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A Novel Approach to Inquiry-Based Learning Models in the Sciences:
Utilization of Case Presentations and Patient Encounter
Workshops in High School Life Science Classrooms

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(ABSTRACT)

A novel approach to inquiry-based learning models is needed in a curriculum that reflects changing demographics, societal demands, and diverse cultural background. The proposed module which is designed to teach the urinary system to Fort Worth Independent District high school biology students as outlined in the Texas Essential Knowledge and Skills (TEKS) guide, represents application of this novel tool in the classroom. It is designed to be implemented in inquiry-based learning classrooms that function to encourage the natural process of inquiry throughout grade levels. The proposed module takes advantage of media resources, introductory case reports, and patient encounter workshops that outline diet, disease, and health disparities as a way to capture student interest in content relevant material, engage students in the daily lessons, and invoke long-term retention of basic life science concepts. Through future research and testing of module design and effectiveness in the classroom, the proposed approach to inquiry-based learning may serve to optimize student understanding of fundamental science concepts and diet and disease as it relates to normal body function, with implications that may affect change in lifestyle. Furthermore, the proposed learning module, if effective, may also serve as a template to be used to teach other life science subjects.

A NOVEL APPROACH TO INQUIRY-BASED LEARNING MODELS IN THE SCIENCES: UTILIZATION OF CASE PRESENTATIONS AND PATIENT ENCOUNTER WORKSHOPS IN HIGH SCHOOL LIFE SCIENCE CLASSROOMS

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"To whom much is given, much is required"- unknown.

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CHAPTER 1

INTRODUCTION

Background

The work of John Dewey and Paul MacLean (along with their successors) has contributed immensely to the present educational practices across the world. The revolutionary educational theories of John Dewey (1859-1952), who spearheaded educational reform during the first half of the 20th century, shaped the progressive education movement by highlighting interaction, reflection, experience, community interest, and democracy as practical components of education[1]. Paul MacLean, professor and head of the Laboratory of Brain Evolution and Behavior at the National Institute for Mental Health in the late 1960s-70s, offered educators a greater understanding of why good teaching strategies work. In addition, he discussed how educators can fine-tune their instructional techniques and reallocate education resources to take advantage of how the brain learns[2]. Through the work of these pioneers, their successors, and educators who offered experiential wisdom, the educational practices of today have ventured away from linear, "sit down-and-learn" instructional approaches toward classrooms that promote "active" learning on the part of the student.

Further educational advancements developed as populations of students became less homogeneous, more diverse and, thus, more multicultural. Between 1950 and 2000, the U.S. population expanded by over 42 million, with U.S. immigrants (Hispanic, Filipino, Vietnamese, and Russians) accounting for 35% of the increase[3]. This trend in national diversity is also reflected through examination of state demographics, such as those of Texas. For example, in one Texas school (Paschal High School- Fort Worth, TX), 14% of the students are African-American, less than 1% are Indian-American, 3% Asian American, 41% Hispanic American and 42% Anglo-American. Moreover, the cultural differences that exist among these populations make American classrooms even less homogeneous[4]. As a consequence, instructional practices that function to meet the needs of homogeneous populations may no longer be sufficient. Academic and social curricula should reflect students' cultural diversity and prior knowledge, along with varied learning styles and preferences.

In response to changing demographics in American classrooms, educators have begun to consider societal needs, responsibilities, and experiences that 21st century youth face daily. Employing an educational system that addresses life lessons, literacy and household demands, along with content knowledge and skills, is now essential if we are to produce students who function successfully in school, home and the workplace. As a result, traditional methods of teaching, wherein the instructor provides a set of stimuli and reinforcements in an effort to elicit a desired outcome from the students, are being replaced by "active-learning" models[5]. These active learning models, called inquiry-based and cooperative learning models, present varied stimuli to students and ask them to become critical thinkers, owners of their education, and team-workers (see Table I). Given the shortcomings of traditional models that focus on mastery of content, with less emphasis on the development of skills and the nurturing of inquiring attitudes, i.e. the 'what' versus the 'how', the constructivist approach, in which students are asked to construct new ideas and concepts based on current/prior knowledge (with teacher guidance), now appears to be a better way to educate today's youth[6]. In this paradigm, education is a mix of traditional lecture, cooperative learning, and inquiry-based learning with a continuing shift away from the former and toward the latter throughout students' academic careers.

Table I: Comparison of Learning Models (Johnson et al. 1991; Smith and Waller 1997)[25].

Traditional Learning	**Cooperative Learning**	**Inquiry-based Learning**
-Low interdependence. Focus on individual performance.	-High positive interdependence. Focus is on joint performance.	-Groups not essential, but highly recommended. Outcome dependent on group interdependence.
-Individual accountability only.	-Both group and self-accountability.	-Both group and self-accountability.
-Little or no attention to group formation. Students often select their own groups, or may be set randomly.	-Teachers form groups based on knowledge, experience and interest.	-Teachers form groups based on knowledge, experience and interest.
-Assignments are prescriptive, with little commitment to each other's learning.	-Assignments may be prescriptive. -Members promote each other's success.	-Assignments are open-ended and foster critical thinking.
-No group processing of the quality of its work. Individual	-Group processed quality of work and how effectively	-Group processes quality of work. Presentation of results

accomplishments are rewarded.	members are working together. Continual improvement is emphasized.	is a must.
-Teamwork skills are ignored.	-Teamwork skills are emphasized and leadership shared by all.	-Teamwork skills are emphasized because real time trouble-shooting is required. Leadership is recommended to coordinate activities and facilitate timely submission of products.

Successful transitions from traditional to new paradigms require increased responsibility on the part of the student and the teacher, while also necessitating increased motivation, incorporation of multiple resources and experiences that are applicable and long-lasting[7]. If student learning is to shift from passive to active, students must be given more responsibility in their classrooms. Students must be allowed to become partial owners of their education. Educator responsibility must also be expanded if attempts to develop a curriculum and climate that can accomplish these objectives are to be successful. Thereby, allowing for a successful transition into new paradigms. In addition, strategies must be developed that function to reflect diverse learning preferences and needs, address needed knowledge and skills, allow for correlation with previous and future concepts, and promote student interest. Moreover, to be effective, teachers must become aware of their own teaching preferences and recognize how these preferences can either help or hinder learning in their classroom[8]. Once realized, teachers can employ a variety of strategies to facilitate learning so that all students have opportunities to succeed in and out of the classroom.

For science educators, paralleling classroom instruction with real-world tasks and healthcare issues provides an approach that may appeal to the needs, interests and learning styles of today's students. It may be that correlating instruction with information gathered from the media and/or dealt with in homes across the nation is a means by which educators can spark and maintain the interest of students as they attempt to equip students with knowledge and skills that can be used and enhanced throughout their lives. In using this methodology, educators should understand the magnitude in which past experiences and cultural background influence how the learner relates to and perceives what is being taught. This is critical to ensuring that connections are made and that information acquired can be applied to new situations[9].

Statement of Purpose

For the purpose of stimulating and maintaining the interest of students as they are introduced to fundamental life science concepts, the proposed teaching tool- to be used within inquiry-based learning approaches- will integrate media-driven, health-related case reports and patient encounter workshops into high school living system instruction. Case reports in which the student assumes the role of the "treating physician" will serve as an introduction to each lesson, while patient encounter workshops, which refer to simulated doctor-patient interaction, will conclude the lesson. It should be noted that case studies and patient encounter workshops are integrated (to some degree) into medical school curricula and premedical enrichment programs across the nation. Its continued use may be attributed to the effects of simulating real-life situations that involve problem solving, increasing responsibility on the part of the student to facilitate learning, and the application of knowledge and skills needed in the classroom, home, and the workplace. The case study/patient encounter methodology may also increase minority student (as well as non-minority) interest in the sciences by offering enlightening insight into healthcare disparities.

This novel tool is designed to be utilized in inquiry-based science classrooms. It functions to connect real-life issues to unit content and engage students in content material; Thereby, leading to meaningful and long-lasting understanding of living systems. Therefore, the goal of this project is to create a high school Life Science teaching module that demonstrates how this approach can be used within inquiry-based instructional approaches to teach about Living Systems. The module is specifically designed to be used by Fort Worth Independent School District Biology teachers. Implementation of this module is expected to increase participating students' interest in and understanding of living systems.

Specifically, the proposed teaching module will focus on the human renal system by examining diet and disease processes that afflict major portions of society. Moreover, student understanding of the *excretory system*, in which the renal system is a major component, is outlined in the Texas Essential Knowledge and Skills (TEKS) guide for High School Biology. This guide, sponsored by the Texas Education Agency, serves to guide Texas educators as they prepare students for the Texas Assessment of Knowledge and Skills (TAKS) exam[10]. Moreover, as a consequence of the pathological associations of the urinary system and its inter-connectedness to other living systems, this module has the potential to affect change in lifestyle and awareness. Again, it should be noted that the proposed approach to stimulating student interest and optimizing student learning is a novel tool (in regards to FWISD Life Science instruction) that may be used to enhance "inquiry-based learning" designs.

In addition to attempting to connect the classroom with the real world, this module will also address diverse learning styles by incorporating lessons and activities that represent cooperative and competitive learning preferences (through independent and group activities), visual-print, visual-screen, auditory and kinesthetic modality preferences, and multiple intelligences. In this way, the transmission of knowledge, the acquisition of that knowledge, and the application of that same knowledge can work to maximize learning experiences for all students. While content mastery is stressed in the module, an emphasis on the process of learning will also be employed, thereby fostering develop of inquiry and literacy skills.

Significance

Developing a new tool that can be utilized in inquiry-based learning classrooms may readily engage students, provoke them to make observations and ask questions, provide answers to lingering questions, and actively connect and integrate daily experiences to the curriculum. As a result, this tool has the potential to give purpose and meaning not just to the material, but to the natural and human worlds that we live in[14]. Furthermore, optimizing an understanding of diet and disease as it relates to normal body function has implications that can affect change in lifestyle; thereby, bringing us one step closer to bridging the gap in healthcare. In this manner, life and quality of life can be intimately connected to lifestyle. If successful, this design can also be used in other dimensions of the life sciences and in other subjects as well, with healthcare disparities as a central theme.

CHAPTER 2:

INQUIRY-BASED LEARNING MODEL

History

In order to understand and appreciate the structure and design of this unique approach to introducing living system content in inquiry-based science classrooms, further exploration of educational pioneers and their contributions, along with examination of inquiry-based learning principles and methodologies is necessary. To begin, by definition, "inquiry" refers to investigation and search for information and knowledge, and encompasses both philosophy and methodology. In science teaching, the word "inquiry" is used to describe two things. In one sense, it is used to describe one characteristic of what science is. In another sense, it is used to describe what students do in a constructivistic lesson. When students are making inquiries, they are questioning and evaluating the information they are obtaining and/or observations they are making. Such an inquiry is a pre-requisite if they are to interpret their experiences in class and try to make sense of them[11].

Inquiry-based education has its basis in the revolutionary educational theories of John Dewey (1859-1952) and the revolutionary findings of Paul MacLean. Dewey was a founder of the philosophical school of pragmatism. Though his work has been accepted with a number of inconsistencies and cannot be easily placed into any one curriculum tradition that has dominated American educational systems over the last century, his influence can undoubtedly be seen in the principles that outline inquiry-based learning approaches. Without attempting to theorize and explain Dewey's philosophy of education (by using its associated terminology) in detail (which is not the purpose of this report), the process of learning and Dewey's theory of experience will be summarized in two major points.

Dewey believed that the world is not passively perceived and thereby known; rather, it is actively understood through inquiry, an integral process of learning. Dewey believed that learning occurs in three distinct phases, beginning with the introduction of a problematic situation, which refers to the stage in which a learner instinctively or habitually responds to an environment that interrupts the ongoing pursuit of the fulfillment of needs and desires[12]. Simplistically stated, Dewey is referring to the natural process that takes place in the brain when introduced to new information. He stressed in *Studies* and subsequent writings that the uncertainty of the problematic situation is not inherently cognitive, but practical and existential, occurring after the introduction of a stimulus. The second phase of the process involves the isolation of the data or subject matter which defines the parameters within which the reconstruction of the initiating situation must be addressed. In the third, reflective phase of the process, the cognitive elements of inquiry (ideas, suppositions, theories, etc.) are entertained as hypothetical solutions to the originating impediment of the problematic situation. The final test of the adequacy of these solutions comes with their employment in action. If a reconstruction of the foregoing situation meets the individual's inherent needs and desires, the information is internalized[12]. Furthermore, Dewey argued that learning occurs by doing, rather than by rote memorization and dogmatic instruction (which was the practice of his day), and that practical, real-life tasks and challenges provide the best opportunities for optimal learning[13].

In response to the above philosophy, the progressive movement of education began, wherein experiential education programs were developed-- the second summary point outlining Dewey's contributions to educational reform. The theory of experience argues that in order to design and conduct education, one must understand how experience occurs. The first principle of the theory of experience is based on continuity and states that past experiences influence present moments, which will impact the experience of all future moments. The second principle, interaction, asserts that present experience arises from interaction between past experience and present situation[14]. Dewey emphasizes that it is the responsibility of the educator to understand the dynamics of present-future interactions in order to construct/facilitate educational experiences that will provide maximum benefit both in the present and future for students.

Although there are as many interpretations of Dewey's vision as there are teachers, there is a well-defined pattern in inquiry-based learning approaches that correlates with Dewey's philosophy of education and his theory of knowledge. His philosophy has been reviewed, critiqued, and revised, but yet it remains one of the most influential theories of his time and beyond. As a result, inquiry-based learning is grounded in his assertion that learning is a process, occurring by way of problem-solving and inquiry, and is influenced by past experiences, relationship to real-life, and whether it is perceived as meaningful. While the development and implementation of inquiry-based learning approaches can be attributed to Dewey's philosophies of education and knowledge, countless educators, philosophers, and students, through experiential wisdom, have influenced the present-day goals, objectives, and application of inquiry-based learning approaches.

In the 1990's, as *The Collected Works of John Dewey* was being newly edited and published by J. A. Boydston, advances in neuroscience, cognitive psychology, technology were also being made, providing "radically new" information on how the brain works[15]. Educators began to integrate educational pedagogy that took advantage of how the brain learns, fine-tuning their instructional techniques and allocation of education resources to complement brain function. For the purpose of this paper, in-depth exploration of brain physiology will not be outlined, but will be addressed in several key principles pertaining to MacLean's Triune Theory, and evidentiary support of sensory input and the emotional framework for learning.

The Triune theory, which was published in 1990 by Dr. Paul MacLean, a scientific pioneer and head of the Laboratory of Brain Evolution and Behavior at the National Institute for Mental Health in the late 1960s-70s, suggests that most behaviors are the result of complex cooperation among these three formations (and systems) of the brain-the reptilian, mammalian and neo-cortex. The reptilian brain, or sensory motor brain, governs voluntary and involuntary muscle movement, and our basic needs for food, shelter and territory. This brain keeps us in touch with our basic instincts and our surrounding physical world. The mammalian brain, or emotional cognitive brain, supervises emotions, relationships and learning. This brain oversees relationships on all levels--neurological, cellular, and our interactions with others. Also, in this brain, learning occurs, especially knowledge and comprehension. The neo-cortex, or intellectual-creative brain, is the realm of higher order thinking skills[16]. Although current brain research suggests a more dynamic and complex interaction of neural pathways, Dr. MacLean's model reveals the importance of environment, challenge and emotion on learning.

In its simplicity, the triune brain theory reveals a remarkable truth about neural functioning, which is supported by even the most updated research utilizing PET and CAT scans. It shows how brain functions coexist and complement each other. Of particular significance to educational planning and practice is the finding that when basic needs are not met or there is a negative, threatening emotional context for learning, the brain may literally downshift to basic, survival thinking.[17] This is commonly referred to as "shut down". Therefore, it's imperative that educators establish a learning environment where students are challenged, but not threatened, are safe, but not coddled, and can express and experience emotion without dysfunction. In an environment like this, the brain maximizes its capabilities and capitalizes on its higher order thinking skills.

MacLean also addressed the effects of sensory and aesthetic appeal on how experiences are perceived, and thus the process of learning. This point will be considered further in the following section.

Overview, Goals and Objectives

(Now that the history has been acknowledged, the structure, design, goals, and objectives of present-day inquiry-based approaches can be examined, as it is important to the understanding of and appreciation for the proposed activities and approach used within inquiry-based learning classrooms.)

Inquiry-based learning approaches are applicable across disciplines and operate on the philosophy that learning begins with questioning. Through questioning (discovery and exploration), students are able to begin the process of problem solving and more effectively find meaning in the material (usefulness) and establish connections with previous experiences through the interconnected network of neural pathways. As suggested in Dewey's philosophies and supported in current scientific literature, the brain is "programmed" to pay attention, store, and later retrieve stimuli that keep us alive and functioning. Information that is not perceived by the brain as a survival skill is thereby discarded. Inquiry builds on this natural process by allowing individuals to make sense out of new information by seeking truth, relevance and meaning through questioning[18]. For optimal effect, questioning should be student-centered, student-facilitated, and teacher-guided, but is often some variation of the above.

Effective inquiry is more than just asking questions. Useful application of inquiry learning involves several factors: a context for questions, a framework for questions, a focus for questions, and different levels of questions. Well-designed inquiry learning produces knowledge formation that can be widely applied[19]. Through the complex process of inquiry, individuals construct much of their understanding of the natural and human-designed worlds. It involves individuals attempting to convert information and data into useful knowledge; it implies a "need or want to know" premise. Inquiry is not so much seeking the right answer -- because often there is none -- but rather seeking appropriate resolutions to questions and issues that can potentially be viewed as useful. Inquiry-based learning approaches attempt to develop skills learners will need and use throughout their lives, as exposure to new information and problematic situations occur. It helps students to cope with problems that are ill-defined and can help students deal with changes and challenges to their understanding[20]. For educators, it is through encouragement, emphasis, and fostering of these skills that student's will be better able to shape their search for solutions and continue the quest for knowledge throughout a lifetime. As suggested, in part, in the previous section, inquiry-based learning models also operate on principles that relate learning to sensory input, aesthetics, application, and cooperation.

Sensory input and aesthetics contribute significantly to the learner's ability to process information. To begin, both factors assist in capturing student interest in material that may otherwise be considered uninteresting and useless; thereby encouraging positive attitudes about learning. Like all aspects of human behavior, attitudes are learned and result from experiences. When educators help students create positive attitudes about learning and content material, they are also establishing a foundation for learning that can be built upon[21]. As a second point of interest, these factors give meaning to the material, a necessary step if one is to pay attention to, store, retrieve, and apply that information in the future. Research supports associating colors, shapes, smells, tastes, and/or positive attitudes with information helps to establish inter-connected, neural pathways in the brain that function symbiotically in an effort to store new information[22].

Inquiry-based laboratory activities, real-life tasks and challenges, and role-playing strategies have become an integral part of curriculum instruction. Moreover, inquiry-based learning models focus on exercising these ideologies by fostering cooperative learning and notions of social responsibility. These principles take advantage of one's natural tendency to communicate and socialize, and on the increasing need to function cooperatively (through teamwork) in the school, home, and workplace[23]. As Dewey recognized, schooling is not just about the individual. It is the coming together of the child's interests with those of the society. The disciplines we study in school represent centuries of collective thought as well as the interests of the larger community in maintaining itself by communicating its knowledge and values to the next generation[24]. Cooperative learning strategies take into consideration individual responsibility to the team as well by assigning roles and specific tasks to each team member, as all parts come together to make a whole. Comparison of inquiry-based and cooperative learning models can be seen in Table 1.

Table I: Comparison of Teaching Models (Johnson et al. 1991; Smith and Waller 1997)[25].

Traditional Teaching Method	Cooperative Teaching Method	Inquiry-based Teaching Method
-Low interdependence. Focus on individual performance.	-High positive interdependence. Focus is on joint performance.	-Groups not essential, but highly recommended. Outcome dependent on group interdependence.
-Individual accountability only.	-Both group and self-accountability.	-Both group and self-accountability.
-Little or no attention to group formation. Students often select their own groups, or may be set randomly.	-Teachers form groups based on knowledge, experience and interest.	-Teachers form groups based on knowledge, experience and interest.
-Assignments are prescriptive, with little commitment to each other's learning.	-Assignments may be prescriptive. -Members promote each other's success.	-Assignments are open-ended and foster critical thinking.
-No group processing of the quality of its work. Individual accomplishments are rewarded.	-Group processed quality of work and how effectively members are working together. Continual improvement is emphasized.	-Group processes quality of work. Presentation of results is a must.
-Teamwork skills are ignored.	-Teamwork skills are emphasized and leadership shared by all.	-Teamwork skills are emphasized because real time trouble-shooting is required. Leadership is recommended to coordinate activities and facilitate timely submission of products.

The goal of inquiry-based learning is to present strong and compelling opportunities for students to succeed inside and outside of school by providing experiences that are motivating, nurturing, challenging, and cooperative, while taking into consideration background, diverse learning needs, and real-life experiences. While much thought and research has been spent on the role of inquiry in science education, inquiry learning can be applied to all disciplines. Inquiry-based learning is grounded in principles that are thought to be inherent to younger populations, which include one's instinctive desire to find things out, the propensity children have to communicate, and the need for individual and social responsibilities[26]. Overall, inquiry classrooms work to create positive attitudes about learning by ending listen-to-learn paradigms and challenging students so that the knowledge and skills learned can be utilized throughout life. However, this is not an easy accomplishment.

Important Considerations

Although the philosophies of inquiry-based models are widely accepted, their implementation in the classroom is not an easy one. Classroom teachers are facing increasing opposition to inquiry-based teaching, arguing that inquiry-based teaching "requires too much time and energy" and results in "too slow content coverage[27]. In most Texas school districts, curriculum is structured around the Texas Assessment of Knowledge and Skills (TAKS) examination. Students are required to achieve a passing score on the TAKS examination in order to advance to subsequent grade levels and meet high school graduation requirements[28]. As a result, teachers are under increasing amounts of pressure to cover TAKS testable material, as teacher, school, and district "ranking" is significantly dependent on how their student's perform on standardized tests. Consequently, less focus may be given by classroom teachers to fostering inquiry skills in learners.

However, in science classrooms, this process of inquiry is essential to the understanding of fundamental concepts and cannot be neglected. Science is, in itself, intimately tied to the world in which students live, learn, communicate, and work. Some studies report that the advantages of inquiry-style learning (in the sciences and across disciplines) may offset the disadvantages of slow content coverage, thereby leading to its acceptance by classroom teachers[29]. This is an important consideration as studies have indicated that the process of inquiry, while it does not contribute solely to higher standardized test scores, it does result in increased student participation and higher classroom grades earned by students[29]. In the following chapter, a unique approach that further increases student motivation, participation, and performance in science classrooms is considered. This novel tool to be utilized within inquiry-based instructional practices considers case reports and patient encounter workshops as a means to increase student interest, understanding, and appreciation for fundamental science concepts.

CHAPTER 3

A NOVEL APPROACH TO INQUIRY-BASED LEARNING

The foundation of the proposed activities is inspired by "traditional" inquiry-based approaches and is designed to be implemented in science classrooms where living systems are covered.

Overview, Goals and Objectives

Through discovery, risk-taking, and exploration, the brain seeks to make meaning of the experiences it faces. The degree in which it engages in inquiry and experimentation is the degree to which real learning occurs. In the following sample teaching module, the previously mentioned principles of inquiry-based instructional approaches are considered, along with additional methods that capture student interest, encourage discovery and risk-taking, and consider diverse learning needs and preferences. This module is specifically designed to be implemented in science classrooms where living systems are covered. For science educators, paralleling classroom instruction with real-world tasks and healthcare issues provides an approach that is capable of appealing to the needs, interests and learning styles of most students. For this reason, the enhanced model utilizes introductory case reports and patient encounter workshops as a means of capturing student interest in content material and providing real-life examples (as seen in the media) of concepts to be learned; Thereby, encouraging the process of discovery and risk-taking. Since diet, disease processes, and health disparities are reflected across populations, it is thought to serve as a theme that is meaningful for most students.

This novel approach to inquiry practices integrates media-driven, health-related case reports and patient encounter workshops into living system instruction in an effort to stimulate student interest and make inquiry-based models more effective. Case reports in which the student assumes the role of the treating physician will serve as an introduction to each lesson, reinforcing the premise that increased student responsibility in the classroom will result in increased student participation and cooperation. Moreover, the utilization of case studies will serve to spark student interest, leading to discussion and questioning that are student-teacher facilitated. The patient encounter workshops, which refer to simulated doctor-patient interaction where one student assumes the role as the "treating physician" while the other assumes the role as the "patient", will serve to culminate the lessons. Dialogue during workshops will be structured around previously presented cases and will reflect learned information as the "patient" recalls fundamental concepts and the "physician" applies that information to the respective case study. This may further connect lesson content to real-life circumstances, thereby contributing to long-term retention of basic concepts and principles.

Case studies and student-oriented workshops have been incorporated into post-secondary curriculum for a number of years, but it has yet to become an integral part of high school biology curricula, specifically in the Fort Worth Independent School District curriculum.

For example, the Wright State University School of Medicine and Duke University School of Medicine have integrated case studies and patient encounter workshops (patient-centered orientation) into their curriculum for their 1st and 2nd year medical students and their Biomedical Scholars (Minority Medical Educational Program for summer scholars), respectively.[30, 31] Its use as a teaching aid functions to broaden student perspectives, access comfort zones, and of course, reinforce and access student understanding of material and may thus be an effective addition to FWISD high school biology curriculum.

For high school students, the case study/patient encounter methodology may also increase minority student (as well as non-minority) interest in the sciences. For example, introductory case studies may be used to reflect demographic disparities by referencing ethnicity, age, socio-economic status, heredity, lifestyle as they relate to disease. For example, research indicates that African-American, Native American and Hispanic women face a 10% to 70% greater risk of dying after a breast cancer diagnosis compared to white women[32]. Research further suggests that certain cancers (liver and stomach) are almost twice as high in the Hispanic population as in the white population and that Asian-Americans face a greater risk of acquiring asthma, while African-Americans have a greater risk of acquiring heart disease and diabetes[32]. Students could be asked to assess or propose why some diseases are more prevalent in certain populations, while speculating about cause and manifestation of the referenced disease process. In a non-homogeneous classroom, which is the case for greater than 60% of American classrooms, facts such as these, which target multiple populations under one common heading-healthcare disparities- can serve as an introduction that is engaging and relevant. Healthcare disparities not withstanding, outlining diet and disease processes have the potential to function as an introduction that captures the interest of the student in a learning situation that is viewed as real and applicable. Thus, the significance of the content area is realized and internalized for long-term use.

In addition, the heterogeneous nature of American classrooms has necessitated consideration of diverse learning styles, which are reflected in modality preferences (preferred mode of learning), in enhanced inquiry-based module design. Learning style has been described as preferred ways individuals process and organize information. They are the cognitive, affective, and physiological traits that individuals consistently employ when perceiving, interacting with, and responding to learning environments[33]. Learning style are often a reflection of one's culture, and may be competitive or cooperative. The three general modality preferences are visual (print-oriented and screen-oriented), auditory, and kinesthetic/tactile. Visual-print modality is related to a preference toward printed or readable material and is often seen in cultures with a long history of written materials and an emphasis on being literate. Visual-screen oriented individuals prefer television, movies, videos, and computer screens as a mode of learning. Younger learners usually fall into this category. Auditory modality is preferred in many groups, wherein oral expression is important, and relies on sound and expression of words as a means for learning[34]. Lastly, kinesthetic/tactile modality relies on the use of movement for expression and is seen in "expressive" cultures and most children (specifically males)[34]. In response to the diversity of learning styles that exist among students, the following module takes responsibility to reflect varying learning needs by providing instructional practices, activities, and assessments (and rubrics) that are consider diverse learning modalities.

Model Design and Methodology

Test Population: High School Biology Students

This teaching module may be used as a resource for high school Biology teachers and is to be used in conjunction with supplemental textbooks and learning aids. Proper utilization of this module will enable educators to access, by compact disk, content relevant material and visual aids that are linked to Living Systems. Teachers will be provided with an appendix that provides introductory material (case reports), worksheets, reading references, laboratory activities, workshop structure and goals, and assessment tools, along with strategies that can be used to implement these activities. Lesson plans will be included and designed for forty-minute class periods.

To cover the details of the renal system as outlined in the TEKS, it is important that each lesson activity has a clear objective. This module requires approximately five hours of instruction and may be better suited for upper level Biology courses in which details of living systems are stressed. The proposed module can also be modified with relative ease due to its non-linear design, allowing for information to be accessed and presented as needed. In accordance with the Texas Essential Knowledge and Skills (TEKS) for Science Checklist, this module expects students to: (1) interpret the functions of systems in organisms including circulatory, digestive, nervous, endocrine, reproductive, integumentary, skeletal, respiratory, muscular, excretory, and immune; (2) compare the interrelationships of organ systems to each other and to the body as a whole; (3) investigate and identify cellular processes including homeostasis, permeability, energy production, transportation of molecules, disposal of wastes, function of cellular parts, and synthesis of new molecules; (4) identify and describe the relationships between internal feedback mechanisms in the maintenance of homeostasis; (5) investigate and identify how organisms, including humans, respond to external stimuli; and (6) analyze the importance of nutrition, environmental conditions, and physical exercise on health.

The use of visual aids, reading assignments, writing assignments, online activities, worksheets and hands-on lab activity that reflect the anatomy, physiology and pathology of the renal system will be the focus of this design. Divergent, convergent, probing, and prompting questioning are provided to channel student thinking and to assess whether learning has occurred or is taking place. In addition, these questioning strategies may also be used to invoke higher levels of cognition by requiring students to make implications, draw sound conclusions, and apply learned concepts when introduced to new material. In alignment with lesson design, varied assessment techniques will also be included to address a range of learning styles and testing preferences.

The following pages will represent a proposed lesson plan that incorporates use of case presentations and patient encounter workshop. The lesson plan is designed to cover the renal system. (See the Appendix section for module appendices that include content, case presentations, worksheets, activities, workshop guidelines, and assessment tools.) Note: Urinary System lesson plan and appendices may be accessed via compact disk for review and possible implementation in the classroom.

Lesson Plan- Urinary System

High School Biology

UNIT: Living Systems- Includes plants and animals, growth and development, functions of systems and homeostasis. **Focus: Renal System**

OBJECTIVE:

1. Student knows that, at all levels of nature, living systems are found within other living systems, each with its own boundary and limit.
2. Student knows the anatomy (both exterior and interior) and physiology of renal system.
3. Student understands that the anatomy of living systems varies taxonomically.
4. Student understands the concept of diffusion, as seen in through the filtration and production of urine by glomerular apparatus, tubules, and ducts.
5. Student knows more than one direct and indirect mechanism in which disease processes are associated with the renal system.
6. Student understands the co-dependent relationship between the renal system and other systems in the human body.
7. Student understands how lifestyle and other stimuli influence normal body function.

RATIONALE: It is necessary for high school biology students to understand that life is sustained in all living organisms through the inter-dependent functioning of systems and organs. It addition, it is necessary to know that life is sustained by the contribution of each living system to the maintenance of the body (homeostasis). Knowing this will better allow students to appreciate the world in which they live in and all it encompasses and to attend to themselves and other living things. It will also provide them with a better understanding of disease processes and its profound effects.

CONTENT:

Introduction
- A. Case Report
- B. Significance

II. Excretory System
- A. Kidneys
    - 1. Function
    - 2. Components
        - a. External
        - b. Internal
    - 3. Urine Production
- B. Bladder
- C. Urethra

D. Glands and Ducts

III. Comparison to Other Organisms

  A. Invertebrate Anatomy

  B. Other Mammals

IV. Interrelationships

  A. Circulatory

  B. Endocrine

V. Pathology

VI. Homeostasis

  A. Within System

  B. Within Organism

VII. Lifestyle

  A. Nutrition

  B. Exercise

TEKS COVERED:
10 A, B; **4B**; **11** A, B and C

MATERIALS:

- Computer/Compact Disk Drive
- Video/Video Projector/Overhead Projector
- Transparencies
- Kidney Models
- Poster Boards and Construction Paper
- Model Poster Board
- Microscopes
- Laboratory Equipment/Supplies
- Markers
- Scissors
- Glue and Tape
- Game Boards and Prizes

Day 1- PROCEDURE: See Appendix B and CONTENT PowerPoint found on Disk

I. Introduction to Renal System

  1. Read/listen to Case Report on: (1) Renal Carcinoma; (2) Bodies Filtration System; (3) Shock- Renal Failure; (4) Diabetes/Healthcare Disparity; and/or (5) Anorexia/Diet. Material will be handed out to each student each day. Allow students to peruse material first and then follow up with read-along/aloud activity. As students read, ask them to highlight 'important' information. See Appendix B.

2. Discuss Report, highlighting responses on board/overhead.
3. Continue Brainstorming to deduce relationship to lesson topic.
4. See Appendix A for content materials.

II. Excretory System

5. Begin lesson by showing visual aids (diagram and models) that outline the components of the excretory system by name.
6. Group students in pairs (neighbor). Handout out worksheet (Appendix C) that is comparable to above slide and allow students to brainstorm about functions of those components and notate responses in appropriate blanks. (3 min.)
7. Review responses.
8. Continue lesson on components and their general function- kidney, renal blood vessels, ureter, bladder, and urethra. Have students fill in and adjust worksheet as needed.
9. Continue to Day 2 if time permits.
10. Introduce Patient Encounter Workshop and give students guidelines. If students have not already been assigned groups, assign groups.

Day 2- PROCEDURE: (See CONTENT Power Point on Compact Disk)
Excretory System

1. Read Case Report.
2. Journal- Recap/complete previous day's lesson and diffusion (covered during fist six weeks- Science Concepts).
3. Discuss.
4. Begin or continue introduction to interior components of kidney- cortex and medulla (pyramid), pelvis, hilum, and calyces. Display Model.
5. Look at histological representation of these structures to reveal filtration apparatus. Power Point slide, overhead projector, or microscope.
6. Discuss diffusion of electrolytes and waste products across filtration membranes. Molecules must meet charge and size requirements.
7. "How does the Kidney filter 180 Liters of Blood a day to produce only 1.5 Liters of Waste product?" Counter-current Multiplier System. Video clip?
8. See Discussion Questions to wrap-up discussion (Appendix D).

III. Comparative Anatomy

9. Overview comparative anatomy of urinary system of fetal pig, frog and earthworm via slide show.
10. Introduce Lab for next day.

Day 3- PROCEDURE- Urine Production (Diffusion) Laboratory
Divide students into groups of four.

1. Journal- What is dialysis? Have class record question/answers in notebooks.
2. Demonstrate dialysis using model/slide presentation to reinforce (Appendix E).
3. Lab Activity- Paper Lab, Dialysis Lab, or Chemical Lab (Appendix F).

Day 4- PROCEDURE

1. Read Case Report.
2. Journal- Brainstorm how urinary system is related to other systems.

IV. Interrelationships

3.Discuss the inter-relatedness of each system and how they work cooperatively to sustain life.

V. Pathology

4. Discuss disease that may affect each of these systems.
5. Show slide show or video of various diseases.
6. Reading Assignment (Appendix G).
7. As homework assignment, have student review case reports from days 1-4. Student should respond to case report as if they were the "treating physician" utilizing classroom information and information obtained from independent research. Provide student with sample report/response. Student responses will be turned in day of assessment and will count as essay question. Provide students with rubric.

VI. Homeostasis

1. Describe its meaning in detail and how it relates on the micro and macro levels.
2. Countercurrent Multiplier System review.
3. Site examples of what would happen if a body system was compromised, i.e. adaptation vs. disease.

Day 5- PROCEDURE

VII. Lifestyle/Worshop

1. Case Report of Healthy Patient.
2. Overview nutritional facts.
3. Overview: Patient Encounter Workshop (Appendix J.)
4. Provide students with Study Guide/Exam Format (Appendix K).

Day 6- ASSESSMENT

Part A- Practical Exam (See Compact disk)

Student will:

1. Identify external and internal features of renal and urinary system, and
2. Identify histological regions and cells of glomerular network and nephron.

NOTE: Gross, model, and histological images may be presented via display and/or Power Point.

Part B- Written Examination (Appendix I)
Student will answer recall, synthesis, comprehensive, and application questions on:

1. Components of excretory system;
2. Physiology of system and individual components;
3. Homeostasis and relationship to other systems;
4. Lifestyle and Nutrition; and
5. Pathology (Essay Assignment: Day 4)

NOTE: Format: Multiple choice, short answer, and essay.

CHAPTER 4

FUTURE DIRECTIONS: WEB DESIGN AND MECHANISMS FOR TESTING THE EFFECTIVENESS OF UTILIZING CASE PRESENTATIONS AND PATIENT ENCOUNTER WORKSHOPS WITHIN INQUIRY-BASED LEARNING APPROACHES

Web-Page Design

To increase accessibility to module, future efforts may include construction of a web page that allows for online access of materials. This may enhance the structure of this design in that it appeals to visual screen-oriented learners and allows for incorporation of multiple resources that may be found on the web. Construction of a web-page would entail an outline of the urinary system and enhanced inquiry-based design, pictures of normal and diseased kidneys, links to content material, teaching aids, laboratory activities, related topics, science journals, and assessment tools. With web-page design and structure in mind, instructional material in hand, and content material ready for upload, this process can be done with relative ease. To begin, two items are necessary (other than a computer with Internet capabilities)- an HTML editor and a place on the web to publish this page. An HTML editor is a web page construction tool that allows for insertion of images into the body of a document and creation of hyperlinks to other pages. They also permit you to reference a file to be used as a background image. Most HTML editors allow for additional HTML code to be inserted as needed[35]. There are many good HTML editors available that can be found on the web by starting a google search and typing in "free HTML editors" or "how to construct a web page". These sites include geocities.com and build-website.com and are free of charge. However, for more advanced and professional features, purchase of Dreamweaver MX and/or Microsoft Front Page 2002 editor programs should be considered.

The next step includes installation of HTML editor and is followed by finding a simple web page on the Internet that is a preferred location for the web page and saving it in a directory. Graphics from that same web page should be copied onto the hard drive of the computer. Publication of constructed homepage on the World Wide Web is now possible. This is accomplished by copying web page, graphics, and all other files to a web server. The Internet service provider (ISP) that you use for Internet access might provide free web hosting to its customers. If not, there are a number of companies that will provide server space at no charge. As a note, instructions on how to upload files to web server and is provided by host services, which will also provide a user ID and password so that others can not access or alter web page files[36]. The only software that is required for uploading files is a web browser, such as Netscape or Internet Explorer. Alternatively, free FTP software (File Transfer Protocol) can be used. Now, reviewing of web page is available for fine tuning and instructional use. Additional information can be found at the following web address: www.build-website.com.

Testing the Effectiveness of Model Design in the Classroom

While the principles and methodologies outlined in the enhanced inquiry-based model and expressed in the sample teaching module are effective in theory, its implementation in a classroom setting may support, discredit, or necessitate revisions in model design. Future efforts that involve testing the effectiveness of this instructional/learning approach in the classroom may provide empirical evidence of its effect and must consider several factors, which include research standards and protocol, teacher/classroom selection, assessment criteria, and interpretation of data results.

In preparation for testing, knowledge of federal regulations and Institutional Review Board (IRB) standards and protocol is necessary. (An overview of IRB mission statement and policies will be addressed in the following section.) Testing on human subjects is a highly regulated process and module design and materials must be submitted to the IRB for review before testing can begin. Furthermore, research coordinators must notify and gain approval of any modifications made to research protocol and design post-submission, and also report to the IRB annually if tracking of subjects is to exceed one year[37]. Once approval is obtained from the IRB and/or other regulatory bodies, testing of module effectiveness in the classroom can begin. Prior to this, teacher/classroom selection, assessment criteria (and tracking options), and how data will be interpreted must be outlined.

It is suggested that a traditional (didactic) learning classroom that is similar to the classroom in which the novel approach to inquiry-based learning will be utilized, with regards to demographics, learning curves (may be obtained from distribution of classroom grades), and classroom/school climate, serve as the control population. If possible, it is suggested that both the "tested" group and the control group are housed at the same institution, in that climates vary from school to school and may skew research findings. Appropriate classroom selection can be accomplished by surveying interested biology teachers in search of information that pertains to their academic and social curricula and selecting those persons whose educational practices are found to be consistent with research design.

Effectiveness of model design can be assessed by evaluation of pre- and post- study performances and attitudes (obtained from surveys that should be distributed to both teacher and student throughout study duration) and through investigation of the relationship between the use of enhanced inquiry-based instructional style and student performance in the classroom as reflected in achievement data, student participation, increase in student inquiry and framework of student questioning, and students' pre- and post-attitudes about learning. Evaluation of these relationships, in-class activities and on lesson/unit assessments, may be used to give value to, support, oppose, and/or re-evaluate key features of this design. In addition to outlining the methods that will used to test the effectiveness of this model, how interpretation of data that is generated should be considered. Along with interpreting data based across instructional styles utilized (which is the primary purpose of testing, possibilities also include stratifying results based on cultural backgrounds, pre-performance level, and/or teacher attitudes about inquiry-based learning approaches. It should be noted that exploration of model effectiveness in the classroom as it relates to performance on national standardized tests would require specialized efforts due to the boundaries that exist between inquiry-practices and standardized-test design. Research coordinators should also be careful when selecting teachers and classrooms that high-stake testing is not over-emphasized, as it influence the tendency of educators to implement inquiry-based learning approaches in their classroom.

Limitations

Due to varied learning environments and resources, there are several limitations to this module that must be considered. In this proposed module, five class periods are devoted to the Excretory System, along with an additional period for student assessment of learning. Unfortunately, given that Living Systems (including plant, animal and homeostasis) are to be covered in the allotted forty days, as indicated in Texas Biology Scope and Sequence, it may not be feasible to focus five days of instruction on this system. As a result, modification of this module may be necessary. Since users of this module are able to navigate through the material in a non-linear manner, instruction can be modified to fit the need and the environment. This may contribute less to the potential limitations of module design than predicted.

Equipment availability may also impose certain limitations on this module. Since portions of this module call for the use of overhead projectors, data video projectors, microscopes, system models, and other relatively expensive equipment, the accessibility teachers have to these items may prove problematic. School budgets, specifically science department budgets, have been a concern of science educators for many years. With a rising interest and dependence on technology, many institutions are not financially able to equip their classrooms with resources that meet the latest technological advances[38]. Financial barriers may also have an affect on the quality of teachers that are hired and school climate.

Additional limitations to consider are the computer user's ability to navigate through the web and unfamiliarity with software/equipment. Teacher/student ideologies about education/preferences may limit the effectiveness of this module. Moreover, teacher understanding and relevance of the material to be presented can greatly influence student engagement, understanding, and application of the material. It is also important to note that the IRB (Institutional Review Board) evaluation process, which oversees implementation of modules (studies), could potentially limit its usage. As noted in the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research, *Protecting Human Subjects: The Adequacy and Uniformity of Federal Rules and their Implementation*, the goal of the IRB is to "…help both in understanding the policies and principles that underlie the regulations governing research with human subjects, and in identifying the issues to which one should be sensitive to in designing or reviewing research proposals"[39]. Thus, even in implementing a project such as the one proposed here, enrolling human subjects (classroom teachers and students) in a research that tests the effectiveness of the module design is a tightly regulated process.

CHAPTER 5

SUMMARY

The principles and methodologies behind utilizing case presentations and patient encounter workshops in life science classrooms is grounded in inquiry based philosophies that work to create a classroom environment that is more conducive to learning. Major goals include increasing student interest and motivation to learn material by integrating introductory case-studies and patient-encounter workshops into FWISD high school, Life Science curriculum. In theory, it is thought that this method may readily engage students in their learning; provoke them to make observations, ask questions, and carry out the process of problem solving; and connect content material to real-life experiences[40]. All of which are thought to give meaning and purpose to new information, a necessary trait if information is to be internalized for long-term use. Furthermore, optimizing an understanding of diet and disease as it relates to normal body function has implications that can affect change in lifestyle; thereby, bringing us one step closer to bridging the gap in healthcare. In this manner, life and quality of life can be intimately connected to lifestyle.

APPENDIX

Appendix A

CONTENT:URINARY SYSTEM

Vast details of the urinary system have been included and may be simplified and/or abbreviated to meet classroom and timing demands..

I. Introduction

A. Overview

The excretory system is used to excrete many chemicals and substances in the body that may be harmful to each individual's health. Components include gastrointestinal track/liver in which feces, non- water soluble waste products, are compiled and eventually expelled, and the urinary system in which water soluble waste products are excreted from the body. Since the components and function of the GI Track and liver are covered under the digestive system, this unit will focus on the Urinary System.

B. Significance

With out the urinary system, we, as human beings would have problems from organs in our body. One of the major components of the urinary system is the kidney, which functions to filter blood and clean it of waste products that are yielded as a result of metabolism; Thereby, producing urine. If the body was unable to filter its blood, an imbalance of fluid and electrolytes in the bloodstream would result. Upon interference of homeostasis, a buildup of toxic wastes would occur, blood volume/pressure would no longer be regulated, cellular processes would be affected, and so on. In addition because kidneys function to produce major hormones and is inter-related to other body systems, massive downstream problems could result.

II. Urinary System (paired kidneys, paired ureters, bladder and urethra)

A. **Kidneys**

1. <u>Function</u>
   - Filter blood and clean it of metabolic waste products.
   - Regulate arterial blood pressure through hormone production and regulation of extracellular fluids and electrolyte.
   - Regulation of blood volume by maintaining homeostatic salt, water, acid/base, and other ion concentrations.
   - Maintain homeostasis through re-absorption.
   - Production of erythropoietin (leads to RBC maturation and bone marrow production) and renin (↑arterial BP)
2. <u>Components</u>
   - External

- Renal Artery
    - Anterior to Renal vein.
    - Feeds kidney oxygenated blood that is to be filtered.
- Renal Vein
    - Posterior to renal artery.
    - Collects deoxygenated, filtered blood that is to be sent to the heart via inferior vena cava.
- Ureter
    - Posterior to renal vein.
    - Collects urine that is formed from filtrate (metabolic wastes + ions + water) and carries it to urinary bladder to be stored.
- Renal Hilum
    - Inward cleft that houses blood vessels and ureter.

- Internal
  - Renal Sinus
    - Internal extension of hilum.
    - Filled with fatty tissue.
  - Renal Pelvis
    - Internal portion of ureter.
    - Branches into major calyces.
  - Cortex
    - Columns of Bertin- inward extension of cortex; found between pyramids.
    - Houses portion of nephron (filtration network).
  - Medulla (Pyramids)
    - Posterior to cortex.
    - Renal Papilla- apex of pyramid, encapsulated by minor calyx.
    - Houses portion of nephron (filtration network).
  - Minor Calyces
    - Encapsulates renal papilla.
    - Branches of major calyces.
    - Collects urine (filtrate) from the renal papilla it surrounds.
  - Major Calyces
    - Branch of renal pelvis that extends outward toward renal lobes
    - Branches into minor calyces.
    - Collects urine from minor calyces.
- Histological

  Nephron- Major Functional Unit
  - Glomerulus
    - Dense network of capillaries.
    - Blood Filtration Site

- Basement membrane and negatively charged endothelial cells have pores that restrict filtration of molecules that do not meet size and charge requirements. Therefore, entry of large (≥70kDA), ? charged molecules, such as proteins and RBC, are restricted.
- Basement membrane/endothelial cells allow entry of small, charged molecules such as water, glucose, amino acids, electrolytes, and nitrogenous substances (urea and creatine).
- Entry of proteins, RBC, etc. indicates PROBLEM!

- Blood supply: renal artery
  - NOTE: renal artery branches into smaller and smaller vessels that extend across kidney lobules until each glomerulus in kidney has blood supply. Vessels that enter glomerulus are called Afferent Arterioles.
  - NOTE: The blood components that are not filterable exit the glomerulus and return to systemic circulation via Efferent Arterioles.

- Bowman's Capsule
  - Space completely surrounding glomerulus.
  - Podocytes of glomerulus allow for filtrate to leave glomerulus and enter capsule.
  - Collects initial filtrate (nephric filtrate).
  - Components:
    - Vascular Pole- where afferent arterioles enter and efferent arterioles exit.
    - Urinary Pole- where filtrate is directed to proximal convoluted tubule.
- Proximal Convoluted Tubule
  - Extension of urinary pole.
  - Main function is reabsorption of solutes, i.e. transport of solutes back into systemic circulation via capillary beds (peritubular network and vasa rectae) that surround tubules.
  - Reabsorbs nearly 100% of glucose/aa and 70% of Na via diffusion mechanisms.
- Loop of Henle
  - Consists of descending, thin and thick ascending limb.
  - 25% of Na reabsorbed.
  - Descending limb is impermeable to water (reabsorption of water back into systemic circulation). Leads to ↑ solute concentration in tubules -hypertonic region.
  - In ascending limb, solute concentration is ↓ due to Na and electrolyte reabsorption.

- Countercurrent Multiplier System.
  - Distal Convoluted Tubule
    - Na is reabsorbed and K secreted via Na/K channels.
    - Secretion of toxins, acids, drugs, and other ions (molecules in peritubular capillaries are secreted into tubule, producing ultrafiltrate.
    - Reabsorption of water and Na.
    - Na/H+ pumps maintain pH by regulating acid/base balance.
    - Under hormonal control of Aldosterone.
    - Macula Densa- modified portion of tubule adjacent to vascular pole. Senses ↑ Na concentrations, causing vasoconstriction of afferent arterioles.
  - Collecting Duct
    - Collects ultrafiltrate from distal convoluted tubule.
    - Urine formation.
    - Reabsorption and secretion of water and other solutes is variable.
    - ADH (Vasopressin), regulates water channels. Inhibition of hormone restricts H20 reabsorption, resulting in ⇓ arterial blood volume (BV).
    - Extends in papillary medulla where urine is delivered to minor calyx.

B. **Bladder**

- Expandable, muscular organ that stores urine.
- Opening in floor of bladder allows for entry of ureters.
- Lined with smooth and skeletal muscle (detrusor) that is sensitive to pressure caused by increased volume of fluid.
- Once fluid volume in bladder reaches app. 300mL, parasympathetic nerve fibers in muscle wall senses increased pressure and causes upper walls of bladder to contract.
- Lower sphincter muscle, which is normally contracted, is overwhelmed by increased pressure. Lower sphincter muscle then relaxes and urine is released from body.
- Process of urine release- Micturition.

C. **Urethra**

- Tube-like structure that carries urine from bladder out of body.
- Passes through penis in male and is app. 20cm long. App. 4cm in females.

D. **Urine Production**

- Urinary Tract

  Renal Artery → Afferent Arterioles → Glomerulus → Capsule → Proximal Convoluted Tubule → Loop or Henle → Distal Convoluted Tubule → Collecting Duct → Papillary Duct → Minor Calyx → Major Calyx → Renal Pelvis → Ureter

- Rate

  180 L of blood/day ------------------→ 1.5 L (6 cups) of Urine Produced/day

  - 99% of fluid that is filtered through kidney is reabsorbed, leaving approximately 1% to be excreted.
  - The amount of urine excreted varies greatly with temperature, water intake, and state of health.
  - No matter how much water one drinks, the blood will always remain at a constant concentration because the kidneys will excrete excess water. A large water intake does not put a strain on the kidneys. Instead it eases the load of concentration placed on the kidneys.

- Process

  - High hydrostatic pressure in afferent arterioles drives filtration of blood through glomerulus.
  - Particles and fluid removed from the blood, the filtrate, moves from glomerulus into Bowman's capsule ⇒ proximal tubule ⇒ loops of Henle ⇒ distal tubule⇒ collecting tubule.
  - The tubules are surrounded by peritubular capillaries, which allows the filtered blood and filtrate pass very close together.
  - The nutrients that the body needs (glucose, H20, Na, and other ions) are reabsorbed into the peritubular capillaries via diffusion. Along with the nutrients that are reabsorbed into the blood, the balance of water and other molecules such as sodium and chloride is established by the reabsorption from the loop of Henle.
  - In the kidneys, active, passive, and osmotic transport are used to transfer molecules such as those mentioned above.

- The active transport of Na^+ out of one side of the tubule membrane and into the peritubular capillaries via Na/K ATPases creates an electrical potential inside the tubule and a concentration gradient inside cell.

- This leads to entry of Na^+ on the opposite side of cell (luminal membrane) via simple diffusion.

- Na is then pumped out of cell, across basolateral membrane, into peritubular capillaries.

    - In the proximal tubule, glucose can enter the cell on the luminal surface via Na/glucose transporters, in which Na moves down its [ ] gradient and glucose moves up its concentration gradient.

    - Once in cell, luminal glucose and Na is pumped out into peritubular capillaries via Na/K ATPase and transmembrane glucose channels, respectively.

- H+ and K+ are secreted directly into the fluid within the tubules via Na/H ATPase and Na/K ATPase, respectively. {Active secretion takes place in distal and convoluted tubules.} Mechanism is coupled to the uptake of Na+.
    - Tubular secretion of H+ is important in maintaining control of the pH of the blood.

- As a result of Na reabsorption, water is osmotically transported into capillaries. The osmotic shifts of water lead to increased solute concentrations in tubule.

    - Takes place throughout tubular system. At collecting duct, H20 is not coupled with Na reabsorption; Reabsorption is under hormonal control.

- In general, wastes are poorly reabsorbed due to their lower membrane permeability, while the essential nutrients are more readily absorbed as their permeabilities are higher.

- Urine is formed in the collecting duct and then exits through the ureter and bladder.

NOTE:

1. **Glomerular filtrate is heavily modified as it passes down the nephron.**

2. **Urine is very different from glomerular filtrate.**

- Because the human body does not maintain a constant water volume, the kidneys have to compensate for the lack of or excess of water consumed.

- The kidneys use a transport system called the counter-current mechanism to accomplish this.

- The name is based on the fact that concentration first increases in the direction of flow, then decreases as flow continues through the ascending parallel loop.

- The mechanism relies on the adjacent, parallel loops of Henle and vasa recta.

- In the descending loop, the concentrations inside and outside the tubule are increasing with the current, with the maximum concentration being reached at the bottom of the loop.

- The increased concentration is the result of the passive diffusion of Na^+ into the tubule and water out of the tubule.

- In the ascending loop, Na^+ (or any solute) is actively pumped out of the tubule.

- As flow continues up the loop, the tubular concentration decreases as does the interstitial (the fluid surrounding the loop) concentration.

- When the filtrate reaches the distal tubule, a net loss of Na^+ and water has occurred through the loops of Henle.

- Because water is impermeable in the ascending loop, the volume at the bottom of the loop is the same as that entering the distal tubule. At the bottom of the loop, the tubular and interstitial concentrations are equal.

- Inside the distal and collecting tubules, the filtrate is either diluted or concentrated to form urine.

- The regulating hormone for this process is ADH (antidiuretic hormone) and is excreted by the pituitary gland.

NOTE:

- The maximum urine concentration is limited by the interstitial fluid concentration at the bottom of the loops of Henle.

- The urine leaving the collecting tubule has the same concentration as the interstitial fluid at that point.

- The interstitial concentrations are largely a function of blood flow in the three regions. In the cortex, the lower concentrations are the result of the large blood flow in the peritubular capillaries.

- The capillary blood carries away excess solute and water in the region.

III. Comparison to Other Organisms

A. Invertebrate Anatomy
B. Other Mammals
*See Biology Text for its associated reading on comparative anatomy.

IV. Interrelationships

A. Circulatory

- Urine formation and its associated hormones that adjust Na and water concentrations in plasma/tubules affect blood pressure.
- Osmoreceptors and Na detectors located major blood vessels influence plasma and urine Na concentrations.

B. Respiratory

- Secretion of H+ into urinary tubules influences the concentration of plasma H+ concentrations. In the blood, H+ binds to the oxygen-carrier- hemoglobin- and affects its ability to bind CO2. Remember during respiration, O2 in the lungs is exchanged for the CO2 in the tissues. Since H+ causes Hb to bind CO2 more tightly, this affects gas exchange; and thus, respiration.

C. Nervous System

- Various components of the nervous system influence water and ion balance in the body, either causing more excretion of one and/or the other, or causing more reabsorption of one and/or the other.

D. Endocrine

Antidiuretic Hormone (ADH)

- ➢ Secreted posterior pituitary
- ➢ Primarily responsible for maintaining blood volume
- ➢ Increased ADH increases permeability of collecting duct to water concentrating the urine
- ➢ Decreased ADH decreases permeability of collecting duct to water increasing volume of urine

Diuretic Drugs

- ➢ Alcohol inhibits secretion of ADH
- ➢ Caffeine blocks ADH at the tubules
- ➢ Other diuretics may be prescribed for high blood pressure, pulmonary edema, and congestive heart failure

Aldosterone

- ➢ Secreted by the adrenal cortex
- ➢ Maintains Na^+ and K^+ balance
- ➢ Causes reabsorption of Na^+ and excretion of K^+ in the distal convoluted tubule.
- ➢ Water intake caused by increased absorption of Na^+ increases blood volume and blood pressure

E. Pathology

- See Appendix G.

V. Homeostasis

A. Within Organism

- Homeostasis is the maintenance of a constant internal environment (the immediate surroundings of cells) in response to changes in:
    - the changing conditions of the external environment.
    - the changing conditions of the internal environment.
- Homeostasis is a self adjusting mechanism involving feedback where the response to a stimulus alters the internal conditions and may itself become a new stimulus.
- Homeostasis works to maintain the organism's internal environment within tolerance limits - the narrow range of conditions where cellular processes are able to function at a level consistent with the continuation of life.
- To maintain cells, tissues and entire organisms within their biological tolerance limits, various mechanisms have evolved. These may be:
    - structural: the animal or plant has particular physical features which help its survival in an otherwise hostile environment.
    - functional: the metabolism of the animal or plant is able to adjust to changes in conditions as they are detected. (The focus of this Area of Study).
    - behavioral: the actions and interactions of the individual, either alone or with others, help it to survive in its particular environment.
- Homeostasis is really the combined result of all of these, a failure of any one of them can result in the death of an individual.

B. Within System

- Osmoregulation is the regulation of water concentrations in the bloodstream, effectively controlling the amount of water available for cells to absorb.
- The homeostatic control of water is as follows:
    - A change in water concentration leads to active via negative feedback control
    - Osmoreceptors that are capable of detecting water concentration are situated on the hypothalamus next to the circulatory system
    - The hypothalamus sends chemical messages to the pituitary gland next to it.
    - The pituitary gland secretes anti-diuretic hormone (ADH), which targets the kidney responsible for maintaining water levels.
    - When the hormone reaches its target tissue, it alters the tubules of the kidney to become more / less permeable to water
    - If more water is required in the blood stream, high concentrations of ADH make the tubules more permeable.
    - If less water is required in the blood stream, low concentrations of ADH make the tubules less permeable.

VI. Lifestyle

A. Nutrition

There are a few ways to help keep your kidneys to stay healthy or at best minimise a condition to an extent. One way is via a healthy diet. Judging by your post to me, I see that you agree!

First thing you will need to do is to limit your salt intake. Sodium helps control blood pressure and fluid buildup. In addition to table salt, there are other sources of high sodium foods you should consider. These would include canned soups and veggies, frozen meals and snack foods such as crisps and crackers. Read the labels carefully before purchasing the food.

- **Sodium** causes water retention in the body. When your kidneys are not functioning properly, this causes a significant problem when you drink liquids that already have high sodium content.
- **Protein** is needed daily to build muscles, repair tissues, and prevent malnutrition and to fight infection. But too much protein causes the kidneys to work over-time. Use foods in moderation to prevent such an issue.
- **Potassium** is a mineral present in most fruits and vegetables. If your kidneys are not functioning well, the potassium level can build up in your blood. Too much or too little potassium in the diet can affect the muscles in the body, particularly the heart.
- **Calories** are necessary in order to supply the energy we require on a day-to-day basis as well as to maintain our body weight. The vegan diet can help stabilize your weight, in turn help you with your kidney function.

B. Exercise

- During exercise in the heat, skin and active muscle tissue compete for a limited cardiac output. The increased blood flow to the skin along with the evaporation of sweat allows heat to be dissipated to the environment while increased blood flow to the muscle allows for the delivery of oxygen and energy substrates. In order to accomplish this dual purpose without a decrease in blood pressure, blood flow to the liver, pancreas, gastrointestinal tract, and kidney decreases. When the intensity of exercise exceeds 50% VO2max, blood flow to the kidney (RBF), filtration rate of the kidney (glomerular filtration rate; GFR), sodium excretion and urine flow rate all decrease by 30-60%. Additional perturbations such as heat stress, sodium depletion, and dehydration may exaggerate these decrements in renal function.
- These changes in renal function during exercise are caused mainly by enhanced activity of the sympathetic nervous system that causes renal vasoconstriction Increases in antidiuretic hormone (ADH), renin, angiotensin II (ANGII), and aldosterone also contribute (see Figure 1). The end results are increased sodium and water conservation by the kidneys and the maintenance of mean arterial pressure during exercise. While these adjustments are beneficial for homeostasis, excessive reductions in renal function can precipitate renal failure.

Appendix B

Case Reports

Descriptive pictures, simulations, and/or representations can be used along with each case study to enhance delivery. Students should be given a handout of case study (with columns for known information and need to know information outlined) prior to introductory read-aloud/along reading. Students should highlight important information. Follow-up brainstorming and questioning should follow. Derived information should be outlined on the board and on student handout. Information will be used for reflection phase of lesson and patient encounter workshop.

You may choose from the following studies each day. Simple and more complex cases have been provided to allow for variations in students' prior knowledge and experience. Cases may be modified to correlate with classroom needs.

Case Study 1
An seventeen year old black male presents in the ER with mid- to lower- level back pain on his left side. Patient tells doctor that the pain started the day of his Homecoming football game, in which he scored one touchdown and passed for 350 yards- a school record. Patient also notes that they almost lost the game when he was sacked the last 3 minutes of the game, but in the next play he ran for 15 yards and scored the game winning touchdown (21-13). In the last week, the pain on his left side has not subsided or worsened, but has been constant and somewhat sharp. The Medical Assistant notes that the patient walks with a slow, gated stride.

PMHx: Until last week, the patient has been athletic and considerably healthy.

Meds: None

Social: Patient is star quarterback on his high school football team.

Case Study # 2

A week of being "totally" depressed, Len gets up the following morning to go to her scheduled Dr.'s visit. Last week she broke up with Jeff, her boyfriend of three weeks. At the clinic, she tells the doctor that she hasn't had an appetite, but has been extremely thirsty and that she is often sleepy. Upon examination, the doctor notes a flushed face, a dry mouth/tongue and thick saliva, warm skin, and dark yellow urine that the patient says that she barely passes more than twice a day. She also tells the doctor upon questioning that when she cries, hardly any tears fall.

PMHx: History of depression, otherwise normal.

Meds: None

Social: Freshman year in high school. Junior -varsity cheerleader and debate team.

Case Study 3

An eighteen year old, Hispanic female presents with worsening headache and shortness of breath for two days. She notes fatigue and that has been worsening despite her attempts to rest. She is now short of breath walking around the house. The patient was ill ten days ago with vomiting, body aches, fever, and sore throat but this resolved after five days. She had then been well with none of these symptoms until two days ago. She is nauseated with a decreased appetite. If asked she will admit to decreased urine output and a reddish brown urine.

PMHx: Until last few months, the patient has been athletic and considerably healthy.

Meds: None

Social: In senior year of high school, living with parents. Denies ETOH or illicit drug use.

Allergies: None Known

Case Study 4

A twenty-five year old black male is brought into the emergency department after being found in his room lying in bed with a suicide note on his desk. The patient reports drinking something that he thought would kill him, but refuses to state what he took. He reports 'stomach pain', frequent urination, and a few episodes of vomiting. The family states that there were a few empty bottles of beer and an empty plastic container near the patient that had no markings on it. Scar tissue is found on patient's right lower abdomen and near left hipbone. Testing reveals complete ADH suppression.

PMHx: DM II

PSHx: Insulin

Social: One pack per day tobacco use

Six pack of beer every 2-3 days

Lives alone.

Meds: none and no one on the house is on any medications. There were no pill bottles found near the patient.

Physical Exam:

The patient was a well developed and nourished male in mild distress from abdominal cramping. He is irritable, uncooperative and smells of alcohol. He has an ataxic gait when he is brought into the emergency department.

BP= 80/50 pulse= 80 bpm rr=14 temp= 97.9 degrees F (orally)

Skin: Moist with no lesions

HEENT:

Mouth/Pharynx excessively dry.

Neck is supple with no masses and a normal thyroid exam

Cardiovasc: enlarged heart, normal lung exam

Abdomen: Normal bowel sounds, non-tender abdomen, no masses, enlarged liver.

Rectal exam is normal

Neuro: The patient has a non-focal neurologic exam. Cerebellar exam is normal except for the noted mild ataxia.

* As the exam proceeds, the patient becomes increasingly agitated and requires restraint. The repeat vital signs are Bp=120/85, p=110 bpm, rr=20 bpm, and a normal temperature.

Labs:

ECG: regular sinus tachycardia with a rate of 110. The PR, QRS, QT, and QTc intervals were normal.

High plasma glucose levels.

Urine= 3+glucose, ketones are negative, protein is positive and there are 1-4 WBC, and 4-6 RBC per high powered field.

Case Study 5

A 25 year old primigravida presented for an anatomy scan at 18 weeks after an initial dating scan at 7.5 weeks. Both fetal kidneys were seen on separate views, but it was difficult to demonstrate both kidneys on the same view. It was uncertain whether this was related to malposition of the kidney or technical difficulties (right breech presentation with spine shadowing). Low lying placenta was also noted.

The patient presented back for a follow-up at 32 weeks.

Findings:
On a normal transverse image of the fetal abdomen, the left kidney was not identified.

Case Study 6

A one- month old female is brought to her pediatrician with a chief complaint of an abdominal mass. Her mother noticed the mass earlier in the week and immediately made an appointment to see the pediatrician. The mother also notes that the infant has been frequently wetting her diapers, although there is no history of fever, vomiting or diarrhea. The infant's perinatal and birth history are unremarkable (spontaneous vaginal delivery at term with a birth weight of 2750 grams). There is a family history of cystic kidneys in the infant's 14 year old brother. The infant's four other brothers and sisters do not have any renal disease and both parents do not have a history of renal disease.

Her physical exam is unremarkable except for a non-tender 7 cm by 8 cm left-sided abdominal mass.

Urinalysis reveals cloudy urine, positive for leukocyte esterase and nitrites. A renal ultrasound is ordered and reveals bilateral enlargement of her kidneys with diffuse echogenicity and microcysts. A hepatic ultrasound reveals periportal fibrosis. The infant is diagnosed with autosomal-recessive polycystic kidney disease and a possible urinary tract infection. She is hospitalized for antibiotic treatment and further evaluation. She improves and is discharged from the hospital. Her renal function is sufficient, but it is anticipated that it will worsen as she grows.

Case Study 7

Despite his weight of nearly 325 pounds, David's family has managed to bring him to the ER for the third time this month. Each time he received a shot of IV medicine to make him urinate some of the nearly 30 pounds of water weight that had collected since the last visit and was now causing him to gasp for breath. As a result, David's kidneys began to enlarged in an effort to compensate for the increased stress on his system.

David had developed severe heart disease secondary to morbid obesity and emphysema from smoking. The ejection fraction of his heart was less than 20% (normal is 60%). David had been ventilated in the past when he was severely short of breath and had informed his family and doctor that he wanted no aggressive life support in the future. In light of this and his frequent visits to the ER, David was referred to home hospice.

Having been disabled for more than two years, David qualified for Medicare; but it did not help pay for the expensive medicines required for his heart and lung conditions. The hospice team developed a plan to help David and his family to manage his illness. The plan included setting up David's medications in a pill box, helping the family budget for medicines not covered under the Medicare Hospice Benefit, and daily weighing to adjust David's water pill dose.

In the first month, David controlled his water weight gain, his depression and anxiety improved, the hospice dietician helped him lose nearly 15 pounds, and a low dose of opioid reduced his constant sense of breathlessness and improved his exercise tolerance. After six months, with no ER visits, the hospice program discharged David since his prognosis seemed to have improved and was probably greater than the six months required for hospice care. One year later, David died. Autopsy identified renal carcinoma as one cause of death.

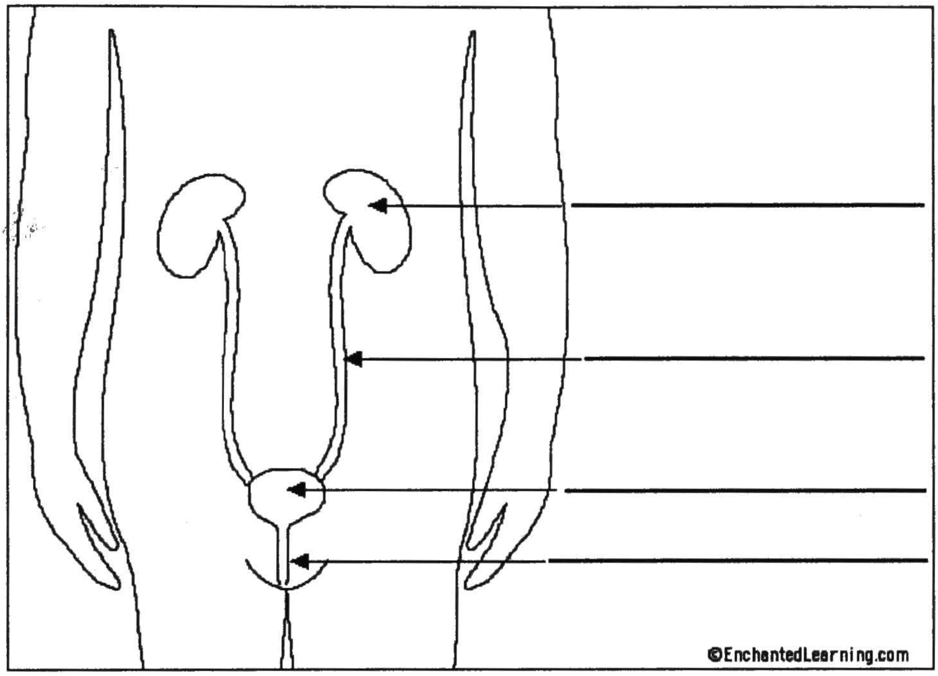
Case Study 8

Fifteen- year old Asian-American female is rushed to ER after collapsing down stairs at her home. Patient lost consciousness upon fall and was not able to regain consciousness. Her parents Mr. and Mrs. Hoang called 911 and the ambulance arrived within minutes. In the ambulance, patient stop breathing and paramedics performed CPR until arrival at the hospital. ER doctors in triage took over. The OR was immediately contacted and Hun was prepped for surgery. While in surgery to stop hemorrhaging, Hun's parents were notified that their daughter was experiencing toxic shock and that her heart, lung, and kidney was experiencing severe dysfunction. The first question the doctor asked was how long had the patient been at this usually low weight.

Appendix C

Worksheet: Components of the Urinary System

Directions: Use the word bank to label each component of the diagram below. Brainstorm function of each component as a group. Write function next to label or on back of this sheet.



Word Bank
1. Pelvis
2. Ureter
3. Kidney
4. Ureter
5. Bladder
6. Urethra

Appendix D

"How does the Kidney filter 180 Liters of Blood a day to produce only 1.5 Liters of Waste product?"

Introduction: (See following link for video clip)
http://www.brainpop.com/health/urinary/urinary/index.weml?&tried_cookie=true

THE FORMATION OF URINE

Every one of us depends on the process of urination for the removal of certain waste products in the body. The production of urine is vital to the health of the body. Most of us have probably never thought of urine as valuable, but we could not survive if we did not produce it and eliminate it. Urine is composed of water, certain electrolytes, and various waste products that are filtered out of the blood system. Remember, as the blood flows through the body, wastes resulting from the metabolism of foodstuffs in the body cells are deposited into the bloodstream, and this waste must be disposed of in some way. A major part of this "cleaning" of the blood takes place in the kidneys and, in particular, in the nephrons, where the blood is filtered to produce the urine. Both kidneys in the body carry out this essential blood cleansing function. Normally, about 20% of the total blood pumped by the heart each minute will enter the kidneys to undergo filtration. This is called the filtration fraction. The rest of the blood (about 80%) does not go through the filtering portion of the kidney, but flows through the rest of the body to service the various nutritional, respiratory, and other needs that are always present.

For the production of urine, the kidneys do not simply pick waste products out of the bloodstream and send them along for final disposal. The kidneys' 2 million or more nephrons (about a million in each kidney) form urine by three precisely regulated processes: filtration, reabsorption, and secretion.

Filtration

Urine formation begins with the process of filtration, which goes on continually in the renal corpuscles (Figure below). As blood courses through the glomeruli, much of its fluid, containing both useful chemicals and dissolved waste materials, soaks out of the blood through the membranes (by osmosis and diffusion) where it is filtered and then flows into the Bowman's capsule. This process is called glomerular filtration. The water, waste products, salt, glucose, and other chemicals that have been filtered out of the blood are known collectively as glomerular filtrate. The glomerular filtrate consists primarily of water, excess salts (primarily Na^+ and K^+), glucose, and a waste product of the body called urea. Urea is formed in the body to eliminate the very toxic ammonia products that are formed in the liver from amino acids. Since humans cannot excrete ammonia, it is converted to the less dangerous urea and then filtered out of the blood. Urea is the most abundant of the waste products that must be excreted by the kidneys. The total rate of glomerular filtration (glomerular filtration rate or GFR) for the whole body (i.e., for all of the nephrons in both kidneys) is normally about 125 ml per minute. That is, about 125 ml of water and dissolved substances are filtered out of the blood per minute. The following calculations may help you visualize how enormous this volume is. The GFR per hour is:

125 ml/min X 60min/hr= 7500 ml/hr.

The GFR per day is:
7500 ml/hr X 24 hr/day = 180,000 ml/day or 180 liters/day.

Now, see if you can calculate how many gallons of water we are talking about. Here are some conversion factors for you to consider: 1 quart = 960 ml, 1 liter = 1000 ml, 4 quarts. = 1 gallon. Remember to cancel units and you will have no problem.

Now, what we have just calculated is the amount of water that is removed from the blood each day - about 180 liters per day. (Actually it also includes other chemicals, but the vast majority of this glomerular filtrate is water.) Imagine the size of a 2-liter bottle of soda pop. About 90 of those bottles equals 180 liters! Obviously no one ever excretes anywhere near 180 liters of urine per day! Why? Because almost all of the estimated 43 gallons of water (which is about the same as 180 liters - did you get the right answer?) that leaves the blood by glomerular filtration, the first process in urine formation, returns to the blood by the second process - reabsorption.

Reabsorption

Reabsorption, by definition, is the movement of substances out of the renal tubules back into the blood capillaries located around the tubules (called the peritubular copillaries). Substances reabsorbed are water, glucose and other nutrients, and sodium (Na^+) and other ions. Reabsorption begins in the proximal convoluted tubules and continues in the loop of Henle, distal convoluted tubules, and collecting tubules (Figure 3). Let's discuss for a moment the three main substances that are reabsorbed back into the bloodstream.

Large amounts of water - more than 178 liters per day - are reabsorbed back into the bloodstream from the proximal tubules because the physical forces acting on the water in these tubules actually push most of the water back into the blood capillaries. In other words, about 99% of the 180 liters of water that leave the blood each day by glomerular filtration returns to the blood from the proximal tubule through the process of passive reabsorption.

The nutrient glucose (blood sugar) is entirely reabsorbed back into the blood from the proximal tubules. In fact, it is actively transported out of the tubules and into the peritubular capillary blood. None of this valuable nutrient is wasted by being lost in the urine. However, even when the kidneys are operating at peak efficiency, the nephrons can reabsorb only so much sugar and water. Their limitations are dramatically illustrated in cases of diabetes mellitus, a disease which causes the amount of sugar in the blood to rise far above normal. As already mentioned, in ordinary cases all the glucose that seeps out through the glomeruli into the tubules is reabsorbed into the blood. But if too much is present, the tubules reach the limit of their ability to pass the sugar back into the bloodstream, and the tubules retain some of it. It is then carried along in the urine, often providing a doctor with her first clue that a patient has diabetes mellitus. The value of urine as a diagnostic aid has been known to the world of medicine since as far back as the time of Hippocrates. Since then, examination of the urine has become a regular procedure for physicians as well as scientists.

Sodium ions (Na^+) and other ions are only partially reabsorbed from the renal tubules back into the blood. For the most part, however, sodium ions are **actively transported** back into blood from the tubular fluid. The amount of sodium reabsorbed varies from time to time; it depends largely on how much salt we take in from the foods that we eat. (As stated earlier, sodium is a major component of table salt, known chemically as sodium chloride.) As a person increases the amount of salt taken into the body, that person's kidneys decrease the amount of sodium reabsorption back into the blood. That is, more sodium is retained in the tubules. Therefore, the amount of salt excreted in the urine increases. The process works the other way as well. The less the salt intake, the greater the amount of sodium reabsorbed back into the blood, and the amount of salt excreted in the urine decreases.

Secretion

Now, let's describe the third important process in the formation of urine. Secretion is the process by which substances move into the distal and collecting tubules from blood in the capillaries around these tubules (Figure 3). In this respect, secretion is reabsorption in reverse. Whereas reabsorption moves substances out of the tubules and into the blood, secretion moves substances out of the blood and into the tubules where they mix with the water and other wastes and are converted into urine. These substances are secreted through either an active transport mechanism or as a result of diffusion across the membrane. Substances secreted are hydrogen ions (H+), potassium ions (K+), ammonia (NH3), and certain drugs. Kidney tubule secretion plays a crucial role in maintaining the body's acid-base balance, another example of an important body function that the kidney participates in.

Summary

In summary, three processes occurring in successive portions of the nephron accomplish the function of urine formation:

1. Filtration of water and dissolved substances out of the blood in the glomeruli and into Bowman's capsule;

2. Reabsorption of water and dissolved substances out of the kidney tubules back into the blood (note that this process prevents substances needed by the body from being lost in the urine);

3. Secretion of hydrogen ions (H^+), potassium ions (K^+), ammonia (NH_3), and certain drugs out of the blood and into the kidney tubules, where they are eventually eliminated in the urine.

Note: Information on this page was obtained from the following link:
http://www.nsbri.org/HumanPhysSpace/focus4/ep-urine.html

Appendix E

Dialysis

Use model if available to demonstrate how dialysis takes place. Models can be ordered from Ward, Frey, or Carolina Science Catalogues. If model, not available, animation of this process can be retrieved at the following links:

http://web.ukonline.co.uk/webwise/spinneret/human2/andial.htm
http://www.kidneypatientguide.org.uk/site/pdanim.html
http://zoology.okstate.edu/zoo_lrc/biol1114/tutorials/Flash/Osmosis_Animation.htm

Choose link that is most suitable to your classroom needs.

Dialysis is the process of removing waste products and excess fluids from the body.

There are a number of reasons why a person may need dialysis. Making the decision to begin dialysis is not easy because it entails a major change in lifestyle, including a dependency on machines to maintain life. However, for most people, a successful dialysis program results in a reasonably normal life. Most people undergoing dialysis are able to eat a tolerable diet, have normal blood pressure, do not have anemia, and avoid progression of nerve damage and other complications.

For acute kidney failure, many doctors recommend dialysis when urine output is low, and they continue the dialysis until the person's blood tests indicate that adequate kidney function has been restored. Short-term or urgent dialysis can also be used to remove certain drugs or poisons from the body.

For chronic kidney failure, doctors may recommend dialysis when tests indicate that the kidneys are not removing metabolic waste products adequately or when a person can no longer perform normal daily activities. Dialysis may be used as long-term therapy for chronic kidney failure or as an interim measure before kidney transplantation.

Dialysis usually requires the effort of a team of people. A doctor completes a dialysis prescription, manages complications, and monitors the process. A nurse monitors the person's general well-being and mental health and educates the person about such issues as exercise. A social worker arranges transportation and home assistance. A dietitian recommends an appropriate diet and monitors the person's response to dietary changes.

Types of Dialysis: Hemodialyis and Peritoneal (See link below for picture)

http://www.merck.com/mrkshared/mmanual_home2/sec11/ch143/ch143d.jsp

Hemodialysis: In hemodialysis, blood is removed from the body and pumped by a machine outside the body into a dialyzer (artificial kidney). The dialyzer filters metabolic waste products from the blood and then returns the purified blood to the person. The total amount of fluid returned can be adjusted. A person typically undergoes hemodialysis at a dialysis center, usually outside of a hospital but sometimes located in a hospital.

Hemodialysis requires repeated access to the bloodstream. A doctor can achieve temporary access by inserting a large intravenous catheter in a big vein, usually one near the neck. An artificial connection between an artery and a vein (an arteriovenous fistula) is surgically created to make long-term access easier. In this procedure, typically the radial artery in the forearm is joined with the cephalic vein. Heparin, a drug that prevents clotting, is administered during hemodialysis to prevent blood from clotting in the dialyzer. Inside the dialyzer, a porous artificial membrane separates the blood from a fluid (the dialysate). Fluid, waste products, and electrolytes in the blood filter through the membrane into the dialysate. Blood cells and large proteins are unable to filter through the small pores of the membrane and so remain in the blood. The dialyzed (purified)

Most people who have chronic kidney failure need hemodialysis 3 times a week.

Peritoneal Dialysis: In peritoneal dialysis, the peritoneum—a membrane that lines the abdomen and covers the abdominal organs—acts as a filter. This membrane has a large surface area and a rich network of blood vessels. Substances from the blood can easily pass through the peritoneum into the abdominal cavity. A fluid (dialysate) is infused through a catheter inserted through the abdominal wall into the peritoneal space within the abdomen. The dialysate must be left in the abdomen for a sufficient time to allow metabolic waste products from the bloodstream to pass slowly into it. Then the dialysate is drained out, discarded, and replaced with fresh dialysate.

A soft porous catheter allows the dialysate to flow smoothly and is unlikely to cause damage. A catheter can be put in place temporarily at the person's bedside, or it may be surgically put in place permanently. One type of permanent catheter eventually forms a seal with the skin and can be capped when not in use.

Various techniques are used for peritoneal dialysis. In the simplest technique, manual intermittent peritoneal dialysis, bags containing dialysate are warmed to body temperature and infused into the peritoneal (abdominal) cavity for 10 minutes. The dialysate is allowed to remain there (dwell time) for 60 to 90 minutes and then drained out in about 10 to 20 minutes. The entire treatment can take 12 hours.

Summary

- The kidneys play a vital role in our body, removing waste products from our blood and controlling its salt levels and acidity.
- Kidney failure results in a build up of waste products in our blood. These waste products start to poison us, and our kidneys may become even less efficient in consequence.
- The dialysis machine is able to carry out many of the roles of our own kidneys.
- Blood is taken from an artery in our arm or leg, and passed into the machine through a pump.
- Inside the machine our blood is brought into contact with a dialysis membrane.
- The dialysis membrane has very small holes that proteins and blood cells cannot pass though, but salts, glucose and waste products can.
- On the other side of the membrane is a specially formulated dialysate solution, this contains all of the salts and glucose that we need, but none of the waste products.
- Salts and glucose pass across the membrane in both directions, but waste products are only present in our blood. As a result the waste products leave our blood and go into the dialysate solution, which is discarded.
- By changing the concentrations of salts in the dialysate solution, the salt levels and acidity of our blood can also be controlled by the dialysis machine.
- The clean blood is now returned to our bodies.
- The dialysis machine cannot do everything our kidneys do, so we may have to take supplementary medication.
- By taking over the job of cleaning up our blood, however, the dialysis machine gives our kidneys a rest.
- This may be enough to allow them to recover, but many people will have to be dialysed regularly until a donor for transplant surgery can be found.

Appendix F

Laboratory Activities

Chemical Lab

-Students can construct a model of a kidney using a semipermeable membrane to filter a completely safe solution which simulates blood. The simulated blood solution contains simulated cells which can not cross the semipermeable membrane, remaining in the kidney model. The resulting filtrate resembles urine, which students test for salt and other waste products. The simulated blood cells can also be seen and counted under a microscope-just like real blood! Grades 7-10. Lab for 40 students.

Test and observe the physical and chemical characteristics of simulated urine, relating the results to a variety of diseases which can be diagnosed through urinalysis. The kit includes a unique formulation of safe, simulated urine which looks and acts like the real thing.

- Order at the following Link: http://www.kelvin.com/Merchant2/merchant.mv?Screen=PROD&Store_Code=K&Product_Code=282241

-Students will gain a basic understanding of urinalysis and the important role it plays in the diagnosis of medical disorders as they test the simulated urine for pH, protein, sugar, crystals and simulated blood cells, which can be viewed under a microscope. Grades 7-10. Lab for 40 students.

- Order at following link: http://www.kelvin.com/Merchant2/merchant.mv?Screen=PROD&Store_Code=K&Product_Code=282243

Dialysis Lab

This simple yet instructive system provides a highly visual demonstration of how the kidney processes blood, excreting waste while conserving water, using a semi-permeable membrane and simulated blood (which contains no biological components).

Salt content can be tested before, during, and after the filtering. Slide smears can be made for microscopic study, allowing students to observe that the "red blood cells" of the simulated blood are not present in the urine. A safe, dramatic re-creation of blood filtration.

Includes: teacher's manual with copymasters of student activities

- Order at following link: http://sciencekit.com/category.asp?c=507571

Appendix G
Reading Assignment

Urinary System Pathology

Problems in the urinary system can be caused by aging, illness, or injury. As you get older, changes in the kidneys' structure cause them to lose some of their ability to remove wastes from the blood. Also, the muscles in your ureters, bladder, and urethra tend to lose some of their strength. You may have more urinary infections because the bladder muscles do not tighten enough to empty your bladder completely. A decrease in strength of muscles of the sphincters and the pelvis can also cause incontinence, the unwanted leakage of urine. Illness or injury can also prevent the kidneys from filtering the blood completely or block the passage of urine.

How are problems in the urinary system detected?

Urinalysis is a test that studies the content of urine for abnormal substances such as protein or signs of infection. This test involves urinating into a special container and leaving the sample to be studied.

Urodynamic tests evaluate the storage of urine in the bladder and the flow of urine from the bladder through the urethra. Your doctor may want to do a urodynamic test if you are having symptoms that suggest problems with the muscles or nerves of your lower urinary system and pelvis (ureters, bladder, urethra, and sphincter muscles).

Urodynamic tests measure the contraction of the bladder muscle as it fills and empties. The test is done by inserting a small tube called a catheter through your urethra into your bladder to fill it either with water or a gas. Another small tube is inserted into your rectum to measure the pressure put on your bladder when you strain or cough. Other bladder tests use x-ray dye instead of water so that x-ray pictures can be taken when the bladder fills and empties to detect any abnormalities in the shape and function of the bladder. These tests take about an hour.

Disorders/Diseases

Glomerulonephritis is a kidney disease. The kidneys' filters become inflamed and scarred and slowly lose their ability to remove wastes and excess water from the blood to make urine. Kidney disease of diabetes, IgA nephropathy, and lupus nephritis are some types of glomerulonephritis. On this hub page, you will find reviewed and categorized links about glomerulonephritis.

Kidney stones is the term commonly used to refer to stones, or calculi, in the urinary system. Stones form in the kidneys and may be found anywhere in the urinary system. They vary in size. Some stones cause great pain while others cause very little. The aim of treatment is to remove the stones, prevent infection, and prevent recurrence. Both nonsurgical and surgical treatments are used. Kidney stones affect men more often than women.

Prostatitis is inflammation of the prostate gland that results in urinary frequency and urgency, burning or painful urination (*dysuria*), and pain in the lower back and genital area, among other symptoms. In some cases, prostatitis is caused by bacterial infection and can be treated with antibiotics. But the more common forms of prostatitis are not associated with any known infecting organism. Antibiotics are often ineffective in treating the nonbacterial forms of prostatitis.

Proteinuria is the presence of abnormal amounts of protein in the urine. Healthy kidneys take wastes out of the blood but leave in protein. Protein in the urine does not cause a problem by itself. But it may be a sign that your kidneys are not working properly.

Renal (kidney) failure results when the kidneys are not able to regulate water and chemicals in the body or remove waste products from your blood. *Acute renal failure (ARF)* is the sudden onset of kidney failure. This can be caused by an accident that injures the kidneys, loss of a lot of blood, or some drugs or poisons. ARF may lead to permanent loss of kidney function. But if the kidneys are not seriously damaged, they may recover. *Chronic renal failure* (CRF) is the gradual reduction of kidney function that may lead to permanent kidney failure, or end-stage renal disease (ESRD). You may go several years without knowing you have CRF.

Urinary tract infections (UTIs) are caused by bacteria in the urinary tract. Women get UTIs more often than men. UTIs are treated with antibiotics. Drinking lots of fluids also helps by flushing out the bacteria. The name of the UTI depends on its location in the urinary tract. An infection in the bladder is called *cystitis*. If the infection is in one or both of the kidneys, the infection is called *pyelonephritis*. This type of UTI can cause serious damage to the kidneys if it is not adequately treated.

Urinary incontinence, loss of bladder control, is the involuntary passage of urine. There are many causes and types of incontinence, and many treatment options. Treatments range from simple exercises to surgery. Women are affected by urinary incontinence more often than men.

Urinary retention, or bladder-emptying problems, is a common urological problem with many possible causes. Normally, urination can be initiated voluntarily and the bladder empties completely. Urinary retention is the abnormal holding of urine in the bladder. Acute urinary retention is the sudden inability to urinate, causing pain and discomfort. Causes can include an obstruction in the urinary system, stress, or neurologic problems. Chronic urinary retention refers to the persistent presence of urine left in the bladder after incomplete emptying. Common causes of chronic urinary retention are bladder muscle failure, nerve damage, or obstructions in the urinary tract. Treatment for urinary retention depends on the cause.

Hypertension (high blood pressure) if untreated can cause chronic kidney failure.

Hemolytic Uremic Syndrome is a complex condition caused by certain strands of Escherichia coli bacteria. It a leading cause of acute kidney failure in infants and young children.

Analgesic Nephropathy is a condition that may result from the long-term use of aspirin or other nonsteroidal anti-inflammatory drugs that contain Ibuprofen. Large amounts of acetaminophen may also harm the kidneys, especially in children.

Renal Artery Stenosis. This is a blockage of the renal artery before it enters the kidney. In older adults, blockages often result when fatty deposits accumulate under the lining of the artery walls (antherosclerosis). Renal artery stenosis can also affect young women who have a condition known as fibromuscular dysplasia, which cause the walls of the arteries to become thicker. Both these conditions are often associated with high bllod pressure.

Renal Carcinoma is cancer of the kidneys. As with most types of cancer, studies show that the risk of kidney cancer increases with age. It occurs most often between the ages of 40 and 70. In addition to affecting men more than women, it is somewhat more common among African-American men than Caucasian men. Other risk factors include tobacco use, obesity, occupational exposure (exposure to asbestos), radiation, and long-term dialysis use. Symptoms include blood in urine, lump or mass on kidney, and less common symptoms of loss of appetite, fatigue, pain on the side that doesn't go away, and general feeling of poor health. Ultrasounds, MRIs, blood work, biopsys, and blood vessel/structure x-rays. Treatment includes surgery, radiation, chemo- and immuno-therapy.

Diabetes (diabetes mellitus, or DM) is a disorder of metabolism--the way our bodies use digested food for growth and energy. Most of the food we eat is broken down into glucose, the form of sugar in the blood. For glucose to get into cells, insulin must be present. Diabetes involves either the lack of insulin production or deficiencies in glucose uptake by insulin, both of which lead to high plasma glucose levels. Symptoms may include fatigue or nausea, frequent urination, unusual thirst, constant hunger, weight loss, blurred vision, frequent infections, and slow healing of wounds or sores. Some people have no symptoms. Diabetes is associated with long-term complications that affect almost every part of the body. The disease often leads to blindness, heart and blood vessel disease, stroke, kidney failure, amputations, and nerve damage.

Anorexia (anorexia nervosa) is a mental illness, with physical and emotional repercussions. A person with anorexia severely limits food intake, has a distorted body image, refuses to maintain a normal body weight, and is intensely afraid of gaining weight, despite being very underweight. Long-term or severe anorexia can lead to serious health problems and even death. Under extreme conditions, the kidney can undergo shock or kidney failure, resulting in

Appendix H

Written Exam (Urinary System)

Name:____________________
Class Period & Date:________

Fill in the Blank

Please fill in blank with answer that best answers question. Each question is work 3 points.

1. During micturition, urine moves out of the urinary bladder via this structure.
   ____

2. What portion of the kidney contains the renal pyramids? __________________

3. What blood vessels function to carry blood from the aorta to the segmental arteries? _____________________

4. What blood vessel receives blood from the renal veins and returns it back to the heart? _____________________

5. What are the two primary functions of the urinary system?
   ____
   ____
   ____

6. The renal artery branches into ___________ arteries before entering the kidney.

Multiple Choice

Each question is worth 1 point each. Please circle letter that best answers question.

7. What structure allow urine to move from the kidneys to the urinary bladder?

    a. Renal vein

    b. Urethra

    c. Ureter

    d. Nephron

8. What are the areas between the renal pyramids called (where the interlobar arteries are located)?

    a. Columns

    b. Hilum

    c. Pelvis

    d. Glomerulus

9. What is the cavity within the kidney that is continuous with the ureter?

    a. Arterioles

    b. Urethra

    c. Calyx

    d. Renal vein

10. What percentage of blood is filtered to the kidney?

    a. Approximately 25%

    b. Approximately 50%

    c. Approximately 75%

    d. Approximately 100%

11. What is the name of the process that allows filtration, reabsorption, and secretion to take place within the kidney?

a. Glycolysis

b. Cellular Respiration

c. Diffusion

d. Micturition

12. Blood that enters __________ brings wastes that come from body cells.

a. Urea

b. Nephron

c. Artery

d. Vein

13. The following table will report information about blood test results for two patients. Tests run for Patient B report that her kidneys are healthy. Based on this information, which of these would you predict her BUN test results would be?

Blood Test Results			
Test	Normal Range	Patient A	Patient B
BUN	8–26 mg/dL		
WBC	5000–10 000/µL		7500/µL

BUN = Blood Urea Nitrogen (BUN is a measure of the amount of urea present in the blood.)
WBC = White Blood Cells

a. 2 ml/dL

b. 15 ml/dL

c. 29 ml/dL

d. 36 ml/dL

14. Which of these diseases is detected by the discovery of excess amounts of glucose in a person's blood?

a. Cancer

b. Asthma

c. Diabetes

d. Cirrhosis

15. Which body part moves urine out of the body?

    a. Urethra

    b. Nephron

    c. Ureter

    d. Glomerulus

Essay

Select two of the three questions to respond to. Your answers should be thorough and should FULLY answer the question. Please circle the question number of the questions that you would like to be graded on. Each response is worth 6 points.

16. How does the urinary system function to maintain homeostasis in the body? In your answer, outline process and how it affects 2 other systems in the body.

____

____

____

____

____

____

____

17. What molecules are usually found in the urine? Consider Na, urea, water, K, proteins, RBC, and glucose usually found in the urine? What determines whether the above molecules will be found in urine?

____

____

____

____

____

____

____

18. Explain how the Endocrine system is intimately associated with the urinary system. Identify hormones (and their function) that play a significant role.

Appendix I

Patient Encounter Workshop Guidelines

This workshop is designed to simulate doctor-patient interaction where one student assumes the role as the "treating physician", while the other assumes the role as the "patient". Dialogue during workshops will be structured around previously presented cases and will reflect learned information as the "patient" recalls fundamental concepts and the "physician" applies that information to the respective case study.

This guideline is to be given to students for review prior to day of workshop. It will serve as an instructional guide, as well as a rubric. Groups are to be formed at the beginning of unit based on interest (give list of topics to students at the end of day one and have them turn list in the following day. Group assignments should be given at the end of day 2) so that students will have an opportunity to collaborate prior to workshop.

1. Using case study handouts that contain your written response to pre-lesson questions and post-lesson findings, identify key points that should be covered. You may model your presentation after provided case studies or you may develop your own. If developing own case study, you must turn in description the day before presentations.
2. Select who will be doctor, patient, nurse and assistant. The roles of each will be outlined on page 3 of this handout. For the purpose of this activity, you will be assigned a group grade only based on your group presentation. However, each individual must submit an outline of their contributions to group presentation. Individuals who do this will be 3 bonus points to be added to overall exam grade (written and practical). Remember to work hard and collaborate.
3. Use sample 'encounter' to model your approach and responses. Remember to include class information and research findings.
4. Groups will be selected in random order on workshop day to present their selected case before class on workshop day (so be prepared!!).
5. A model encounter will take place the day before workshop to better prepare you for your presentation.
6. You will be given 10 minutes of class-time on day of workshop to prepare.
7. Your workshop presentation will constitute 50% of your practicum exam grade.
8. See the following rubric for expectations and point distribution. You should collaborate with your group members prior to workshop day to ensure that expectations are met.

Rubric (Presentation)

Excellent (9-10pts)	**Good** (7-8pts)	**Average** (5-6pts)	**Fair/Poor** (4 pts or below)
4 or more class information points were incorporated.	3 or less class information points were incorporated.	2 or more class information points were incorporated.	1 or no class information points were incorporated.
3 or more research findings were identified.	2 or less research findings were identified.	Only 1 research findings was identified.	NO research findings were identified.
Audience was provided handouts AND presenters utilized props during presentation.	Audience was provided handouts OR presenters utilized props during presentation.	Audience was NOT provided with handouts and/or presenters utilized props during presentation.	Dialogue between participants was professional and exuded confidence.
3 or more comments each were made by "Nurse" and "Medical Assistant" during presentation.	2 comments each were made by "Nurse" and "Medical Assistant" during presentation.	1 comment each were made by "Nurse" and "Medical Assistant" during presentation.	NO comments each were made by "Nurse" and "Medical Assistant" during presentation.
Proper diagnosis, symptoms and treatment were identified.	Proper diagnosis, symptoms and treatment were identified.	Proper diagnosis, symptoms and treatment were identified.	Proper diagnosis, symptoms and treatment were identified.
Group presented teacher with printout of their research findings. **YES** or **NO.**	Group presented teacher with printout of their research findings. **YES** or **NO.**	Group presented teacher with printout of their research findings. **YES** or **NO.**	Group presented teacher with printout of their research findings. **YES** or **NO.**
Presentation was original. **YES** or **NO.**			

NOTE: Each requirement must be met in order to receive desired grade. The final two rows will serve as a bonus of 1 point each. These points can be utilized for the purpose of increasing presentation score if one or more of the requirements are not met in a given field or, if a score of excellent has already been obtained, the additional points can be used to increase overall practicum exam grade. Remember, your grade on this assignment will represent 50% of your practicum exam grade.

Description of Roles

"Physician"
He/she will:
-Facilitate flow of presentation, along with "patient".
-Present/apply research findings and class information along in an effort to deduce diagnosis, outline symptoms, and provide treatment options to the patient.
-Contribute to pre-workshop research and planning.

"Patient"
He/she will:
-Facilitate flow of presentation, along with "physician"
-Present 'reason for visit' to Medical Assistant or Nurse.
-Use classroom information to facilitate questioning.
-Contribute to pre-workshop research and planning.

"Nurse or Medical assistant"
He/she will:
-Present 'reason for visit' to "physician" using medical terminology.
-Request needed tests for the purpose of deducing diagnosis.
-Prep "patient" for needed exams or tests.
-Contribute to pre-workshop research and planning.

"Assistant", Other
He/she will:
-Be the liaison between group and teacher if assistance is needed prior to presentation day.
-Serve as guest of patient or any other medical office staff during presentation.
-Add originality to presentation… you decide how.
-Contribute to pre-workshop research and planning.

Appendix J

Exam Review

Part A- Practical Exam (See Compact Disk)
Student will:

- Identify external and internal features of renal and urinary system, and
- Identify histological regions and cells of glomerular network and nephron.

NOTE: Gross, model, and histological images may be presented via display and/or Power Point.

Part B- Written Examination (Appendix I)
Student will answer recall, synthesis, comprehensive, and application questions on:

- Components of excretory system;
- Physiology of system and individual components;
- Homeostasis and relationship to other systems;
- Lifestyle and Nutrition; and
- Pathology (Essay Assignment: Day 4)

NOTE: Format: Multiple choice, short answer, and essay.

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