that the tendo Achillis is not divided, the flexor brevis digitorum, abductor hallucis, abductor minimi digiti, and flexor accessorius are divided more extensively, and the plantar vessels are cut farther from the bifurcation.

Chopart's operation is an amputation at the mediotarsal joint (Fig. 145). In the dorsal flap are cut the integuments, the extensor communis and brevis digitorum, extensor proprius hallucis, tibialis anticus, peroneus tertius and brevis, the musculo-cutaneous, anterior tibial, and two saphenous nerves, the dorsal artery, and the dorsal plexus of veins. In the plantar flap are found divided the integuments, plantar fascia, flexor brevis digitorum, abductors of the great and little toes, flexor accessorius, and tibialis posticus tendon. If the flap be well dissected up, parts of the short flexors of the great and little toes, the abductor hallucis, and transversus pedis will be found cut in the flap. The tendons of the long flexors of the digits and great toes, the peroneus longus, and the plantar vessels and nerves are also divided (Fig. 145).

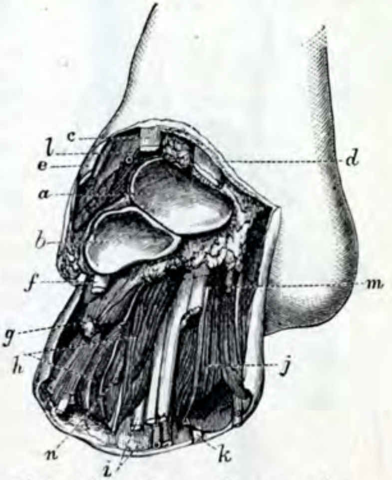

Fig. 145.—Chopart's operation. (*Agatz.*)

a, Astragalus; *b*, os calcis; *c*, extensor proprius hallucis; *d*, tibialis anticus; *e*, extensor communis digitorum; *f*, peroneus longus; *g*, adductor minimi digiti; *h*, flexor brevis digitorum; *i*, flexor longus digitorum; *j*, abductor hallucis; *k*, flexor longus hallucis; *l*, dorsalis pedis artery; *m*, internal plantar artery; *n*, external plantar artery.

Lisfranc's operation consists in amputation through the tarso-metatarsal line of joints (Fig. 146). In the dorsal flap the same structures are divided as are cut in the corresponding flap in Chopart's amputation. In the plantar flap also the parts divided are the same as in that procedure, with the exception that the flexor accessorius (quadratus) and the tendon of the tibialis posticus escape section. The articulations between the three outer metatarsals and the corresponding tarsal bones form a line sufficiently straight to be traversed by the knife in one cut when once the blade has been introduced.

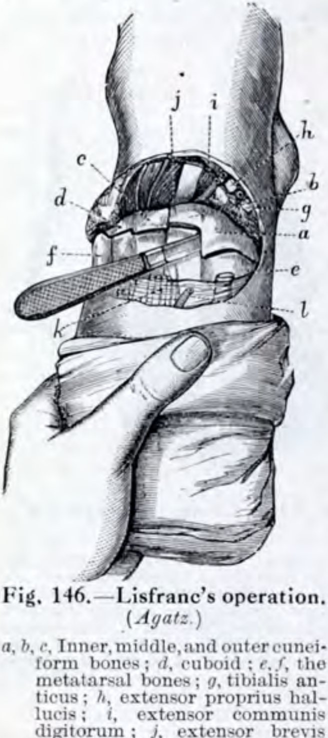

Fig. 146.—Lisfranc's operation. (*Agatz.*)

a, b, c, Inner, middle, and outer cuneiform bones; *d*, cuboid; *e, f*, the metatarsal bones; *g*, tibialis anticus; *h*, extensor proprius hallucis; *i*, extensor communis digitorum; *j*, extensor brevis digitorum; *k*, extensor tendons; *l*, dorsalis pedis artery.

The joint also between the first metatarsal and internal cuneiform bones is in a straight line and readily opened. The most difficult part of the disarticulation concerns the separation of the second metatarsal bone, which is deeply lodged between the tarsal segments. The chief bond of union between this bone and the tarsus is effected by a strong interosseous ligament which passes between it and the internal cuneiform (internal cunei-metatarsal). In Fig. 146 the knife is placed in the position required to divide that ligament, and in Fig. 147 the ligament is shown.

In the **subastragaloid amputations** a disarticulation is effected at the subastragaloid articulations. The astragalus is the only bone of the foot left behind, and forms the summit of the stump.

Nerve supply of the lower limb.—In Fig. 148 is shown the cutaneous nerve supply of the inferior extremities on both the anterior (extensor) and the posterior (flexor) aspect, and

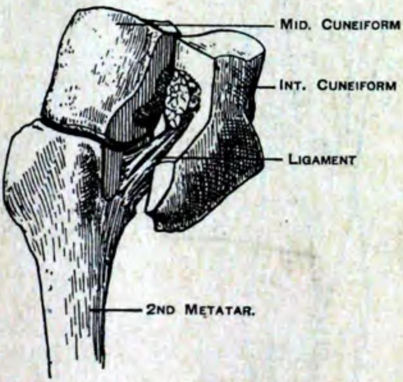

Fig. 147.—The ligament of Lisfranc (internal cunei-metatarsal). (*After Poirier.*)

in Fig. 149 are seen the cord segments from which they are derived. Paralyses of the lower limbs are common, but are more often due to some lesion in the inferior segments of the spinal cord than to damage received by any one individual nerve. Cases, however, are recorded where a single trunk has been injured and a limited form of paralysis has followed in consequence.

Paralysis of the anterior crural (femoral) nerve has been caused by injuries to the lower part of the vertebral column implicating the cauda,

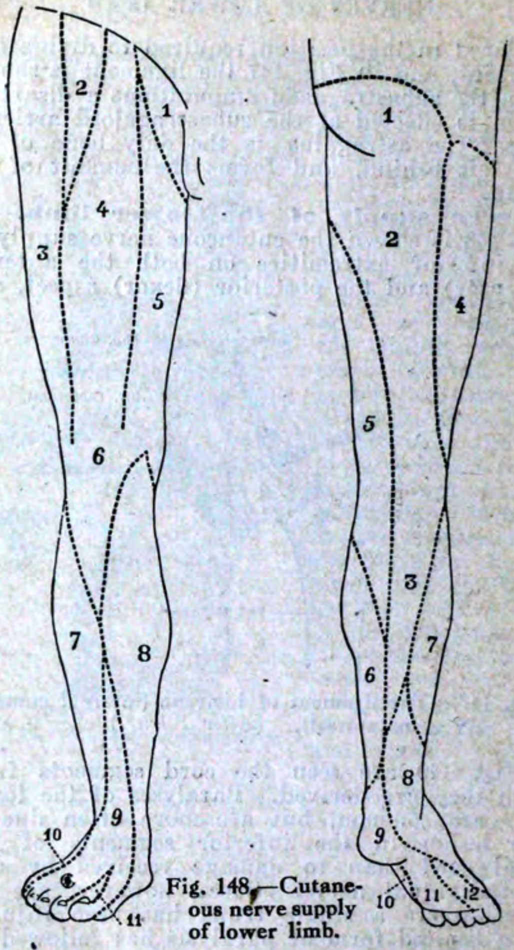

Fig. 148.—Cutaneous nerve supply of lower limb.

Anterior aspect.—1, Ilio-inguinal; 2, genito-crural; 3, external cutaneous; 4. middle cutaneous; 5, internal cutaneous; 6, patellar plexus; 7. branches of external popliteal; 8, internal saphenous; 9, musculo-cutaneous; 10, external saphenous; 11, anterior tibial. *Posterior aspect.*—1, 2, and 3, Small sciatic; 4, external cutaneous; 5, internal cutaneous; 6, internal saphenous; 7, branches of external popliteal; 8, short saphenous: 9, posterior tibial; 10, internal saphenous; 11, internal plantar; 12, external plantar.

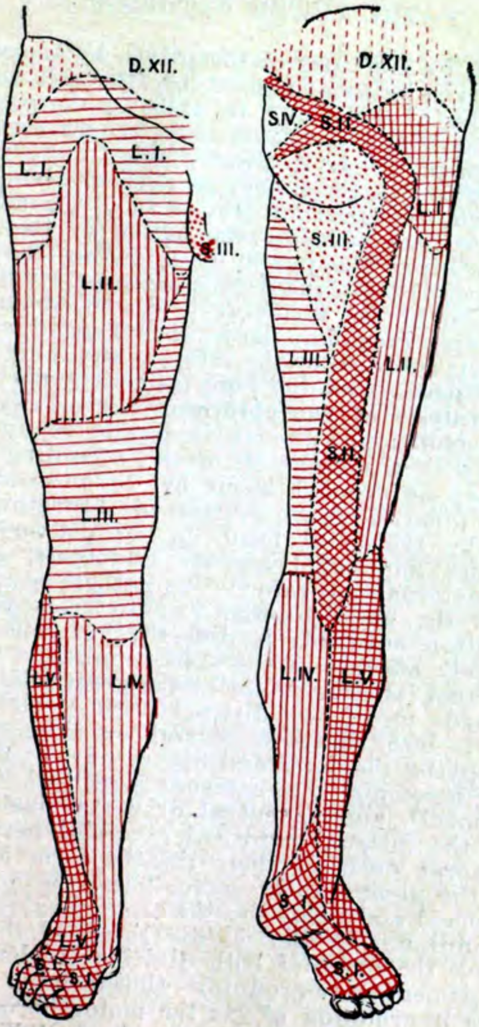

Fig. 149.—Showing the skin areas in the lower extremity supplied by the lumbar and sacral segments of the spinal cord. (*After Head.*)

On each area is indicated the segment of the cord by which it is supplied. For the nerves supplying each area, *see* Fig. 148.

equina, by fractures of the pelvis, by tumours of the pelvis, by psoas abscess, by fractures and dislocations of the femur, by stabs in the region of the groin, and particularly by gunshot injuries of these parts. In this nerve lesion the patient is unable to flex the hip or to raise the body from the recumbent position (ilio-psoas). The adductor muscles may simulate the action of the flexors of the hip. The power of extending the leg at the knee is lost (quadriceps extensor cruris); the function of the sartorius is destroyed and that of the pectineus impaired. Sensation is impaired in parts supplied by the internal and middle cutaneous nerves and the long saphenous nerve.

Paralysis of the obturator nerve alone is a rare condition, although it may be found associated with a like lesion of the preceding trunk. It may be brought about by the pressure exercised upon the nerve in cases of obturator hernia and by the fœtal head during delivery. The muscles implicated are the adductors, gracilis, and external obturator. The patient is unable to press the knees together, or to cross the legs. Rotation outwards is difficult, but sensation is scarcely affected in the skin supplied.

From its commencement the **great sciatic nerve** is made up of two distinct parts, each enclosed in its own sheath—a dorsal or extensor part, occupying the outer and deeper part of the nerve and becoming the external popliteal (common peroneal), and a ventral or flexor part, becoming the internal popliteal or tibial nerve. The adjacent parts of their sheaths form a septum on the great sciatic nerve, but occasionally the peroneal and tibial sheaths are separate from the beginning. In the middle third of the sciatic trunk the fibres of both divisions undergo a reassortment—a re-grouping—thus forming a plexus. This re-grouping affects the motor fibres in particular (*see* Compton, *Journ. Anat.*, 1917, li. 103). The various nerve-bundles occupy definite and constant positions in the great nerve-trunks.

Paralysis of the internal popliteal (tibial) nerve.—There is inability to flex the ankle and to flex the toes (flexor longus digitorum, flexor proprius hallucis, tibialis posticus, gastrocnemius, and soleus). The patient is unable to stand upon the toes, owing to loss of function in the two last-named muscles. The power of inverting the foot is impaired (tibialis posticus), and lateral movement in the toes is lost owing to paralysis of all the small muscles of the sole. Sensation is impaired over the plantar aspect of the toes, the sole, and in part of the lower half of the back of the leg.

In **paralysis of the external popliteal (common peroneal) nerve** the action of the muscles on the front of the leg is lost. The foot hangs down and the toes catch at the ground in walking. The foot can be neither dorsiflexed nor everted (extensor communis digitorum, extensor proprius hallucis, peroneal muscles). Adduction is imperfect, owing to paralysis of the tibialis anticus. Extension of the toes is only possible to the slight extent effected by the interossei. The arch of the foot becomes flattened owing to loss of the support furnished by the peroneus longus. Sensation is impaired over the front and outer side of the leg and on the dorsum of the foot, and also over some part of the back of the leg, owing to paralysis of the communicans peronei.

The fibres destined for any particular muscle are not assorted in one fasciculus until near their point of exit from the nerve-trunk; hence a nerve-trunk such as the internal popliteal may be partly divided without any apparent effect. This circumstance is taken advantage of in cases of infantile paralysis. In a case where the external popliteal is affected, action of the extensor muscles may be restored by suturing that nerve to a slip partially separated from the internal popliteal.

When the great sciatic nerve itself is paralysed, there will be, in addition to the loss of function in the two preceding nerves, an inability to flex the knee owing to paralysis of the hamstrings, while rotation of the limb may be impaired by loss of power in the quadratus femoris and obturator internus. Mr. Sherren found that the knee may still be flexed in such cases through the action of the gracilis, and that sensation is completely lost in only part of the sole of the foot.

A knowledge of the **segments of the cord from which the nerves of the lower limb arise** often assists the surgeon in localizing certain lesions. Section of a nerve-root, as may happen in fracture of the spine, or destruction of its centre in the spinal cord, gives rise to paralysis in a definite group of muscles and anæsthesia of a certain area of skin. The skin areas supplied by the lumbar and sacral segments are shown in Fig. 149, and these segments, according to Kocher, innervate the following groups of muscles: *Third lumbar*, the psoas, iliacus, pectineus, sartorius and adductors; *fourth lumbar*, quadriceps extensor cruris; *fifth lumbar*, gluteus medius and minimus, tensor fasciæ femoris and hamstrings; *first sacral*, gluteus maximus, short external rotators of the hip-joint, peronei, extensors of the toes and flexors of the ankle; *second sacral*, gastrocnemius, soleus, long flexors of the toes and extensors of the ankle-joint and muscles of the sole.

For the principles underlying the distribution of the limb nerves the reader is referred to p. 335. In the lower as in the upper limbs there is a considerable variation as to the segmental origin of the nerves, the variations tending towards either a *prefixed* or a *postfixed type* (see p. 335).

PART VI

THE SPINE AND SPINAL CORD

CHAPTER XXVII

THE SPINE

THE vertebral column combines in a remarkable way many very different and complicated functions. It acts as the central pillar of the body, and as the column that supports the weight of the head. It connects the upper and lower segments of the trunk. It gives attachments to the ribs. It has the property of mitigating the effects of shocks that are transmitted from various parts of the body. It permits, to a wonderful degree, of a number of most complicated movements. It forms a solid tube for the reception of the spinal cord. Finally, it represents a triumph in balancing, for in the erect position twenty-four vertebral segments are balanced one upon another by a system of active muscles, the whole resting on the sacrum as a base and supporting the skull as a crown.

It owes much of its elasticity, and of its power of breaking up divers forces communicated to it, to its **curves.** Of the four curves, two, the dorsal and sacral, are primary and are due to the formation of the thoracic and pelvic cavities, the curvatures being permanent owing to the shape of the vertebræ entering into their formation. The other two, the cervical and lumbar, are compensatory curves, and depend mainly upon the action of muscles and the shape of the intervertebral discs. The dorsal and sacral curves appear in fœtal life; the lumbar and cervical curves appear after birth, following the assumption of the erect position. The infant's spine appears straight. The only marked curve seen in the back of the young child is a general curving of the column backwards, a kyphosis. When the infant is first encouraged to sit erect, this is the outline assumed by the spine, and in some weakly children, and especially in those afflicted with rickets, this curvature is often very pronounced. The *intervertebral discs*, twenty-three in number, make up nearly one-fourth of the entire length of the spine. If the discs be removed, and the vertebræ be articulated in the dry state, the cervical and lumbar convexities almost disappear, and the column tends to present one great curvature, the concavity of which is forwards, and the most marked part of which corresponds to a point just below the middle of the dorsal region. This somewhat resembles the curve seen in the spines of the aged, and in such individuals it may be to no small extent due to the shrinking of the intervertebral discs.

It is by means of the discs that the **movements of the spine** are in the main permitted, and it will be found that they are most developed in regions where most movement is allowed. They act also as springs in giving elasticity to the column, and in economizing muscular action, while at the same time they play the part of buffers in modifying the effect of shocks transmitted along the spine.

Although the motion permitted between any two individual vertebræ is not extensive, yet the degree of movement capable of being exercised in the column as a whole is considerable. While lateral movements and those of flexion and extension are restricted in the dorsal region, those of rotation are free; hence scoliosis of the spine is most marked in this region. Movements from back to front (flexion and extension) and from side to side (lateral flexion) are freest in the cervical, dorso-lumbar and lumbar regions. From a surgical point of view the weakest part of the spinal column is between the ninth dorsal and third lumbar vertebræ. Here side-to-side and back-to-front movements occur most freely; above this region the spine is supported by the thorax; below, the intervertebral discs are larger and stronger, and the supporting ligaments and muscles better developed.

It is impossible to insist too strongly on the fact that the muscles of the back and trunk are the sole agents in **maintaining the spine erect.** The moment they are thrown out of action the spinal column loses its rigidity and collapses. All four groups of muscles which act on the spine are concerned: the extensors (erector spinæ); the flexors (longus colli, scaleni, quadratus lumborum); the lateral flexors (erector spinæ, quadratus lumborum, internal and external oblique): rotators (external and internal oblique, multifidus spinæ, semispinalis, and rotatores spinæ). By these muscles the vertebræ are maintained balanced on their intervertebral discs, one above the other. The ligaments are slack, and the surfaces of the articular processes are in only light contact. When the muscles approach exhaustion, owing to prolonged maintenance of the erect posture, partial relief may be obtained by allowing a certain degree of rotation and lateral flexion to take place. Thereby the articular processes are brought into firm contact, the ligaments become somewhat tightened, and a certain degree of passive support is obtained. School children, for instance, after sitting some time with their bodies erect, place an arm on the desk and rotate the body until the vertebræ are partly locked. In this posture the muscles are rested, but, if the position be much indulged in, the muscles become weakened in their action, and the spine may assume permanently a partial scoliosis.

Scoliosis. — In very few people do the spines of the vertebræ lie in a perfectly straight line down the back. There is commonly a slight degree of lateral curvature. If the pelvis be tilted laterally, as when the limbs are unequal in length, a compensatory lateral curve is produced. In scoliosis, lateral curvature is combined with a rotation of the vertebræ, the spinous processes turning to one side of the median line and the bodies to the opposite. It is a disease of adolescents, due to a weakness of the spinal muscles, which are unable to maintain the vertebræ in the position necessary for the erect posture. Each vertebra is provided with three levers, a posterior (the spinous process) and two lateral (the transverse processes and attached ribs). The erector spinæ acts on the lateral levers; the multifidus spinæ and muscles for the upper extremity on the posterior. It is through training these muscles by suitable exercises that the vertebræ can be restored to, and maintained in, their normal positions. The ribs form the most powerful spinal levers; in exercises to restore deformities of the spine this should be kept in mind. All the respiratory muscles act indirectly through the costal levers on the spine; hence respiratory exercises are suitable for the treatment of postural defects. Dr. Halls Dally has shown that in all forms of breathing, and especially in forced respiration, spinal movements are always present.

Sprains of the vertebral column.—The many joints and ligaments of the part, and the varied and violent movements to which it may be exposed, render it very liable to be the seat of sprains. These injuries, however, cannot reach any great magnitude, for so closely are the individual vertebræ articulated that any force severe enough to produce other than slight tearing of the ligaments will tend to cause a fracture or dislocation of the bones.

Sprains are most commonly met with in the cervical and lumbar segments of the spine. This localization is due to the mobility of these parts, and to their tendency to diffuse any violence transmitted to them, and so to render it more general. For it is to be noted that the more localized an injury, the more likely it is to produce a fracture or dislocation rather than a sprain.

In the cervical region, also, the tendency to sprain is increased by the near articulation of the column with the head, and the possibility of any violence applied to the skull being transmitted to the spine. Since the introduction of Röntgen rays in the diagnosis of such injuries it has become apparent that many lesions formerly regarded as sprains are really fractures of the body of the vertebra or of the neural arch (Sherren).

Sprains of the spine are not apt to be associated with the external evidences of ecchymosis, since between the skin and the column there intervene not only many layers of muscles, but also dense expansions of fascia.

It has already been pointed out that sprains in the loin, produced by severe bending forwards of the column, may be associated with some damage to the kidney and consequent hæmaturia (p. 448).

A sprained back is often the seat of a considerable degree of pain and stiffness, which persists long after the immediate effects of the lesion must have passed away. Such a condition may be understood by noticing that the column presents a vast number of separate articulations, each provided with cartilage, synovial membrane, and capsular ligaments. These joints have no qualities that exempt them from the common evils incident to sprains of more superficial articulations; and there is little doubt that the long-felt pain and inconvenience often depend upon some synovitis of the vertebral joints. In a few cases this synovitis has gone on to suppuration, and in one instance at least the pus so formed found its way into the spinal canal and induced some mischief in the cord. The muscles, too, are frequently ruptured, and processes of the vertebræ may be torn away.

In some cases the *transverse processes of the fifth lumbar vertebra* are massive and come in contact with the base of the sacrum when the body is moved sideways. Such movements may be accompanied by pain and may be the cause of certain conditions of weakness in the lumbar region of the spine (Goldthwaite).

Fractures and dislocations of the spine.—The effects of violence applied to the column are much diminished by the general elasticity of the spine, by its curves, and by the circumstance that it is composed of a number of separate segments. Each vertebra meets the one immediately above or below it at three points of contact, the body and the two articulating processes. The bodies are separated by the intervertebral disc, which acts as an excellent spring or buffer in modifying the effects of violence. The articulating processes are more or less wedge-shaped, the thin edge of one being applied to the base of the other. When a force that tends to compress the vertebræ together is applied to the column, the bases of the two wedges are brought into closer and closer relation, and thus an increasing resistance is offered to the compressing power.

The parts of the spine most liable to injury are (1) the atlanto-axial, (2) the cervico-dorsal, and (3) the dorso-lumbar. In the atlanto-axial region the parts not only enjoy a very considerable degree of movement but are very directly influenced by many forms of violence applied to the head. In the two other regions it will be noted that a flexible part of the spine joins a comparatively rigid segment of it, and thus violence applied to the column in either of these districts is apt to be concentrated rather than diffused. The sternum and ribs act as a splint to the dorsal part of the column. The mechanism is in a way illustrated by the circumstance that a fishing-rod when it snaps commonly breaks near a joint, that is to say, at a spot where a flexible segment of the rod meets a less elastic portion. In the dorso-lumbar region, moreover, the vertebræ, although they have to support almost as much weight as have those of the lumbar region proper, are yet disproportionately small in size. Being placed, also, near the middle of the column, they can be influenced on all sides by a powerful amount of leverage. The gravity of all injuries to the spine depends upon the risk of damage to the cord enclosed in the column. Apart from this complication, fractures and dislocations in this region are apt to do well, and, if the patient survive, the former lesions nearly always heal readily.

The position of the cord within the vertebral canal and the arrangement of its membranes are such as to present many facilities for escaping injury from violence. These will be dealt with subsequently in speaking of the cord itself. It may, however, be noted here that the construction of the vertebræ, and their relation to one another, are of a character to afford much protection to the cord, even in cases where they themselves are extensively damaged. "Being lodged in the centre of the column, it (the cord) occupies neutral ground to forces which might cause fracture. For it is a law in mechanics that when a beam, as of timber, is exposed to breakage, and the force does not exceed the limits of the strength of the material, one division resists compression, another laceration of the particles, while the third, between the two, is in a negative condition" (Jacobson, Holmes's "System"). Now, it happens that fractures of the spine are most often due to violence that bends the column forwards.

The anterior segment, in such a case, will be subject to compression, the posterior to laceration, and the intermediate portion will be in a neutral condition. When the spine is examined, it will be found that its anterior part, composed of the large cancellous bodies, is excellently adapted to resist the effects of compression, while its posterior parts, composed of slighter and more compact bones and surrounded by many strong ligaments, are well arranged to resist the effects of a tearing force. The spinal cord, situated between these two divisions, occupies the position of least danger.

The vertebræ may be fractured without being dislocated, but a dislocation without a fracture seldom occurs.

It would appear, indeed, that a luxation of the spine, with no fracture of the bone, cannot occur in either the dorsal or lumbar regions. Jacobson, in the essay above referred to, writes: "I believe I am correct in stating that there is no case recorded, and thoroughly verified, in recent years, of dislocation of the lumbar or dorsal vertebræ unaccompanied with any fracture of the body, transverse or articular processes." Dislocation without fracture is, however, met with in the cervical spine. When it occurs it most often involves the fifth vertebra, which, with the rest of the column above it, is displaced forwards and downwards. The luxation is usually bilateral and incomplete, and is the result of a forcible bending of the head and upper part of the spine forwards and downwards. When situated high up the displacement may be appreciated by an examination of the part through the pharynx. The degree of deformity may be slight, and the spinal injury overlooked. The paralysis below the level of the dislocation may be incomplete; so that a diagnosis of injury to the brachial plexus may be made when it is really one of the spine and cord (Sherren). In the complete bilateral dislocation the cord is usually hopelessly crushed. These luxations have been reduced by forcible extension, although the circumstances under which such a procedure is advisable are neither frequent nor very distinctly marked.

Since, in severe injuries, dislocation and fracture are so usually associated, it is common to deal with these lesions under the title of **fracture-dislocation.** They may be due (*a*) to indirect, (*b*) to direct violence.

(*a*) The injuries from **indirect violence** are by far the more common. They are due to a violent bending of the head, or of the spine above the seat of lesion, forwards and downwards. Thus, the cervical spine has been more than once broken by a "header" into shallow water; these accidents were particularly common in the first summer of the Great War, when English soldiers undergoing training were bathing in unfamiliar shallow pools. In all cases the dislocation occurred in the lower cervical region, where the flexible cervical met the more rigid dorsal segment of the spine. In several cases death was caused by the careless handling of the unconscious patient, for the cervical part of the cord then lay unprotected and subject to injury during any unguarded movement. The dorsal vertebræ have been fractured and displaced by the acute bending of the column produced by a heavy sack falling upon the back of the neck.

This form of injury is most commonly met with in the cervical and upper dorsal regions. These parts of the column possess great mobility, the bodies that compose them are not large, and are influenced by violence applied to the head. In a well-marked case there is some crushing of the vertebræ involved, and the usual deformity depends upon the centrum above sliding downwards and forwards upon the centrum below. Complete displacement of any two vertebræ from one another is prevented by a locking of the posterior processes. In some cases the luxation is complete, a condition that is least frequently met with in the lumbar spine.

In the cervical and dorsal regions the parts, after the dislocation, may often be returned to their normal position; but in the loins this replacement is usually impossible, owing to the locking of the large and powerful articular processes. In the neck the laminæ and spines may be fractured, while the articulating processes, being broad and nearly horizontal, usually escape, even when there is much displacement of the parts. In the dorsal spine the laminæ and articular processes are always torn when displacement occurs. In the lumbar region the articular processes usually escape fracture although they are violently torn asunder. In all cases there is more or less laceration of the intervertebral discs, and the supraspinous, interspinous, and capsular ligaments are torn, as are also the ligamenta subflava. When the bodies are much crushed and displaced the anterior and posterior common ligaments are commonly ruptured.

(*b*) In the fracture-dislocations due to **direct violence** the lesion may be at any part of the spine. Some form of direct violence is applied to the back, and the column tends to become bent backwards at the spot struck. In the previous class of injuries it will be noted that the anterior segments of the vertebræ suffer compression, while the posterior suffer from the effects of laceration and a tearing asunder of their parts. In lesions due to direct violence the circumstances of the injury are reversed; the posterior segments tend to be crushed together, while the bodies on the front of the spine are separated.

Much displacement is very rarely met with in this form of accident. To produce separation of the vertebræ the violence must be extreme, and as a rule the force expends itself upon a crushing of the hinder portions of the spinal segments. It follows from this that injury to the cord is less common and less severe in lesions due to direct violence than in those due to indirect violence. In the atlanto-axial region the atlas and occipital bone have been dislocated from one another by direct violence, although the most frequent lesion is a dislocation of the former forwards upon the axis, a lesion usually, if not always, associated with fracture of the odontoid process. The transverse process of the atlas can be felt between the mastoid process and the jaw when it is in normal position (E. Corner).

The spinous processes may be broken off as a result of well-localized blows or of sudden strains or contractions due to muscular action. The prominent spines in the lower cervical region and the long processes of the dorsal tract of the column are those that usually suffer. The lumbar spines are less frequently broken, being comparatively small and well protected by the great muscles of the back.

Since the introduction of X-rays as an aid to diagnosis it has been found that in falls, and as a result of sudden muscular effort, it is not uncommon for the transverse processes of the lumbar vertebræ to be broken. In this connexion it should be remembered that it is not uncommon for a costal process to be attached to the first lumbar vertebra—a *lumbar rib*—thus simulating a fracture of a transverse process. In great exertions, as in lifting or carrying heavy weights on the back, the psoas and quadratus lumborum may actually fracture the transverse processes of the lumbar vertebræ to which they are attached.

In some instances of fracture-dislocation and of fracture alone the spine has been **trephined**, or rather portions of the laminæ and spinous processes have been resected (**laminectomy**). By this means the spinal canal has been freely opened up, effused blood has been allowed to escape, and the cord has been freed from pressure. The laminæ are divided as near the transverse process as possible, and the tough ligamenta subflava require careful division.

The column is reached through a median

incision, and the great muscular masses are cleared from the spinous processes and laminæ on either side. The wound being nearly median, the bleeding is not excessive. The dorsal spinal plexus of veins lies along the spines and over the laminæ. On the deep surface of the laminæ lie the posterior longitudinal spinal veins.

This operation has also been carried out with success in cases of paralysis due to pressure upon the cord by displaced bone or inflammatory exudations in caries of the spine (Pott's disease). It has to be noted, however, in the last-named class of case, that the condition exhibits a tendency to spontaneous cure.

CHAPTER XXVIII

THE SPINAL CORD

THE spinal cord is, in the adult, about 18 inches in length, and extends from the lower margin of the foramen magnum to the lower edge of the body of the first lumbar vertebra. In some cases, particularly in women and children, it ends at the second or even third lumbar, and in other instances at the last dorsal vertebra. It is to be noted also that in flexion of the spine the cord is a little raised. When the body is bent and the arms are stretched out the lumbar part is raised 10 mm. In the earlier months of fœtal life the medulla spinalis occupies the whole length of the vertebral canal, but after the third month the canal and lumbar and sacral nerves grow so much faster than the cord, that by the time of birth it reaches no farther than the third lumbar vertebra. Obviously it is a great advantage, in cases of injury, that the spinal cord does not occupy that part of the vertebral pillar which joins the base of the column, and which not only permits of considerable movement, but is liable also to frequent wrenches and strains. It is important to recollect that, although the cord itself ends at the spot indicated, the dura mater, the arachnoid, and the collection of cerebro-spinal fluid extend as far as the third piece of the sacrum (Fig. 151). Injuries inflicted, therefore, upon the spine as low down as this latter point may cause death by inducing inflammation of the meninges. The cord in the dorsal region measures about 10 mm. from side to side, and 8 mm. in the antero-posterior direction. The cervical enlargement is largest opposite the fifth or sixth cervical vertebra, where it measures about 13 mm. from side to side. The greatest part of the lumbar enlargement is opposite the twelfth dorsal vertebra, where its lateral measurement is about 12 mm.

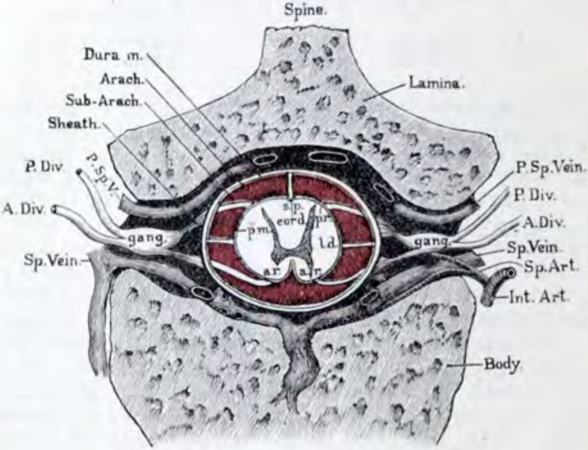

Fig. 150.—Section through spinal cord, membranes, and spinal canal.

a.r., At origin of anterior root; p.r., at origin of posterior root; s.p., septum posticum; p.m., pia mater; l.d., ligamentum denticulatum. The arachnoid (arach.), dura mater (dura m.), and subarachnoid space are shown.

The **spinal dura mater** is a strong and substantial membrane, and between it and the walls of the vertebral canal a considerable space exists, occupied by loose areolar tissue and a plexus of veins (Fig. 150). It is tough, and may remain undamaged when the cord is completely severed by a crushing force. It will be readily understood that injury and inflammation of the meninges, as results of lesions applied to the spine, are much less frequent than are like complications after injuries to the skull. The looseness of the spinal dura mater, its freedom from any but slight and occasional attachments to the bone, and the space around it in which effusions can extend with little possibility of becoming limited, will explain the rarity in the spine of those complications which follow upon depressed bone and extravasations of pus and blood in connexion with the dura mater within the skull. The plexus of thin-walled veins that occupies the interval between the theca and the bones may prove a source of extensive hæmorrhage in cases of injury to the column. The blood so poured out tends to gravitate to the lowest part of the canal, and when sufficient in quantity may produce pressure effects upon the medulla spinalis.

Over the arches at the posterior aspect of the vertebræ is situate a plexus of vessels (the dorsi-spinal veins) that receives blood from the muscles and integuments of the back. These vessels communicate through the ligamenta subflava with the venous plexuses within the spinal canal, and by means of this communication inflammation from without may be conducted to the theca of the cord. Thus, spinal meningitis has followed upon deep bedsores, and upon suppurative affections situated in the immediate vicinity of the spinal laminæ.

Within the dura mater are two spaces, the **subdural** and the **subarachnoid**, as in the skull (*see* p. 37). The arachnoid is closely applied to the dura mater, the subdural being merely a potential space, while the subarachnoid is extensive (Figs. 150 and 151), and occupied by cerebrospinal fluid which surrounds the cord, and is continuous with the great subarachnoid spaces at the base of the brain (Fig. 10, p. 39). By means of this open communication inflammatory affections may readily spread from the cord to the brain. Into these spaces blood may be extravasated in cases of injury. Instances have been recorded where the theca has been opened by a wound, and the cerebro-spinal fluid has escaped in large quantities The fluid normally contains 0·05 per cent. of albumin, but if the membranes are inflamed the percentage may be double that amount. In certain conditions the pressure

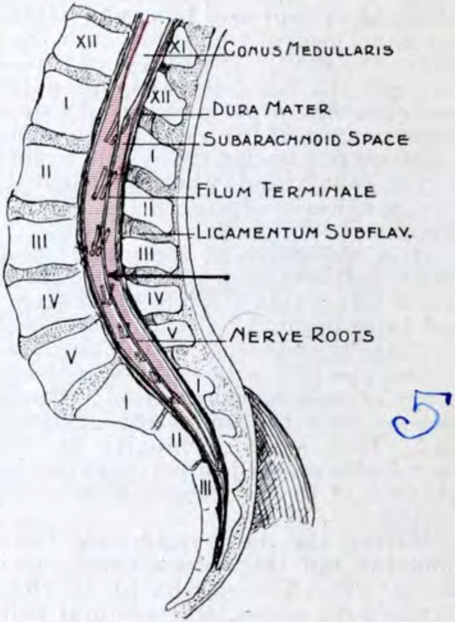

Fig. 151.—Vertical section of the lower part of the spinal column to show the position and extent of the subarachnoid space.

The arrow shows the point for lumbar puncture.

of the fluid may rise to such an extent as to cause death. In normal conditions the fluid is absorbed at any pressure above that of the surrounding veins (Hill). In the recumbent posture the pressure should support a column of water

2 inches high; in the upright posture, 6–8 inches. With each muscular effort, as in coughing or in sudden expiratory exertion, the intraspinal veins dilate and the cerebro-spinal pressure rises. In disease it may rise to ten times the normal amount. The pressure may be relieved by a *lumbar puncture*, made by thrusting a needle 8–10 cm. long into the subarachnoid space in the lumbar region of the spine. A point is selected between the third and fourth lumbar spines, exactly in the middle line, because here the interlaminar spaces are widest and the danger of wounding blood-vessels and nerve-roots is less than if a lateral point were selected. The fourth lumbar spine may be readily identified because it lies on a level with the highest points of the iliac crests (Fig. 152). The interlaminar space is much increased when the spine is bent forwards; hence the patient is placed bent and reclining on the side, or in a sitting posture and leaning forwards. The point of the trocar is pushed in the direction of the umbilicus (Flack). The needle perforates the ligamentum subflavum between the laminæ. Convulsions follow if the pressure be reduced much below the normal. At this level the cord cannot be injured, but the needle may pierce one of the lower nerve-roots, causing twitching in muscles of the lower extremity.

The *injection of stovaine or allied substances into the subarachnoid space* to produce spinal analgesia is performed at the same point as lumbar puncture. The injection should not be made until the cerebro-spinal fluid escapes freely from the cannula when the trocar is withdrawn, for unless this occurs the cannula is not yet within the subarachnoid space. Usually 20–30 cm. of fluid is withdrawn, and replaced by an equal amount of fluid or serum. In cases of cerebral compression there is a risk, when fluid is suddenly withdrawn, of the medulla and cerebellum being forced like a cork into the foramen magnum, becoming thus compressed and anæmic, with sudden death as a result. Mr. Barker has pointed out that the lowest part of the subarachnoid space when the body is supine is that

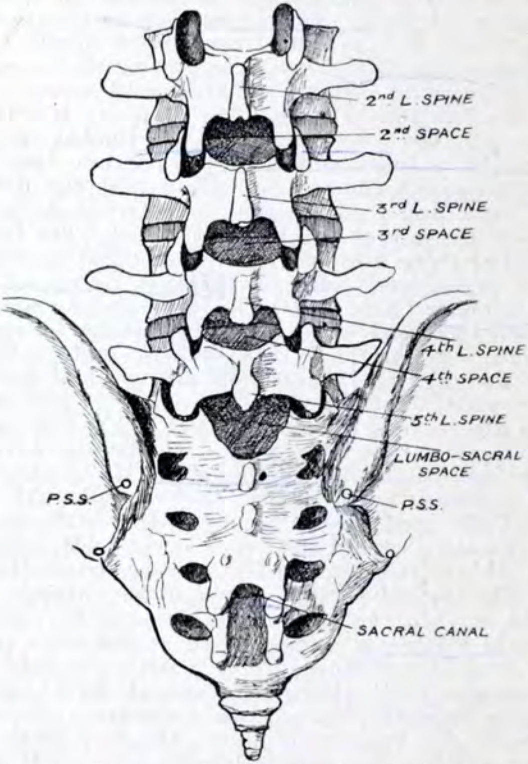

Fig. 152.—Diagram of the lumbar interlaminar spaces, showing the position of the fourth lumbar spine.

situated in the mid-dorsal region, and that therefore a fluid which is of greater specific gravity than that of the cerebro-spinal fluid (1007) will tend, if injected in the lumbar region, to gravitate to that part. By raising and lowering the patient's shoulders the rate of diffusion of the anæsthetic can be regulated to a considerable degree. Injections have also been made in the upper dorsal and cervical regions through the interlaminar spaces, the spine being bent to extend these to their greatest width.

The position of the cord is such that it is not readily reached in incised and punctured **wounds** The only spots at which it is easy of access are the intervals between the atlas and occiput and the

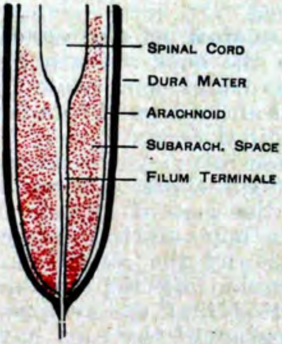

Fig. 153.—Diagrammatic vertical section of the conus medullaris, filum terminale, and spinal membranes.

atlas and axis. Many cases have been recorded of fatal wound of the cord in these positions. Lower down in the column the medulla spinalis may be reached if the wound have a certain direction. Thus a case is reported where a pointed body entered the canal between the ninth and tenth dorsal vertebræ, having been introduced from below upwards.

Several examples of damage to the cord by sword or bayonet wounds have been put on record, but in most of these instances the wound was associated with some fracture of the protecting bone. Modern bullets, with their high velocities, cause great damage when they enter the spinal canal, not only to the structures lying in their immediate track, but also to remote parts. Such bullets, when they enter the cerebro-spinal cavity —a closed cavity—exercise an explosive effect, leading to hæmorrhages and bruising of all parts within the enclosed space.

The pia mater forms a strengthening sheath for the cord. On it the arteries ramify before entering to supply its substance. The vertebral, intercostal, lumbar, ilio-lumbar, and lateral sacral arteries send twigs along the nerve-roots to the cord.

Concussion of the cord.—After certain injuries to the back a train of symptoms, usually of a severe and complicated character, has been described and assigned to a concussion or shaking of the spinal cord.

In these injuries it is assumed that, as a result of a sudden shock transmitted to it, the cord becomes the seat of minute hæmorrhages, which lead to a more or less severe disturbance of its function; and the condition has been compared to concussion of the brain, although it must be admitted that the symptoms often accredited to concussion of the cord have a character more complex than those seen in like lesions of the more complex organ.

The spinal cord is swung or suspended in its bony canal, and is separated from the walls of that canal on all sides by a considerable interval. It is, indeed, only held in position by the nerve-trunks that pass out from it through the intervertebral foramina, and by its connexions with the theca. Above, it is connected with that part of the brain that lies upon the largest intracranial collection of cerebro-spinal fluid (p. 38), and it would appear that the most violent movements possible of the brain within the skull could be but very feebly communicated to the spinal cord. The cord, moreover, within its theca, is surrounded on all sides by a space occupied by cerebro-spinal fluid. It is difficult to understand, therefore, how a structure so protected can be so violently disturbed by a shock received upon the body as to undergo a grave and progressive loss of function. The cord is, indeed, somewhat in the position of a caterpillar suspended by a thread in a phial of water. It would probably be difficult permanently to disturb the internal economy of such an insect (even if it had a structure as elaborate as the cord) by other than violence that would be comparatively excessive.

Contusion and crushing of the cord.—As has already been observed, the gravity of fractures and dislocations of the spine depends upon the extent of the damage received by the cord. In these accidents it is very usual for some part of the injured vertebra to be projected into the spinal canal, so as to press upon or actually crush the delicate nerve-centre that it contains.

It is needless to observe that the cord is extremely soft, and thus it happens that it may be entirely broken up by violence without the membranes being perceptibly damaged. Indeed, in fracture-dislocations it is unusual for the theca to be torn, and it is possible for the cord to be quite crushed at some one spot without the corresponding membranes being in any way lacerated. The amount of damage inflicted upon the cord will vary, of course, with the magnitude of the accident; but, other things being equal, it will be found to be more severely injured in fracture-dislocations of the cervical and dorsal segments than in like lesions in the lumbar spine. In the atlanto-axial region the amount of displacement that follows upon luxation of the two bones from one another is such that the cord is, as a rule, severely crushed, and death ensues instantaneously, as is seen in cases of death by hanging. In the cervical and upper dorsal segments of the column the vertebral bodies are small, the spine is mobile, the fractures met with in these parts are usually due to indirect violence, and are associated with much displacement. In the lower dorsal region, again, the greater rigidity of the spine renders any displacement, when it does occur, likely to be considerable. In the lumbar region, on the other hand, it must be noted that the cord only extends to the lower border of the first vertebra. The bodies of the vertebræ, also, in this district, are very large and cancellous, and can undergo a severe amount of crushing without a corresponding degree of displacement being produced. The part, too, is well protected by the large intervertebral discs, and by the immense masses of muscle that surround the spine in the loins. Such portion of the spinal cord as extends into the lumbar region is protected also by the many cords of the cauda equina, which, by their looseness and comparative toughness, tend to minimize the effects of violence.

The degree of displacement of bone required to produce pressure effects upon the cord is often greater than would be supposed. At post-mortem examinations portions of injured vertebræ have been found encroaching upon the spinal canal to a considerable extent in cases where no evidences of damage to the cord existed during life. Dr. J. W. Ogle reports the case of a man who, after an injury to the neck from a fall, presented no spinal symptoms until three days had elapsed. He ultimately became paralysed, and died thirty-two days after the accident. The autopsy revealed a dislocation forwards of the sixth cervical vertebra, of such an extent that the body below projected at least $\frac{1}{2}$ an inch into the spinal canal.

The remarkable manner in which the cord will accommodate itself to a slowly progressing pressure is often well seen in the results of chronic bone-disease in the column.

The symptoms due to injury to the cord and to the nerves contained in the spinal canal will obviously depend upon the situation and extent of the lesion. The diagnosis of the situation of the lesion is complicated by the relation the nerves bear to the various vertebræ, and by the fact that the majority of the great trunks arise from the cord at a spot above the point at which they issue from the vertebral canal. The two highest nerves, the first and second cervical, pursue an almost horizontal course in their passage from the cord to their points of exit from the canal. The remaining nerves take a more and more oblique direction, until at last the lowest nerve-trunks run nearly vertically downwards as they pass to their respective intervertebral foramina.

Points of exit of nerves from the vertebral canal.—The first cervical nerve leaves the canal above the first cervical vertebra. The remaining cervical trunks escape also above the vertebræ after which they are named, the eighth cervical nerve leaving the canal between the last cervical and the first dorsal vertebræ. The dorsal, lumbar, and sacral nerves have their points of exit *below* the vertebræ after which they are named. Thus, the first dorsal nerve will pass through the foramen between the first and second dorsal vertebræ, and so on.

Points of Origin from the Cord

The first cervical nerve arises from the cord opposite the interval between the atlas and occiput.

The second and third cervical nerves arise from the cord opposite the axis.

The fourth, fifth, sixth, seventh, and eighth cervical nerves arise from the cord opposite the third, fourth, fifth, sixth, and seventh vertebræ respectively.

The first four dorsal nerves arise from the cord opposite the discs *below* the seventh cervical and the first, second, and third dorsal vertebræ respectively.

The fifth and sixth dorsal nerves arise from the cord opposite the lower borders of the fourth and fifth vertebræ.

The remaining six dorsal nerves arise from the cord opposite the bodies of the sixth, seventh, eighth, ninth, tenth, and eleventh vertebræ.

The first three lumbar nerves arise from the cord opposite the twelfth dorsal vertebra.

The fourth lumbar nerve arises from the cord opposite the disc between the twelfth dorsal and first lumbar vertebræ.

The last lumbar nerve, together with the sacral and coccygeal nerves, arises from the cord opposite the first lumbar vertebra.

It will be seen, therefore, that in noting the symptoms due to crushing of the entire nerve contents of the vertebral canal at a certain spot, account must be taken, not only of the effects of damaging the medulla at that point, but also of the result of lacerating nerve-trunks that may issue there, although their origins are above the seat of lesion. The cord is also very often only damaged in part, or it may entirely escape, while one or more nerves are crushed by the fractured vertebræ or by fragments of bone separated by the lesion.

In fracture-dislocations the upper vertebral body, as already stated, usually glides forward, with the result that the anterior and antero-lateral parts of the cord are brought into violent contact with the projecting border of the vertebra below the seat of lesion.

It is in these parts of the cord that the main motor tracts run, and thus it happens that motion is more often lost in the parts below the site of the injury than is sensation. If there be partial motor and sensory paralysis, the disturbance of the former function is likely to be in excess of that of the latter. In no case, indeed, does there appear to have been a loss of sensation without, at the same time, some disturbance in the powers of movement. If the grey matter of the cord be not severely damaged, reflex movements appertaining to that segment of the cord can usually be induced in the paralysed parts by proper stimulation. If those reflex movements be lost, it may be inferred that the grey matter is broken up, and that the entire spinal medulla has been crushed at the seat of lesion.

The higher up the fracture in the column the greater is the tendency for the **function of respiration** to be interfered with. If the lesion be at the upper end of the dorsal spine, then not only will all the abdominal muscles be paralysed, but also all the intercostals. A fracture associated with injury to the cord, when above the fourth cervical vertebra, is, as a rule, instantaneously fatal. The phrenic nerve comes off mainly from the fourth cervical nerve, receiving contributions also from the third and fifth. The fourth nerve issues just above the fourth cervical vertebra. If the cord be damaged immediately below this spot, the patient can breathe only by means of the diaphragm; and if the lesion be so high as to destroy the main contribution to the phrenic, respiration of any kind becomes impossible.

Certain **disturbances of micturition** are frequent in cases of injury to the cord. The reflex centre for this act is lodged in the lumbar enlargement. The irritation of the vesical walls, produced by the increasing distension of the bladder, provides the needful sensory impulse. This impulse is reflected to the nerves controlling the bladder muscles, and especially to the detrusor urinæ, and by their contraction the organ is emptied (p. 488). The action, however, can be inhibited by voluntary impulses passing down from the brain to the lumbar centre, and the tendency to a frequent discharge of urine is resisted by contraction of the sphincter. When, therefore, any part of the cord between the lumbar centre and the brain is damaged, inhibition can have no effect. Immediately after the accident the temporary suspension of reflex actions from shock produces some retention of urine, and after that the bladder empties itself at frequent intervals, the patient being unconscious of the act and unable to influence it.

If the centre itself be damaged in the lumbar cord, the bladder itself may attain a power of periodical action, over which, of course, the patient has no control; and a like result will follow if the nerve connexions between the cord and bladder below the spinal centre have been destroyed. The principal nerves connecting the medulla spinalis with the bladder are the third and fourth sacral.

The act of **defæcation** also is apt to be disturbed in a like manner. Here there is, as in the previous case, a reflex centre in the lumbar enlargement, with motor and sensory nerves connecting it below with the rectum and its muscles; and also between this centre and the brain are tracts, but little known, along which inhibitory actions can extend. In lower animals the brain has but an imperfect control of these reflex centres, but even in them this control can be established by education.

When the centre itself is damaged, or the connexion severed that unites it with the viscus, the patient will suffer from incontinence of fæces and will be unable in any way to control the act. When the cord is damaged at any spot between the reflex centre and the brain, then the act of defæcation will be performed at regular intervals, without either the patient being conscious of the act or being capable of inhibiting it.

In some injuries to the cervical cord the patient has suffered from **severe vomiting** for some time after the accident, or has exhibited a remarkable alteration in the action of his heart. Mr. Erichsen, for example, reports the case of a man who, after a severe blow upon the cervical spine, continued to vomit daily for several months. In the other category, instances have been recorded where the pulse has sunk as low as 48, or even 36 or 20, after lesions to the column in the neck.

It should be remembered that the accessory trunk has origin from the cord as low down as the sixth or seventh cervical nerves. Some details concerning the position of centres in the spinal cord, connected with areas of skin, groups of muscles, and viscera, have been given already when dealing with the nerve supplies of the abdomen and extremities (*see* pp. 361 and 646).

Spina bifida.—This term refers to certain congenital malformations of the vertebral canal associated with the protrusion of some of its contents in the form of a fluid tumour. The malformation usually consists in an absence of the neural arches and spines of certain of the vertebræ, and the tumour therefore projects posteriorly. Spina bifida is most common in the lumbo-sacral region, the neural arches of the last lumbar and of all the sacral vertebræ being absent. In development the neural arches close first in the dorsal and last in the lumbo-sacral region. Next in frequency it is found limited to the sacral region. It is rare elsewhere. (1) The membranes may protrude alone (*spinal meningocele*). (2) The membranes may protrude together with the spinal cord and its nerves (*meningo-myelocele*). (3) The membranes may protrude with the cord, the central canal of which is dilated so as to form a sac-like cavity (*syringo-myelocele*).

The **meningo-myelocele** is the most common form. The first-named variety is rare, the last-named very rare. The fluid which distends the sac is cerebro-spinal fluid, and is continuous with that system of the cord and brain. When compressed, the fluid is forced into the subarachnoid spaces at the base of the brain, which is forced upwards against the anterior fontanelle, where its impact may be felt. The tumour becomes enlarged and tense when the child cries. The distension of the cerebral and spinal veins forces the fluid in the direction of least resistance. The wall of the sac is formed by (1) the membranes, (2) the skin, and (3) an intermediate membrane corresponding to the flattened-out, unclosed neural lamina which represents the lumbar part of the spinal cord and to which the nerves are attached. Hence, with spina bifida there is usually a greater or less degree of paralysis and anæsthesia, with malformation of the lower limbs and perineum.

The defect is produced at an extremely early stage of development, and hence part of the cord or of the nerves in the region of the tumour may be absent or defectively developed. In some cases the nerve affection takes the form of club-foot of a severe grade. In other instances there is more or less complete paralysis of the lower limbs, bladder, and rectum.

Operations upon the cord.—The late Sir Victor Horsley and others have cut down upon the spine and removed a tumour from the spinal cord with perfect success, and with relief to the symptoms from which the patient was suffering. The spinal canal has also been exposed in certain cases where callus in an old fracture of the spine was pressing upon the cord, or where a small osseous growth was encroaching on the canal.

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