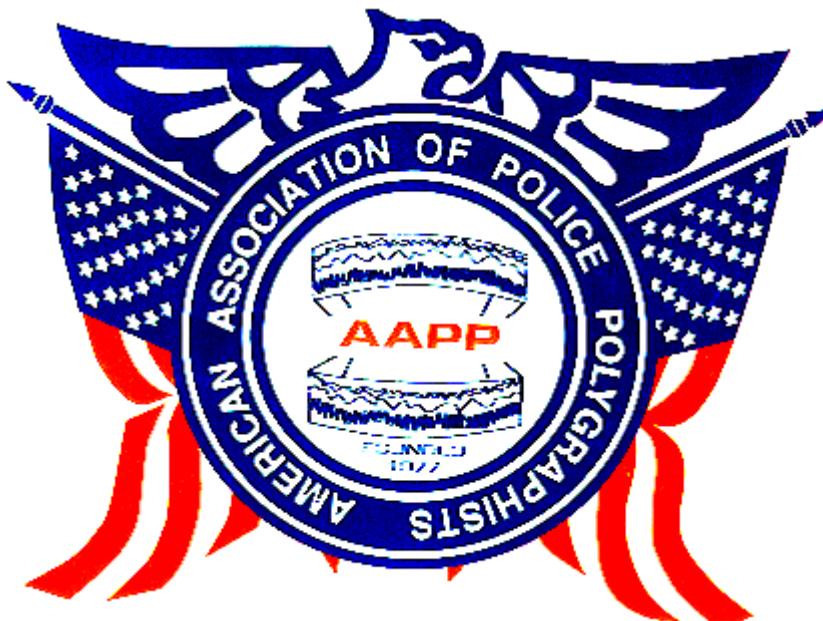


# The Police Polygraph Digest

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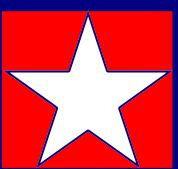
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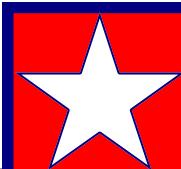
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*Deadline for the March 2015 issue is January 15th, 2015*



# Insurance is about Peace of Mind

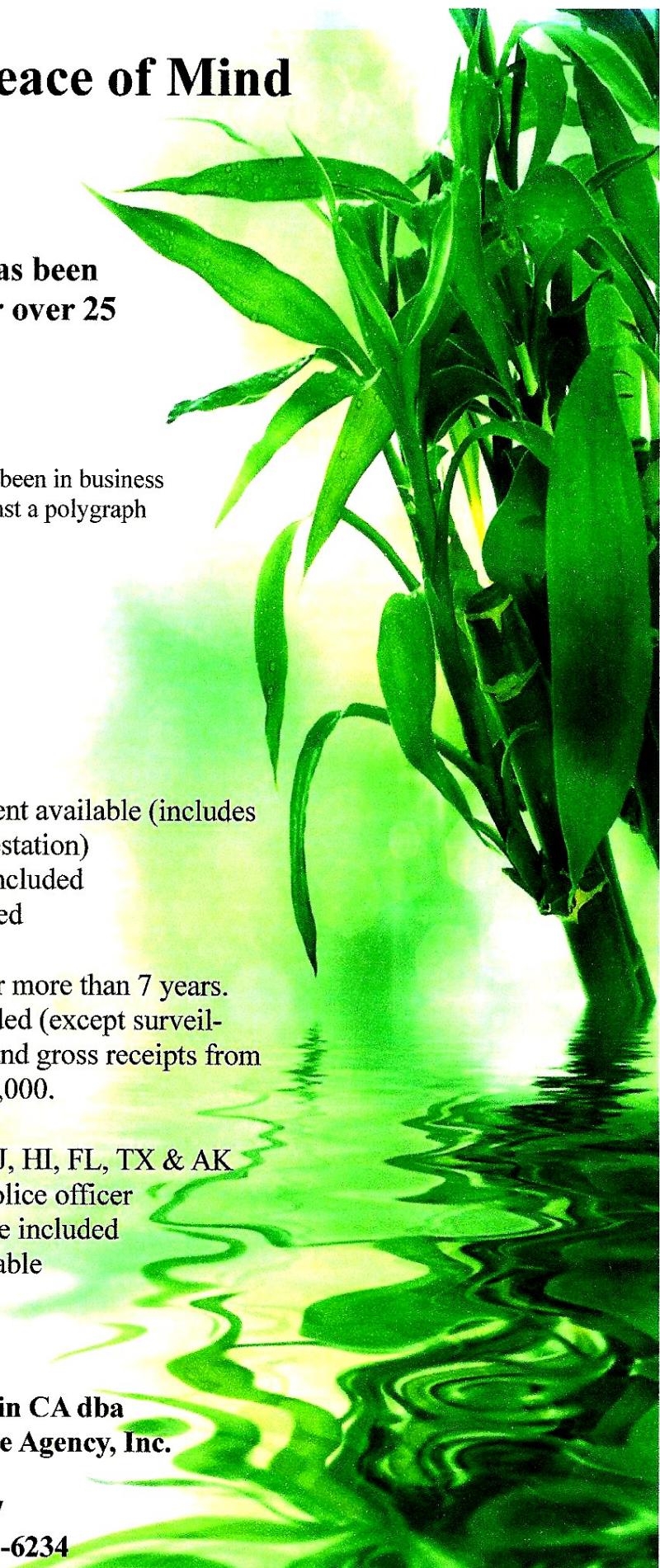
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# A PHYSIOLOGY MANUAL FOR PDD LIFELONG LEARNERS OF THE SCIENCE

(Part 1)

**Joel Reicherter and Mark Handler**

## 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 **Systto** relevant questions concerning a matter in question. The **Cardiovascular em (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.

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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. We are also incredibly grateful to Don Krapohl who inspired this project, coaxed it to completion, and formatted its final version.*

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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*<sup>3</sup>. 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.

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

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<sup>3</sup> Begins on page 23.

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  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ ,  $\text{Ca}^{++}$  and  $\text{H}^+$  etc. The + sign indicates a loss of an electron, the – sign indicates a gain of an electron. The  $\text{Ca}^{++}$  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 ( $\text{NaCl}$ ) would be a good example. Salt could be represented  $\text{Na}^+ \text{Cl}^-$  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 ( $\text{Na}^+$ ), Potassium ( $\text{K}^+$ ) and Chloride ( $\text{Cl}^-$ ), (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.  $\text{K}^+$  is the most important ion for establishing resting potential. The selective permeability of the neuron membrane permits some of the  $\text{K}^+$  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<sup>+</sup> 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<sup>+</sup> to enter the cell and move toward the axon. When enough Na<sup>+</sup> 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<sup>+</sup> 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<sup>+</sup> 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<sup>+</sup> enters the cell, the neuron will pump out the Na<sup>+</sup> and pull K<sup>+</sup> 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<sup>+</sup> 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 visualize the design. Observe the drawing in the *detailed section* of the manual. Since the depolariza-

tion 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  $\text{Na}^+$  or  $\text{Cl}^-$ . If  $\text{Na}^+$  enters, the post synaptic neuron will generate a new action potential. If  $\text{Cl}^-$  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 path-

way 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 offspring. 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 ( $\text{Na}^+$  and  $\text{Cl}^-$ ) 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 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**. Simultaneous-

ly, 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 pres-

sure 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 slowly 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 respirato-

ry 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**

*Continued on Page 22*

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# **DETAILED SECTION OF PHYSIOLOGY OVERVIEW FOR PDD LIFELONG STUDENTS OF THE SCIENCE**

## **(Part 2)**

**Mark Handler and Joel Reicherter**

### **INTRODUCTION**

See Overview for Introduction.

### **PHYSIOLOGICAL AND CHEMICAL BACKGROUND**

#### **A. Chemical level of organization**

1. The basic structure of an atom- The structure of an atom consists of the nucleus, which contains the protons and the neutrons tightly bound together. Protons have a positive electrical charge and neutrons are neutral. Protons and neutrons have about the same mass, which is designated as one atomic mass unit. Each proton and each neutron is one atomic mass unit. Electrons have a negative electrical charge and are small in comparison to protons or neutrons. Electrons have about 1/2000 of the mass that a proton or neutron has and are usually designated as zero atomic mass units.
2. Ions are important in cell signaling- An ion is an atom with a positive or negative electrical charge. Calcium ( $\text{Ca}^{++}$ ), Potassium ( $\text{K}^+$ ), Chlorine ( $\text{Cl}^-$ ) and Sodium ( $\text{Na}^+$ ) are all involved in nerve impulse conduction. Ion flow across the membrane conducts the nerve impulse.
3. Molecule- When two or more atoms combine chemically, they form a molecule. Molecules can consist of two or more of the *same* atoms (hydrogen or  $\text{H}_2$ ) or they can form compounds, which are molecules of *different* atoms ( $\text{H}_2\text{O}$  or water).

### **III. HUMAN BODY ORGANIZATION -cells-tissues-organs-systems-organism**

#### **A. CELLS**

1. The cell is the basic structural and functional unit of a living organism.
2. There are three generalized regions of human cells and their functions-
  - a. The nucleus lies near the center of the cell and manages the cell's activities through its DNA construction.
  - b. The cell or plasma membrane separates the cell from its internal environment of a watery mix of ions and nutrients, often referred to as extracellular or interstitial fluid. The membrane serves

as a regulator of what substances will enter the cell and what will be excreted. Many specialized cells have unique molecules known as receptors, which regulate the movements of certain ions into or out of the cell. As a result of this regulation, cells can have more positive ions on the outside of the cell membrane, which will establish a charge difference between the outside and inside of the cell. This is known as a resting potential. Specialized cells in the nervous and muscular systems can use resting potential to conduct impulses or action potentials. These signals are sent to the organ systems, instructing specific physiological activity.

c. The cytoplasm is the fluid-filled region between the nucleus and the plasma membrane. It contains numerous small structures called organelles that in effect are the machinery performing the cell's specialized activities.

3. The plasma (or cell) membrane separates the cell into two areas:

- a. Intracellular, and
- b. extracellular.

4. *Interstitial fluid* is an extracellular fluid that bathes our cells. It is derived from our blood and contains the many substances needed for metabolism. Cells extract the nutrients they need from this fluid through a process known as selective permeability. The process of selective permeability allows needed nutrients to enter the cell while keeping out undesirable material.

5. *Diffusion* across a cell membrane occurs when ions and molecules scatter to equalize their concentration in an environment. Ions and molecules tend to move from higher concentrations to lower concentrations. This process is called diffusing down their concentration gradients.

a. *Simple diffusion* is one of two basic diffusions that occurs when substances are able to cross the cell membrane without having to use a channel. This happens with such things as oxygen and carbon dioxide. Oxygen concentrations are always higher in the blood than inside the tissue cell, so oxygen constantly enters the cell by diffusing down its concentration gradient. Carbon dioxide (CO<sub>2</sub>) is one of the "waste products" produced by the cells and it is in higher concentrations inside the cell than outside. CO<sub>2</sub> diffuses down its concentration gradient by the process of simple diffusion.

b. *Facilitated diffusion* is the second basic diffusion. It involves the movement of substances across the membrane that are either too large to pass through passively, or, are lipid-phobic (meaning they are insoluble to the lipid bilayer that forms the cell membrane). Facilitated diffusion uses proteins that construct passageways or pores through the membrane.

c. Osmosis is a special type of diffusion. Osmosis is the net movement of a liquid (usually water) across a selectively permeable membrane when there is a difference in concentration of solutes on either side of the membrane. The liquid is driven by the difference in solute concentrations on the two sides of the membrane. A selectively permeable membrane is one that allows unrestricted passage of water, but not solute molecules or ions, so only the water moves from one side to the other.

The different concentrations of the solute results in different concentrations of “free” water molecules on each side of the semi-permeable membrane. On the side of the membrane with higher free water concentration (i.e., a lower concentration of solute), more water molecules are available to bounce around and hit the pores in the membrane. More hitting of the membrane results in more molecules passing through the pores, which in turn results in net diffusion (movement) of free water from the compartment with high concentration of free water to that with low concentration of free water.

6. *Active transport* is an important process to cell membranes. Sometimes substances cannot passively navigate through the cell membrane. This may be due to size, charge, or because it cannot dissolve through the bi-lipid (fatty) layers of material that make up the cell walls. Active transport uses proteins called *transport systems* to move ions "uphill" against their concentration gradient. One very important transport system is the sodium-potassium ( $\text{Na}^+ - \text{K}^+$ ), which helps keep the proper concentration in intracellular and extracellular. The concentration gradients of sodium and potassium are essential for our muscle and nerve cells to function properly.
7. *Vesicular transport* is a process whereby large particles and molecules can be transported across cell membranes inside of small sacs called vesicles. This process is called exocytosis. One way cells communicate with one another is by the release of chemicals called neurotransmitters. The little sacs attach to the inside of the membrane, fuse with it, and spill out the neurotransmitter so it can contact the adjacent cell. The sacs are reabsorbed by the cell, and recycle themselves to be used again.
8. *Membrane potential*, or voltage, is the amount of electrical potential energy across a membrane. In cells, the plasma membrane separates oppositely charged particles. If there are more positively than negatively charged particles gathered on one side (e.g., the outside of the cell membrane), the difference results in *membrane potential*, much like a battery. If there becomes a way for the charged particles to flow, a current will arise. All cells are said to be polarized because they establish a membrane potential with the inside of the cell membrane being more negatively charged than the outside of the membrane. Cells use this membrane potential to communicate by opening channels that allow current to flow in or out of the cell. This will be discussed later in the section on the nervous system.
9. *Chemical signaling* is a primary way cells in the nervous system, and hormones in the endocrine system, communicate using neurotransmitters. Different cells respond in different ways to the same neurotransmitter or hormone. Some transmitters can increase the activity in one cell and decrease the activity in another. The end result depends upon the receiving target cell.

## B. TISSUE

1. *Tissue* - Groups of similar cells that combine to perform a related function are called tissue. There are four types of primary tissue that form the body: epithelial, connective, muscle, and nervous.
2. *Epithelia* - Epithelia forms the boundaries between different environments for an organism. Epithelium provides protection, absorption, filtration, excretion, secretion, and sensory pathways.

3. *Connective Tissue* - Connective tissue "connects" body parts. Functions of connective tissue include support, storage, and protection of the body. Skin, blood, bone, ligaments, and cartilage are all examples of connective tissue.

4. *Muscle Tissue* - Muscle tissue has the unique ability to shorten or contract. The three types of muscle tissues are skeletal, cardiac, and smooth. Smooth muscle is found in the walls of hollow organs like our blood vessels and stomach. It is called smooth because it has no striations or stripes. Smooth muscles can contract (constrict) or dilate (enlarge) and can be used to adjust the movement of substances. Smooth muscles are highly involved in the adjustment of blood pressure.

## C. ORGAN and ORGAN SYSTEMS

1. *Organ* - An organ is a discrete structure that performs a specific function composed of different tissue types.

2. *Organ system* - Organ systems are composed of organs working together for a common purpose. There are 11 organ systems in the human body. They are: cardiovascular, respiratory, nervous, integumentary, muscular, skeletal, digestive, endocrine, lymphatic, urinary, and reproductive systems.

3. In PDD, we are primarily concerned with the respiratory, cardiovascular, nervous, and integumentary systems. These systems contribute to the physiologic measurements we collect during PDD exams. A basic understanding of the physiologic properties underlying the measurements is essential for a sound foundational knowledge base.

a. Respiratory system- (air movement through the nasal cavity, pharynx, larynx, trachea, bronchus, lung). This system removes carbon dioxide and continually supplies blood with oxygen.

b. Cardiovascular system- (heart, blood vessels). The heart pumps our blood and our blood vessels transport it throughout the body to all cells. Blood carries oxygen, carbon dioxide, nutrients, waste and more throughout the body.

c. Nervous system- (brain, spinal cord, nerves). This is the control system of the body. It responds to internal and external changes, and activates muscles and glands.

d. Integumentary system- (skin, hair, nails). This system forms the external body covering and protects deeper tissues from injury. It houses cutaneous receptors, sweat glands, oil glands, and synthesizes (makes) vitamin D.

## D. ORGANISM

1. *Organism* - The living organism (animal or plant) that represents the sum total of all organ systems working together.

## E. HOMEOSTASIS & ALLOSTASIS

1. *Homeostasis* - Homeostasis is a term used within the scientific community to describe the maintenance of the internal viability of organisms. The word homeostasis is derived from the Greek *homeo*, which means "same," while *stasis* means "stable," thus, "remaining stable by staying the

same.” American physiologist Walter Cannon coined the term “homeostasis” to refer to the processes by which constancy of the fluid matrix is maintained. It is used to describe the maintenance of internal parameters within a relatively narrow window. Homeostasis is maintained through the “integrated” actions of numerous body systems. For example, sufficient nutrients must be present in the blood and the cardiovascular system must be functioning properly to provide those nutrients to all of the cells in the body. Waste products, like CO<sub>2</sub>, must not be allowed to accumulate in the cells and must be continuously removed. The core temperature of a healthy person is maintained within a relatively narrow band in spite of the changing climates.

2. *Homeostatic mechanism of actions* - Homeostatic reflexes adjust to maintain a constant set point or level, much like a thermostat in a home. Homeostasis involves a *negative feedback loop* because it waits for something to happen before acting. A feedback loop involves a central control module which receives input regarding a condition, processes it, and then sends an output signal to maintain a set point. The central control center in a negative feedback system sends a correction to reverse the change from a set point to maintain a constant or fixed state. Positive control feedback systems enhance a stimulus that is already present. The classic feedback control model of homeostasis in psychophysiology describes compensatory responses to restore detected imbalances rather than enhancing what is already there and thus is considered negative. Homeostasis describes the regulation of the body to a balance, by single point tuning such as blood pressure, blood oxygen level, blood glucose, or blood pH. Baroreceptor reflex in blood pressure is the classic, prototypic homeostatic system whose inputs, outputs, and controls are well characterized. But blood pressure set points can, and do, change depending on the circumstances. Additionally, blood pressure can be changed through a variety of ways, not necessarily through one simple negative feedback system.

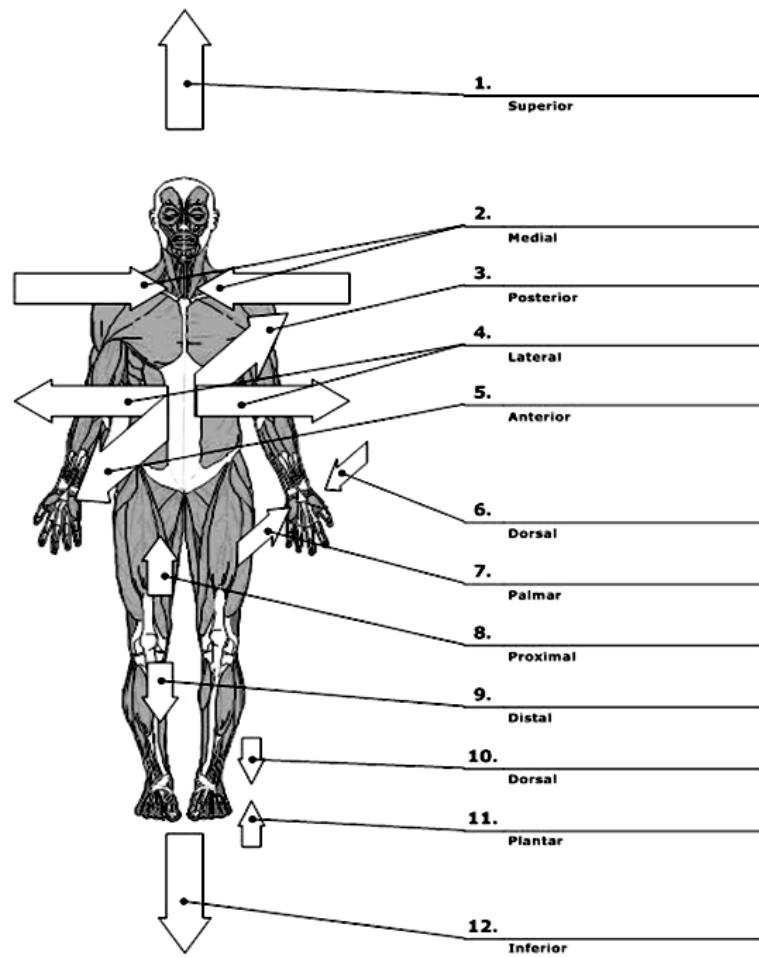
3. *Allostasis* - Allostasis is the process of achieving stability, or homeostasis, through physiologic or behavioral change. This term is derived from the Greek: *allo* meaning change, and *stasis* meaning “stable”. That is, some changes are necessary to maintain stability or viability. These changes are presumed to be aimed at ensuring the overall viability of the organism. Allostasis encompasses both behavioral and physiologic processes directed towards maintaining adaptive states of the internal environment. One common example is the ever changing relative blood pressure in a person over the course of the day. Researchers have found mean arterial blood pressure will fluctuate to meet demands, or in an anticipation of a demand.

4. *Allostasis as a feed-forward regulatory process* - The allostatic model acknowledges the organism can use prior information to predict demand and adjust proactively before the demand is needed. Cannon recognized the body can respond in anticipation of a disturbance or agitation. For example, blood pressure typically rises slightly during the moments just before a person stands after having been sitting or relaxing. The anticipatory increase in blood pressure is adaptive, and serves to prevent lightheadedness by preventing the gravitational pull of blood to the feet by this positional change. The anticipatory increase in blood pressure is not in response to environmental or physiologic feedback, but can be thought of as a form of adaptive learning from past experiences with the action of standing. If a subject takes medication which blocks these blood pressure changes, the feed forward action can be blocked and the subject becomes dizzy.

## F. ANATOMICAL NOMENCLATURE

1. The standard body position known as the *anatomical position* - A position in which the body is standing erect, feet slightly apart, palms facing forward with the thumbs pointing away from the body. The terms "right" and "left" are used with reference to the body being described and not the person observing that body.
2. *Sagittal plane* - A sagittal is a vertical plane that divides the body section being viewed into right and left. Mid-sagittal describes a sagittal plane directly down the middle of the part viewed. Imagine splitting your body from the top of your head down through your crotch and then being able to look into either the left or right half of your body.
3. *Frontal or Coronal plane* - A frontal or coronal plane splits a body into anterior (front) and posterior (back) views. Imagine splitting your body from the top of your head through both shoulders, down to your feet and looking at the front half or back half of your body.
4. *Horizontal or Transverse plane* - A horizontal or transverse plane runs across and separates the body viewed into superior and inferior planes. These are sometimes referred to as cross-sectional planes. Imagine cutting straight across your stomach and being able to look at the upper or lower half of your body.
  - a. Superior (cranial)- A direction towards the head or upper end of the structure.
  - b. Inferior (caudal)- A direction away from the head end and towards the lower part of the structure.
  - c. Posterior (dorsal)- A direction towards the back or behind.
  - d. Anterior (ventral)- A direction towards the front or in front of something.
  - e. Medial- On the inner side or towards the center.
  - f. Lateral- On the outer side or away from the middle.
  - g. Proximal- Closer to the origin of the body part or the point of attachment.
  - h. Distal- Farther from the origin of the body part or point of attachment.

## View Orientation and Anatomical Planes



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6. The *dorsal body cavity* and the two subdivisions- The dorsal body cavity encases the organs that comprise the central nervous system, the brain and the spinal cord.
7. The *ventral body cavity* and the two major subdivisions- The two major subdivisions of the ventral body cavity are the thoracic cavity and the abdominopelvic cavity.
8. The *thoracic cavity* - The thoracic cavity contains the pleural cavities which encase the lungs and the medial mediastinum. The mediastinum encloses the thoracic organs as well as the pericardial cavity, which surrounds the heart.
9. The *diaphragm* - The diaphragm is a dome shaped muscle that is extremely important for breathing. It separates the thoracic cavity from the inferior abdominopelvic cavity.
10. The *abdominopelvic cavity* - The abdominopelvic cavity contains two parts. The superior abdominal cavity contains the stomach, liver, spleen and intestines, as well as related organs.
11. The *pelvic cavity* lies inferior and contains some reproductive organs, the bladder, and the rectum.

## **IV. THE NERVOUS SYSTEM**

### A. The basic functions of the nervous system-

1. The nervous system monitors information about changes inside and outside of the body. It perceives or senses the information about change and forms decisions.
2. It causes muscles, glands, organs, and additional portions of the nervous system to respond (monitor, interpret and command). The nervous system is the master control/coordinator system in the body. Control/coordination is accomplished through:
  - a. Monitoring changes inside and outside body sensory input
  - b. Integrating sensory input and determining output
  - c. Affecting responses (motor output)
3. The Nervous system partners with the endocrine system. Nervous system responses are quick and short lived, while endocrine responses are slower and longer lasting.

### B. The structural and functional divisions of the nervous system-

1. The nervous system can be broadly separated into two primary divisions, the central nervous system (CNS) and the peripheral nervous system (PNS).
2. The CNS consists of the brain and spinal cord and can be considered the command center of the body. The CNS receives information, interprets the information, and then commands actions based on the interpretation. The PNS can be thought of as the system that carries messages to and from the CNS.
3. *The subdivisions of the PNS -*
  - a. The PNS can be broken down into two subdivisions, one that carries information into the CNS (the sensory or afferent division) and one that carries the impulses away from the CNS (motor or efferent system).
    - i. Sensory fibers from all over the body, such as the eyes, ears, nose, mouth, skin, joints, internal organs, and muscles send impulses to the CNS via the afferent or sensory division of the PNS.
  - b. The motor or efferent division transmits commands from the CNS to all body parts, which are called effector organs, because nerve impulses affect them. Effector organs then respond to the commands of the CNS to perform functions the CNS has determined are necessary.
4. *The motor division of the PNS -*
  - a. The motor division can be thought of as having two major parts, the somatic nervous system and the autonomic nervous system (ANS).
  - b. The somatic nervous system is often called the voluntary nervous system because the nerve fibers control voluntary movement of skeletal muscles. For example, we use these

nerves to command our fingers to type on a computer keyboard, or to pick up a book to study.

- c. The ANS consists of nerves that regulate the activity of smooth muscles (like blood vessels, cardiac muscles, and glands). These activities are generally considered outside of our control and so this system is sometimes referred to as the involuntary nervous system. The ANS has two functional subdivisions, the sympathetic branch and the parasympathetic branch.

5. The historical view of the functional division of the ANS -

- a. The purpose of *sympathetic* branch of the autonomic nervous system has been thought to be related to mobilizing the body systems for stressful or emergency situations; the fight or flight response. The *parasympathetic* branch has been proposed to support conservation of energy, nonemergency functions, "resting and digesting," etc.
  - i These descriptions of function are often based on the seminal work of Walter Cannon in the first half of the 20th century. Cannon and others analyzed the function of the ANS in experimental animals and developed theories that drive our current conceptual approach to the ANS.
  - ii Cannon coined the phrase "homeostasis," which he used to describe the coordinated physiological processes that maintain a steady state within the organism. Cannon believed the sympathetic nervous system was primarily responsible for maintaining homeostasis. Cannon also believed the sympathetic nervous system acted broadly (all at once and hence the name sympathetic) to restore imbalances in homeostasis. He believed there was a widespread and diffuse output aimed at returning the body's internal state to the narrow band needed to support life.
  - iii In contrast, the parasympathetic branch functions were considered to be more discreet, having greater specificity. Cannon believed the effects of the sympathetic and parasympathetic nervous systems were generally opposite in the same organ and his ideas of an all or nothing sympathetic defense response and a specific restorative parasympathetic nervous system have influenced the conception of the functionality of the ANS.

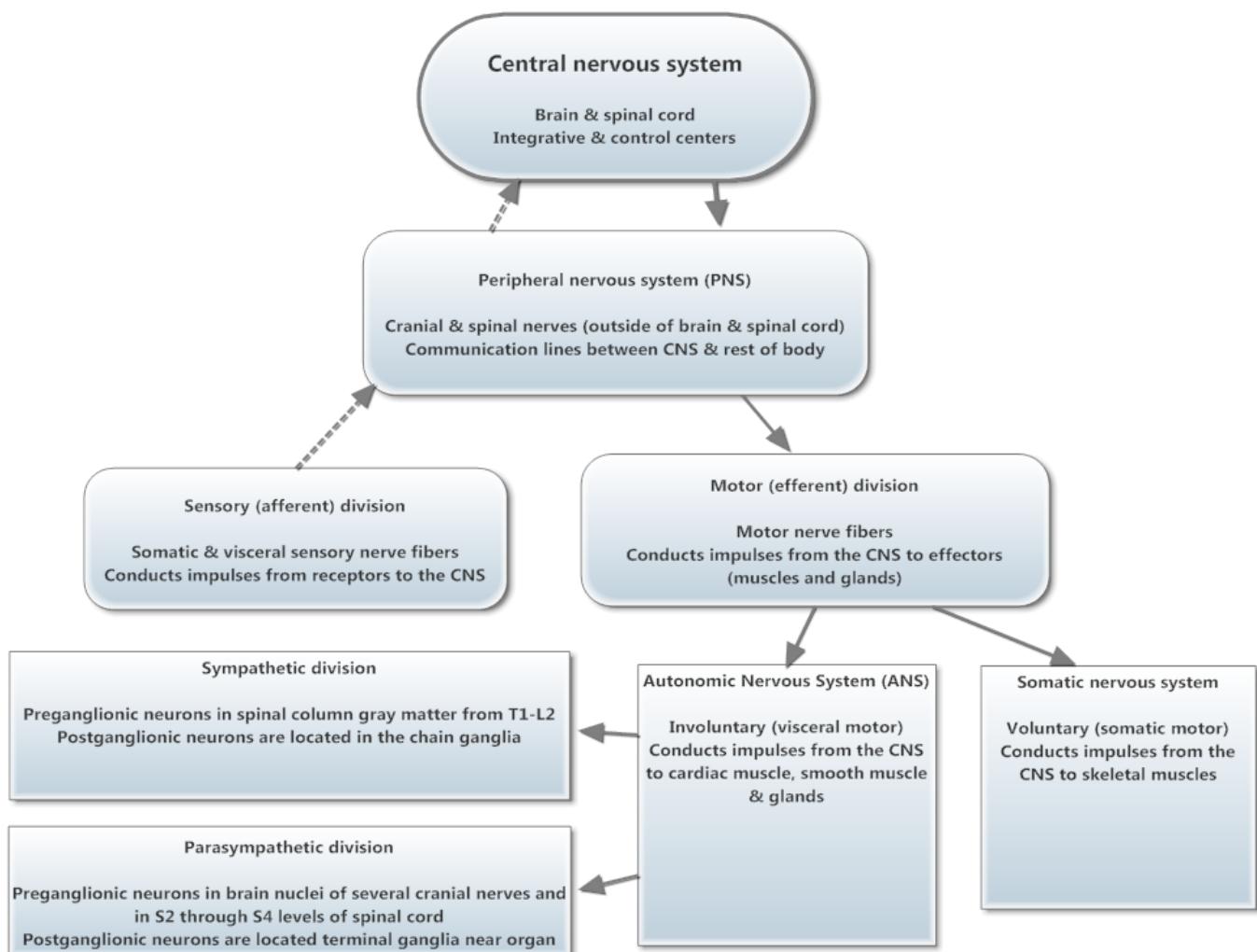
6. A *current* view of the functional division of the ANS -

- a. Wilfrid Janig, a modern physiologist, points to a number of inconsistencies in the historical functional separation of the divisions of the ANS. Janig makes a very convincing case for the idea that the separation between the sympathetic and parasympathetic branches of the ANS is anatomical as opposed to functional.
- b. The parasympathetic outflows are cranial (from the head area) and sacral (from the lower spine area) while the sympathetic branches originate in the thoracolumbar (from the thoracic and lumbar parts of the spinal column).
- c. Some organs are "dually innervated" meaning they are innervated by both branches of the ANS and these innervation actions are antagonistic. The end result however is a coordinated, and conceivably larger or more "fine-tuned" response. Dual innervation allows the CNS to activate both the sympathetic and parasympathetic branches of the ANS, which c

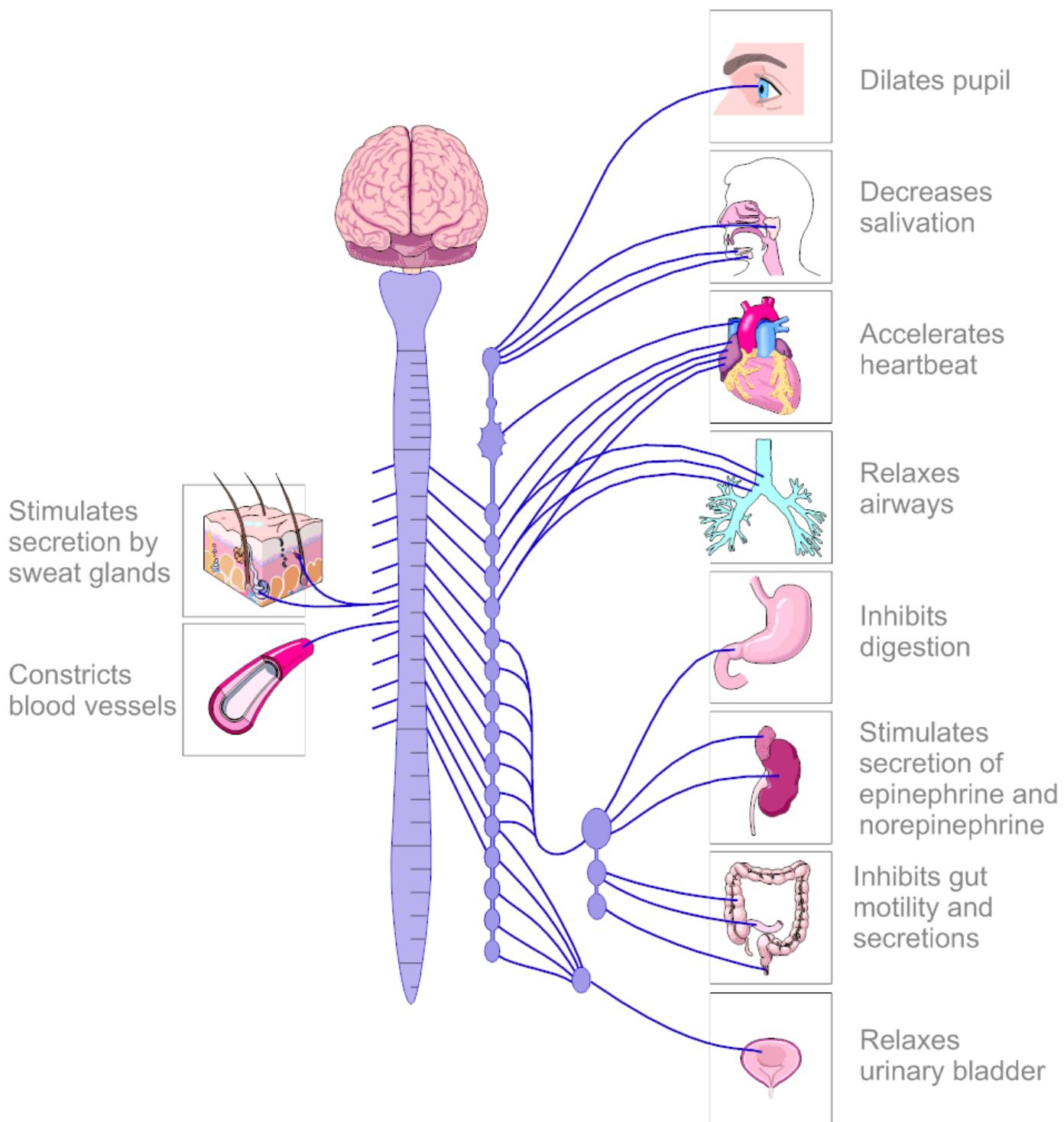
an act synergistically to improve the response. Heart rate is an example. Parasympathetic activation may result in slowing the heart while sympathetic innervation will speed the heart. A coordinated (integrative) action comprised of a reduction of parasympathetic innervation and increase in sympathetic innervation can result in a potentially greater and faster response.

- d. Janig points out that modern evidence more strongly supports a theory of integrative actions of the ANS, as opposed to a simple all or nothing action of one branch or the other.
- e. Berntson and Cacioppo have also questioned the historical doctrine of the two branches being functionally opposing systems. They point out that both branches can have similar effects on certain organs. They have shown that in some cases, one system activates at certain times, while the other system activates at other times. For example, at higher blood pressures, heart rate is controlled primarily by vagal (parasympathetic) activity, while at lower blood pressures, by sympathetic activity.
  - i. Berntson and Cacioppo proposed a multidimensional model of autonomic regulation to account for conditions where the two systems are not reciprocal, but instead uncoupled (not acting at the same time) or coactive.

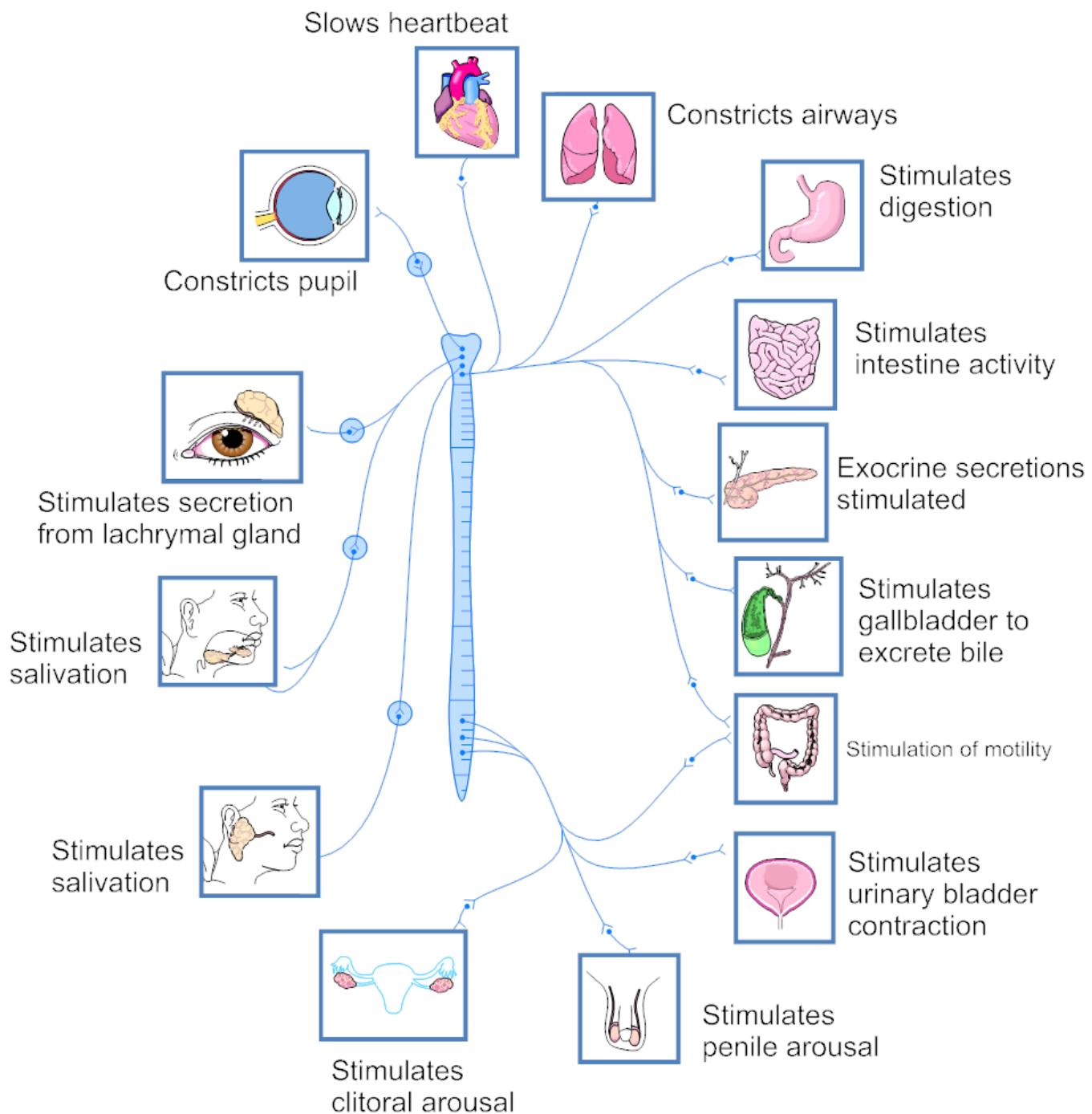
## 7. A general outline of the nervous system



8. Organs innervated by the sympathetic nervous system.

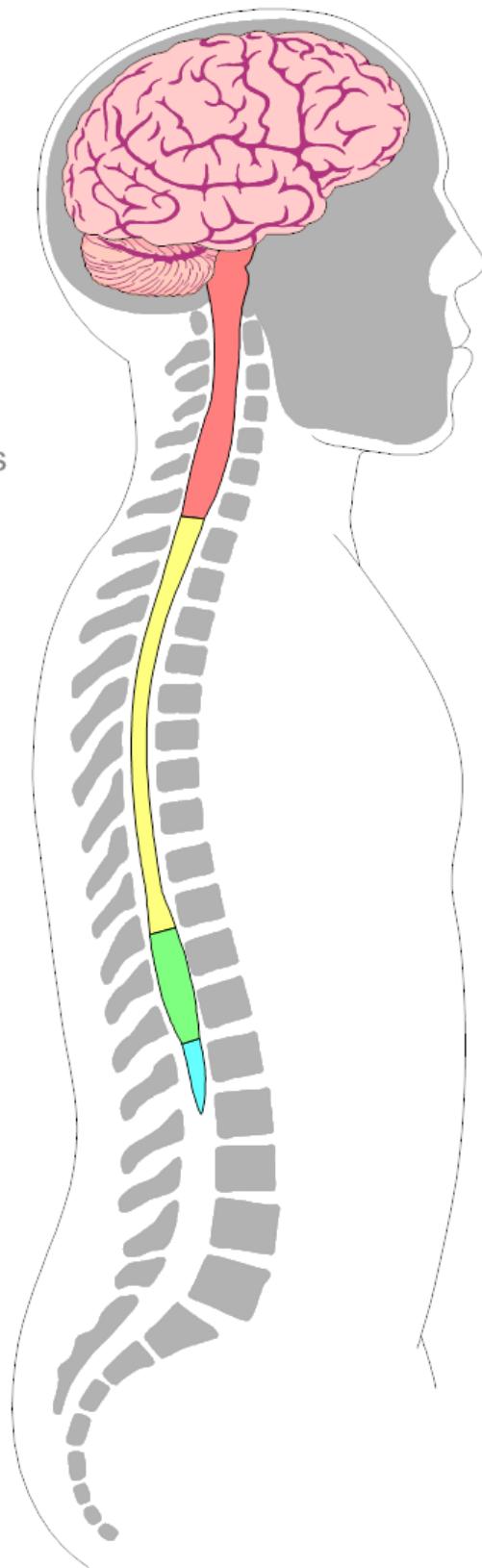


9. Organs innervated by the parasympathetic nervous system.



10. The location of the CNS-

Lateral view of figure showing central nervous system and its associated encasing skeletal structure.



## 11. The two principle types of nervous cells

- a. Nervous system tissue can be essentially divided into two main types of cells: neurons, the nerve cells that transmit signals, and neuroglia or supporting cells that surround, assist, and support the neurons.
- b. Some of the functions of neuroglia- Neuroglia or "glial" are support cells that make up about 85-90% of all brain cells. There are five main different types of neuroglia cells.
- c. In the CNS there are four different "glial" cells; astrocytes, microglia, ependymal, and oligodendrocytes.
- d. The glial cells of the PNS are Schwann cells. All glial have unique functions but one important purpose is to provide support for neurons by keeping them separate from one another. Also, some glial cells improve communication between cells by wrapping themselves around a portion of the neuron, thus insulating it. This results in faster conduction, much the same as wrapping a leaking garden hose with duct tape moves the water faster from one end of the hose to the other by reducing leakage.

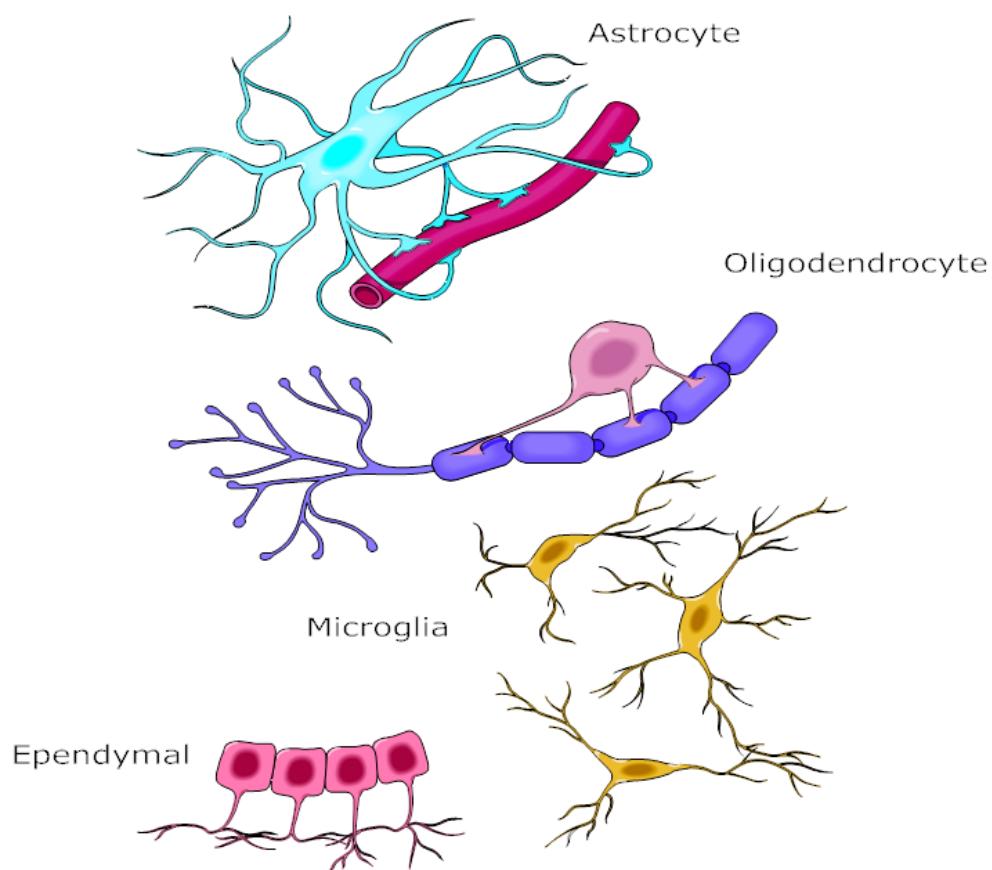
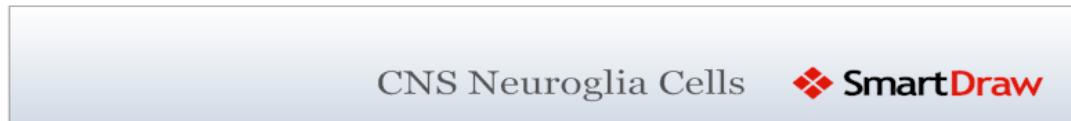


Image showing the four types of CNS neuroglia cells.

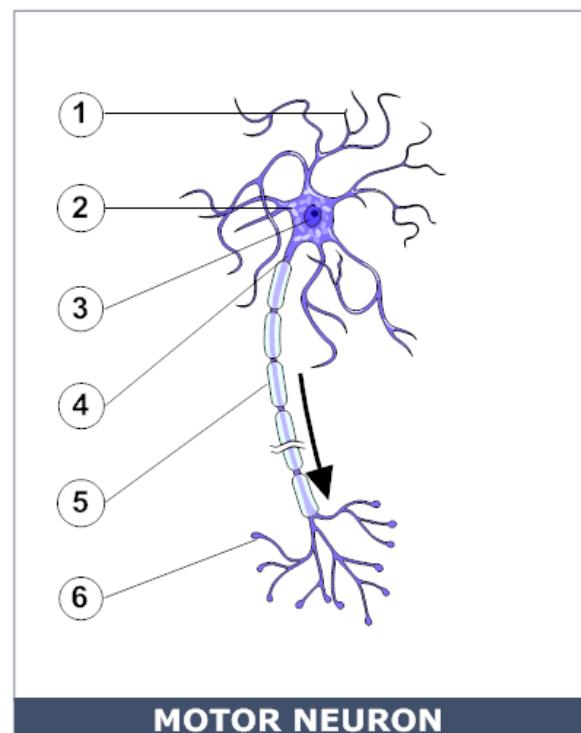
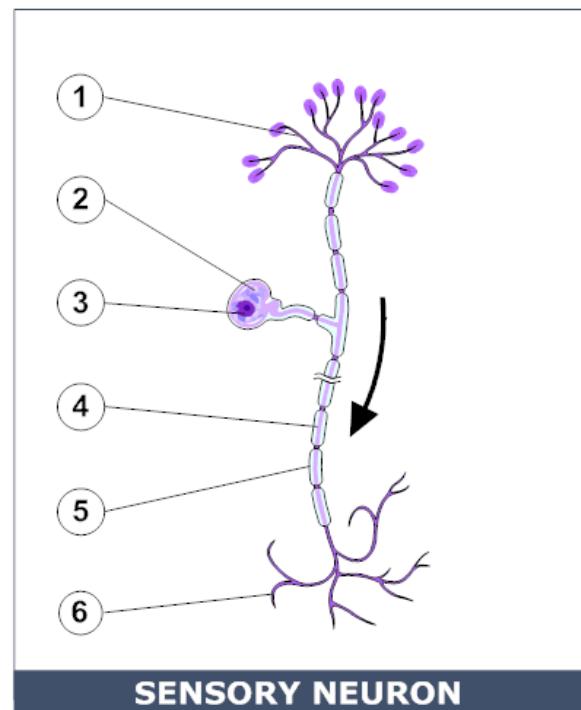
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12. The basic parts of the neuron and a description of their purposes-

- a. Cell body- The cell body (or soma) contains the *nucleus* and other organelles involved in the biosynthetic activities to support cell life and function.
- b. Dendrites- The dendrites comprise the main input or receptive areas of the cell. They receive incoming information from numerous sources and convey this information on towards the cell body.
- c. Axons- Each neuron has a single axon that projects from a part of the neuron called the axon hillock. Once the axon leaves the axon hillock, it narrows to a relatively uniform diameter for the remainder of its length. Axons can range in length from non-existent to several feet. Axons are usually a single process for most of their length, though they can have branches or collaterals. At the end of axons, there are numerous (thousands) of terminal branches called axon terminals. Axons are the conducting component of the neuron during its communication with other neurons. Axons transmit nerve impulses away from the cell body to the axon terminals.
- d. Axon Terminals- Axon terminals are the knob-line bulbs at the terminal end of the axon. They contain the secretory component of the neuron. Upon reaching the terminals, an impulse causes chemicals (neurotransmitter) stored there to be released from the axon terminals. These neurotransmitters interact with adjacent cells and can cause those cells to become excited or inhibited.
- e. Myelin- Myelin is a white colored, fatty tissue that covers some axons. Myelin protects the axon and insulates the axon from others. Myelinated fibers are able to conduct nerve impulses faster than those that are unmyelinated.
  - i. Myelin in the PNS is composed of Schwann cells and myelin in the CNS is composed of oligodendrocytes. In the PNS, Schwann cells wrap around the axon but leave small gaps called Nodes of Ranvier. These gaps occur at regular intervals along the axon because of the size of the Schwann cell providing the myelination. The gaps contribute to the increased speed of conduction.

## 13. Major parts of the sensory or motor “model neuron”

### NERVOUS SYSTEM Types of Neurons



#### 1. DENDRITE/RECEPTOR...

a slender, branched projection of a neuron, which conducts the electrical stimulation received from other cells to and from the cell body, or soma, of the neuron from which it projects.

#### 2. CELL BODY (SOMA)...

the bulbous end of a neuron, containing the nucleus and is where most protein synthesis occurs.

#### 3. NUCLEUS...

controls chemical reactions within the cytoplasm and stores information needed for cellular division.

#### 4. AXON...

a long slender projection of a neuron which conducts electrical impulses away from the neuron's cell body.

#### 5. MYELIN SHEATH...

an electrically insulating phospholipid layer that surrounds the axons of many neurons, composed of about 80% lipid fat and about 20% protein. It helps prevent the electrical current from leaving the axon and causing a short circuit in the brain.

#### 6. AXON TERMINAL...

a specialized structure at the end of the axon that is used to release neurotransmitter and communicate with target neurons.



**KMG** Kurtsdale Medical Group

14. *Action potentials*- An action potential is the conductance of an electrical impulse along the length of an axon. The way most excitable neurons communicate is through action potentials.
- Recall our discussion about cells. The cell membrane has a potential (voltage difference) across it like a battery. This negative membrane potential (more negative inside the cell membrane compared to the outside of the cell membrane) results from the ion concentration. An action potential results in a brief (a couple of milliseconds or thousandths of a second) depolarization of the membrane and this continues along the axon until it reaches the terminals where the neurotransmitters are released.
  - Action potentials are not graded; they keep the same strength from start to finish. If a neuron is sufficiently stimulated, it can transmit an action potential or nerve impulse. The propagation of the action potential comes from opening gates on the axon that are sensitive to voltage changes and that allow certain ions to pass through because of the decrease in voltage.
  - Remember when we discussed sodium and potassium earlier and mentioned they were ions involved in neuronal communication. Changes in voltage open and close gates along the axon that allows ions to enter or leave. This lowers the voltage of the adjacent section of the axon and gates open and close there allowing more ion movement and this decreases the voltage of the next adjacent part of the axon. This "chain reaction" of depolarization and opening of gates allows a current to move down the axon to the axon terminals where it ultimately results in the release of the neurotransmitter from the terminal bulbs.
15. The two types of *gated membrane ion channels*- Plasma or cell membranes contain two basic types of gated ion channels: *chemically gated* and *voltage gated*. The term gated is used to describe the idea that there is a gate in the membrane that is open or closed.
- Chemically gated or neurotransmitter gated channels open or close when the appropriate neurotransmitter binds there. It can be visualized as a locked open or closed gate and only when the correct key (neurotransmitter) is used can the gate become unlocked and then change from opened to closed or visa-versa.
  - Likewise, voltage gated ion channels open or close based on membrane potential.
    - Each ion channel is generally selective for just which ion or ions it will allow to pass when open. Once opened, ions pass very quickly through the gate based on the electrical charge and chemical or concentration gradient. Ions will move away from an area of similar charge towards an area of opposite charge which is along their electrical potential. Ions will flow from areas of higher to lower concentration, which is called the concentration gradient. Together the electrical and concentration gradients are referred to electrochemical gradients and they are what effect ion movement across open ion channels. Ions will tend to balance out based on the electrochemical gradients.
16. The action of neurotransmitters- Neurotransmitters are chemicals that neurons release that stimulate or inhibit other neurons or effector cells.

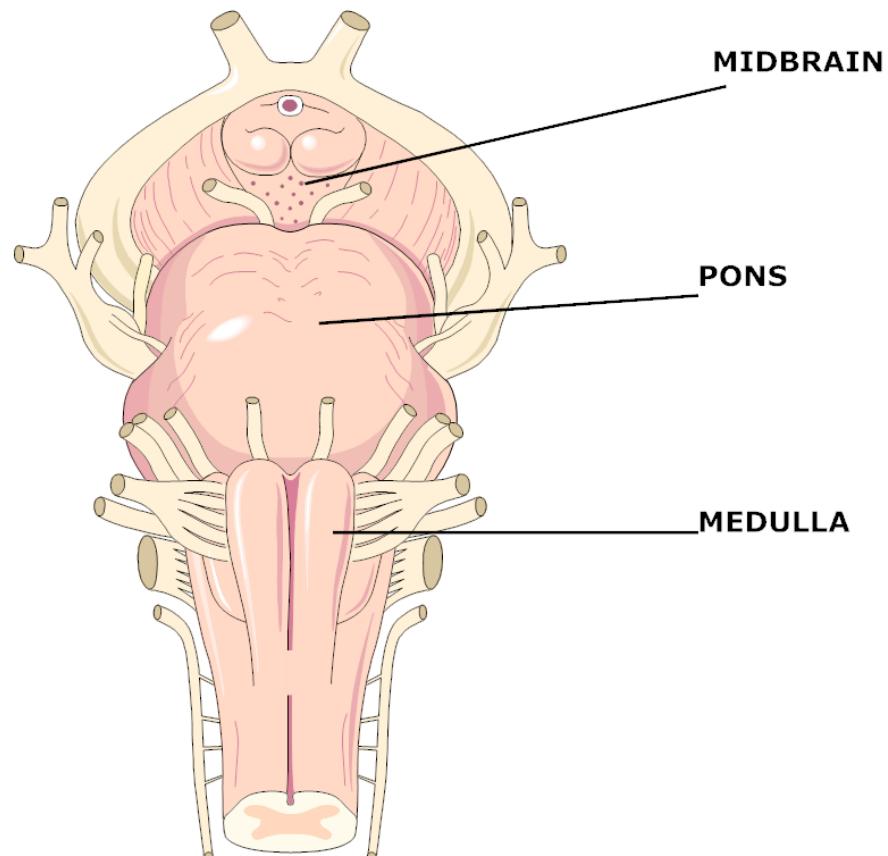
- a. Neurons use neurotransmitters and their electrical signals to communicate with other cells (neurons, glands, and muscle). The cell releasing the neurotransmitter is called the pre-synaptic cell and the cell upon which it acts is called the postsynaptic neuron.
  - b. The neurotransmitter is released into a small fluid filled gap between the neuron and the effector cell which is called the synaptic cleft. This functional space or point of close contact between two neurons or between a neuron and an effector cell is called the synapse. Some neurons release only one neurotransmitter at a synapse but most make and/or release more than one neurotransmitter. Some of the neurotransmitters we will discuss are;
    - i. Acetylcholine (ACh)- This was the first neurotransmitter to be identified and probably the most studied. ACh is released at neuromuscular junctions, which are where neurons synapse with muscle cells for movement. In the ANS, ACh is the presynaptic neurotransmitter for all preganglionic neurons both sympathetic and parasympathetic. ACh is the postsynaptic neurotransmitter for all parasympathetic postganglionic fibers. It is also the neurotransmitter for postganglionic fibers for the eccrine sweat glands which are a member of the sympathetic nervous system and are responsible for the electrodermal activity measured in polygraph.
    - ii. Norepinephrine (NE) - An excitatory or inhibitory neurotransmitter, depending on the receptor. NE is found in the CNS and the PNS. In the PNS, NE is the main post-ganglionic cells of the sympathetic nervous system.
    - iii. GABA- This is the principle CNS inhibitory neurotransmitter in the brain. Alcohol and antianxiety drugs of the benzodiazepam class enhance GABAs effect. GABA manifests its inhibitory effect on cells by opening chloride channels and allowing extra negatively charged chloride to enter the cell. This extra negative charge hyperpolarizes the cell, bringing it further away from threshold and making it harder for the cell to fire and initiate an action potential. It tends to make the cells less active.
    - iv. Glutamate- This is a principle excitatory CNS neurotransmitter in the brain. Glutamate is very important for learning and memory because of its action in the medial temporal lobe of the brain. A little goes a long way, however, as excess glutamate leads to excitotoxicity. This occurs when neurons literally excite themselves to death, and is common during strokes. Some medical treatments for stroke now include drugs to combat the excessive glutamate released during strokes to prevent cell death in the brain.
17. The *spinal cord*- This bundle of nervous tissue runs from the base of the brain stem to some where between the first to the third lumbar region and it provides the afferent (to the brain) and efferent (away from the brain) conductance pathways.
- a. The spinal cord is composed of "white matter" and "gray matter." The gray matter consists mostly of neuron cell bodies and neuroglia, and is shaped like a butterfly or the letter H. The gray matter can be divided into a dorsal half (in the back) which is generally the sensory input and a ventral half (in the front), which is generally the motor output.
  - b. The sensory afferent fibers enter through the dorsal half where they connect to the sensory cell bodies in an area known as the dorsal root ganglion. The cell bodies for the motor

output mostly lie in an area called the ventral horn, sending their fibers out through the ventral roots.

- c. White matter in the spinal cord is composed of nerve fibers, both myelinated and unmyelinated. There are fibers that ascend to the brain, carrying sensory input, and fibers that descend for motor output. Additionally, there are fibers that cross from one side of the spinal cord to the other called transverse or commissural fibers. The white matter is the communication transport section of the spinal cord, much like phone lines for telecommunication.

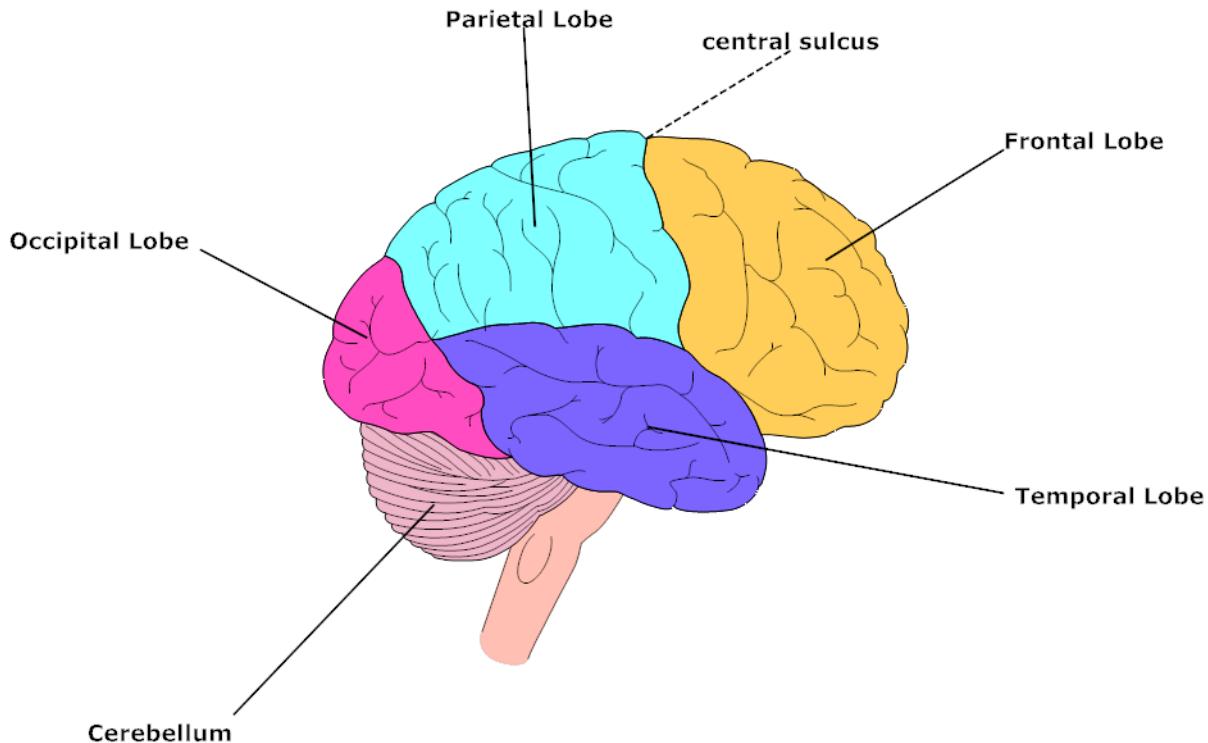
18. The brain stem- Working from an inferior to superior direction, the brain stem is comprised of the medulla oblongata, pons, and midbrain.

- a. The brain stem contains many important nuclear groups that result in the automatic behavior programs necessary for survival. The brainstem provides a pathway for fiber tracts running between the higher and lower brain center.



Anterior view of the brainstem. Midbrain (mesencephalon), pons, medulla oblongata and spinal cord are visible.

19. The functions provided by the *cerebellum*- The cerebellum is a large structure located dorsal to the pons and medulla. It processes inputs from the cortical areas responsible for motor actions, sensory receptors, and brain stem inputs. The cerebellum is concerned with coordination of movements.
20. The *lobes* of the human brain- The hemispheres of the brain are subdivided into five major lobes on the basis of some of the major grooves.
- The *frontal lobe* consists of the area in front of what is known as the central sulcus and is the largest of all lobes. It contains important motor and language related areas in posterior part and many functions related to social behavior and higher mental activities towards the frontal part.
  - The *parietal lobe* is located parallel to the central sulcus and contains much of the somatosensory related cortex.
  - The *occipital lobe* is primarily related to visual functions and is located at the back of the brain.
  - The *temporal lobe* contains many different regions including sensory areas for auditory and olfactory functions. This lobe contains two very important structures related to memory and emotion called the amygdala and the hippocampus.



Lateral view of the brain with the different lobes depicted with color.

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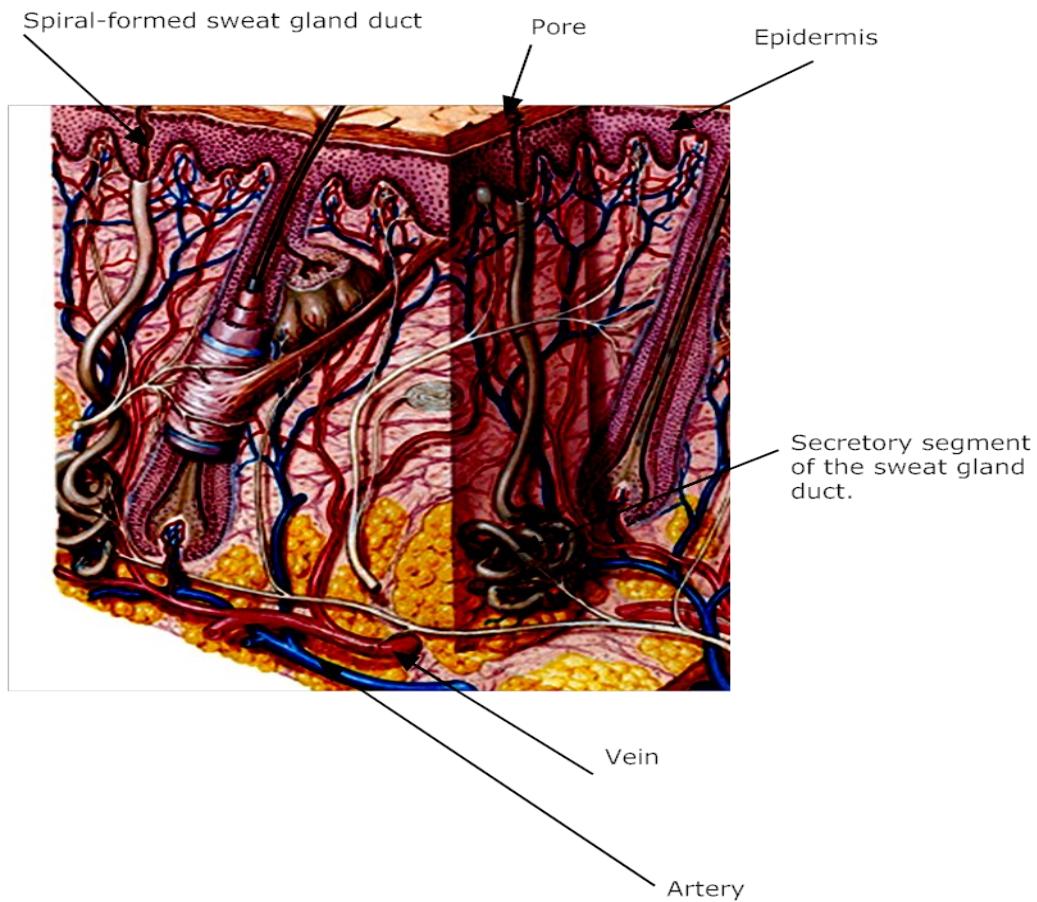
21. The *diencephalon* and some functions - The diencephalon forms the central portion of the forebrain and consist of the thalamus, the hypothalamus, and the epithalamus.
- The thalamus is the largest part of the diencephalon and contains about fifty smaller nuclei which each have their own functional specialty. Thalamus is a Greek word meaning "inner room." It receives virtually all inputs to the brain including sensory, emotional, and motor related input. The only sensory input that bypasses the thalamus is the olfactory system. The *Thalamus* plays a key role in integrating and mediating motor activity, sensation, cortical arousal, learning, and memory. The thalamus is the means by which almost all information gets to the cortex to be processed.
  - The hypothalamus is named for its position directly below the thalamus (hypo means lower). In spite of its small size, the *hypothalamus* is the grand conductor of homeostatic control of the body. Hypothalamus is part of the autonomic control center, the emotional response control center, and directs life supporting behaviors such as food and water intake and sleep. The hypothalamus controls the release of hormones from the endocrine system which also helps maintain homeostatic balance of the body.
  - The *epithalamus* consists of the pineal gland, which helps regulate sleep, and the choroid plexus, which manufactures cerebrospinal fluid.
22. Psychophysiology concepts relating to the CNS. The concept of the "*limbic system*" from a historical, anatomical, and present day perspective-
- Around 1939, an American anatomist named James Papez proposed that the central parts of the brain including the hypothalamus, parts of thalamus, the cingulate gyrus, the hippocampus, and their interconnections, form a "harmonious mechanism" by which all emotion is generated, and from which emotional expressions result. Following Papez' proposal, the size and structures attributed to this "limbic system" have expanded to include a substantial portion of the brain. Modern neuroscientists seem to agree there is no scientific justification for a "limbic system." Many of the so-called limbic structures have multiple purposes that go beyond emotion. Indeed, some do contribute to generation and expression of emotion, but this poorly reasoned association does not justify a specific "system" of the brain dedicated solely to emotion.

## V. EDA AND THE INTEGUMENTARY SYSTEM-

### A. The Integumentary System

- The skin consists of a complex set of organs called the integumentary system, which serves a protective function. We will limit our discussion of skin to predominately those aspects related to understanding the mechanisms of electrodermal activity (EDA).
  - Skin protects the body from environmental threats such as temperature, chemical, mechanical, and infectious microorganisms.

- b. From a sensory standpoint, skin houses various receptors to provide afferent information related to touch, pain, and temperature.
  - c. Skin participates in perspiration, which keeps the skin moist and allows the body to excrete fluids. Skin can be hairy or glabrous (hairless).
2. A typical cross section of the skin and some of the important features-
- a. Skin is composed of various characteristic layers, though all layers are not uniformly found in all skin. Skin essentially consists of two main layers; an outer layer called the epidermis, and a thicker lower layer, the dermis.
  - b. The epidermis is composed of five layers with each layer becoming progressively hornier (tough and calloused). The outer layer of the epidermis is the stratum corneum. The epidermis, the layering most important to EDA, consists of regularly arranged cells that become drier as they move towards the stratum corneum. The glabrous skin found on the palms (palmer) and soles of the feet (plantar) has a thick epidermis and also a relatively thick stratum corneum. The stratum corneum has a very important role in producing the EDA we measure in polygraph.



3. The action of sweating of the eccrine sweat glands-
  - a. Sweat glands secrete directly onto the skin surface. The greatest density of sweat glands is found on the forehead, the palms, and the soles.
  - b. The sweat glands of the palm are considered eccrine sweat glands, which means the secretions do not contain something called cytoplasm.
  - c. The sweat glands can be subdivided into the secretory portion and the duct. The secretory section is located deep within the skin and is comprised of an irregularly coiled duct. The duct extends from the secretory section to the sweat gland pore opening on the surface of the skin.
  - d. Efferent fibers from the sympathetic nervous system innervate the eccrine sweat glands. These are referred to as sudoriparatory fibers. The sudoriparatory fibers use acetylcholine to innervate the secretory part of the sweat gland.
  - e. The hypothalamus is generally regarded as the controlling center for all ANS function including sweat gland innervation. Hypothalamic sympathetic activity can be elicited by a number of brain structures, not the least of which includes the cerebral cortex. A variety of mental functions have been found to demonstrate the ability to activate the eccrine sweat glands and cause an EDA reaction.
4. A mechanism of sweating and how that contributes to EDA-
  - a. Human sweat contains a certain amount of sodium and chloride ions. The precursor of sweat in humans has a considerably higher concentration of both. As sweat makes its way up through the duct, it loses some of the sodium and chloride ions. This is the theory behind NaCl reabsorption, that reabsorption may prevent excessive loss of NaCl. Sweat does not continuously flow out of the sweat duct but rather is ejected in pulses. Rhythmic contractions of the secretory and sweat duct portions are thought to be the source of pulses that are suspected of being the force that drives sweat up and out of the ducts.
5. "*Emotional sweating*"- Increased sweating as a result of mental activity, especially during emotional arousal, is referred to as "emotional sweating." Emotional sweating occurs primarily on the glabrous skin on the palmar and plantar surfaces of the body and is likely activated via the hypothalamus. EDA reactions during polygraph testing can be a result of emotional sweating.
6. Some of the putative CNS origins of EDA-
  - a. EDA can be elicited by higher level CNS processes (cortical) but can also come from structures considered to be subcortical. The hypothalamus seems to be one of the primary initiators of EDA reactions from an emotional standpoint. A part of the brain called the basal ganglia may contribute to EDA responses in preparation for motor actions.
7. Some of the suggested biological roles of EDA-

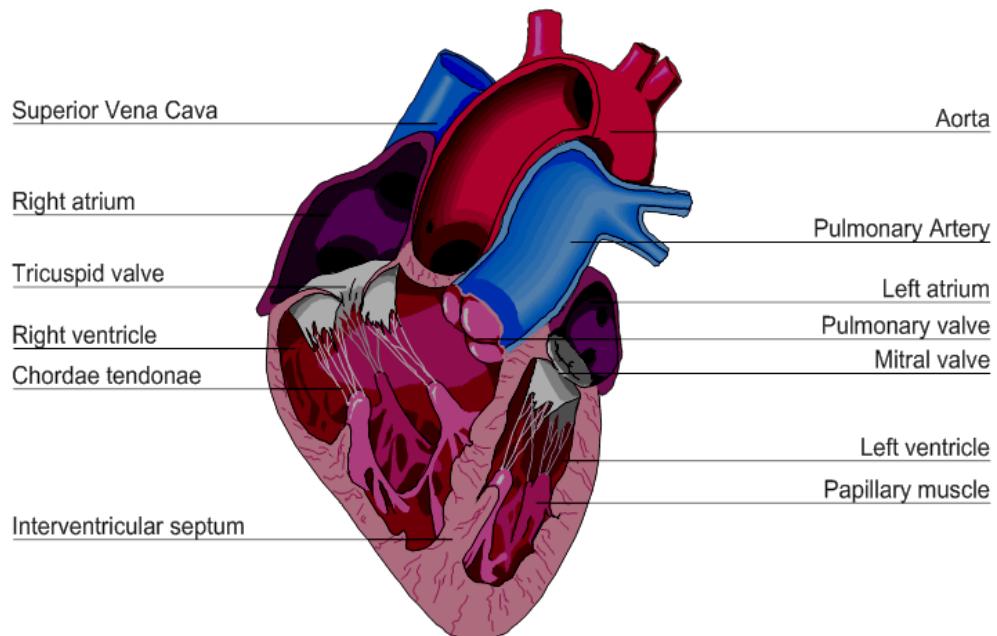
- a. Sweating may be a biologically adaptive function that serves a number of purposes. Hydration provides optimal friction and tactile sensitivity. One is able to feel and grip better when their hands are slightly moist. Footing is arguably better when the feet are slightly moist or tacky. Skin is also less likely to sustain injury when slightly moist.
- b. Skin is more resistant to abrasion and cutting when moist than when dry.

## VI. THE CARDIOVASCULAR SYSTEM

### A. The chambers of the heart-

1. The heart has four chambers, two ventricles and two atria. The ventricles are the discharge chambers and discharge blood to the body (left ventricle) or to the lungs (right ventricle). The atria are the receiving chambers for blood returning from the body (right atria) or the lungs (left atria).

### Parts of the Internal Heart

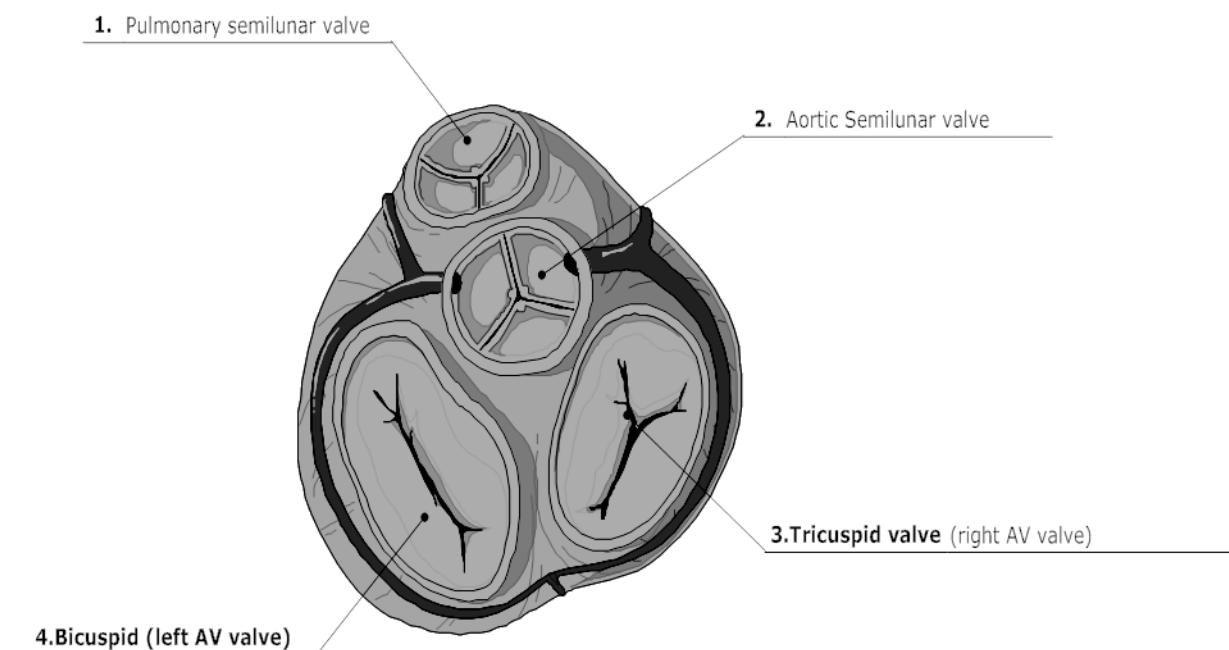


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B. The major heart valves-

1. There are two atrioventricular (AV) valves, one on each side of the heart, which separate the atria from the ventricle, preventing back flow.
2. The right AV valve is called the tricuspid valve because it has three flexible cusps or flaps. The left AV valve is called the bicuspid valve because it has only two cusps or flaps.
  - a) The bicuspid valve is sometimes referred to as the mitral valve as it is said to resemble a miter, the hat worn by a bishop.
3. There are two semilunar valves (SL), one at the discharge site of each ventricle. The SL valves guard against backflow by flattening out and slamming shut when pressure is higher on the discharge side.
  - a) SL valves are so named because of their three crescent moon shaped cusps.

### Heart Valves

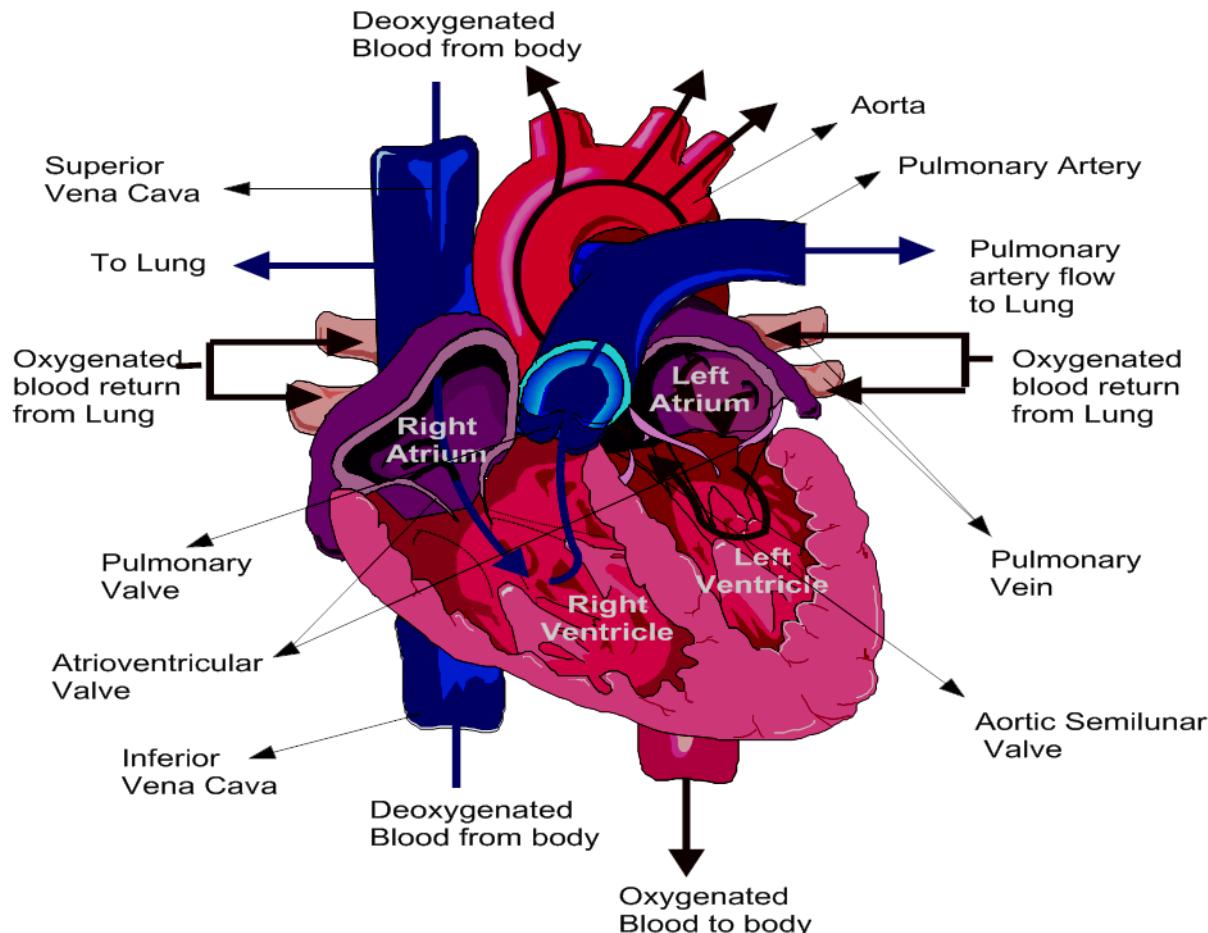


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C. The pathway of blood flow through the heart-

1. The right side of the heart is the *pulmonary circuit* which directs carbon dioxide rich blood to the lungs. Returning blood enters and fills the right atria. The right atria contracts, forcing blood through the tricuspid valve and into the right ventricle. The right ventricle compresses, sending blood out the pulmonary semilunar valve to the lungs via the pulmonary arteries. It is here that carbon dioxide is exchanged for oxygen.

2. The left side of the heart is the *systemic circuit pump*. It is responsible for transportation of blood through the cardiovascular system. The freshly oxygenated blood is returned to the left atria of the heart via the pulmonary veins. The left atria contracts and directs blood through the bicuspid or mitral valve to the left ventricle, which pumps blood out of the aortic semilunar valve into the aorta.



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#### D. The purpose of the *cardiovascular system*-

1. The cardiovascular system is a completely closed structure consisting of the heart muscle, arteries, capillaries, and veins. A primary purpose of the cardiovascular system is to transport nutrients and oxygen to body tissues and remove metabolic wastes and carbon dioxide from the body tissues.

#### E. *Blood pressure* and how is it measured-

1. Blood pressure is a measurement of force per unit of area exerted on a blood vessel wall. It is typically expressed in units of millimeters of mercury, written "mmHg." Blood pressure is usually expressed medically in terms of systolic pressure over diastolic pressure.

2. In polygraph testing, the cardiograph waveform depicts changes in relative blood pressure throughout the examination. For the sake of our paper, when we discuss blood pressure, we refer to systemic blood pressure as measured at the monitoring site, unless otherwise stated.

F. *Peripheral resistance-*

1. Blood flow occurs within the body's closed circulatory system and is normally expressed in milliliters per minute, written as "ml/min." Peripheral resistance is a term used to describe the overall restriction to blood flow within the blood vessels and it is a function of blood viscosity, vessel length, and vessel diameter. Thicker blood, longer vessels, or smaller diameter vessels each increase resistance to flow.

G. How cardiac output and peripheral resistance effect blood pressure-

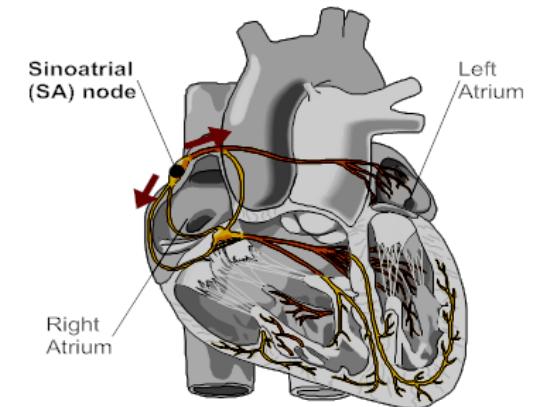
1. Blood pressure is determined by cardiac output and peripheral resistance. Cardiac output is the amount of blood the heart is pumping for a given time period. Cardiac output is a function of stroke volume times the number of beats per minute.
2. Stroke volume is how much the heart pumps (ml/beat) and is a function of how hard the heart beats (contractile force) and how much blood is available to pump (end diastolic volume, or EDV).
3. EDV is the volume of blood in a ventricle at the end of filling. The greater the EDV, the greater the distention (stretching) of the ventricle. An increase in EDV increases the preload on the heart. It increases the amount of blood ejected from the ventricle, during systole, through the Frank-Starling mechanism. EDV is generally controlled by venous return or the blood returned to the venae cavae prior to being delivered to the right atrium.
4. Additionally, a physiologist named Bainbridge observed that right atrial distention produced an increase in heart rate. Bainbridge found the reflex arc responsible for this tachycardia was mediated through an increase in sympathetic effect and a decrease in parasympathetic effect.
5. There are two primary factors that increase venous return: the respiratory pump and the muscular pump. The respiratory pump describes pressure changes in the venae cavae that result from breathing. As we inhale, chest pressure decreases, negative pressure is generated, and blood is "sucked" back towards the heart. The greater the depth or length of inhalation, the greater the amount of negative pressure influence created for venous return. The muscular pump describes the manner in which the skeletal muscle contraction presses against veins to force blood back towards the heart.
6. Peripheral resistance affects blood pressure by increasing or decreasing the pressure against which the heart pumps. The greater the overall vasoconstriction, the greater the pressure. As vasodilation occurs, blood pressure decreases.
7. In summary, there are several factors affecting blood pressure. Cardiac output increases by accelerating the heart rate, contractile force, or end diastolic volume. Altering the di

diameter of the blood vessel increases or decreases peripheral resistance to flow. Any combination of these factors can result in a rise in blood pressure.

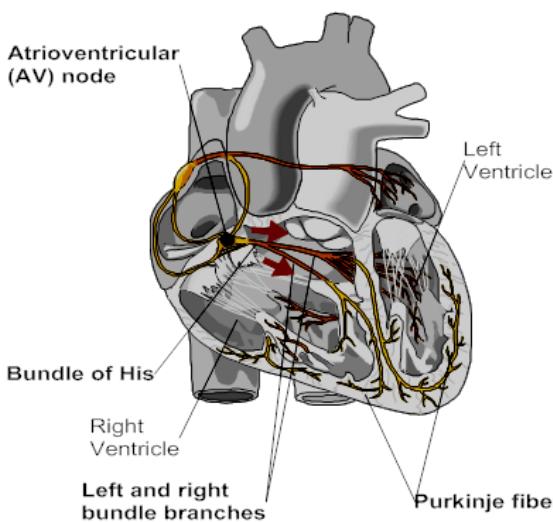
H. The *electrical conduction system* through the heart-

1. The heart is able to contract (beat) without influence from outside nervous systems. There is, however, a great deal of neural input to the heart, which coordinates the heart's activities with that of other systems that support life.
2. Electrical conduction begins at the sinoatrial (SA) node in the right atria, which intrinsically generates impulses at the rate of about 75 times per minute. This small mass is known as the "pacemaker," as it sets the cadence that is known as sinus rhythm.
3. From the SA node, the signal is sent through intermodal fibers into both atrial muscle walls, and then into the atrioventricular node located near the tricuspid valve. This node holds the signal for a moment, allowing the atria to fully contract before it passes the signal on.
4. From the AV node, the signal progresses to the atrioventricular (AV) bundle, which is located in the upper portion of the septum that separates the ventricles. This is sometimes called the bundle of HIS, named after its discoverer.
5. From the bundle of HIS, the signal splits into the right and left bundle branches as they progress down the septum. The right and left bundle branches send the impulses to the Purkinje fibers that are located in the ventricles. The left ventricle has a thicker muscular wall due to greater pressure requirements needed to pump blood through the increased resistance of the entire body than the right ventricle has pumping just to the lungs.

## Electrical Conduction System of the Heart (cardiac conduction system)



The heart's electrical system controls all the events that occur when your heart pumps blood. Each beat of your heart begins with an electrical signal from the sinoatrial node, called SA node.



The signal is generated as the two vena cavae fill your heart's right atrium with blood from other parts of your body. The signal spreads across the cells of your heart's right and left atria. This signal causes the atria to contract. This action pushes blood through the open valves from the atria into both ventricles.

The signal arrives at the AV node near the ventricles, where it slows for an instant to allow your heart's right and left ventricles to fill with blood. The signal is released and moves to the His bundle located in the walls of your heart's ventricles.

The signal is released and moves next to the bundle of His located in your heart's ventricles. From the bundle of His, the signal fibers divide into left and right bundle branches which run through your heart's septum.

The signal leaves the left and right bundle branches through the Purkinje fibers that connect directly to the cells in the walls of your heart's left and right ventricles. As the signal spreads across the cells of your heart's ventricle walls, both ventricles contract, but not at exactly the same moment. The left ventricle contracts an instant before the right ventricle. This pushes blood through the pulmonary valve (for the right ventricle) to your lungs, and through the aortic valve (for the left ventricle) to the rest of your body.

As the signal passes, the walls of the ventricles relax and await the next signal.

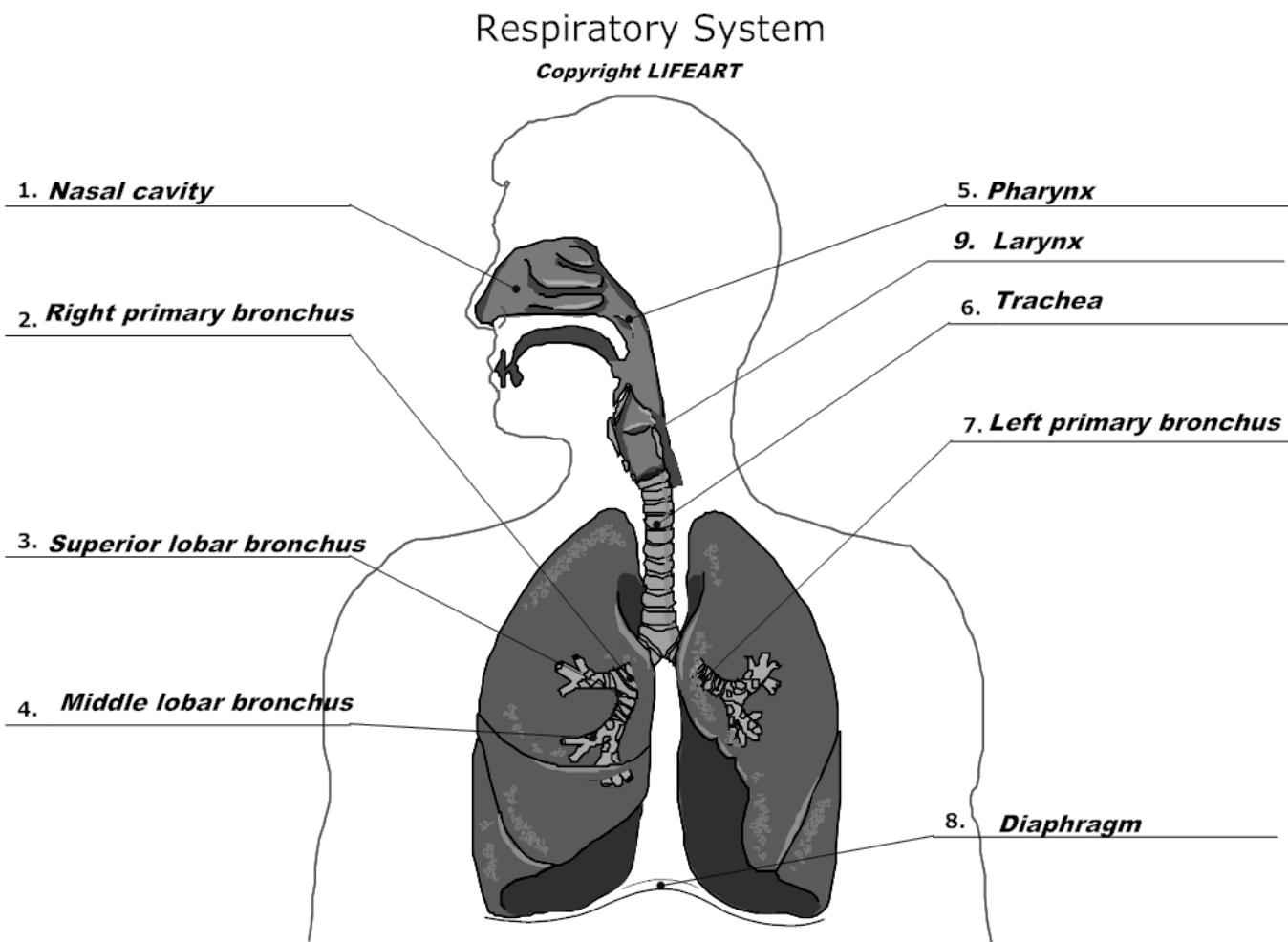
Source: National Heart Lung and Blood Institute, National Institutes of Health. nhlbi.nih.gov  
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## VII. THE RESPIRATORY SYSTEM

### A. The function of *respiration*-

1. The primary function of the respiratory system is to supply the cells of the body with oxygen, and to vacate the body of carbon dioxide.
2. Pulmonary ventilation (breathing) describes the collective actions that move air into and out of the lungs.
3. External respiration describes the exchange of oxygen for carbon dioxide in the alveoli, the microscopic air sacs in the lungs.

- Internal respiration describes the exchange of oxygen for carbon dioxide between blood and tissues.
- Cellular respiration describes the cellular metabolic reactions that consume oxygen to produce energy molecules and carbon dioxide.



#### B. Describe *breathing*-

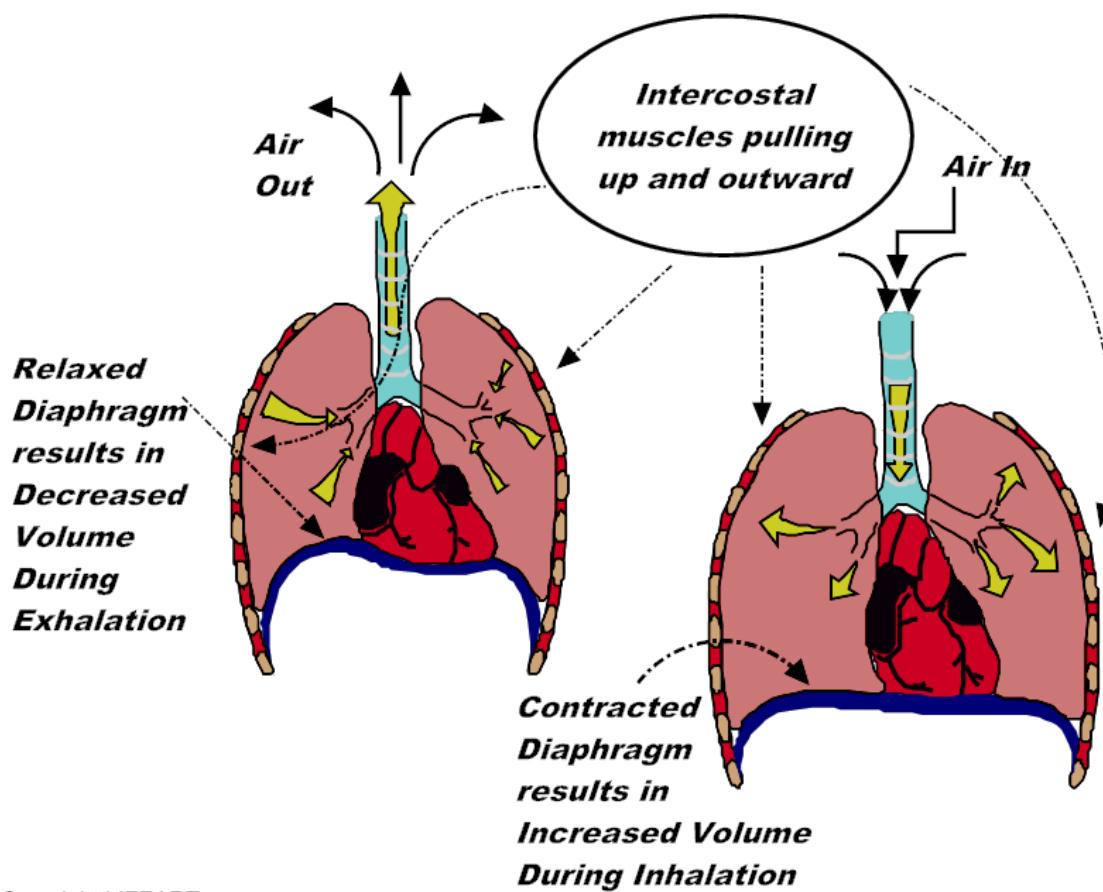
- Breathing involves moving air through the airway (dead air space) composed of the nasal cavity, pharynx, larynx, trachea, bronchi bronchial tree, then into the lungs.
- The airway, through which the air travels, warms, humidifies, and cleans the air before directing it to the lungs.
- The nasal passageway contains olfactory receptors which are unusual in that their input bypasses the thalamus and is sent directly to cortical and limbic system areas of the brain that stimulate memory.
- The pharynx connects the nasal cavity and mouth to the larynx.

5. The larynx is composed primarily of cartilage, vocal cords, and other connective tissue, and connects the pharynx to the trachea.
6. The trachea, composed of C shaped cartilaginous rings, is a flexible tube that connects the larynx to the bronchi.
7. The bronchi enter the lungs and branch out to form secondary and tertiary bronchi leading to terminal bronchioles and finally into alveoli air sacs.
8. Pulmonary capillaries surround the alveoli sacs providing the pathway for blood flow to and away from them. It is at this junction the exchange of oxygen for carbon dioxide takes place.

#### C. The mechanics of breathing-

1. The mechanics of breathing generates a pressure differential between the inside and outside of the lungs, causing air to move one direction or the other.
2. Air, as with fluids, moves from areas of higher pressure to lower pressure regions. Just before inspiration, the differential pressure between the inside and outside of the lungs (intrapulmonary pressure) is zero. At zero, there is no air movement.
3. The act of breathing causes the pressure inside of the lungs to be lower than that outside and thus air flows inward (Boyle's Law), similar to the concept of drawing a fluid up into a syringe. This negative intrapulmonary pressure is made possible by the expansion of the lungs resulting from the ventilation dynamics of the diaphragm and intercostal muscles.
4. The muscles of normal, quiet inspiration (eupnea) include the diaphragm and the external intercostals. The diaphragm is a large, domed shaped muscle that separates the abdominal cavity from the thoracic cavity. The diaphragm is attached to the sternum and is the muscle most responsible for eupneic breathing. During normal quiet breathing the diaphragm contracts, causing it to descend about one half inch into the abdominal cavity. This results in stretching the thoracic cavity downward, increasing its volume.
5. Simultaneously, contraction of the external intercostal muscles lift the rib cage and pull the sternum outward, like a handle on a bucket. The external intercostal muscles are innervated by nerves leaving the first through the eleventh thoracic segments of the spinal column.
6. The lungs are passive. They have no capacity to expand or contract on their own and are subject to external forces, much like a sponge absorbs and releases water. Each lung is encased by one continuous serous tissue folded over itself called the pleural membrane. The parietal pleura portion is attached to the outer wall of the thoracic cavity with the visceral pleura bonding directly to the lungs. This creates a small space between the two pleurae which is called the interpleural space, or pleural cavity. Both pleurae secrete a fluid into the cavity which reduces friction between them. Just prior to inspiration, the pressure within the pleural cavity is about 4mmHg below atmospheric pressure. This negative pressure between the pleura membranes keeps the lungs sucked to the chest wall

thus preventing them from collapsing inward. As the thoracic cavity expands, the lungs are pulled into an expanded mode, reducing the pressure in the alveoli (intrapulmonic pressure), resulting in air being pulled into the lungs.



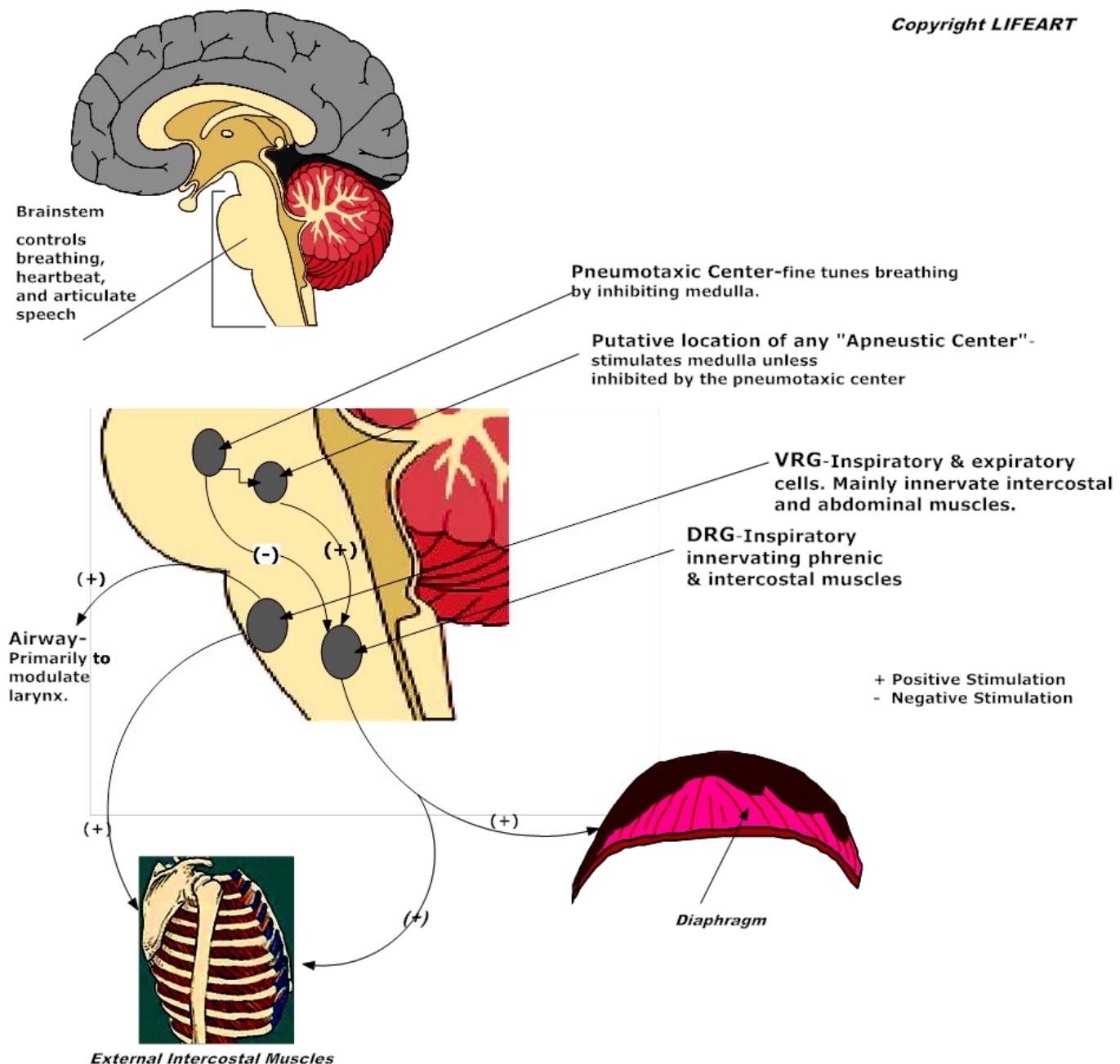
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7. The combination of the contractions of the diaphragmatic and intercostal muscles results in an action that increases the thoracic cavity by approximately 500 milliliters. This increase causes a drop of intrapulmonary pressure of about 1-2 mmHg and air rushes into the lungs.
8. Expiration during eupneic breathing is passive and is accomplished through the elastic nature of the lungs and relaxation of the inspiratory muscles. As the muscles relax and the lungs recoil, the volume of the thoracic cavity decreases and there is no longer a difference in pressure between the inside and outside of the lungs. Additionally, alveoli ducts and bronchioles have elastic fibers that recoil inward, expelling air. Finally, inward pull resulting from the surface tension of water vapor in the alveoli also contributes to lung volume decrease. The intrapulmonary pressure rises to about 1 mmHg above atmospheric pressure to force air out of the lungs.

#### D. The regulatory control of breathing-

1. Vegetative regulations of visceral body organs, including breathing dynamics, are controlled in part by nuclei and centers in the brain stem.

2. The respiratory rhythmicity centers are located in the lower brain stem, medulla oblongata, with refining regulatory centers in the pons.
3. In the medulla, the rhythmic respiratory center is comprised of two distinct respiratory areas known as the dorsal respiratory group (DRG) and the ventral respiratory group (VRG). The DRG neurons are the primary innervators of the phrenic nerve and thus the diaphragm muscle.
4. The VRG, a column of individual nuclei stacked upon one another, contains mostly expiratory neurons and receives drive input from the DRG. The VRG is also involved in innervating the larynx and pharynx via vagal motoneurons, which assists in maintaining airway patency. During inhalation, the VRG innervates the external intercostal muscles and has some connection to the phrenic nerve. Expiratory neurons, originating in the VRG, project to the internal intercostal muscles and abdominal muscles. These muscles, however, function mostly during intense and rapid exhalation, such as during exercise when passive exhalation would take too long.
5. Modulatory centers such as the pontine respiratory group (formerly called the pneumotaxic) and a putative “apneustic center,” located in upper area of the pons, appear to be associated with phase-related activity. If nuclei exist that form an apneustic center it seems they may function as a “cut off switch,” terminating inspiration. While this center has not been positively identified, it is presumed to be located at about the same level as the pontine respiratory group. Investigators who have experimentally transected the brain stem at this level have been able to produce apneusis (inspiratory spasms or cramps), but only if they also serve the vagus nerve. This suggests any “apneustic center” that exists receives input via the vagus nerves in order to prevent apneusis. While not well defined, the function of the respiratory related neurons in the pons seems to be to “fine tune” the action of eupneic respiration, helping to provide a smooth transition between inspiration and expiration. The ponto-medullary respiratory rhythmicity center, however, can be influenced by the emotional limbic system centers as well as the cognitive cerebral cortical areas.



General locations of central nervous system nuclei responsible for rhythmic regulatory control of breathing. DRG and VRG generalized location and effects on the diaphragm and intercostal muscles during eupneic breathing. Copyright LIFEART and reprinted with permission of LIFEART and SmartDraw, Inc.

#### E. The major reflexes that affect the breathing cycle-

1. A number of reflexive (automatic) actions can have an effect of the depth and rate of breathing.
2. Stretch receptors within the airways have the potential to influence the respiratory cycle. One such stretch receptor reflex, known as the Hering-Breuer inflation reflex, can result in decreased respiration drive. As the lungs expand through pulmonary inflation, it activates the sensors of these stretch receptors, which project via the vagus nerve to the DRG and

the pontine respiratory group. The end result is bronchial dilation and increased expiration time, resulting in a decrease in respiration rate. This seems to be a protective reflex, which has developed to prevent the lungs from over-expanding.

3. Irritant receptors are located throughout the airway and can be activated by certain chemicals, gasses, smoke, dust, and very cold air. Activation by these vectors is transmitted primarily by the vagus nerve and can result in bronchial constriction, which functions to protect the airways from the noxious agent.
4. Chemoreceptors are located centrally in the medulla and peripherally in the great vessels of the neck. The central chemoreceptors are exquisitely sensitive to carbon dioxide, which is the most tightly controlled chemical factor. Carbon dioxide diffuses into the cerebral spinal fluid and forms carbonic acid, which liberates hydrogen ions, resulting in a drop in the pH of the cerebral spinal fluid. It is these hydrogen ions that actually excite the central chemoreceptors in the medulla, which in turn stimulates ventilation. The peripheral chemoreceptors, however, are more responsive to oxygen levels in the blood. Chemoreceptors sensitive to oxygen are located in the aortic and the carotid bodies. If the circulating level of oxygen drops substantially, these act to stimulate respiration rate and depth. Under normal conditions, oxygen levels in the blood affects breathing only indirectly by enhancing the sensitivity of the central carbon dioxide sensors.

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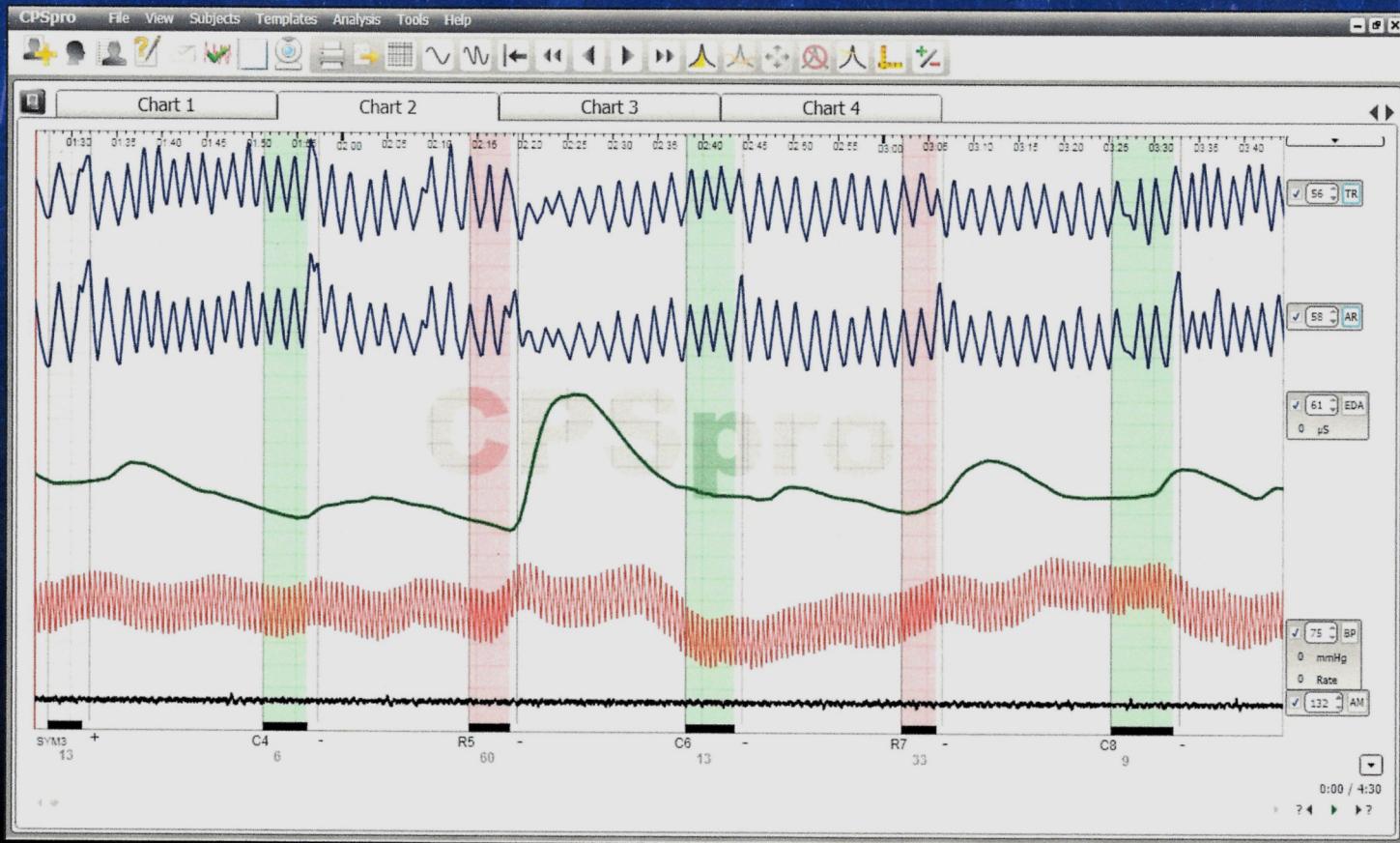
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Fort Myers, Florida  
January 5-March 13, 2015  
April 27-July 3, 2015  
August 31-November 6, 2015

#### University of Florida, Gainesville, Florida

May 4-July 10, 2015  
November 9-13, 2015

#### Post Conviction Sexual Offender Training Course

Fort Myers, Florida  
March 16-20, 2015  
**November 9-13, 2015**

#### Advanced Examiner's Course

Fort Myers, Florida  
March 23-27, 2015

### Academy of Polygraph Science Latin America, Inc.

12945 Seminole Blvd, Building One, Suite 15  
Largo, FL 33778-2315  
Director: Arno Horvath  
Phone: (727) 531-3782  
Phone: (727) 433-6266  
Fax: (727) 286-6140  
Email: [polygraphacademy@hotmail.com](mailto:polygraphacademy@hotmail.com)  
Website: [www.abhpolygraphscience.com](http://www.abhpolygraphscience.com)

### American International Institute of Polygraph

P.O. Box 2008  
619 highway 138 West  
Stockbridge, GA 30281  
Toll free: 866-477-5180  
Fax: 770-960-1377  
Local: 770-690-1377  
Email school: [AIP@Qpolygraph.com](mailto:AIP@Qpolygraph.com)  
Director: [CHUCK@Qpolygraph.com](mailto:CHUCK@Qpolygraph.com)  
Manager: [XAN@Qpolygraph.com](mailto:XAN@Qpolygraph.com)  
Website: [www.polygraphschool.com](http://www.polygraphschool.com)

#### Basic Examiner's Course

Atlanta, Georgia (USA)  
January 5 - March 13, 2015  
May 18 - July 23, 2015  
August 10 - October 31, 2015

#### Overseas locations and dates

April 13 - June 19, 2015  
September 14 - November 20, 2015  
Location: South Africa  
May 4 - July 10, 2015  
Location: Asia

### The Backster School of Lie Detection

861 6th Ave, Suite 403  
San Diego, CA. 92101  
Office: (619) 233-6669  
Fax: (619) 233-3441  
Main Office e-mail: [CleveBackster@cs.com](mailto:CleveBackster@cs.com)  
Greg's Desk e-mail: [BacksterPolygraph@Cox.net](mailto:BacksterPolygraph@Cox.net)  
iPhone/iPad e-mail: [gca1265@me.com](mailto:gca1265@me.com)  
Website: <http://backster.net/>

#### Basic Examiner's Course

Sofia, Bulgaria  
March 16, 2015  
Kennewick, Washington  
Sept. 14, 2015

*"Live as if you were to die tomorrow. Learn as if you were to live forever."*  
*Mahatma Gandhi*

**Behavioral Measures UK, Polygraph Training Centre**  
Behavioral Measures & Forensic Services Southwest, Inc.  
1720 Regal Row, Suite 120  
Dallas, TX 75235  
Director: Donnie W. Dutton  
Phone: (972) 437-4597  
Email: [accounting@behavioralmeasures.com](mailto:accounting@behavioralmeasures.com)  
Website: [www.behavioralmeasures.com](http://www.behavioralmeasures.com)

**Canadian Police College Polygraph School**  
1 Sandridge Road  
Ottawa Ontario Canada  
PO Box 8900 KIG 3J2  
Desk: 613-998-0886  
Fax: 613-990-8588  
Email Director: [Donald.m.macaulay@rcmp.grc.gc.ca](mailto:Donald.m.macaulay@rcmp/grc.gc.ca)  
Website: [www.ccp.gc.ca](http://www.ccp.gc.ca)

#### **Basic Examiner's Course**

CPC Ottawa, Canada  
January 12 – March 21, 2015  
September 1 – November 27, 2015

**The Instituto Latinoamericano de Poligrafia Mexico**  
Genova No. 33, Despacho 503  
Col. Juarez del Cuauhtemoc  
06600, Mexico  
Director: Sandra Zambano  
Phone : (305) 445-1653 or (+55) 5208-7823  
Email: [Lpi2007@gmail.com](mailto:Lpi2007@gmail.com)  
Website: [www.ilpm.com.mx](http://www.ilpm.com.mx)

#### **Basic Examiner's Course**

Mexico  
August 5 – October 26, 2015

**International Academy of Polygraph Deception Control, Inc.**  
1835 South Perimeter Road, Suite 125  
Fort Lauderdale, FL 33309  
Director: Scott Walters  
Phone: (954) 771-6900  
Email: [iap@deception.com](mailto:iap@deception.com)  
Website [www.deception.com](http://www.deception.com)

#### **Basic Examiner's Course**

Fort Lauderdale, Florida  
February 16 – April 24  
October 5 – December 11

**International Polygraph Training Center**  
Colima No. 385-2  
Colonia Roma Norte  
Mexico DF 06700  
Director: Raymond Nelson  
US Phone: 303-587-0599  
E-mail: [raymond.nelson@gmail.com](mailto:raymond.nelson@gmail.com)

**Latin American Polygraph Institute**  
Carrera 46 #93-70 Barrio La Castellana  
Bogota, Colombia  
Director: Sidney Wise Arias  
Phone: Bogota (571) 482-9421 or  
Direct from USA: (305) 432-4077  
US Address: 730 Coral Way, Suite 102  
Coral Gables, FL 33134  
Email: [swarias@bellsouth.net](mailto:swarias@bellsouth.net)  
Website: <http://www.latinamericanpolygraph.com/>

#### **Basic Examiner's Course**

Bogota, Colombia  
September 20 – December 20, 2015 (Day)  
August 25 – December 20, 2015 (Night)

**Marston Polygraph Academy**  
390 Orange Show Lane  
San Bernardino, CA 92408  
Director: Thomas M. Kelly  
Phone: 877-627-2223  
Email: [mail@marstonpolygraphacademy.com](mailto:mail@marstonpolygraphacademy.com)  
Website: [www.marstonpolygraphacademy.com](http://www.marstonpolygraphacademy.com)

#### **Basic Examiner's Course**

**San Bernardino, California**  
January 5 – March 13, 2015  
April 6 – June 12, 2015  
July 6 – September 11, 2015  
October 5 – December 11, 2015

#### **Post Conviction Sexual Offender Training Course**

San Bernardino, California  
March 16 – March 20, 2015 Basic Polygraph  
June 15 – June 19, 2015  
September 14 – September 18, 2015  
December 14 – December 18, 2015

#### **Continuing Education & Refresher Course**

San Bernardino, California  
June 23 – June 25, 2015  
September 22 – September 24, 2015

**Maryland Institute of Criminal Justice**

8424 Veterans Highway, Suite 3  
Millersville, Maryland 21108-0458  
Director: Billy H. Thompson and Vickie Murphy Carr  
Phone: 410-987-6665 or 800-493-8181  
Fax: 410-987-4808  
E-mail: [mdmicj@aol.com](mailto:mdmicj@aol.com)  
Website: <http://www.micj.com>

**Basic Examiner's Course**

Millersville, Maryland  
• January 5 – March 13, 2015  
• April 6 – June 12, 2015  
September 14 – November 20, 2015

**Post Conviction Sexual Offender Training Course**

Millersville, Maryland  
• March 16-20, 2015  
November 30-December 4, 2015

**National Center for Credibility Assessment**

7540 Pickens Avenue  
Fort Jackson, SC 29207  
Director: William Norris  
Phone: 803-751-9100  
Fax: 803-751-9108  
E-mail: [William.Norris@ncca.mil](mailto:William.Norris@ncca.mil)  
Website: <http://www.ncca.mil>

**Basic Examiner's Course**

Ft Jackson, South Carolina  
January 6 – April 8, 2015  
March 24 – June 23, 2015  
June 2 – September 1, 2015  
August 18 – November 19, 2015

**National Polygraph Academy**

1890 Star Shoot Parkway, Suite 170-366 nu  
Lexington, KY 40509  
Director: Pam Shaw  
Phone: 859-494-7429  
E-mail: [shaw.national@gmail.com](mailto:shaw.national@gmail.com)  
Website: [www.nationalpolygraphacademy.com](http://www.nationalpolygraphacademy.com)

**Basic Examiner's Course**

Little Rock, Arkansas  
January 26, 2015

**Advanced Continuing Education**

Columbus, Ohio  
September 29, 2015

**New England Polygraph Institute**

P.O. Box 825  
Center Harbor, NH 03226  
Director: David J. Crawford  
Phone: 603-253-8002  
E-mail: [kacdc@worldpath.net](mailto:kacdc@worldpath.net)  
Website: [www.newenglandpolygraphinstitute.com](http://www.newenglandpolygraphinstitute.com)

**Basic Examiner's Course**

Center Harbor, New Hampshire  
February 9 – April 17, 2015

**NCTC Polygraph Training Institute**

c/o Dept. of Military & Veterans Affairs Building 8-64  
Fort Indiantown Gap  
Annville, PA 17003-5002  
Director: Elmer Criswell  
Phone: 717-673-9345 or 877-806-6293  
Fax: 717-861-2070  
E-mail: [lietestec@aol.com](mailto:lietestec@aol.com)  
Website: <http://www.counterdrug.org>

**Polygraph School of Science, Inc.**

202 E. McDowell Road, Suite 258  
Phoenix Arizona 85004  
Office: (602) 272-8123  
Fax: (602) 272-9735  
Email School: [Office@azpeinc.com](mailto:Office@azpeinc.com)  
Email Director: [l.wells@azpeinc.com](mailto:l.wells@azpeinc.com)  
Website: [www.azpolygraphschool.com](http://www.azpolygraphschool.com)

**Texas Department of Public Safety Law Enforcement Polygraph School**

PO Box 4087  
Austin, Texas 78773-0001  
Director: Brian Vaughan  
Phone: 512-424-2200  
Fax: 512-424-7166  
E-mail: [Felicia.Ruiz@dps.texas.gov](mailto:Felicia.Ruiz@dps.texas.gov)

**Basic Examiner's Course**

Austin, Texas  
January 5 – March 13, 2015

**Advanced Continuing Education**

Austin, Texas  
April 13 – April 17, 2015

**The Polygraph Institute**

19179 Blanco, Ste 105-812  
San Antonio, TX 78258 (mailing address)  
10223 McAllister Fwy, Suite 201  
San Antonio, TX 78216 (physical address)  
Director: J. Patrick O'Burke  
Office: 817-290-0033 or 210-377-0200  
Fax: 210-481-7639  
Website: [www.thepolygraphinstitute.com](http://www.thepolygraphinstitute.com)

**Basic Examiner's Course**

San Antonio, Texas  
Feb 23 - May 1, 2015  
Sept 7 - Nov 13, 2015

**Validated Interview Technique**

San Antonio, Texas  
Feb 9 – 13, 2015  
Call to Schedule a course!

**Pcsot/Jpcot Course**

San Antonio, Texas  
May 4 - May 8 (San Antonio)  
Nov 16 - Nov 20 (San Antonio)

**TDLR CONTINUING EDUCATION COURSE:**

Call for schedule in 2015

**Virginia School of Polygraph**

7885 Coppermine Drive  
Manassas, VA 20136  
Director: Daryl L. DeBow  
Phone: 703-396-7659 & 571-435-1207  
E-mail: [polygraph1@verizon.net](mailto:polygraph1@verizon.net)  
Website: <http://www.virginiaskoolofpolygraph.com>

**Basic Examiner's Course**

Manassas, Virginia  
March 2 - May 8, 2015

Newport News, Virginia  
September 8 - November 13, 2015

# AAPP 38th Annual Seminar

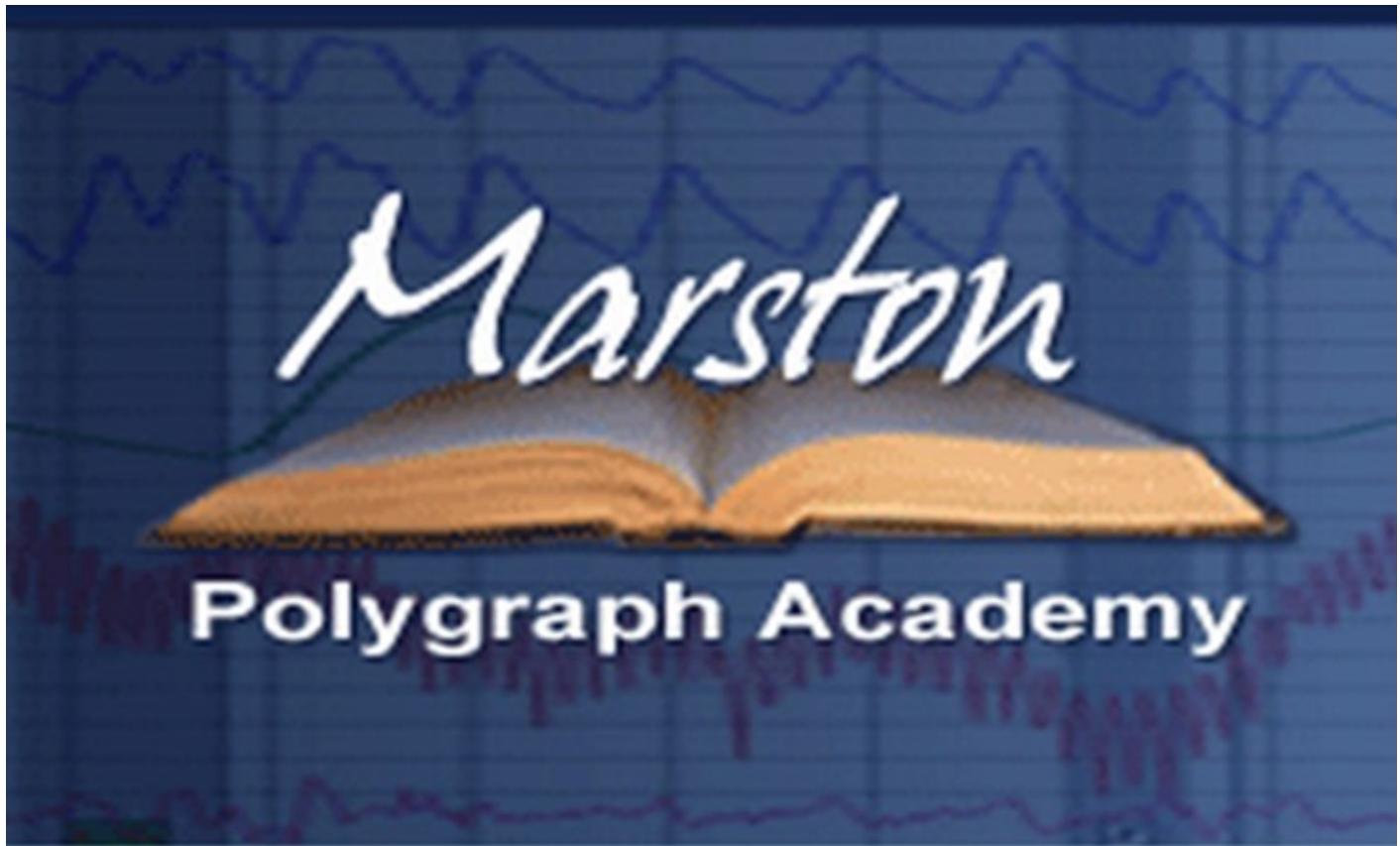
## May 31 - June 5, 2015



May 31 - June 5, 2015

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Bob Heard

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***38<sup>th</sup> Annual AAPP Seminar***  
***Co-Sponsored by the Michigan Association  
of Polygraph Examiners***  
***May 31 – June 5, 2015***

**Amway Grand Plaza Hotel  
Grand Rapids, MI**

**CLASS/EVENT SCHEDULE**

**Sunday, June 1, 2015**

TIME	EVENT	Room
	<i>Golf Tournament</i>	<i>Details to be Announced</i>
1:00p – 5:00p	Registration	Julie & Mark Gerspacher AAPP National Office Manager Crew: AAPP BOD
5:15p – 5:45p	Worship Service—Barry Cushman AAPP Chaplain	Location TBA
6:15p – 8:00p	President's Reception * Bring your registration drink tickets!	Location TBA

## Monday, June 1. 2015

TIME	EVENT	INSTRUCTOR	ROOM
6:15a – 7:30a <b>(Board Members 6:00a)</b>	<b>Registration</b>	<b>Julie &amp; Mark Gerspacher</b> <i>National Office Manager</i> <i>Crew: AAPP BOD</i>	
8:00a – 9:00a	<b>Opening Ceremony</b>	Opening Prayer Honor Guard- National Anthem- Pledge of Allegiance President's Welcome Housekeeping Rules Special Announcements	Ambassador Ballroom
<b>9:00a – 10:00a</b>	<b>Spouse Breakfast</b>	<b>Breakfast for Member Spouses and Guests</b>	<b>TBA</b>
9:00a – 12:00p	Case Presentation: 1993 Murder Case of Lativia Johnson	Sgt. Kristen Rogers, Grand Rapids PD & Trooper Clint Elwood, Nebraska State Patrol	Ambassador Ballroom
12:00p – 1:00p	<i>Lunch- on your own</i>		
1:00p - 5:00p	Homicide/Polygraph Investigation Aliahna Lemmon, Fort Wayne, IN	John Zagelmeier & Brian Sell	Ambassador Ballroom (West)
1:00p - 5:00p	False Confessions	Mark Handler & Adam Sibley	Ambassador Ballroom (East)
1:00p - 5:00p	Managing a Polygraph Unit	Matt Hicks & Dennis Westerman	Vandenberg Room
Contact Elmer in the Seminar Area	QC Your Charts Available by appointment throughout the week.	Elmer Criswell	TBA

## Tuesday, June 2, 2015

TIME	EVENT	INSTRUCTOR	ROOM
8:00a – 12:00a	DLC with Utah	Ben Blalock	Ambassador Ballroom (West)
8:00a – 12:00a	Interview & Interrogation	J. Patrick O'Burke	Ambassador Ballroom (East)
8:00a – 12:00p	Eyewitness Identification Errors	Ted Todd	Vandenberg Room
12:00p – 1:00p	Lunch- on your own		
12:00p – 1:30p	<i>State &amp; National Leadership Luncheon Invitation Only</i>	<i>Jim Wardwell AAPP- Vice President State Association Leadership</i>	TBA
1:00p – 5:00p	PSCOT	Chip Morgan	Ambassador Ballroom (West)
1:00p - 5:00p	Interview & Interrogation	J. Patrick O'Burke	Ambassador Ballroom (East)
1:00p – 5:00p	Pre-employment Interviews	Ted Todd	Governor's Room
<u>1:00p – 3:00p</u>	Axciton		
3:00p – 5:00p	Stoelting		
6:00p	Tuesday Night Function	General Membership	Grand Rapids Public Museum

## Wednesday, June 3, 2015

TIME	EVENT	INSTRUCTOR	ROOM
8:00a-12:00p	Annual Business Meeting		Ambassador Ballroom
8:00a-12:00p	DIA Meeting		Governor's Room
12:00p – 1:00p	Lunch- On your own		
1:00p - 5:00p	Managing Countermeasures	Walt Goodson	Ambassador Ballroom
1:00p – 5:00p	Federal Meeting		Governor's Room
3:00p - 5:00p	School Directors Meeting	Jim Wardwell & Bob Heard	TBA

## Thursday, June 4, 2015

TIME	EVENT	INSTRUCTOR	ROOM
8:00a – 12:00p	Persuasive Pre-Test (TDLR approved)	James Mull & Dennis Westerman	Ambassador Ballroom (West)
8:00a – 12:00p	Validated Techniques	Guillermo Witte	Ambassador Ballroom (East)
8:00a – 12:00p	PSCOT	Chip Morgan	Governor's Room
12:00p – 1:00p	LUNCH – on your own		
1:00p – 3:00p	Persuasive Pre-Test (TDLR approved)	James Mull & Dennis Westerman	Ambassador Ballroom (West)
3:00p – 5:00p	Psychological Aspects That Can Affect the Polygraph	Tiffany Collier	Ambassador Ballroom (West)
1:00p – 5:00p	Physiology	Pam Shaw	Governor's Room
1:00p – 5:00p	Interview & Interrogation	J. Patrick O'Burke	Ambassador Ballroom (East)
1:00p – 3:00p	Lafayette		Vandenberg Room
3:00 – 5:00p	Limestone		Vandenberg Room
5:00p – 7:00p	Cocktail Hour/Awards	General Membership	TBA
7:00p – 9:00p	Annual Banquet	General Membership	Grand Ballroom

## Friday, June 5, 2015

TIME	EVENT	INSTRUCTOR	ROOM
8:00a – 12:00p	Question formulation, Pre & Post-Test, False Confessions	Bob Heard	Ambassador Ballroom (West)
8:00a – 12:00p	Inside the Mind of a Sex Offender	Troy Timmons	Ambassador Ballroom (East)
12:00p – 1:00p	LUNCH – on your own		
1:00p – 5:00p	Question formulation, Pre & Post-Test, False Confessions	Bob Heard	Ambassador Ballroom (West)
1:00p – 5:00p	Using Personality Disorders to Enhance Confessions	Mike Gougle & Tiffany Collier	Ambassador Ballroom (East)

## Closing Remarks – AAPP President Immediately following last speaker

**NOTE: Although seldom done, the AAPP reserves the right to change class times, topics and speakers without advanced notice**

### MORE THINGS TO DO IN GRAND RAPIDS!!!



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So why not get a taste of our many local craft breweries with your own self-guided craft beer tour and see for yourself why [thestreet.com](#) put Grand Rapids on the Top 10 Vacation Cities for Beer Lovers list!

*Refer to the November Journal for a list of things to do in Grand Rapids*

Michigan has more lighthouses than any other state - and many of them line the Lake Michigan coast, just a short drive from Grand Rapids.

[Grand Haven Light-house.](#) Approx. 35 miles.

[Holland Harbor Light-house.](#) Approx. 35 miles

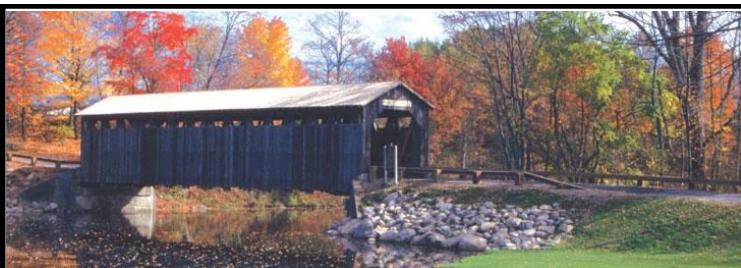
[Muskegon South Pier Light-house.](#) Approx. 44 miles.

[White River Light Station.](#) Approx. 60 miles

[For more info go to: <http://www.experiencegr.com/things-to-do/historic-sites/lighthouses/>](http://www.experiencegr.com/things-to-do/historic-sites/lighthouses/)



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11/14



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| 2) * <b>Option 2 – Contact us for other tablets/devices:</b>                 |           |

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