A Physiology Manual for PDD Lifelong Learners of the Science

(Part 1)

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I. INTRODUCTION

Many practitioners of the science of psychophysiological detection of deception (PDD) have entered the profession in mid-career from disciplines other than the life sciences or biology. Typically, many entering PDD come from the criminal justice or related professions with limited exposure to the life sciences. In polygraph science, the investigator must record and evaluate visceral physiological data from selected body organ systems regulated by the brain. This means the polygraph professional must gain and maintain a sufficient understanding of the basis of physiologic changes they are attempting to measure. These physiological parameters required for PDD assessment are typically studied in the life science disciplines.

Despite the general public's view, there is no metric of lie detection. PDD science can, however, provide a statistical measure of the probability of truthful or deceptive responses to relevant questions concerning a matter in question. The **Cardiovascular System (heart), Integumentary System (skin), and Respiratory System (breathing)** regulated by the **Central Nervous System** need to be reasonably understood by the polygraph examiner to be an effective decision maker in PDD science. Terms written in boldface type in this manual are of increased importance. They are reviewed in general terms in the *Overview*, Part 1 section and more thoroughly described in the *Detailed Section,* Part 2. Students and lifelong learners may want to ensure they have an especially good grasp on these terms.

This project began in 2005 when one author Joel Reicherter (JR) shared the outline for his 62-hour physiology course, arguably the most comprehensive and challenging physiology courses taught in any PDD training regimen, with the other author Mark Handler (MH). MH took the outline and developed what later became the "detailed" section of the current document. The authors felt readers would benefit from a less detailed overview and JR first-authored that section of this document. There were two intentions: First, to create a document that could be used as a foundation for review of this sometimes difficult subject—a physiology-*light* – and, second, to provide the more motivated or curious examiner a tool with which one might get deeper "into the weeds."

The general outline of the overview should follow fairly closely with the *Detailed Section*[3]. There may be some overlap of the information in those sections, as editing out all redundant material may have left one or the other difficult to understand. We ask the reader's pardon and tolerance for redundancy. We also ask for errors to be brought to our attention, and accept the responsibility *a priori* for errors or omissions.

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Author's note: One examiner who epitomizes our belief in lifelong learning tirelessly reviewed and edited this document. Without Dale Austin's attention to detail, deep understanding of the PDD examiner learning process and overall expertise in PDD this document would be considerably less than it is. The authors and our profession owe Dale Austin a great debt of gratitude. This document has been previously published on the APA website.

3 Begins on page 23.

We believe a professional's, and a collective profession's, learning should never stop. We have developed this document for those students, examiners and schools who share our ideals. We hope the reader finds it useful and hope to be able to update it as we continue to learn, and as time permits.

II. PHYSIOLOGICAL AND CHEMICAL BACKGROUND

In a healthy body, the body-systems work together in harmony in a balanced internal physiological environment of wellness. This is described as being in a *homeostatic state of equilibrium*, otherwise known as *homeostasis,* or as a medical term, in a "state of wellness." If an external circumstance disrupts this balance within the organ systems, a state of sickness might develop. However, routine changing environments such as exercise, compared to the relaxing state of reading a book, will naturally cause an alteration in the homeostatic balance in the body systems. The physiological adjustments made in homeostatic balance within the organ systems were recently described in the PDD setting by Mark Handler as *allostasis*, which is described in the *Detailed Section* under *Homeostasis and Allostasis.*

All physiological activities addressing living activities follow basic laws of chemistry. Much of the chemistry occurring in the human body is beyond the scope of this manual, but there are a few important concepts which must be addressed to provide a fundamental understanding for those learning PDD science.

To begin our study, all matter on earth is composed of only 92 naturally occurring different atoms, also described as elements. The living body is composed of 26 of that total. Examples of these atoms, you no doubt have heard, include hydrogen, carbon, nitrogen and oxygen. These four elements constitute about 96% of the body. Calcium, phosphorus, potassium, sulfur, sodium, chlorine, magnesium and iron constitute 3.8%. The remaining 14 elements are classified as trace elements because collectively they constitute only 0.2%. All elements are typically represented with one or two letters from the English language alphabet. For instance, **C** represents carbon, or **Ca** represents calcium.

Briefly, these atoms are composed of particles called protons, neutrons and electrons. The total number of protons and neutrons in each atom are found in the center of the atom (nucleus) and is referred to as the atomic mass. The lightest in atomic mass is hydrogen, which has only 1 proton, and 0 neutrons. The heaviest atom is uranium, which has 92 protons and 146 neutrons. The protons have a positive charge compared to neutrons, which have no charge. Orbiting in prescribed areas or shells around the nucleus are negatively charged electrons. Atoms usually have equal numbers of positive protons and negative electrons organized in the various areas (shells) around the center of the atomic nucleus. This arrangement of positive and negative charges makes the atom neutral. More information about the architectural design can be found in the detail section of this work, or in basic chemistry or anatomy and physiology texts. For basic understanding of PDD, however, it won't be necessary to research additional chemistry concepts unless you are inspired to do so.

Since there are multiple forces acting on these atoms, based on the number and location of electrons in an atom, sometimes electrons are pulled away or attracted to another atom. When that happens, an atom that loses an electron is left in a positive state, which is referred to as a positive ion or cation. If the atom gains an electron it is referred to as a negative ion or anion. Some of the most important ions you will see in physiology are sodium, potassium, chlorine (also called chloride), calcium and hydrogen. The symbol notation will be Na^+, K^+, Cl^-, Ca^{++} and H^+ etc. The + sign indicates a loss of an electron, the – sign indicates a gain of an electron. The Ca^{++} symbol indicates two electrons have been lost. These ions, and others, play significant roles in Nervous, Cardiovascular, Respiratory, and Sweat Gland function, and ultimately in the physiological events that occur during PDD examinations.

Other forces of physics and chemistry will cause atoms to share electrons in the outer shell resulting in a **sharing (covalent) bond** between two or more atoms forming **molecules.** Water, carbohydrates, and proteins are good examples of molecules. In other cases, one or more electrons will be liberated from one atom and received by another, resulting in a positive ion and negative ion. In this case, the attraction between the two ions would be called an **ionic bond** forming a compound but not a molecule. Salt (NaCl) would be a good example. Salt could be represented Na+ Cl- but for convenience, the + and – are often not displayed.

III. HUMAN BODY ORGANIZATION

All living things, including the human body, are organized into **cells** which perform living activities. In more advanced life forms, various kinds of cells are organized into **tissues,** which perform more complex functions than a single cell does. Tissues are organized with each other to form **organs,** which perform more complex functions than does a tissue. Organs are organized with each other to form **systems,** which perform even more complex functions. Finally, the integrated mix of eleven different systems forms the **human being** organism.

As a model, consider the human being organism as our nation. The states would represent the systems, counties would represent the organs, cities and towns would represent the tissues, local neighborhoods would represent cells, and the people would represent the atoms, ions, and molecules.

Cells: View the cells as factories. Depending on the nature of the cell (factory), the factories, with its workers (**molecules and ions**), can produce a variety of products, useful to the local economy or the larger domains (counties, states, nation). Like any industry, raw materials must be delivered to the factory by trucks (**blood**), pass through the factory gates (**cell membrane**), converted to a product (**proteins or other complex molecules**), then shipped out through the factory gates (cell membrane) to other destinations by trucks (blood). As in any factory, the workers need to be organized and directed by the foremen and company directors (**enzymes and hormones**).

In all functional factories, the specific ways in which products are produced depend on the factory's organization, the ways raw materials and building supplies enter the factory, and how the products manufactured are packaged and shipped.

Just as a factory has a central decision making office, so does a cell. The nucleus of the cell is where the **DNA, in the chromosomes,** stores all the blue prints to make the product. Of course the blue print plans can't make the product in the office. The plans must be sent to the assembly line in the factory (**various organelles located in the cytoplasm**).

Tissues: Tissues are aggregates of different kinds of cells working together for a common and more complex purpose. Using the cell model above, visualize one factory manufacturing wheels, another fenders, another leather seats, another windshields, and another carpeting. All these products are shipped to the factory that assembles all the manufactured parts, producing an automobile (**Tissue**).

Organ: Now imagine factories which are producing sedans, SUV's, and sport cars, other factories building trucks and vans, and additional factories manufacturing planes, trains, etc. (**Organs**).

System: All the various vehicles transport people or products from one place to another within the nation's transportation system. The human body not only has a transportation system (Circulatory System), it also has ten other specialized systems.

Organism: Now consider the combination of a national transportation system, medical system, farming system, educational system, housing system, clothing system, police and military system (for protection), etc., managed and directed by a central government (**Brain and Endocrine System**). All together it's a nation (**Human Being).**

Now that we've laid out the working concept of human body organization, we are ready to explore those body systems that most directly respond in a way that produce the most significant signal values in PDD assessment.

IV. NERVOUS SYSTEM

Now that you have been introduced to human body organization, it is important to study, in a little bit more detail, the physiological events of those systems specifically used in the diagnosis of PDD examinations. You can always explore more details of systemic physiology in the expanded section of this manual or the texts listed in the reference section.

The most significant cell in the nervous system—the "star" of the show— is the **neuron.** Although there are other support cells associated with nervous system function, much like support characters who play vital roles in supporting the show's star in a Broadway Show, we must focus most of our attention on neurons, with only an occasional reference to the support cells.

There are three main neuron stars in this show, **Association (interneurons), Sensory Neurons, and Motor Neurons.** The motor neuron has been the most studied in neurophysiology because of its size, rather elegant design, and relative easy access to researchers. Please refer often to the incorporated diagrams in the *Detailed Section* for better understanding.

Ions of various types can be separated in a discriminating way between the extracellular (interstitial) fluid and the internal cellular environment due to the highly significant **selectively permeable membrane** design of neurons and other cells. Many physiologists consider the extracellular fluid as the ocean, and human cells as all the living organisms in that ocean.

Ions such as Sodium (Na+), Potassium (K+) and Chloride (Cl-), (Chlorine before gaining an electron), can move in an electrical field. Ions capable of this movement are known as **electrolytes.** When Neurons use electrolytes to conduct a current-like impulse, it is known as an **action potential**. Neurons use action potentials to communicate and direct all body organs to perform their duties for the ultimate useful function of the body. Neurons, therefore, are referred to as *excitatory cells*. When your physician requests the laboratory draw your blood for analysis, the test will likely include an evaluation of your electrolytes. A blood test for electrolytes is simple and important. An imbalance of electrolytes can be caused by many factors including diet, medications, life style, etc. If the electrolyte levels are significantly imbalanced, all body physiology, including nervous system, cardiovascular system, respiratory system and sweat gland activity, can be significantly affected.

A resting potential must exist before neurons can conduct an action potential. Before a current can be created to turn on a light, a resting potential must exist to draw on the battery's stored power. The resting potential of the battery is quantified into units called **volts**. Since a neuron is so tiny, the unit of power is measured in **millivolts** (mV). Although batteries and neurons share similar concepts of stored energy, there are differences between them as to how that energy is converted into a current (amps, in electricity) or an action potential in neurons.

Cell voltage is calculated by measuring the **difference** between the charged molecules and ions on the outside of the cell membrane compared to the inside of the cell membrane. The resting potential difference in most neurons is about -70 mV. (Convention dictates that the resting potential, measured in mV, compares the inside of the cell to the outside. If the voltage was measured from the other side of the membrane it would be +70 mV.) In the heart and some specialized cells, the resting potential may be -90 mV or some other voltage. K+ is the most important ion for establishing resting potential. The selective permeability of the neuron membrane permits some of the K+ ions to diffuse out of the cell. As that happens, the cell is left less positive, or in effect, negative. As more potassium diffuses outward at a declining rate, the positive nature of the ion is electrochemically attracted back into the cell. There will come a point when the diffusional force driving K+ out of the cell falls into equilibrium with the electrochemical force to bring it back (like a tug-of-war game at a standstill). At about -70 mV, those forces are equal, which establishes the **Resting Potential**.

A visual description of sensory and motor neurons can be viewed on subsequent pages in the detailed section. The most significant parts of a neuron, in order of conduction of a nerve impulse, are the dendrites, cell body, axon and telodendria (synaptic terminals branches). For simplicity sake, many details of how a neuron generates and conducts impulses (action potentials) will not be described in this manual, but can be read in any of the associated texts listed in the reference section.

Neuron

A neuron will receive a stimulus signal of many different types on the dendrites or cell body, which may alter membrane receptors (**chemical gates**) to permit Na+ to enter the cell and move toward the axon. When enough Na+ ions reach the axon, the voltage difference across the axon cell membrane will fall from **-70 mV** to about **-55 mV**. When that voltage occurs, **voltage gates--**special molecules in the axon cell membrane sensitive to that voltage--will open. This forms a channel, which allows many more Na+ in the extra cellular fluid to rush into the axon because the inside of the axon is negative and the concentration of sodium is lower than the outside. In a millisecond, the inside of the axon next to the cell body will become **+30 mV**. This change in transmembrane voltage from -70mV to +30 mV is referred to as **depolarization**. Sodium ions that just rushed into the axon will move to the adjacent area because the rest of the axon is still resting at -70 mV. This reduces the membrane potential to -55 mV, causing additional adjacent voltage sensitive channels to open. More Na+ then rushes into the cell, causing that spot on the axon to depolarize. These events keep reproducing in a manner very similar to knocking down a row of dominos. Once it starts, it can't be stopped. In neurophysiology, these repeating events are the **action potential**. Once it starts, just as with the domino model, it's self-generating in an **all or none** fashion. The firing of a gun is another model reflecting this concept. The bullet is not discharged until the pressure requirement of the firing pin onto the primer is reached. If the pressure is inadequate, the bullet is not discharged. The minimum stimulus needed to engage the action potential within a cell is often referred to as the **threshold stimulus**.

After the Na+ enters the cell, the neuron will pump out the Na+ and pull K+ back to their original positions so a new action potential can occur. This can occur 80 to 100 times per second. The chemical mechanism of the sodium/potassium pump is beyond the scope of this manual, and therefore, won't be described.

Some action potential needs to occur as quickly as possible, such as in a pain pathway. Therefore, neuron axons are wrapped in a special fatty membrane known as **myelin**, which is produced by **Schwann cells** or other special **glial cells**. Visualize wrapping a piece of paper around a pipe, then another layer next to the first wrap, but leaving a small space, and so on. This is what the Schwann cells do. As a result, the Na+ can only move into the cell at these spaces (**nodes of Ranvier**) between the Schwann cells. A string of hot dogs in the butcher shop may help you visualized the design. Observe the drawing in the *detailed section* of the manual. Since the depolarization can only occur at the nodes between the Schwann cell wrappings, the action potential effectively skips along the axon, known as **saltatory** conduction. The autoimmune disease multiple sclerosis (MS) results when the myelin is destroyed. Action potentials can't occur normally, leaving the patient's nervous system less effective.

When the action potential reaches the end of the axon, which may be less than a single mm in length, or up to one meter long, it spreads out like branches of tree. This branching pattern is referred to as **telodendria.** This allows the neuron to communicate with many other neurons. Any word with "telo" in the prefix means "end of". Tiny bulbous terminals (end bulbs) are at the end of the telodendria. These terminals contain vesicles that store highly specialized molecules called **neurotransmitters.** The branching like design of the cell body are also called dendrites, but not telodendrites, as you note from the drawing in the *Detailed Section.*

You will also see that the terminal ends of the axon come intimately close--but don't touch--the dendrites or cell body of the next neuron. This space or gap is known as the **synapse.** When the action potential reaches the end bulb, a complex reaction takes place causing a neurotransmitter to be released into the synaptic cleft (see diagram). The neurotransmitter will connect (like a key in a lock) to a special receptor on the post synaptic dendrite or cell body membrane causing a channel to open. Depending on the neurotransmitter and receptor combination, different ions could be allowed to enter the cytoplasm of the post synaptic neuron. Usually it will be either Na+

or Cl- . If Na+ enters, the post synaptic neuron will generate a new action potential. If Cl- enters the post synaptic neuron, it will not generate a new action potential because the inside becomes more negative (inhibitory). When the inside voltage of the cell is more negative, it is further away from the threshold voltage and an action potential is less likely (it is inhibited). Both excitatory and inhibitory management is necessary for proper management of the nervous system. Think of managing the operation of an automobile. There will always be a mixture of gas pedal and brake to properly operate the car. Unfortunately, sometimes accidents occurs when the gas pedal or brake are not properly coordinated. Guess what? Sometimes the proper neurotransmitters and receptors are not engaged properly resulting in bad behavior or inadequate regulation of body organs, which cannot be maintained adequately.

In PDD and other psychological sciences, several of the most important neurotransmitters to be understood are: **Norepinephrine (NE), Acetylcholine (Ach), Dopamine, Serotonin, Gamma aminobutyric Acid (GABA) and Glutamate.** Psychopharmacology addresses the issues of depression, anxiety, hyperactivity and other behaviors. This science has become intensified in recent years as the physiology and control of these neurotransmitters have become better understood.

The widespread use and abuse of prescription drugs as well as the illicit drug consumption has become an increasing concern in PDD. No drug is known to be site-specific, that is alters the neurological effect only at the relevant question or only at the comparison question. But we are concerned that the use of drugs could make assessment of physiological response more difficult to evaluate. Also keep in mind that some subjects elect to not take their prescribed medications the day of the test, or they may use an excessive dose, thinking it will interfere with the examination. These self-medicating individuals are creating additional problems when they withhold their prescribed medications, such as a rebound effect when a drug is suddenly withdrawn without medical supervision.

Central Nervous System

The Central Nervous System **(CNS)** is composed of the brain and spinal cord. The brain is an exceedingly complex organ from any level of study. We must, therefore, approach this subject somewhat topically. More details of brain function are described in the *Detailed Section*.

The largest part of the brain is composed of the **cerebrum** which is divided into two hemispheres, often described as the **right brain** and **left brain**. The two hemispheres are connected by many axons collectively known as the **corpus callosum,** which allows one hemisphere to communicate with the other. Each hemisphere is characterized by bumps, **gyri,** and indentations, **sulci**. The brain is functionally segregated into lobes, described as **frontal, parietal, occipital, and temporal**. Considerable research has studied these areas of the brain and the role each plays in our behavior. These lobes are found in both the right and left hemisphere, but contribute different aspects of our personality and behavior. These behavior patterns are often described as brain lateralization. For instance, certain areas in the left hemisphere are more dedicated to language skills while the right hemisphere may be more involved with music or judging speed and distance. Needless to say, these are very interesting areas of study and will be addressed to some degree later.

The surface of the brain is the **cortex** and is typically described as **gray matter** because of the appearance. The gray matter is composed of billions of neurons with trillions of synaptic connections. The brain areas can assess many incoming signals through this network, and direct the body to respond appropriately.

The brain can receive direct signals (action potentials) from the 12 pairs of cranial nerves. Some of these cranial nerves are classified as **sensory,** such as the optic nerve, which conveys visual signals to the brain. Others may be **motor,** which carry outflow signals from the brain to various areas of the body. Other cranial nerves are mixed because they contain both sensory and motor axons. The cranial nerves have specific names and are often identified by Roman numerals. Of the twelve pairs of cranial nerves, the Vagus Nerve (number X) is the most important to PDD examiners. You will learn more about this nerve in the Detailed Section.

In the science of psychophysiology, the birthing mother of PDD, the prefrontal lobe of the cerebral cortex is considered the center of our **cognitive skills.** The **limbic system,** while not technically a system, is a functional group of selective areas, which channels all of the incoming signals into **emotional assessments** such as fear, anger, pleasure, sense of well-being, etc. Much of our personality is the product of the cognitive and emotional expression of these incoming signals. **White matter** is located under the brain's cortex of gray matter. **White matter** is composed of **myelinated axons,** again named because of the appearance. Recall, a "myelinated axon" is a term conveying the concept that action potentials are being conducted from one place in the body to another by way of salutatory conduction.

At the base of the brain is the **brain stem**, which is composed of several subdivisions. The most important is the **medulla oblongata**, or just "medulla" for short. The medulla is responsible for coordinating the outflow of action potentials to most of the body's organs. The PDD examiner is recording this coordinating activity from the medulla and vagus nerve during a polygraph examination. The vegetative outflow from the brain stem, which includes the medulla, is regulated by the inputs from the cognitive and emotional areas of the brain.

Spinal Cord and Peripheral Nervous System

In addition to cranial nerve input and output signals to and from the brain, the spinal cord also provides major input and output signals. The spinal cord contains gray and white matter which is described further in the Detailed Section. The gray matter in the central part of the spinal cord contains an elaborate network of synaptic connections. The white matter surrounds the gray matter. The white matter is further partitioned into ascending and descending tracts of axons. The ascending tracts convey action potentials from various body organs to the brain for assessment. The descending tracts convey motor action potential back to the body organs.

The spinal cord communicates with the body organs through 31 pairs of spinal nerves, all of which contain sensory and motor axons. These 31 pairs of nerves comprise the peripheral nervous system and will be described further in the *Detailed Section*. Briefly, most of the axons in the spinal nerves, about 95%, will synapse to skeletal muscles and control voluntary movement referenced as the **somatic nervous system (SNS).** The remaining axons form complex pathways that eventually synapse in soft organs, blood vessels, glands, and other areas to make physiological adjustments during times when the environment, or mental thoughts (cognition), provoke a perception of stress or rest. This system is the **autonomic nervous system** and is of particular interest to PDD science.

Autonomic Nervous System

The autonomic nervous system (ANS) is composed of the **sympathetic division and the parasympathetic division**. The human being is in a continuous state of evaluating environmental signals entering the brain through the eyes, ears, nose and skin. Based on experience and learning, the brain assesses the signal data and makes appropriate decisions. The decisions include marshalling together the body organs for the most appropriate response. Sometimes, it might be a perception of danger. Other times, it could be the aroma of food cooking, which stimulates hunger. Or perhaps the brain anticipates a potentially pleasurable or unpleasurable experience is about to occur and therefore needs to coordinate the organ systems to address the stimulus. Like a central government working with a local government, the brain, by way of the ANS, can make appropriate adjustments in the organs and cell factories to meet current situations.

During the formative years, the limbic system of emotion is the driving force to satisfy a pleasurable stimulus, such as the sight of a chocolate cookie. However, what if it's 10 minutes before dinner, and the mother says, "not now, wait until after dinner." The three year old begins to cry, lacking the understanding of his mother. In the immature state, the stimulus of pleasure rules behavior. When the child matures, the cognitive part of the brain rules the limbic system and hopefully better directs the behavior. The ANS will drive the organ systems to respond appropriately based on the cognitive emotional mix. The details of this ANS management of body organs, particularly the cardiovascular system and eccrine sweat gland activity, will be described in the *Detailed Section.*

Mature humans recognize a variety of environmental stimuli, to which we react appropriately. We continuously assess situations from pleasant to dangerous, causing organ activity to increase or decrease accordingly.

The sympathetic nerve pathways originating in the brain stem are activated when the higher brain centers recognize a need for heightened awareness. The spinal cord provides the main pathway out of the brain through a specialized synaptic connecting system known as the **sympathetic chain ganglia**. Following synaptic communication, post synaptic action potentials communicate to the respective organs that will best respond to the environmental circumstance the brain has recognized. This complex series of physiological responses is often referred to as **"fight or flight."** Further discussion regarding sympathetic reactions can be seen in the *Detailed Section*.

The parasympathetic nerve pathways may also be activated by higher brain areas when the brain perceives the environment as tranquil. This pathway out of the brain is through selective cranial nerves, particularly, the Vagus Nerve, (cranial nerve X), and a pathway exiting the lower spinal area. Additional information concerning parasympathetic reactions is available in the *Detailed Section*.

It has been widely studied in the medical science of psychophysiology that many individuals have a degree of difficulty regulating the sympathetic and parasympathetic balance the continuously changing environmental circumstances present. Extreme cases are described as "manic depression," or more commonly, "bi-polar disorder." Numerous pharmaceutical agents have been developed to help the brain more properly assess the environmental landscape. This branch of medical science has greatly assisted individuals with various psychic anomalies; however, the profound misuse and abuse of these drugs is an increasing concern to the PDD examiner.

Let us now explore those systems regulated by the ANS, which provide the most diagnostic information related to PDD.

Integumentary System

The integument, more commonly referred to as the skin, provides multiple benefits to overall body function. Its histology (tissue design) is organized into two primary areas. The cutaneous membrane is composed of the **dermal (or dermis) and epidermal (or epidermis)** layers plus a hypodermis, which contains fat cells. Connective tissue anchors the cutaneous membrane to underlying structures. Overall, the skin provides protection from infection (referred to as the first line of defense), secretion of waste products, thermoregulation, increased grasping ability, tactile detection of external environmental changes (sense of touch), storage of lipids (fat), and the synthesis of vitamin D3.

For PDD purposes, the focus of attention will be on the cutaneous membrane and its electrical properties. The epidermis is composed of four or five layers of skin cells called keratinocytes. The body is mostly covered by four layers of thin skin. Thick skin covers the palms of the hands and soles of the feet and is completely hairless. The epidermis has no blood supply--it is "avascular"--while the dermis is highly vascular with robust physiological activity. At this point, you may be asking how the epidermis stays alive without a blood supply.

The deepest layer of the epidermis is the stratum germinativum (basale layer), which lies adjacent to the vascular dermis, from which it receives life support supplies. As the skin cells reproduce, they are pushed upward away from the blood supply and begin dying, a process takes several weeks to complete. As the progression continues, the cells develop distinguishing characteristics, which the science of dermatology has classified into identifiable layers. The outermost layer, the corneum, contains multiple layers of dead cells, which protect the body from infection. While these cells continuously flake off, they are replaced by reproducing new cells from the germinativum layer pushing up their off-spring. Advanced forensic science has focused attention upon the corneum's exfoliation of cells, conducting DNA sampling of these cells, testing who may have visited a crime scene.

The dermis--sometimes described as "true skin" because of actual blood supply--contains hair follicles, as well as numerous types of nerve endings providing tactile information to the brain. The functional understanding of the sweat glands of the dermis, classified as **eccrine sweat glands**, is most important to the PDD examiner. These glands are widely spread over the entire body, but are most densely populated on the palmer surface of the hands and fingers. See the diagram in the *Detailed Section*.

Most eccrine sweat glands secret a fluid containing sodium chloride ions, urea, uric acid, ammonia, and other chemicals. Although sweat from these glands has no apparent scent, bacteria that live on the skin can feast on the chemical wastes of the body and create a detectable odor. Because of easy access to data recording and the scientific evidence of the cognitive/emotional mix of brain function related eccrine sweat glands, they have become a good metric in psychophysiological studies and hence PDD evaluation.

Another class of sweat glands known as **apocrine sweat glands** secret their contents into hair shafts located mostly under the arms and in pubic areas. These sweat glands contain a more complex mix of secretions but don't become active until puberty. Bacteria on the skin surface will feast on these secretions at an even higher rate than the eccrine secretions. Coupling one's unique body chemistry with this sweat and bacteria metabolism creates a personalized scent that can be recognized by the family dog who knows exactly who's who in the family or house guests. Many behavioral scientists believe the apocrine gland function may elicit even more signal value of the brain's perception of cognitive and emotional stimuli than eccrine gland function. Due to their location, however, this hypothesis has not been widely studied.

Eccrine gland function of thermoregulation is accomplished by providing a water medium on the surface of the skin for the cooling effects of evaporation. Sweat glands on the palmer surface of the hand and fingers, however, improves grasping ability. There is some debate in PDD as to the better site to record sweat gland activity. Using gel pads on the thenar and hypothenar area of the hand or electrodes on the finger tips are both good locations to record the sweat gland activity. Were an examiner to encounter a person without hands, the plantar surface of the feet also have a high density of eccrine sweat glands.

Since sweat contains electrolytes (Na+ and Cl-) in the watery mix, the surface of the skin can become a good conductor of electricity when sweat glands become more active. In PDD science, an increase in electrodermal activity (EDA) provides good signal value of the brain's perception of the question. The skin conductance (and resistance) changes observed during PDD examinations is governed by **Ohm's Law (I=V/R).** I represents current (amperage), V represents voltage and R is resistance. Ohm's law may be rewritten as R=V/I to isolate the resistance component. Different aspects of the equation will be evaluated based on the specific polygraph manufacturer. In most psychophysiological laboratories, the voltage or current is held constant by the instrument. When the sweat glands are activated, water and NaCl are secreted. This increases conductance (or reduces resistance) to the flow of electricity between the contact points of the electrodes (fingertips or palmer surfaces). When either the current is held constant, a change in resistance will be reflected by a change in the result will be an increase in voltage. When the voltage is held constant, a change in conductance is reflected by a change in the measured current flow. The PDD examination can be a stress/cognition evaluator. Is the examinee experiencing more stress/more cognition to the Relevant or Comparison Questions as they relate to their goal of passing the PDD test? As more sweat is produced, quantifiable resistance declines resulting in associated changes in voltage and/or current. These changes are what produce the upswing and duration seen in the EDA tracing.

Most body organs are dually innervated, that is, regulated by the sympathetic nerve pathways when stress increases, or by the parasympathetic nerve pathways when the stress is either dissipated or a sense of rest is perceived. One of the most widely secreted neurotransmitters at the synapse of sympathetic pathways of the target organ is norepinephrine (**NE).** Acetylcholine **(Ach)** is commonly released from parasympathetic pathways. **Sweat glands are unusual in that regard.** Sweat glands only need to be activated by sympathetic stimulation and will simply return to a less active state when the stimulation is reduced. Another notable difference is that Ach is the neurotransmitter in the sympathetic management of the eccrine sweat glands. This exception is somewhat perplexing.

Of concern to PDD examiners, is the proliferation of prescribed drug therapies which may either increase or decrease Ach release in certain organs. The digestive system, for instance, is dominated by parasympathetic release of Ach. A side effect of these drug therapies, classified as either a cholinergic agonist or cholinergic antagonist, is the unintentional effect it may have on sweat gland physiology. Just as a reminder, never suggest to a polygraph subject not to take his/her prescribed medication because of an upcoming polygraph test. When in doubt, always get the advice of the health care professional. Never interfere with the examinee's healthcare protocol.

Cardiovascular System

The cardiovascular system can be likened to a transport system within a nation. The blood is the vehicle which is capable to bringing the raw materials (nutrients from the digestive system) to the factories (cells) located in many locations (systems, organs, and tissues). As in any nation, (human body) there are millions of different kinds of factories which produce products of all kinds. Some factories produce products for local use, while others produce products for use in other places. As in a nation, the body's eleven systems are not all simultaneously functioning at maximum capacity. The nation's varied infrastructure can adapt to meet the changing environmental conditions depending on situations presented. The human body can also make the necessary adjustments. For instance, you wouldn't be having dinner (activating the digestive system) while working out at the gym (activating muscles, tendons and ligaments).

Blood

Although blood chemistry and physiology has not been the subject of PDD study, a brief introduction to its composition and function will be helpful to your understanding of human physiology and to the physiological activities which do play direct roles in PDD evaluation. Further study of blood is not required for practitioners of PDD science.

Blood is comprised of to two major components: formed elements (various cells), and plasma (a molecularly complex watery composition). The mix of blood components can vary somewhat depending on one's size, gender, and physical condition. An average person has about 5 liters of blood, consisting of roughly 45% cells and 55% plasma. Approximately 99% of the cells are described as red blood cells (RBC), and less than 1% is a mixture of five different kinds of white blood cells (WBC) and platelets. The RBCs contain complex molecules known as hemoglobin, which has a red color under light. Hemoglobin is responsible for transporting oxygen from the lungs to the tissues. It also carries most of the carbon dioxide produced by the cell's metabolism to the lungs to be discharged to the air. It is the combination of hemoglobin with oxygen which gives blood a bright red color in arteries, the vessels delivering blood to the tissues. Deoxygenated hemoglobin is dark red in veins, the vessels that return blood from the tissues. There has been a long standing myth portrayed that blood is blue and turns red when it hits the air. Don't believe it. It's a bad joke played out on the naïve.

The key concept of understanding blood is that the RBCs pick up of oxygen from the lungs, deliver it to the cells, and upon return, carry carbon dioxide from the cells to the lungs. WBCs are responsible for defending the body from infections. The plasma delivers nutrients and a host of regulatory molecules to the cells and returns a host of waste products from cell metabolism to the kidneys and liver to be excreted from the body.

As mentioned above, not all systems are performing to their maximum capacity at all times. As the brain perceives either a threatening circumstance or a need to address a stressful situation, selective adjustment in organ system physiology must be made. Since oxygen delivery and nutrient support is vital to the systems addressing the stress, it is now important for the understanding of PDD how this is accomplished. Already described, albeit briefly, the blood is the vehicle of delivery, but must be pumped in a manner that selectively increases delivery as circumstances require. Here comes the heart.

Heart

The heart, simply put, is a pump. Its design, however, is elegant. In fact, the heart has two pumping systems within the single organ. The right side of the heart is composed of the **Right Atrium,** a receiving chamber for blood returning from the tissues and **the Right Ventricle,** a pumping chamber sending the blood to the lungs so it can unload carbon dioxide and pick up oxygen. The left side of the heart receives blood coming back from the lungs in the **Left Atrium**, while the **Left Ventricle** pumps blood to the organ systems of the body. Why two separate receiving and pumping chambers?

The short answer is that pumping blood through just the lungs requires about one third the pressure than the same action through the other systems of the body. The lung design is composed of very delicate thin walled membranes, which cannot tolerate high pressure, but more about lung design when we get to the Respiratory System.

The other (non-respiratory) systems in the body, in their collective design, require a much higher pressure than what is provided to the lungs. This is to overcome the resistance of thousands of miles of blood vessels comprising the human body vascular network of **arteries, capillaries, and veins.** For this circulatory system to work, two separate receiving and pumping chambers, each with different pressure generating pumps is required. Inspection of the muscular wall of the right ventricle compared to the left ventricle wall reveals the left ventricle has considerable more muscle mass than the right ventricle. Again, this is because it must generate a pressure force significantly greater than the right ventricle.

It is helpful to inspect the vascular design of the arteries and veins to get an appreciation of the blood vessel map. Starting with the right heart pump, notice the **superior vena cava,** a large blood vessel vein returning blood from the head, shoulders, and arms, into the right atrium. The largest blood vessel (by diameter) in the body is the **inferior vena cava**. It returns blood from the legs, abdomen, and chest. Blood from the right atrium is delivered to the right ventricle and pumped through the pulmonary trunk, which branches into left and right pulmonary arteries to the lungs. The left heart pump receives blood from each lung into the Left Atrium by the **left and right pulmonary veins.** Blood from the left atrium is delivered to the left ventricle and pumped into the **ascending aorta** for distribution to the body organs. More about systemic blood flow distribution later.

An easily understood law of physics can be applied to the heart pumping cycle. If the volume of a chamber decreases, the pressure (which is force per area) in the chamber will increase and vice versa. This concept was originally applied to gases and is widely known as Boyle's Law. Since the pressure in the ventricles oscillates between the contractile phase and the relaxation phase, a valve system must be employed to ensure blood will flow in only one (forward) direction. A **tricuspid valve, located** between the right atrium and right ventricle, is forced closed when the ventricle contracts forcing the blood to enter the pulmonary artery toward the lungs. It is sometimes called the right atrioventricular (AV) valve. When the ventricle contracts, which would permit the blood to go backward into the atrium, the valve leaflets are secured by chordae tendineae anchored to the inside wall of the ventricle (see diagram). This prevents these valves from flapping completely into the atrium. When the right ventricle is contracting, so is the left ventricle. A similar valve design exists between the left ventricle and left atrium (the left AV valve). Due to the pressure on this side of the heart being about three times greater, the two flap design of the **bicuspid valve** is more effective. This valve is often referred to as the **mitral valve** in clinical settings because it is said to look like a bishop's miter or hat. When the pressure increases in the left ventricle, blood is pumped into the ascending aorta for distribution to the organ systems.

After the ventricles contract, they must relax. By relaxing, the volume in the ventricles increases, causing the pressure to fall. This has the potential to suck (return) the blood that each ventricle pumped out during the previous cycle. Suction forces of the relaxing ventricles, however, actually prevent that from occurring because of valve with a three flap-like cusps in its design. These valves are described as the pulmonary and aortic **semi lunar valves** because of their appearance. During the cardiac cycle, as the ventricles oscillate between contraction and relaxation, the cuspid valves close, then open, followed by the semi lunar valves closing, then opening. The closing of the valves causes characteristic sounds which can be detected with a stethoscope. The closing of the cuspid valves is commonly described as the first sound or **lubb.** The closing of the semilunar valves is described as the second sound or **dupp.** These sounds result from blood bouncing off of the valves.

When the lubb sound occurs, the left ventricle is pumping blood through the systemic arteries, generating an increase in pressure referred to as the **systolic pressure** or **systole**. Simultaneously, the right ventricle is pumping blood to the lungs. When the ventricles relax, the systemic arterial pressure falls, referred to as the **diastolic pressure** or **diastole.** Note there are no valves between the venous blood return to either the right or left atrium (see the heart diagram). Since the ventricles are the pumping workhorses, when they are in the diastolic phase of the cardiac cycle, about 80% of the blood returning to the heart is sucked through the atria into the ventricles. When the thin walled right and left atria contract, the remaining 20% of the blood is pumped into the ventricles, joining the blood the ventricles pulled in during the relaxing phase of the cardiac cycle.

When individuals experience diminished ventricular contraction, the rebounding phase is diminished, much like a rubber ball thrown gently against the wall bounces back softly compared to a ball thrown vigorously against the wall. When the right ventricle weakens, swollen ankles (edema) are often detected because blood and tissue fluids are not being efficiently pulled back by the weakened right ventricle. When the left ventricle weakens, fluids accumulate in the lungs, often leading to pneumonia and other respiratory difficulties.

The cardiac cycle is governed by both an **intrinsic conductive system** and an **extrinsic conductive system**. Both of these management systems will be described in the *Detailed Section*. Briefly, though, when the cognitive and emotional brain assessment of an environmental stimulus is provocative, a sympathetic pathway releasing the neurotransmitter, norepinephrine **(NE)** to the heart's intrinsic conductive system occurs and a parasympathetic pathway decreasing the release of Ach to the heart occurs. This is similar to stepping on the gas and coming off of the brake at the same time. The synergistic effect on the heart is more effective than either one in isolation. This response will increase cardiovascular dynamics. Conversely, when the brain perceives the environment as tranquil, the vagus nerve, with the release of acetylcholine **(Ach),** dominates relaxing cardiovascular dynamics.

Like all well managed industrial plants, feedback information from the workers or foreman on the job would be welcomed information back at headquarters. Feedback information in cardiovascular system comes from two major areas reflecting blood pressure and blood chemistry. After you have inspected the blood vessel map, take notice of the ascending aorta leaving the left ventricle. It bends sharply (aortic arch), then descends into the chest and abdomen branching many times. At the top of the aortic arch arise three main arteries, **brachiocephalic, left common carotid** and **left subclavian**. The first artery, the brachiocephalic, divides into the right common carotid artery and right subclavian artery. The second branch is the left common carotid artery and the third branch is the left subclavian artery. The carotid arteries are the main vessels delivering blood to the brain. Each carotid artery bifurcates into an internal and external carotid artery. The **carotid sinus** is where the internal carotid arteries begin a small dilation of the artery. There are many specialized nerve cell receptors in the walls of the carotid sinus and arch of the aorta. The receptors detect blood pressure and blood chemistry changes. Action potentials are relayed by cranial nerve IX and X to the brain stem and other brain areas based on what these cells detect. The heart rate and force of each cardiac cycle are then adjusted through the ANS to meet the body's blood flow needs.

Sphygmomanometer

Blood pressure is routinely evaluated as part of a medical assessment. Blood pressure is measured by placing a rubber bladder around the arm. The bladder, which is connected to a pressure gauge, is inflated with air until the pressure is great enough to overcome the left ventricle's contractile strength. The technician or doctor listens for the sound of passing blood below the cuff with a stethoscope. When no sound is detected the pressure in the cuff is greater than the left ventricle can overcome. Next, the air is slowing let out of the cuff. The first sound in the stethoscope indicates some blood is passing through the artery, but still partially restricted by the pressure in the cuff. The ventricular pressure created by the contracting ventricle, which is causing the blood to flow, is greater than the pressure in the cuff and is referred to as the **systolic pressure.** This pressure may be about 120 mmHg in many individuals. Air continues to be let out of the cuff until no sound can be heard which indicates the cuff is no longer offering resistance to the blood flow. This is referred to as the **diastolic pressure,** which may be about 80 mmHg. Blood pressure can have a wide range of values based on age and many other factors. If too extreme, the doctor may declare the blood pressure is abnormal and prescribe a medication.

In PDD science, variations in heart rate, relative blood pressure, and **pulse pressure** (the difference between the systolic and diastolic pressures), can provide diagnostic value in calculating the probability of deception. The sphygmomanometer, (hereafter referred to as the blood pressure cuff) used in the PDD, is secured on the arm for nearly five minutes during the recording of a single chart. This could become very uncomfortable and even cause distorted physiological recordings if the pressure was maintained between systolic and diastolic pressures. By adjusting the cuff pressure below diastolic pressure to about 60 mmHg, cardiac cycles and other pressure dynamics can still be recorded with instrument amplification because the artery under the cuff is pulsating against the tissues in the arm with each cardiac cycle. It would be helpful to observe the blood vessels of the arm from diagrams. Make particular note of the brachial artery because that is the blood vessel the cardio cuff is monitoring.

Respiratory System

The respiratory system is dedicated to extrapolating oxygen from, and returning carbon dioxide to, the atmosphere. The respiratory system is exposed to the environment and is subject to being invaded by pathogenic airborne diseases in the process of performing these roles. The system must be adaptive and be able to develop defensive mechanisms to prevent infectious diseases, or at least minimize the effect of these potential pathogens.

The respiratory system, by expiring air through the larynx (voice box), can create sounds for speaking, singing, and even louder sounds to signal danger or summon help from others. The nasal portion of the respiratory system detects stimuli of olfactory (sense of smell) which is alerts us to food and its taste as well as signaling danger such as smoke or the pleasure of attractive aromas. The sense of smell is also a stimulus to memory.

The respiratory system even participates in the regulation of blood pressure. A specific hormone is activated in the lungs which can help raise blood pressure. Blood pressure is also modified by the simple mechanics of breathing. The regular dynamics of inhalation reduce pressure in the thorax which helps to dilate the vena cava which reduces resistance and thus helps to suck blood back to the heart, raising blood pressure. Also, during inhalation the heart beats faster resulting in respiratory sinus arrhythmia. A faster beating heart is like a faster pumping pump and can result in increase in blood pressure.

During exercise, breathing rate increases. As a consequence, blood pressure increases because more blood is pulled back to the heart, at a faster rate. In addition to this respiratory pump, many veins are located between muscles. These veins are squeezed during exercise, which helps pump the blood back to the heart (muscular pump). Perhaps it's more easily visualized that exercise creates the combined effect of two additional "pumps" which becomes the heart's "best friend."

After long periods of inactivity, such as sitting at a computer desk or driving a car for a long period of time, blood pressure begins to fall and a person may begin to yawn. The action of yawning intensifies the respiratory pump, drawing more blood back to the heart, raising blood pressure, at least for a short time. Think about waking up in the morning. After a night of sleeping, you need to raise blood pressure to stand vertically and start moving about. How do you accomplish that? You got it. You start yawning and stretching to activate the respiratory and muscular pumps while still in bed to raise blood pressure. If you get out of bed too quickly, you might stumble or fall because your blood pressure is too low from sleeping all night. This concept of forcing blood back to the heart to raise blood pressure by yawning and stretching is known as **Starlings Law of the Heart**. Within limits, the concept states the more blood returned to the heart, the more will be pumped out. Increased inhalation and increased muscular movements will increase blood **stroke volume (ejection volume).**

It becomes a concern in PDD that breathing dynamics are under somatic control, and can be controlled and modified. Skillful regulation of breathing cycles, that is, practicing **countermeasures,** can have detrimental effects on the cardiovascular system as well as EDA during a PDD examination. If you are an experienced examiner, you have observed that when a subject takes a deep breath, whether purposely or otherwise, the other recorded channels in a polygraph become contaminated, thus reducing or eliminating their diagnostic value.

Ventilation Anatomy

Pulmonary ventilation (breathing) begins as air flows into the body through the nares (nostrils), then the nasal passageway, and into the pharynx. The pharynx is shared with the oral cavity (mouth), which directs food into the esophagus while air is directed into the **larynx** (voice box), then into the **trachea.** This dichotomy is designed so that inhalation of air and swallowing of food or liquid cannot occur at the same time, that is, we can't swallow and breathe at the same time. The airway is protected from food or liquid entering it by a cartilaginous flap-like structure called the epiglottis. The epiglottis presses over the opening (glottis) of the larynx when swallowing.

The trachea divides into left and right **bronchi,** which continue to branch like a tree until the branches become microscopic (bronchioles) and terminate into millions of thin walled air sacs named **alveoli.** The microscopic alveoli are organized into two organs, the right and left lungs. The alveoli are surrounded with blood capillaries designed to receive oxygen from the air and return carbon dioxide to the air. The physiology of this gas exchange can be reviewed in detail in the text books or the *Detailed Section* of this manual if you are interested in a deeper understanding of the ventilation process.

When discussing respiration, what is most important to the PDD examiner is to be aware that gases exchanged in the lungs are needed to maintain metabolic requirements of the entire body. The exchange of oxygen and carbon dioxide, like all other molecular movements, are governed by laws of physics. Namely, gases move from areas of high concentration to areas of low concentration.

When the body is under stress, such as during exercise or perceiving a threatening circumstance, the autonomic nervous system (ANS) will stimulate the airway, particularly the trachea, bronchi, and bronchioles. This action dilates the airway, reducing airflow resistance, permitting air to flow more easily through the conduction zone between the atmosphere and the alveoli of the lungs.

In a typical challenging or intense athletic event, both a dilation of the airway by the autonomic nervous system, and an increase of ventilation dynamics (breathing rate) controlled by the somatic nervous system occurs, typical of the fight or flight reaction.

In the PDD setting, however, **a most unusual circumstance is present,** particularly for the subject attempting deception. All polygraph examinees are directed not to move during the presentation of the question series, in an effort to avoid artifact contamination of the polygraph recordings. In effect, the physiological oxygen demands are met by the autonomic stimulated-dilated airway for a body **not in motion**. Consequently, ventilation dynamics of breathing cycles is reduced. Typically the amplitude of each breathing cycle is reduced and the respiratory breathing cycles are reduced when the subject perceives the question more challenging their goal of passing the test, than another question. These respiratory dynamic patterns are recorded through the ventilation transducers. If the wave length pattern were placed in a straight line compared to a less threatening question, one could observe the **Respiratory Line Length (RLL) (or respiratory line excursion)** would often be shorter when the more challenging question is presented.

Ventilation Dynamics (Breathing)

On average, during restful or relaxing times, a person inhales and exhales about 12 – 14 times a minute, referred to as quiet breathing or eupnea. The diaphragmatic muscle, which separates the thoracic (chest) cavity from the abdominal cavity, contracts, enlarging the chest cavity. While the diaphragm is contracting, external intercostal muscles between the ribs are pulling the rib cage upward and outward, contributing to chest expansion.

Between the lungs and the chest wall is a double layered membrane, the parietal and visceral pleurae. Between the enclosed layers is a slit-like space with a pressure average of approximately -4mmHg below atmospheric pressure. This negative pressure acts as a suction to hold the lungs to the thoracic side wall. During inhalation, the lungs are pulled outward with the expanding thoracic cavity. In consequence, as the lungs expand, the intrapulmonary pressure within the airway and alveoli also decreases about 1mm Hg, causing air to be pulled into the alveoli (recall Boyle's law of pressure/volume earlier in this manual). During exhalation, the chest wall passively returns to its resting state while the diaphragm relaxes. This phase of quiet breathing forces air out of the lungs.

For an average person, the amount of air exchanged during a single breath is about 500ml, known as the **tidal volume**. During stressful breathing (hyperpnea), other muscle groups and muscles under the external intercostal muscles, the internal intercostal muscles, actively pull the rib cage down so the breathing cycle rate can increase to meet the oxygen demands of contracting muscles. This increased breathing cycle is not likely to be seen during a PDD examination.

Regulation of Breathing Cycles

The respiratory rhythmicity centers are located mainly in the medulla oblongata of the brain stem. These centers can be modulated by areas above the medulla, such as centers in the pons. They can also be modulated by cognitive and emotional areas of the brain. You may recall, the respiratory system also participates in making voice sounds of speech, loud sounds of emotion, singing, etc. Therefore, respiratory centers can be voluntarily adjusted to meet these desires, but needs to have master control of breathing cycles for gas exchange to meet metabolic demands. Some examinees, as you may have observed, will manipulate their breathing cycles. When altered from rhythmic patterns, changes in the cardiovascular physiology can be affected. These factors are of great concern to the PDD examiner.

Chemical changes in the blood such as oxygen, carbon dioxide, and acid levels, affect the characteristic of breathing cycles. The most significant breathing center in the medulla is the Dorsal Respiratory Group (DRG). When certain blood chemicals are changing, the DRG sends out action potentials to the spinal cord. This connects to pathways leaving the spinal cord in the cervical areas of C3, C4, and C5 to form the **phrenic nerves,** which innervate the diaphragm. Other pathways leave the spinal cord in the thoracic region to innervate the intercostal muscles. These pathways lead to the inspiration phase of breathing. Special nerve cells and elastic fibers signal the brain that the lungs have stretched enough, stopping the inspiration and allowing expiration to occur **(Hering-Breuer Reflex).**

There are many other factors which affect how the respiratory system performs its duties, but the physiological details go beyond the scope of this manual. They can be researched further if desired, along with many other physiological activities of the organ systems.

As mentioned earlier, the authors realize the life science background of most PDD examiners is limited by the career choices made before deciding to enter this field. That being said, we hope everyone can appreciate the need to understand the physiological basis we have outlined, albeit in a limited way, so that you will have a good understanding how the human body responds in the PDD setting.

End of Part 1