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From Cells to Clinics- The Role of College Biology Education in Shaping Future Physician Assistants

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An undergraduate student choosing to continue her profession in the medical field fearfully accepts that with the daydream of making it, comes a reality with endless hours of learning, studying and hands on experience. She has days where she questions her own life choices and others that bring her peace in knowing her calling. To be a medical professional, a prescribed set of courses are required as an undergraduate to form an educational foundation in various subjects including the sciences, liberal arts, and environmental sciences. These classes establish a conceptual understanding of knowledge that form the basis that doctors and nurses need to fulfill their daily tasks of diagnosing, treating, and healing patients. As a senior in college, I am taking the next steps to becoming a Physician Assistant (PA). In this paper, I will be discussing topics within five separate courses that I have completed which I feel have the most impact on my future career as a Physician Assistant in the hospital. The courses that I have selected are Microbiology, Comparative Physiology, Neuroscience Foundations, Bio-medical Ethics and Genetics. I will tie relationships between concepts learned in each class to real life situations a physician assistant may face on the job.

The physician assistant profession requires a knowledge and skills foundation like any medical doctor. One of the most important and challenging responsibilities of the profession is diagnosing and treating patients. Microbiology provides a framework for identifying specific viruses that cause disease, how to stop the disease from spreading, and how to fight infection. Microbes are the fundamental building blocks of microbiology; they encompass bacteria, fungi, archaea, protists, and viruses.

Microbiology is the study of microorganisms, their structure, functions, and behaviors in the environment. Microbes are tiny living organisms that cannot be seen with the naked eye. They include bacteria, fungi, archaea, protists, and viruses. Viruses are not alive as they lack the ability to metabolize or use energy and cannot replicate independently of a host cell. Microbes are vital to the human body. Most microbes are good and stimulate the immune system while producing natural antimicrobials that prevent disease, but microbes can also cause disease (Weiman, 2015). Microbes that cause disease are known as pathogens which occur most frequently in mucosal membranes - when a microbe enters a host cell – thus harming and infecting the cell. The infection becomes a disease when there is damage to the host that inhibits its functions (Weiman, 2015). One of the roles of a physician assistant is to detect the infectious

viruses that are present within a patient through the evaluation of symptoms and laboratory testing.

Viruses are detected based on their small size and their reliance on host cells for replication (Frank, 2014). They contain either DNA or RNA, in which these sequences can be detected and amplified through a Polymerase Chain Reaction (PCR). PCR tests detect DNA sequences of specific organisms that are either viruses or bacteria. This test is used in hospitals to confirm certain illnesses patients may face, and aid with diagnoses. PCR uses a heat-resistant DNA polymerase along with DNA primers to amplify the targeted DNA sequence. Consecutive heating denatures the DNA then cools to bind primers (Frank, 2014). PCR testing detects the presence of genetic material from viral or bacterial organisms. In microbiology, students detected and counted viruses through viral culturing techniques.These techniques are known as plaque assays that involve a serial dilution, adding a diluted virus sample directly into a tube of soft agar, to which a host was previously added and poured onto agar plates. The solidified agar immobilized the bacteria, allowing the viral particles to infect the cells, creating clear, visible spots called plaques where the cells die. After incubation, plaques were counted to figure out how many viruses infected the original sample. Plaque assays are counted to understand how the viruses behave.

Staining procedures in the laboratory are performed to reveal chemical and physical differences between cell surfaces in bacteria and help in diagnosis. The Gram stain separates bacteria into two groups, Gram-positive and Gram-negative bacteria. Gram-positive bacteria have a thick layer of peptidoglycan in their cell walls, which provides structural support. Peptidoglycan absorbs the crystal violet dye used in the Gram stain, so the Gram-positive bacteria turn purple (Frank, 2014). Gram-negative bacteria have a thinner layer of peptidoglycan in their cell walls, and have an outer layer composed of lipopolysaccharides (LPS) and phospholipids. The LPS provides an extra layer of structure for the outer membrane but prevents the absorption of crystal violet dye (Frank, 2014). It is important to learn how cultures grow and what to look for, especially if a PA is reading lab results. When a foreign organism is detected in the body, it is important to remember that different microbes colonize in humans, most of which are healthy normal flora (Frank, 2014). Normal flora are microbes that fight pathogenic bacteria and help food metabolize. They rarely cause disease and would not be treated by medical professionals.

In Microbiology we learned about bacterial diversity and the bacteria that cause different diseases. There are around 1,300 bacterial phyla that exist, but four of them were noted throughout the course: Proteobacteria, Actinobacteria, Firmicutes and Bacteroidetes. The group that would be seen the most in a clinical setting of a hospital would be Proteobacteria. This past summer I worked in the emergency room as a technician. I had many hands-on patient care roles, one being running urine analyses, pregnancy tests and stool tests. I also swabbed for strep throat and COVID-19. The most common bacteria discussed both in the classroom and in the hospital were members of the order *Enterobacteriales* and the genus *Staphylococcus,* clinically seen as urinary tract infections, pneumonia, and hospital infections. Microbiology is used frequently in the medical world when detecting bacteria and diagnosing patients. I was able to learn about *Enterobacteriales* and *Staphylococcus* in the classroom then see the diseases they cause firsthand in the emergency room.

When a medical professional goes through the process of diagnosis, the pathogen is detected through laboratory tests to identify viral organisms. After the diagnosis, a physician assistant will develop a treatment plan. Microbiology introduces antimicrobial agents, also known as antibiotics. Antibiotics are antimicrobial drugs that are classified based on molecular structure, mechanism of action, and activity. After the bacteria are identified, susceptibility testing takes place to test the effectiveness of the antibiotic that would be used to fight against or kill off the bacteria (Frank, 2014). Antibiotics can be man-made substances, substances produced by microorganisms, or substances that are chemically modified (Frank, 2014). It is important to know that bacteria can become susceptible to certain antibiotics.

The most prevalent antibiotic-class used in hospitals and clinics are β-Lactam antibiotics (Pandey & Cascella, 2024). An example is Penicillin which is effective against gram-positive bacteria. The target is cell-wall synthesis through the mechanism of a transpeptidation reaction, which in simplest forms the enzyme binds to the antibiotic and weakens the cell wall and kills the bacteria (Pandey & Cascella, 2024). While working in the emergency room, Penicillin was frequently used as an antibiotic for patients with bacterial infections, even though many patients were allergic. A large problem the medical field has been facing is viral organisms' resistance to antimicrobial agents. Infections that become more common among bacterial populations begin to resist the drugs trying to kill them (Abushaheen et al., 2020). Pathogenic bacteria can deactivate or modify the antibiotic. Enzymes such as β-lactamase chemically break open the antimicrobial

agent and inactivate the antibiotic. Bacterial enzymes deny the access of antibiotics to target cells (Abushaheen et al., 2020). Because of antibiotic inefficiency, viral infections can reform themselves and establish new strains that counteract antimicrobial drugs, thus slimming treatment options for medical professionals (Abushaheen et al., 2020).

Microbiology forms the framework for understanding infectious diseases. The class enables undergraduate biology students to learn about microbial life and how important bacterial presence is in medicine. A physician assistant meets with patients daily who suffer from bacterial infections. It is a part of their job to identify the bacteria causing the disease, stop the bacteria from spreading, and develop a long-term treatment plan. Making informed decisions in the management of disease is vital to the profession, but to do so they must recognize the behavior of microorganisms and their impact on the human body. Microbiology is a fundamental course necessary for the education and practice of a physician assistant.

Comparative Physiology is a biology upper-level course that provides students with a detailed understanding of how physiological processes vary among species. This course explores mechanisms of organ systems in mammals, and such knowledge is beneficial for aspiring physician assistants. There are three concepts that I took away from this class that I can take into my professional career. The first topic is basic research; how discoveries of animal functions can contribute to human medicine. Researching the physiological mechanisms of how other species survive can contribute to improving human health. The second topic is the physiology of the mammalian lung and the respiratory cycle. To go into emergency medicine, one must be familiar with the respiratory system because many patients enter the emergency room with trouble breathing or more serious illnesses such as pneumonia, and a physician assistant will treat these patients. I will discuss the mammalian heart and its electrical activity. This concept is relevant to patients seen in the emergency room, where heart problems are frequently encountered and managed by physician assistants.

Basic research is experimental research performed to understand or bring awareness to the foundations of agriculture, endangered species conservation and medicine. Animal experiments, cell studies, physiological and biochemical investigations are examples of basic research that have advanced medical practices (Röhrig et al., 2009). Many medical discoveries benefiting humans have come from ordinary functions of animals. In one study discussed in lecture, spider silk fibers were used as a new material in artificial nerve constructs to promote

nerve regeneration in rats, hopefully to be used in human medicine (Allmeling et al., 2008). Nerve grafts were constructed from isogenic veins composed of spider silk fibers that were supplemented with Schwaan cells which are cells that maintain and regenerate axons of neurons in the peripheral nervous system. The experiment was conducted to determine if these nerve grafts made of spider silk fibers would connect a 20-mm gap of the sciatic nerve in rats and promote nerve regeneration (Allmeling et al., 2008). Results showed that after six months the nerve graft maintained its original volume, became embedded in the host tissue and was well-vascularized. Histologically there was no sign of inflammation. The sciatic nerve was regenerated along with nerve fibers and sheaths. Overall, the spider silk fibres were successful in being internal orientation structures that promoted Schwaan cell migration (Allmeling et al., 2008). As discussed in lecture, basic research of the foundation for ground-breaking medical discoveries. One other research discovery is found in naked mole-rats and their resistance to cancer. There have never been tumors observed in these animals, and it was discovered that through experimentation, the fibroblasts in naked mole-rats show contact inhibition. Contact inhibition is an anti-cancer mechanism that stops cell division when cells have reached high density (Seluanov et al., 2009). Potentially, this discovery will prevent the spread of cancer in humans. Although physician assistants do not perform basic research, they are involved in the application of the research findings in clinical settings.

The mammalian lung is very complex, and lung physiology is important to know for a physician assistant when diagnosing patients and accurately interpreting diagnostic tests. According to the textbook *Animal Physiology: Fourth Edition*, by Richard W. Hill (2016), the trachea divides into the primary bronchi, which are the two major airways, which enter the two lungs. The bronchi divides and re-divides into smaller branches termed bronchioles, and on the end of these bronchioles form alveolar ducts and sacs that contain the alveoli. The lungs themselves are composed of airways and blood vessels which vary in size. Human lungs are spongy and alveolar. Large amounts of alveoli, air-filled sacs, provide a large amount of surface area for gas exchange between oxygen and carbon dioxide due to their thin walls. The thinner the alveolar membrane, the greater the amount of gas exchange between the air and the bloodstream. Humans experience tidal gas exchange. Oxygen from the environment is inhaled at a partial pressure of 100, this air then enters the lung and mixes with stale air composed of CO2, which decreases the partial pressure. At the same time of mixing, oxygen-poor blood from body tissues

meets the walls of the lung and picks up oxygen and releases carbon dioxide (Hill et al., 2016). This results in an increase in partial pressure in the blood, but the partial pressure in the blood as it leaves the lung is lower than the total partial pressure of oxygen during exhalation. The respiratory cycle begins with inhalation and ends with exhalation and is constantly repeating to ensure a constant oxygen intake. The exchanging of air coming in and out of the body is known as tidal volume. In humans, resting tidal volume is 500 ml (Hill et al., 2016). This number is determined by taking the difference of the volume of air present at the end of inhalation and at the end of exhalation. There is always air present in the lungs, even after the most forceful exhalation. The air that remains is termed as the residual volume, which varies among body sizes (Hill et al., 2016). The respiratory cycle is prominent in gas exchange between oxygen and carbon dioxide. A physician assistant must detect changes or abnormalities in human respiration, and to do so, must determine a healthy respiratory system from a diseased one.

One of the most frequent respiratory diseases seen in the emergency department is pneumonia. This disease is often misdiagnosed in elderly patients, resulting in prolonged illness and even death. This occurance is frequent in the emergency room; the challenge is identifying the cause of the infection early so that the appropriate antibiotic can be administered (Woolfrey, 2012). Causal agents of this infection are bacteria or viruses that cause inflammation of the lung. Pneumonia frequently arises because of viral infections such as influenza. The problem that the emergency department faces is recognizing the disease, ruling out all other possible respiratory diseases, choosing an effective antibiotic that will manage symptoms, and determining if the stage of pneumonia is severe enough for hospitalization (Woolfrey, 2012). The disease is obtained through the ingestion of small amounts of foreign material or by direct inhalation from an infected, contagious person. For clinical pneumonia to develop there must be a defect in host defense (Woolfrey, 2012). These mechanisms of impairment include decreased lung elastic recoil, where the lungs struggle to deflate air during exhalation because of loss of elastic fibers and alveolar surface area. This defect usually occurs in the elderly. Respiratory epithelium damage is another example of a host deficit caused by smoking and upper respiratory tract infections (Woolfrey, 2012). Identifying the cause of the infection that brings on pneumonia is very challenging for medical professionals in the ER because there could be many different causes. Matching the cause with the right treatment is important to control the infection, particularly when the patient is at a higher risk of dying. Microbial testing takes longer than the

ER assessment, and treatments are needed right away. The type of pneumonia can be deciphered based on severity of symptoms and diagnostic imaging (Woolfrey, 2012).

During my time as a technician in the ER, I saw patients in different stages of infection. The most critical pneumonia cases - mostly caused by *Streptococcus pneumoniae*, were given antibiotics right away as they were experiencing high fevers, rough coughs with brown mucous, and imaging that showed white clumped globs that scattered throughout the lungs. The less critical cases experienced a dry cough and did not have high fevers. A quick method to rule out pneumonia in the ER is to consider external contact of the patient combined with host factors which could lead to the causal agent (Woolfrey, 2012). Initial assessments should not only ask about symptoms but should also ask where the patient thinks they obtained the infection in the first place – if they traveled, if they came in close contact with animals, or if there is mold growing in the household. The pathogens that cause pneumonia have overlapping symptoms which could cause confusion when deciding on antibiotics, but to improve diagnosis, certain pneumonia pathogens have been categorized based on causal patient conditions. An example the article provides is the pathogen *Klebsiella*. This specific pathogen can be associated with symptoms of fevers and a thick mucus that is a dark red. What sets this pathogen apart from other potential candidates is the health status of the patient, usually suffering from alcoholism, COPD, or diabetes (Woolfrey, 2012). Pneumonia is frequent in the emergency department and can often be challenging to develop a treatment plan, but with the right methods of assessment a physician assistant can determine the causal agent and figure out a treatment plan.

To detect any cardiac abnormalities in patients, a physician assistant is educated in heart physiology. In comparative physiology, students learned the mechanisms of the heart using the textbook *Animal Physiology: Fourth Edition* by Richard W. Hill (2016). The movement of blood through the heart, myogenic hearts and electrical impulses were concepts discussed in lecture to further our physiological understanding of mammalian hearts. In humans, the heart is four chambered and consists of two ventricles and two atria. The left side of the heart receives oxygenated blood from the lungs and the strong muscular left ventricle pumps the blood into the systemic tissues of the body. The blood enters the left atrium and is carried in pulmonary veins, which drain the lung. Blood flows into the muscular left ventricle, then through the systemic aorta, which branches off sending blood to the upper half of the body and through blood vessels that take blood to and from the systemic tissues. Valves are blood barriers found between the

atrium and ventricle and the ventricle and aorta that serve to prevent backflow. Blood becomes deoxygenated after oxygen has been dropped off to the essential body tissues that require oxygen to perform their functions. Deoxygenated blood returns through the vena cava, large cardiac veins that push blood into the right atrium. The right side of the heart pumps blood through the pulmonary circuit which consists of blood vessels that take blood to and from the lungs. The right ventricle sends blood into the pulmonary trunk which divides into the pulmonary arteries carrying deoxygenated blood away from the heart and to the lungs (Hill et al., 2016). Blood circulates continuously in this way.

The myocardium is the heart muscle that facilitates the pumping of blood throughout the body. Mammals possess compact myocardium in which the muscle cells are closely packed together to help facilitate the movement of blood. It is extremely dependent on oxygen which comes from blood flowing through coronary arteries and veins (Hill et al., 2016). Coronary veins carry oxygenated blood out of the myocardium and into the right atrium. The coronary arteries arise from the systemic aorta and carry oxygenated blood to capillary beds in the myocardium (Hill et al., 2016). Coronary arteries are essential for oxygen supply; if an artery becomes blocked, oxygen will fail to reach the part of the myocardium it provides, leading to muscle failure indicating a myocardial infarction, or more commonly known as a heart attack (Hill et al., 2016).

Acute myocardial infarction (AMI) is one of the most prominent causes of mortality despite advances in diagnosis and treatment. Early detection of symptoms is necessary for patient survival, and an aspiring physician assistant should learn the potential biomarkers. The article titled *From Classic to Modern Prognostic Biomarkers in Patients with Acute Myocardial Infarction* provides an overview of contemporary prognostic biomarkers in patients at risk for heart attacks (Stătescu et al., 2022). The presence of a myocardial injury can be detected from multiple abnormal biomarkers, rather than a singular biomarker that could predict the risks and prognosis of a myocardial infarction. Researchers have attempted to obtain a single biomarker through proteomics viewed after an AMI takes place. Through proteomic technologies, the types of protein present in the myocardium are identified, and changes in the cellular and molecular levels of the structure and function of the ventricles are detected (Stătescu et al., 2022). This article suggests that multiple biomarkers are needed to develop a prognosis and risk assessment for a myocardial infarction. Biomarkers of inflammation are one of many that predict the

development of cardiovascular disease. C-Reactive Protein (CRP) is strongly associated with atherothrombosis, a progressive disease where a blood clot forms in the arterial wall which narrows the arterial lumen (Mojca, 2003). Atherothrombosis is a strong indicator of myocardial infarction. CRP is an "acute phase protein" whose concentrations in the blood plasma are increased in response to inflammatory processes that arise from high concentrations of plasma cytokines present in the liver. C-Reactive Proteins are detected 4-6 hours after a myocardial infarction when an inflammatory response rises to peak level (Stătescu et al., 2022). During inflammation, cytokines which function to control the growth and activity of blood cells are secreted and ultimately release myofibroblasts that work to preserve the structure of the ventricles. CRP elongates the inflammatory process and dictates the levels of inflammation (Stătescu et al., 2022). Myocardial necrosis is the death of body tissue in the myocardium. Biomarkers of myocardial necrosis contribute to the multi-biomarker strategy for determining a prognosis and risk assessment for a myocardial infarction. Platelets are small anucleated cells that do work in maturing bone marrow. They are released into the bloodstream to form blood clots in situations that cause an extreme amount of blood loss. When an AMI occurs, there is a pattern of platelets that contribute to blood clotting in arteries because of plaque buildup which is composed of cholesterol and other substances. Mean platelet volume (MPV) is a reliable and detectable indicator of platelet activity (Stătescu et al., 2022). An increase in MPV detected in STEMI patients can predict cardiovascular death within 30 days after admission. Multiple abnormal biomarkers that detect different cardiovascular abnormalities must be considered when attempting to predict the risks and prognosis of a patient.

The contraction of the heart is facilitated by the electrical activity of the muscle cells. Cell membranes of muscle cells are polarized electrically; at rest the inside of the cell is negative, and the outside is positive. When an action potential occurs in the heart's pacemaker, a wave of depolarization scatters along the membrane and stimulates the beginning of contraction. Adjacent muscle cells in the myocardium are electrically coupled to cause rapid and direct depolarization of neighboring cells, causing the entire unit to contract. The process of depolarization in the heart is known as conduction (Hill et al., 2016). When a mass of muscle cells is depolarizing, the timing differs. Some cells are starting to depolarize while others are in the process. The difference in timing forms a voltage difference in electrical potential between depolarized and unpolarized regions of the myocardium. This voltage difference in the heart causes ionic currents

in the tissues and body fluids. Electrocardiograms (EKG) are used to measure the electrical current and voltage difference of the heart. (Hill et al., 2016).

An EKG is a portable machine that works through the placement of external leads or electrodes on to the skin. In a 12-lead EKG used in the ER, one electrode is placed on both legs and arms. The labeled electrodes V1 and V2 are placed directly across from each other on the 4th intercostal space directly neighboring the sternum. V3 is placed midway between V2 and V4, lead V4 is placed directly under the breastbone, and V5 is in a straight line with V4. The last lead V6 is placed in line with V4 and V5 below the armpit. The image that is shown when the electrodes are connected shows the waveforms of depolarization happening in the heart. The P wave is the first small hump that represents the depolarization of the atria. The QRS complex is the spike that represents ventricular depolarization. Repolarization of the ventricles is represented by the T wave, the small hump following the QRS complex (Hill et al., 2016). During my time as an ER technician, one of my many roles was to perform EKGs on patients coming in with chest pain. I was allowed no more than 10 minutes upon arrival to perform and document the EKG, and as soon as the image was printed, I gave it to the doctor on the case. Comparative physiology provides the student with a basic understanding of physiological mechanisms of different species. This information is useful for a physician assistant in that it helps a physician assistant understand circulation, respiration, and metabolic processes so that they can diagnose and treat patients in a clinical setting.

Neuroscience Foundations is an introductory course that explores the fundamental principles of neuroscience, emphasizing the mechanical, electrical, and chemical properties of neurons. Topics include the excitable nature of neurons, the ionic basis of action potentials, synaptic neurotransmission, and chemical sensory and motor systems. Taking this course allows for a deeper understanding of specific neuronal systems. Students who are successful will be able to summarize neuronal function, describe how neurons communicate, and characterize the cells and processes that are vital for various systems. The laboratory is set up like a graduate-level course where students act as neuroscientists and conduct experiments to characterize neurological defects present in mutant strains of *C. elegans*, a microscopic roundworm with a simple nervous system. The Neuroscience foundations course relates to the role of a physician assistant by providing a comprehensive understanding of the nervous system. Growing this knowledge will prepare a physician assistant for patients with neurological conditions, enabling them to

effectively assess, diagnose, and treat patients with neurological disorders. This course enhances critical thinking skills which are essential for making clinical decisions and solving complex medical cases.

Neurons are excitable cells that make up the nervous system. They are responsible for sensing changes in the environment, communicating these changes with other neurons, and signaling the body to produce a response to these changes. Glial cells surround neurons in the brain and provide them with support, insulation and nutrients. Neurons are made up of dendrites that resemble tree branches sticking out from the soma, which is the center of the neuron containing the nucleus. Dendrites are covered in synapses that receive a synaptic input from the environment that will be transduced, producing a bodily response. The message travels along the axon, which is composed of a tail made of myelin sheaths extending into branched structures called axon terminals. The axon is highly specialized, and its function is to transport neuronal information over long distances (Bear et al., 2016). Neurons contain membranes that are selectively permeable to specific ions. The influx or efflux of these ions determines what is called a membrane potential (Vm), which is the voltage across the membrane. The membrane potential offsets the driving force of ions against the concentration gradient. Ion channels selective to their own facilitate the movement of ions across the membrane, and ions flow in a net movement from high to low concentration. Current refers to the movement of electrical charge (ion flow) across the membrane. If there are no channels present on the membrane, there will be no current (Bear et al., 2016).

Membrane potential is a concept that students tend to be confused with, but it needs to be understood if a physician assistant is tasked with assessing neurological symptoms in patients because abnormal changes in membrane potential causes symptoms to arise. It is also important to know when administering antiepileptic drugs as they work to decrease the rate of ion exchange across the membrane (Lin et al., 2017). According to the Neuroscience textbook used in the course, the inside of a neuron is more negative than the outside of the cell (Bear et al., 2016). The resting membrane potential in humans is –65 millivolts (mV), which is necessary for the nervous system to perform its functions. Ions that affect membrane potential more than others are potassium (K+), sodium (Na^+), and Calcium (Ca^{2+}). The neuronal membrane potential depends on the concentration of these ions on either side of the membrane, K^+ is more concentrated on the inside and Na^+ and Ca^+ is more concentrated on the outside. The equilibrium potential (E_i) for an

ion is the membrane potential that would result if the given ion was inside the membrane. The resting membrane potential of –65 mV approaches the equilibrium potential of K^+ which is –80 mV but does not reach it because Na^+ still enters the cell. Potassium is the most permeable ion when the membrane is at its resting state. Ion concentration in the membrane is dependent on ion pumps, the most prominent being the sodium-potassium pump (Bear et al., 2016). The sodium-potassium pump exchanges internal Na^+ for external K^+ so that K^+ is concentrated on the inside of the membrane. The pump pushes the ions against their concentration gradients, and to do so requires energy in the form of ATP (Bear et al., 2016). Understanding the concepts of membrane potential is important when learning how neurons communicate. Membrane potential is the base concept for the generation of action potentials in neurons, which allow them to communicate with each other and transmit information to the brain to perform bodily functions.

Synaptic transmission is the biological method in which neurons communicate. According to the text provided in the course, action potentials within neurons are transferred by synaptic transmission. Action potentials occur when a neuronal stimulus meets the body. An example of this is when someone steps on a sharp object and the point penetrates the foot. The sharp pain that follows is caused by action potentials within the nerve fibers in the skin. The stab is the result from the stretching of neuronal membranes. Voltage-gated sodium channels in the membranes of the nerve fibers open and allow the influx of Na^+ ions. Because of the negative charge on the inside of the membrane, Na^+ ions cross the membrane. Their entry causes membrane depolarization, where the inside of the membrane becomes less negative. If depolarization reaches a certain level or threshold, an action potential will occur (Bear et al., 2016). The increase in membrane potential during depolarization from the resting potential of –65 mV is caused by the influx of positive Na^+ ions that enter the membrane. The change in membrane potential during different phases of depolarization is mediated by the ion flux. After depolarization occurs, and an action potential takes place, hyperpolarization brings the membrane potential back to rest. It is mediated by the opening of potassium channels causing the efflux of K^+ ions out of the cell (Bear et al., 2016). Action potentials are crucial for the transmission of information within the nervous system.

The mechanism of synaptic transmission involves action potentials within neurons being transferred to other neurons. Information transferring takes place in the synaptic cleft, which connects the axon of the presynaptic cell with the dendrite of the postsynaptic cell. Stimulation of

the presynaptic cell by depolarization will change the end plate potential or response of the postsynaptic cell and will fire an action potential. The beginning of synaptic transmission involves neurotransmitters, which are chemicals that allow neurons to communicate with each other throughout the body (Sheffler et al., 2024). The neurotransmitters are loaded into vesicles in the pre-synaptic cell. An action potential enters the pre-synaptic cell and brings on depolarization of the neuronal membrane, thus opening voltage-gated calcium channels located on the pre-synaptic membrane. The opening of these channels allows for an influx of Ca^{2+} ions which facilitate the binding of synaptic vesicles to the presynaptic membrane. The neurotransmitters inside the vesicles, once attached to the membrane, are released into the synaptic cleft, and bind to receptors on the postsynaptic cell. Ligand gated ion channels facilitate the movement of Na^{+} ions in and out of channels. The influx of Na^{+} ions make membrane potential more positive, thus becoming depolarized (Bear et al., 2016). The depolarization reaches a threshold, firing an action potential post-synaptically. It is important for a physician assistant to know the process of synaptic transmission because many neurological disorders like Alzheimer's disease, depression and epilepsy involve abnormalities in synaptic transmission. Many drugs used for neurological function target synaptic transmission by harmonizing neurotransmitter levels. A physician assistant must know how these medications work synaptically to properly administer them to patients.

Chemical sensory systems and motor systems involve the gustatory and olfactory systems, or in simpler terms, taste, and smell. Taste and smell are both sensory systems, responding to external stimuli. The input would be the stimulus, which is transduced into neural signals for neuronal processing, to produce an output or response to the stimulus. The gustatory system involves the detection, perception, and association of tastants, or the substances that stimulate the taste buds (Bear et al., 2016). The five basic tastes, also known as tastants, are salty mediated by salt, sweet mediated by sugar, sour mediated by protons, bitter mediated by alkaloids, and umami mediated by amino acids. There are multiple taste cells within a taste bud that act as receptors for the chemicals that enter the mouth. Basal cells surround taste cells to give structural support, and gustatory afferent axons form connections with taste cells and the brain (Bear et al., 2016).

According to the Neuroscience textbook, there are two models of perception or pathways that connect a sensory input to the output produced in response (Bear et al., 2016). The labeled

line perception is a direct pathway of receptors in the central nervous system that connect the stimulus to the output. The receptor cells run parallel; there would be a labeled live for sweet, a labeled line for salty, etc. Population coding is the other type of pathway in which taste receptor cells have a certain pattern that runs different ways, connecting different taste receptors (Bear et al., 2016). The receptors give off multiple signals for different tastes, for example with a food that is salty and sweet, receptors will signal different patterns tastants Taste cells are activated by tastants, which stimulate depolarizations within taste cells called receptor potentials. The receptor potential elicits action potentials in gustatory cells, which stimulate an action potential to the brain. Tastants are transduced into neural signals by the opening of channels and by g-protein coupled receptors (Bear et al., 2016). Salty and sour receptor cells are activated by the opening of sodium channels and H^+ channels, which causes a depolarization of the membrane potential, thus sending action potentials to the brain. For bitter, sweet, and umami tastants, receptor cells are activated by G-protein coupled taste receptors (GPCRs). Bitter receptors are named T2R. Sweet and umami receptors are named TIR (Bear et al., 2016). These receptors bind to GPCRs to activate a g-protein using energy in GTP form. The G-protein activates phospholipase C (PIC), an enzyme involved in signaling pathways. PIC is catalyzed into second messengers IP3 and DAG that activate the release intracellular Ca^{2+} ions. Ca^{2+} ions release ATP, sending neuronal signals to the brain through the gustatory afferent axons (Bear et al., 2016).

The olfactory system is activated by different organic molecules called enantiomers that have certain levels of detection. The nasal cavity is where it all takes place; the olfactory epithelium surrounds the nasal cavity and contains sensory receptors that interact with the enantiomers (Bear et al., 2016). Sensory receptor nerve endings project from the epithelium into the olfactory bulb, which is in the brain. Odor transduction occurs in the cilia, where the olfactory receptor neurons are found. The receptor potentials in the cilia bring the membrane potential of olfactory receptor neurons to threshold, resulting in the firing of an action potential along olfactory receptor neurons into the olfactory bulb (Bear et al., 2016). Perceptions of smell go through population coding, where combinations of receptor neurons can discriminate between different compounds. Olfactory receptor neurons express a single olfactory receptor protein. The expression of the olfactory receptor is restricted to a specific zone within the nasal epithelium. The glomerulus, located in the olfactory bulb, is the zone that receives the smell. The gustatory

and olfactory systems are complex in nature and depend on the nervous system to activate taste and smell in humans.

In Neuroscience Lab, students performed experiments on *C. elegans* worms to identify neuronal genetic mutations within a specific mutant strain. These microscopic roundworms possess a very simple nervous system that is easily detected due to their transparent bodies. Researchers take advantage of *C.* elegans short generation time and fully sequenced genome to perform genetic studies and observe the effects of specific genes on neuronal development and behavior. These studies can provide insight into the nervous system and genetic mutations that can possibly affect humans.

Concepts learned in college genetics are prominent for the knowledge of medical professionals in health care settings. The most valuable concepts taken from this course were basic genetics including DNA structure and gene expression, the human genome, and medical genetics. A physician assistant will understand genetic disorders and how to recognize certain symptoms. Family histories are important to ask about when discussing a patient's cause of illness, because many diseases are hereditary. According to the textbook titled *Understanding Genetics: A New York, Mid-Atlantic Guide for Patients and Health Professionals,* the human genome is the total composition of genetic material that makes up a human being. The genetic material is packed into two sets of chromosomes, one set coming from the mother and the other set coming from the father. Each cell contains 23 pairs of chromosomes, and in these chromosomes are many genes. Genes are the basic unit of heredity; they decide what visual and physiological traits are obtained from our parents. Genes also set instructions for building proteins in the form of DNA (deoxyribonucleic acid). Each gene has a specific DNA sequence arranged in a double stranded helix. Each cell has a full set of DNA, but all cells are selective to activate certain genes with certain functions. The genes active in a brain cell differ from genes active in a kidney cell because they require different proteins to perform different functions. The nucleotide sequence within a DNA molecule identifies the types of genes present and their functions. Every individual has their own genome sequence that consists of base pairs. Base pairs that form DNA are made of nucleotides and are named adenine, guanine, cytosine, and thymine. When paired, they make up DNA sequences that encode for proteins with specific functions. Genes are the most important component of the human genome because they contain all the biological information (Brown, 2002). Genes code for one or multiple proteins with the help of

messenger RNA (mRNA) that directs the synthesis of the proteins. There are multiple functions of human genes that are known; most of them encode for proteins, some are involved in gene expression and replication, some carry out the functions of a cell, and some are involved in the transduction of an external stimulus (Brown, 2002).

Many diseases are caused by genetic abnormalities. By encoding proteins, genes dictate the efficiency of food metabolism, elimination of toxins, and work to build up immune response. Genetic diseases are caused by changes in the DNA sequences of genes that perform specific functions. Mutations altar proteins so that they do not perform their normal functions. The mutation can either partially damage the protein, giving the possibility of regaining normal function, or the protein can be permanently altered. Additional causes of genetic diseases that have more of an impact on human health occur in chromosomes. Chromosomal abnormalities affect the overall number of chromosomes within a chromosomal set. The most common mutation is where a chromosome is taken away or an extra is added. A chromosomal set has 46 chromosomes and one set of sex chromosomes (Genetic Alliance & The New York-Mid-Atlantic Consortium for Genetic and Newborn Screening Services, 2009). To identify genetic diseases, genetic testing is performed in clinical settings by physician assistants. To diagnose, treat, and cure diseases caused by genetic mutations, genetic testing analyzes human chromosomes, genes, and proteins to detect mutations (Franceschini et al., 2018). Genetic testing is used for pre-natal screening, identifying carriers of genetic disorders when planning to have children, and diagnosing patients with rare genetic disorders based on family history (Franceschini et al., 2018). The type of test depends on the type of abnormality that is monitored. The three basic tests are cytogenetic, biochemical, and molecular. Cytogenic testing examines the whole set of chromosomes for abnormalities that may cause a defect. Under the microscope, white blood cells are readily accessible and are extracted for cell cultures. After several days, chromosomes extracted from the white blood cells are stained and their structure is ready to be analyzed (Genetic Alliance & The New York-Mid-Atlantic Consortium for Genetic and Newborn Screening Services, 2009). Biochemical testing is performed to monitor the different types of proteins involved in biochemical reactions in cells. Tests measure protein activity and the size or quantity of the protein. A protein sample is required for these tests found in blood, urine, or fluid in the spine. Molecular testing is performed for small DNA mutations. Direct DNA testing is the most effective method to discovering a genetic disease, any tissue sample may be used and only

requires small amounts of sample (Genetic Alliance & The New York-Mid-Atlantic Consortium for Genetic and Newborn Screening Services, 2009). Physician assistants should understand the principles behind genetic testing techniques and be able to interpret test results to accurately diagnose patients.

Medical genetics is known as a medical specialty that is new to the United States (Korf, 2002). It possesses major influence over medical research involving the human genome and its linkage to human health. Genetics contributes to medical practice in three categories. The first category involves disorders that affect chromosomes or single genes (monogenic) such as down syndrome and sickle cell anemia. Medical geneticists are involved with patients who have these disorders and are active in the long-term treatment and diagnosis processes. The second genetics category in medicine deals with the more common disorders that alter a single gene function, have incomplete penetrance, and affect patients of older ages (Korf, 2002). These disorders include breast and ovarian cancer, colon cancer and disorders that affect the heart muscles. The third category involves the most common disorders among patients such as diabetes, cancer, high blood pressure and heart disease. Most of these disorders involve a complex genetics contribution. Multiple genes contribute to each of these disorders (Korf, 2002). Genetics is involved in the work of healthcare practitioners.

The roles of physician assistants in patients with monogenic or chromosomal disorders do not contribute to the diagnosis of the disorder, that comes from the specialist. When a diagnosis is established, the physician assistant aids in medical decision making for the family of the patient. They are there to provide long-term care for the person affected and emotional support for the family. The specialist on the other hand diagnoses and manages the problems that affect the part of the body where they are experts in. An example of this provided by the article titled *Genetics in Medical Practice* is a neurologist that specializes in neurodegenerative disorders (Korf, 2002). Screenings of fetuses in the womb for monogenic disorders are becoming more frequent so a plan can be developed, and precautions could be made if the child carried the mutated gene. To care for individuals with this type of disorder, a physician and physician assistants are faced with challenges of detecting and informing patients who have an increased risk of carrying the mutated gene (Korf, 2002). The recognition of disorders like down syndrome requires extensive education. Family history is prominent when it comes to diagnosis of a

genetic disorder and must be asked when a patient is being evaluated to see if any genetic testing should be performed early.

The use of genetics in medicine for patients with more common disorders such as diabetes or cardiovascular disease is very common when trying to improve the quality of care. Most of these disorders are caused by multiple genes as well as environmental factors. Even though these disorders are very common and seen among millions of people, the genetics behind them are insanely complex in nature. Identifying the genes affected and understanding how these mutations cause certain deficiencies can help understand the cause and possible treatment plans that would benefit the patient the most (Korf, 2002). The impact that genetics has on medicine is becoming more important with the diagnosis of common disorders. The collaboration of medical geneticists and physicians will produce quality care for patients who experience genetic disorders. Genetic testing may become more detailed in the evaluation of specific disorders.

Bio-medical ethics is known as a discipline of ethics that deals with moral issues addressed in medicine and in medical research (Vevaina et al., 1993). It is about morality, being able to choose the right or wrong option that would ultimately benefit the good of the patient. Bioethics is applied ethics, which uses moral principles to resolve moral issues faced in medicine. Bioethics focuses on health care and seeks to answer tough moral questions (Vaughn, 2020). Is abortion morally permissible? Should doctors, PAs, and nurses always tell the truth despite the feelings of the patient? Should physicians be allowed to help end a terminally ill patient's life? Medical professionals are faced with these questions daily, and bioethics seeks the answers by applying moral principles (Vaughn, 2020). This upper-level course is offered to a wide range of students varying from philosophy to biology majors. Bio-medical ethics is especially important to an aspiring physician assistant because it guides their decision-making process in complex medical situations when dealing with a wide variety of moral dilemmas concerning patient care. Healthcare providers work to advocate for their patients, prioritizing their overall health and well-being. When faced with adversity concerning the life of the patient, moral principles that guide decision-making can help make tough decisions.

There are five moral principles used in bioethics that are extremely influential to the moral issues faced in health care and medical research. These principles are autonomy, nonmaleficence, beneficence, utility, and justice (Vaughn, 2020). According to the textbook used in this course written by Lewis Vaughn, autonomy is a person’s right to self-governance and

self-determination. With this principle, people can make decisions for themselves. Patients have the power to make choices that would benefit their own good. Physicians and other health care workers should not push their own opinions on patients to try and sway their decision-making; for an autonomous person should be treated with respect. To violate someone's autonomy is to override their personal decision-making. Even if the violation is to benefit the person, it is still considered morally wrong. Giving treatment without a patient's consent, providing care against their will, and restraining patients for no viable reason are examples of violating autonomy (Vaughn, 2020). For patients to make independent decisions, they must be adequately informed of their medical circumstances. Informed consent is an important precept in bioethics which requires the patient receives all relevant information concerning the medical procedure, treatment, or study they are involved in. A physician or physician assistant provides the details of the purpose, risks, benefits, and alternative options for the procedure (Vaughn, 2020). If the patient has all the information about the medical intervention, they can either confirm or deny following through. However, some people are not considered autonomous and require a legal guardian to make decisions for them. Patients who are mentally disoriented or confused, children and infants are not autonomous. Even though autonomy is a fundamental human right, alcoholics, drug addicts, and mentally unstable patients are often labeled as not autonomous because addiction can impair the ability to make fully rational decisions.

When the patient's life is at risk, a physician assistant may step in and override their autonomy to do their job to save their life. Paternalism is the act of overriding a patient's decision-making for their own good (Vaughn, 2020). Numerous controversies arise from paternalistic decisions. Weak paternalism is used when a patient cannot act autonomously, the purpose of making decisions for the patient is done to protect them from harm. Strong paternalism is where the controversies lie; an example used in the text is researchers who develop a life-saving drug administer the drug to a patient without their knowledge. Another example is a physician hides the truth about the health of a terminally ill patient to try and spare any feelings of hopelessness (Vaughn, 2020). Autonomy is considered the most important principle in bioethics, as it recognizes a patient's dignity and self-determination. Autonomy guides healthcare professionals in their relationships with patients. It emphasizes the importance of informed consent and shared decision making.

The second moral principle in biomedical ethics is nonmaleficence. It asks us not to inflict harm intentionally or unintentionally on others (Vaughn, 2020). The action of nonmaleficence has been embraced by healthcare professionals across the globe as they have made it their mission to do no harm to those they care for. To violate this principle, a PA would perform an action that would deliberately harm or injure the patient. If a PA administers a drug that they know induces seizures, the patient's life would be put at risk and the PA would be going against this principle. If the life of the patient was put at risk due to negligence and carelessness from the actions of the PA, this would also count for going against nonmaleficence even though there was no motive. Although medical treatment is known to be painful, it is expected for healthcare professionals to carry out their work with the utmost care and gentleness to try their best to prevent any unnecessary harm to the patient. The benefits of the treatments must outweigh the burdens; the physician should choose the best course of action for the patient that will still provide an enjoyable life (Varkey, 2021). The principle of nonmaleficence is expected to be upheld and exercised daily by physicians and PAs in any health care setting. Beneficence is the third moral principle in bioethics that is expected to be carried out by healthcare providers.

Beneficence goes along with nonmaleficence in saying that we should promote the good of others and prevent any hard done on to them (Vaughn, 2020). It is expected for physicians, physician assistants, nurses, and researchers to uphold this principle as their duties in healthcare are to help and fix. Although it is morally good to help others and prevent harm, some may argue that it is not a duty that we are obliged to follow. In certain professions that promote the public's well-being, beneficence is an innate principle that should be practiced daily. Physicians who choose to practice beneficence do everything in their power to properly care for and heal the patient while providing an understanding and calming presence. They find themselves in situations where they must decide if ending a patient's life is the ultimate harm, or if it is best for the patient. This situation would occur only if the patient were nearing the end of life, is brain dead, is not responding to medical treatment, or is terminally ill. Assisting a patient in ending their own life is known as physician assisted suicide. The physician or physician assistant gives a lethal injection to the patient to administer themselves, ultimately killing the patient (Goligher et al., 2017). It has become one of the most discussed topics in medicine, but the American Medical Association (AMA) ultimately decided against physician assisted suicide. The AMA only

endorses passive euthanasia, which is withholding life-sustaining measures with the patient's consent (Vaughn, 2020). Permitting physicians to engage in administering lethal injections would ultimately do more harm than good. With the physician's role as a healer, euthanasia is incompatible, and could ultimately pose serious societal risks.

Utility is the fourth moral principle and says that we should produce the most favorable balance of good over bad (Vaughn, 2020). In the real world, there is no such thing as just promoting the good of others or just harming them. There is no way we can help everyone and prevent harm or neglect at the same time. For example, the ER's waiting room is full of patients waiting for a bed, being neglected by the hospital staff as they wait to be seen. They are in excruciating pain as they wait and tend to become impatient. There is no possible way every patient can be seen at once. To help some, others must suffer for some time, and that is just the reality. Utility comes into play when a physician must decide whether a certain treatment is right for a patient, that is, the benefits outweigh the risks. The example that the textbook uses is a man with a clogged artery can go through two different treatment plans. The first plan is an open-heart surgery that would clear the artery, but potential risks are death and injury. The second option is to administer a drug for a certain amount of time that would decrease cholesterol and require the patient to go on a low-fat diet. With both options presented to the patient, the one that would prevent harm would be administering the drug and going on a diet (Vaughn, 2020). To practice utility is to choose the course of action that is the safest for the patient, or to choose the option that would benefit the most people.

The last principle in biomedical ethics is justice. Justice is people getting what they deserve as humans or what is fair to them. There are several categories of justice, but the one that relates to medicine is distributive justice, which refers to the fair distribution of health-care resources. The principles of distributive justice address how health care should be distributed within a society. They are equal share, according to need, according to effort, according to contribution, according to merit, and free-market exchanges (Varkey, 2021). Health care is a big debate in bioethics; people tend to disagree with who can receive health care and who cannot. Bio-medical ethics is a course that all aspiring medical professionals should take as it guides decision-making processes in complex medical situations that physicians face every day. A strong understanding of biomedical ethics equips physician assistants with skills necessary to provide the utmost care for their patients while knowing how to face ethical challenges.

An undergraduate biology student takes courses that will help him or her excel in any scientific profession they choose to follow. In reflecting on the vigorous yet fulfilling journey toward my career in the medical field, the undergraduate courses that are provided to biology majors relate to the professional responsibilities of a physician assistant. The courses that I selected that I believe I can take along with me in my medical career are Microbiology, Comparative Physiology, Neuroscience Foundations, Bio-medical Ethics and Genetics. Each of these courses, in their own distinct ways, formed a conceptual basis of knowledge that I need to continue my path to becoming a physician assistant in the hospital. These five courses established the groundwork for diagnosing and treating patients, administering treatment plans for patients, testing for genetic diseases, distinguishing neurodegenerative diseases, and treating patients with the utmost care. Throughout my four years here at Coastal Carolina University, I have built a solid foundation supporting the pursuit of my future career as a Physician Assistant.

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