Classic Science

For the Family

STUDENT COPY

ADVANCED BIOLOGY:

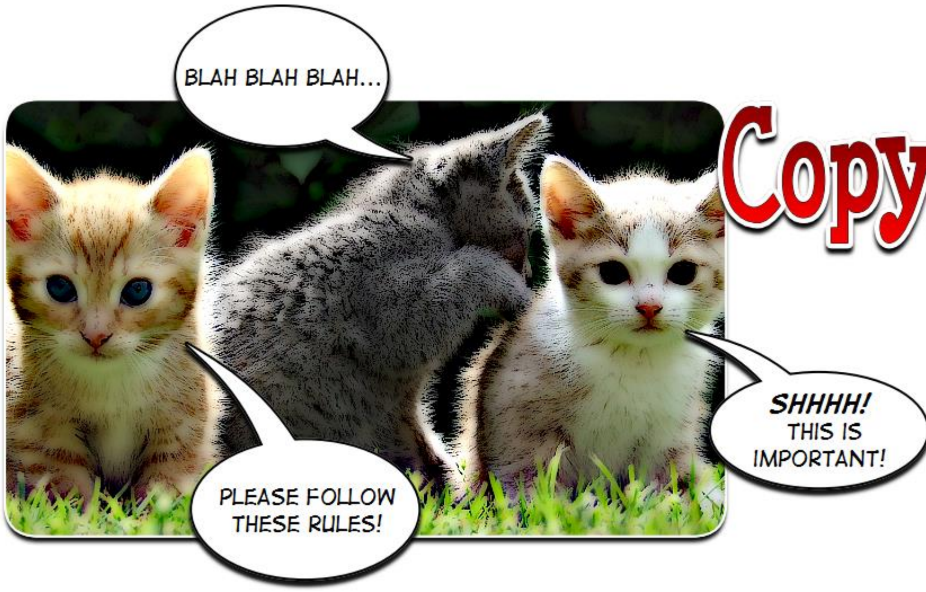
ANATOMY and PHYSIOLOGY

I FIND THIS HUMERUS...

The lab of MR.Q

zzzz...

Scott McQuerry



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This product is the fruit of my 15-year labor in science education. Having worked with homeschool families over these years I have gained an appreciation for your needs, struggles and wants. I could not make this curriculum any simpler for your child to master the concepts of science. It is easy to follow, relatively cheap (I tried to keep it under the cost of a tank of gas), and adaptable to various needs at home and as fun as humanly possible.

Like I said, I am an "army of one." I have no problem with you using this one copy for your entire family. However, if you give or loan this book out to another family you are putting a lot of pressure on me. If this happens too often, I may not be able to continue producing this curriculum. I am not telling you to keep this curriculum a secret, but I have provided some options for you should another family wish to use this curriculum:

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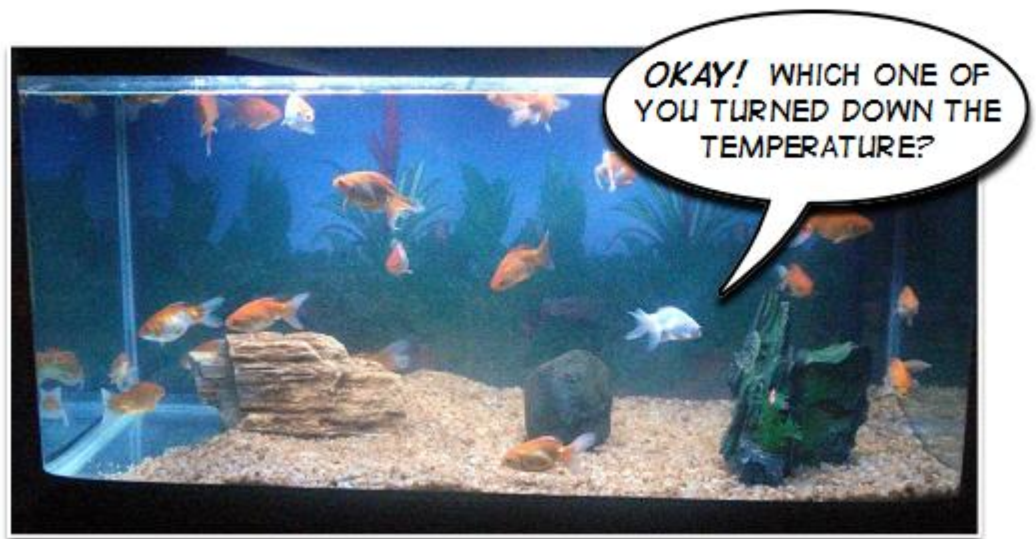
Chapter One

Body sections and Homeostasis

Before we get started digging in too deeply, let me ask you to imagine going to the pet store and picking up all of the supplies needed to set up an aquarium. What would you need?

You'd likely pick up the aquarium, a filter, a feeder, a heater, an air pump, water, and the fish itself. All of these items must be in working order so that your fish will survive, correct?

The air pump must supply a continuous supply of oxygen to the water for the fish to live. The filter will keep all of the fish waste from poisoning the water. The heater (with the help of its tiny thermostat) will maintain a relatively constant water temperature for the fish as well. And, the feeder will naturally provide a steady supply of food for it to live.



What does all of this have to do with the human body?

Well, you can break down each individual item within your aquarium into various physical objects and their functions, right? This is how the study of the human body is broken down as well. The study of the body's physical structures (heart, lungs, fingers, toes, etc.) is known as **anatomy** while the study of their functions is known as **physiology**.

In this book, we will be studying both the anatomy and physiology of the human body at the same time. And if you have spent any time at all working with the books in this series you should have learned that everything in the universe is connected together. There is no exception to this rule within the human body as well.

Everything within the human body is connected to each other!

Let's look back at our aquarium to see how everything can be connected together. First of all, I mentioned that the heater within your aquarium contains a tiny thermostat. You wouldn't want to place a heater within your aquarium without a way to turn it off and on automatically. You'd cook your fish if you did!

The thermostat "tells" the heating elements to turn on when its thermometer senses the water temperature is too cold. And it will allow these elements to remain on until the thermometer senses that the water temperature is too high. When this occurs, the thermometer will send its information to the thermostat which will turn off the heating element and allow the water to cool down on its own before starting over again.

The maintaining of the aquarium's water temperature is very similar to how our own bodies regulate our temperature as well.

(No. We do not have little aquarium heaters within our bodies. However, you are going to LOVE how it is truly done!)

The property which regulates our internal environment to create a stable and constant set of properties is known as…

Homeostasis

It is the goal of this book to describe several of these properties as it relates to the various structures within our body. Although the desired effect of homeostasis is to maintain a constant level of properties such as temperature, oxygen levels, amount of sugar within the blood, etc., the method in which this can occur may take one of two different forms:

Negative feedback and Positive feedback

To explain how these methods work, let's look again at how our aquarium heated up. The aquarium heater contains a receiver which is the thermometer, a control center which is the thermostat, and an effector which is the heating element itself. "Feedback" is the message sent from the thermometer to the thermostat indicating the temperature of the water. Since the effector (heating element) acted to reverse what was being sensed by the receiver (thermometer) the action is said to be negative. Therefore, **negative feedback** occurs when the message results in a reversal of the direction of change. A cold water temperature triggers a reaction causing it to be warmed and vice-versa. Negative feedback is much more common within our bodies as you will see.

Positive feedback occurs when the message results in an increase of the change. For example, if the thermometer sensed the water temperature was getting colder, it would send a message to the thermostat which would turn on an effector that would cool the water down even more! Naturally, this would not be something you (or the fish) would typically want to happen; however, there are instances within the human body where positive feedback is necessary for our survival. You will explore both of these feedback methods in your studies of anatomy/physiology.

Since we are on the topic of structures within the body, you should understand another concept that tends to cause trouble in the minds of most anatomy/physiology students:

Size

The size of objects within the human body can be a little challenging. That is why we will be focusing a lot on this concept throughout the book. It is very important that you have a strong understanding of the relative size of structures as compared to each other. For your reference, here is a general look at how the structures of the human body are organized from smallest to the largest:

Cells, Tissues, Organs, Organ systems, and Organisms

Can we study things smaller than cells? You bet! How about larger things than organisms? Of course! What is most important is that you can identify the difference in size between these items as we work through our studies.

Simply put, groups of cells work together to create specific tissues; and, groups of tissues work together to create organs, and so on... In addition, throughout this book you will learn how atoms and molecules affect our cells as well. However, the majority of our time will be spent within the five structures mentioned above. Learn them well, as it is vitally important that you can identify how they work together.

The following chart will give you a brief idea of the major organ systems within the human body...

Systems providing protection, support, and movement of the organism		
Integumentary system	Protection against injury and dehydration; defense against foreign invaders; regulation of temperature	Skin, hair, and nails
Skeletal system	Supports, protects, and allows for body movement; formation of red blood cells	Bones, cartilage, and joints
Muscular system	Causes body movement	Muscles and tendons

Systems providing integration (the interpretation of things you can sense) and regulation		
Nervous system	Enables sense organs reasoning and memory; regulates body activities	Brain, spinal cord, and nerves
Endocrine system	Chemically controls and integrates many processes	Pancreas and glands

Systems providing internal transport and protection		
Circulatory system	Transports materials via blood; regulates acid-base balance; protects against disease and fluid loss	Heart, blood vessels, and spleen
Immune	Defense against foreign invaders; formation of white blood cells	White blood cells, lymph vessels and nodes

Systems providing absorption and secretion		
Respiratory system	Supplies oxygen to the blood and eliminates carbon dioxide; helps regulate acid-base balance	Nose, pharynx, larynx, trachea, lungs
Digestive system	Processes ingested foods for cellular use; eliminates undigested wastes	Tongue, teeth, pharynx, esophagus, stomach, small intestine and large intestine; liver and pancreas
Urinary system	Filters blood; regulates chemical balance of blood	Kidney, urinary bladder, and ureters

System providing longevity		
Reproductive system	Produces gametes and sex hormones; reproduces the organism	Gonads and genital organs

Imagine if you lived in a world without the cardinal directions of north, south, east and west.

Can you think of any potential problem that may occur? Here's a simple scenario. What if you were to become lost in a forest and needed to find your way home? Luckily, you pull out a map which says "turn right at the large oak tree." You may find your way to the large oak tree and turn right but you may soon find yourself still lost within the woods. Without a standard reference point on your map, "turning right" could mean north, south, east, or west depending on which direction you approached the oak tree. Your perspective is vital to your survival in this case.

This situation is very similar within all of the sciences. A common language is needed to help find our way around. This brings us to the three **planes of reference** which are imaginary flat surfaces passing through the body. These fictional divisions are frequently used to help identify specific locations in, on, and around the body. These planes include:

Sagittal plane

Divides the body into right and left portions; these areas are identified from a patient's perspective. For example, when you go to the doctor and complain about a pain in your left leg, the doctor will examine your left leg despite the fact that from her perspective, your left leg is on the right side!

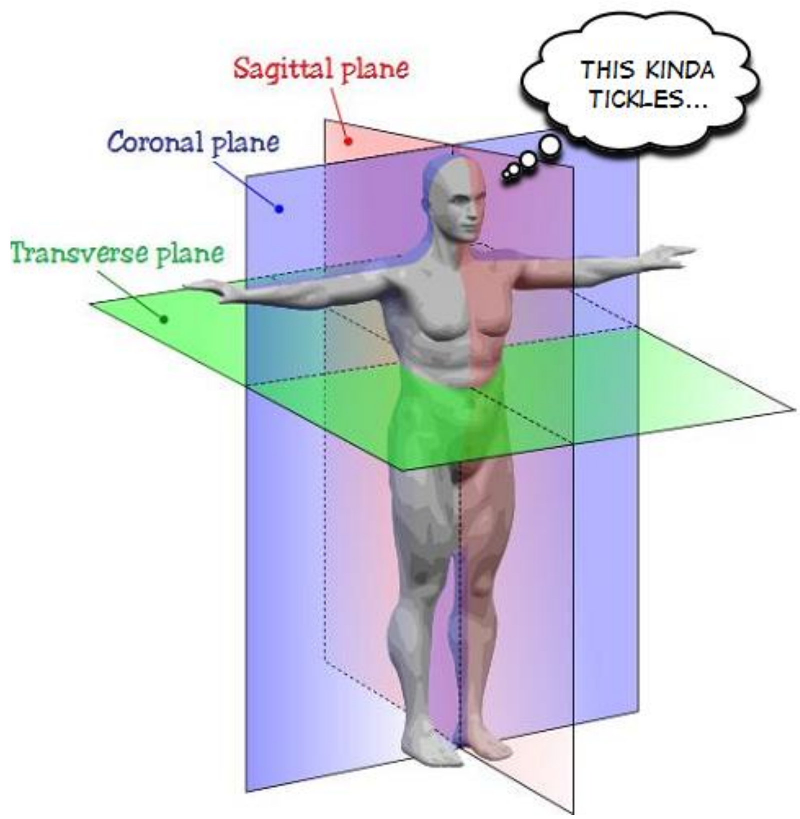
Coronal (frontal) plane

Divides the body into **anterior** (front half) and **posterior** (back half) portions

Transverse plane

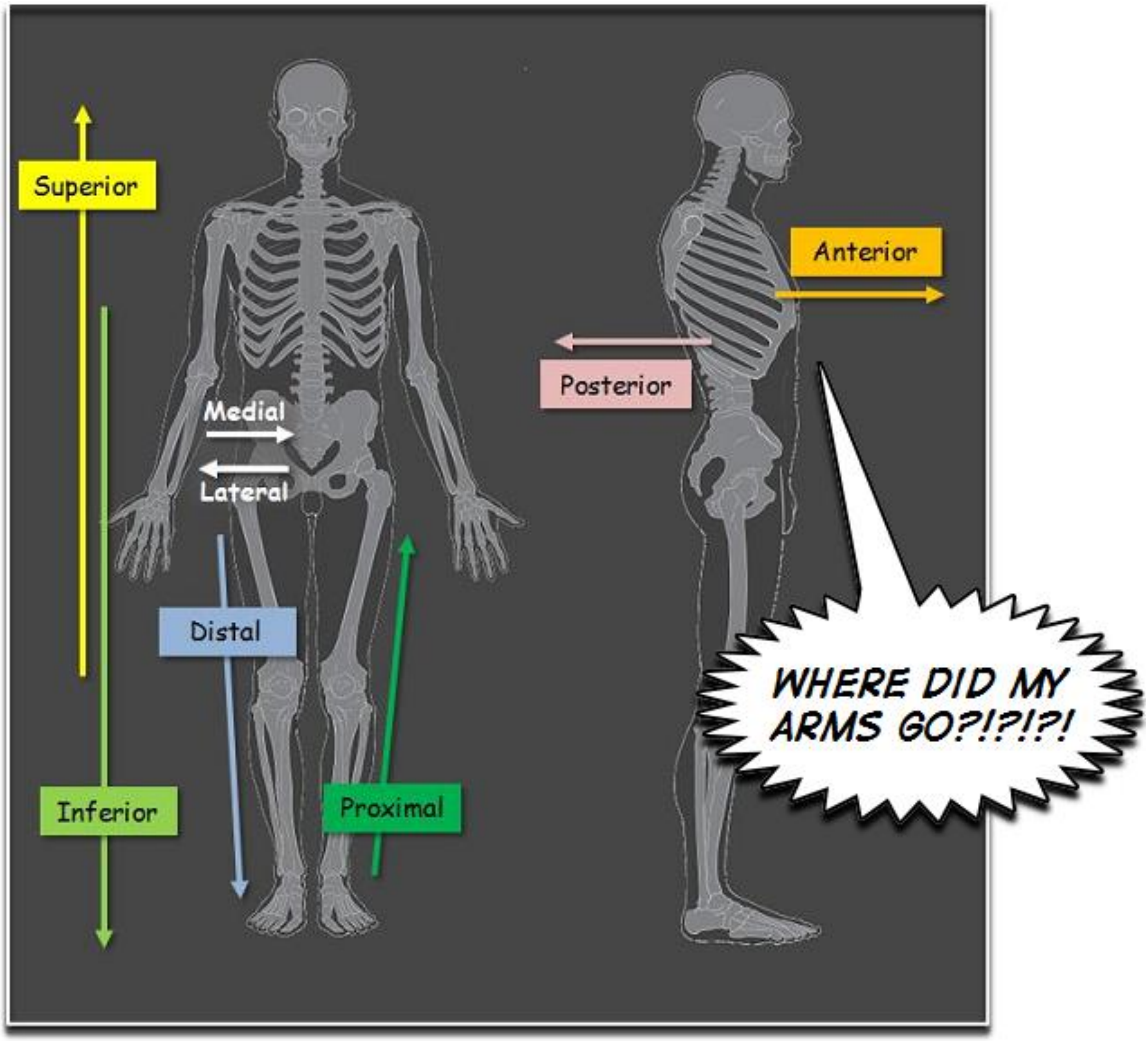
Divides the body into **superior** (top half) and **inferior** (bottom half) positions

Don't let all of these names confuse you. Most of the directional terms used to describe the human body can be found in the chart below. You may want to spend a little time reviewing them as they may pop up throughout the book. And remember - these terms are universal for all humans regardless if they are sitting, standing, or laying down!



Directional terms for the human body

Term	Definition	Example
Superior	Toward the head; toward the top	The head is superior to the shoulders.
Inferior (caudal)	Away from the head; toward the bottom	The knees are inferior to the head.
Anterior (ventral)	Toward the front	The nose is on the anterior side of the body.
Posterior (dorsal)	Toward the back	The shoulder blades are posterior to the toes.
Medial	Toward the midline of the body	The heart is medial to the shoulders.
Lateral	Away from the midline of the body	The ribs are lateral to the lungs.
Internal (interior)	Away from the surface of the body	The heart is internal to the skin.
External (superficial)	Toward the surface of the body	The muscles are external to the bones.
Proximal	Towards or near to the trunk of the body	The elbow is proximal to the hand.
Distal	Away from the trunk of the body	The foot is distal to the knee.



Okay! It's time to start digging into the meat of our studies (no pun intended). Remember to look for the key concepts of homeostasis, size, and direction throughout your studies. And never forget the most important rule within anatomy and physiology:

Everything within the human body is connected to each other!

Match the following vocabulary terms with their correct definition:

anatomy	**interior**	**posterior (dorsal)**
anterior (ventral)	**lateral**	**proximal**
coronal (frontal)	**medial**	**sagittal plane**
distal	**negative feedback**	**superior**
external (superficial)	**physiology**	**transverse plane**
homeostasis	**planes of reference**	
inferior (caudal)	**positive feedback**	

1)	______________	a set of three planes (imaginary flat surfaces) passing through the body used to identify specific locations in, on, and around the body
2)	______________	away from the midline of the body
3)	______________	away from the surface of the body
4)	______________	away from the trunk of the body
5)	______________	occurs when the feedback results in an increase of the change
6)	______________	occurs when the response to a stimulus (feedback) results in a reversal of the direction of change
7)	______________	directional term meaning "toward the back"
8)	______________	directional term meaning "toward the bottom"
9)	______________	directional term meaning "toward the front"
10)	______________	directional term meaning "toward the top"
11)	______________	plane of reference which divides the body into anterior and posterior portions

12)	______________	plane of reference which divides the body into inferior and superior portions
13)	______________	plane of reference which divides the body into right and left sides
14)	______________	the property which regulates our internal environment to create a stable and constant set of properties
15)	______________	the study of the body’s physical structures
16)	______________	the study of the body's functions
17)	______________	toward the midline of the body
18)	______________	toward the surface of the body
19)	______________	toward the trunk of the body

Choose the correct answer from the following questions:

1) **The plane of reference which divides the body into equal right and left parts is called:**
   A) sagittal
   B) oblique
   C) transverse
   D) frontal
   E) coronal

2) **Which of the following lists correctly identifies the level of structural organization from smallest to largest in size:**
   A) tissue, cellular, organ system, organ, organism
   B) cellular, tissue, organ system, organism, organ
   C) cellular, tissue, organ, organ system, organism
   D) cellular, tissue, organ, organism, organ system
   E) organism, organ system, organ, tissue, cellular

3) **Which of the following organ systems is linked most accurately to the function it provides:**
   A) respiratory system - digestion
   B) nervous system - excretion
   C) muscular system - maintaining boundaries
   D) integumentary system - movement
   E) nervous system - responsiveness

4) **Which of the following elements of a system detects a change in its environment:**
   A) receiver
   B) control center
   C) effector
   D) stimulus

5) Imagine seeing a large object moving dangerously fast to you. Which of the following lists correctly describes your actions as you attempt to get out of the way?

A) receiver, stimulus, control center, effector, response
B) stimulus, effector, control center, receiver, response
C) receiver, stimulus, control center, effector, response
D) stimulus, receiver, control center, effector, response
E) effector, stimulus, control center, receiver, response

6) Which of the following directional terms for the human body have opposite meanings:

A) medial and anterior
B) external and proximal
C) posterior and intermediate
D) distal and proximal
E) medial and distal

Application Question:

Identify the correct directional terms for the following areas of the body: (i.e. caudal, dorsal, distal, etc.)

a. The navel is __________ to the nose.

b. The nipple is ___________ and ___________ to the lung.

c. The upper arm is ____________and __________ to the forearm.

d. The eye is ____________ to the ear.

Chapter Two

Cells and Tissues

This week we will be looking at the two smallest structures on our anatomical list:

Cells and Tissues

As you should know by now, cells are the basic building blocks of all life and are the foundation for tissues, organs, organ systems, and the entire organism itself. Even though our cells have a variety of different functions within the human body, all cells share a few common structures.

The cell is a fluid-filled container surrounded by a **cell membrane** and contains a set of specialized structures called **organelles.** Each organelle maintains its own unique function for the cell's survival. The cell's internal fluid, **cytoplasm**, is a storage area for gases, food, wastes, and a variety of items which are vital to the cell's survival.

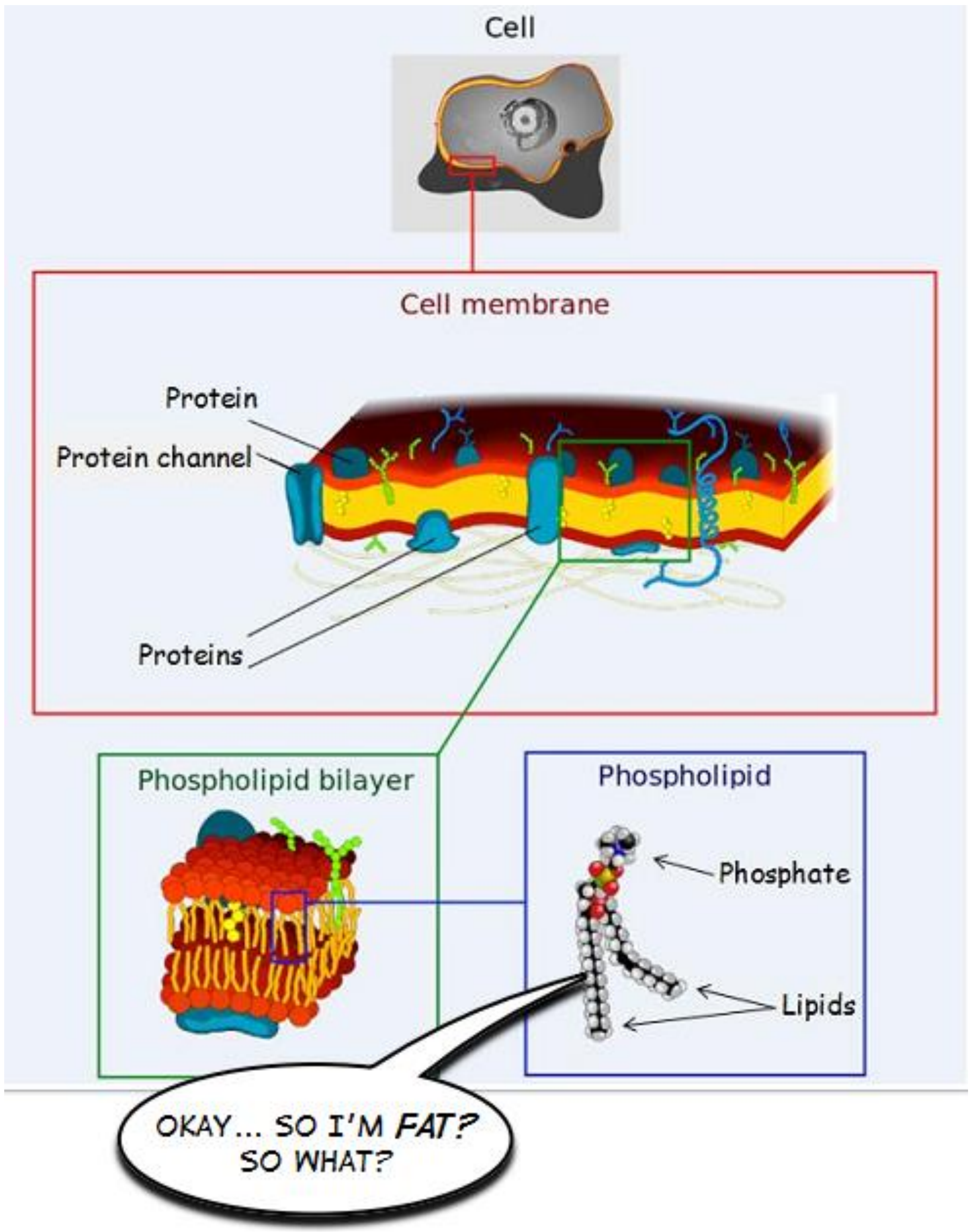
We do not have enough time to talk about each of the individual organelles in this book; however, it is worth discussing how items can be transported into and out of a cell. You will see this process from time to time throughout the various organs and organ systems.

Let's take a closer look at the cell membrane.

It is common sense that our bodies require food and water in order to survive. More specifically, these nutrients must find their way into the cell; and, once they are used up and converted to waste materials, they must be removed from the cell in some way.

How is this done? To know this you first must understand what the structure of a cell membrane looks like.

Cell membranes are made up of a bilayer of large molecules known as **phospholipids** which contain two separate parts: a molecule known as a **phosphate** (a chemical made of one atom of phosphorus and four oxygen atoms) and two long "tails" of **lipids** (aka – fat). If you were to cut an ice cream sandwich in half and look inside, the sandwich portions would represent the phosphate and the ice cream would be the location of the lipids. Now imagine taking several straws and driving through the ice cream sandwich. The straws which pass through the entire sandwich represent various types of **proteins** (large organic molecules each possessing a unique function) that exist within the cell membrane. It is through these straws that water, nutrients, and waste products can travel back and forth.

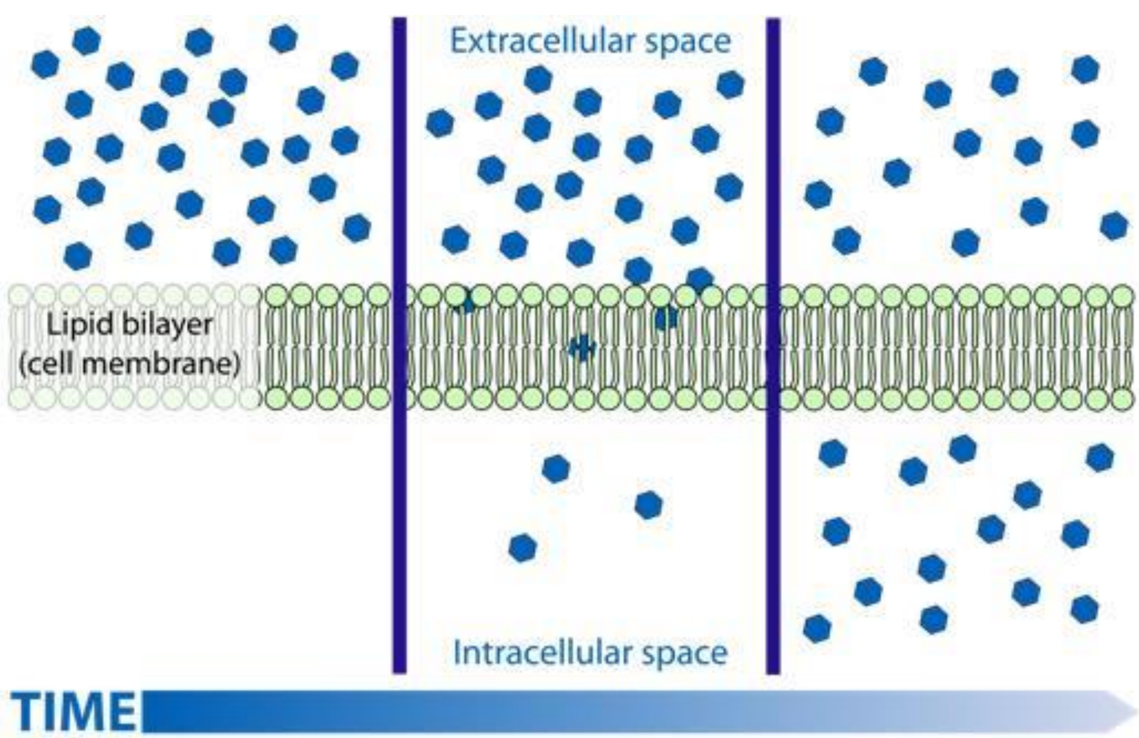


The cell membrane is known as a **semipermeable** membrane which means that it regulates which substances are allowed in and out of the cell in specific ways. The four main methods of moving items through the membrane are:

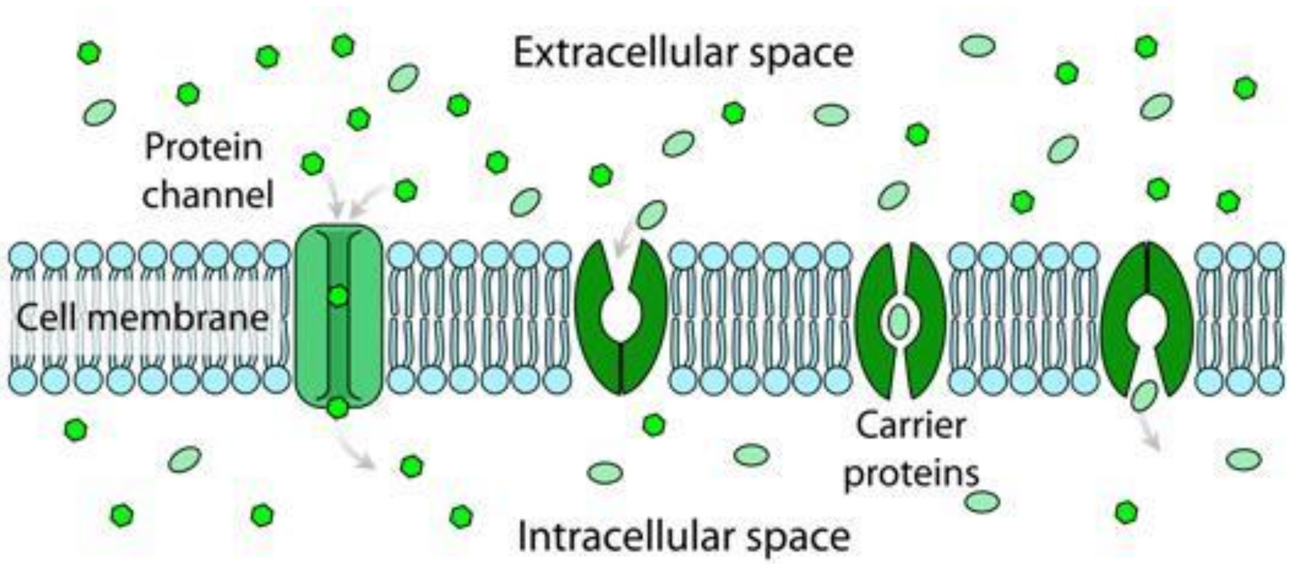
Diffusion, Osmosis, Facilitated diffusion, and Active transport

Diffusion is simply the movement of any substance from an area of high concentration to an area of low concentration. This is how oxygen enters the blood within the lungs. When we inhale, the concentration of oxygen within our lungs becomes much higher than is found within the blood. Therefore, oxygen diffuses from the lungs to the blood.

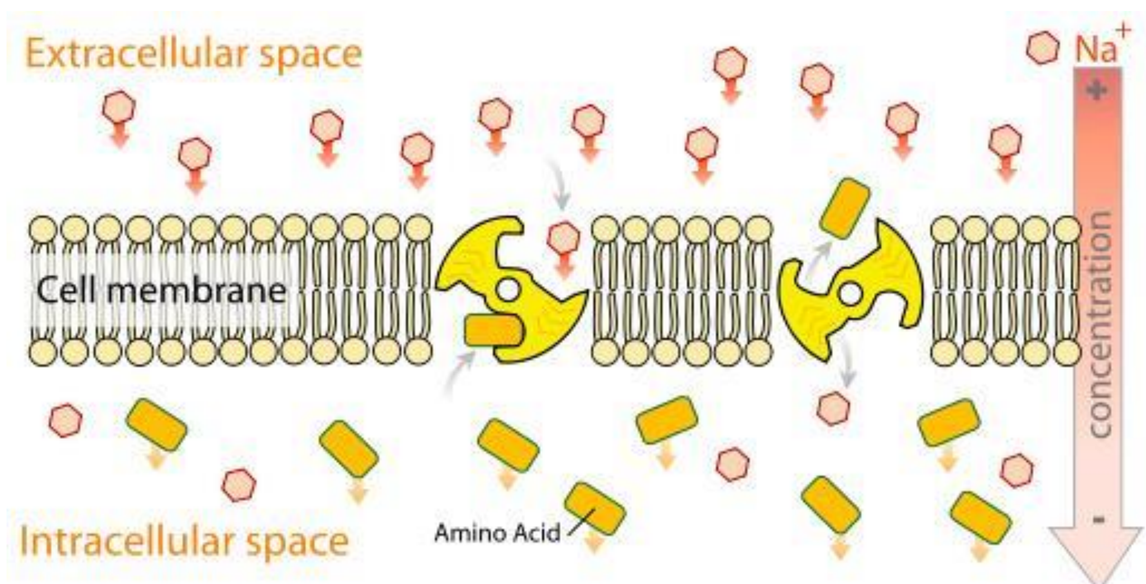
Osmosis is a special type of diffusion in which only water is being transported through a semipermeable membrane. It is safe to assume there are always substances dissolved within the water in our bodies. Therefore, during osmosis, water will naturally pass through the membrane from areas with low concentrations of dissolved substances into areas which contain high concentrations of dissolved substances.



To understand **facilitated diffusion**, think back to the "proteins" you stuck through your ice cream sandwich model. Some proteins within the cell membrane act as gates or revolving doors which are specific for only certain types of particles to pass through.



Active transport works very much like a pump which can drive particles in and out of the cell against the normal flow of diffusion. Much like facilitated diffusion, proteins within the cell membrane are used as these organic pumps. Naturally, this takes a lot more energy to accomplish but it does get the job done!



As you read earlier, cells have a variety of different functions within the human body. As groups of cells divide and bond together in the first few weeks/months of our life, they begin to differentiate into four anatomically different classes of cells, each containing its own unique functions. These four groups of cells continue to grow in numbers and become what is referred to as tissues.

There are four main types of tissues found in the human body:

Epithelial, Connective, Muscle, and **Nervous**

Epithelial tissue

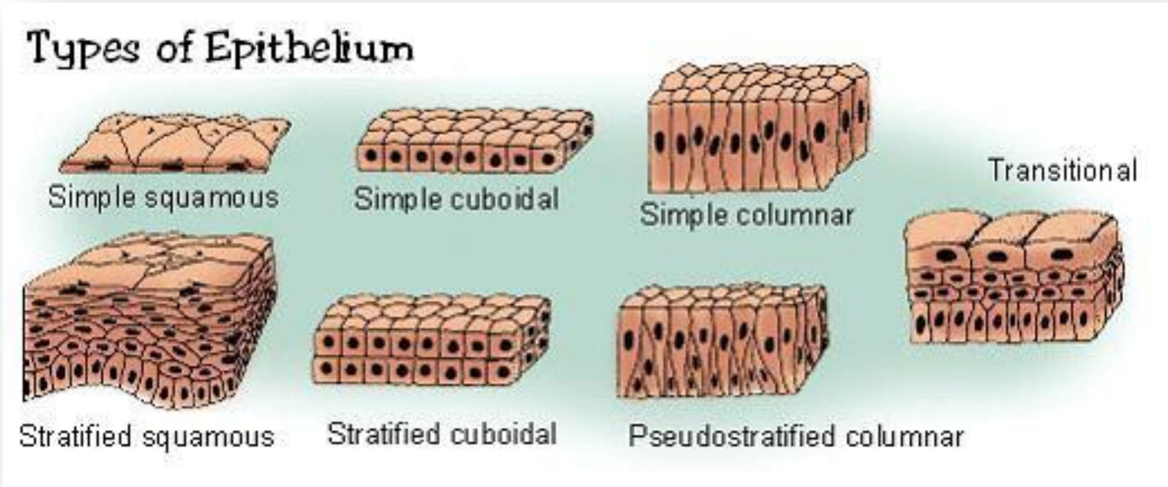
Epithelial tissue covers the outside of the body, the surfaces of all our organs, **body cavities** (any space in the body between the skin and the outermost tissues of the internal organs), and various **glands** which are responsible for creating and releasing specific chemicals throughout the body.

Our skin is made up of epithelial tissue which protects us from potentially dangerous objects in our environment. One way it accomplishes this is by producing the protein **keratin** which covers the epidermis of our skin and serves as an effective outer barrier. Epithelial tissue also is responsible for absorbing nutrients and gases within the digestive and respiratory systems. It secretes several different chemicals throughout our body and it helps the body excrete urine.

Epithelial tissue can be placed into several different categories depending on the number of layers it contains and on its shape. Single-layer epithelial tissue is known as **simple** while tissue with more than one layer is called **stratified**. The shape of the tissue cells also help to classify the epithelial tissue. **Squamous** identifies a thin, flat cell; **cuboidal** is cube-shaped; and, **columnar** cells are much taller than they are wide. The following chart will help you identify the general locations and functions for each of the major epithelial cells in the human body:

Epithelial Tissue Types

Epithelial Tissue type	Structure	Function	Location
Simple squamous epithelium	Single layer of flattened, tightly bound cells	Diffusion and filtration	Forms capillary walls; lining alveoli and body cavities; covering organs
Simple cuboidal epithelium	Single layer of cube-shaped cells	Excretion, secretion, or absorption	Covering surface of ovaries; lining salivary ducts
Simple columnar epithelium	Single layer of column shaped cells	Protection, secretion, and absorption	Lining digestive tract, gallbladder, and excretory ducts of some glands
Stratified squamous epithelium (keratinized)	Multilayered, contains keratin, outer layers flattened and dead	Protection	Epidermis of skin
Stratified squamous epithelium (not keratinized)	Multilayered, lacks keratin, outer layers moistened and alive	Protection and pliability	Linings of oral and nasal cavities, esophagus, vagina, and anal canal
Stratified cuboidal epithelium	Usually two layers of cube-shaped cells	Strengthening of lumen walls	Ducts of larger sweat glands, salivary glands, and pancreas
Pseudostratified columnar epithelium	Single layer of columnar cells	Secretion and absorption	Trachea and upper respiratory tract
Transitional epithelium	Numerous layers of rounded nonkeratinized cells	Swelling	Lining urinary bladder and portions of ureters and urethra



Connective tissue

Connective tissue is the most widespread tissue as it is found around all muscles, blood vessels, and organs. There are four main types of connective tissue in the human body:

Connective tissue proper, Cartilage, Blood, and **Bone**

With the exception of blood, connective tissue acts as "cellular glue" by forming the framework and support structures for all of our body tissues and organs.

Of these four connective tissues, **cartilage** and the **connective tissue proper** both provide a wide array of functions to the human body. Although these two connective tissues contain types which vary in function, both share common features which allows for the support, cushioning, and flexibility of the majority of structures throughout the body.

By far, the majority of connective tissues are made up of a group of proteins collectively known as **collagen**. Nearly 30% of the total protein content within humans is collagen, thus making it the most abundant protein in the human body. Collagen has a significant commercial value to modern industry. Through simple procedures, this protein can be modified into a highly usable compound known as **gelatin**.

Future chapters will focus upon the both blood and bone tissues. But first, you may be wondering...

How can blood be considered a tissue?

Connective tissue is actually a combination of fluid and fibers of various strengths known as a **matrix**, and a few cells. By this definition, our blood is a form of connective tissue as it is a combination of various types of cells, cell parts, and a fluid called **plasma** which contains several dissolved substances as well.

On the following page you will find a chart identifying the name, location, and function of the many types of connective tissue in the human body. As you can see, there is a wide variety of uses for this tissue!

Connective Tissue Types

	Connective Tissue type	Function	Location
Connective tissue proper	Loose (areolar)	Binding and packing; protection and nourishment; holds fluids	Deep to skin; surrounding muscles, blood vessels, and organs
	Dense fibrous	Strong, flexible	Tendons, ligaments
	Elastic	Flexibility	Arteries, larynx, trachea, bronchi
	Reticular	Absorbs waste material	Liver, spleen, lymph nodes, bone marrow
	Adipose (fat)	Stores fat (lipids)	Hypodermis, surrounds most organs
Cartilage	Hyaline	Covers and protects bones; provides support	Joints, trachea, nose
	Fibro-cartilage	Withstands tension and compression	Knee joint and spinal discs
	Elastic	Flexible strength	Outer ear, larynx, ear canal
Bone	Spongy bone	Light, strong, vascular, internal support	Interior of bones
	Compact bone	Strong support, passage of nutrients and waste	Exterior of bones
Blood	Blood	Movement of nutrients	Circulatory system

Muscle tissue

Muscle tissues are made up of a collection of elongated cells which **contract** (shorten) to enable the movement of the organism or its internal organs. This type of tissue makes up over one half of our total body weight. Even while we rest, these tissues are always contracting and expanding a little bit which generates a lot of heat for our bodies. There are three different types of muscle tissue which are named after their location within the body:

Cardiac muscle, Skeletal muscle, and Smooth muscle

Cardiac muscle is an **involuntary** tissue (this means it doesn't need to be told what to do by your brain) which is responsible for pumping blood. It is found in the walls of the heart and is **striated** in appearance. A tissue which is striated contains visual stripes on its surface when viewed under a microscope.

Skeletal muscle is responsible for movement and is considered a **voluntary** tissue. It is classified as "voluntary" because an organism has full control over its movement. The cells which make up skeletal muscle are very long and threadlike and are also referred to as **muscle fibers**. Much like cardiac muscle, skeletal muscle is also striated in appearance.

Smooth muscle is responsible for slow, involuntary movements of the internal organs. It can be found in the **lumen** which is the inside space of a tubular structure like the **esophagus** (the muscular tube which carries your food to the *stomach*). Smooth muscle is not striated, which is the reason for why it has been named "smooth".

Muscle Tissue Types

Characteristic	Skeletal muscle	Smooth muscle	Cardiac muscle
Location	Attached to tendons which are attached to bones	Walls of blood vessels and lumen of organs	Only in the heart
Function	Movement of the body	Movement of materials through lumen and control of blood vessel diameter	Pumping of blood
Cell shape	Long and cylindrical	Spindle-shaped (think of a stretched football)	Branched
Striations	Present	Absent	Present
Mode of control	Voluntary	Involuntary	Involuntary

Nervous tissue

Nervous tissue is responsible for creating and sending **nerve impulses** throughout the body. A nerve impulse can be considered a wave-like signal that moves through the body by an electric current. Nervous tissue is made up of two different structures:

Neurons (nerve cells) and Neuroglia (supporting cells)

The **neurons (nerve cells)** are responsible for sending the nerve impulses throughout the body in a method we will be looking at in a future unit. Neurons are assisted by nearly five times as many supporting cells called **neuroglia.** Specific neuroglia cells are responsible for the production of **myelin**, a lipid which covers parts of the neurons and is vital for the promotion of nerve impulses. You will explore more about nervous tissue during your study of the nervous system.

You have just learned the basics of how cells transport materials in and out of the cell membrane and the four main tissues of the human body. The next few chapters will go much deeper into each specific tissue as it relates to individual organs and organ systems.

I know it's a lot of information, but I know you can do it! I'll see you next week when we dig deeper into...

...the Skin!

Match the following vocabulary terms with their correct definition:

active transport	**facilitated diffusion**	**organelles**
body cavity	**gelatin**	**osmosis**
cardiac muscle	**glands**	**phosphate**
cartilage	**involuntary**	**phospholipids**
cell membrane	**keratin**	**plasma**
collagen	**lipid**	**proteins**
columnar	**lumen**	**semipermeable**
connective tissue	**matrix**	**simple epithelial tissue**
connective tissue proper	**muscle fibers**	**skeletal muscle**
contracts	**muscle tissues**	**smooth muscle**
cuboidal	**myelin**	**squamous**
cytoplasm	**nerve impulse**	***stratified epithelial tissue***
diffusion	**nervous tissue**	**striated tissue**
epithelial	**neuroglia**	
esophagus	**neurons (nerve cells)**	

1)	______________	voluntary tissue which is responsible for movement
2)	______________	"gates" or "revolving doors" within cell membranes which allow certain types of particles to pass through
3)	______________	a chemical made of one atom of phosphorus and four oxygen atoms
4)	______________	a lipid which covers parts of the neurons and is vital for the promotion of nerve impulses
5)	______________	a collection of elongated cells which contract (shorten) to enable locomotion of the organism or movement of the internal organs
6)	______________	a combination of fluid and fibers of various strengths which makes up connective tissue

7)	______________	a pump which drives particles in and out of the cell against the normal flow of diffusion
8)	______________	a special type of diffusion in which only water is being transported through the membrane
9)	______________	a thin, flat skin cell
10)	______________	a wave-like signal that moves through the body by an electric current
11)	______________	actions which are not controlled by the brain
12)	______________	an involuntary tissue making up most of the heart's mass which is primarily responsible for pumping blood
13)	______________	any space in the body between the skin and the outermost tissues of the internal organs
14)	______________	compound formed from processed collagen; used for a variety of industrial products
15)	______________	cube-shaped skin cell
16)	______________	epithelial tissue made of a single layer
17)	______________	epithelial tissue made of several layers
18)	______________	fat
19)	______________	fluid portion of blood
20)	______________	fluid within a cell which acts as a storage area for gases, food, wastes, etc.
21)	______________	group of proteins making up ~30% of all connective tissues; easily and widely converted into gelatin for industrial uses
22)	______________	large molecule made up of a phosphate and two long "tails" of lipids; found in doubled layers as the main component of cell membranes
23)	______________	large organic molecules each possessing a unique function)

24)	______________	most widespread tissue; acts as "cellular glue" forming the framework and support structures for all body tissues and organs
25)	______________	organs responsible for creating and releasing specific chemicals throughout the body
26)	______________	property of the cell membrane which regulates the substances allowed in and out of the cell
27)	______________	protective covering which surrounds a cell
28)	______________	protein produced and used by the epidermis of the skin which provides a protective barrier against infection
29)	______________	responsible for creating and sending nerve impulses throughout the body
30)	______________	responsible for sending the nerve impulses throughout the body
31)	______________	responsible for slow, involuntary movements of the internal organs
32)	______________	skin cells which are much taller than they are wide
33)	______________	specialized structures within a cell
34)	______________	supporting cells: help to support the neurons throughout the body
35)	______________	the inside spaces of a tubular structures such as the esophagus
36)	______________	the movement of any substance from an area of high concentration to an area of low concentration
37)	______________	the muscular tube which carries your food to the stomach
38)	______________	tissue which covers the outside of the body, outer surfaces of organs, body cavities, and various glands
39)	______________	tissues which contain visual stripes on its surface when viewed under a microscope

40)	______________	to shorten
41)	______________	type of connective tissue responsible for protection of bones and flexibility of joints; not as rigid as bone tissue but less flexible than muscle tissue
42)	______________	type of connective tissue which includes tendons, ligaments and fat tissue; strong and flexible tissue which allows the body to hold onto fluids, absorb waste material, and stores fat
43)	______________	very long and threadlike cells which make up skeletal muscle

Choose the correct answer from the following questions:

1) **Facilitated diffusion requires the use of:**
   A) phospholipids
   B) protein gates or channels
   C) cytoplasm
   D) epithelial tissue
   E) organelles

2) **The epithelial tissue found within internal areas that are regularly exposed to friction, such as the esophagus, is:**
   A) transitional
   B) simple squamous epithelium
   C) pseudostratified columnar epithelium
   D) simple cuboidal epithelium
   E) stratified squamous epithelium

3) **The movement of a fluid through a cell membrane from a lower concentrated area to a higher concentrated area is called:**
   A) active transport
   B) bulk transport
   C) osmosis
   D) diffusion

4) **Fat is otherwise known as:**
   A) adipose tissue
   B) loose connective tissue
   C) osseous tissue
   D) areolar tissue
   E) dense connective tissue

True or false:

5) The four main tissue types are squamous, simple, cuboidal, and columnar.

6) The process of facilitated diffusion does not require energy.

7) Stratified epithelium consists of one layer of epithelial cells.

8) Smooth muscle cells are spindle-shaped cells that have an involuntary mode of control.

Application Question:

Compare the cell shapes and thicknesses of the epithelium tissues. Focus specifically on tissues which provide protection and those which carry out diffusion and/or secretion of materials.

Chapter Three

Integumentary System

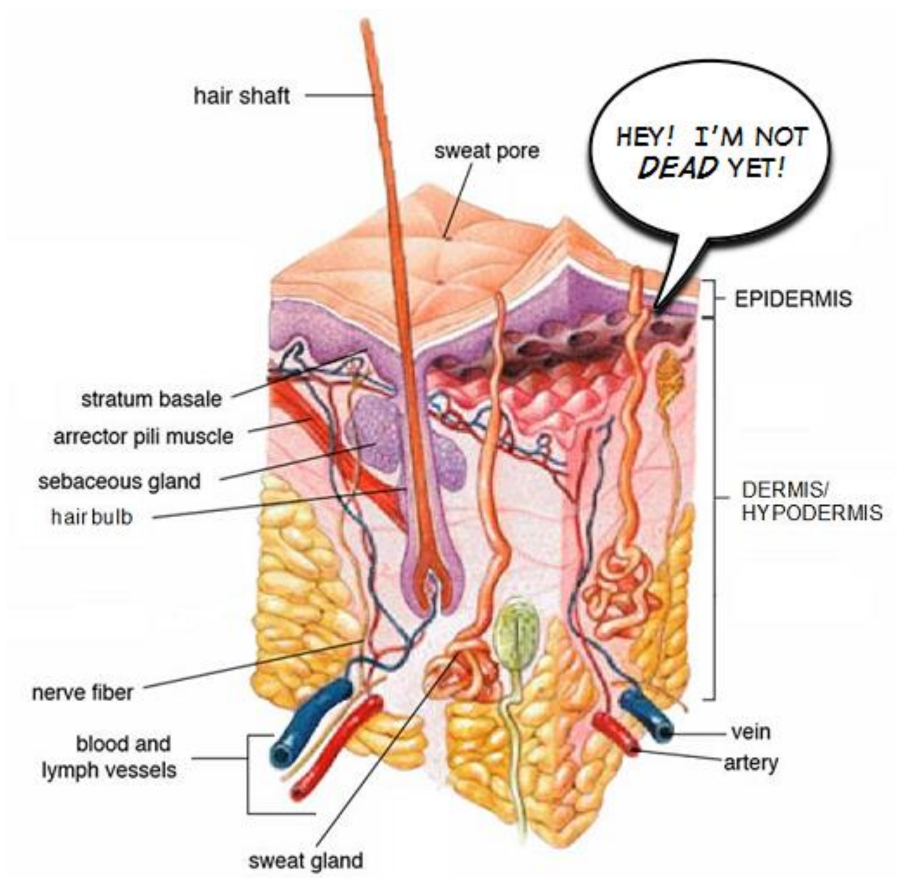
It's time to start looking at the organ systems within our bodies. Our first stop...

The Integumentary System

The **integumentary system** is made up of our skin and all of the items which can be found within the skin including hair, nails, and glands.

The outermost layer of our skin we see every day (which is known as the **epidermis**) is made up of 30-50 layers of stratified squamous epithelium. These tissue layers are external (towards the surface of the body) to a second layer of the skin known as the **dermis/hypodermis**.

As with all of the organs in the human body, the function of the skin is largely determined by its structure. The outer epidermis is **avascular** meaning it is not supplied with any nutrients from the blood. Without a regular supply of oxygen, the cells within these layers of our skin are dead.



Yes... All of the skin you see on the human body is actually made up of dead cells!

In fact, it takes an average of seven weeks for the outermost layers of epidermis to be completely removed from your body. That's right! You are shedding your skin at this very moment! If fact, you lose approximately 600,000 particles of skin per hour, which is about 1.5 pounds (680 grams) per year!

But if you are constantly shedding skin, where do the new layers of tissue come from?

As you move deeper into the epidermis you pass through several sub-layers of tissue until you finally reach one known as the **stratum basale**. This sub-layer is attached to the dermis/hypodermis layer of the skin with the help of a connective tissue known as **basement membrane**. The dermis/hypodermis as well as the stratum basale is **vascular** as they are regularly supplied with nutrients from the blood. As the stratum basale receives plenty of nutrients from the dermis/hypodermis blood supply through the basement membrane, it regularly grows and divides into new cells. The deeper cells within the stratum basale remain close to the dermis/hypodermis layer as they remain in contact with the rich nutrient supply. The cells that are not close to the dermis/hypodermis are pushed outward, towards the surface of the skin. And, within seven weeks these cells become the outermost layers of the epidermis where they perish due to a lack of nutrients from the blood.

The stratum basale has another very important function:

This vascular layer of the skin creates a specific chemical known as **vitamin D.** What is unique about this compound is the energy source required for its production - the sun! Specific wavelengths of light from the sun allow the stratum basale to generate this very important vitamin. Once secreted throughout the body, vitamin D (also known as the "sunshine vitamin") is responsible for the absorption of the elements calcium and phosphorus from the foods we eat. These two elements, as you will learn, are vital for the structure of the skeletal system.

Three other functions occur within the epidermis are worth mentioning here:

1) Special cells within the epidermis regularly produce a protein known as *keratin*. As the dead cells are pushed externally, keratin spreads throughout the tissue layers, toughening the tissue layers and creating a semi-waterproof barrier on the surface of the skin.

2) Within the stratum basale you will find cells which are responsible for the production of a pigment called **melanin**. Melanin is a brown-black pigment which varies in concentration among different ethnic groups and is very good at absorbing harmful ultraviolet light. The formation of a tan several hours/days after being exposed to the sun is due to an increased production of melanin within the epidermis.

3) Hair, nails, **sudoiferous glands** (sweat-producing), and **sebaceous glands** (oil-producing) all begin to form within the epidermis during our early development. As we grow, these structures grow deep into the lower layer (dermis/hypodermis) of skin where they can be more firmly supported and nourished. Speaking of which...

Let's look under the epidermis and explore the second layer of the skin – the dermis/hypodermis

As stated above, the dermis/hypodermis is vascular in nature and contains several types of connective tissue fibers. These fibers provide the elasticity and strength needed to support the hair, nails, glands, and **sensory receptors**.

Sensory receptors respond to various stimuli to the skin which include touch, pressure, temperature, and pain. Certain areas of the body have a much higher concentration of sensory receptors such as the palms of the hands, soles of the feet, lips, and **genitalia** (sex organs) which make them very sensitive to stimuli.

In addition to sensory receptors, the dermis/hypodermis also supports the structures of the hair. A single hair follicle receives all of its nutrients from the dermis/hypodermis into an enlarged **bulb** containing the **root** of the hair follicle. The root is vascular in nature and receives its nutrients from the blood supply. What we see sticking out of our skin is the **shaft** of the hair. Just as our outermost skin layers are made up of dead tissues, the hair we see is made up of layers of keratin-rich dead cells. As new cells develop within the root of the cell, older cells get pushed farther away. Without a steady source of nutrients from the bulb, these cells die and are compacted as they travel externally through our skin. Yep... all of the hair we can see on our bodies are made up of layers of dead cells too!

What causes the different colors of our hair?

Well, for our blond, brunette, and black-haired friends out there it is the amount of melanin in the hair follicle that determines its color. As we grow older, our production of melanin slows down which, in turn, causes our hair to turn grey or white. As for you red heads out there, you can thank a completely different iron-containing pigment (**trichosiderin**) for your scarlet curls.

Hair follicles also help with the functions of our oil-producing glands as well. The sebaceous glands within the dermis/hypodermis secrete an acidic chemical known as **sebum** onto the shaft of the hair follicle where it can be spread to the surface of the skin. Sebum helps to protect, lubricate, and further waterproof the skin. Due to its acidic nature, it also helps to defend the skin from bacteria which cannot live in acidic environments.

To give you an idea of how many things are packed into your skin, take these facts into consideration...

In an average square inch ($6.4cm^2$) of skin, the following approximate amounts of items can be found:

20 feet (6.1 meters) of blood vessels

600+ sweat glands

60+ hair follicles

and nearly 100 sebaceous glands

Your skin is literally packed with things that help you every day! And we haven't even begun to look at the nervous system which will add another 77 feet (23.5 meters) of nerve cells and more than a thousand nerve endings which allow us to feel sensations such as pressure, temperature, and pain all within that same square inch!

We are going to spend a lot of time on our nervous system in future chapters, but for now I have saved one more important function of the dermis/hypodermis for you...

The skin helps to maintain our constant body temperature!

In order to explain this, think back to Chapter One when we were looking at our aquarium heater. The heater contained a thermometer (receiver), a thermostat (control center), and heating coils (effector). Our bodies can perform the same functions but with much different structures.

First of all, the sensory receptors in our skin act much like a thermometer. These receivers gather information about the temperature on the surface of the skin and send this information to a control center known as the **hypothalamus**. This is a gland in our brain that acts like a thermostat for our body. The hypothalamus can send information back to the skin to help control the internal temperature of the body through a variety of effectors which can cause the following responses:

Regulation of blood flow through specific areas of the body, Sweating, and Shivering

Let's say you're outside on a hot summer day. Your skin has detected that its surface temperature is well above 98.6 degrees so it sends a message to the hypothalamus which then begins to set things in motion to cool you down. By allowing the inner walls of the blood vessels to become thinner through a process known as **vasodilation,** blood is allowed to flow more freely through the warmed area. In addition, heat is allowed to escape through the vessels more readily and into the epidermis where it can be released into the environment thereby cooling the individual.

If you have ever exercised to the point that your face becomes flushed, you have seen vasodilation in action! At the same time, our sudoriferous glands secrete sweat onto the surface of the skin, taking with it much of this newly released heat from the blood. Once at the surface, the sweat (and heat) is carried away from the skin through evaporation. Cool, huh?

This negative feedback process will continue until the hypothalamus detects the skin temperature falls below 98.6 degrees. At this time it triggers the process of **vasoconstriction** which thickens the blood vessel walls and reduces blood flow. This "thickening" of the blood vessel walls insulates the vessels and prevents heat from escaping into the surrounding areas. If further heat is needed for the body to remain near 98.6, the hypothalamus may induce the body to shiver. This increased movement by the muscles of our body generates a quick burst of heat to our system thereby warming us up a tiny amount.

Next week, you will begin digging under the surface of our epidermis to study the various structures which make up...

...the Skeletal System

Anatomy & Physiology - Connections

The integumentary system, much like all of the other future systems you will be exploring are directly connected to the cardiovascular system. This is accomplished due to the vascular nature of the dermis/hypodermis layer which is regularly supplied with nutrients from the blood.

In addition to the nutrients supplied by the cardiovascular system, the skin drains excess fluids and nutrients through the lymphatic system. The integumentary system also acts as a physical barrier to foreign and potentially damaging organisms from entering our body. This function is one of several performed by the immune system.

Future studies of these independent systems will help you identify how the integumentary system is connected to the other systems of the body.

About the "Connections"

Even though you will be moving through this text one body system at a time, **all** of the body systems you will be exploring are closely connected to each other. Remember, the primary goal for your body is to maintain homeostasis with all of the functions it performs. Therefore, in each of these "Connections" you will have the opportunity to see how the current body system you are exploring influences the other systems you have previously studied.

As you may probably guess, these "Connections" will not be exhaustive in their scope. A collegiate course/textbook will provide a much more thorough examination of the interconnectedness between all of the systems. Nevertheless, this text will give you a strong foundation for the main concepts concerning the anatomy and physiology of the human body and the cooperative nature of its systems to achieve homeostasis.

Match the following vocabulary terms with their correct definition:

avascular	**integumentary system**	**stratum basale**
basement membrane	**melanin**	**sudoiferous glands**
bulb	**root**	**trichosiderin**
dermis/hypodermis	**sebaceous glands**	**vascular**
epidermis	**sebum**	**vasoconstriction**
genitalia	**sensory receptors**	**vasodilation**
hypothalamus	**shaft**	**vitamin D**

1)	______________	a brown-black pigment responsible for absorbing harmful ultraviolet light within the skin
2)	______________	a gland in our brain which acts like a thermostat for the body
3)	______________	a system consisting of the skin, hair, nails, and glands within the skin
4)	______________	a vascular "anchor" for an individual hair follicle
5)	______________	acidic chemical secreted by sebaceous glands near hair follicles to the surface of the skin; used to protect, lubricate, and waterproof the skin
6)	______________	being regularly supplied with nutrients from the blood
7)	______________	chemical created within the stratum basale through exposure to the sun; responsible for the absorption of calcium and phosphorus
8)	______________	connective tissue which attaches the stratum basale to the dermis
9)	______________	enlarged base at the end of a single hair which contains its root
10)	______________	internal layer of skin; interior to the epidermis
11)	______________	iron-containing pigment within red-haired individuals

12)	______________	not being supplied with nutrients from the blood
13)	______________	oil-producing glands
14)	______________	receptors within the skin that respond to various stimuli such as touch, pressure, temperature, and pain
15)	______________	sex organs
16)	______________	sub-layer of tissue attached to the dermis with the help of the basement membrane
17)	______________	sweat-producing glands
18)	______________	the outermost and visible layer of skin
19)	______________	thickening of blood vessel walls
20)	______________	visible portion of the hair
21)	______________	widening the internal walls of blood vessels

Choose the correct answer from the following questions:

1) **The outermost layer of skin is:**
   A) not avascular
   B) called the dermis/hypodermis
   C) composed of connective tissue
   D) covered with keratin
   E) vascular

2) **The epidermis is made up of 30-50 layers of which type of tissue?**
   A) simple columnar epithelium
   B) areolar tissue
   C) dense fibrous connective tissue
   D) stratified squamous epithelium
   E) adipose tissue

3) **The darkening of the skin that occurs when a person is exposed to the sun is due to:**
   A) melanin
   B) keratin
   C) oil
   D) sweat

4) **Sweat glands associated with hair are:**
   A) sudoriferous glands
   B) sudoriferous glands and sebaceous glands
   C) sebaceous glands

5) **Although you get wet while swimming, a tough protein within the skin prevents it from soaking up moisture like a sponge. This substance is:**
   A) vitamin D
   B) keratin
   C) melanin
   D) sebum

6) **A splinter penetrates to the deepest layer of the epidermis on your foot. This layer is called the:**
   A) stratum granulosum
   B) stratum spinosum
   C) stratum corneum
   D) stratum lucidum
   E) stratum basale

Application Question:

Exposure to a hot environment causes the body to sweat. The hotter the environment, the greater the sweating. Two anatomy and physiology students are arguing about the mechanism involved: Student A claims this response is a positive feedback mechanism, and student B claims it is a negative feedback mechanism. Do you agree with student A or student B and why?

Chapter Four

Skeletal System

This week, we are going to explore the one concept most people quickly associate the study of anatomy and physiology with:

The Skeletal System

In order to move forward into this topic I would highly recommend reviewing the information back in Chapter Two since we will be spending a lot of time dealing with connective tissues.

The skeletal system is made up of three individual structures:

Bones, Cartilage, and Joints

If you add in the fact that your bones are responsible for creating all of your blood (another connective tissue), you can easily state that the majority of your skeletal system is made up of connective tissues.

This system performs five different functions for the human body:

Support

Our skeletal muscles are attached to bones through the use of **tendons** (a type of connective tissue proper). Without bones, however, there would be no rigid foundation to support these skeletal muscles and our bodies would look (for lack of a better term) like a sack of meat within the skin.

As you learned back in Chapter Two, *cartilage* is a flexible connective tissue found throughout the body and is primarily made of the protein *collagen*. It is cartilage which gives our bones protection and support while providing flexibility to our body.

Protection

Several of our vital organs such as the brain and heart are protected by various types of hardened bone. In addition, our blood is created within the protective walls of specific bones.

Movement

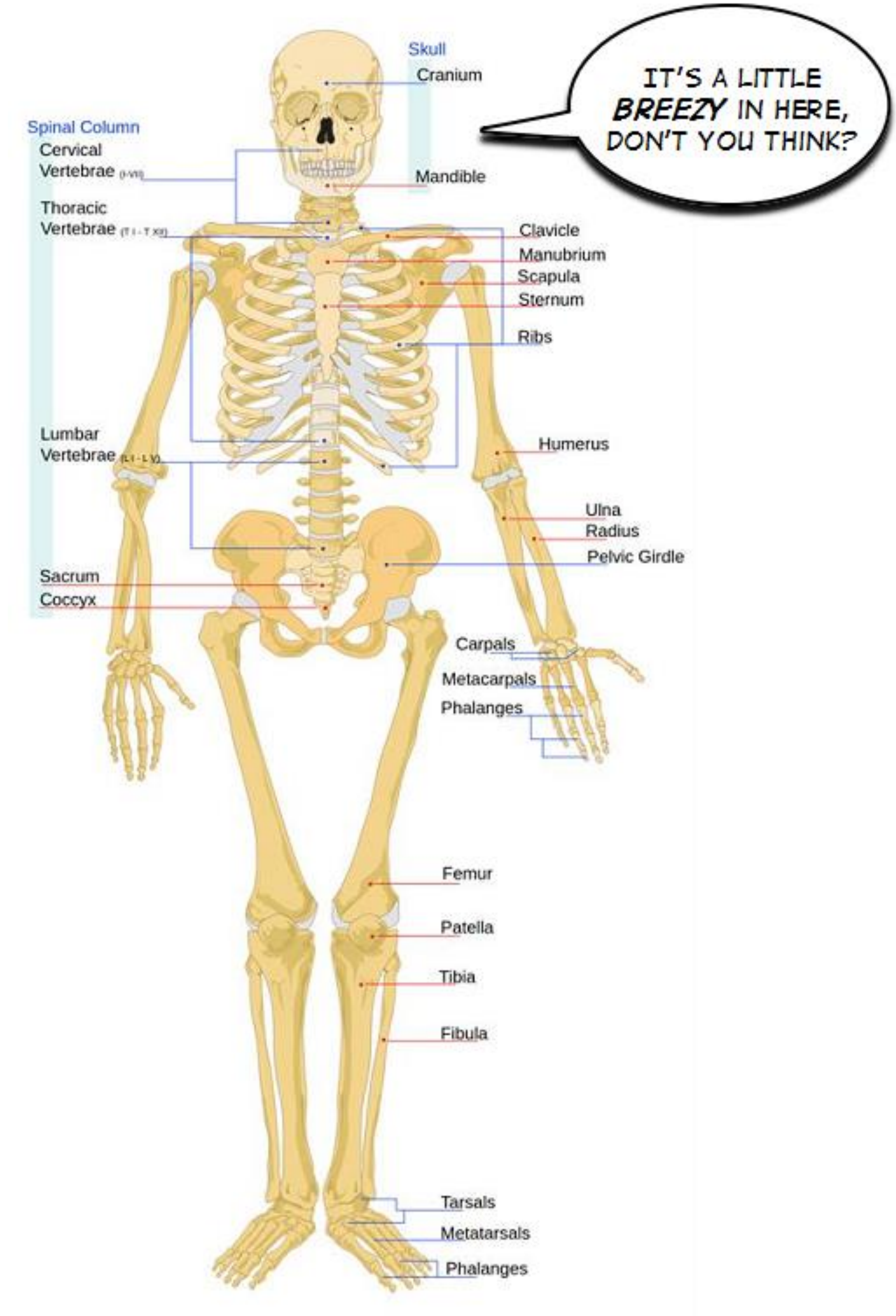
Our bones are attached to each other with a type of connective tissue proper called **ligaments**. These strong and flexible connective tissues allow our bones to act as levers when their attached skeletal muscles contract (get shorter). As our muscles contract, our bones are pulled together through their connections at the joints.

Blood formation (Hematopoiesis)

As stated above, our bones are the areas where new blood cells are being formed. We will explore this in more detail very soon!

Mineral storage

Within the human body, the majority of the elements calcium and phosphorus can be found within the bones and teeth. The large amount of these two elements gives our bones their rigid features. Both elements are very important to various functions of the human body which include the structure and function of our muscles, blood, and DNA. When additional calcium and phosphorus are needed throughout the body, these elements can be taken from the bones. If you recall from Chapter 2, the element phosphorus is used in the construction of cell membranes.


IT'S A LITTLE
BREEZY IN HERE,
DON'T YOU THINK?
Skull
Cranium
Mandible
Spinal Column
Cervical Vertebrae
Thoracic Vertebrae
Lumbar Vertebrae
Sacrum
Coccyx
Clavicle
Manubrium
Scapula
Sternum
Ribs
Humerus
Ulna
Radius
Pelvic Girdle
Carpals
Metacarpals
Phalanges
Femur
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges

Even though there are 206 bones in the typical human skeleton, you are **not** going to be asked to memorize all of them. You're welcome ☺

However, you should be familiar with all of the major bones of which there approximately thirty. The location of these bones can be found in two areas that have been labeled:

The Axial Skeleton and the Appendicular Skeleton

The **axial skeleton** is responsible for protecting the head, neck, and trunk of your body. These bones include the *skull*, the **vertebral column** (your spine), and the *rib cage*. The **appendicular skeleton** includes the rest of your bones such as the pelvis and all of the bones of your **extremities** (your arms and legs).

As you can see, our bones have a variety of structures and each has its own unique function as well. We can organize all of these bones into four different categories based upon their shape:

Long bones, Short bones, Flat bones, and Irregular bones

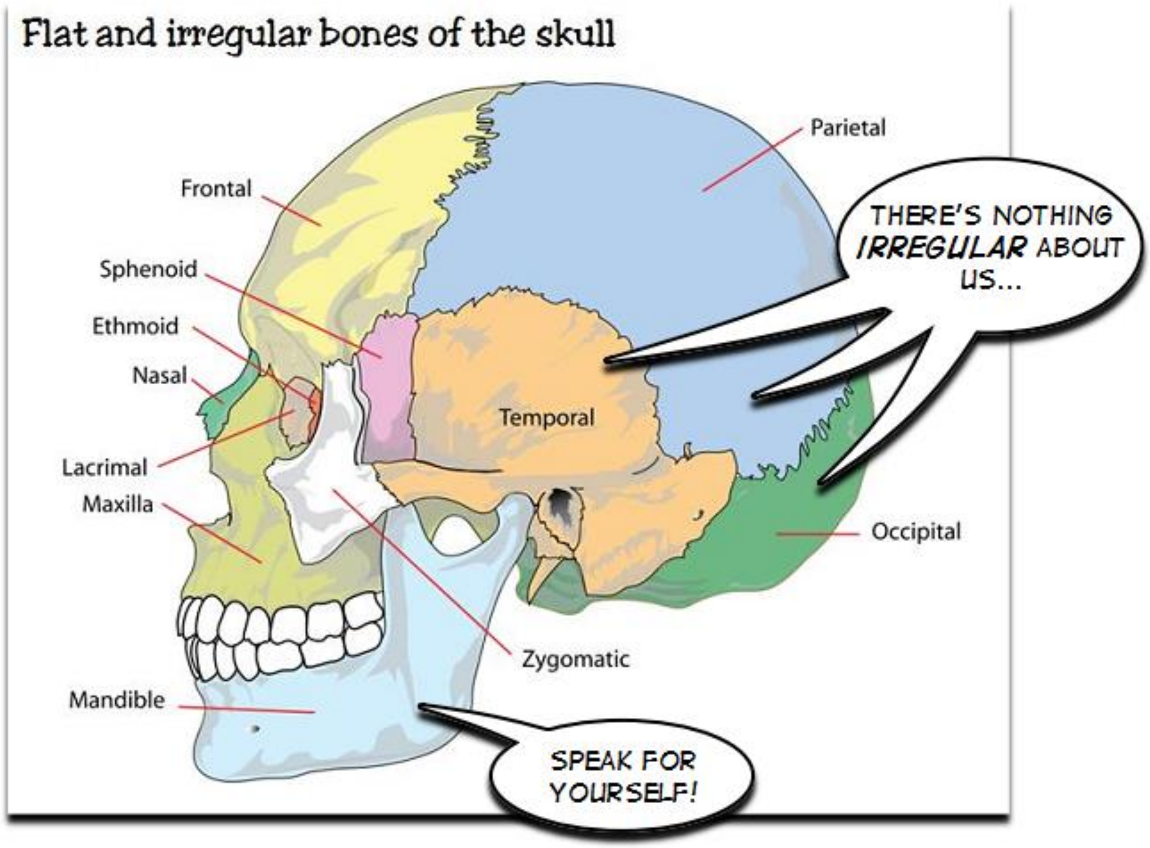
Long bones are those which are typically found within the arms and legs. These bones are like the main walls in the foundation of your home. They hold and support the majority of your body weight at any given time.

Short bones can be found in your wrists and ankles and their functions are usually to allow our bodies to move more freely.

Flat bones, like those found in your skull and pelvis, have a flattened structure (as their name implies) and can usually be found protecting the softer tissues/organs in our bodies.

Irregular bones have many different shapes. Each bone in our vertebral column, our jawbone (**mandible**), and our kneecap (**patella**) are all examples of irregular bones.

We could spend a tremendous amount of time looking at the various structures and functions for each type of bone; however, let's spend our time on the largest of the bones – the long bones.



The following chart will tell you each of the long bones in the body and their general location:

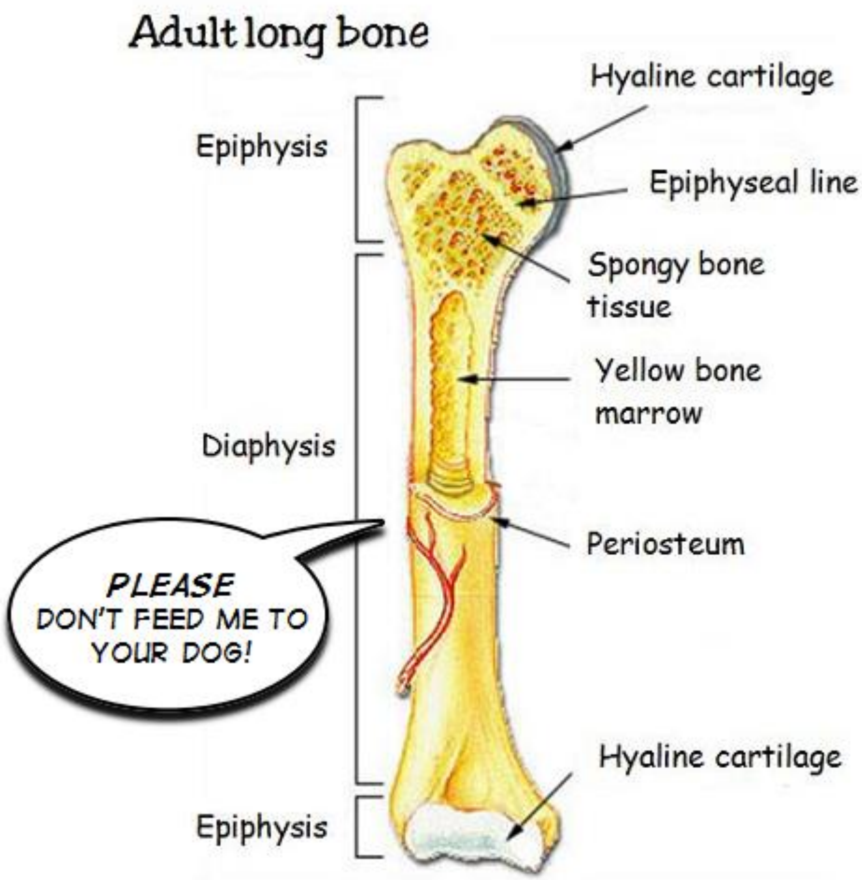
Long bones within the human body:

Long Bone	Location
Humerus	Upper arm
Radius	Lateral bone in the lower arm
Ulna	Medial bone in the lower arm
Femur	Upper leg
Tibia	Medial bone in the lower leg
Fibula	Lateral bone in the lower leg
Phalanges	Fingers and toes
Metacarpals	Between the fingers and the short bones of the wrists
Metatarsals	Between the toes and the short bones of the ankles

Like most bones of the skeleton, the long bones are composed of **compact bone tissue** and **spongy bone tissue**. Compact bone tissue is the hard outer layer, while the spongy bone tissue is the porous, highly vascular inner portion. The structure of the long bones includes a long shaft called a **diaphysis** capped on both ends with an enlarged rounded end called an **epiphysis**.

The epiphysis is made up of spongy bone tissue and is filled with **red bone marrow**. It is within the red bone marrow that **hematopoiesis** (the formation of blood cells) takes place. A thin layer of compact bone tissue surrounds and protects each epiphysis.

The diaphysis is made up mostly of compact bone tissue which gives it considerable strength. A hollow area can be found within the diaphysis which is filled with **yellow bone marrow.** This type of marrow serves as a storehouse for fat which can be converted into energy if needed.



Even though our bones are covered in a protective layer of compact bone tissue, it is still a living organ! This means the bones must have a way of receiving nutrients from the blood and removing waste from their cells. This is accomplished through the **periosteum**, which covers our bones and allows for the transfer of nutrients and waste in addition to providing areas of attachment for tendons.

How are bones formed and how do they grow?

This is another one of those questions we could spend all day talking about. To make things a little simpler we are going to look at a basic model for bone development also known as **ossification**.

Before we are born, the main bone-building cells during our development are known as **osteoblasts**. These cells absorb the mineral calcium from the blood supplied by the mother (primarily through the digestion of milk and dairy products as well as through leafy greens and other foods) and begin creating bone tissue. As the tissue is being generated, more osteoblasts become integrated into the new tissue (much like gravel being added to concrete) and mature into **osteocytes** which help to maintain and support the ever growing layers of skeletal tissue. While this is occurring, another type of cell within the skeletal tissue known as the **osteoclasts** secrete proteins that act to <u>destroy the bone</u>.

Why would you want your newly-formed bone to be destroyed?

If you remember, the largest bones in your body, *the long bones,* have a hollow interior shaft that acts as a storehouse for fat. There has to be a way to hollow out that bone! This is where the osteoclasts get to work. These cells break down the calcium-rich tissue inside the diaphysis until a hollow opening exists within the bone. The osteoclasts continue to break down the inside of your bones until a specific thickness is achieved (which is determined by your DNA but we'll get into that another day). At this point, the osteoblasts continue to form new bone tissue at the same rate as the osteoclasts are destroying it! This keeps the thickness of your bones relatively stable throughout your life while constantly providing new and fresh tissues to be formed. Cool, huh?

Throughout childhood, your number of osteoblasts outnumbers the osteoclasts. This is a good thing as it allows your body to continually grow! However, the number of osteoblasts becomes much lower as we age. This creates a series of potential problems for our bones as we get older.

In addition to its cooperation with the osteoblasts, the osteoclasts also perform a couple of other very important functions as well. When you do not have enough calcium within your body, the osteoclasts work to destroy parts of your bones to release some of its calcium into your blood supply. And, whenever you break a bone, it is the osteoclasts which help to repair the break!

That explains how your long bones become hollow. But how to they become "long"?

Your long bones continue to lengthen from birth through adolescence. This lengthening is achieved by the activity of two cartilage plates, called **epiphyseal plates** (also known as the **growth plates**), and are located where the diaphysis meets the epiphyses on both of its ends. The growth plates continually produce new cartilage and push these cells towards the end of the epiphyses where they eventually become transformed into bone.

These "plates" continue to provide new cartilage until we reach our adult height (normally before the age of 25). As new cells develop on these areas the length of the shaft (diaphysis) increases at both ends and the ends of each bone (epiphyses) moves farther apart. After we reach our adult height, the epiphyseal plates stop developing new cartilage between the epiphysis and diaphysis and the existing cartilage eventually is transformed into bone. All that remains of the growth plate at this time is a small line of cells in the epiphysis area known as the epiphyseal line.

Let's take a brief look at some of the other bones within your body…

Skull

The skull contains a total of 22 different bones; eight of these are flat bones which are joined together to protect your brain and sense organs while the remaining 14 bones give your face its shape and helps to hold your teeth in place.

Vertebrae

Vertebrae are the small irregular bones within your vertebral column (backbone or spine) which help you move your head and chest while encasing and protecting your **spinal cord** (a large bundle of nerve fibers). Your "backbone" curves in four different areas:

Cervical (neck) curvature

Thoracic (chest) curvature

Lumbar (small of the back) curvature

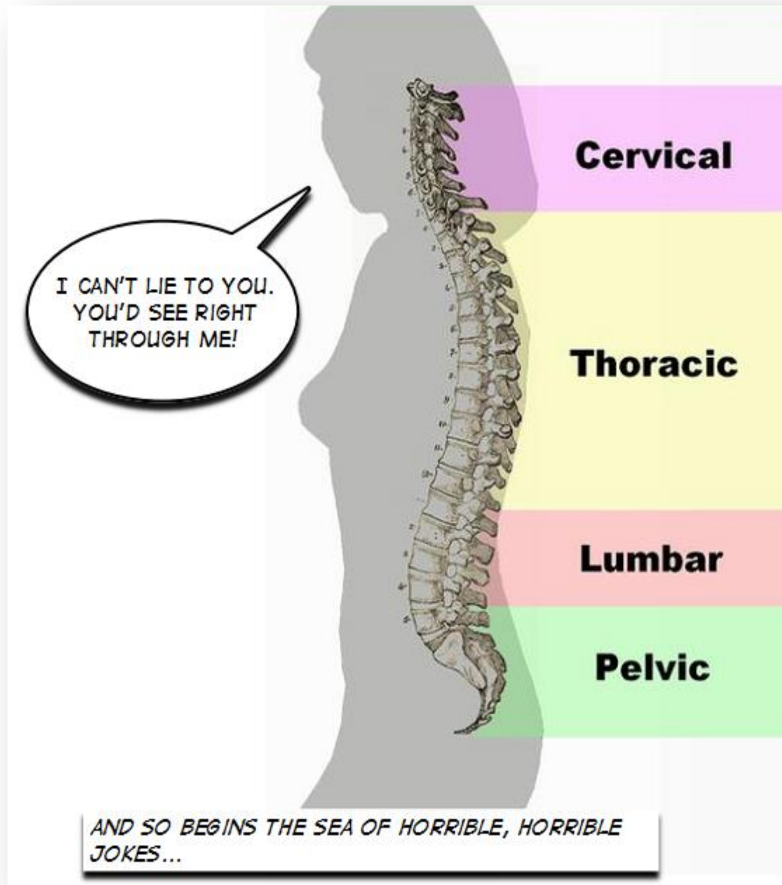
Pelvic curvature

Cervical (neck) curvature

Contains seven vertebrae and is found within the neck

Thoracic (chest) curvature

Contains twelve vertebrae and is attached to the ribs



Lumbar (small of the back) curvature

Contains five vertebrae and supports a significant amount of the human body's weight

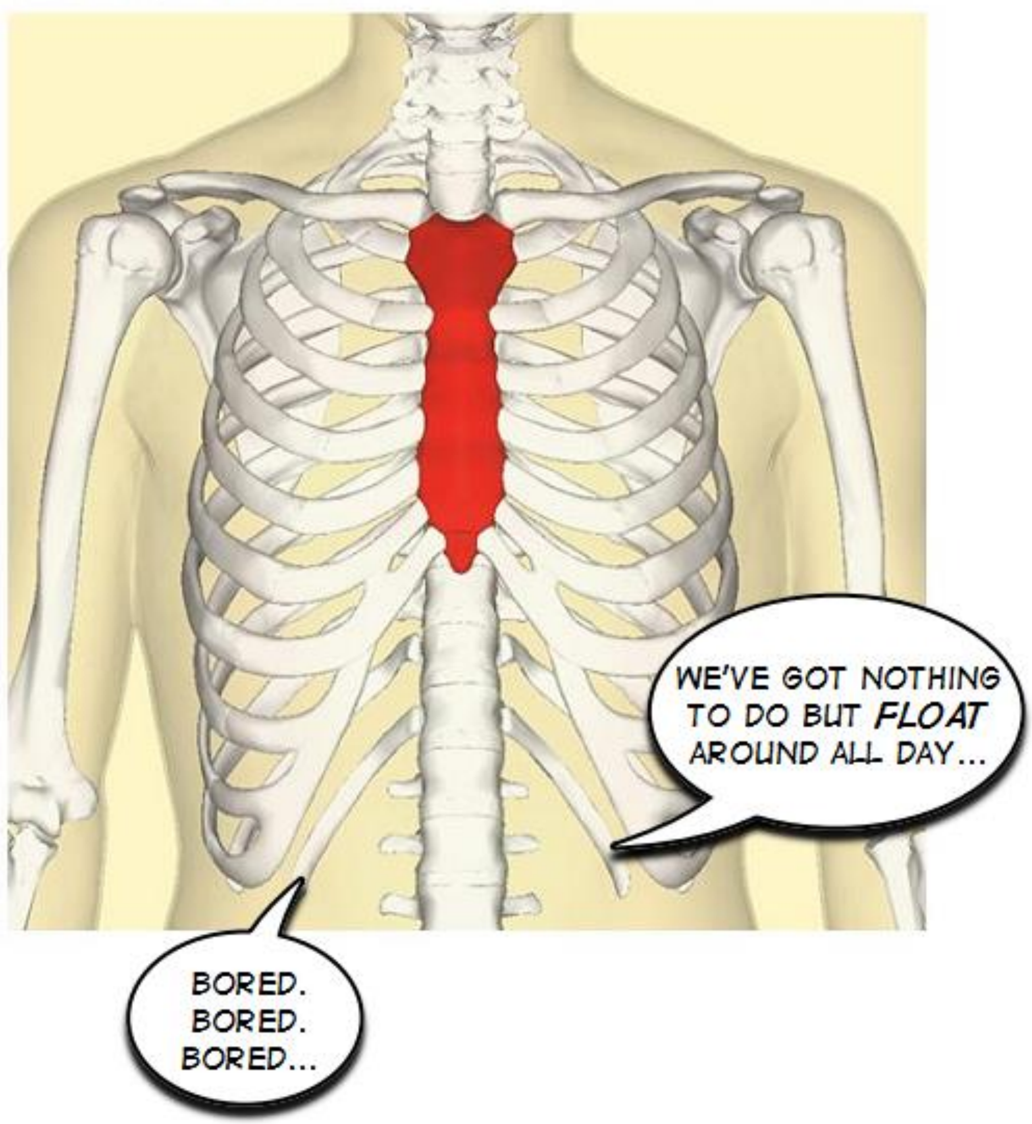
Pelvic curvature

The pelvic curvature contains five vertebrae which are fused together and is known as the **sacrum**. The sacrum is attached to our **pelvis** (hipbones) and four more fused vertebrae which make up the **coccyx** (tailbone).

Ribs

Twelve pairs of ribs attach to the thoracic curvature of the spine and make up what is called the **rib cage**. The rib cage is responsible for protecting most of the organs within the axial skeleton and plays an important role in the act of breathing. The first seven pairs of ribs are attached to the **sternum** (breastbone) in the front (anterior) of our body. The eighth, ninth, and tenth pairs of ribs are attached to the seventh pair of ribs and are called **false ribs**. The last two pairs of ribs are not attached to the ribcage at all and are known as **floating ribs.**

Sternum (red) and Ribs



What about the structures that holds bones together?

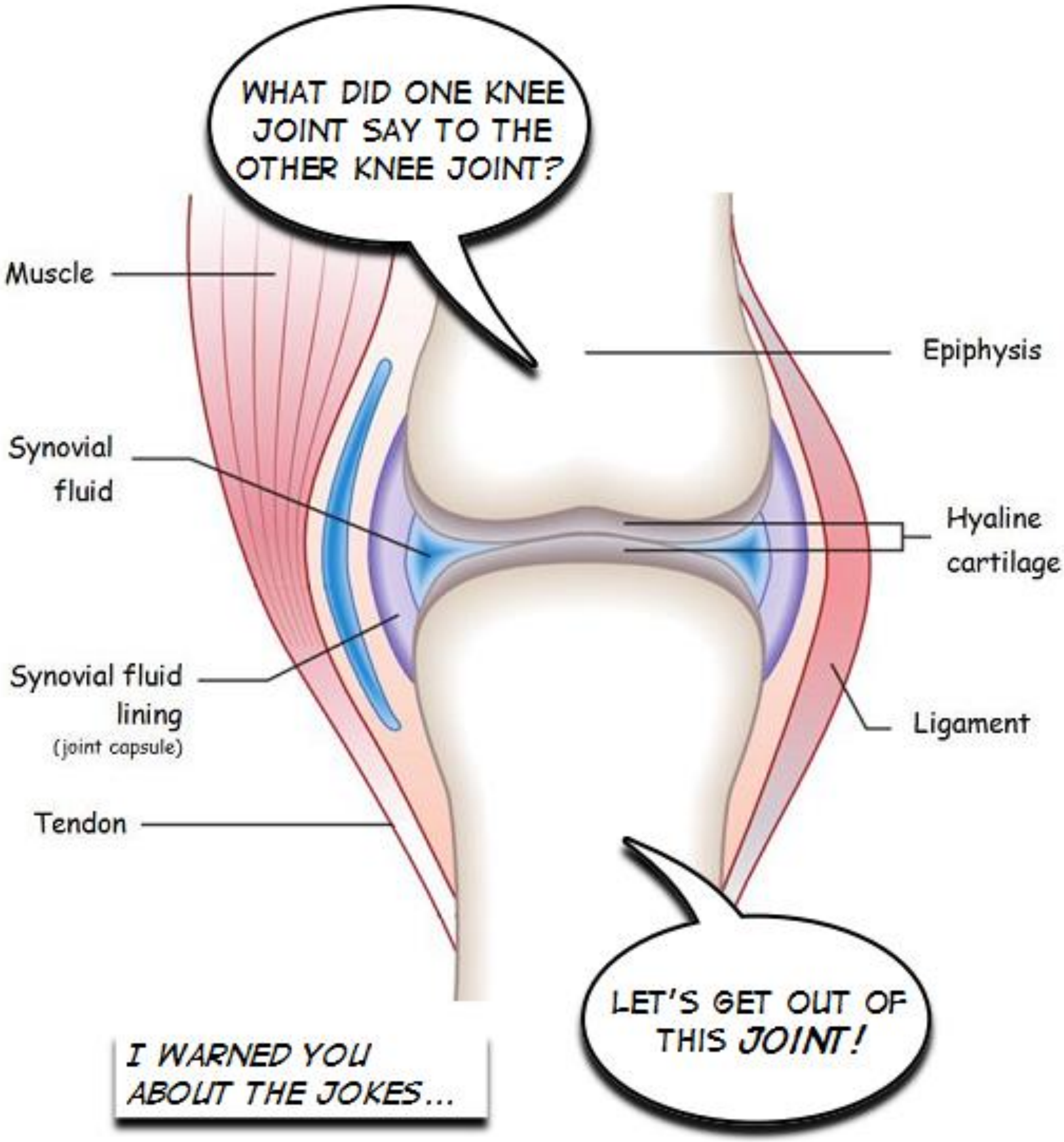
Every area in the human body that holds two bones together is known as an **articulation** (joint). The ends of bones that are connected to other bones through a joint (like the knee or elbow) tend to be covered with a type of cartilage called **hyaline**. This smooth connective tissue is very slippery and allows tissues to move/slide over each easily. However, not all joints allow bones to move at all! There are three different types of joints in the human body:

Fibrous, Cartilaginous, and Synovial

Fibrous joints do not allow any movement to exist at all between the two bones. These are very rigid connections. The joints between the eight flat bones of the skull are examples of fibrous joints. I don't believe you would want the bones of your skull to start moving around!

Cartilaginous joints are made up of either hyaline cartilage or fibro-cartilage and provide little if any movement at all. The rigid connections between the ribs and the sternum are cartilaginous joints which do not allow any movement; however, our vertebrae are separated by disks of fibro-cartilage which allow slight movement under pressure and are still classified as cartilaginous joints.

Synovial joints include all freely moving joints in the human body such as those found in the shoulders, knees, elbows, wrists, etc. Within this type of joint a hyaline layer of cartilage covers the ends of the connecting bones allowing the bones to move more freely against each other. In addition, a synovial joint is entirely contained within a sealed fluid-filled "pocket." This fluid is known as **synovial fluid** and helps to lubricate the cartilage between the bones.


WHAT DID ONE KNEE JOINT SAY TO THE OTHER KNEE JOINT?
Muscle
Epiphysis
Synovial fluid
Hyaline cartilage
Synovial fluid lining
(joint capsule)
Ligament
Tendon
LET'S GET OUT OF THIS *JOINT!*
I WARNED YOU ABOUT THE JOKES...

Anatomy & Physiology - Connections

How the following body systems affect the skeletal system		How the skeletal system affects the following body systems	
Integumentary	Production of vitamin D needed for calcium and phosphorus absorption	Provides framework for muscle and integumentary systems	**Integumentary**

Match the following vocabulary terms with their correct definition:

appendicular skeleton	**hematopoiesis**	**rib cage**
articulation	**hyaline**	**sacrum**
axial skeleton	**irregular bones**	**short bones**
cartilaginous joints	**ligaments**	**spinal cord**
cervical (neck) curvature	**long bones**	**spongy bone tissue**
coccyx	**lumbar curvature**	**sternum**
compact bone tissue	**mandible**	**synovial fluid**
diaphysis	**ossification**	**synovial joints**
epiphyseal plates	**osteoblasts**	**tendons**
epiphysis	**osteoclasts**	***thoracic (chest) curvature***
extremities	**osteocytes**	**vertebrae**
false ribs	**patella**	**vertebral column**
fibrous joints	**pelvic curvature**	**yellow bone marrow**
flat bones	**pelvis**	
floating ribs	**periosteum**	
	red bone marrow	

1)	______________	8th-10th pairs of ribs which are attached to the seventh pair of ribs
2)	______________	a large bundle of nerve fibers protected within the vertebral column
3)	______________	a section of the spinal cord which contains five vertebrae and carries most of the weight of the human body
4)	______________	a section of the spinal cord which contains twelve vertebrae and is attached to the ribs
5)	______________	a type of connective tissue proper which connects bones to other bones

6)	______________	a type of connective tissue proper which connects muscles to bones
7)	______________	all freely moving joints in the human body such as those found in the shoulders, knees, elbows, wrists, etc.
8)	______________	arms and legs
9)	______________	bones having many different shapes; examples include the jawbone and kneecap
10)	______________	bones which are responsible for protecting the head, neck, and trunk of the body
11)	______________	breastbone; attaches the first seven pairs of ribs
12)	______________	cells found within the center of a bone which secrete proteins that destroy bone tissue
13)	______________	enlarged rounded end of a long bone
14)	______________	five vertebrae which are fused together forming one part of the pelvic curvature
15)	______________	flattened bones found in the skull and pelvis which typically protect softer tissues/organs
16)	______________	fluid found within a sealed pocket containing a synovial joint; helps to lubricate the fibro-cartilage between the bones
17)	______________	form of connective tissue which is very smooth and allows tissues to move/slide over each easily
18)	______________	found in wrists and ankles; allows the body to move more freely
19)	______________	found within spongy bone tissue of long bones; site of blood cell production
20)	______________	hard outer layer of bones
21)	______________	hipbones
22)	______________	jawbone

23)	______________	joints which are made up of either hyaline cartilage or fibro-cartilage and provide little if any movement
24)	______________	joints which do not allow any movement to exist at all between the two bones
25)	______________	joints; an area in the human body that holds two bones together
26)	______________	kneecap
27)	______________	last two pairs of ribs which are unattached to any other structures
28)	______________	long shaft of a long bone
29)	______________	mature osteoblasts; assist in the maintenance and support of growing skeletal tissue
30)	______________	permeable covering over bones which allows for nutrient/waste transfer and sites for attachment by tendons
31)	______________	porous, highly vascular inner portion of bones
32)	______________	process of bone development
33)	______________	small bones of the backbone
34)	______________	storehouse for fat; found in the long hollow area within the diaphysis of long bones
35)	______________	tailbones; four fused vertebrae found within the pelvic curvature
36)	______________	the backbone or spine
37)	______________	the lower skeleton containing the pelvis and all of the extremities
38)	______________	the lowest section of the spinal cord which contains the sacrum, pelvis, and coccyx
39)	______________	the main bone-building cells during human development
40)	______________	the process of blood formation
41)	______________	those which are typically found within the arms and legs

42)	_____________	top section of the spinal cord which contains seven vertebrae within the neck
43)	_____________	twelve pairs of ribs attach to the thoracic curvature of the spine
44)	_____________	two cartilage plates found where the diaphysis meets the epiphyses on both of its ends; areas where new cells continue to grow thereby lengthening the long bones

Choose the correct answer from the following questions:

1) The most important minerals stored in bones are:

A) calcium and iron
B) calcium and potassium
C) sodium and potassium
D) calcium and phosphorus
E) sodium and phosphorus

2) Which of these are bone-forming cells:

A) osteocytes
B) osteoclasts
C) periosteum
D) red bone marrow
E) osteoblasts

3) The scientific term used to describe the formation of bone is:

A) osteoarthritis
B) epiphysis
C) osteoporosis
D) ossification
E) articulation

4) The axial skeleton contains which combination of the following bones:

1. skull
2. arms and legs
3. ribs and sternum
4. vertebrae
5. pelvis

A) 1, 2, 3, 5 B) 1, 3, 4 C) 1, 3, 4, 5 D) 2, 5 E) 2, 3, 4, 5

5) Which of these bones is NOT a long bone found in the leg:

A) femur
B) fibula
C) radius
D) tibia
E) patella

6) Fingers and toes are referred to as:

A) tarsals
B) carpals
C) metatarsals
D) metacarpals
E) phalanges

Application Question:

While playing on her swing set, 10-year-old Sally falls and breaks her right leg. At the emergency room, the doctor tells her parents that the proximal end of the tibia where the epiphysis meets the diaphysis is fractured. Sally's leg is put into a cast and eventually heals. During a doctor's visit eight years later, Sally learns that her right leg is 2 cm shorter than her left. The doctor tells her this is likely because of her accident. What might account for this difference in length?

Chapter Five

Muscular System – Part I

Back in Chapter Two you learned a little about the various tissues in the human body. For the next two chapters we are going to spend a lot of time exploring these tissues in greater detail. It's time to look at..

The Muscular System

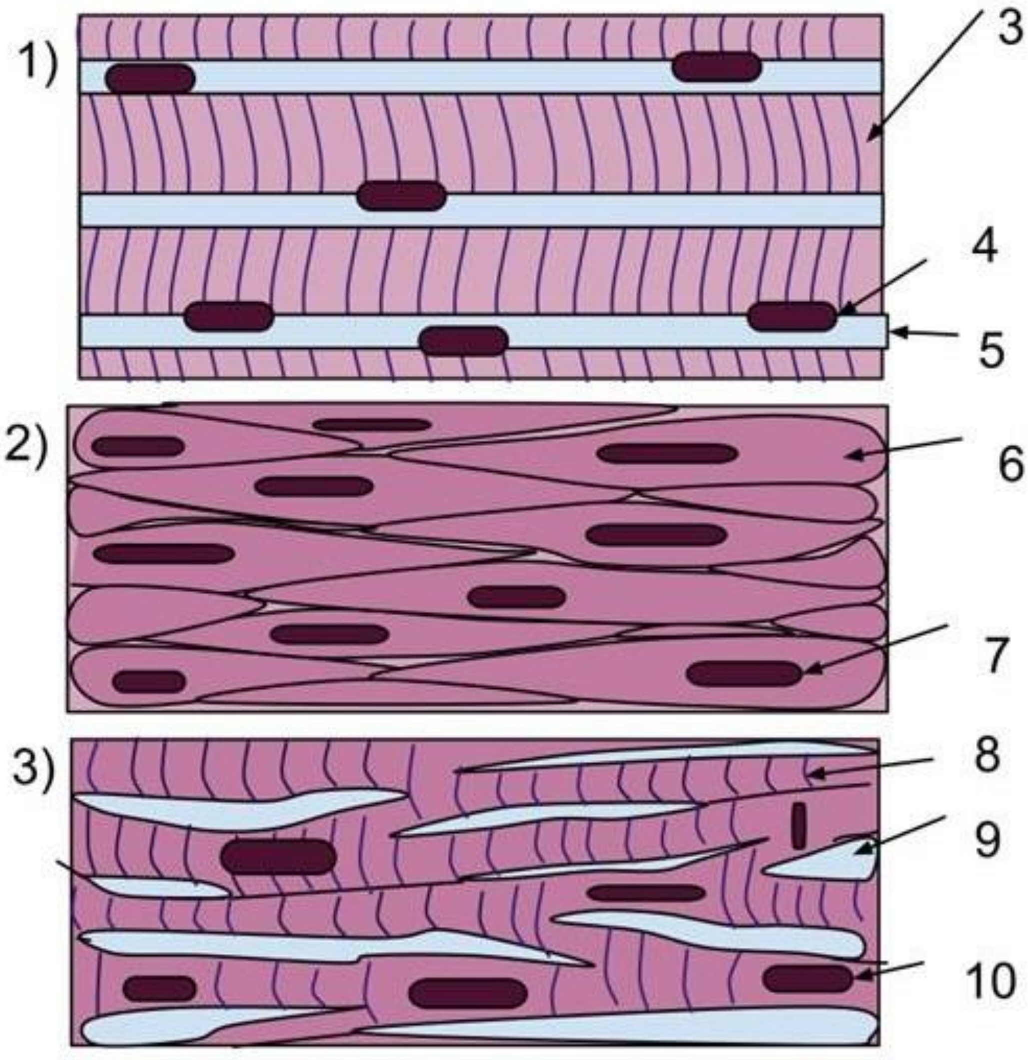
As you recall, muscle tissues can be placed into three different types:

Cardiac, Skeletal, and Smooth Muscles

Although the cardiac and smooth muscles are extremely important to the muscular system, it is the skeletal muscle that will dominate nearly all of our time for now! As you read in Chapter Two:

"Skeletal muscle is responsible for movement and is considered a voluntary tissue. It is classified as "voluntary" because an organism has full control over its movement. This is not the case with the remaining muscle types. The cells which make up skeletal muscle are very long and threadlike and are also referred to as muscle fibers. Much like cardiac muscle, skeletal muscle is also striated in appearance."

If you have ever walked through the meat department of your local grocery store you have seen numerous examples of skeletal muscle. This is the fleshy part of the beef, chicken, or pork that is commonly referred to as "meat." We too are composed of meat in the form of skeletal muscles. It provides our bodies with a way of standing upright (against the pull of gravity), moving around, staying warm, and generally holding our entire body together as they are attached to the bones of our skeletal system through tendons.



1) Skeletal muscle cells are long tubular cells with striations (3) and multiple nuclei (4). The nuclei are embedded in the cell membrane (5) so that they are just inside the cell. This type of tissue occurs in the muscles that are attached to the skeleton. Skeletal muscles function in voluntary movements of the body.

2) Smooth muscle cells are spindle shaped (6), and each cell has a single nucleus (7). Unlike skeletal muscle, there are no striations. Smooth muscle acts involuntarily and functions in the movement of substances in the lumens. They are primarily found in blood vessel walls and walls along the digestive tract.

3) Cardiac muscle cells branch off from each other, rather than remaining along each other like the cells in the skeletal and smooth muscle tissues. Because of this, there are junctions between adjacent cells (9). The cells have striations (8), and each cell has a single nucleus (10). This type of tissue occurs in the wall of the heart and its primary function is for pumping blood. This is an involuntary action.

Since we are on the topic of bones and tendons, let's look at how our muscles can move these structures around. In the previous chapter, you learned about how our synovial joints allow for the motion of bones throughout our bodies. A few of these various motions can be identified with nearly all freely-movable joints in the body and can be found in the chart below:

Movements around synovial joints

Name	Type of motion	Example
Rotation	turning around an axis	Moving your head around the vertebrae of the neck
Flexion	decreasing the angle between two bones	Bending your head towards your chest
Extension	increasing the angle between two bones	Bending your head back from your chest to its resting position
Hyperextension	extension of a joint beyond its normal range of motion	"Whiplash" effect in the neck after being struck from behind
Abduction	movement away from the midline of the body	Extending all of your fingers outward on your hand
Adduction	movement toward the midline of the body	Bringing all of your fingers together before you shake somebody's hand

Here are a couple of tricks for you to remember about all of these motions:

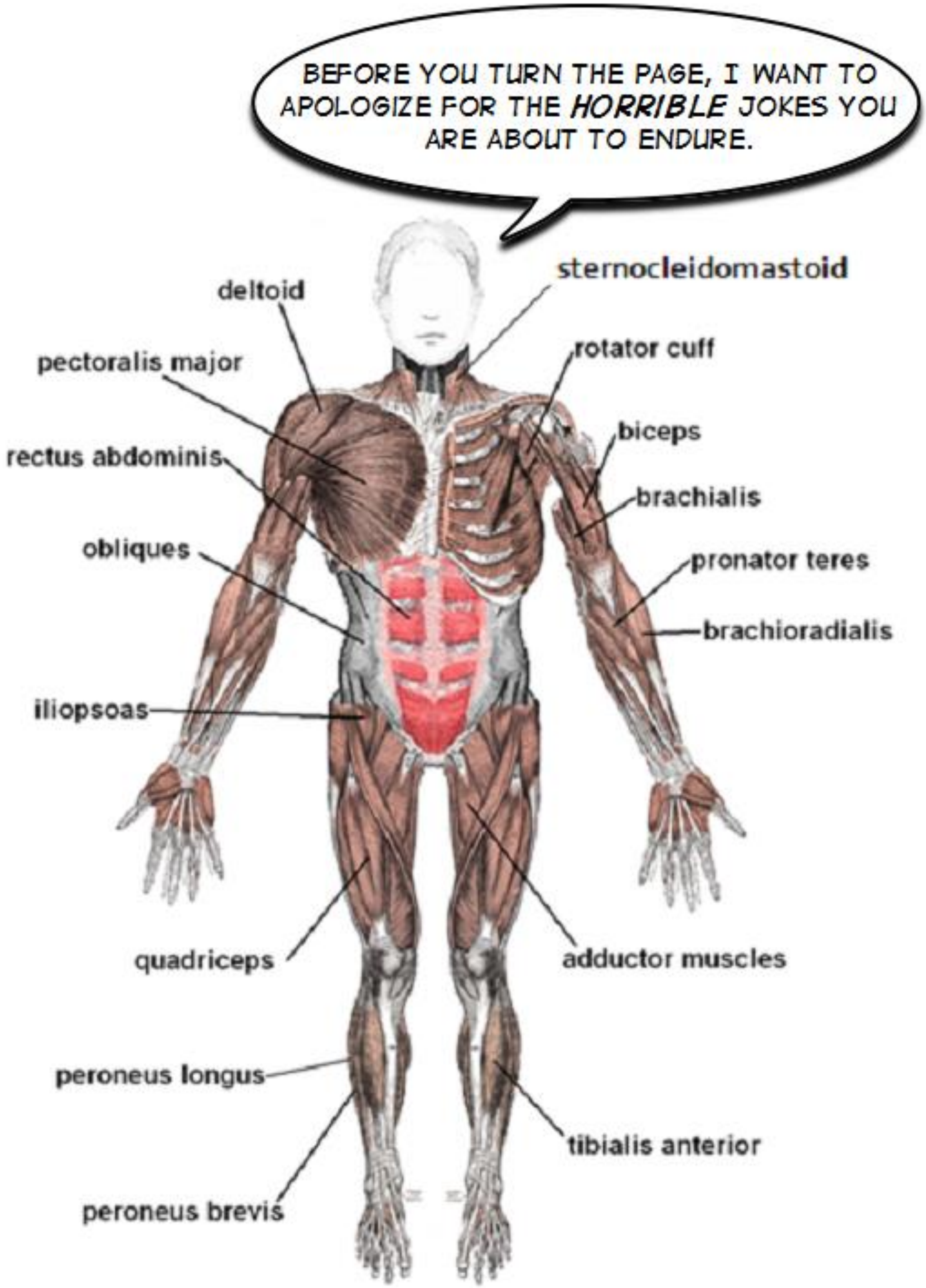
Extension movements always reverse the flexion movements because whenever you are standing straight up, all of your joints are at full extension.

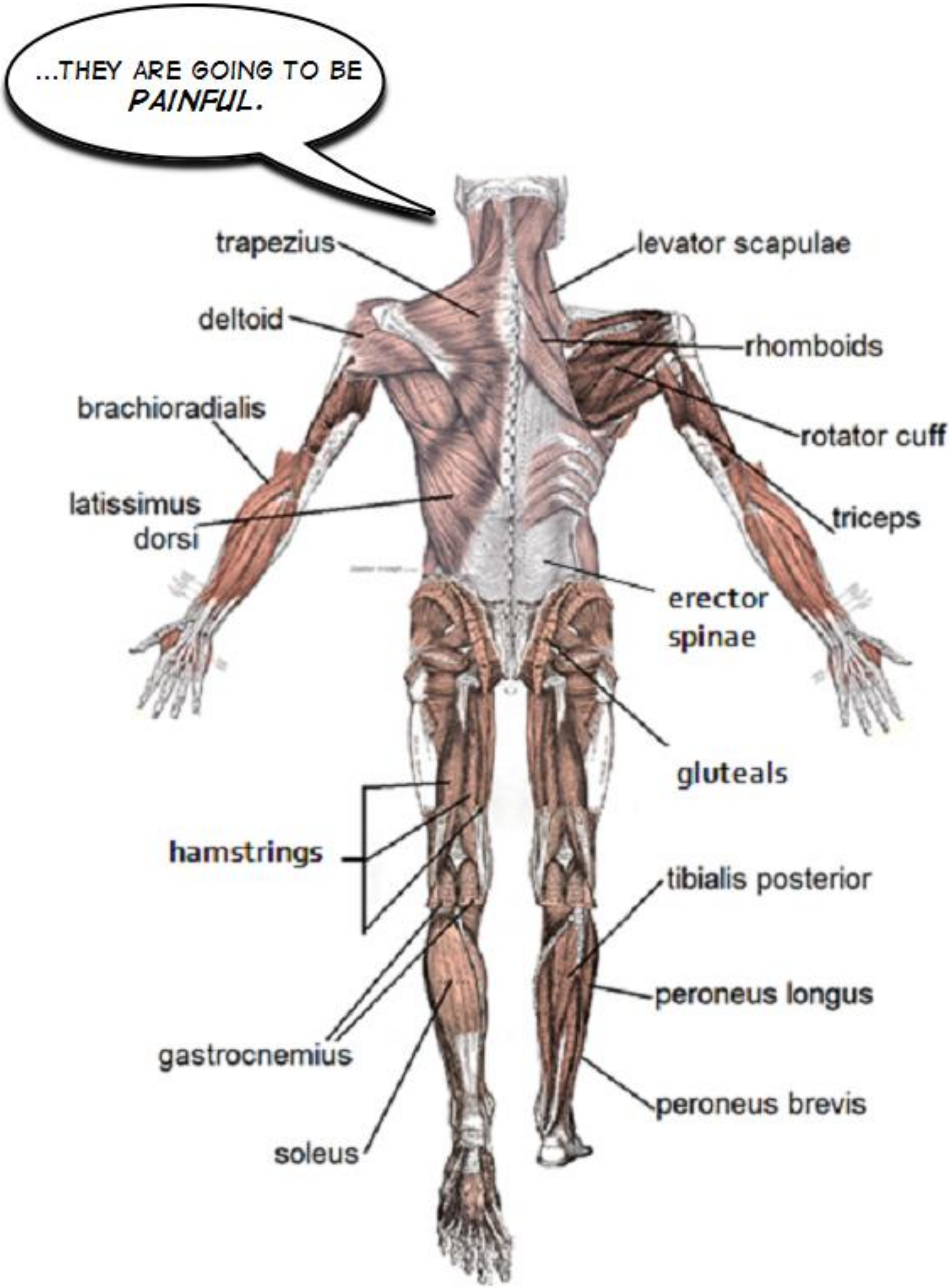
Also, an easy way to remember the difference between abduction and adduction is to remember that if you are **abduct**ed, you are being taken away; and, during **add**uction, the extremity is being **add**ed to the body!

These various motions will help you to remember the major muscles of the human body.

The remainder of this chapter will focus on the major muscles within the human body. To be honest, there are over 600 individual muscles within the average human!

Relax! You are not going to have to memorize all of them!


BEFORE YOU TURN THE PAGE, I WANT TO APOLOGIZE FOR THE *HORRIBLE* JOKES YOU ARE ABOUT TO ENDURE.
sternocleidomastoid
deltoid
rotator cuff
pectoralis major
biceps
rectus abdominis
brachialis
obliques
pronator teres
brachioradialis
iliopsoas
quadriceps
adductor muscles
peroneus longus
tibialis anterior
peroneus brevis


...THEY ARE GOING TO BE
PAINFUL.
trapezius
levator scapulae
deltoid
rhomboids
brachioradialis
rotator cuff
latissimus
dorsi
triceps
erector
spinae
gluteals
hamstrings
tibialis posterior
peroneus longus
gastrocnemius
peroneus brevis
soleus

We are only going to explore the major muscles found within the neck, back, chest, arms, legs, hip, shoulder, and abdomen along with some of the major movements caused by these muscles. The following chart will identify these major muscles (or groups of muscles):

Muscle	Location	Movement
Sternocleidomastoid	Neck	Rotation and flexion of head/neck
Trapezius	Neck	Rotation and extension of head/neck
Latissimus dorsi	Shoulder	Adduction, extension, and rotation of shoulder
Pectoralis major	Shoulder	Adduction, flexion, and rotation of shoulder
Deltoids (group of muscles)	Shoulder	Abduction and rotation of shoulder and arm
Rectus abdominus	Abdomen	Flexion of spine
Internal and external obliques	Abdomen	Flexion and rotation of spine
Erector spinae (group of muscles)	Abdomen/Spine	Extension of spine and rotation of trunk
Biceps	Arms	Flexion of elbow
Triceps	Arms	Extension of elbow
Quadriceps (group of muscles)	Knee/hip	Flexion of hip and extension of the knee joint
Hamstrings (group of muscles)	Knee/hip	Extension of hip and flexion of knee joint
Gastrocnemius	Knee	Flexion of knee joints
Gluteals (group of muscles)	Hip	Abduction and extension of the hip

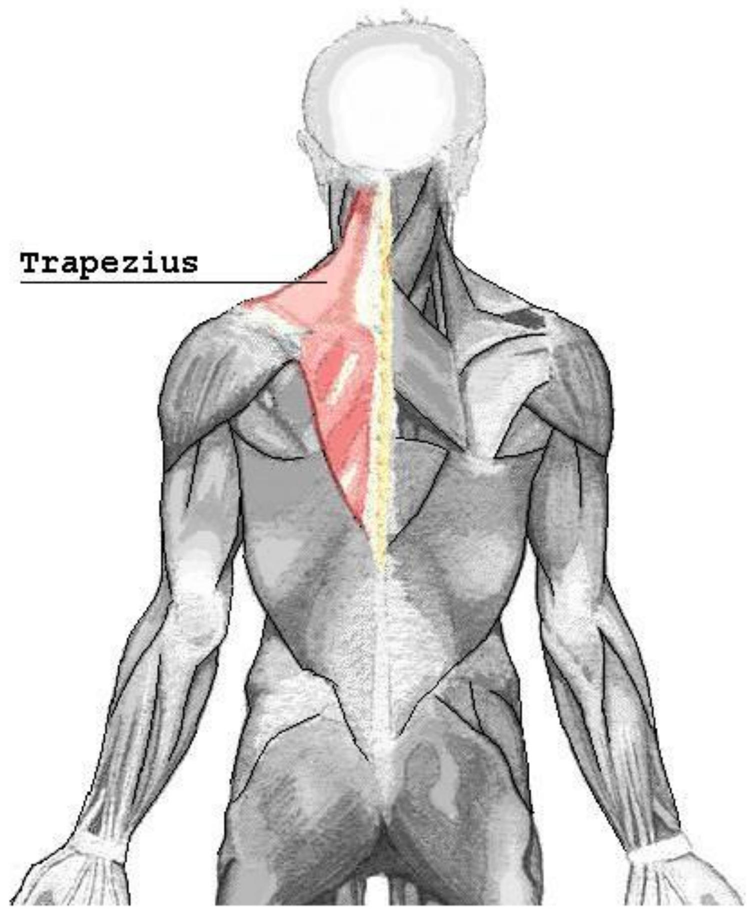
Since skeletal muscles are voluntary, let's do a little stretching while learning more about these muscles!

A pair of **sternocleidomastoid (SCM)** muscles can be found on both sides of the neck. If you would like to feel these muscles, a few simple moves are all you will need to do. First of all, shaking your head as if you were saying "no" uses both of the SCM muscles located on the opposite sides of your neck. If you were attempting to place your chin on your chest or your ears on your shoulders, the stretch you would feel in your neck would be from your SCM muscles as well!

Head/Neck rotation

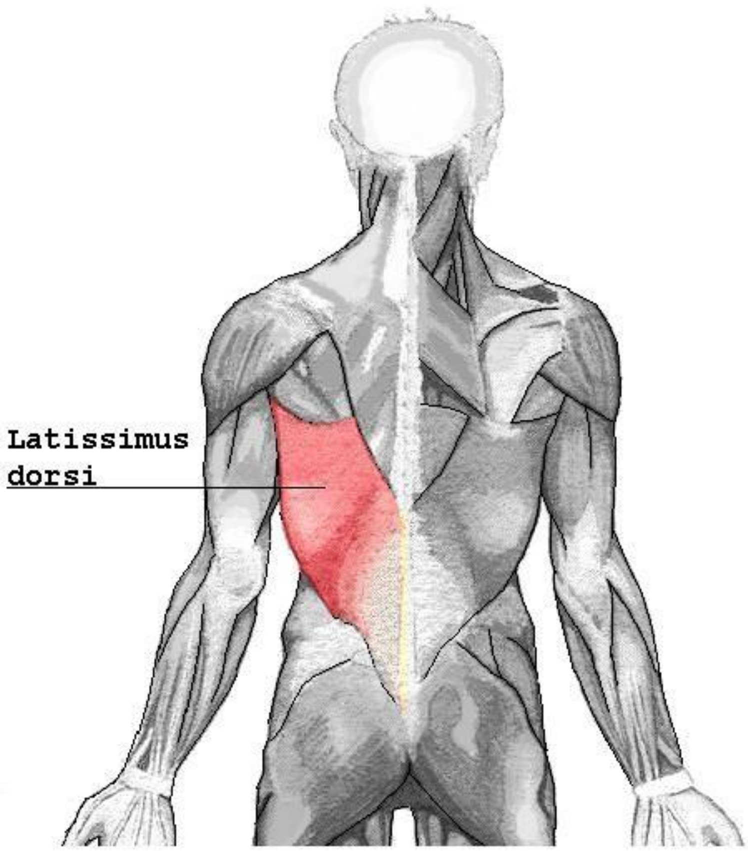
Neck flexion

The **trapezius** muscles are found towards the upper posterior area around your neck and are connected to your shoulder blades (**scapula**). Much like the SCM, when you shake your head or try to place your ears to your shoulders, you are using your trapezius muscles. However, the trapezius reverses the flexion of the SCM by extending the head and neck backwards.

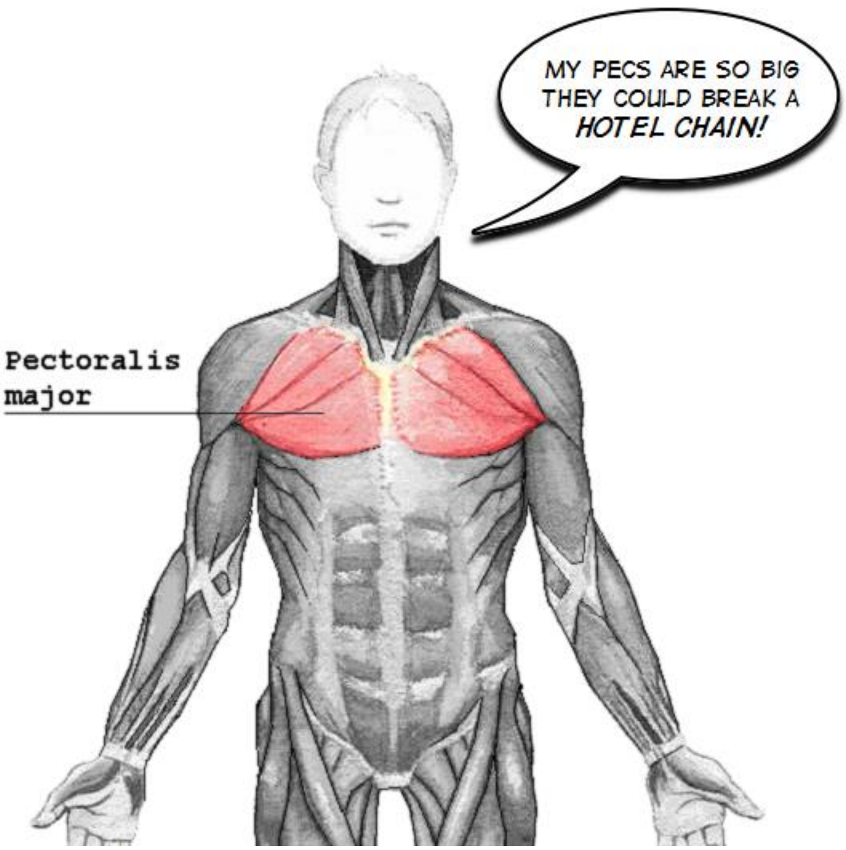


Remember! Just as you witnessed between the SCM and the trapezius - For every flexion movement there has to be a reverse motion - an extension!

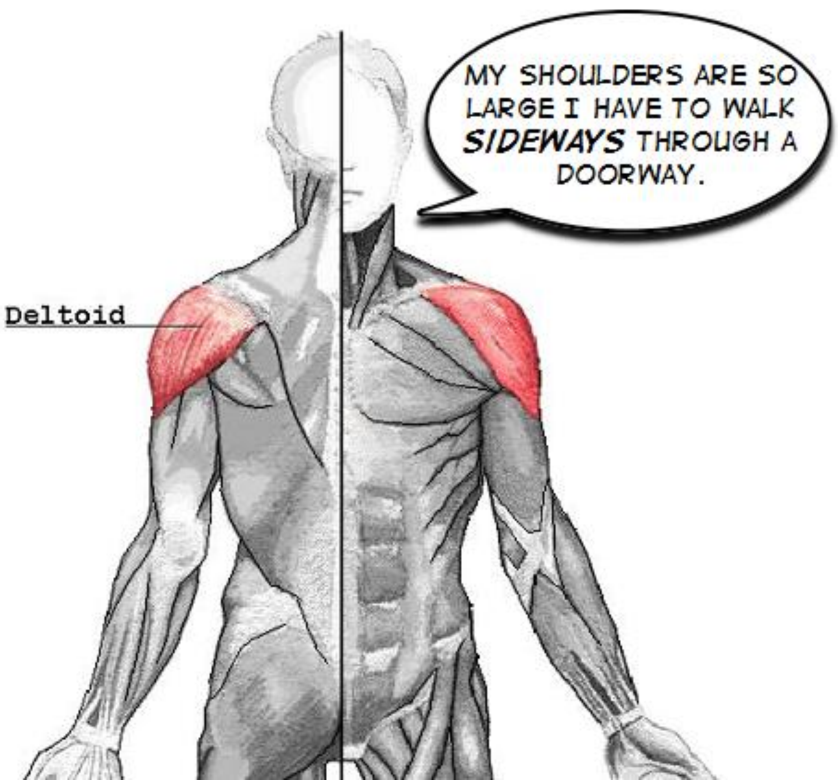
The **latissimus dorsi** (also known as the **lat**) is a large muscle located on the back. This muscle is responsible for a wide variety of movements involving your shoulders. The following images may help you identify these different motions:



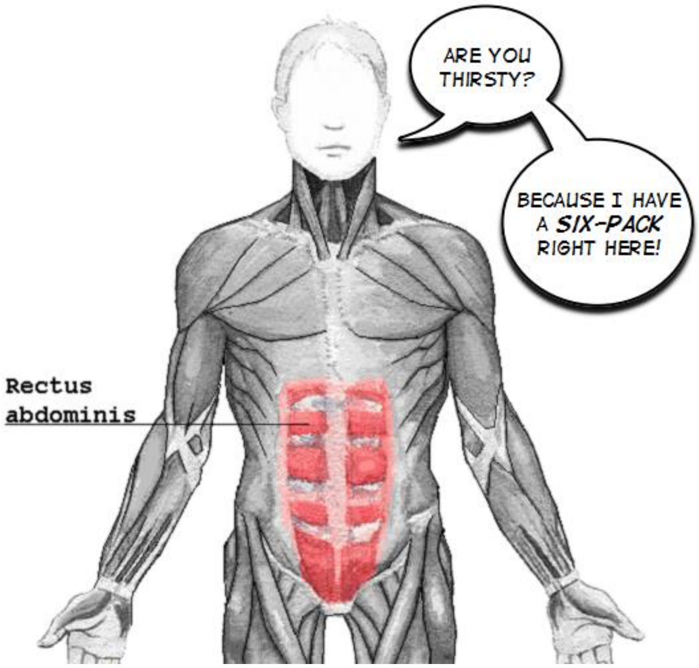
The **pectoralis major** are muscles found in your upper chest and act to lower your arm back to its resting position (adduction). When you raise your arm as if to answer a question or be called upon, a part of the pectoralis major is responsible for the flexion of your arm..



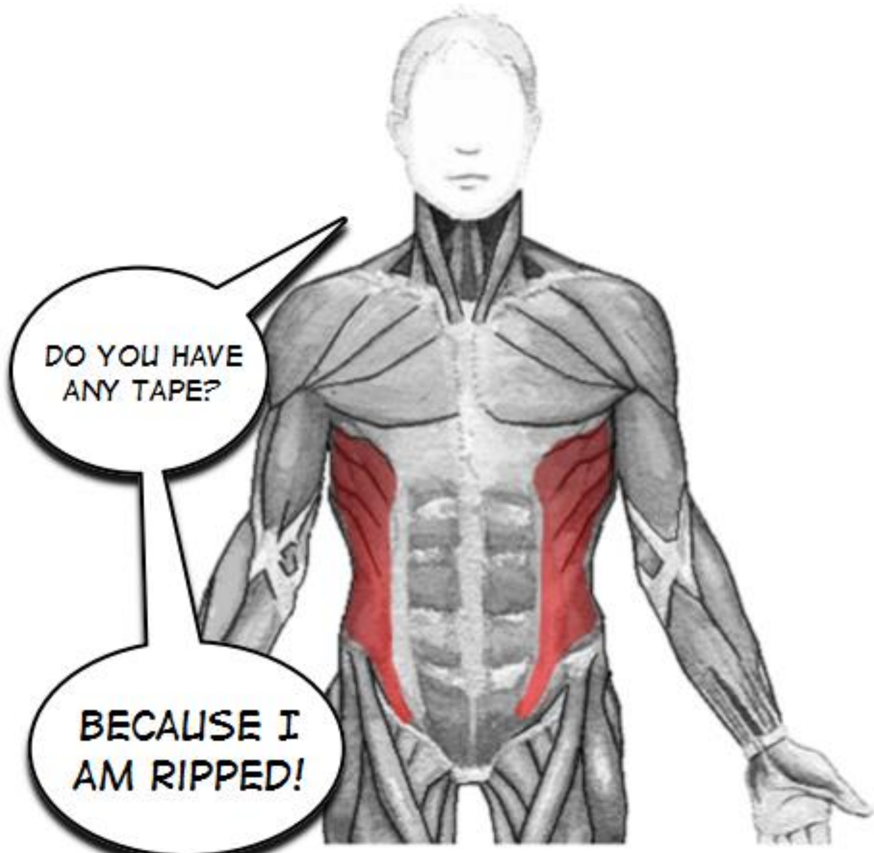
The **deltoids** are a group of muscles on your shoulders that are responsible for a wide range of motion in your body. The deltoids work with your pectoralis major to perform many of the same motions. However, there is one major difference - your deltoids are responsible for lifting your arm upwards from the side of your body (abduction). Your pectoralis major and latissimus dorsi are responsible for lowering your arm back down (adduction). Keep this in mind as you look at the following illustrations:



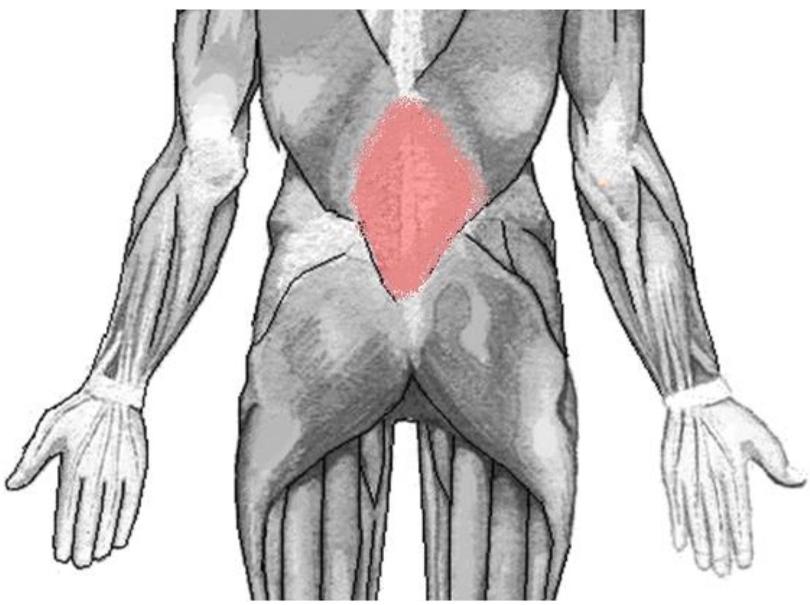
The **rectus abdominus** is also known as the "six pack" and it is responsible for flexing the spine. This muscle is anterior (in front of) the spine and is one of several muscles found in the abdomen.



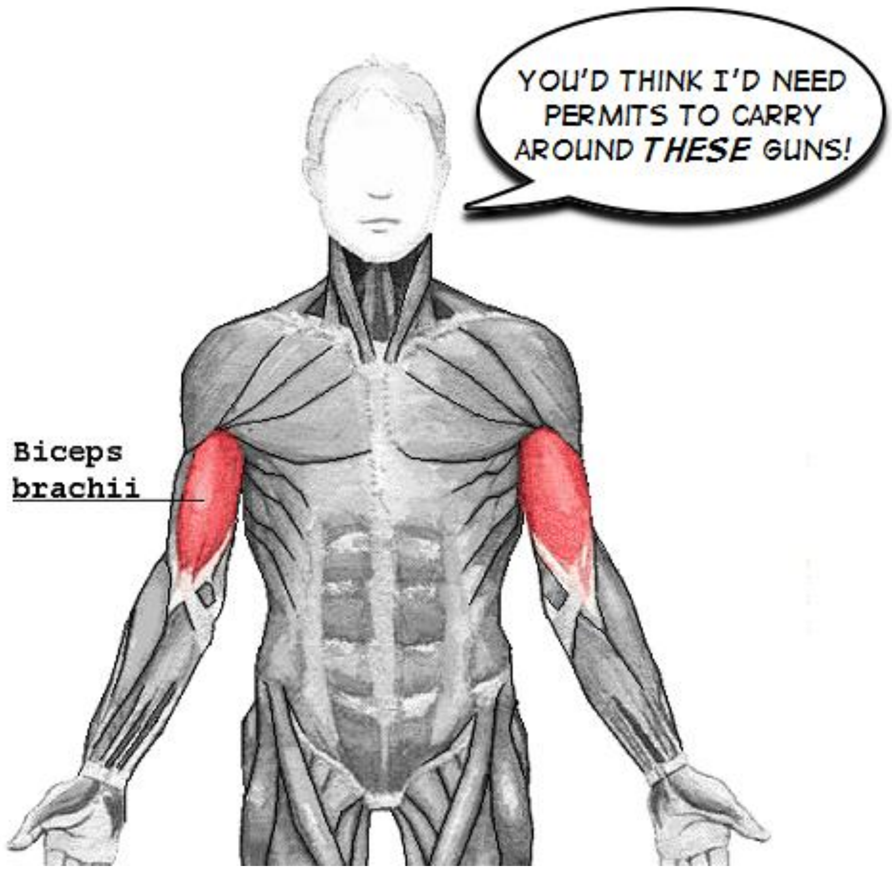
The **internal and external obliques** are additional muscles found within the abdomen. Both are responsible for the flexion of the spine (much like the rectus abdominus); however, these muscles also help our bodies to bend from side to side.



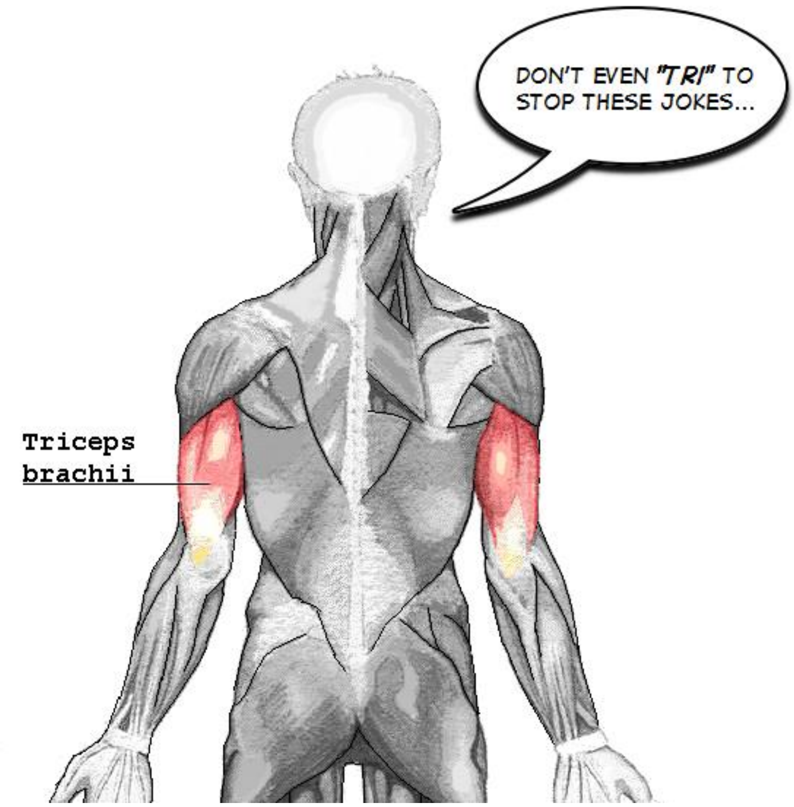
The **erector spinae** is a group of muscles located on each side of the spinal column along the lumbar, thoracic, and cervical regions. As it is posterior to the abdomen, the erector spinae extends the back to a straightened position as well as rotating the trunk/spine from side to side.



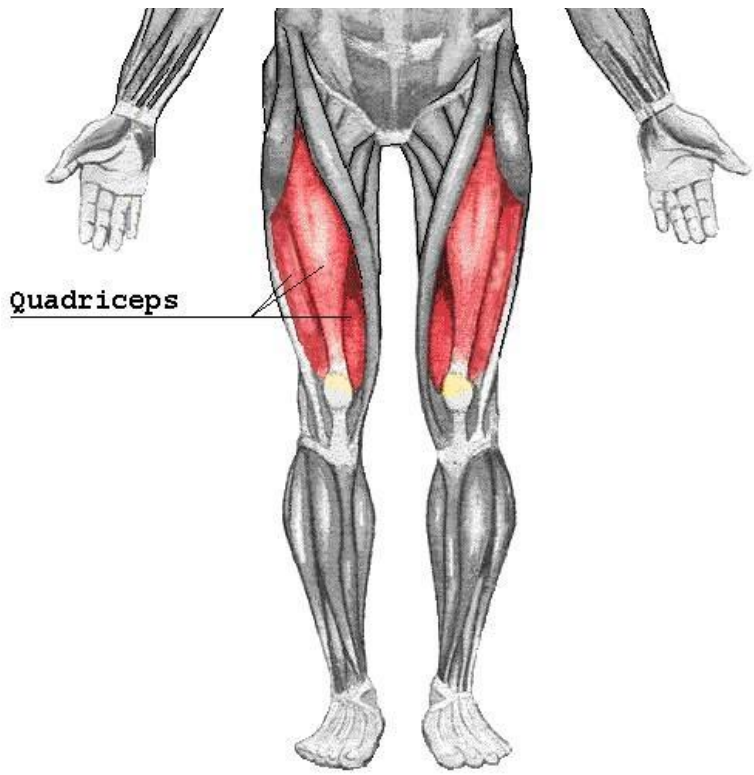
The **biceps** are attached to both the shoulder and elbow joints within our upper arm. The act of lifting an object generally requires the use of our biceps.



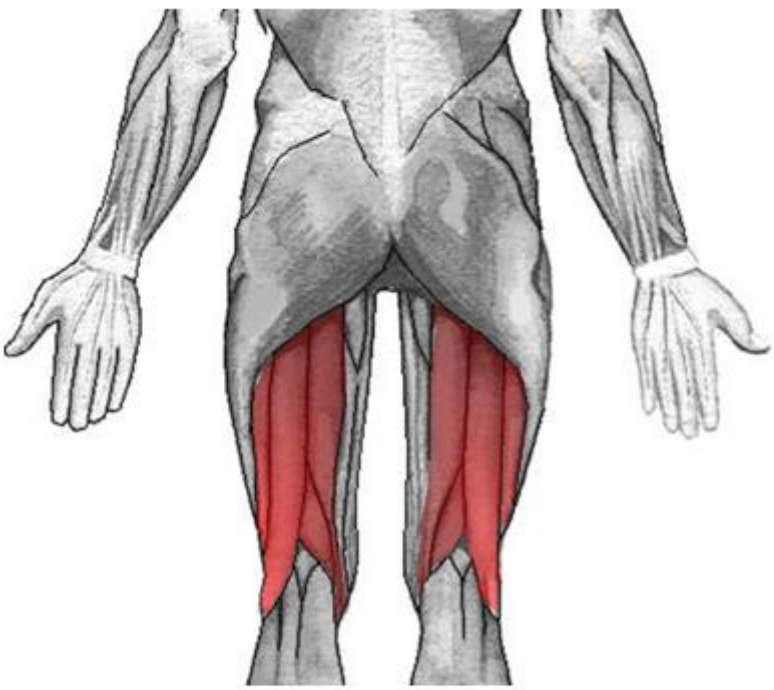
Just as our bodies are able to lift objects using our biceps, it is our **triceps** that allow us to lower objects through the motions of our elbows.

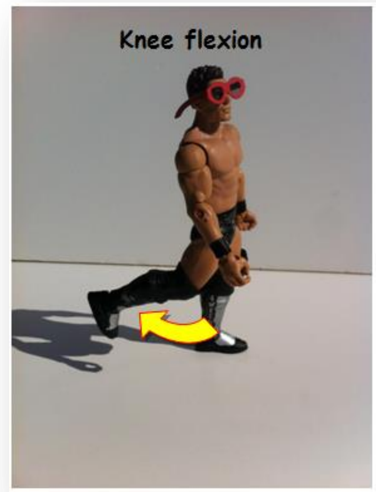


The **quadriceps** are a group of four muscles in our upper leg that are located on the anterior side. The main purpose of these muscles is the forward movement of our legs either through the motion of the knee joint (extension) or our hip joint (flexion).

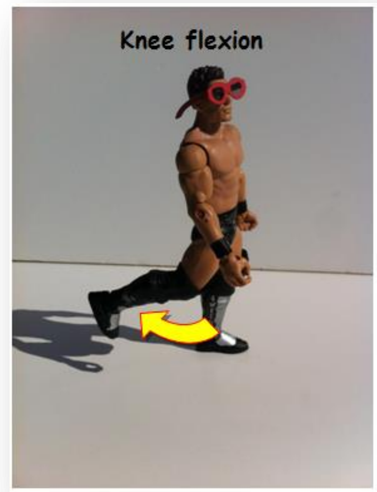


The **hamstrings** are another group of muscles in our upper leg; however, these muscles are found on the posterior side of our thigh. The hamstrings act to bend our knee through flexion of its joint. They are also responsible for extending our hip joints backwards. Both of these movements work to reverse the actions of the quadriceps on the front of the thigh.

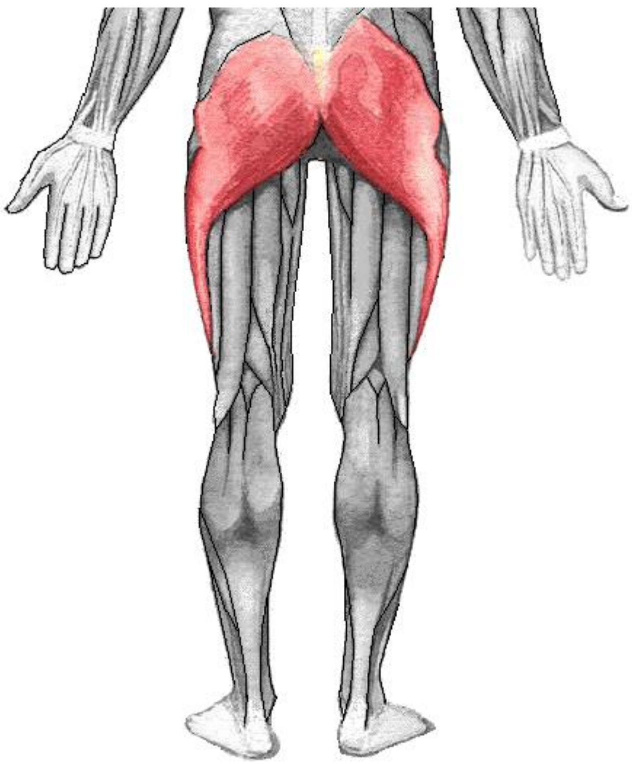




On the lower leg, the calf muscle, also known as the **gastrocnemius**, assists the hamstrings to flex our knees.



Our **gluteals**, also known as our buttocks, are a group of three muscles which help to move our hip joints much like that of our hamstrings. Additionally, the gluteals are also responsible for the abduction and lateral rotation of our hip. If you are familiar with the old dance move known as "the Twist", the movement of your leg is accomplished through the lateral rotation of your hip.



Now that you have a good understanding of what kinds of movements exist within the human body, let's spend some time looking at HOW these muscles move. See you next week!

Match the following vocabulary terms with their correct definition:

abduction	**gastrocnemius**	**rectus abdominus**
adduction	**gluteals**	**rotation**
biceps	**hamstrings**	**scapula**
deltoids	**obliques**	**sternocleidomastoid**
erector spinae	**latissimus dorsi (lat)**	**trapezius**
extension	**pectoralis major**	**triceps**
flexion	**quadriceps**	

1)	____________	a group of four muscles in the anterior side of the upper leg; responsible for extension of the knee joint and flexion of hip
2)	____________	a group of muscles located on each side of the spinal column along the lumbar, thoracic, and cervical regions; extends the back to a straightened position
3)	____________	a group of muscles on your shoulders ; responsible for abduction, horizontal abduction and adduction; flexion/extension, and medial/lateral rotation
4)	____________	a large muscle located on the back; responsible for extension, adduction, and medial rotation at shoulder joint
5)	____________	buttocks; a group of three muscles which move the hip joints and are responsible for the lateral rotation of the hip
6)	____________	calf muscle; assists the hamstrings to flex the knees
7)	____________	decreasing the angle between two bones
8)	____________	group of muscles in the posterior side of the upper leg; responsible for extension of the hip and flexion of knee joints
9)	____________	increasing the angle between two bones

10)	______________	movement away from the midline of the body
11)	______________	movement toward the midline of the body
12)	______________	muscles found in your upper chest ; responsible for adduction, horizontal adduction, flexion/extension, and medial rotation at the shoulder joint
13)	______________	muscles found towards the upper posterior area of neck and are connected to the scapula; responsible for rotation, extension and lateral flexion of head/neck
14)	______________	muscles in the upper arm which allow us to lower objects through the motions of the elbow and/or shoulders
15)	______________	muscles which attached to both the shoulder and elbow joints within our upper arm; responsible for the act of lifting objects
16)	______________	muscles within the abdomen responsible for the flexion of the spine and allows the body to bend from side to side
17)	______________	one of several muscles found in the abdomen; anterior to the spine and responsible for its flexion
18)	______________	shoulder blades
19)	______________	turning around an axis
20)	______________	two muscles located on the side of the neck responsible for rotation, flexion, and lateral flexion of head/neck

Choose the correct answer from the following questions:

1) Which one of the following muscles is involved in abduction of the shoulder joint:

A) biceps
B) triceps
C) deltoid
D) latissimus dorsi
E) pectoralis major

2) While doing the exercise known as "jumping jacks," your arms and legs move laterally away from the midline of your body. This motion is called:

A) rotation
B) adduction
C) flexion
D) abduction

3) A muscle located on the anterior (ventral) side of the body is the:

A) gluteals
B) gastrocnemius
C) latissimus dorsi
D) pectoralis major

4) Muscle tissue that is classified as "involuntary" would be:

A) skeletal muscle only
B) cardiac muscle only
C) cardiac muscle and skeletal muscle
D) smooth muscle only
E) cardiac muscle and smooth muscle

5) **Which of these muscles is NOT responsible for flexion or extension of the arm?**
   A) hamstrings
   B) triceps
   C) biceps
   D) A and C
   E) B and C

6) **True or False**: Skeletal muscles need nerve stimulation for contraction to occur.

7) **True or False:** A prime mover of the arm that causes it to adduct is the deltoid.

Application Question:

A patient was involved in an automobile accident in which the car was "rear-ended" resulting in a whiplash injury of the head (hyperextension). What neck muscle(s) might be injured in this type of accident? What is the easiest way to prevent such injury in an automobile accident?

Chapter Six

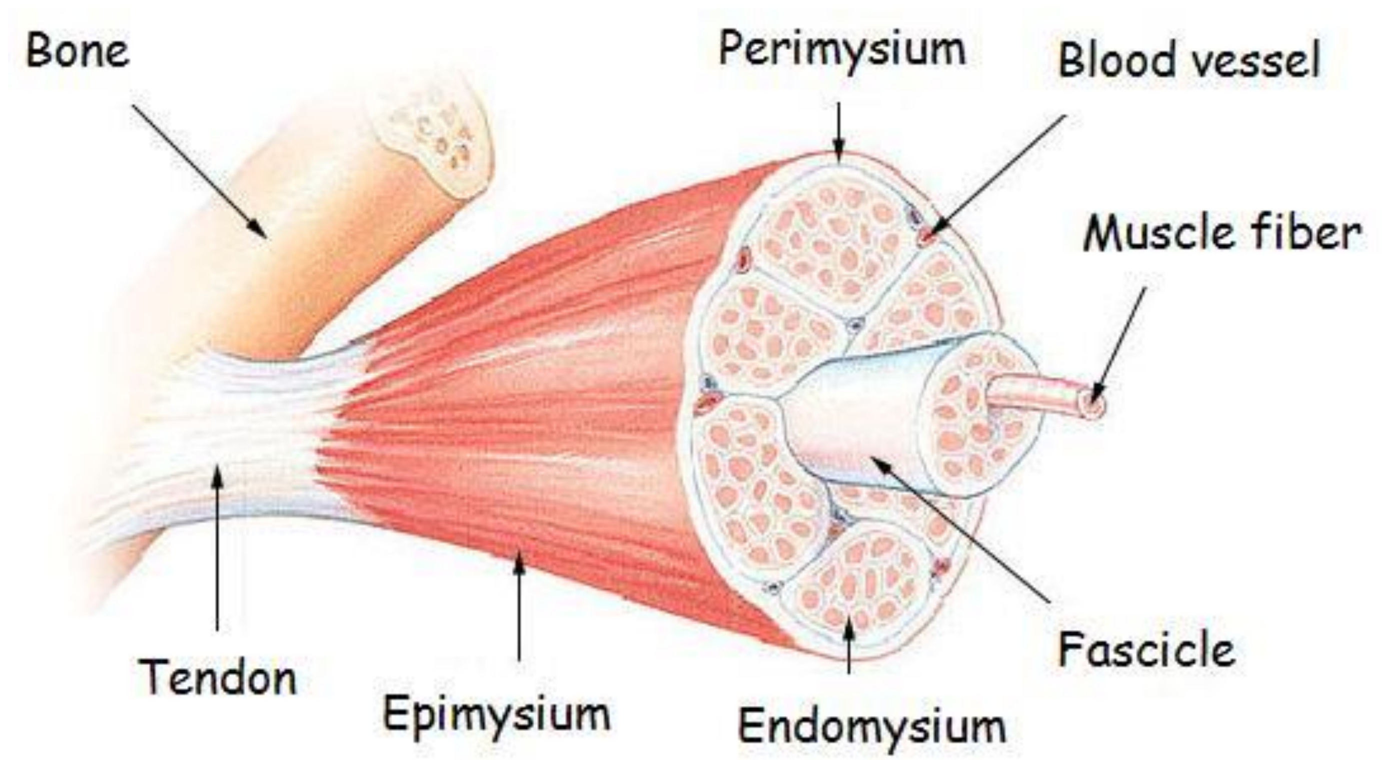
Muscular System – Part II

Back in Chapter 2 you looked briefly at the following information about the three muscle tissue types. For this week we have added four more rows in which we will explore:

Characteristic	Skeletal muscle	Smooth muscle	Cardiac muscle
Location	Attached to tendons which are attached to bones	Walls of blood vessels and lumen of organs	Only in the heart
Function	Movement of the body	Movement of materials through lumen and size of blood vessels	Pumping of blood
Cell shape	Long and cylindrical	Spindle-shaped (think of a stretched football)	Branched
Striations	Present	Absent	Present
Mode of control	Voluntary	Involuntary	Involuntary
What starts the contraction?	Only by a nerve cell	Self-stimulation through other smooth cells	Self-stimulation through other cardiac cells
Speed of contraction	Fast (0.05 seconds)	Slow (1-3 seconds)	Moderate (0.15 seconds)
Sustainability of contraction	Not sustainable	Sustainable indefinitely	Not sustainable
Likelihood of fatigue	Varies according to use of muscle	Generally does not fatigue	Minimal chance

It is true that all muscle cells contract (shorten) to create some form of motion within the human body; however, the different structures and functions of our three different muscle tissues require different stimuli to begin the contraction.

Let's begin by looking at skeletal muscle and how its structure is related to its function.



If you were to examine a single skeletal muscle, you would find it covered in a layer of connective tissue known as the **epimysium**. This connective tissue protects the skeletal muscle from damage as it slides back and forth against other muscles and bones. The epimysium continues to the end of the muscle where it becomes thicker and forms the main component of the muscle's tendon – the site of connection between a muscle and bone.

Now, if you were to cut the skeletal muscle and look inside you would find bundles of 10-100 muscle fibers (cells) known as **fascicle**. Surrounding all of the bundles of fascicle (and under the epimysium) is another layer of protective connective tissue known as the **perimysium**. Each of the individual muscle fibers within the fascicle can be very long, some reaching 35cm (~14 inches) in length and are protected by yet another layer of connective tissue called **endomysium**. The primary component of the endomysium is the protein *collagen* which you first learned about back in Chapter 2. If you were to look even further into one of these muscle fibers, you would find hundreds of long protein chains called **myofibrils**. It is the movement of these myofibrils that cause skeletal muscle cells to contract (shorten).

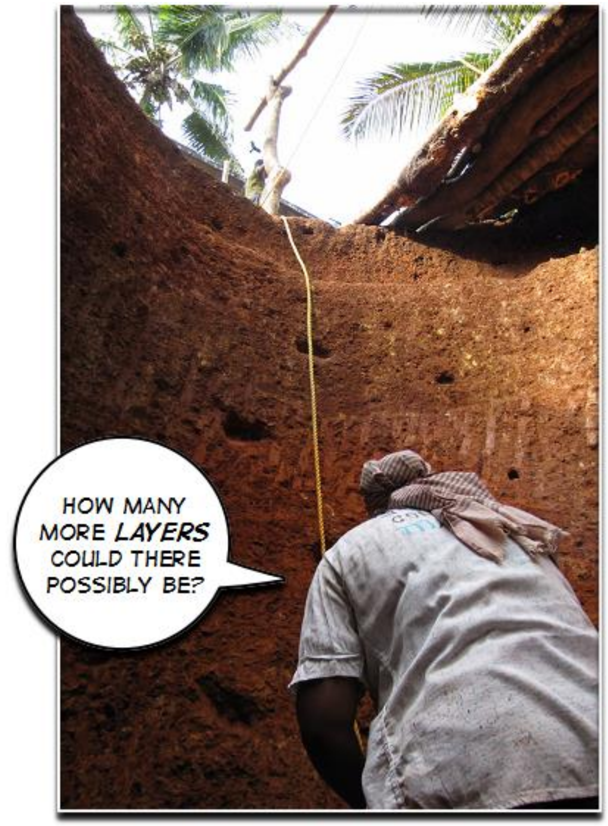
Before we go any further, let's take a look at this structure from another angle. Imagine working for a large grocery store and having to unload a supply of spaghetti to place on the shelves. The loading truck arrives and delivers a crate of several large boxes all wrapped together with protective plastic wrap. This plastic wrap would be considered the epimysium and the large boxes would be the perimysium. The large box ***and*** *all of the smaller individual bags of spaghetti it protects symbolizes the fascicle.*

Each of these individual bags of spaghetti, therefore, represents an individual muscle fiber

The small plastic bags which protect the spaghetti symbolize the endomysium; and, the spaghetti itself represents the myofibrils of the muscle fiber.

Each myofibril can be broken down even further into small segments called **sarcomeres**. Imagine using a marker to place a dot on each individual strand of spaghetti every inch down its length. The segment between each dot would be considered a sarcomere.

To be more realistic, you would have to place a dot every 2 micrometers or 0.00007 inches apart from each other. This would allow for up to 10,000 dots on your strand of spaghetti!



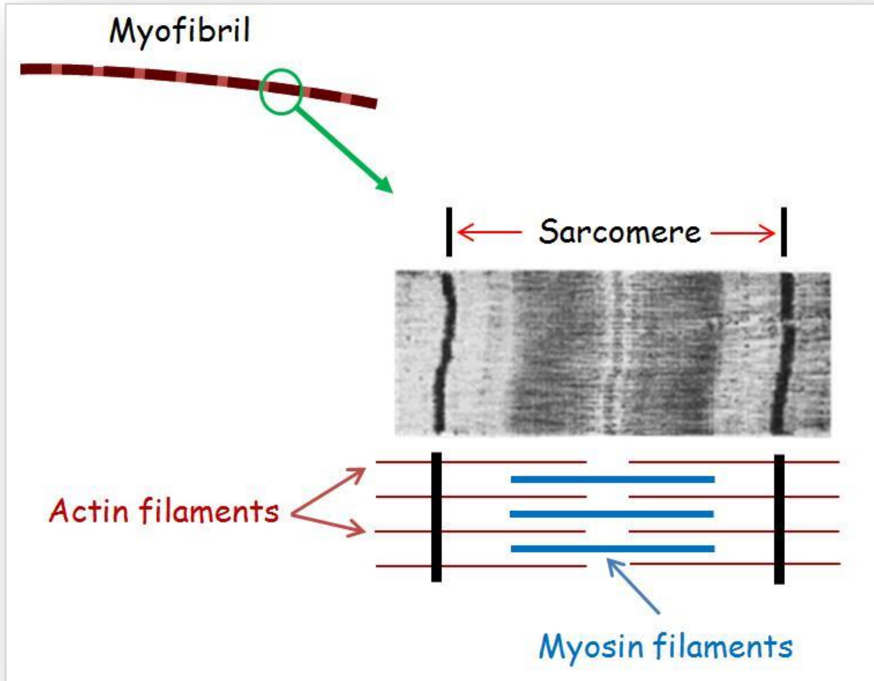
It is the sarcomeres that are responsible for the contraction of a muscle.

Within each sarcomere you will find two long strands of proteins known as **actin** (a thin strand) and **myosin** (a thick strand). The actin strands are attached to the walls of each sarcomere while the myosin rests between the actin strands in the center of the sarcomere. During a contraction the thick strands of myosin pull the actin strands closer together. This pulls the walls of the sarcomere closer to each other and, with all of the sarcomeres contracting at the same time, the entire muscle fiber shortens in length!

Here's another way to think about this process:

1. Place the palms of your hands towards you with your fingertips touching each other. Your fingers will represent the actin and myosin strands and your thumbs will be the walls of a sarcomere.

2. Push your fingers together so that they slide past in between each other without bending. This represents the contraction of the sarcomere and should bring your thumbs closer together as well.
3. In reality, each sarcomere is attached to another set of actin and myosin strands within another sarcomere.



The shortening of the sarcomere and the subsequent contraction of your entire muscle fiber is known as the **sliding filament theory**.

But how does the skeletal muscle fiber know when to contract?

That is a good question! There are four key steps to muscle contraction and relaxation:

1. A skeletal muscle must be activated by a *nerve cell (neuron)* which is attached to each muscle fiber. You first learned about neurons back in Chapter 2. This type of cell is the building block for the nervous system and is responsible for sending signals throughout the body. In this case, the nerve cell instructs the muscle fiber to release a chemical known as **acetylcholine** which acts as a chemical signal to the muscle fiber.

2. This "chemical signal" helps to diffuse **calcium ions** (a particle of calcium which has lost two of its electrons) into the myofibrils from the cytoplasm of the muscle fiber.
3. An extensive series of steps occurs at this stage with the calcium ions being the key players in the pulling of the sarcomere walls together, thereby creating the muscle fiber contraction.
4. When a muscle cell is no longer activated by a nerve cell, the diffusion of calcium into the myofibrils stop and the contraction ends.

Remember! Skeletal muscles can only pull during a contraction!

A contraction pulls the walls of sarcomeres together and causes the muscle fiber to shorten. When the contraction is over, the sarcomere walls do not snap back into place! This is why skeletal muscles attach to the skeleton and move in pairs -- one muscle moves the bone in one direction and another muscle moves it back the other way. As you learned in the previous chapter, <u>every flexion needs an extension and every abduction needs an adduction!</u>

Think about your biceps. This muscle is responsible for <u>pulling</u> your lower arm closer to your body causing your upper arm to be <u>flexed</u> or contracted (flexion). It is at this time when your bicep appears to be much larger in size. This is due to the overlapping of actin and myosin layers within the contracted muscle. To relax your arm back to its resting position, the triceps (located posterior to the biceps) <u>pull</u> on the lower arm causing it to be <u>extended</u>.

What about cardiac and smooth muscles?

There are similarities, as well as differences, in comparing cardiac, smooth and skeletal muscle contractions. Although all muscle fibers contract, they do not all contain sarcomeres. Skeletal and cardiac muscles contain sarcomeres which provide the appearance of striations when viewed through a microscope. Unlike the long, cylindrical cells of skeletal muscles, cardiac cells are branched in appearance and overlap each other considerably. Although this provides a different structure to the tissues found within the heart, the steps which describe the contraction of cardiac muscle is very similar to that of skeletal muscles.

Unlike cardiac and skeletal muscle tissue, smooth muscles contain no sarcomeres at all. This is the reason for its lack of striations. Smooth muscle contains the proteins actin and myosin which allow for its contraction to take place; however, without actin's ability to be anchored to the wall of a sarcomere, the shortening of this muscle cell can occur in all directions simultaneously.

How about an interesting fact about a particular type of smooth muscle?

Small bundles of smooth muscles known as **arrector pili muscles** can be found attached to the bulb and root of a hair follicle. When these muscles contract, the attached hair stands upright causing the organism to retain a small amount of heat. This is accomplished as air becomes trapped between each hair within the epidermis of the skin. These pockets of warm air are commonly referred to as **goosebumps**.

Now back to the differences between the muscle types…

Other differences can be found between these three muscle tissues in terms of their speed of contraction. Skeletal muscle contracts the fastest and, therefore, can fatigue the fastest as well. Since this muscle type is voluntary and under the control of our own thought process, its contraction cannot be sustainable and must relax at some time. This is the direct opposite from smooth muscle which has the slowest speed of contraction (1-3 seconds) and can remain contracted without end. These never ending contractions take place because smooth muscle cells do not need the impulse from a nerve cell to contract as they can stimulate each other to cause the shortening of their cells.

Cardiac muscles also contain cells which can stimulate each other and do not require any nerve cells to maintain a contraction. These muscles rarely fatigue as their beating rhythm allows for periodic resting periods which allows the tissues to temporarily relax.

Anatomy & Physiology - Connections

How the following body systems affect the muscular system		How the muscular system affects the following body systems	
Integumentary	Removes excess heat from the body; production of vitamin D; protects internal organs	Creation of facial expressions	**Integumentary**
Skeletal	Storehouse for calcium and phosphorus; provides sites of attachments for muscles	Provision of movement and support	**Skeletal**

Match the following vocabulary terms with their correct definition:

acetylcholine	**epimysium**	**perimysium**
actin	**fascicle**	**sarcomeres**
arrector pili muscles	**goosebumps**	**sliding filament theory**
calcium ions	**myofibrils**	
endomysium	**myosin**	

1)	______________	a particle of calcium which has lost two of its electrons
2)	______________	a protective connective tissue surrounding each muscle fiber
3)	______________	a protective connective tissue surrounding the fascicle
4)	______________	bundles of 10-100 muscle fibers (cells) within each skeletal muscle
5)	______________	chemical released by muscle fibers to diffuse calcium ions into myofibrils thereby causing a muscle contraction
6)	______________	hundreds of long protein chains found within muscle fibers (cells)
7)	______________	layer of connective tissue covering an individual skeletal muscle
8)	______________	long thick strands of protein resting between strands of actin within the center of a sarcomere; responsible for pulling actin strands together during a contraction
9)	______________	long thin strands of protein attached to the walls of each sarcomere that are pulled by myosin to cause the contraction of muscle tissue
10)	______________	pockets of warm air trapped between hair follicles within the epidermis of the skin

11)	____________	small bundles of smooth muscles attached to the bulb and root of a hair follicle
12)	____________	small segments along a myofibril that are responsible for the contraction of a muscle
13)	____________	the shortening of the sarcomere and the subsequent contraction of the entire muscle fiber

Choose the correct answer from the following questions:

1) **Goosebumps are formed when…**
   A) sudoriferous glands release sweat
   B) melanin is produced
   C) vitamin D is synthesized
   D) the arrector pili muscles contract to stand hairs upright
   E) sebaceous glands release oil

2) **Place these structures of the skeletal muscle in order from largest to smallest:**
   1. fascicle
   2. actin
   3. muscle fiber (cell)
   4. myofibril
   5. sarcomere

   A) 1, 3, 4, 5, 2
   B) 2, 5, 4, 3, 1
   C) 1, 4, 3, 2, 5
   D) 3, 1, 2, 4, 5

3) **Which one of the following best describes the structure of myosin:**
   A) sarcomeres
   B) epimysium
   C) thick filaments
   D) thin filaments
   E) all myofilaments

4) **A sarcomere is:**
   A) an area skeletal muscle that performs no function
   B) the wavy lines on the cell, as seen in a microscope
   C) segments along a myofibril which induce the contraction of a muscle
   D) an area within a myofilament

5) **During skeletal muscle contraction, filaments of myosin pull on the following structures:**
   A) actin filaments
   B) myosin filaments
   C) thick filaments

6) **Striated muscle tissue type(s) that can be described as having a single, long, and cylindrical shape would include:**
   A) skeletal muscle only
   B) cardiac and smooth muscle
   C) cardiac and skeletal muscle
   D) cardiac muscle only
   E) smooth muscle only

Application Question:

A young farmer milked cows by hand each morning before school. One morning he slept later than usual and had to hurry to get to school on time. As he was milking the cows as fast as he could, his hands became very tired, and for a short time he could neither release his grip nor squeeze harder. Explain what you believe happened.

Chapter Seven

Protection, Support, and Movement: What can go wrong?

This week, we are going to look at a few of the possible problems that may exist within the skin, muscles, and bones. We could spend months studying all of the disorders that may occur within these three different systems. However, it's probably best to give you a brief look at some of the more common problems that can occur and a few of the possible ways our bodies and our doctors can help in the recovery process.

First of all, always remember that our bodies are very good at fixing the problems they encounter!

Our bodies have a natural set of defenses which act to keep foreign invaders (such as bacteria and viruses) from entering and/or spreading within ourselves. And, in the times when our tissues are damaged by these invaders or through other means such as bruising or cutting, our bodies have a general response to repair the damaged tissues as well.

How is this done?

It generally occurs through a two-step process:

Inflammation and Regeneration

The process of **inflammation** involves swelling, redness, excessive warmth, and pain in the area that contains the damaged tissues. A buildup of fluid (**edema**) typically results in most inflamed areas as well which causes the noticeable symptom of swelling. These actions produce an environment which is not favorable for bacteria and viruses to grow and reproduce.

For example, bacteria and viruses can naturally be found on the surfaces of sharp objects. When we are accidentally cut by these objects, these damaging organisms can enter our body and easily find the resources needed for their growth and reproduction. An inflammatory response, therefore, attempts to keep these **pathogens** (harmful organisms) from spreading throughout the body by altering the tissue's environment.

The second step in the repair of damaged tissue is **regeneration**. During this stage the body attempts to restore homeostasis by replacing or repairing the damaged tissues so they may perform their normal functions. This stage actually occurs during the inflammatory response while the pathogens are being destroyed.

This entire chapter is devoted to the study of tissue damage in one form or another. Most of the time, the minor cuts and scrapes we receive are repaired naturally by our bodies and no trace of these damages can be found. It is without doubt that nearly all of us have experienced the misfortune of receiving a paper cut; however, it is unlikely that we can find any trace of these injuries a year after the fact. Unfortunately, some of our injuries are much more severe and visible traces of their occurrence can be found years later. By this, I am referring to the presence of **scars**.

Scars

As you learned in Chapter 3, our skin is made up of two layers: the outer epidermis and the deeper dermis/hypodermis.

When we receive a cut that reaches deep into the lower dermis/hypodermis layer, a large amount of connective tissue sometimes "fills the gap" that has been created. This replaces the normal layers of epidermis that would normally be created by the stratum basale layers. This connective tissue continues to grow and produce new layers of cells much like the stratum basale. However, as these cells reach the outer layers of our skin, they do not appear the same as the surrounding tissue.

Another common problem with our skin can be found in the presence of **blisters**.

Blisters

The two layers of our skin are connected together by a connective tissue known as the basement membrane. This is a seamless connection much like connecting two pieces of paper together with glue. But, as you may have experienced before, the act of gluing two pieces of paper together can be tricky because of air pockets that sometimes occur during the connection. These "air pockets" are what occur during the formation of a blister. Damage to the epidermis either by burning or friction (as in the continual rubbing of your shins against a new pair of shoes) can cause the epidermis to separate from the dermis/hypodermis at the basement membrane. Much like the air bubbles which form under the glued papers, the opened space between the layers of skin quickly fill with fluid from the damaged area as your body attempts to fix this separation.

Since we have mentioned burns, this may be a good time to identify the different types of burns and how they relate to the structure of our skin.

Burns

The burning of our skin is caused by exposure to excessive heat and can be placed into three different categories:

First-degree burns

These are burns which damage only the epidermis. They are typically red and painful, but not swollen and blistering. Sunburns are a good example of first-degree burns.

Second-degree burns

These are burns which damage the epidermis and the upper region of the dermis/hypodermis. Much like first-degree burns, these are red and painful as well. However, blisters typically form with second-degree burns.

Third-degree burns

Third-degree burns are severely painful. These burns may turn the skin white or charred in appearance. Heat from these burns destroys all layers of the skin, including blood vessels and nerve endings. Unlike with first- and second-degree burns, skin damaged by third-degree burns does not regenerate. Without the protective barrier of the skin, bacteria and viruses can easily enter the body; however, the largest threat is that of dehydration as the body cannot prevent water from evaporating from the body.

Let's move deeper into the body and look at what can affect our bones.

You have learned that our bones are actually living tissue and not simply hardened deposits of minerals that help to move our bodies. Our bones receive just as much exercise as our muscles when we use them regularly. In fact, our bones increase in size and strength when they go through different stresses such as those found during exercise.

It is a known fact that our bone tissue quickly breaks down when it is not being used. Some estimates state that bones which do not receive any form of exercise can lose up to a third of their mass after a few weeks! So don't spend all your time learning about anatomy and physiology… get out there and move!

Back in Chapter 4, you discovered that the growth of our bones involves a delicate balance between bone-developing cells (osteoblasts) and the bone-destroying cells (osteoclasts). The rate of development must equal that of its destruction or a problem will soon occur – especially if the rate of destruction is faster than that of development. This is the primary issue involved with a condition known as osteoporosis.

Osteoporosis

If the rate in which the osteoclasts destroy your bones is faster than the osteoblasts can grow new tissue, a bone can become very thin and be easily broken. **Osteoporosis** is more severe in women as their bones are normally smaller and thinner than those of males. Additionally, the chemical known as **estrogen** helps to maintain bone mass, so the loss of estrogen as a woman ages contributes to more severe osteoporosis.

Bone tissues within the spine may also become damaged if they become abnormally curved in a disorder called **scoliosis**.

Scoliosis

Scoliosis is the most common abnormal curvature of the spine and causes lateral (side) bending of the backbone. This curvature occurs either in the thoracic region, the lumbar region, or both of these regions. At this time, there is no known cause for most cases of scoliosis but it can be treated with specific braces on the back and with surgery.

The last condition we will look at occurs within the synovial joints of our skeletal system and is known as **arthritis**.

Arthritis

The name arthritis actually describes a group of disorders which affect synovial joints. Although there are many different causes for arthritis, they all involve damage to the cartilage which exists between the bones of synovial joints. One type of arthritis (known as **osteoarthritis**) commonly affects our larger, well-worn joints such as the hips and knees. Referred to as "wear and tear" arthritis, this disorder tends to affect us as we grow older and is the result of our everyday activities.

Another type of arthritis, **rheumatoid arthritis**, is caused by the inflammation of tissues within the synovial joints. Unlike osteoarthritis, this type usually affects the smaller joints first, such as those in the fingers, hands, and feet. This painful disorder can lead to the complete loss of functioning in the joint.

Let's see what is going on with our muscles now…

Instead of focusing our time on any of the numerous muscular disorders, I believe we should look at problems which occur on a daily basis to nearly all of us. First of all, let's spend a little time on the topic of <u>muscle fatigue</u>.

Muscle cells are very efficient at breaking down sugar into a chemical known as **ATP (adenosine triphosphate)** which is the main source of chemical energy needed for muscle fibers to contract. Typically, oxygen is present during the conversion of sugar to ATP (**aerobic respiration**); however, when oxygen is limited (**anaerobic respiration**) such as during a period of intense physical activity when oxygen is being used extensively, a waste product is created (**lactic acid**), which interferes with the process of muscle contraction and causes your muscles to become <u>fatigued</u>.

A "pulled muscle" is different from muscle fatigue. With pulled muscles, the muscle fibers have been stretched too far which causes them to tear apart. If an area of your body looks like it is bruised and/or swollen and you are in a good deal of pain a day after the activity, you likely have a pulled muscle.

What about muscle cramps?

You learned in Chapter 6 that all skeletal muscles move in pairs – because skeletal muscles can <u>only</u> pull! Therefore, when you are moving an object, your muscles first contract then stretch back when another muscle pulls it from an opposite direction. However, sometimes a muscle contracts with such force it stays contracted and no other muscle acts to stretch it back into place. This is a **muscle cramp**. The inability of muscles to stretch the muscle fibers back into place can be caused by a number of minor chemical or nerve cell problems. These problems occur when our muscles are fatigued, cold, or depleted of vital minerals needed for our nerve cells to function.

Muscle spasms are another frequent problem one may encounter during exercise. A muscle spasm is a strong, painful, and consistent <u>involuntary</u> contraction. Remember, an involuntary action is one that simply occurs without our will. A "charley horse" is a common muscle spasm in the leg that occurs when our muscles are overworked. When this happens, the muscle in our leg feels painfully tight and requires rest and time for it to end its contraction.

What happens to our muscles as we get older?

As we get older our muscle fibers tend to get smaller and lose their ability to pull with as much force as when we are young. This causes our muscles to become less elastic and causes exercise to become more strenuous and recovery to become more difficult.

Since there is no time machine or fountain of youth, how do we combat these problems?

Keep moving, stay active, and continue to exercise throughout your life!

Match the following vocabulary terms with their correct definition:

aerobic respiration	**first-degree burns**	**pathogens**
anaerobic respiration	**inflammation**	**regeneration**
arthritis	**lactic acid**	**rheumatoid arthritis**
ATP (adenosine triphosphate)	**muscle cramp**	**scars**
blisters	**muscle spasms**	**scoliosis**
estrogen	**osteoarthritis**	**second-degree burns**
	osteoporosis	**third-degree burns**

1)	______________	a group of disorders which affect synovial joints
2)	______________	a large amount of connective tissue that replaces cut layers of epidermis resulting from a cut into the lower dermis/hypodermis layer
3)	______________	a strong and painful involuntary contraction of muscles
4)	______________	a type of arthritis caused by the inflammation of tissues within the synovial joints
5)	______________	a type of arthritis commonly affects the larger, well-worn joints such as the hips and knees
6)	______________	burns which damage only the epidermis
7)	______________	burns which damage the epidermis and the upper region of the dermis
8)	______________	chemical which helps to maintain bone mass and regulates the organs and tissues within the female reproductive system
9)	______________	compound created by cells which acts as the main chemical fuel for all bodily processes
10)	______________	condition in which bones become abnormally thin and brittle; caused by the excessive activity of osteoclasts

11)	______________	conversion of sugar to ATP at times when oxygen is in abundance
12)	______________	conversion of sugar to ATP at times when oxygen is limited
13)	______________	disorder causing abnormal curvature of the spine and lateral (side) bending of the backbone
14)	______________	first stage of tissue repair; identified by swelling, redness, excessive warmth, and pain in the area that contains the damaged tissues
15)	______________	fluid-filled pocket between the epidermis and the dermis/hypodermis; caused by burning or friction
16)	______________	harmful agents that invade the body
17)	______________	heat from these burns destroys all layers of the skin, including blood vessels and nerve endings
18)	______________	produced by muscle fibers during exercise which interfere with the ability of calcium ions to produce muscle contraction
19)	______________	second stage of tissue repair in which the body attempts to restore homeostasis be replacing/repairing damaged tissues back to their normal functions
20)	______________	situation in which a muscle contracts with such force it stays contracted and no other muscle acts to stretch it back into place

Choose the correct answer from the following questions:

1. **Anaerobic respiration occurs without the presence of:**
   A) glucose
   B) oxygen
   C) lactic acid
   D) ATP
   E) carbon dioxide

2. **What is the first threat to life from a massive third-degree burn:**
   A) blood loss
   B) infection
   C) dehydration
   D) unbearable pain

3. **True or False:** Joe just burned his hand on a hot pot. A blister forms and the burn is painful. Joe's burn would best be described as a third-degree burn.

4. **True or False:** In first-degree burns, only the epidermis is damaged.

5. **True or False:** Lactic acid results from aerobic respiration.

6. **True or False:** A muscle spasm results when the muscle is involuntarily contracted and fails to immediately relax.

Application Question:

Imagine the following experiment was run in a typical classroom. The normal rate of respiration for a group of resting students was determined. In Experiment A, students ran in place for 30 seconds and then immediately sat down and relaxed, where the rate of respiration was again determined. The same procedure was run for students in Experiment B; however, these students held their breath while running in place. What differences in the rate of respiration would you expect for the two different experiments? Defend your answer.

Chapter Eight
Nerves

In the next four chapters we will be looking at the single most important system in our bodies that help to maintain homeostasis:

The Nervous System

The main functions of this vital system are to receive signals concerning what is going on inside and outside our bodies (**perception**); to sort and direct these signals to other areas of the body (**integration**); and, to manage the responses of the organ systems to these signals.

Think about how fast we can react to a stimulus such as a baseball being thrown at us. Much like the aquarium story we explored back in Chapter One, our bodies contain receivers (which we will learn about this week), which send signals to a control center (known as the **Central Nervous System** or **CNS**), so that the effectors (again, this is what you will explore this week) will respond to what the control center tells it to do. And all of these actions have to occur very fast or that baseball that is moving closer towards your head is going to hurt a lot!

In order to understand the functions of the nervous system, we need to look at its most basic structure:

The Nerve Cell

The nerve cell (neuron) is very similar to most of the 50-100 trillion cells in your body. They are surrounded by a cell membrane, contain DNA, and carry out many of the normal processes of regular cells.

However, there are two very important differences between neurons and the other cells within your body...

Structure and Signaling

In terms of structure, neurons are the longest cells in the human body. Some of these individual cells can reach over three feet in length! A typical neuron consists of a branched end known as the **soma** which contains the cell nucleus. Each of the branches spreading out from the soma are known as **dendrites** and are structures which receive an incoming stimulus. A long slender body known as the **axon** extends from the soma as well. Axons take information away from the soma and move them towards the central nervous system. In a little bit we will talk about how these "messages" are sent; however, we still need a little more information about the structure of a nerve cell.

First of all, the axons of nerve cells tend to be packed together like a cable into long strands which we call **nerves**. And...

Nerves are classified by the direction in which they send information:

Sensory (or **afferent**) **nerves**: Send information from sensory receivers (e.g., in skin, eyes, nose, tongue, ears) TOWARD the central nervous system.

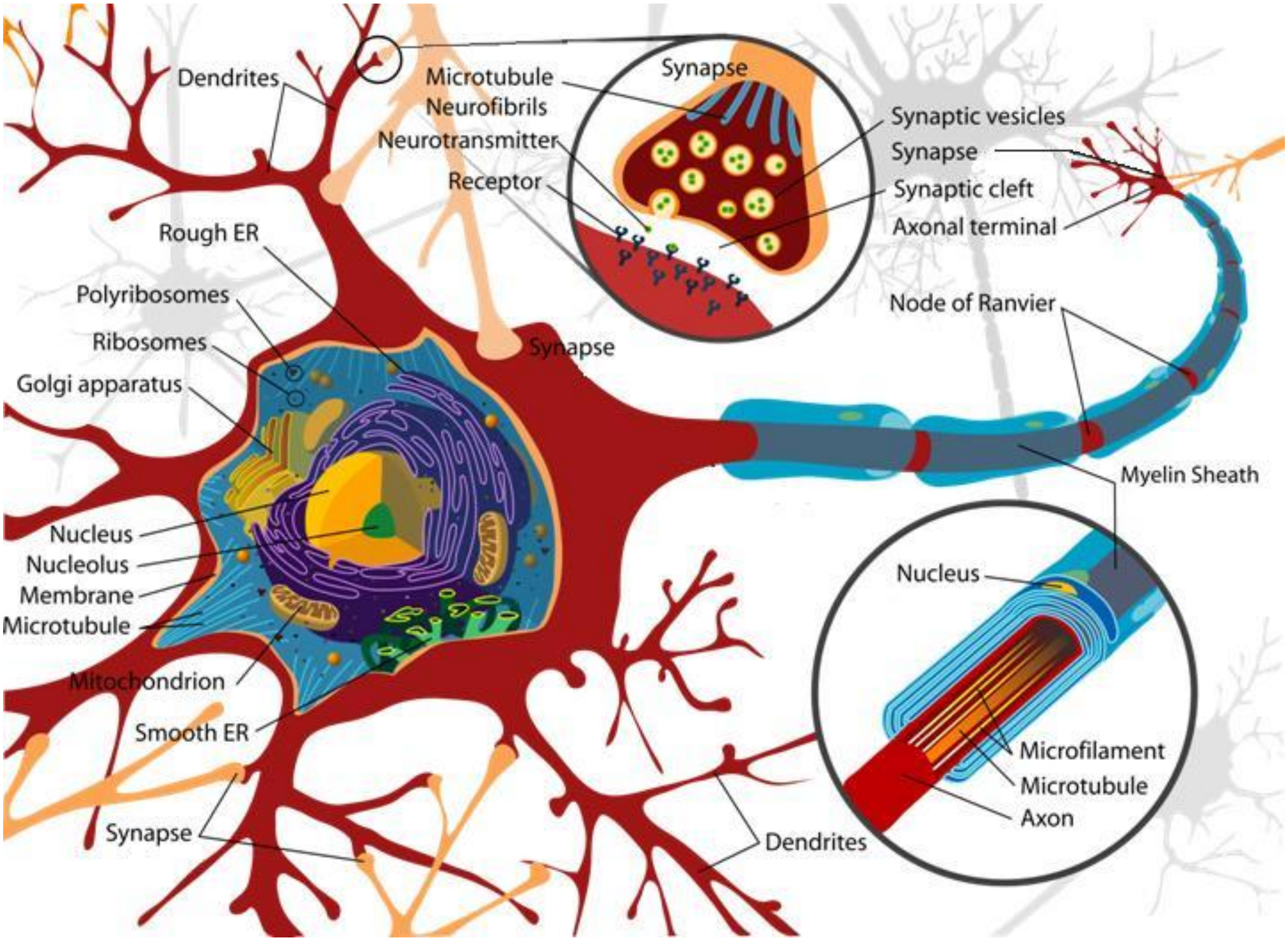
Motor (or **efferent**) **nerves**: Send information AWAY from the central nervous system to the effectors (e.g. muscles or glands.)

If you need a little help keeping all this in your memory, try this little device:

<u>A</u>fferent connections <u>a</u>rrive, and <u>e</u>fferent connections <u>e</u>xit.

<u>D</u>endrites <u>d</u>eliver impulses while <u>a</u>xons send them <u>a</u>way.

The Anatomy of a Neuron



Now what about these "messages" sent by neurons?

This next section deals with how neurons differ from ordinary cells in the body in terms of how they signal other cells. Neurons communicate with each other through an **electrochemical process**. This means that chemicals cause an electrical signal to be sent through your nerve cells. How can this happen?

Well, to understand this you have to understand one basic thing about electricity...

The movement of electrons causes electricity to occur!

Nearly all objects we come into contact with in the world are electrically neutral at rest. This means the amount of positively-charged particles (**protons**) within an object is roughly identical to the amount of negatively-charged particles (**electrons**) as well. However, there is another fact within the universe which states that nothing every really stays at rest. This is true for the protons, but it is especially true for the electrons as they are over 1800 times smaller than protons and constantly in motion!

Here's what all this has to do with our neurons…

Two important elements in the human body (sodium and potassium) have the ability to lose one of their negatively-charged electrons spinning around their nuclei. When this happens, these elements become a little more positively-charged. Whenever an element loses or gains one or more electrons it is known as an **ion**. The symbol for a sodium ion is $\mathbf{Na^+}$ while the symbol for the potassium ion is $\mathbf{K^+}$. By moving a huge amount of these charged particles in and out of a neuron, the charge of the cell can be changed from being electrically neutral to electrically positive or negative. As a nerve cell becomes more negatively charged, it drives electrons along the axon of the nerve cell causing an electric current to flow!

Don't forget! Neurons are just like ordinary cells. As you learned in Chapter 2, the cell membrane around these cells are semipermeable which means they can control which substances (like ions) are allowed in and out of the cell.

You probably noticed the words "at rest" in the above few paragraphs were underlined. Here's why...

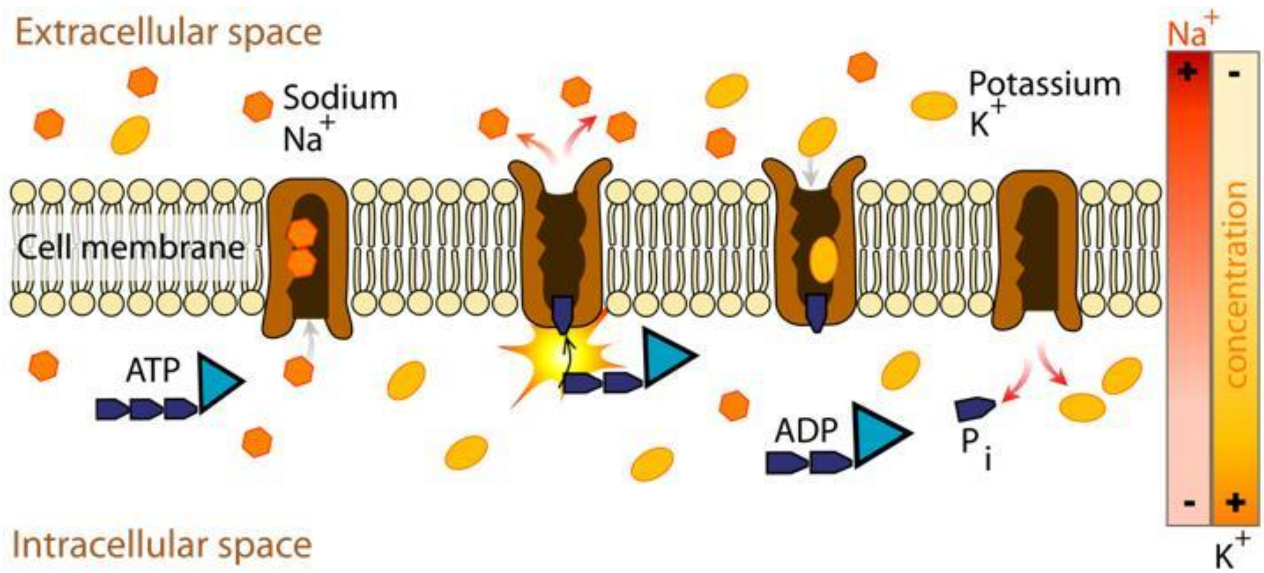
When a neuron is not sending a signal, it is "at rest" and contains a slightly negative charge as compared to its outside environment. This occurs because many of the particles within the neuron contain an abundance of electrons and maintain a negative charge. These particles cannot pass through the neuron's membrane because of its semipermeable nature.

A more thorough explanation of this would be...

At rest, there are relatively more sodium ions outside the neuron and more potassium ions inside a neuron. If you were to calculate all of the ion charges that exist on both sides of the cell membrane of a neuron, you would find that the internal environment of a neuron is more electrically negative than its surroundings. The semipermeable nature of the membrane is maintained by active transport, diffusion, and filtration systems (these later two are collectively referred to as *passive transport systems*). Diffusion and filtration systems allow ions to *passively* move through the cell membrane of the neuron through openings along the surface of the neuron. In contrast, *active* transport systems along each neuron (known as **sodium/potassium pumps)** use chemical energy (ATP) to move three sodium ions out of the neuron for every two potassium ions it allows in.

The bottom line is this... When you measure all of the charges within a neuron, it remains electrically negative at rest. This charge is known as the **resting potential**.

Sodium/Potassium Pump



Within the sodium/potassium pump, the chemical known as ATP (adenosine triphosphate) loses one of its three phosphate ions which allows for the release of energy to drive three sodium ions out of the cell for every two potassium ions it allows in. After losing one of its phosphates, ATP becomes the molecule known as ADP (adenosine diphosphate.)

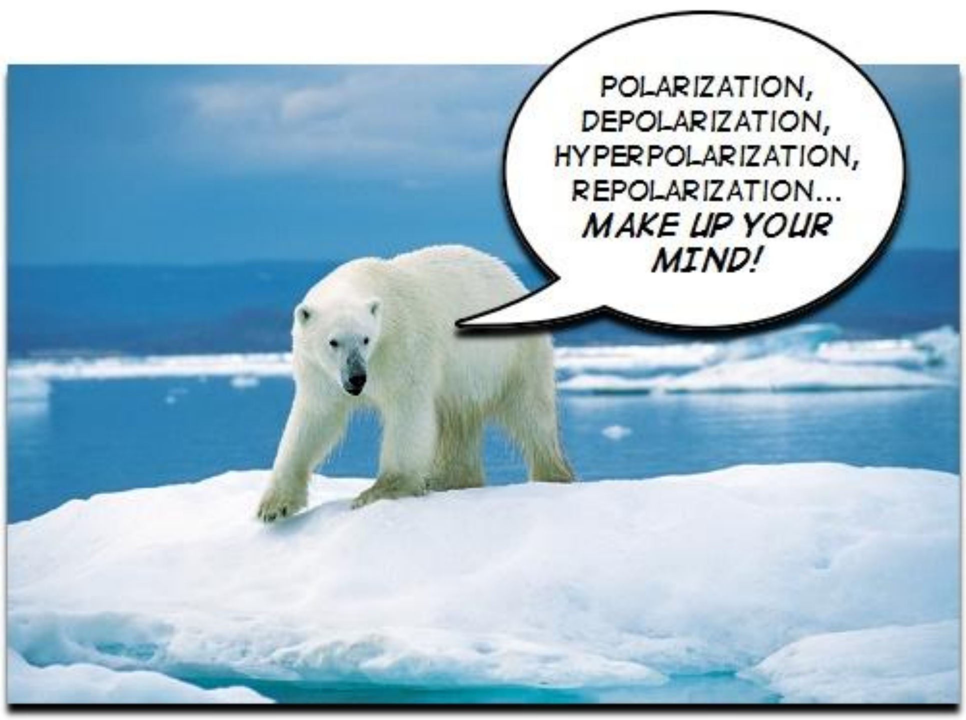
So what happens when a neuron is not "at rest"?

When a neuron is not at rest, a series of actions occur which result in a nerve impulse and is the "signal" or "message" we have been talking about throughout this chapter. A nerve impulse has five steps:

Polarization, Depolarization, Repolarization, Hyperpolarization, and the Refractory period

We've already discussed this first step. The **polarization** stage of a neuron exists when the electrical charge on the outside of the neuron is positive while the electrical charge on the inside of the membrane is negative. At this time, an abundance of sodium ions can be found outside the neuron as compared to the inside. The unbalanced negative charge of the neuron at rest is thereby known as its resting potential.

When the dendrites of a cell receive a stimulus, they allow a large amount of sodium ions to enter the cell. This begins a series of actions known collectively as an **action potential**. As a wave of positively-charged sodium ions enters the neuron, it ceases to be polarized (negatively charged) and begins to move more towards a positive charge (known as **depolarization**.)



Perhaps this visual will help:

Imagine a long hallway filled with doors of two different sizes - large and small. During the action potential, the smaller doors would continue to open, one-after-another, like a domino effect, allowing sodium ions to fill up the hallway.

This "hallway" symbolizes the axon of the nerve cell.

As each of these smaller doors open and sodium ions begin to enter the hallway at one end, the larger doors open and the larger potassium ions begin to <u>leave</u> the hallway (neuron) as well. Once the potassium ions pass through the doorway, the large doors close behind them along with the smaller doors nearby. This action triggers the opening of adjacent small and large doors farther down the hallway. This results in a wave-like effect of incoming sodium ions and departing potassium ions.

The movement of the larger positively-charged potassium ions from the inside of the cell begins to lower the now positively-charged cell back to a more negative charge. This process is known as **repolarization** and continues until too many potassium ions have escaped the cell, causing the internal charge of the neuron to be way too negative! At this stage, the neuron is said to be **hyperpolarized**.

With more potassium ions outside the cell rather than inside, the neuron is not even close to being at rest!

This is when the sodium/potassium pump gets to work! Through active transport, this pump drives three sodium ions out of the neuron for every two potassium ions it allows back in. During this time (known as the **refractory period**) a neuron can no longer send any more signals through its axon until it has reached its resting potential once again and the number of sodium ions outside the cell is in greater quantity than the number of potassium ions inside the cell. Once this is completed, the nerve cell can receive another stimulus and send another electrochemical signal down its axon.

How quickly do nerve impulses travel?

This question depends on a particular substance you first read about back in Chapter 2 – myelin. This lipid protects and insulates the axon much like the rubber/vinyl covering protects and insulates an electrical wire. This analogy is not entirely perfect as gaps exist within the myelin covering along the axon.

These gaps are very important as they regulate the speed of a nerve impulse!

As previously described, sodium and potassium ions move in and out of a neuron through a wave of doors opening and closing along the length of an axon. This occurs within nerve cells containing no myelin covering. However, the presence of myelin blocks many doors along its length. A few doors can open, then several are blocked by myelin, then another row of doors are allowed to open and so on. The few doors that are allowed to open, therefore, permit a faster rush of ions to be moved through the axon.

Imagine a crowd of people surrounding a stadium and attempting to get through one of many gates. What would happen if only a third of the gates were opened? People would crowd through the available openings at a much faster rate! This is very similar to the movement of sodium and potassium ions passing through the neuron's cell membrane along a myelinated axon.

Therefore, the speed in which the nerve impulse can perform is much greater! Here are some numbers for you...

The slowest nerve impulses travel at 1.7 miles per hour (2.7 km/hr) in small unmyelinated nerve cells.

Nerve impulses in large myelinated neurons can travel at 269 miles per hour (433 km/hr) or faster!

What happens when the nerve impulse reaches the end of the cell?

Much like reaching a dead end in a road, a nerve impulse would not travel very far at all if it could not find its way into other nerve cells. The location where two nerve cells meet and transmit signals to each other are known as **synapses.** Every synapse requires the action of two cells: the **presynaptic neuron** and the **postsynaptic neuron**. The presynaptic neuron is the cell that sends the message, while the postsynaptic neuron is the cell that receives the message. Some synapses allow the electrochemical signal to jump from one neuron to another in areas known as **gap junctions**. In other parts of the body, neurons communicate with other neurons or to muscle tissue by releasing chemicals called **neurotransmitters**. In short, presynaptic neurons release transmitters which influence receptors on the postsynaptic neurons or muscle tissue to create a response to a stimulus.

You have gathered a lot of information about how an individual nerve cell gathers information and sends a signal. Now you need to learn where this signal ends up! Next stop...

The Central Nervous System

Match the following vocabulary terms with their correct definition:

action potential	**integration**	**proton**
axons	**ion**	**refractory period**
Central Nervous System	**motor nerves**	**repolarization**
dendrites	**nerves**	**resting potential**
depolarization	**neurotransmitters**	**sensory nerves**
electrochemical process	**perception**	***sodium/potassium pumps***
electron	**polarization**	**soma**
gap junctions	**postsynaptic neuron**	**synapses**
hyperpolarized	**presynaptic neuron**	

1)	______________	a long cable-like bundle of nerve cell axons
2)	______________	a series of actions during a nerve impulse in which a large amount of sodium ions enter the cell after the dendrites receive a stimulus
3)	______________	active transport system which uses energy to move three sodium ions out of the neuron for every two potassium ions it allows in
4)	______________	an element which has lost or gained one or more electrons
5)	______________	areas between synapses in which an electrochemical system can jump from one neuron to another
6)	______________	cell body of a nerve cell
7)	______________	chemical which allow for neurons to communicate with other neurons
8)	______________	control center of the nervous system; consisting of the brain and spinal cord
9)	______________	electrically negative charge of all neurons

10)	______________	method of communication between neurons in which chemicals are released thereby triggering a nerve impulse
11)	______________	negatively-charged particle within an atom; 1800+ times smaller than a proton
12)	______________	period of time after repolarization when an excess of potassium ions have left the neuron causing it to become more negative
13)	______________	period of time during a nerve impulse in which a neuron can no longer send any more signals along its neuron before its resting potential is reached once again
14)	______________	period of time during a nerve impulse when waves of positively-charged sodium ions enters the neuron; this causes the neuron to become more positively charged
15)	______________	proton-charged particle within an atom
16)	______________	send information AWAY from the central nervous system to the effectors (e.g. muscles or glands)
17)	______________	send information from sensory receivers (e.g., in skin, eyes, nose, tongue, ears) TOWARD the central nervous system
18)	______________	special structures extending from the surface of nerve cells which receive a stimulus
19)	______________	special structures within a nerve cell which move nerve impulses towards the CNS
20)	______________	stage of a neuron in which the electrical charge on the outside of the neuron is positive while the electrical charge on the inside of the membrane is negative
21)	______________	stage within a nerve impulse when the movement of positively-charged ions from the inside of the cell begins to lower the positively-charged cell back to a more negative charge

22)	______________	the cell that receives the message from the presynaptic neuron
23)	______________	the cell which sends a message
24)	______________	the location where two nerve cells meet and transmit signals to each other
25)	______________	the receiving of signals concerning what is going on inside and outside the body
26)	______________	the sorting and directing of signals to other areas of the body

Choose the correct answer from the following questions:

1) The areas of a neuron that typically receives incoming stimuli are called:
   A) soma
   B) dendrites
   C) gap junctions
   D) synapses
   E) axons

2) The diffusion of potassium ions out of a neuron causes it to experience:
   A) repolarization
   B) an action potential
   C) a nerve impulse
   D) a depolarization

3) The conduction of nerve impulses is fastest in neurons that are:
   A) sensory
   B) unmyelinated
   C) cerebral
   D) motor
   E) myelinated

4) A chemical that is released from presynaptic neurons to create a nerve impulse is called:
   A) an ion
   B) an action potential
   C) the sodium-potassium pump
   D) a neurotransmitter

5) Afferent nerves are called __________, and motor nerves are called __________.

A) peripheral nerves; cranial nerves
B) sensory nerves; efferent nerves
C) cranial nerves; peripheral nerves
D) motor nerves; sensory nerves
E) mixed nerves; motor nerves

6) An action potential is caused by an influx of these ions into the cell:

A) both potassium and sodium
B) potassium
C) sodium
D) magnesium
E) calcium

Application Question:

Lithium ions reduce the ability of sodium ions (Na^+) to pass through the membrane of a cell. Predict the effect lithium ions in the extracellular fluid (fluid found outside of a neuron) would have on the response of a neuron to stimuli.

Chapter Nine

Central Nervous System

In the last chapter, you learned how nerve cells (aka-neurons) are the most basic structure within the nervous system. This week, we are going to bundle up large numbers of these neurons and follow the path of their impulses towards the control center of the body in a little place we call the...

Central Nervous System (CNS)

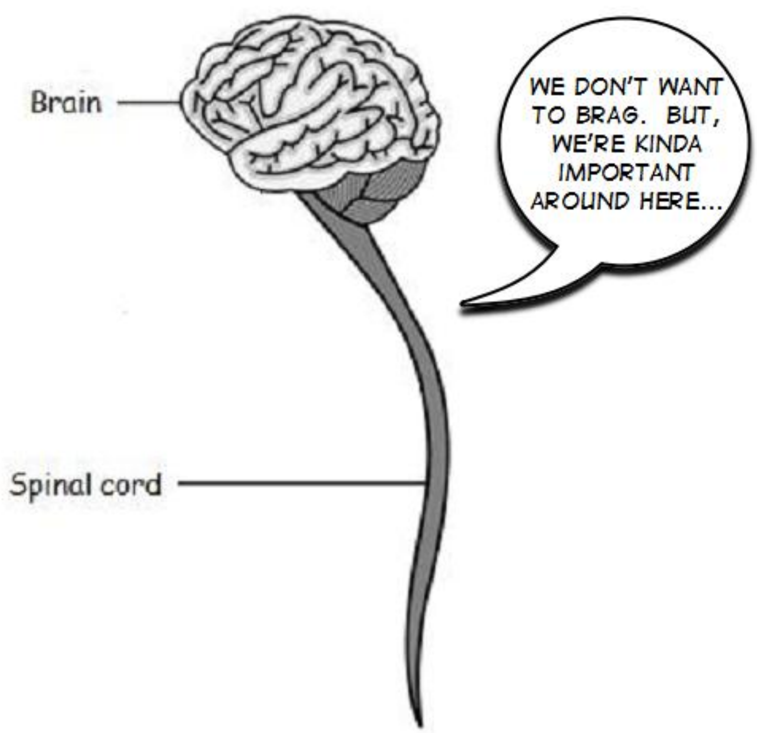
The central nervous system lies in the center (go figure) of every nerve impulse throughout our bodies and contains only two different organs:

The Brain and Spinal Cord

Before we explore these amazing organs, let's go through a little review...

The main functions of the nervous system are to receive signals concerning what is going on inside and outside our bodies (perception); to sort and direct these signals to other areas of the body (integration); and, to manage the responses of the organ systems to these signals.

Neurons send nerve impulses from the sensory receivers throughout our bodies (like the skin, eyes, tongue, etc.) toward the organs of the CNS. Once received, these organs react by sending new impulses to the effectors (muscles or glands) that allow us to react to a stimulus. The nerves that send signals towards the CNS are known as sensory (afferent) nerves while those which carry the response impulses are called motor (efferent) nerves.



Let's look at how the body protects its control center!

To begin with, brain and spinal cord are two organs which are attached to each other and are protected by specialized bones. The **skull** surrounds the brain and the *vertebral column* protects the spinal cord. Both of these skeletal protectors are made up of a number of individual layers of tissues. The most important of these tissues are known as the **meninges**. The meninges are the three innermost fiber-like layers of tissue that cradles the brain and spinal cord within the skull and vertebral column. The space between the meninges and the organs is filled with a specialized fluid known as **cerebrospinal fluid** or **CSF**. This fluid helps to support the brain and spinal cord by allowing it to "float" within their bony protectors.

Think of it like this...

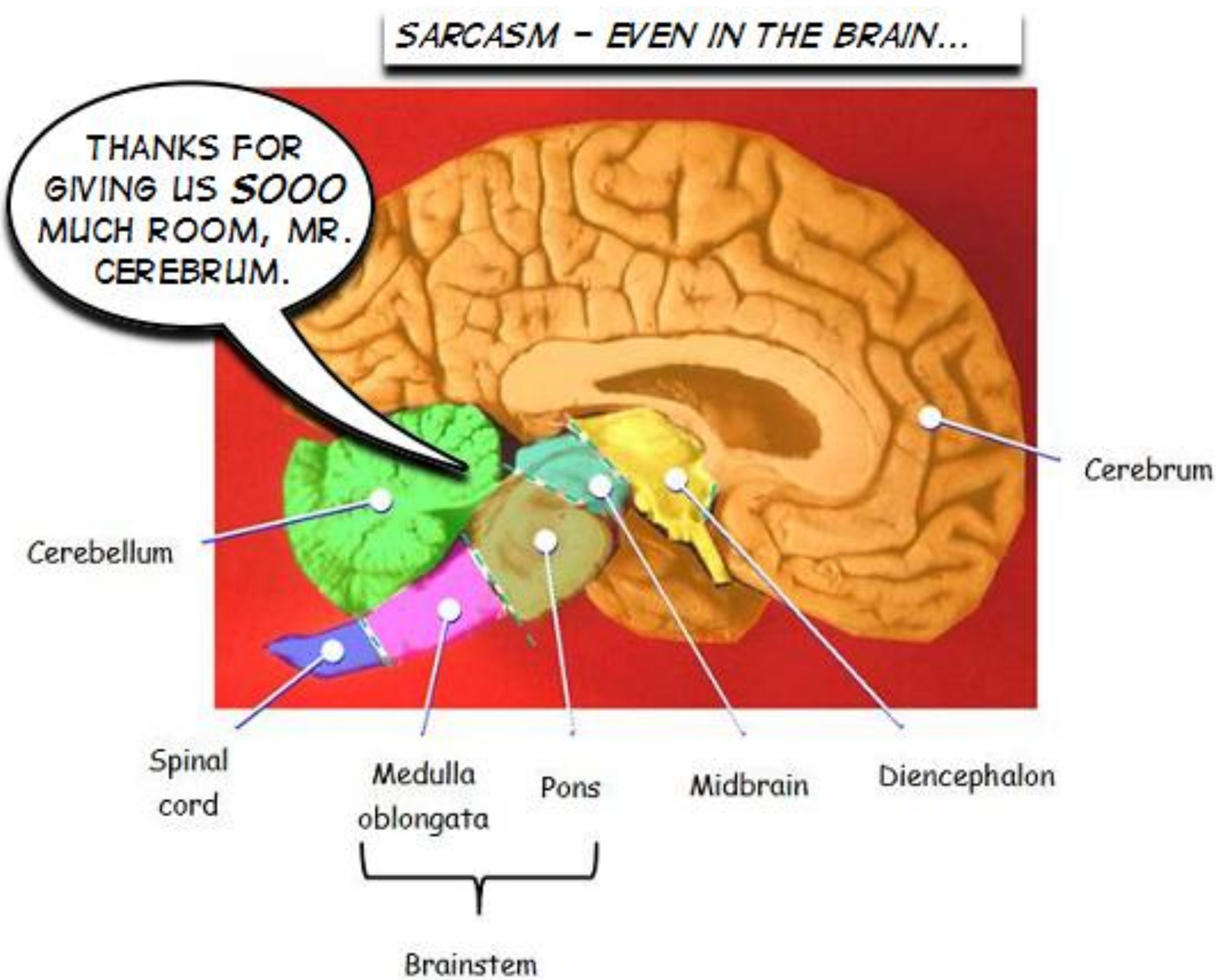
The brain is like a person driving a car. If the car hits a wall, the car will stop immediately; however, the driver will continue moving forward and will hit the steering wheel very fast unless he is wearing a seat belt. Without the seat belt, the driver may suffer a serious injury.

The tough, fibrous layers of the meninges act like seat belts which hold the brain in position. The CNS would be the bumper of the car which cushions the brain from sudden bumps as well.

Now that you know how the body protects the CNS, let's take a closer look at each of these two amazing organs. Our first stop... the brain!

The **brain** is one of the largest organs in the human body with an average weight of 3 pounds (1.36 kg) and contains roughly 100 billion neurons. There are six major areas of the brain which we will now explore:

Medulla oblongata, Cerebellum, Cerebrum, Diencephalon, Midbrain, and the Pons



Medulla oblongata

The **medulla oblongata** connects the spinal cord to the brain and is responsible for nearly all of the main functions within the cardiac, respiratory, and digestive systems. In many instances, nerve impulses will travel from the body into the spinal cord and upward into the brain through sensory/afferent nerves. Once the brain has processed the signal, it sends a nerve impulse back into the spinal column through motor/efferent nerves. Two large bundles of these afferent and efferent nerves can easily be seen within the medulla oblongata and are known as **the pyramids**. Many of these nerves cross from one pyramid to another as nerve impulses travel to and from the CNS. The crossing of nerves between the pyramids is the main reason why the right side of the brain controls the left side of the body and vice versa.

Pons

The **pons** (a Latin word meaning "bridge") does exactly as its name implies. It connects the various areas of the brain into one single area. The pons is located above the medulla oblongata and anterior to the cerebellum.

In addition to acting as a bridge, the pons also relays information from the medulla oblongata to other areas of the brain and is responsible for several functions of the respiratory system. Together, the pons and medulla oblongata are known as the **brainstem**.

Midbrain

The midbrain is located between the pons and the diencephalon and is typically classified as a portion of the brainstem. This area of the brain is associated with the sensations of motor control, sleep/wake cycles, and alertness. In addition, it also serves as a relay station for the sensations of vision and hearing.

Cerebellum

The **cerebellum** also is known as the "little brain" or "small brain." Despite its name, this section is the second-largest area of the brain. The cerebellum is located in the posterior area of the brain, just above the brainstem. Inside its structure, the cerebellum resembles a tree called the **arbor vitae**, or "tree of life."

It is the cerebellum you can thank for the coordination of your movements, including your balance, equilibrium, and posture.

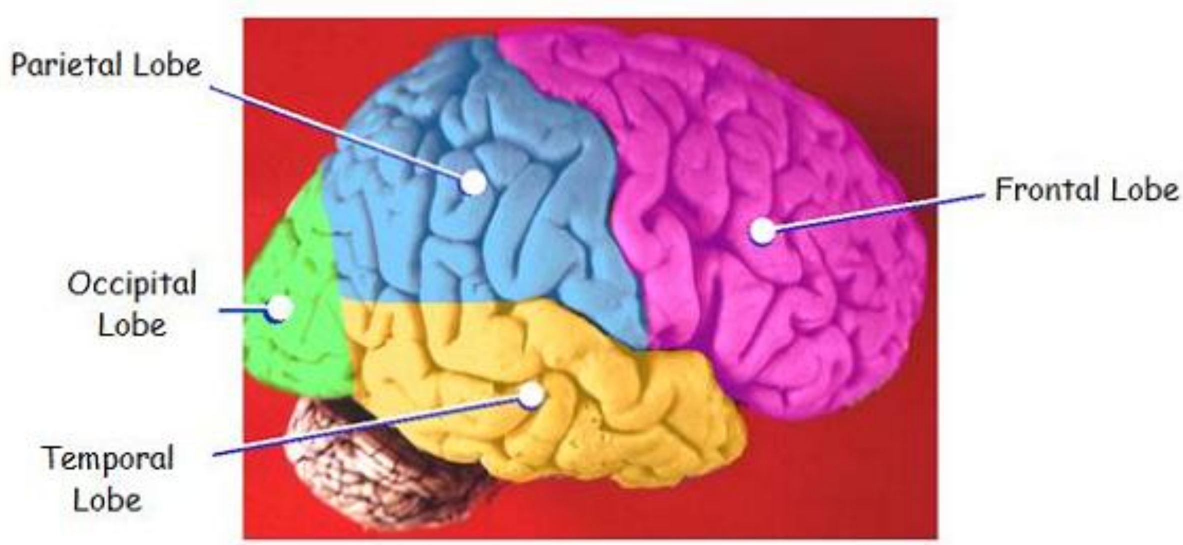
Cerebrum

The **cerebrum** is often called the "true brain" and makes up the majority of the brain's mass. If I were to ask you to close your eyes and imagine what a brain looks like, you would likely think about a wrinkly mass of tissue that contains a thin valley through its center separating it into two sections. Right? Both of these sections are known as the **right and left cerebral hemispheres**. The "wrinkly mass" you can picture in your mind is a thin layer of tissue known as the **cerebral cortex.**

Each hemisphere has a set of controls for sensory and motor activities of the body which eventually pass through the pyramids. Due to the neural "wiring" within the pyramids, the right hemisphere of the brain controls the left side of the body and vice versa. In addition, the upper areas of the cerebral cortex control the lower body activities while the lower areas of the cortex control upper-body activities as well! Cool, huh?

The cerebral cortex is divided into areas (**lobes**) each responsible for specific functions in the body:

Name of lobe	Location in brain	Function of lobe
Frontal lobe	Anterior section	Intelligence, memory, and idea association
Parietal lobe	Upper middle section	Sensations of temperature, touch, and sense of position and movement as well as the perception of size, shape, and weight
Temporal lobe	Lower middle section	Responsible for the perception of hearing
Occipital lobe	Posterior area	Responsible for the perception of vision



THE CEREBRAL CORTEX IS PRETTY HARD TO MISS.

Diencephalon

The **diencephalon** is a region between the midbrain and the cerebrum. This area of the brain can be broken down into separate structures as well, the most important of which being the **thalamus** and *hypothalamus*. The thalmus acts as a processing center for most of the sensory information received by the brain. Nerve impulses traveling through the thalamus are typically directed to specific areas of the brain that are prepared to respond to specific stimuli. The hypothalamus, as you learned back in Chapter 3, is also a vital area as it has the important jobs of regulating body temperature, water balance, sleep-wake cycles, hunger, satiation, emotions, and many of the chemical messengers which move throughout our body.

Now that you have a good idea about our brain, let's take a look at the second organ of the CNS - the spinal cord!

The **spinal cord** looks like a long oval-shaped cylinder about 0.5 inches (1.3 centimeters) in diameter with two deep grooves running down its length and is found in openings in the bones within the vertebral column. It extends from the medulla oblongata downward through the vertebrae for approximately 16 to 18 inches (42 to 45 centimeters). As stated above, the cord is surrounded and protected by the three-layered meninges which are filled with cerebrospinal fluid.

You might be thinking that the length of the spinal cord is a little small compared to your spinal column.

As your body is developing, bone tissue grows much faster than nerve tissue. Therefore, the bones of the vertebrae column extend far beyond the length of the cord itself. Typically, the cord only reaches close to where the last ribs are attached to the spine. But it doesn't end there!

The spinal cord continues to extend down the vertebrae column as a series of thin nerves resembling the shape of a horse's tail. Because of this shape, this collection of nerves is known as **cauda equina** which is Latin for "horse's tail."

What makes up the spinal cord?

Two types of solid material make up the inside of the spinal cord (and the brain as well): **gray matter** and **white matter**. Gray matter consists of unmyelinated neurons which are grayish in color. Due to the lack of myelin, the neurons which make up the gray matter carry the slowest nerve impulses in the brain. The white matter (yes... it really does look white due to the presence of the white-colored myelin) consists of thousands of myelinated nerve fibers that send nerve impulses up and down the spinal cord. It is the afferent nerves within the white matter that carries the primary nerve impulses to the brain and the efferent nerves of white matter which carry impulses away from the brain.

How does the brain communicate with the spinal cord and the rest of the body?

This is bit of a gray area (no pun intended) because of the number of nerve impulses that exist in our bodies. The nerves, spinal cord, and brain work together to keep you aware of what is going on inside and outside of your body.

However, not all nerve impulses reach the brain. Some are managed solely by the spinal cord itself. For example, your spinal cord makes you drop a frying pan you didn't realize was very hot until it was too late. Before the nerve impulses reach your brain and you become aware of the pain, you've already released the pan!

Other times, nerve impulses remain entirely within the brain. Our eyes, for example, are attached to *optic nerves* which are connected directly to the brain. This helps us to react quickly to stimuli we sense in our environment by bypassing the spinal cord.

And in some occasions, the CNS is completely taken out of the process. Our hearts, for example, do not require our spinal cord or brain to instruct it to beat. As you learned back in Chapter 2, the function of cardiac muscle tissue is involuntary and operates without the use of the brain or spinal cord.

Where do we go from here?

Well, there are thirty-one pairs of **spinal nerves** which are attached to the sides of the spinal cord and 12 pairs of **cranial nerves** attached to the brain which eventually spread out throughout our bodies. Remember, all of these nerve impulses have to get to and from the CNS. Therefore, all of these nerves will be the focus of our study next week as we explore...

the Peripheral Nervous System

Match the following vocabulary terms with their correct definition:

arbor vitae	**frontal lobe**	**occipital lobe**
brain	**gray matter**	**parietal lobe**
cauda equina	**lobes**	**the pyramids**
cerebellum	**medulla oblongata**	**skull**
cerebral cortex	**meninges**	**spinal cord**
cerebrospinal fluid	**pons**	**temporal lobe**
cerebrum	**cerebral hemispheres**	**white matter**
cranial nerves	**spinal nerves**	
diencephalon	**thalamus**	

1)	______________	12 pairs of nerves attached to the brain which spread throughout the body
2)	______________	31 pairs which are attached to the sides of the spinal cord
3)	______________	a large bundle of nerve fibers protected within the vertebral column
4)	______________	a relay and processing center for most sensory information received into the brain
5)	______________	a specialized fluid located in the space between the meninges and the organs
6)	______________	area of the brain which connects the spinal cord to the brain
7)	______________	collection of fused irregular bones which protect the brain
8)	______________	connects the various areas of the brain into one single organ; located above the medula oblongata, below the midbrain and anterior to the cerebellum

9)	______________	extension of thin nerves below the vertebrate column resembling the shape of horse's tail
10)	______________	lobe of the cerebral cortex which is responsible for intelligence, memory, and idea association
11)	______________	lobe of the cerebral cortex which is responsible for sensations of temperature, touch, and sense of position and movement as well as the perception of size, shape, and weight
12)	______________	lobe of the cerebral cortex which is responsible for the perception of hearing
13)	______________	lobe of the cerebral cortex which is responsible for the perception of vision
14)	______________	makes up the majority of the brain's mass; separated into right and left hemispheres
15)	______________	neurons and unmyelinated dendrites and axons and is grayish in color within the brain
16)	______________	one of two main organs of the CNS; control center for most neural activity throughout the body
17)	______________	region between the midbrain and the cerebrum; contains the thalamus and hypothalamus
18)	______________	second-largest area of the brain; found above the medulla oblongata; responsible for movements, balance, equilibrium, and posture
19)	______________	specialized areas of the cerebral cortex which is responsible for specific functions in the body
20)	______________	thousands of myelinated nerve fibers that send nerve impulses up and down the cord

21)	______________	three fiber-like layers of tissue that cradles the brain and spinal cord within the skull and vertebral column
22)	______________	tree of life; name given to the anatomy of the cerebellum
23)	______________	two halves of the cerebrum
24)	______________	two large bundles of afferent and efferent nerves within the medulla oblongata; responsible for right/left sides of the brain controlling opposite sides of the body
25)	______________	wrinkly mass surrounding the right/left cerebral hemispheres

Choose the correct answer from the following questions:

1) **Control of temperature, emotions, hunger, and thirst are functions associated with the:**
   A) thalamus
   B) cerebellum
   C) hypothalamus
   D) medulla oblongata
   E) cerebrum

2) **White matters refers to:**
   A) unmyelinated neurons within the spinal cord
   B) unmyelinated neurons within the CNS
   C) unmyelinated neurons within the brain
   D) myelinated neurons within the CNS
   E) myelinated neurons within the brain

3) **The medulla oblongata is also known as the:**
   A) diencephalon
   B) brain stem
   C) pineal gland
   D) hypothalamus
   E) cerebellum

4) **The term "central nervous system" refers to the:**
   A) spinal cord and afferent nerves
   B) autonomic and efferent nerves
   C) brain, spinal cord, and efferent nerves
   D) brain and afferent nerves
   E) brain and spinal cord

5) The inability to remain balanced can result from damage to the:

A) hypothalamus
B) cerebrum
C) midbrain
D) cerebellum
E) thalamus

6) Lobe that is responsible for your ability to determine the weight of an object:

A) frontal lobe
B) occipital lobe
C) parietal lobe
D) temporal lobe

Application Question:

Cerebral meningitis is a condition in which the meninges of the brain become inflamed as the result of viral or bacterial infection. Do you believe this condition can be life threatening? Why or why not?

Chapter Ten

Peripheral Nervous System

Okay... Let's start this week off with a little review:

The main functions of the nervous system are to perceive what is going on inside and outside our bodies; to integrate these signals to other areas of the body; and, to manage the responses of the organ systems to these signals.

The signals we receive and the responses they trigger are sent as electrochemical nerve impulses along bundles of individual nerve cells called nerves.

Many of these signals are sent directly to a central nervous system which consists of two organs: the brain and spinal cord.

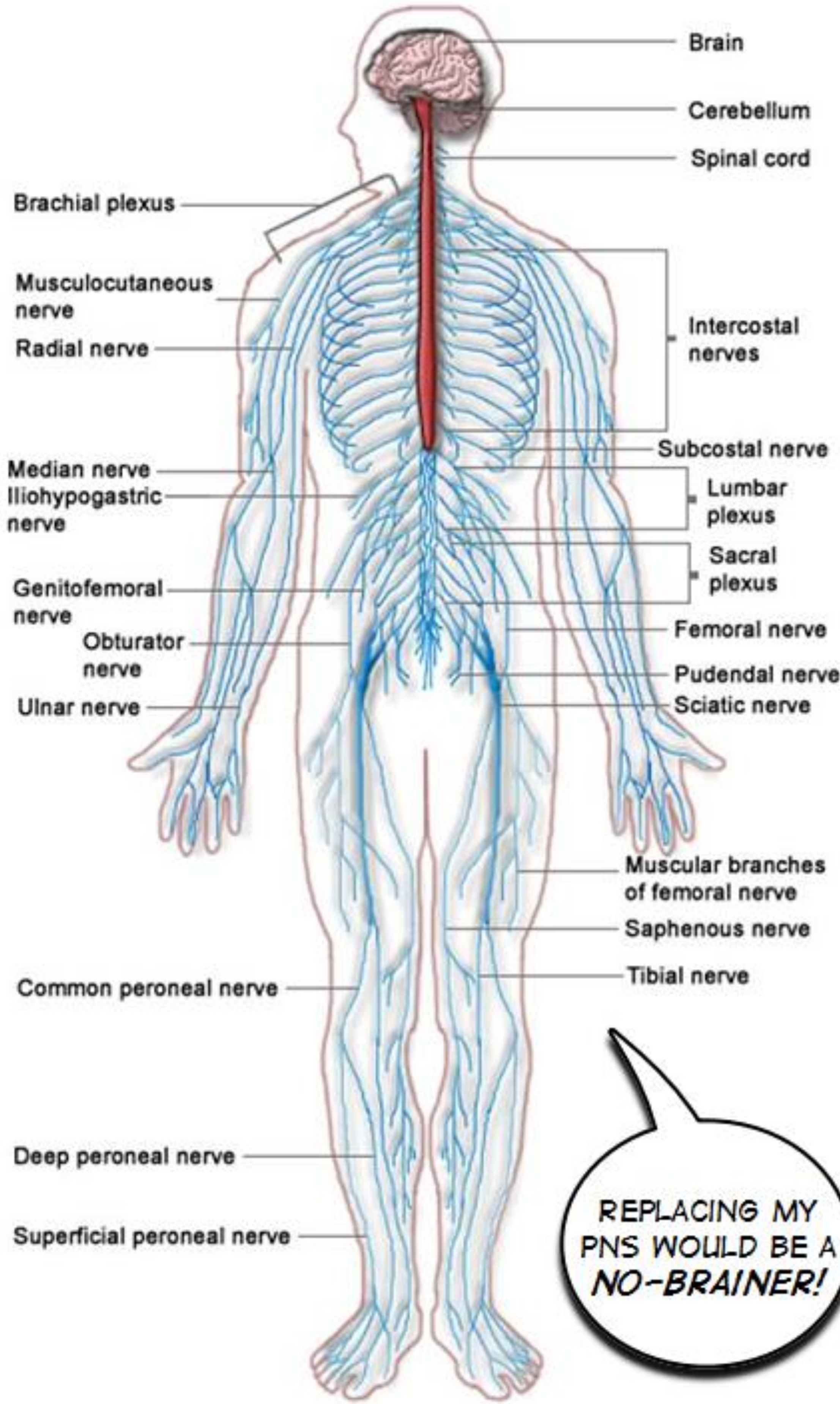
Now it's time to study the pathways of nerves attached to the central nervous system which send these signals. These large areas of efferent nerves make up the second division of the nervous system known as the...

Peripheral Nervous System (PNS)

All communication from the central nervous system to the rest of the body is accomplished through the peripheral nervous system. And, as you have learned before, specialized nerves allow this communication to exist:

Sensory (or afferent) nerves send information from the body TOWARD the central nervous system; and motor (or efferent) nerves send information AWAY from the central nervous system.

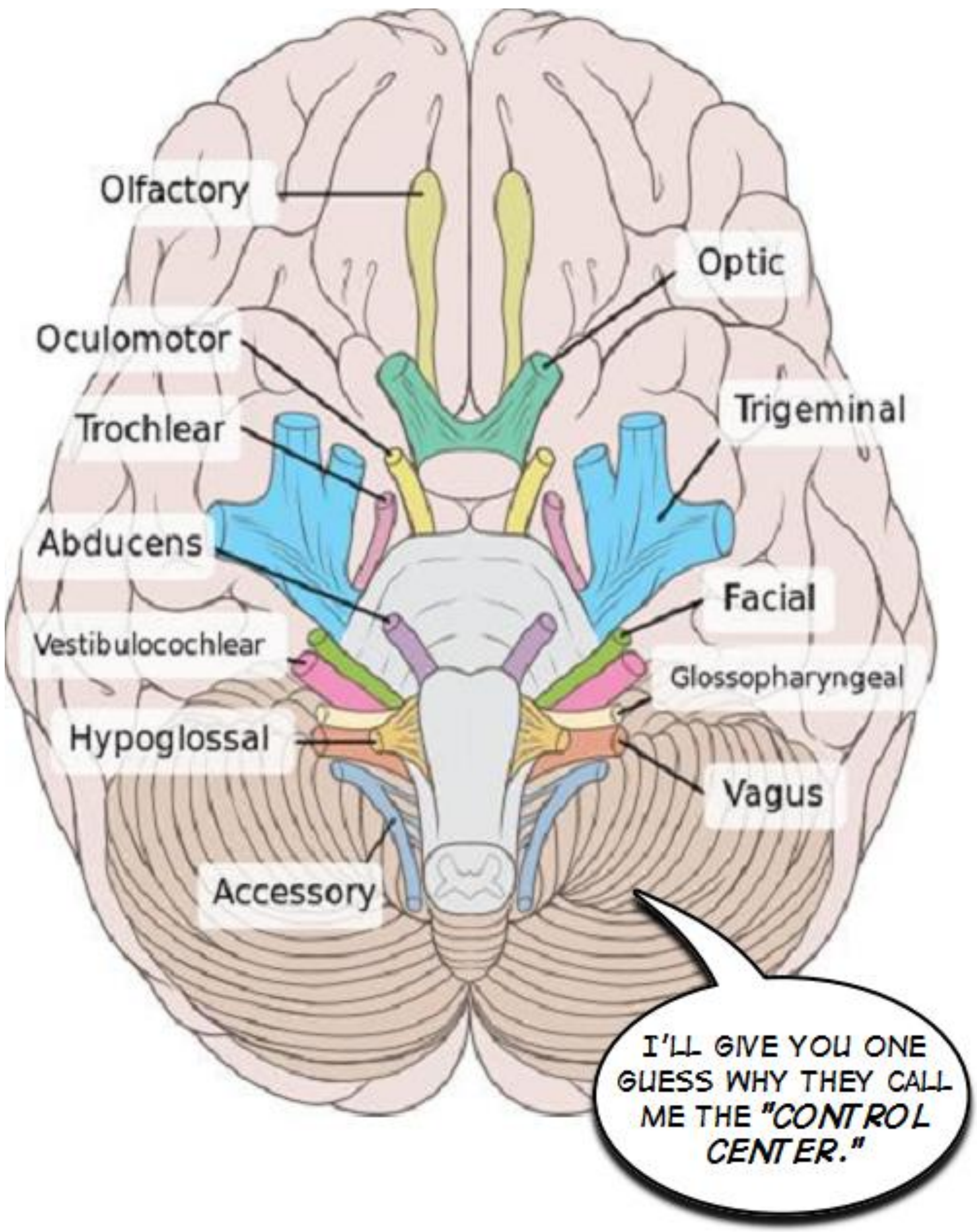
If you were to place all of the nerves within the PNS end-to-end in your body, it would stretch for approximately 93,000 miles (150,000 kilometers) in length! Impressive? That distance measures approximately four times around the planet!


Brain
Cerebellum
Spinal cord
Brachial plexus
Musculocutaneous nerve
Radial nerve
Intercostal nerves
Subcostal nerve
Median nerve
Iliohypogastric nerve
Lumbar plexus
Sacral plexus
Genitofemoral nerve
Femoral nerve
Obturator nerve
Pudendal nerve
Ulnar nerve
Sciatic nerve
Muscular branches of femoral nerve
Saphenous nerve
Tibial nerve
Common peroneal nerve
Deep peroneal nerve
Superficial peroneal nerve
REPLACING MY PNS WOULD BE A *NO-BRAINER!*

The peripheral nervous system has been divided into two subdivisions:

Somatic Nervous System and Autonomic Nervous System

You briefly read last week of the thirty-one pairs of spinal nerves attached to the sides of the spinal cord and 12 pairs of cranial nerves attached to the brain. All of these cranial and spinal nerves make up the **somatic nervous system**. These nerves connect the brain and spinal cord to structures such as the skin and the skeletal muscles.



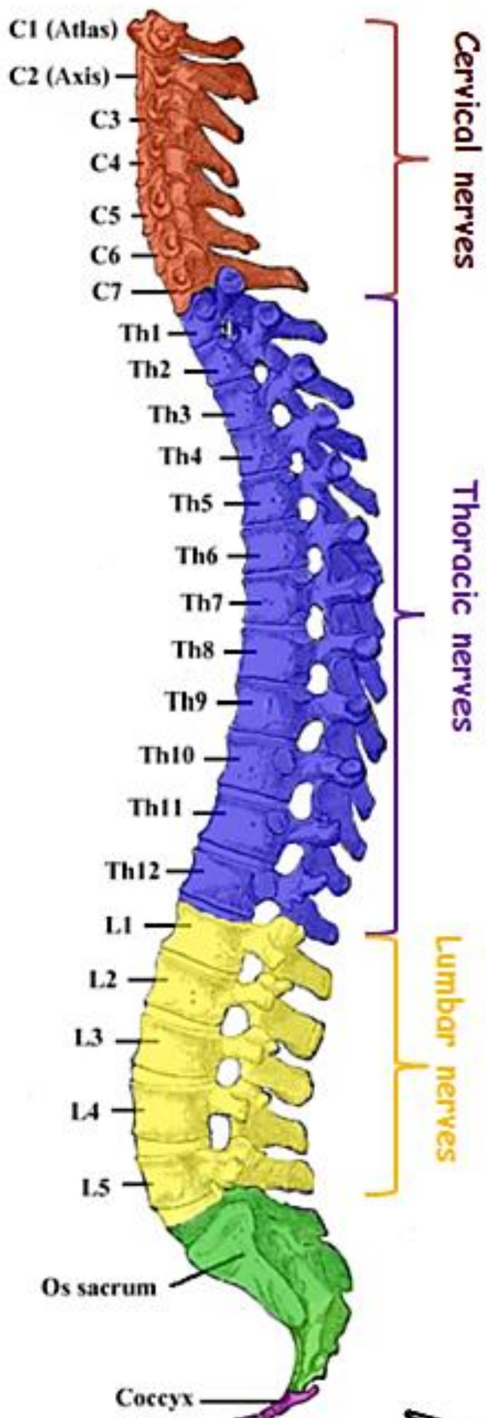
The cranial nerves are connected directly to the brain and are identified by both Roman numerals and their function. As you will notice in the chart below, these nerves are attached to movements and sensations in and around the head.

Cranial nerves and their function:

Name of Cranial Nerve	Function
I Olfactory	Smell
II Optic	Vision
III Oculomotor	Movement of the eye, eyelid, pupil, and lens
IV Trochlear	Movement (rotation) of the eye
V Trigeminal	Sensations to the face, including scalp, forehead, cheeks, upper lip, tongue, and lower jaw; regulates the act of chewing
VI Abducens	Movement (abduction) of the eye
VII Facial	Facial expressions, taste, secretion of tears and saliva
VIII Vestibulocochlear	Hearing and balance of the body
IX Glossopharyngeal	Taste, swallowing and secretion of saliva
X Vagus	Swallowing, coughing, voice production; monitors blood pressure and oxygen and carbon dioxide levels in blood
XI Spinal Accessory	Voice production; movement of head and shoulders
XII Hypoglossal	Movement of tongue during speech and swallowing

The somatic nervous system also contains thirty-one pairs of spinal nerves as well. These nerves are connected directly to the spinal cord. In addition, spinal nerves are identified by the nearest individual vertebrae to which their attachment is located along the spinal cord. For example, the cervical nerves attach to the spinal cord alongside the first two vertebrae, C1 and C2.

Spinal nerves - location and function:



Location	Function
C1-C6	Flexes neck
C1-Th1	Extends neck
C3, C4, C5	Moves diaphragm (mostly C4)
C5, C6	Shoulder movement, raise arm (deltoid); flexion of elbow (biceps); C6 externally rotates the arm
C6, C7	Extends elbow (triceps) and wrist
C7, Th1	Flexes wrist
C7, Th1	Moves small muscles of the hand
Th1 -Th6	Intercostals and trunk above the waist
Th7-L1	Abdominal muscles
L1, L2, L3, L4	Thigh flexion
L2, L3, L4	Thigh adduction
L4, L5, S1	Thigh abduction
L5, S1, S2	Extension of leg at the hip (gluteus maximus)
L2, L3, L4	Extension of leg at the knee (quadriceps)
L4, L5, S1, S2	Flexion of leg at the knee (hamstrings)
L4, L5, S1	Flexion of foot
L4, L5, S1	Extension of toes
L5, S1, S2	Flexion of foot
L5, S1, S2	Flexion of toes

The somatic nervous system uses all of these cranial and spinal nerves to connect the body to the central nervous system. However, as you learned in the last chapter, there are some occasions where the CNS is not a part of a nerve impulse at all. In these cases, a second division of the peripheral nervous system does all the work. This system is known as the...

Autonomic Nervous System

The **autonomic nervous system** is responsible for all of the involuntary activity in the body. If you remember from previous chapters on muscles and tissues, an involuntary action takes place without any help from the CNS. Specifically, these actions take place within smooth and cardiac muscle tissue.

The autonomic nervous system is broken down into three divisions:

Sympathetic nervous system
Parasympathetic nervous system
Enteric nervous system

The **sympathetic nervous system** is often called the "fight or flight" system because it usually increases your alertness, increases your heart rate, and generally prepares your body to deal with emergencies. On the other side, the **parasympathetic nervous system** helps your body to conserve energy and tends to slow your heart rate.

The **enteric nervous system** is localized solely within the smooth muscle tissue of the digestive system.

Even though both the somatic and autonomic subdivisions of the peripheral nervous system are responsible for transmitting nerve impulses throughout the body, there is one very important difference I hope you will remember:

The **somatic nervous system** works with voluntary muscles such as skeletal muscles while the **autonomic nervous system** deals with involuntary muscles such as cardiac and smooth muscles.

Much like the rule concerning opposing muscles causing flexion and extension, the autonomic nervous system has a similar rule:

The sympathetic and parasympathetic systems typically have opposing actions.

But why do we need two systems opposing each other in the human body? The answer to this question can be found with our old friend...

Homeostasis

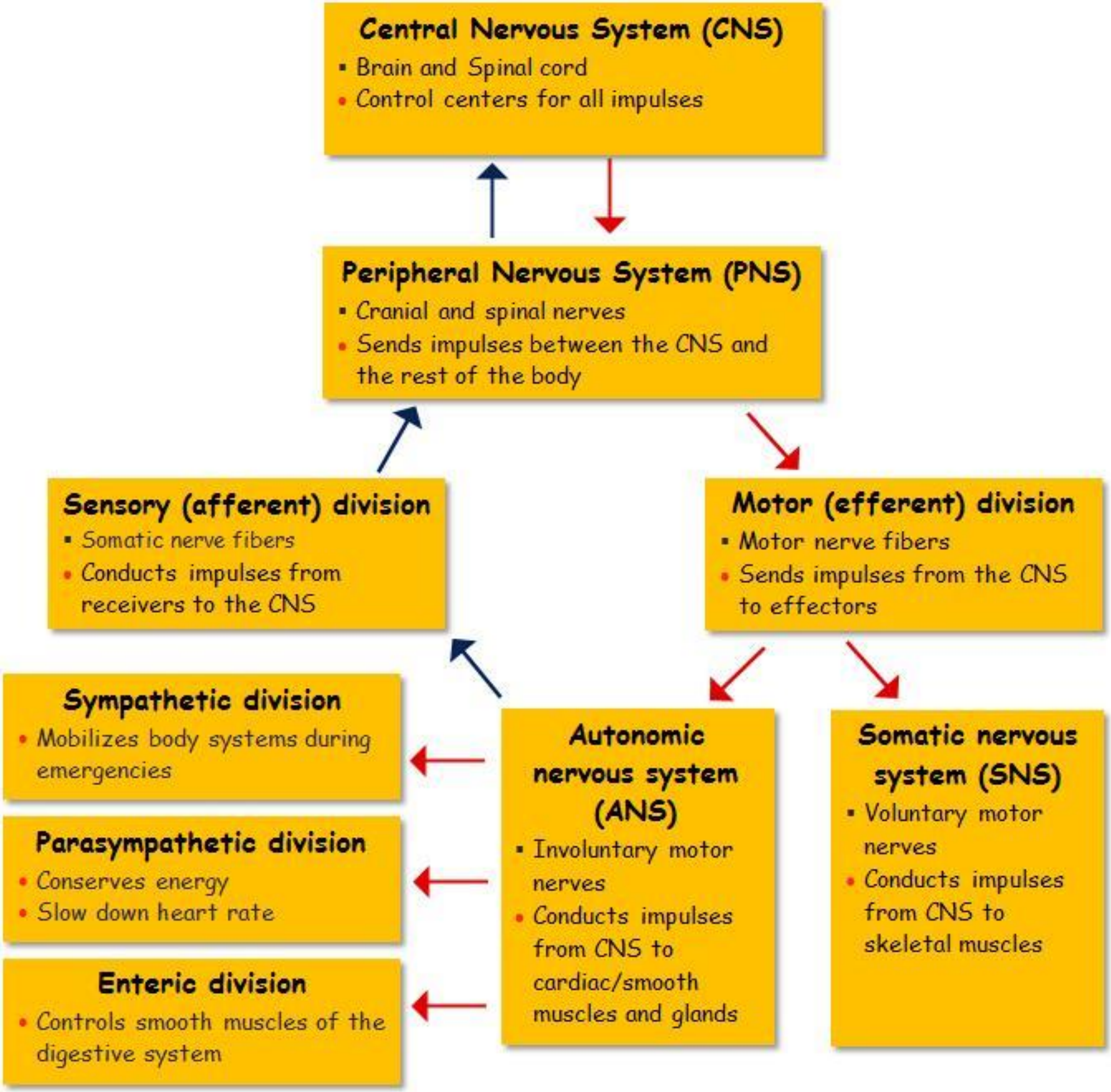
Looking back to our analogy of the aquarium in Chapter One, our bodies will act in a certain way until an opposing action brings it back to a balanced level. This can be felt when the sympathetic system makes your heart race when you are frightened.

But your heart doesn't continue to race, does it?

Hopefully not! It is the parasympathetic system which slows it down to a safe and comfortable rate. The same can be said of your lungs as the sympathetic system relaxes your lungs allowing air to flow into your body while the parasympathetic contracts the lungs and forces air out of your body. There are plenty of these involuntary actions within the human body that take place without any help whatsoever from the CNS:

Digestion of your food, Production of tears, Goosebumps, Sweating, ...and many more!

With all of these "nervous systems" floating around, your head may be spinning. On the following page you will find a flow chart that may help you separate all of the different divisions within the nervous system.



Naturally, we could spend months studying each of these individual systems; however, we have to stop here. Next week, we are going to take a look as some of our special senses. See you next week!

Match the following vocabulary terms with their correct definition:

enteric nervous system	**glossopharyngeal nerve**
autonomic nervous system	**hypoglossal nerve**
somatic nervous system	**lumbar nerves**
spinal accessory nerve	**oculomotor nerve**
sympathetic nervous system	**olfactory nerve**
vestibulocochlear nerve	**optic nerve**
parasympathetic nervous system	**thoracic nerves**
sacral and coccygeal nerves	**trigeminal nerve**
abducens nerve	**trochlear nerve**
cervical nerves	**vagus nerve**
facial nerve	

1)	______________	cranial nerve; responsible for the function of facial expressions, taste, secretion of tears and saliva
2)	______________	cranial nerve; responsible for the function of hearing and balance of the body
3)	______________	cranial nerve; responsible for the function of smell
4)	______________	cranial nerve; responsible for the function of swallowing, coughing, and voice production; also monitors blood pressure and oxygen and carbon dioxide levels in blood
5)	______________	cranial nerve; responsible for the function of taste, swallowing and secretion of saliva
6)	______________	cranial nerve; responsible for the function of vision
7)	______________	cranial nerve; responsible for the function of voice production; movement of head and shoulders
8)	______________	cranial nerve; responsible for the movement of tongue

9)	______________	cranial nerve; responsible for the abduction of the eye
10)	______________	cranial nerve; responsible for the rotation of the eye
11)	______________	cranial nerve; responsible for the movements of the eye, eyelid, pupil, and lens
12)	______________	cranial nerve; responsible for the sensations to the face and regulates the act of chewing
13)	______________	helps the body to conserve energy and tends to slow the heart rate
14)	______________	known as the "fight or flight" system because it usually increases the alertness and generally prepares the body to deal with emergencies
15)	______________	localized solely within the smooth muscle tissue of the digestive system
16)	______________	nerves which connect the brain and spinal cord to structures such as the skin and the skeletal muscles; works with voluntary muscles only
17)	______________	responsible for all of the involuntary body activity
18)	______________	spinal nerve; responsible for functions pertaining to the head, neck, and shoulders
19)	______________	spinal nerve; responsible for functions pertaining to the hips, tail bone, buttocks, rectum, anus, and sex organs
20)	______________	spinal nerve; responsible for functions pertaining to tissues found between the shoulders and intestines
21)	______________	spinal nerve; responsible for tissues found within the lower abdomen and all lower extremities

Choose the correct answer from the following questions:

1) Preparing the body for the "fight-or-flight" response during threatening situations is the role of the:

A) sympathetic nervous system
B) somatic nervous system
C) enteric nervous system
D) afferent nervous system
E) parasympathetic nervous system

2) Which one of these muscle types is NOT directly controlled by the autonomic nervous system:

A) smooth muscle
B) cardiac muscle
C) skeletal muscle

3) The cranial nerve that contains sensory fibers that are involved in hearing is:

A) cranial nerve VIII
B) cranial nerve II
C) cranial nerve IX
D) cranial nerve III
E) cranial nerve V

4) The peripheral nervous system consists of:

A) the spinal and cranial nerves
B) the brain and spinal cord
C) spinal nerves only
D) cranial nerves only
E) the brain only

5) The sympathetic and parasympathetic nervous systems are subdivisions of the:

A) autonomic nervous system
B) voluntary nervous system
C) somatic nervous system
D) central nervous system
E) peripheral nervous system

6) The effects of the sympathetic nervous system are essentially opposite of the:

A) autonomic nervous system
B) enteric nervous system
C) central nervous system
D) parasympathetic nervous system

Application Question:

Lindsay was watching a scary late-night horror movie when she heard a door slam and a cat's yowl. The hair rose on her arms and she was covered with goose bumps. Based upon your knowledge from this chapter, which section and subsection of the human nervous system do you believe is associated with the development of goose bumps because of Lindsay's situation? What evidence can you use to defend your idea?

Chapter Eleven

Sense Organs

In the past three chapters, we have explored the pathways of electrochemical signals through specialized cells known as neurons. In addition, we have also spent some time looking at the central nervous system and how it regulates our responses to various stimuli to our bodies.

This week, we will be fine-tuning our look at the peripheral nervous system by studying the very important and specialized functions which make up our...

Senses

Our senses can be broken down into two separate groups based upon their location in the body:

Special senses

These senses include our sense of smell, hearing, vision, taste, and balance and are produced by very specific organs found only in certain areas of the body.

General senses

These senses can generally be found throughout our body as they are associated with our skin. These senses include touch, pressure, pain, and temperature.

All of these senses require some form of sensory receptor (as you learned back in Chapter 3) which can detect changes in the environment and trigger a nerve impulse within the body. These receptors can be in the form of specialized neurons or other types of specialized cells which respond to particular stimulus.

The five different variations of sensory receptors listed below each responds to a different type of stimulus:

Name of sensory receptor	Responds to....
Chemoreceptors	...chemical compounds such as odor molecules
Photoreceptors	...light
Thermoreceptors	...changes in temperature
Mechanoreceptors	...changes in pressure or movement
Pain receptors	...stimuli that result in the sensation of pain

We could spend an entire week on each of these receptors. However, for the remainder of this chapter, let's focus more on four of our specialized senses:

Smell, Taste, Hearing, and Vision

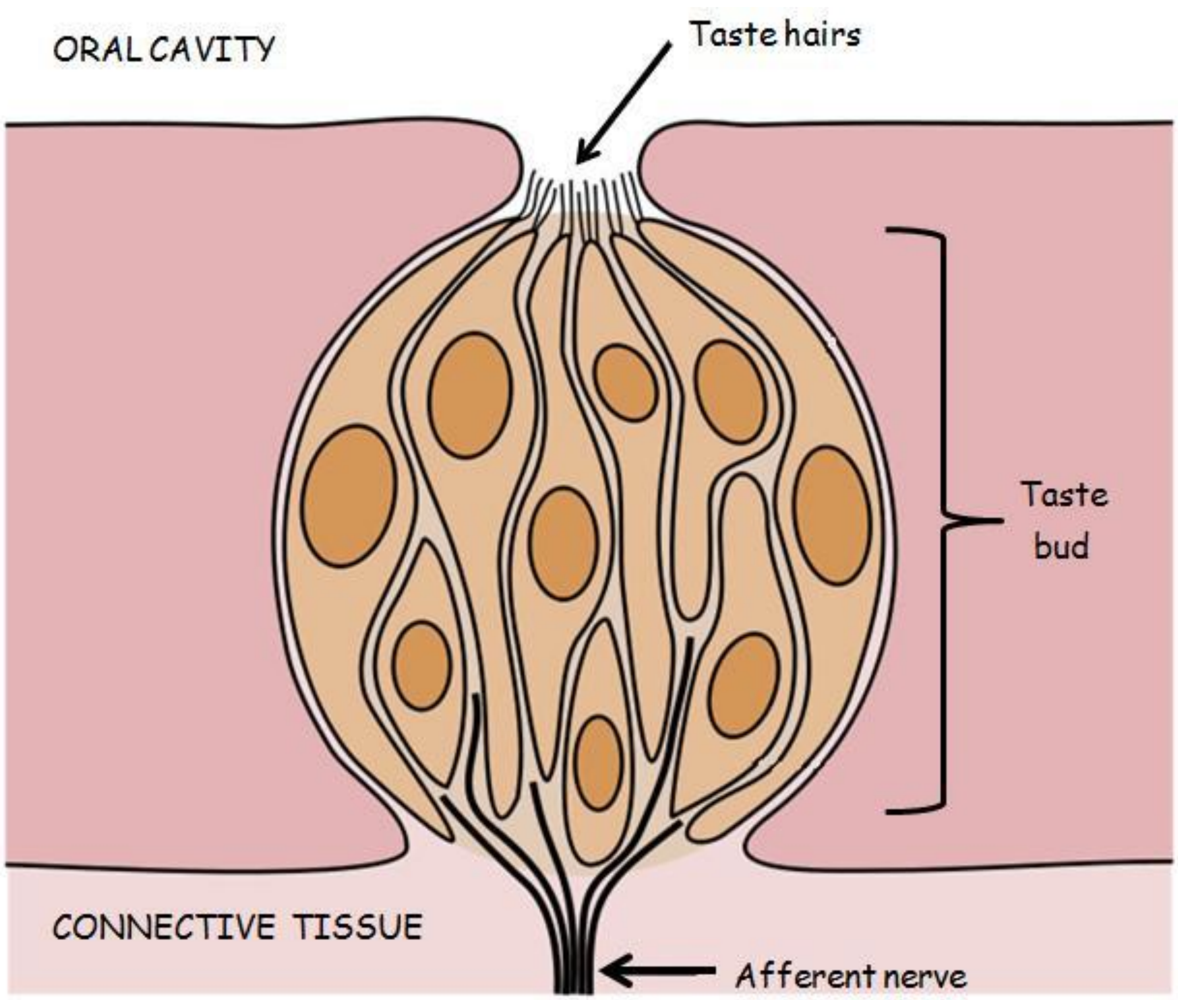
Smell

Chemoreceptors are responsible for our ability to detect different odors in the environment. These sensory receptors are specialized neurons as they do not contain dendrites but branches of fingerlike projections from the cell body called **cilia**. Each cilia contains one of nearly 4000 different "locks" which can only be opened by a specific "key" found on a particular molecule that has been inhaled.

When the individual key (which is attached to the outer surface of the inhaled object) finds its lock on a particular cilia, a nerve impulse is generated from its chemoreceptor towards the CNS. It is the brain which can identify which particular chemical is being smelled and can act accordingly.

Taste

Much like our sense of smell, our ability to taste is very specialized as well. This is due to bundles of specialized cells known as **taste buds** located on the superior surface of visible "bumps" mushroom-shaped projections on your tongue known as **papillae**. An adult has nearly 10,000 taste buds on the surface of the papillae. Individual cells within the taste buds contain specialized structures called **taste hairs** that act very similarly as the chemoreceptors found on cilia. Each taste hair is able to detect specific molecules using the same "lock and key" method. Once detected, a nerve impulse is sent to the brain for the sensation to be identified.



Generally speaking, our taste buds can detect four major types of taste sensations: sweet, sour, salty, and bitter. However, other sensations have also been identified such as metallic, **alkaline** (non-acidic compounds such as those in garlic, raw spinach, and broccoli), and **umami** (which is a flavor associated with a particular chemical called monosodium glutamate otherwise known as MSG).

All taste buds are able to detect each of the four basic taste sensations; however, most taste buds are more sensitive to only one type of taste sensation and can be found in clusters on particular areas of the tongue:

Taste Sensation	Area of the Tongue
Sweet	Tip of the tongue
Sour	Sides of the tongue
Salty	Tip and front edges of the tongue
Bitter	Back of the tongue

Hearing

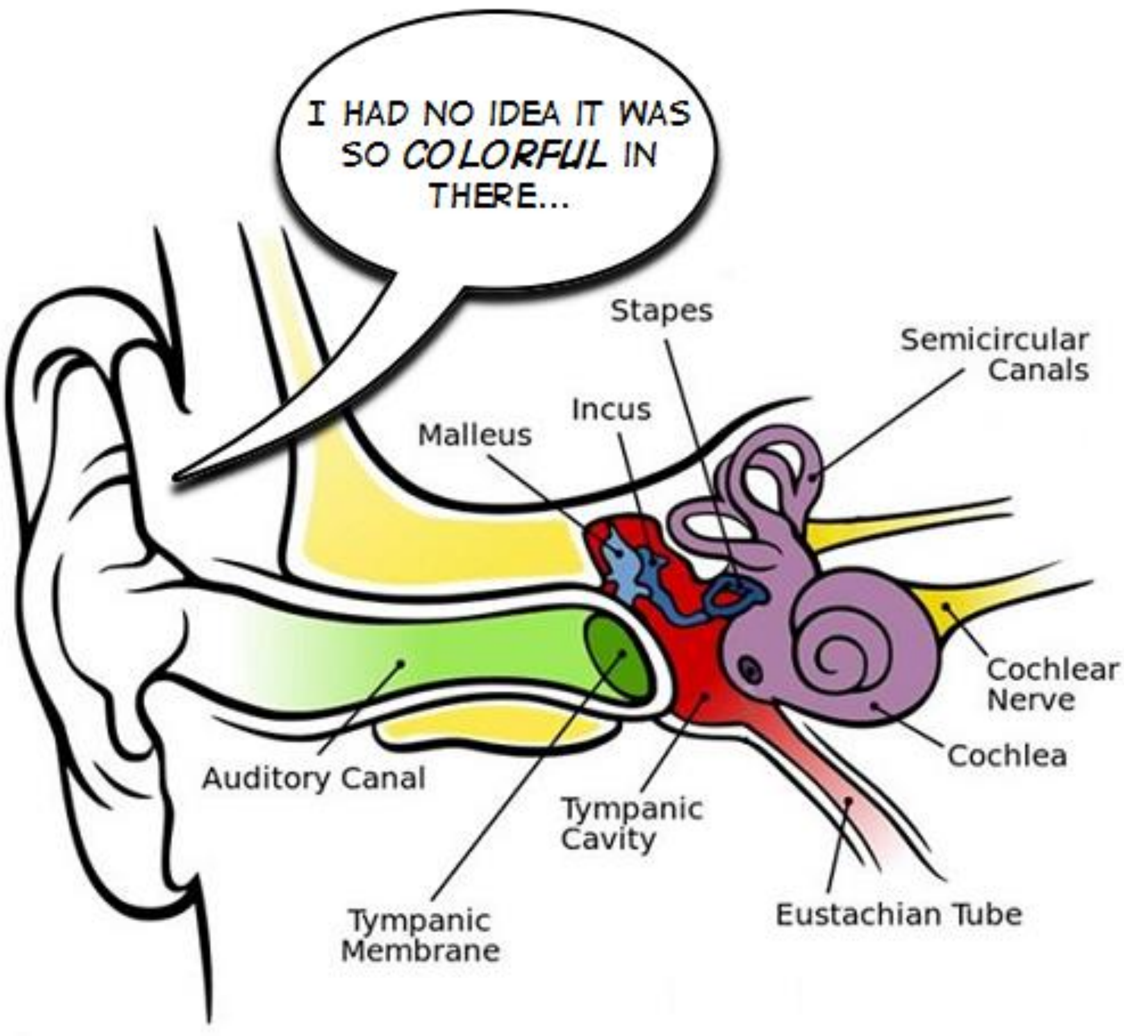
Our ears are more than just a place to hold onto our glasses. Before you explore the physiology of how we hear sounds, you need to understand the anatomy of the three major parts of the ear:

the **External ear, Middle ear,** and **Inner ear**

The **external ear** is the visible part of the ear and is made up of a funnel-shaped structure called the **pinna** attached to a 1 inch (2.5 cm) tube called the **auditory canal** which ends at the **eardrum** (**tympanic membrane**).

The **middle ear** (**tympanic cavity**) is a small, air-filled space within the skull which contains the tympanic membrane and three small bones called **auditory ossicles**.

The auditory ossicles are known as the **malleus** (hammer), **incus** (anvil), and **stapes** (stirrup).



The middle ear is connected to the throat by another structure known as the **Eustachian tube**. This tube is very important as it maintains equal amounts of air pressure on both sides of the eardrum. When our bodies experience an increase in air pressure, the eardrum is pushed inward and causes a decrease in hearing; however, as more air is allowed to pass through the Eustachian tube, the air pressure inside the tympanic cavity can increase as well. This results in our eardrum being forced back to its normal position. In this instance, we experience the "popping" of our ears.

The **inner ear** is the last stop on our journey through the anatomy of the ear. Within this area, our sense of hearing is created by a spiral-shaped fluid-filled chamber called the **cochlea**. Mechanoreceptors line the walls of the cochlea and react to stimuli from the middle ear to transmit nerve impulses to the CNS.

How do our ears sense sound?

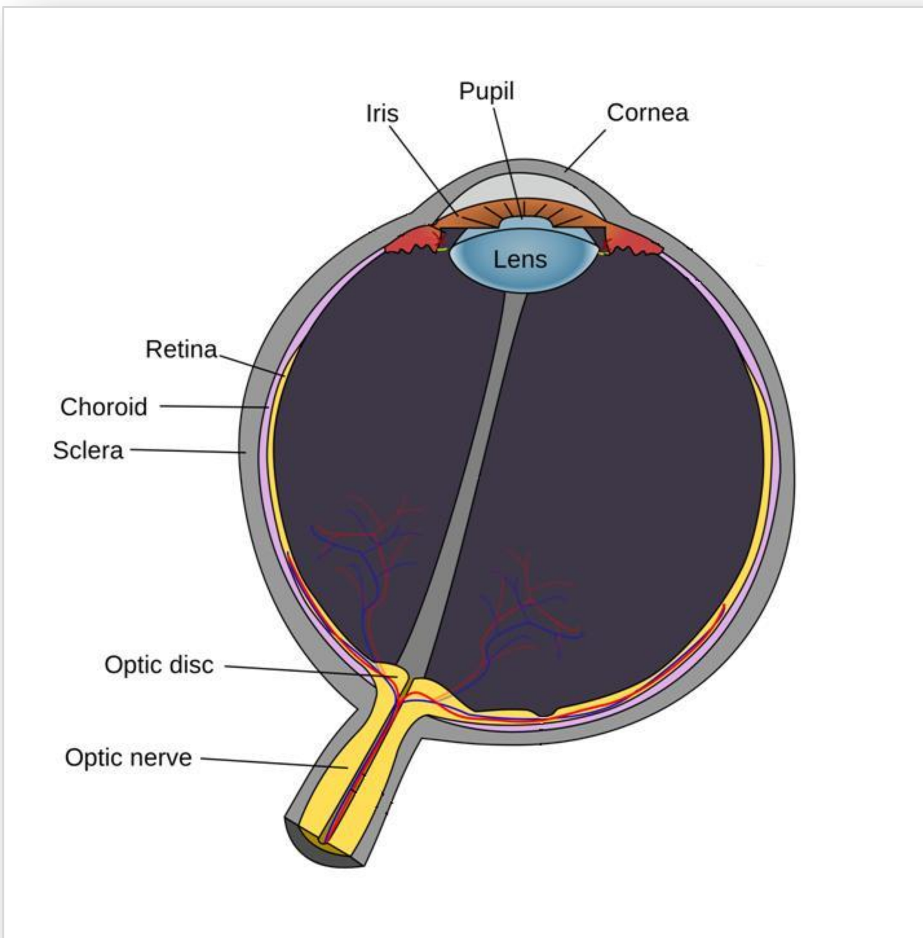
First of all, a sound wave is a vibration in the air that enters the auditory canal. A sound wave strikes the eardrum and causes it to vibrate. This vibration causes the three small bones in the middle ear to vibrate as well which, in turn, transfers this energy to the cochlea. The mechanoreceptors within the cochlea transmit nerve impulses to the brain which translates them into a sound you can understand.

Vision

Our eyes are complex anatomical structures. We could spend weeks just looking at this amazing organ! For the purpose of this book, however, let's look at a few of the basic structures and functions of the eyes...

Structure	Function
Sclera	White part of the eye; maintains the eye's shape
Cornea	Refracts (bends) and focuses light rays (much like the lens of a camera or telescope) into the pupil
Pupil	Black part of the eye which allows light to enter the eyeball
Iris	Changes the size of the pupil by thereby regulating the amount of incoming light; this is the colorful part of the eye
Lens	Refracts (bends) incoming light as well; focuses light onto the retina
Retina	Absorbs light; forms nerve impulses which are transmitted to brain
Optic nerve	Transmits nerve impulses to the brain

Simply put, the amount of light which enters the eye through the pupil is regulated by the iris. The pupil enlarges when the amount of available light is diminished so as to allow the maximum amount of light to enter the eye.



During periods of excessive light, the iris reduces the diameter of the pupil by blocking the majority of incoming light. As the light is passed through the pupil, it is bent by the cornea and then the lens which focuses the light onto the retina where photoreceptors begin a nerve impulse which is then sent via the optic nerve to the brain.

There are two different photoreceptors in the retina:

Rods

Rods are specialized for vision in dim light; they cannot detect color, but they are very good at detecting movement and visualizing shapes without much detail. Each eye may contain up to 125 million rods.

Cones

Cones provide us with color vision and work best within bright light. Each eye may contain up to seven million cones. Out of all the colors of the rainbow, cones can only detect three different colors of light: blue, green, and red.

If our eyes can only see three different colors, how do we visualize all the different colors of the rainbow?

Our brain determines the various colors of the rainbow by combining the amount of nerve impulses from all three types of cones. For example, our brain will be able to sense the color yellow by combining many nerve impulses from green cones and only a few from red cones.

(Yes... the mixing of red and green light will give you the color yellow! This is much different that when you mix the <u>*pigments*</u> *red and green. This mixture gives you a brownish pigment.)*

What about our sensation of temperature?

Much like our fishbowl analogy we have been mentioning throughout this textbook, our bodies have their own "thermometers" throughout our skin. The sensations we feel with increasing and decreasing temperatures are caused by two different nerve endings called:

Cold receptors and Warm receptors

Cold receptors are sensitive to temperatures that fall under 50°F (10°C). At this temperature, the cold receptors begin to stimulate **pain receptors** and provide us with the sensation of freezing. When temperatures reach above 113°F (45°C), **warm receptors** stimulate pain receptors which produce a burning sensation.

We've been spending a lot of time discussing how messages can be sent through electrochemical signals via nerves. Now it's time to look at another system which has the ability to send signals throughout our body. However, this new system uses an entirely different transportation system. See you next week!

Anatomy & Physiology - Connections

How the following body systems affect the nervous system		How the nervous system affects the following body systems	
Integumentary	Sensory receptor triggers nerve impulse; hair provides physical barrier/protection for skull	Controls arrector pili muscles (goosebumps) and secretions from sweat glands	**Integumentary**
Skeletal	Provision of calcium for nerve impulse/muscular contraction; protection of brain and spinal cord	Regulation of skeletal muscle contractions	**Skeletal**
Muscular	Specialized muscles provide facial expressions and vocal sounds	Regulation of skeletal muscle contractions	**Muscular**

Match the following vocabulary terms with their correct definition:

alkaline	**general senses**	**pinna**
auditory canal	**incus**	**pupil**
auditory occicles	**inner ear**	**retina**
chemoreceptors	**iris**	**rods**
cilia	**lens**	**sclera**
cochlea	**malleus**	**special senses**
cold receptors	**mechanoreceptors**	**stapes**
cones	**middle ear**	**taste buds**
cornea	**optic nerve**	**taste hairs**
eardrum	**pain receptors**	**thermoreceptors**
eustachian tube	**papillae**	**umami**
external ear	**photoreceptors**	**warm receptors**

1)	______________	a 1 inch (2.5 cm) tube within the pinna of the external ear
2)	______________	a flavor associated with a particular chemical called monosodium glutamate (MSG)
3)	______________	a small, air-filled space within the skull which contains the tympanic membrane and three small bones (auditory ossicles)
4)	______________	absorbs light; forms nerve impulses which are transmitted to brain
5)	______________	black part of the eye which allows light to enter the eyeball
6)	______________	branches of fingerlike projections from the cell body of dendrites; responsible for identifying specific chemicals

7)	______________	bundles of specialized cells located on the surface of the tongue, the roof of the mouth, and within the throat
8)	______________	changes the size of the pupil thereby regulating the amount of incoming light; colorful part of the eye
9)	______________	contains the cochlea; site where vibrations from middle ear are transferred into nerve impulses involving the sense of hearing
10)	______________	divides the external ear from the middle ear; vibrations from this membrane induce the mechanical act of hearing
11)	______________	funnel-shaped structure within the center of the visible, external ear
12)	______________	nerve endings within the skin that are are sensitive to temperatures that fall under 50°F (10°C)
13)	______________	nerve endings within the skin that are sensitive to temperatures above 113°F (45°C)
14)	______________	non-acidic compounds
15)	______________	one of three small bones in the ear known as the "anvil" within the middle ear that induces the sensation of hearing through its vibration
16)	______________	one of three small bones in the ear known as the "hammer" within the middle ear that induces the sensation of hearing through its vibration
17)	______________	one of three small bones in the ear known as the "stirrup" within the middle ear that induces the sensation of hearing through its vibration

18)	______________	photoreceptors in the retina; specialized for vision in bright light and can detect color
19)	______________	photoreceptors in the retina; specialized for vision in dim light and cannot detect color
20)	______________	refracts (bends) and focuses light rays (much like the lens of a camera or telescope) into the pupil
21)	______________	refracts (bends) incoming light as well; focuses light onto the retina
22)	______________	senses produced by very specific organs found only in certain areas of the body; includes the senses of smell, hearing, vision, taste, and balance
23)	______________	senses that can generally be found throughout our body as they are associated with the skin
24)	______________	sensory receptor which responds to changes in pressure or movement
25)	______________	sensory receptor which responds to changes in temperature
26)	______________	sensory receptor which responds to chemical compounds such as odor molecules
27)	______________	sensory receptor which responds to light
28)	______________	sensory receptor which responds to stimuli that result in the sensation of pain
29)	______________	specialized structures on the surface of taste buds which identify specific molecules
30)	______________	spiral-shaped fluid-filled chamber within the inner ear whose mechanoreceptors transmit nerve impulses to the CNS concerning our sense of hearing

31)	______________	the visible part of the ear
32)	______________	three small bones within the tympanic cavity known as the malleus (hammer), the incus (anvil), and stapes (stirrup); vibrations from these bones induce vibrations within the cochlea
33)	______________	transmits nerve impulses to the brain
34)	______________	tube which connects the middle ear to the throat and maintains air pressure between both sides of the eardrum
35)	______________	visible mushroom-shaped projections on your tongue which contain taste buds
36)	______________	white part of the eye; maintains the eye's shape

Choose the correct answer from the following questions:

1) **Sound waves entering the external auditory canal hit the eardrum, also known as the:**
    A) cochlea
    B) ossicles
    C) tympanic membrane
    D) stapes
    E) incus

2) **One of the three small bones within the middle ear known as the "anvil" is also called the:**
    A) incus
    B) stapes
    C) malleus
    D) bony labyrinth
    E) cochlea

3) **What structure of the eye focuses light on the retina:**
    A) optic nerve
    B) lens
    C) cornea
    D) sclera
    E) iris

4) **Which one of the following is part of the inner ear?**
    A) Eustachian tube
    B) auditory ossicles
    C) stapes
    D) cochlea
    E) malleus

5) **The colorful portion of the eye that has a rounded opening through which light passes is the:**
   A) cornea
   B) sclera
   C) iris
   D) lens
   E) retina

6) **True or False:** The pupil is the circular opening in the iris through which light passes.

7) **True or False:** In order to hear sound, vibrations pass from the eardrum to the ossicles, and on to the cochlea.

Application Question:

Phil has surgery to remove polyps (non-cancerous growths of tissue) from his sinuses. After he heals from the surgery, he notices that his sense of smell is not as strong as it was before the surgery. Can you suggest a possible reason for this?

Chapter Twelve

Endocrine System – Part I

So far, we have spent a great deal of time learning how the human body sends electrochemical signals through miles of fiber to respond to an infinite amount of stimuli. This week, we will look at another system that controls and coordinates the functions of all of the human body systems:

The Endocrine System

You learned back in Chapter 2 that the epithelial tissue which covers the outside of the body contains areas known as *glands* which are responsible for creating and releasing specific chemicals throughout our body. These chemicals, known as **hormones**, are chemical messengers which travel throughout our body and help to maintain homeostasis much like the functions of our nervous system.

Most functions performed by hormones are kept in balance through negative feedback mechanisms.

In fact, both the nervous system and the endocrine system work together to control and regulate the actions of other cells, tissues, and systems within the body. They both are responsible for sending chemical signals in the body and they are known to control each other as well. At times, the nervous system controls the production of hormones; and, some hormones are capable of creating or halting the flow of nerve impulses as well. These are examples of how negative feedback works to maintain homeostasis within the body.

So how are these two systems different?

The biggest difference between these two systems can be found in the response time for each system to respond to a stimulus. The nervous system utilizes a much faster mechanism of transporting a nerve impulse which can range from 1.7-269 mph (2.7-433 km/hr). By comparison, a response from the endocrine system may take several hours! This delay in response is caused by the slower path by which hormones travel - the blood.

Glands are not connected to other cells or tissues through networks of nerve cells. Once they secrete their hormones, it is the blood which transports these messengers throughout the body. Even though our blood is traveling at a pretty good rate (on average it takes under a minute for a blood cell to travel throughout the body), it still can take some time for these chemicals to reach their intended **target cells** which are in need of a hormonal response. And with the normal life expectancy of a hormone being less than one hour, a gland may be secreting lots of its chemical messengers over a long period of time before the target cells can be reached.

Target cells utilize a similar "lock and key" method of detecting specific hormones just as our chemoreceptors do for our sensations of smell and taste. Target cells have special receptors (locks) on their outer membranes that fit specific "keys" located on individual hormones. Once bound together, the chemical message can be read and interpreted by the cell.

What other differences exist between these two systems?

Even though both systems release chemical signals within the body, it is a question of distance which causes these systems to be different. If you recall from Chapter 8, chemical signals are shared where two nerve cells meet through areas known as *synapses* within the nervous system. The distance between these two cells are amazingly small compared to the distance traveled by hormones throughout the massive network of blood vessels throughout the body.

In addition, the effects caused by hormones tend to last longer than those of nerve impulses...

If the speed of the nervous system can be imagined to be a race car, then the endocrine system could be compared to a semi-truck. Both get the job done, but they each require different amounts of time to start up and slow down!

It's time to start looking at the key organs which make up the endocrine system. Allow me to introduce you to the major endocrine glands:

Pituitary, Thyroid, Parathyroid, Pineal, and Adrenal glands

In addition to these glands, the human body has several organs which have the important role as producers of chemical messengers. The following chart will give you a brief list of these organs and the hormones they secrete:

Gland/Organ	Hormone(s) produced
Anterior lobe (pituitary)	Thyroid-stimulating hormone (TSH) Adrenocorticotropic hormone (ACTH) Follicle-stimulating hormone (FSH) Lutenizing hormone (LH) Prolactin (PRL) Growth hormone (GH)
Posterior lobe (pituitary)	*Antidiuretic hormone (ADH) *Oxytocin
Thyroid	Thyroxine (T_4) Triiodothyronine (T_3) Calcitonin (CT)
Parathyroids (4)	Parathyroid hormone (PTH)
Adrenal (cortex)	Mineralocorticoids (Aldosterone) Glucocorticoids (Cortisol)
Adrenal (medulla)	Epinephrine (adrenaline) Norepinephrine (noradrenaline)
Pancreas	Insulin Glucagon
Thymus	Thymosins
Pineal	Melatonin
Ovaries	Estrogens Progesterone
Testes	Testosterone Inhibin

** These hormones are not produced by the pituitary's posterior lobe; rather, they are produced by the hypothalamus and <u>secreted</u> by the posterior lobe.*

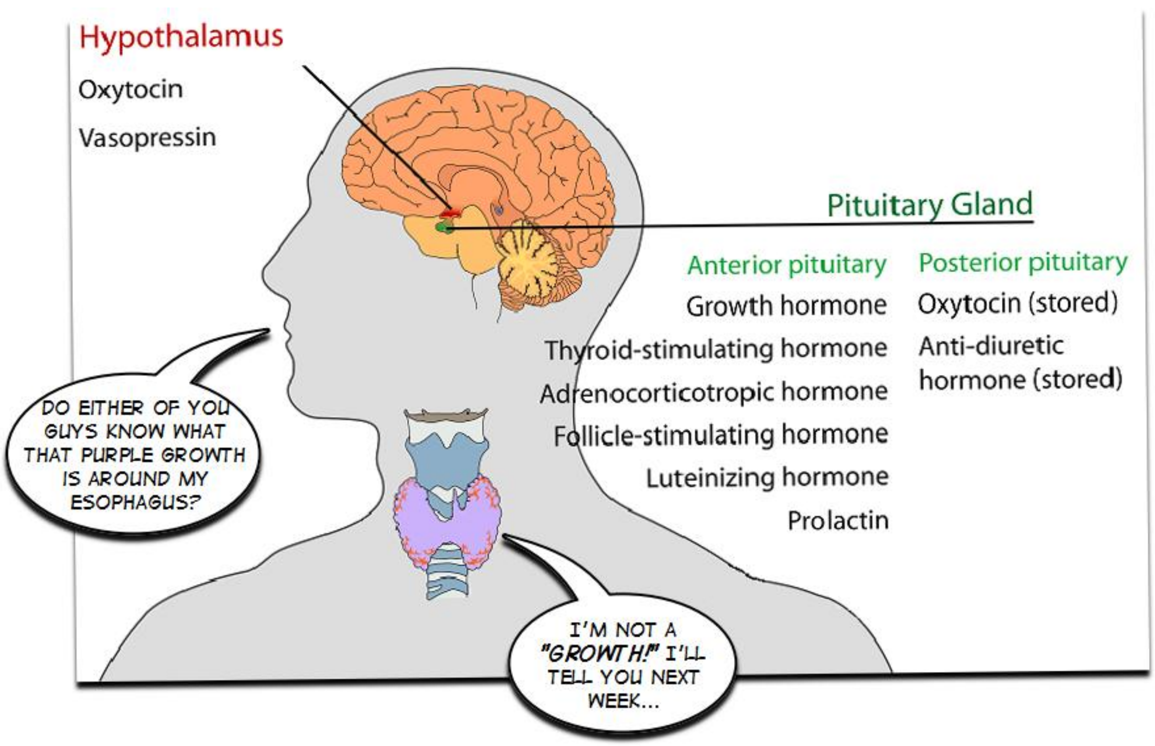
Pituitary glands

It doesn't take a rocket scientist to see from this chart that the **pituitary glands** (yes… there are two of them!) produce the majority of the hormones in our body. In fact, your understanding of this gland is vital to bridging the gap between the nervous system and the endocrine system. Let me explain...

This "bridge" was first mentioned back in Chapter 9 when you learned of a structure known as the *hypothalamus* existing between the medulla oblongata and the cerebrum. This part of the brain is responsible for regulating a large amount of our vital functions including body temperature, water balance, sleep-wake cycles, appetite, emotions, and nearly all of the hormones within our body.

The hypothalamus acts like a supervisor to the pituitary gland by receiving stimuli from the brain and delegating orders into this vital structure of our endocrine system.

All of these glands and organs are important; however, it is the pituitary gland working with the hypothalamus in the brain that really keeps this system working!



The pituitary gland is protected quite well by the bones and tough membranes within the skull. It is about the size and shape of a large flattened pea. On average, it measures 0.4 inches (1 cm) long, 0.4 to 0.6 inches (1 to 1.5 cm) wide, and 0.1 inches (0.5 cm) thick. It contains two different sections known as the **anterior lobe** and the **posterior lobe**.

As you can see from the chart, the anterior lobe is responsible for the majority of hormones produced by the pituitary gland and takes up about 75% of its size. Only the anterior lobe is responsible for manufacturing hormones. It is the hypothalamus which is responsible for producing the hormones ADH and oxytocin and delivering them into the posterior lobe for transport throughout the body.

The hormones produced in the anterior lobe of the pituitary gland include the following:

Follicle-stimulating hormone (FSH):
Target cells for this hormone = **Ovaries** in females and **testes** in males

This hormone has different functions for the reproductive systems of men and women. In men, FSH stimulates the production of **sperm** (male reproductive cells) within the **testes** (male reproductive organs).

In women, FSH stimulates the production of **eggs** (female reproductive cells) within the **ovaries** (female reproductive organs).

Luteinizing hormone (LH):
Target cells for this hormone = Ovaries in females and testes in males

LH stimulates the production of hormones utilized by the reproductive system. These hormones include *progesterone*, *estrogen*, and *testosterone*. Each of these hormones has specific actions which affect males and females in different ways.

Prolactin (PRL):
Target cells for this hormone = **Mammary glands**

PRL is a hormone which helps women to produce milk to feed young offspring from their **mammary glands** through a process called **lactation**.

Thyroid-stimulating hormone (TSH):
Target cells for this hormone = Thyroid gland

TSH controls the production of two hormones within the thyroid gland: *thyroxine* *(T_4)* and *triiodothyronine (T_3).*We will look at these two hormones in the next chapter when we explore the thyroid gland in detail.

Adrenocorticotropic hormone (ACTH):
Target cells for this hormone = Adrenal cortex gland

ACTH acts on the adrenal cortex gland to produce the hormones *cortisol* and *aldosterone*. Both of these hormones play an important part in regulating the amount of sugar and minerals within our bodies.

Growth hormone (GH):
Target cells for this hormone = Muscle and bone tissue

Growth hormone acts on many different skeletal tissues within the body to stimulate their growth. This is the only hormone secreted by the anterior lobe of the pituitary gland that has a general effect on nearly every cell in the body.

Only two hormones are associated with the posterior lobe of the pituitary gland:

Oxytocin and Antidiuretic hormone (ADH)

Don't forget! The posterior lobe of the pituitary gland does not produce these two hormones. It is the hypothalamus which takes care of this job. The posterior lobe is responsible for transporting these two important hormones to the target cells of the body.

Oxytocin:

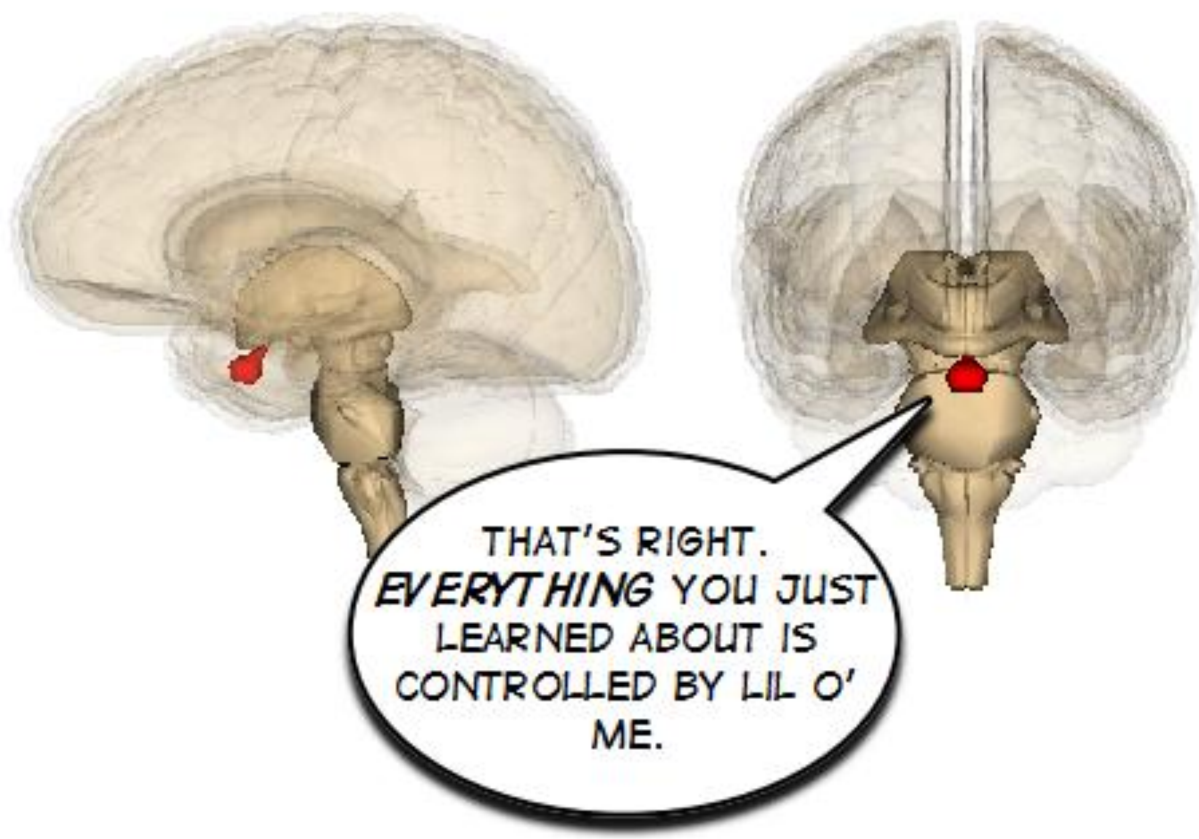
Target cells for this hormone = **Uterus**

The female **uterus** is an organ where offspring are grown during pregnancy. Oxytocin stimulates the smooth muscles of the uterus to contract which helps to push the child out during childbirth.

Antidiurectic hormone (ADH):

Target cells for this hormone = Kidney cells

The release of **ADH** into the bloodstream is used to balance the volume of fluids within the body. When your body is dehydrated, losing dangerous amounts of blood (known as a **hemorrhage**), or your blood contains a high concentration of ions, ADH acts on cells within the kidney to decrease the amount of urine that is to be excreted.



As you can see, the pituitary gland is rather busy throughout the day! We owe our lives to the functions of these organs. In the next chapter, we will be exploring the rest of organs and hormones of the endocrine system.

Match the following vocabulary terms with their correct definition:

adrenocorticotropic hormone (ACTH)	**hormones**
antidiurectic hormone (ADH)	**lactation**
prolactin (PRL)	**mammary glands**
luteinizing hormone (LH)	**ovaries**
growth hormone (GH)	**oxytocin**
thyroid-stimulating hormone (TSH)	**pituitary glands**
anterior lobe	**posterior lobe**
eggs	**sperm**
hemorrhage	**target cells**
	testes
	uterus

1)	______________	cells identified for specific chemical reactions by individual hormones
2)	______________	chemical messengers which travel throughout the body and help to maintain homeostasis
3)	______________	female reproductive cells
4)	______________	female reproductive organs
5)	______________	glands which produce and secrete milk in females
6)	______________	hormone which acts on many different tissues within the body to stimulate their growth
7)	______________	hormone which acts on the adrenal cortex gland to produce the hormones cortisol and aldosterone
8)	______________	hormone which helps women to produce milk from their mammary glands

9)	______________	hormone which stimulates the smooth muscles of the uterus to contract during childbirth
10)	______________	hormone which targets ovaries and testes; stimulates the production of hormones utilized by the reproductive system
11)	______________	hormone which targets the kidney cells to balance the volume of fluids within the body
12)	______________	hormone which targets the thyroid gland to control the production of thyroxine (T4) and triiodothyronine (T3)
13)	______________	male reproductive cells
14)	______________	male reproductive organs
15)	______________	one of two lobes within the pituitary gland; produces thyroid-stimulating hormone and adrenocorticotropic hormone
16)	______________	one of two lobes within the pituitary gland; receives and transports antidiuretic hormone and oxytocin which are produced by the hypothalamus
17)	______________	organ where offspring are grown during pregnancy
18)	______________	process by which women produce milk from their mammary glands
19)	______________	the loss of a large amount of blood
20)	______________	two glands located within the skull; responsible for the majority of hormone production

Choose the correct answer from the following questions:

1) Which of these hormones does NOT play a role in reproduction:
A) estrogen
B) luteinizing hormone
C) testosterone
D) follicle-stimulating hormone
E) antidiuretic hormone

2) Which one of the following hormones is NOT produced by the anterior lobe of the pituitary gland:
A) thyroid-stimulating hormone
B) oxytocin
C) growth hormone
D) prolactin
E) luteinizing hormone

3) Negative feedback mechanisms regulate:
A) hormones of the anterior lobe of the pituitary gland
B) very few hormones
C) most hormones
D) hormones of the posterior lobe of the pituitary gland

4) The hypothalamus is most closely connected with the:
A) thymus gland
B) thyroid gland
C) pituitary gland
D) pineal gland
E) pancreas

5) **Growth hormone:**
   A) acts on the adrenal cortex to produce cortisol and aldosterone
   B) is produced by the posterior lobe of the pituitary gland
   C) promotes growth in long bones and skeletal muscles
   D) is secreted by the thymus gland

6) **The chemical messengers of the endocrine system are known as:**
   A) stimuli
   B) neurons
   C) effectors
   D) hormones
   E) target cells

Application Question:

Predict the effect of a hot environment on ADH secretion and explain why this effect is advantageous to the human body.

Chapter 13

Endocrine System – Part II

Before we continue looking at the rest of the endocrine system, let's take a quick look back on the chart we studied last week:

Gland/Organ	Hormone(s) produced
Anterior lobe (pituitary)	Thyroid-stimulating hormone (TSH) Adrenocorticotropic hormone (ACTH) Follicle-stimulating hormone (FSH) Lutenizing hormone (LH) Prolactin (PRL) Growth hormone (GH)
Posterior lobe (pituitary)	Antidiuretic hormone (ADH) Oxytocin
Thyroid	Thyroxine (T_4) Triiodothyronine (T_3) Calcitonin (CT)
Parathyroids (4)	Parathyroid hormone (PTH)
Adrenal (cortex)	Mineralocorticoids (Aldosterone) Glucocorticoids (Cortisol)
Adrenal (medulla)	Epinephrine (adrenaline) Norepinephrine (noradrenaline)
Pancreas	Insulin Glucagon
Thymus	Thymosins
Pineal	Melatonin
Ovaries	Estrogens Progesterone
Testes	Testosterone Inhibin

Now it's time to continue our journey through the endocrine system with an exploration of the...

Thyroid and Parathyroid glands

The **thyroid gland** is located in the neck and is in front of (anterior) to the *trachea* (aka – the windpipe). It is a large gland weighing an average 1.2 ounces (34 grams) as compared to the pituitary gland which weighs in at 0.02 ounces (0.5 grams).

The thyroid gland stores the hormones it creates in spherical sacs called **follicles**. Three important hormones are secreted by this gland which is known as:

Thyroxine (T_4), Triiodothyronine (T_3), and Calcitonin (CT)

Although T_3 and T_4 have similar functions, differences exist within their chemical structures as T_3 contains only three atoms of iodine while T_4 has four. Of the two, T_4 is produced in greater volume accounting for nearly 90% of all manufactured hormones by the thyroid.

Triiodothyronine (T_3) and Thyroxine (T_4)
<u>Target cells for this hormone = Nearly all cells throughout the body</u>

The entire body depends upon these two hormones for its survival because:

The primary functions of T_3 and T_4 are to increase the rate in which cells use oxygen and food to produce energy!

In addition to this vital function, these two hormones also perform the following tasks within the human body:

- Increases the heart rate and forces the contraction of heart muscle
- Assists in the regulation of oxygen and carbon dioxide levels in the blood
- Stimulates the formation of red blood cells to enhance oxygen delivery
- Supports the growth of bones in developing children

It may be easy to think of these glands as separate entities, each performing their own functions independently of each other; however, this is definitely not the case! If you recall from the last chapter, the thyroid is controlled by a particular hormone (TSH) which is produced by another gland – the pituitary gland! Don't ever forget:

Everything in your body is connected together.

The thyroid is not exception to this rule, but the following story may help you to understand how it performs within the human body:

The thyroid gland is much like a car - it's where the fuel goes in, combusts, and provides the power for everything else to work. A car is run by an engine which relies on fuel as well. In a similar way, the thyroid gland takes in a different type of fuel – the element <u>iodine</u>, and turns it into T_3 and T_4 hormones which influence how energy gets transmitted to the body's tissues. FYI - We normally receive our daily amount of iodine from the iodized salt in our diet.

What about the other thyroid hormone - calcitonin?

Calcitonin (CT):
<u>Target cells for this hormone = Bone tissue</u>

In addition to stimulating bone growth, **calcitonin** helps to regulate the amount of calcium found in the blood. When calcium levels are increased, calcitonin is released to lower this concentration to a safer level.

That is about all there is to say about the thyroid gland for now. Let's take a look at its counterpart...

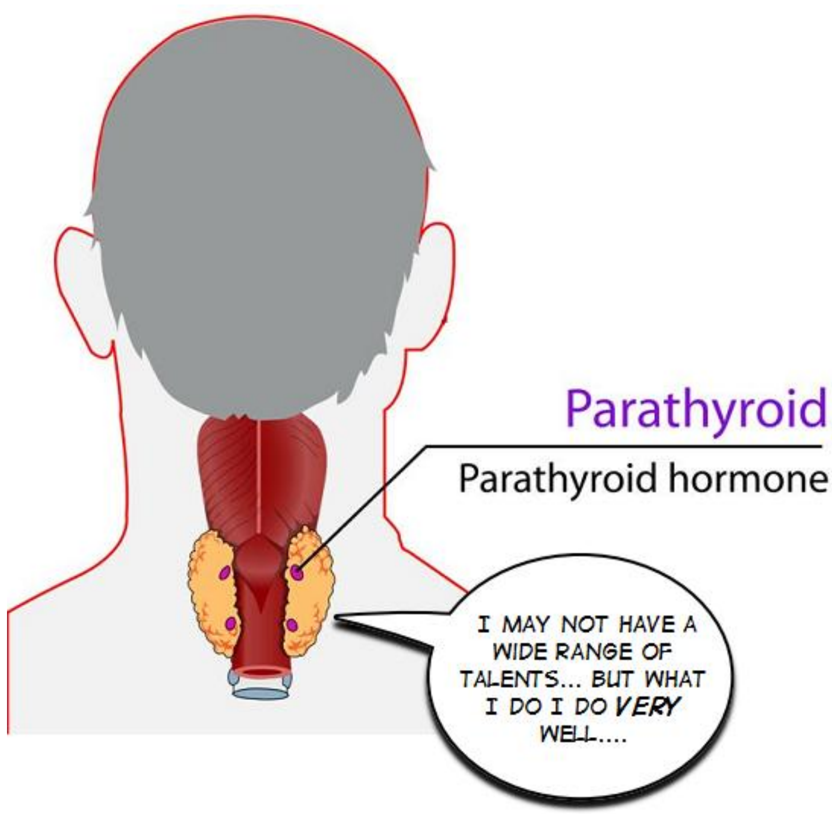
Parathyroid glands

There are four **parathyroid glands** found on each side of the back (posterior) surface of the thyroid gland. These glands are very small, pea-sized organs weighing only around 0.015 ounces (0.4 grams) each. The main function of these glands is to produce the hormone called **parathyroid hormone (PTH).**

Parathyroid hormone (PTH):
<u>Target cells for this hormone = Bone tissue and kidneys</u>

The main function of PTH is to increase the levels of calcium (for bones) in the blood which it accomplishes in a variety of ways:

- PTH stimulates osteoclasts to break down bone tissue and release calcium from the bone into the blood. (Check back in Chapter 4 for a review of this process!)
- PTH blocks the action of osteoblasts from absorbing calcium in the blood during the process of bone development.
- PTH encourages the absorption of calcium and phosphorus from the small intestine into the bloodstream during digestion.
- PTH lowers the amount of calcium lost in our urine by assisting the kidneys in reabsorbing this element back into the blood stream.



How does PTH and calcitonin help to promote homeostasis?

When the concentration of calcium within the blood is too high, the thyroid gland secretes calcitonin to remove this element from the blood. There is no way for the thyroid to know when to stop secreting calcitonin. So, when the amount of calcium begins to fall below safe levels, the parathyroid starts to release PTH until the blood calcium levels increases to its normal value.

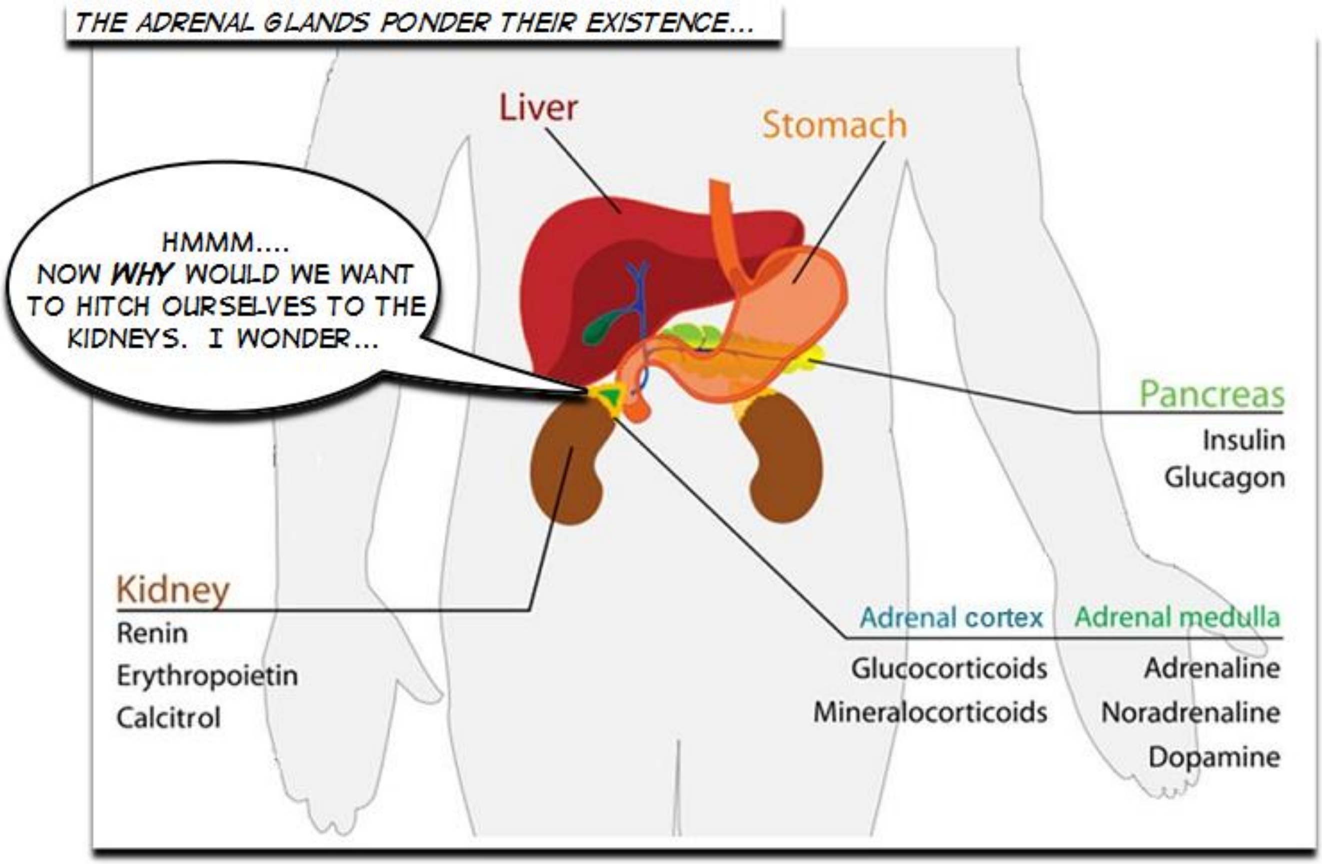
It's like a never-ending ride on a see-saw with both ends constantly in motion!

We've been talking a little about our kidneys and you may have picked up on a few hints about the function of this important organ. Simply put, both of your kidneys filter the bloodstream in order to get all of the toxins out of your blood, and they also regulate the amount of water within the blood as well. We will spend a considerable amount of time in future chapters discussing this organ.

Until that time, we are still not done exploring the endocrine system. So, let's look at two more glands that are found <u>on top</u> of the kidney...

The Adrenal Glands

The **adrenal glands** can be found on top of each kidney. Each of these yellow-colored glands weighs close to 0.19 ounces (7.5 grams) and has a pyramid shape. Each adrenal gland is constructed of two separate glands themselves. The tiny, innermost section of the adrenal gland is a separate gland known as the **adrenal medulla.** This organ is surrounded by a much larger gland known as the **adrenal cortex**. Of the two, the adrenal cortex makes up approximately 90 percent of the mass of entire adrenal gland.



Let's look at each of these glands separately!

Adrenal cortex

The adrenal cortex secretes more than two dozen different hormones called **corticosteroids** each serving a unique purpose. Most of these hormones can be grouped into two main categories:

Mineralcorticoids and Glucocorticoids

Mineralocorticoids

The primary mineralocorticoid is the hormone called **aldosterone**. This hormone is responsible for increasing the amount of sodium into the blood by removing it from the urine. In addition, aldosterone also helps to remove the element potassium from the blood into the urine. Why would it do these things?

Homeostasis

Simply put, aldosterone is released when the amount of sodium in our blood is too low or when the amount of potassium is too high.

Glucocorticoids
The primary glucocorticoid is the hormone **cortisol**. This hormone is released when our blood contains a low amount of sugar. The presence of cortisol triggers a series of actions which result in the release of sugar into the bloodstream.

That's right! This is another example of homeostasis in action!

In addition to the release of sugar, cortisol also stimulates the breakdown of fats and proteins which can be used as energy sources.

Adrenal medulla

The adrenal medulla produces the hormones **epinephrine** (also known as **adrenaline**) and **norepinephrine.** The production of these two hormones is regulated by the nervous system. By far, the main hormone that is produced by the adrenal medulla is epinephrine.

You learned back in Chapter 10 that the sympathetic nervous system increases your alertness and generally prepares your body to deal with stress and emergencies. Both hormones secreted by the adrenal medulla regulate this **"fight or flight"** system in your body. These hormones affects nearly all body tissues both directly and indirectly as their main function at times of stress is to elevate the heart rate, thus increasing the blood flow throughout the body.

Now let's look at the longest of the glands we will be studying...

The Pancreas

The **pancreas** is an elongated organ which is about 6 inches (~15cm) long and can be found between your stomach and small intestine. There are several different types of cells which make up the pancreas, each of which produce different types of hormones. However, the two most important of these has to be the following:

Insulin and Glucagon

Much like the hormone cortisol, **glucagon** stimulates the *liver* (you will learn more about this organ in future chapters) to convert a particular type of sugar known as **glycogen** within your body into a more usable sugar called **glucose**. This simple sugar is used to generate the compound ATP (adenosine triphosphate) which is the chemical fuel needed for most bodily processes. You first learned about this important chemical back in Chapter 7. As you may have guessed, glucagon is released when the blood glucose levels in our body fall below normal levels which, in turn, trigger the eventual release of ATP into the bloodstream.

So what controls glucagon from producing too much sugar into the bloodstream?

This is when **insulin** gets to work! Insulin is secreted when blood sugar levels rise above normal values. Insulin does a very good job at helping cells absorb as much sugar (glucose) out of the bloodstream. In addition, insulin also helps to convert glucose back into glycogen which can be easily stored by the liver for use when blood glucose levels drop once again.

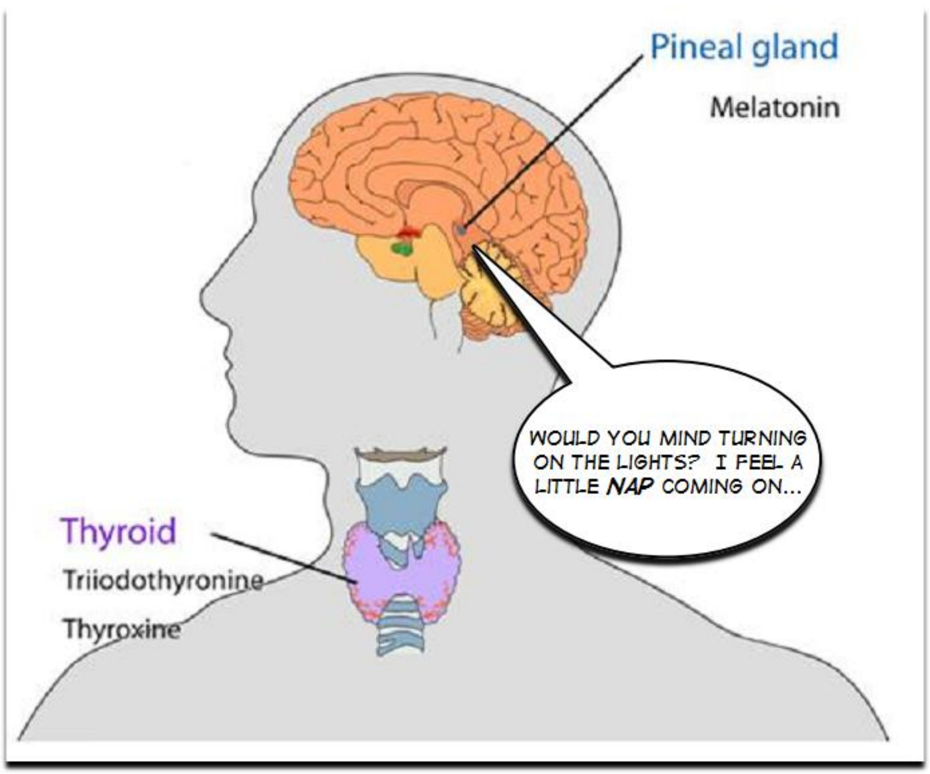
Two more glands worth mentioning include the:

Thymus gland and the Pineal gland

The **thymus gland** can be found directly between the lungs and ranges from 0.17-1.2 grams (5-35 grams) depending upon the age of the individual. Unlike most glands, the thymus continues to grow until the individual reaches **puberty** (a period of time in which a series of physical and chemical changes in a child's body matures into an adult body). Upon the end of puberty, the thymus gland begins to shrink in size throughout the life of the individual.

The thymus gland produces several hormones, called **thymosins**, which help the immune system by assisting in the production of **T cells**. These immune cells attack foreign substances as they enter our body.

The tiny **pineal gland** can be found near the center of the brain, between the two hemispheres. This gland is roughly the size of a grain of rice and seems to control at least one pattern within our body. The pineal gland secretes the hormone **melatonin** during periods of darkness and acts to regulate our sleep-wake cycle. This cycle, also known as a **circadian rhythm** (as it repeats every 24 hours), can be controlled by the level of melatonin released into our bodies which induces drowsiness. Melatonin's production is directly linked to our bodies exposure to bright light.



Our last stop within our study of the endocrine system deals with our ability to reproduce. These last two glands are known as:

The Ovaries and Testes

You learned about these two glands previously during our discussion on the follicle-stimulating (FSH) and lutenizing (LH) hormones. The ovaries (female reproductive organs) and the testes (male reproductive organs) are the target cells for these two hormones. Both of these organs are responsible for secreting their own unique hormones as well:

Ovaries

Hormones produced: Estrogen and Progesterone

Although both **estrogen** and **progesterone** are found in men and women and stimulate a long list of functions, it is women who carry a larger volume of these hormones. Their primary functions in women involve the preparation and maintenance of their bodies before and during pregnancy. This includes the regulation of the organs and tissues within the reproductive system of women.

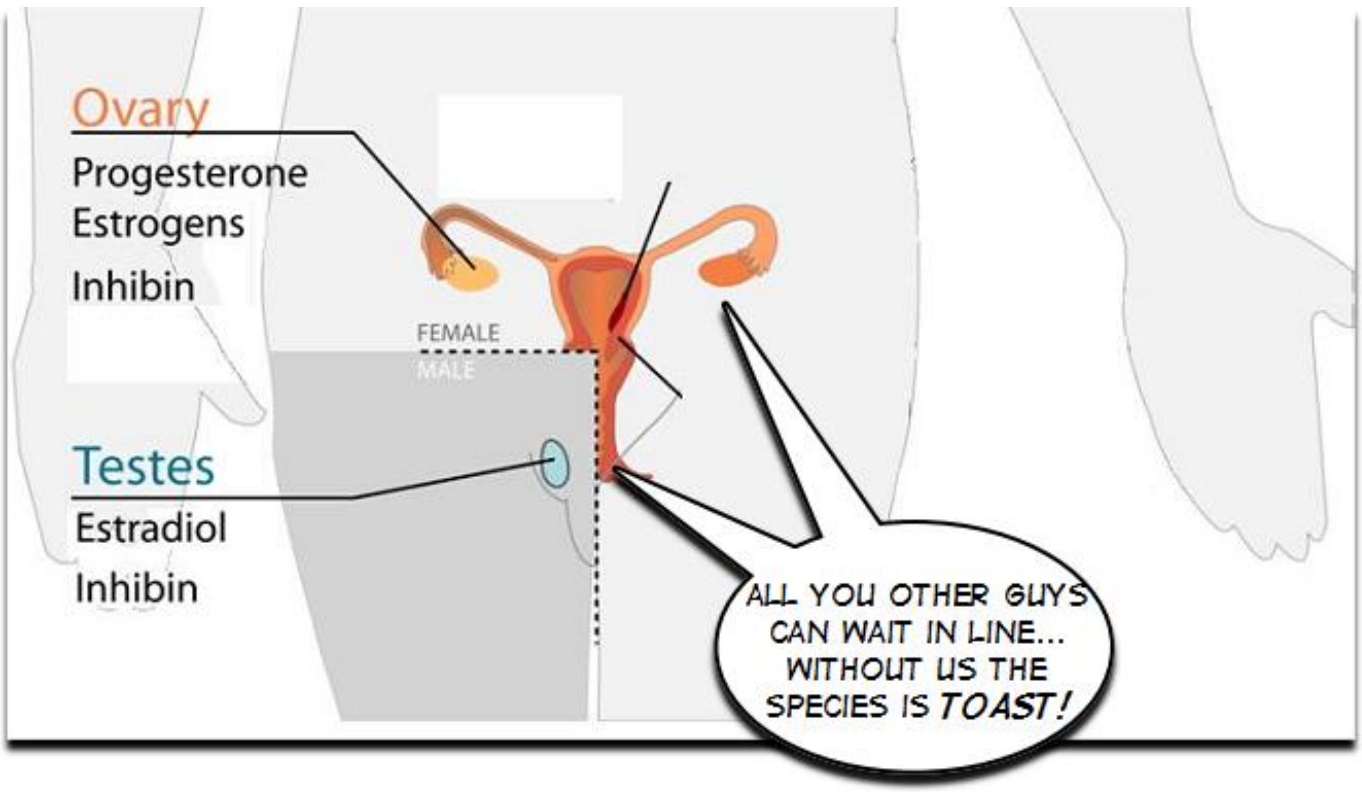
Testes

Hormones produced: Testosterone and Inhibin

By far, the hormone **testosterone** is the most important male hormone secreted by the testes. Much like progesterone and estrogen, testosterone is created in the reproductive organs of both males and females; however, it is typically found in greater quantities within males as it stimulates the growth of male reproductive tissues, bones, muscles, and body hair at the beginning of puberty. And, it also plays a vital role (along with estrogen) to stop the growth of new cells along the epiphyseal plates at the end of puberty, thereby regulating the height of an individual. In addition, testosterone also acts upon the respiratory system to cause a deepening of the voice.

In addition to testosterone, the testes also produce a hormone called **inhibin** which acts to lower the amount of FSH secreted into the bloodstream.

Yep! Homeostasis in action once again!



Anatomy & Physiology - Connections

How the following body systems affect the endocrine system		How the endocrine system affects the following body systems	
Integumentary	Protection of endocrine organs; synthesis of vitamin D	Testosterone stimulates the growth of body hair; PRL develops mammary glands; corticosteroids affect blood flow within skin	**Integumentary**
Skeletal	Additional protection for endocrine organs	Multiple hormones regulate bone growth and development; calcium levels managed by PTH and calcitonin	**Skeletal**
Muscular	Additional protection for endocrine organs	Multiple hormones oversee muscle growth and development; calcium levels managed by PTH and calcitonin	**Muscular**
Nervous	Hypothalamus regulates pituitary gland secretions; nervous system controls the adrenal medulla	Hormones regulate fluid and nutrient concentrations for nerve impulses	**Nervous**

Match the following vocabulary terms with their correct definition:

adrenal cortex	**glucagon**	**pineal gland**
adrenal glands	**glucocorticoids**	**progesterone**
adrenal medulla	**glucose**	**puberty**
aldosterone	**glycogen**	**T cells**
calcitonin	**inhibin**	**testosterone**
circadian rhythm	**insulin**	**thymosins**
corticosteroid	**melatonin**	**thymus gland**
cortisol	**mineralocorticoid**	**thyroid gland**
epinephrine	**norepinephrine**	**thyroxine (T_4)**
estrogen	**pancreas**	**triiodothyronine (T_3)**
fight or flight response	**parathyroid glands**	
	parathyroid hormone	

1)	_______________	a complex sugar stored by the liver for use when blood sugar levels increase or decrease
2)	_______________	a gland which is located in the neck and is in front of (anterior) to the trachea ; secretes the hormones thyroxine, triiodothyronine, and calcitonin
3)	_______________	a glucocorticoid hormone secreted by the adrenal cortex responsible for increasing the level of sugar within the blood
4)	_______________	a mineralocorticoid hormone secreted by the adrenal cortex; responsible for increasing the amount of sodium (and water) into the blood and to remove potassium from the blood into the urine
5)	_______________	a series of physical changes in which a child's body matures into an adult body
6)	_______________	a simple sugar created from glycogen within the liver; used as fuel for most cellular functions within the body

7)	______________	an elongated organ 6in (15+cm) found between the stomach and small intestine; responsible for producing several hormones, the most important being insulin and glucagon
8)	______________	comprises ~90% of the adrenal gland; secretes 2+ dozen corticosteroid hormones
9)	______________	four glands found on each side of the back(posterior) surface of the thyroid gland ; responsible for producing the hormone parathyroid hormone (PTH)
10)	______________	gland found directly between the lungs; secretes thymosin hormones which help the immune system produce T cells
11)	______________	gland found near the center of the brain; regulates the sleep-wake cycle of humans through the secretion of the hormone melatonin
12)	______________	hormonal response to emergency situations; regulated by epinephrine which elevates the heart rate, thereby increasing both blood and oxygen flow throughout the body
13)	______________	hormone produced by the thyroid gland which stimulates bone growth and helps to regulate the amount of calcium found in the blood
14)	______________	hormone released from the parathyroid glands; responsible for increasing the levels of calcium (for bones) and phosphorus (for cell membranes) found within the blood
15)	______________	hormone responsible for lowering the amount of follicle stimulating hormone within the blood stream
16)	______________	hormone secreted by the adrenal medulla; works with epinephrine to regulate the fight or flight response in humans during times of stress
17)	______________	hormone secreted by the adrenal medulla; works with norepinephrine to regulate the fight or flight response in humans during times of stress

18)	______________	hormone secreted by the ovaries which works along with estrogen to prepare and maintain women before and during pregnancy
19)	______________	hormone secreted by the ovaries which works along with progesterone to prepare and maintain women before and during pregnancy
20)	______________	hormone secreted by the pancreas which helps cells to absorb sugar from the bloodstream
21)	______________	hormone secreted by the pancreas which stimulates the liver to produce an increased amount of glucose to be released into the bloodstream
22)	______________	hormone secreted by the pineal gland; regulates the circadian rhythm of humans
23)	______________	hormone secreted by the thyroid gland which contains four atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
24)	______________	hormone secreted by the thyroid gland which contains three atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
25)	______________	hormone which stimulates the growth of male reproductive tissues, bones, muscles, body hair, and the deepening of one's voice
26)	______________	hormones produced by the thymus gland
27)	______________	immune cells which attack foreign substances as they enter our body
28)	______________	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being aldosterone
29)	______________	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being cortisol
30)	______________	one of 2+ dozen hormones secreted by the adrenal cortex
31)	______________	sleep-wake cycle of humans; controlled by the hormone melatonin secreted by the pineal gland

32)	_____________	small section of the adrenal gland responsible for producing the hormones epinephrine (also known as adrenaline) and norepinephrine
33)	_____________	two glands which sit on top of each kidney and separated into two sections known as the medulla and the cortex

Choose the correct answer from the following questions:

1) **Which of these hormones is released by the adrenal medulla:**
   A) sex hormones
   B) aldosterone
   C) glucocorticoids
   D) epinephrine

2) **Rising blood levels of aldosterone results in the removal of ______ from the urine.**
   A) calcium
   B) sodium
   C) iodine
   D) potassium
   E) hydrogen

3) **The hormone that appears to help regulate our sleep-awake cycles is:**
   A) melatonin
   B) thyroxine
   C) progesterone
   D) inhibin
   E) glucagon

4) **Estrogens do all of the following EXCEPT:**
   A) stimulate menstruation in preparation for fertilization
   B) help maintain pregnancy
   C) stimulate growth of facial hair
   D) prepare the uterus to receive a fertilized egg during reproduction

5) **Insulin causes:**
   A) a decrease in the concentration of blood glucose
   B) an increase in blood pressure
   C) an increase in the production of glucagon
   D) an increase in the concentration of blood glucose

6) **__________ is controlled by and regulates the function of insulin within the blood stream.**
   A) oxytocin
   B) glucagon
   C) testosterone
   D) thyroid hormone

Application Question:

How is the hormone calcitonin controlled by a negative feedback mechanism, and what effect does calcitonin have on blood calcium levels?

Chapter 14

Integration and Regulation: What can go wrong?

Throughout the past several chapters you have explored how various kinds of signals can be transported throughout the body. Some of these are done electrochemically, such as the nerve impulses within the central and peripheral nervous systems while others rely solely on the production and distribution of chemicals, as with the endocrine system.

In this chapter, we are going to explore a few of the problems that may occur within our nervous and endocrine systems and a few of the ways we can prevent or correct these issues.

Let's begin by taking a brief look at the topic of pain. If you have ever spent time in a doctor's office, you may have needed the use of **local anesthetics** (numbing agents) to reduce the amount of pain that you may experience. Local anesthetics block the sensation of pain by keeping sodium ions from entering and leaving the cell membranes of neurons. And as you learned back in Chapter 8, a nerve impulse cannot be created without the movement of sodium ions. Without this electrochemical signal, your central nervous system cannot detect any signal of pain. Two examples of local anesthetics include **novocain** for tooth pain and **lidocaine** which is used to numb an area of skin.

Since we are on the topic of neurons…

Back in Chapter 8 you also learned about the protective myelin covering which partially surrounds the axon of nerve cells. As you recall, gaps within the myelin covering allows nerve impulses to move much faster as sodium and potassium ions are forced in and out of the neuron at a faster rate.

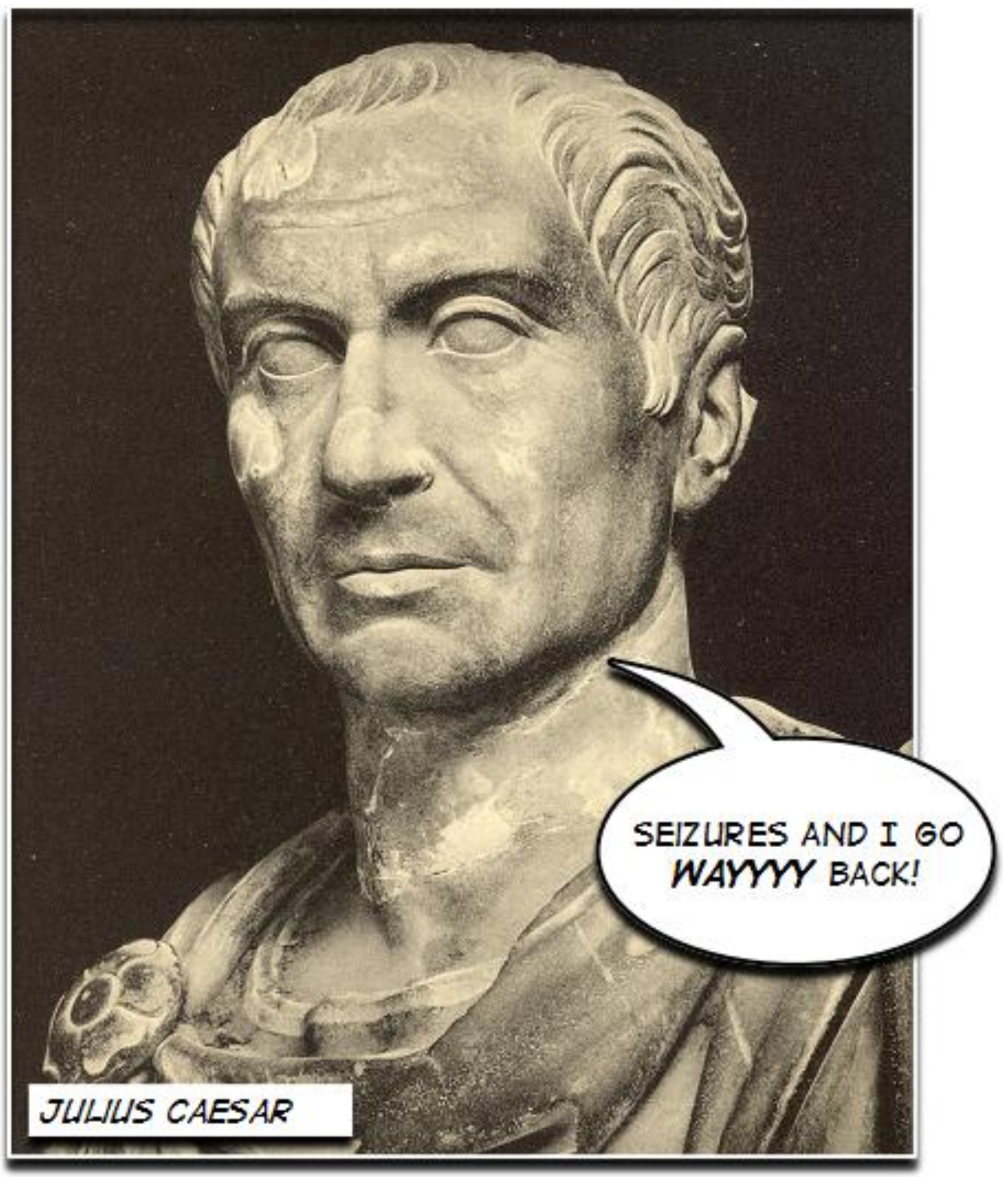
If myelin is destroyed or is not present at all, neurons cannot function properly. This may cause serious problems within the muscular system by slowing down or completely blocking the ability of muscles to function. This condition occurs in patients diagnosed with the disease called **multiple sclerosis (MS)**. The term "sclerosis" means the "hardening of a body tissue" or "scarring" which affects the myelin covering. This debilitating disease is thought to be caused by the body's own immune system mistakenly identifying myelin as a foreign pathogen. A condition where the body attacks its own healthy cells is known as an **autoimmune disease**.

Alzheimer's disease is another example of how our bodies may inadvertently cause a destructive series of events in our health. This disease occurs when structural changes of neurons cause the unneeded death of a large number of cells within the brain. As brain cells continue to perish, an individual will likely begin to experience a loss of memory. This condition leads to more serious losses in function until the patient can no longer perform daily activities.

Damage does not have to occur to neurons for a person to experience a problem…

If the nerve impulses within your brain travel much faster than normal, a brain disorder may exist which is known as **epilepsy**. Under normal circumstances, neurons can carry nerve impulses at a rate of 80 impulses per second. During an epileptic seizure, these same nerve impulses may travel six times faster than its normal rate. This increased activity can cause a range of behaviors ranging from relatively minor changes in sensations and behaviors to severe reactions including convulsions, seizures, or loss of consciousness.

Although a specific cause for epilepsy is not known, scientists have connected an imbalance in the amount of neurotransmitters (chemicals which allow neurons to communicate with each other or with neighboring muscle tissue) within the brain to this disorder.



What could happen if your head gets hit really hard?

Many problems can occur with a strong blow to the head. Let's first look at a couple situations that are not life-threatening...

Concussions and Amnesia

The term "**concussion**" is a general name given to any minor injury to the brain that is caused by a blow to the head. Typically, these injuries are not life-threatening and may cause a wide range of symptoms which may occur immediately or after a period of several days. A few of these symptoms may include the following:

Headaches, neck pain, confusion, difficulty remembering things, exhaustion, mood changes, loss of sleep, blurred vision, and ringing in the ears

A severe concussion can also cause **amnesia** which is the <u>complete loss of memory</u> that may be caused by a blow to the head. On some occasions, a patient may not be able to recall the moments before the trauma to their head has occurred. Other times, a patient is able to remember all of their previous memories up to the point of the trauma; however, they are unable to store any new long-term memories. In this second form of amnesia, a patient may have a partial or complete inability to recall the recent past. It is even possible for a patient to have both of these symptoms as well.

Since we are on the topic of the brain...

A huge amount of blood is needed by your brain to replenish the nutrients and remove wastes from all of its nerve cells. When a blood vessel that supplies blood to the brain becomes blocked, a condition called a **stroke** can occur.

Without a fresh supply of nutrients or a method of disposing of wastes, nerve cells immediately begin to suffer. This causes a series of symptoms including headaches, numbness on one side of the body, confusion or trouble speaking, seeing, walking, talking, and/or balancing. A stroke is to be considered very dangerous to a person's health. Medical treatment must be administered to any stroke victim immediately.

Let's look at some of the problems that can occur with our human senses!

Smell and Taste

Unfortunately, our ability to smell and taste our favorite foods begins to decline as we age. Of the two, our sense of smell takes a nose dive much faster (no pun intended) as the chemoreceptors in our nose are constantly exposed to the harsh conditions of the outside environment. Our sense of smell is also reduced as the number of taste buds in our mouth decreases beyond the age of 50. The interconnection between smell and taste is easy to discover when we have a cold. During this time the chemoreceptors in our nose are typically covered in a thick layer of **mucus** to protect our body from further infection. Without our ability to smell different odors, most food tastes bland. Mucus is a thick, slippery solution that is produced in several areas of the body and performs several different functions.

Hearing

Sound waves can be blocked from the central nervous system in two different ways:

Conduction deafness and Sensorineural deafness

In **conduction deafness**, damage within the middle ear prevents a nerve impulse from being created entirely. Injury to the three bones of the middle ear or the eardrum itself can be the cause of this type of deafness. If an injury occurs within or beyond the inner ear, a nerve impulse may be generated, but the damage prevents the signal from reaching the central nervous system. This blockage creates **sensorineural deafness** within the patient.

Both of these forms of deafness can be caused by a variety of sources. A few of these include disease, exposure to damaging chemicals, injury to the middle/inner ear from loud sounds, and genetic disorders.

A less serious condition with our hearing also exists for individuals who suffer from...**motion sickness.** This ailment takes place when our body undergoes rapid changes in speed and/or direction. This can also occur in some people when they not able to see a horizon in front of them such as when traveling along a hilly, winding road. Dizziness, fatigue, nausea, and vomiting can occur in people with motion sickness. These rapid changes in velocity can fool the mechanoreceptors within our middle ears which inform the central nervous system about our body position. These receptors may inform our brain that we are falling at times when a horizon line cannot be seen or when we accelerate rapidly. The results of this sensation can induce any of the conditions mentioned above.

Vision

There are a large amount of problems which may affect our sense of vision. For example, an individual with high blood sugar (known as *diabetes*) has an increased risk of damaging ones vision. The increased amount of sugar within the blood scratches the blood vessel walls within the retinas of the eyes. This damage can cause the blood vessels to burst within the eye which can cause scar tissue to form near the retina. If too much scarring builds up, the retina can detach from the eye causing blindness.

A different problem with our vision may occur which can be blamed on our DNA. Disorders within our genetic code are responsible for the inability to perceive one or more colors. This is known as **color blindness** and, as you learned in Chapter 11, is connected to the proper functioning of cones (photoreceptors within the retina) in our eyes. Without a proper way to detect the colors red, blue, and green, our central nervous system cannot accurately determine the various shades or blends of individual colors in the environment.

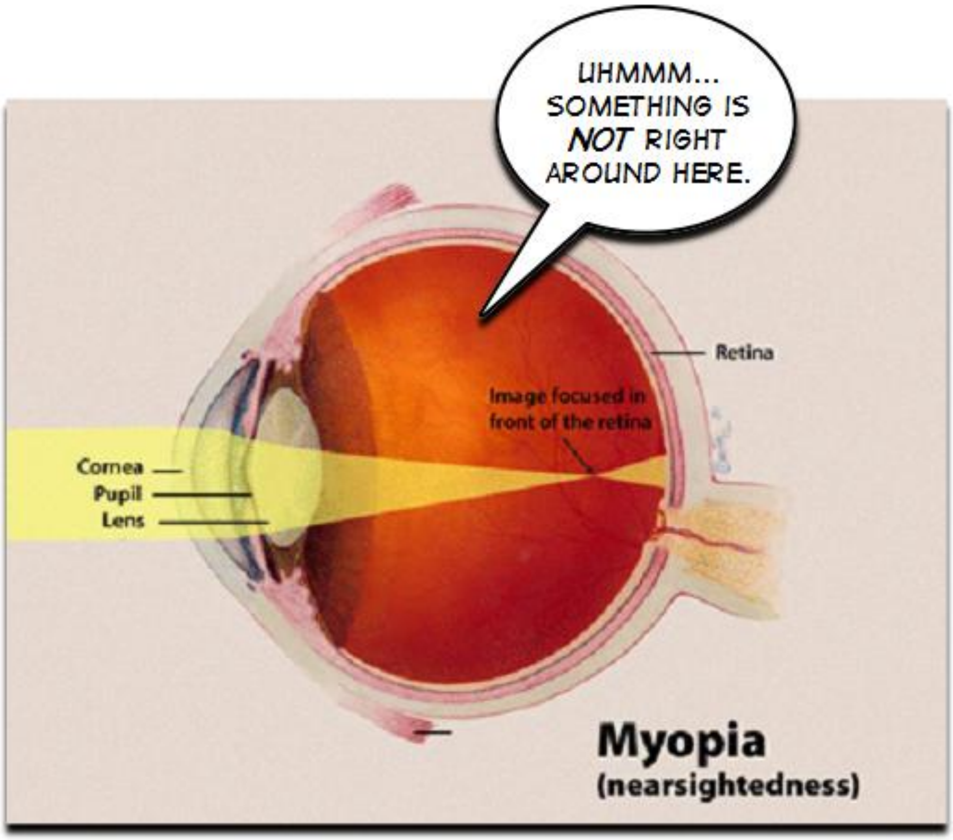
Two other issues pertaining to vision need to be mentioned:

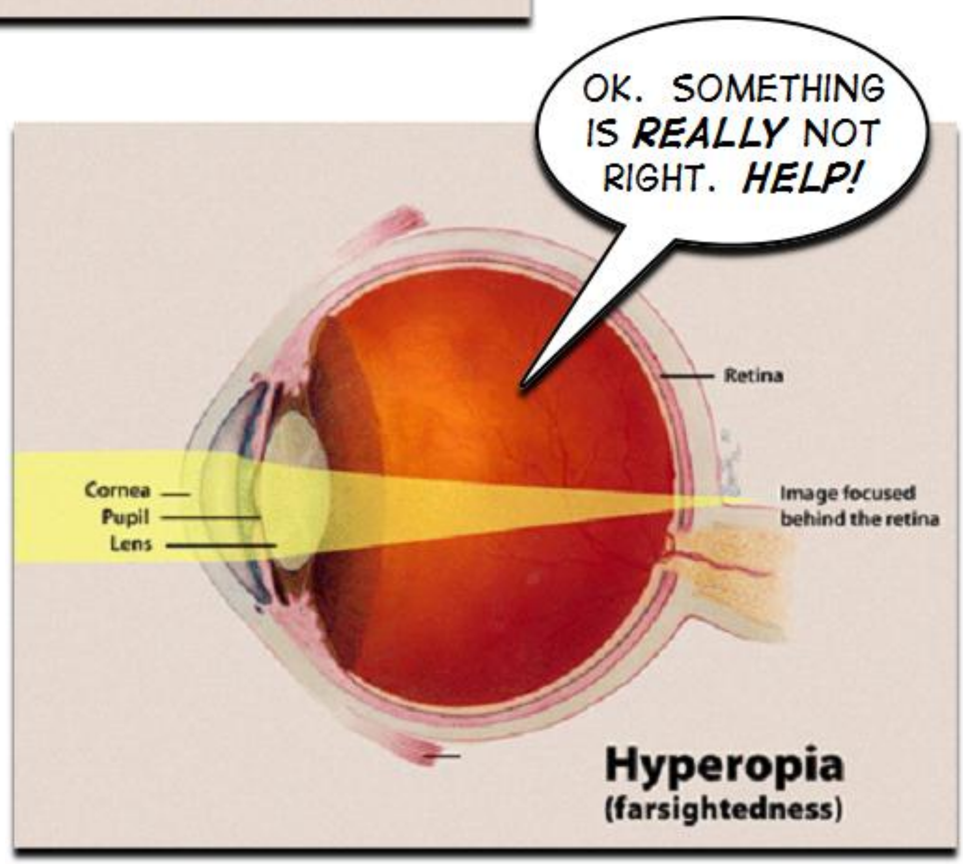
Myopia (Nearsightedness)
and
Hyperopia (Farsightedness)

Nearsightedness is the ability to see objects <u>near</u> you, but not far away. As you can probably guess, **farsightedness** is the ability to see objects <u>far away</u>, but not near to you.

Both of these issues involve a defect in the eye which causes the images we see to be focused either too close or too far away from the lens. To help understand this situation, imagine using a magnifying glass over an object. In order to have an image focus through the magnifying glass, you likely have to move the glass up and down until the image becomes clearly visible.

This is similar to what happens within person with myopia or hyperopia. If your eyes cannot place the focused image onto each of the retinas, the image will remain blurry to the observer.



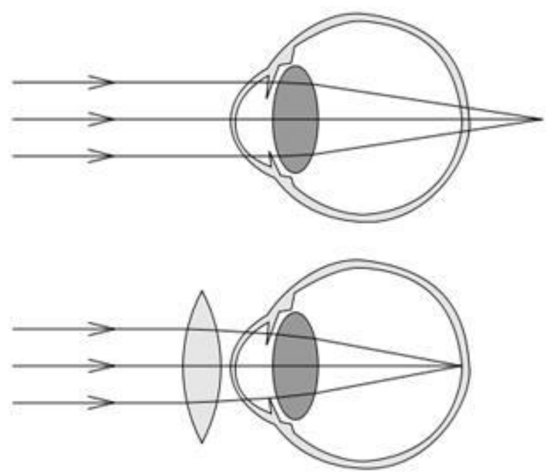


Corrective lenses such as glasses or contact lenses can be used to fix this problem. The different types of lenses which can be used to help these conditions include:

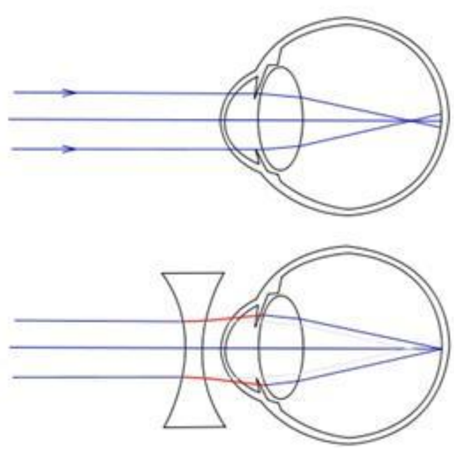
Concave lenses and Convex lenses

Concave lenses bend light outwards and is thinner in its center. If you look at something through a concave lens it appears smaller than it really is. On the other hand, **convex lenses** bend light inwards as they are thickest in the center. This type of lens makes objects appear much larger than they actually are. The lens of a magnifying glass is a convex lens. Convex lens are prescribed to lessen the effects of hyperopia.

Hyperopia and the restoring of vision with a convex lens



Myopia and the restoring of vision with a concave lens



Out of the massive amounts of problems which may exist within the endocrine system, we are only going to look at a few of the big issues.

Our first stop will be to look at how the process of aging affects the endocrine system.

Of all the processes of the endocrine system, it is the hormones associated with our reproductive system that are affected the most as we age. For example, the female ovaries decrease in size as a woman ages and no longer responds to the hormones FSH and LH, thereby causing a reduction in the secretion of estrogen in the body. Without the presence of estrogen, a woman's body cannot prepare physiologically for the act of pregnancy. On a different note, some tissues become less sensitive to being stimulated by hormones as we age.

Two separate disorders may exist within people who have abnormal levels of the human growth hormone (GH).

As you learned back in Chapter 12, human growth hormone targets nearly all muscle and bone tissues within the body to stimulate their growth. A child with a lower than average amount of growth hormone can expect to grow at a much slower rate and will likely result with a short physique in his/her life. On the opposite side, a child can expect to grow very tall (over 7 feet/2.1 meters) if an abnormally large amount of growth hormone is produced during and beyond adolescence. This is known as **gigantism** and can result in excessive thickening of the head, hands, and feet as well.

Let's take a look at disorders which affect the thyroid gland.

An individual producing excessive amounts of the hormones thyroxine (T_3) and triiodothyronine (T_4) from an overactive thyroid is said to have **hyperthyroidism**. As you learned in Chapter 13, these two hormones act to increase the rate in which cells use oxygen and nutrients to produce energy. Therefore, an increase in these hormones can produce symptoms such as sudden weight loss, rapid heartbeats, nervousness, irritability, and increased sweating.

You also learned that our thyroid gland is similar to a car which takes in fuel and turns it into T_3 and T_4 hormones which influence how much energy gets transmitted throughout the body. Therefore, during hyperthyroidism, the "car" gets revved up but it doesn't go anywhere. There's lots of energy being released, but it's not doing anything practical.

But what if your "car" doesn't start or is sputters?

This would be an analogy to another thyroid disorder – **hypothyroidism**. An individual with hypothyroidism produces lower than average amounts of T_3 and T_4 hormones. This produces feelings of fatigue and coldness, dry skin and hair, weight gain, and muscle cramps.

The "car" is filled with fuel but is unable to convert it into the energy needed to make it move. Both hyperthyroidism and hypothyroidism may cause the thyroid to grow very large which is known as a **goiter**. While we are on the topic of energy, let's wrap up this chapter with one final disorder that was mentioned earlier….

Diabetes

Diabetes is a medical condition which is caused by the inability of the pancreas to produce or utilize the hormone insulin. As you learned in Chapter 13, insulin helps cells absorb excess sugar within the bloodstream. Without insulin, the amount of sugar within the blood increases significantly. This excess sugar is then forced out of the body through the urine and cannot be utilized as an energy source for the cells within our body. This can be a very serious problem for the body!

As was mentioned earlier, this is just a brief look into some common disorders which affects our nervous and endocrine systems. We could spend the rest of the year studying just these few conditions alone without mentioning the hundreds of other disorders that exists within these two systems.

I hope some of you will consider a more thorough study of these medical conditions in your future careers! We need scientists and doctors out there who are able to study these debilitating conditions.

Match the following vocabulary terms with their correct definition:

Alzheimer's disease	**diabetes**	**local anesthetics**
amnesia	**epilepsy**	**motion sickness**
autoimmune disease	**gigantism**	**mucus**
color blindness	**goiter**	**multiple sclerosis (MS)**
concave lenses	**hyperopia**	**myopia**
concussion	**hyperthyroidism**	**novocain**
conduction deafness	**hypothyroidism**	**sensorineural deafness**
convex lenses	**lidocaine**	**stroke**

1)	______________	a condition in which a vessel that supplies blood to the brain becomes blocked, inducing a series of potentially life-threatening symptoms
2)	______________	a condition where the body attacks its own healthy cells
3)	______________	a disease in which changes within neurons cause the death of a large number of cells within the brain
4)	______________	a form of deafness in which an injury occurs within or beyond the inner ear; a nerve impulse may be generated, but the damage prevents the signal from reaching the central nervous system
5)	______________	a form of deafness; caused by damage within the middle ear which prevents a nerve impulse from being created
6)	______________	a general name given to any minor injury to the brain that is caused by a blow to the head
7)	______________	a medical condition which is caused by the inability of the pancreas to produce or utilize the hormone insulin

8)	______________	a thick, slippery solution that is produced in several areas of the body; its functions are varied and plays an important role in several body systems
9)	______________	condition caused by an abnormally large amount of growth hormone being produced during and beyond adolescence
10)	______________	condition caused by the overproduction of the hormones thyroxine (T_3) and triiodothyronine (T_4)
11)	______________	condition caused by the underproduction of the hormones thyroxine (T_3) and triiodothyronine (T_4)
12)	______________	condition in which the thyroid has grown very large; can be caused by hyper- or hypothyroidism
13)	______________	disease in which a neuron's myelin is destroyed or lost; causes serious problems within the muscular system by slowing down or completely blocking the ability of muscles to function
14)	______________	disorder of the brain; characterized by nerve impulses within the brain traveling much faster than normal
15)	______________	lens which bends light inwards; its structure is thickest in its center
16)	______________	lens which bends light outwards; its structure is thinnest in the center
17)	______________	local anesthetic used for tooth pain
18)	______________	local anesthetic used to numb the surface of the skin
19)	______________	minor condition caused when the body undergoes rapid changes in speed and/or direction

20)	______________	numbing agents which block the sensation of pain by keeping sodium ions from entering and leaving the cell membranes of neurons
21)	______________	the ability to see objects far away, but not near to you
22)	______________	the ability to see objects near you, but not far away
23)	______________	the inability to perceive one or more colors
24)	______________	the loss of memory that may be caused by a blow to the head

Choose the correct answer from the following questions:

1) **Your friend Shelly suffers from myopia (nearsightedness). You remember from your physics class that concave lenses cause light waves to spread or diverge and that convex lenses cause light waves to converge. What type of corrective lenses would you suggest to your friend – concave or convex lenses?**

2) **Excess secretion of growth hormone after long bone growth has ended (as an adult) is called**:
   A) dwarfism
   B) epilepsy
   C) gigantism
   D) hyperthyroidism

3) **The inability to see distant objects is termed "nearsighted" or:**
   A) goiter
   B) myopia
   C) hyperopia
   D) astigmatism

4) **Sensorineural deafness occurs when there is damage within or beyond the:**
   A) inner ear
   B) middle ear
   C) outer ear

Application Question:

As a person ages, the speed of nerve impulses through action potentials and the transmission of neurotransmitters decreases. List at least two possible explanations for this occurrence.

Chapter 15

Blood – Part I

During the next few weeks, we will be exploring the primary method of how our body transports nutrients, wastes, and other various chemicals. And since we are talking about transportation, we are going to need some form of vehicle to get us from point A to point B. Therefore, our next two chapters will be dealing with this amazing vehicle commonly known as...

Blood

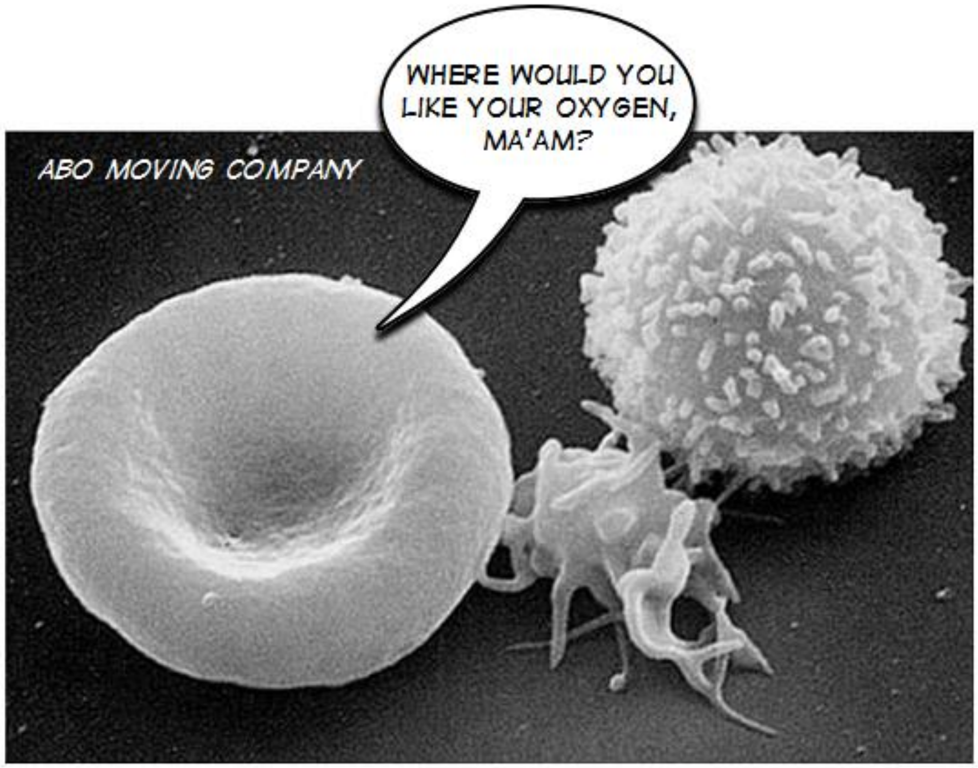
Way back in Chapter 2 we explored the following question:

How can blood be considered a tissue?

Our blood is a form of connective tissue as it is a combination of various types of cells, cell parts, and a fluid called plasma which contains several dissolved substances as well. Although there are many different things floating around in our blood, we will be spending most of our time on the following four substances:

Red blood cells (erythrocytes),
White blood cells (leukocytes),
Platelets,
and **Plasma**

The function of all these items help to move things throughout our bodies, regulate homeostasis by maintaining a constant body temperature, pH, and blood pressure, and protect us from various forms of infection. As you learned in Chapter 4, all of the solid particles within our blood (red blood cells, white blood cells, and platelets) are formed through a process called hematopoiesis that occurs within the red bone marrow of our bones.



Scanning electron micrograph of blood cells. From left to right: human erythrocyte, platelet, and leukocyte.

Let's take a closer look at each of the solid particles in more detail...

Red blood cells (erythrocytes)

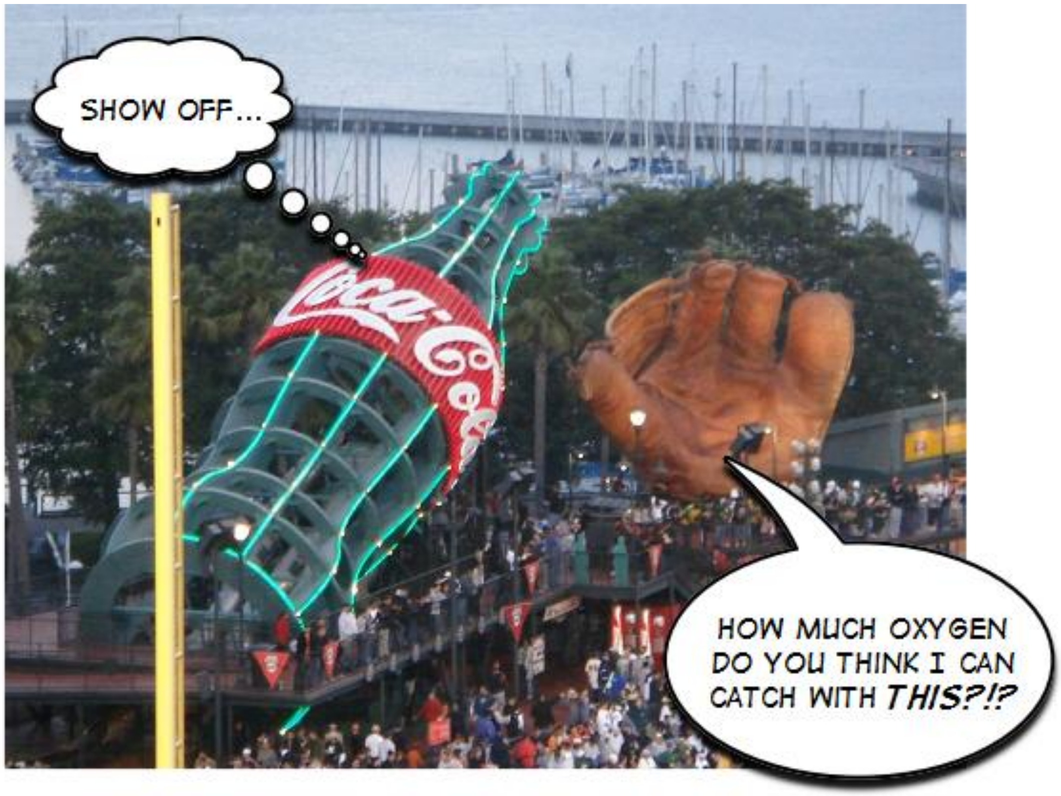
The shape of **red blood cells (RBC)** has been compared to that of a flattened hamburger bun or donut. This shape allows the cells to stack on top of each other easily and to squeeze through very narrow blood vessels. In addition, this shape also allows for the maximum amount of gases to pass through its membrane as we will explore very shortly.

The red blood cells make up nearly one-third of all the cells in the body and almost all of the solid material found in the blood. In fact, if you were to stack all of the red blood cells in your body like crackers in a tube, you could stretch that tube around the Earth 1.25 times. That is about 31,000 miles (49,890 kilometers) in length!

One of the main functions of the red blood cells is the transport of oxygen and carbon dioxide gases. This is accomplished through a protein within each cell called **hemoglobin**. Think of hemoglobin as four baseball gloves stitched together.

Why baseball gloves?

Because each glove has the ability to "catch" or "bind to" a single molecule of oxygen gas



Within each of these "gloves" is another smaller molecule known as **heme** which contains an atom of iron in its center. Iron has a tendency to bind with oxygen very easily. In fact, when iron binds with oxygen a new molecule is formed which is known as iron oxide. I am certain you have seen iron oxide in your life because it has a very distinctive brown color, and a very familiar name...

Rust

That's right! Those scabs which form over cuts on the surface of your skin that eventually turns brown are actually molecules of rust! And since each red blood cell contains approximately 280 million hemoglobin molecules, a single red blood cell has the ability to carry more than one billion oxygen molecules!

Homeostasis plays an important role in the production of red blood cells as it is directly linked to the amount of oxygen within our body.

When the hormone **erythropoietin** is released into the blood, it signals the skeletal system to increase the rate of red blood cell production. How does the body determine when this is needed? The release of erythropoietin is triggered when the body detects a low level of oxygen within the blood.

There are times when the blood does not contain a safe amount of oxygen gas.

For example, a dangerous condition known as **anemia** occurs when a person has a low level of red blood cells or hemoglobin. Without plenty of these tiny oxygen transporters, the body will not contain enough of this important gas. Another example of how low oxygen levels in the blood can occur is when an individual is placed in high altitudes. Locations in higher altitudes contain lower amounts of atmospheric gases, including oxygen.

If you live in an area that is close to sea level and vacation to a location that is much higher in elevation, you likely felt the effects of a decreased amount of oxygen – headaches, muscle cramps, and exhaustion are normal if you decide to physically exert yourself immediately upon arrival. Typically, a couple of restful days within a higher elevation will help your body acclimate to the low oxygen levels. Then you can consider that early morning jog!

What is the lifespan of a red blood cell?

Red blood cells only exist for approximately four months within the human body before they become worn down and break apart. Each of these cells undergoes a huge amount of damage in their short life span. In fact, nearly 150 million red blood cells are being destroyed every minute.

White blood cells (leukocytes)

We could spend a full year studying the various types and functions of the **white blood cells**. As the key players within the immune system you would think their presence within the body would be amazing. This, however, is not entirely true. Less than one percent of our blood is made up of leukocytes whose function is to protect us from foreign invaders that find their way into our bodies. These tiny protectors utilize a wide array of mechanisms to identify and attack unwanted objects in the body. Some white blood cells, which we will discuss in future chapters, are known as **phagocytic cells** which literally mean "cells that eat." I'll let your imagination run wild with that one until our study of the immune system.

Until then…

When compared to red blood cells, leukocytes make up a very small amount of space within the blood. But don't let that fool you! Consider this fact, if you were to make a cube that is one millimeter in length, width, and height (one cubic millimeter) you would find a staggering ~10,000 of these hungry cells!

That is a fairly impressive number even though you would find nearly 5 million red blood cells in that same cubic millimeter.

Why aren't leukocytes found in greater numbers throughout the blood stream?

Well, as you learned in Chapter 7, pathogens such as bacteria begin to grow rapidly in damaged connective tissues such as when we cut our skin. This damage causes inflammation to take place and is a location where white blood cells are needed very quickly.

It is true that white blood cells are found within the bloodstream; however, these defenders typically use the blood for <u>rapid</u> transportation between organs and other tissues during an inflammatory response to our internal systems. Typically, white blood cells are found within the connective tissues of the body. And even though they are not found in the <u>bloodstream</u> for long periods of time, some types of leukocytes have life spans that can be measured in <u>decades</u>! You'll have to wait until our study of the immune system to learn more about these amazing cells. Until then, let's move to our last type of cell found within the blood...

Platelets

Much like red and white blood cells, **platelets** are formed within the marrow of our bones. However, the contents and functions of these unique cells are much different than its counterparts. One of these differences can be found in its lifecycle. The life expectancy of most platelets is around 7-12 days, which is considerably shorter than the 120 days of a typical red blood cell and the old-timers of the blood stream (aka – the leukocytes).

Despite their relatively short life spans, the structure and function of platelets separate them considerably from both red and white blood cells. Platelets are membrane-bound "packets" of cytoplasm – a gel-like substance that fills up a cell and holds all the cell's internal organelles. Many dissolved molecules along with the proteins actin and myosin (check back in Chapter 6 for a review) can be found within the cytoplasm, all of which play a role in the two main functions of platelets:

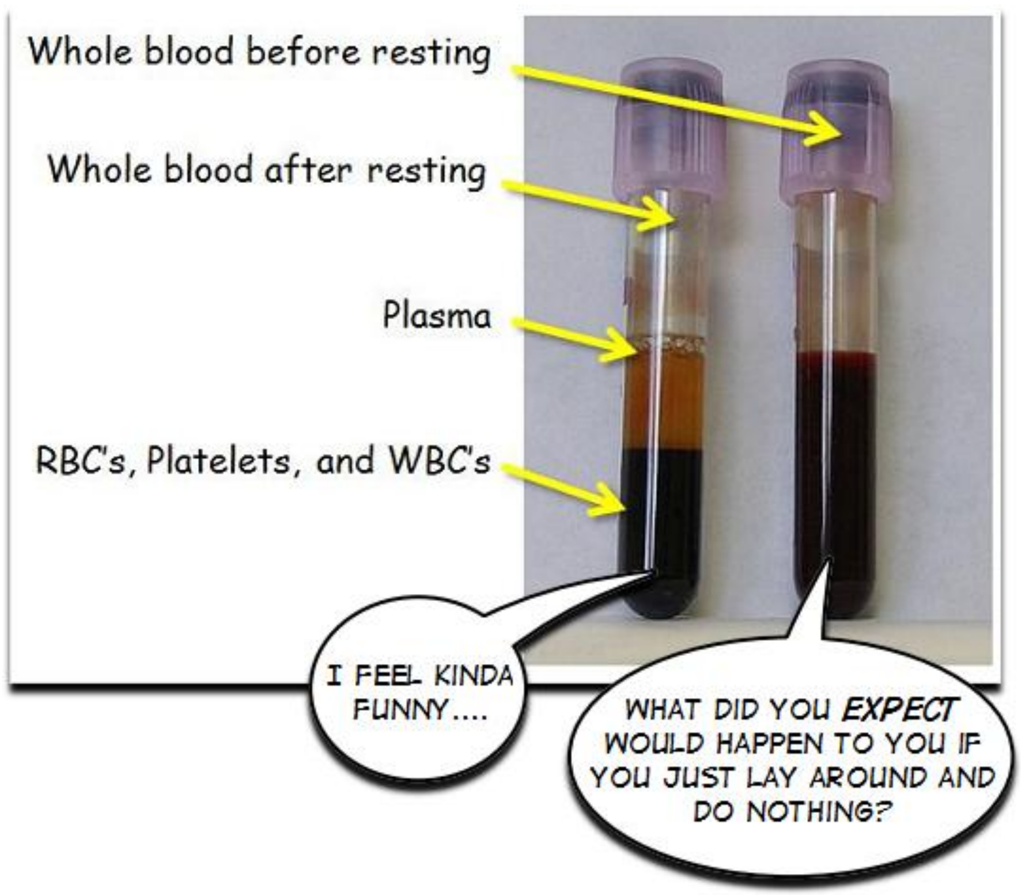
#1: Platelets temporary patch the walls of damaged blood vessels and control the **clotting** of blood.

Whenever a blood vessel is damaged by cuts or other forms of injury, platelets act to plug up the broken vessels, reducing the amount of blood loss. This "plug" of platelets is known as a **blood clot**. Blood clots <u>must</u> form if we are to stop bleeding after an injury; however, harmful blood clots can also form which can cause serious damage. For example, if a blood clot dislodges and travels to the brain, it can cause a stroke which you explored in the last chapter.

**There is another player in the formation of a blood clot, but you are going to have to wait until next chapter to find out who this is. Stay tuned!*

#2: Platelets help to seal breaks in the walls of our blood vessels.

Platelets contain actin and myosin, the proteins found within the sarcomeres of muscle cells which contract to allow muscular movement (check back in Chapter 6 for a review.) As platelets plug up the damaged blood vessels, they begin to contract due to their high concentration of actin and myosin. This contraction pulls the platelets, and the blood vessels they are attached to, closer together. Thus, the contractive properties of platelets help to seal up blood vessels that have been injured.



The amount of platelets in the blood is considerably higher than those of the white blood cells; however, they only make up a small fraction of the total blood volume. In any sample of blood, the number of platelets makes up about 10% of the number of red blood cells in that volume. For example, if 5 million red blood cells are found within one microliter of blood, the same volume of blood would contain ~500,000 platelets.

That finishes our study of the solid particles found within our blood. In the next chapter we take a closer look at the fluid component of blood and how various types of this tissue are shared by people throughout the world.

Match the following vocabulary terms with their correct definition:

anemia	**heme**	**platelets**
blood clot	**hemoglobin**	**red blood cells**
erythropoietin	**phagocytic cells**	**white blood cells**

1)	______________	"cells that eat"
2)	______________	a "plug" of platelets within a damaged blood vessel
3)	______________	a dangerous condition occurring when a person has a low level of red blood cells or hemoglobin
4)	______________	hormone which is released into the blood and signals the skeletal system to increase the rate of red blood cell production
5)	______________	iron-containing molecule found within hemoglobin
6)	______________	major component of blood; responsible for transport of oxygen and carbon dioxide gases throughout the body
7)	______________	phagocytic cells within the blood ; major component of the immune system
8)	______________	protein within red blood cells consisting of heme which binds to a single oxygen gas molecule
9)	______________	short-lived packets of cytoplasm and dissolved molecules within the blood; assist in the immune response to the vessels of the cardiovascular system

Choose the correct answer from the following questions:

1) **The hormone that regulates the rate of erythrocyte production is called:**
    A) renin
    B) vasopressin
    C) erythropoietin
    D) leukopoietin

2) **Which one of the following formed elements is the most abundant:**
    A) platelets
    B) leukocytes
    C) erythrocytes
    D) white blood cells

3) **Blood cell formation is called __________ and occurs within the bone marrow.**
    A) hemolysis
    B) heme
    C) hematopoiesis
    D) hemoglobin
    E) hemostasis

4) **The average functional lifespan of a red blood cell is:**
    A) the body's lifetime
    B) 50-75 days
    C) 100-120 days
    D) one year
    E) 20-30 days

5) **There are an average of __________ white blood cells per cubic millimeter of whole blood.**
   A) 100-1000
   B) 4000-11,000
   C) 11,000-20,000
   D) 50,000-100,000
   E) 1 million-3 million

6) **True or false:** Erythropoietin is released to stimulate white blood cell production in response low levels of oxygen within the blood.

7) **True or false:** Leukocytes are more numerous in blood than erythrocytes.

Application Question:

Some people use chemicals known as barbiturates to reduce feelings of anxiety. Barbiturates cause hypoventilation, which is a reduced rate of breathing, because they decrease the activity of the parts of the brain responsible for our breathing. What do you suppose happens to the red blood count of a habitual user of barbiturates? Defend your answer.

Chapter 16

Blood – Part II

Before we start exploring the liquid part of blood...

Plasma

...let's take a quick look at some information about the general properties of our blood:

Volume

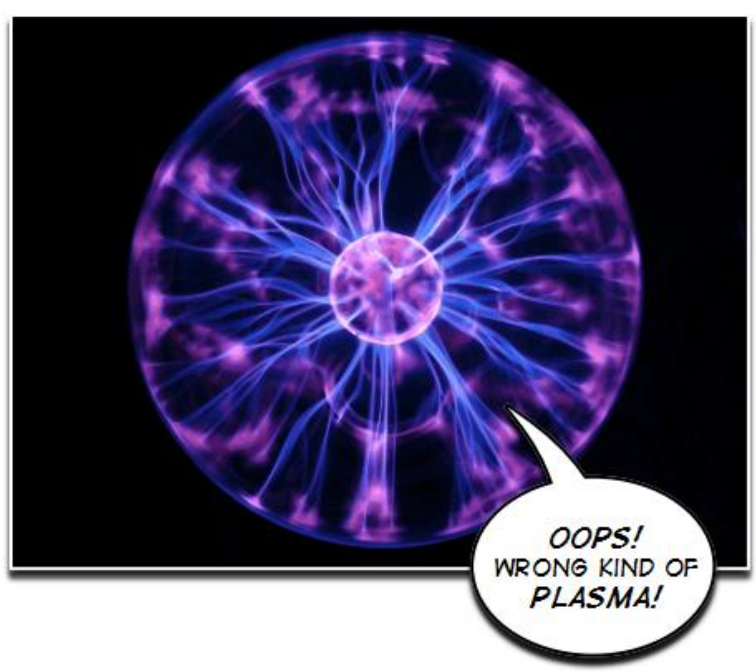
An adult male contains 5–6 liters (5.3–6.4 quarts) of whole blood while an adult female contains 4–5 liters (4.2–5.3 quarts).This difference in blood volume is due to the larger average body size of males.

Temperature

Blood temperature is about 38°C (100.4°F). This temperature is slightly above the normal body temperature of 37°C (98.6°F). The extra heat within the internal blood is spread throughout the body before it reaches the epidermal layers of our skin.

Thickness

The **viscosity** of blood is roughly five times that of water. Viscosity refers to the relative thickness of a fluid. The high volume of solid particles, dissolved proteins and other molecules within the plasma give blood the consistency of a sticky and thickened fluid.



pH

Blood is slightly alkaline (non-acidic), with an average pH of 7.4.

In the last chapter, you explored the solid particles which make up blood:

Red blood cells, White blood cells, and Platelets

All of these solid particles float within a fluid known as plasma which takes up nearly half (46-63%) of the total volume of blood. Within this fluid, three main proteins can be found which are all produced by the *liver* (an organ of the digestive system you will learn about in Chapter 25):

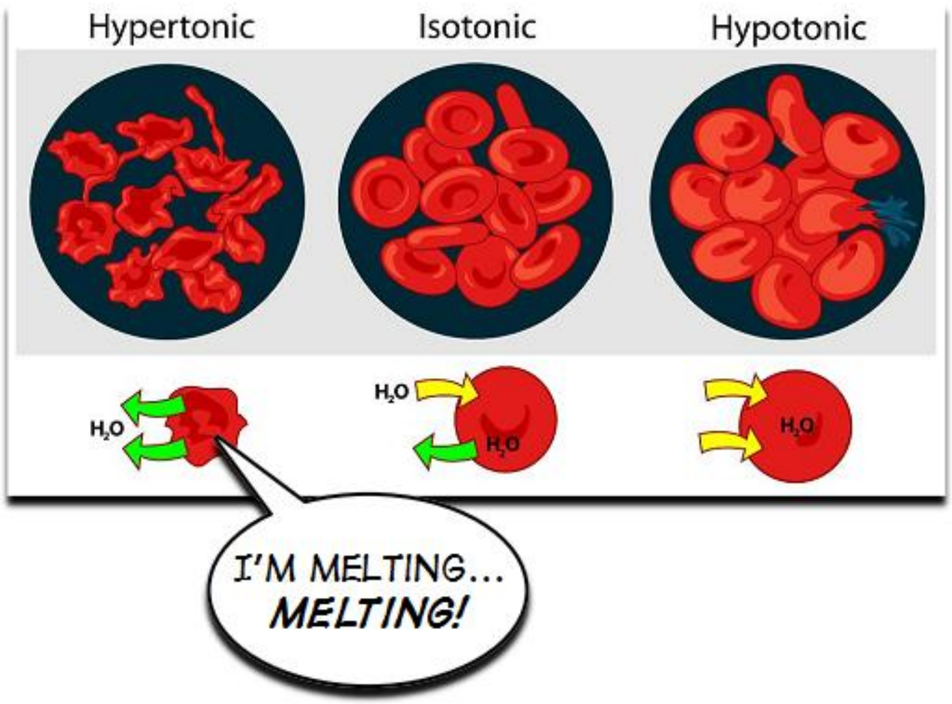
Albumins, Globulins, and Fibrinogen

Albumins

Albumins make up close to 60% of the plasma proteins. The relatively large numbers of these proteins help to keep water from leaking out of the blood vessels by "plugging up" the tiny holes which exist within its walls. It can be said, therefore, that albumins regulate the **osmotic pressure** of our blood. Osmotic pressure is defined as the pressure needed to prevent water from moving through a permeable substance (like our blood vessels). This movement of water across a permeable substance (osmosis) requires a couple of important definitions first:

All substances (such as albumins, glucose, red and white blood cells, etc.) that are found floating within the fluid plasma are known as ***solutes****. The liquid that holds these solutes together is known as the* ***solvent*** *and is primarily the water found within the plasma itself. When you have a mixture of a solute and a solution, scientists call this a* ***solution****. By this definition, blood is to be considered a solution.*

*Solutions containing fewer solutes as compared to another fluid which are separated by a permeable membrane are known as **hypotonic**; solutions with more solutes as compared to another fluid are known as **hypertonic**; and, solutions with equal concentrations of solutes are known as **isotonic**.*

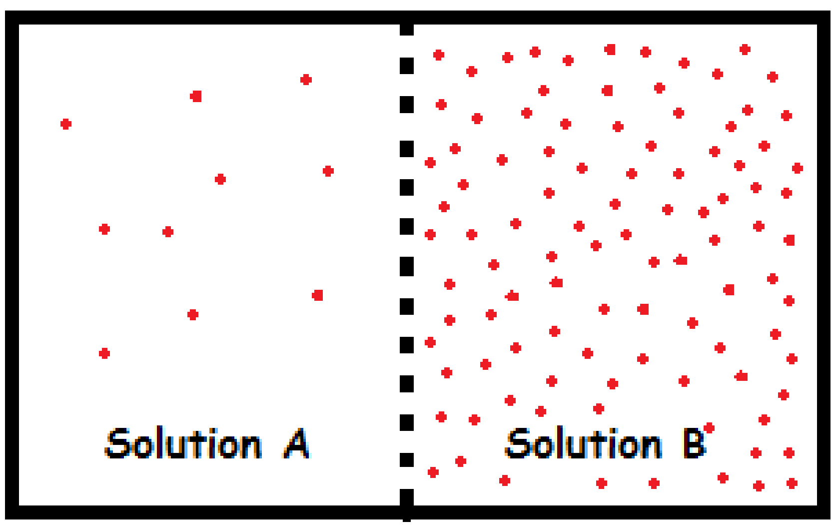


Now that you understand how a solute gets dissolved by a solvent to make a solution, let's take a look at how you can best remember the movement of water through the process of osmosis:

Water flows from the solution with the lower solute concentration into the solution with higher solute concentration. This flow will continue until the concentrations on both sides are equal and are considered isotonic.

Here's an example of how osmosis works:

Let's represent the porous walls of a blood vessel as the dotted line in the center of the drawing below. "Solution B" represents the inside environment of the blood vessel and is filled with albumins and other plasma proteins swimming in a sea of water. This solution would be considered hypertonic. "Solution A" is the outside environment of the blood vessel. It, too, is filled with water and represents any number of various tissues within the body; however, its concentration of solutes is not nearly as high as represented by the fewer red dots. This makes Solution A hypotonic as compared to Solution B. Given the uneven amounts of proteins inside the blood vessel and the presence of water on both sides of the blood vessel wall, which direction will the water flow?



If you said the water would flow from Solution A into Solution B you would be correct! Within Solution B, some of the pores within the wall get "plugged up" with plasma proteins; however, this does not happen in Solution A. Therefore, water is more likely to flow from Solution A into Solution B. The presence of more solutes in Solution B causes the osmotic pressure of this solution to be greater than in Solution A.

Globulins

Globulins are the second most abundant proteins within the plasma (35%). The functions of the globulins are twofold:

Protection and Transport

One specific type of globulins are known as **antibodies** (also known as **immunoglobulins**) and do a very good job at attacking foreign invaders that find their way into the bloodstream. If you are thinking this action is similar to the white blood cells' protective qualities, you would be correct as antibodies are created by white blood cells!

Transport globulins bind to important compounds that may otherwise be excreted out of the body. Thyroid hormones, testosterone, and the element iron utilize transport globulins as "taxis" to circulate throughout the body.

Fibrinogen

Fibrinogen works with the platelets in our blood to help with the formation of a blood clot. Fibrinogen normally accounts for roughly 4% of plasma proteins. When blood vessels become damaged, as you learned last week, platelets act to plug up the holes.

However, platelets need some form of support in order to hold together. This is the function of fibrinogen. As more and more fibrinogen proteins assemble around the plug of platelets, they become intertwined and begin to form long strands which are called **fibrin**. It is fibrin which provides structural support to the platelets at the site of injury.

As fibrinogen goes through the process of becoming fibrin, it is removed from the plasma and attaches itself around the platelets. Thus, the plasma which exists downstream from the site of an injury contains no cells or molecules needed to form a blood clot and is known by another name - **serum**.

Basically, plasma is whole blood without any red blood cells, white blood cells and platelets…

…while serum is plasma without any fibrinogen.

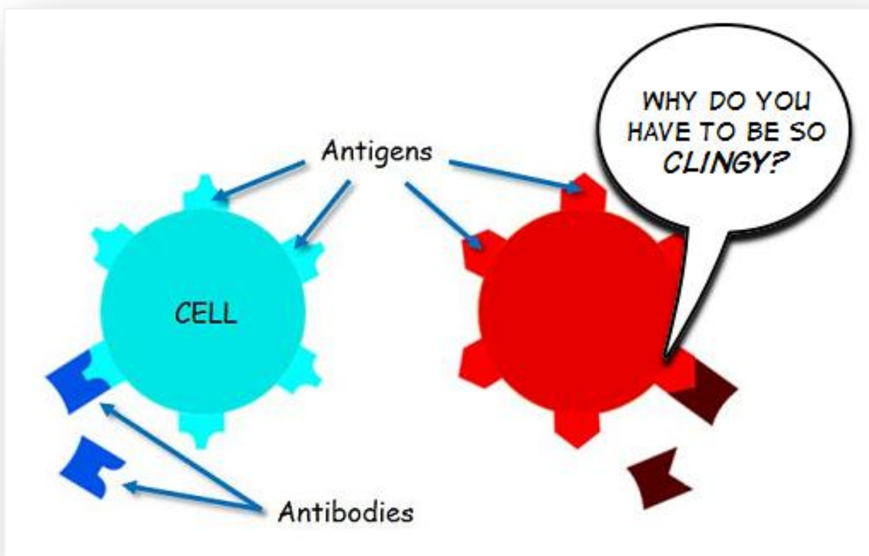
Why is this important?

That is a good question! Plasma and serum are used by doctors and researchers for entirely different purposes. Plasma is collected from whole blood that is donated by individuals and provided to patients who are in need of the vital plasma proteins. In addition, plasma can be tested for the presence of various diseases. Serum is typically used to test for an individual's **blood type** and will be explored throughout the remainder of this chapter.

Back in Chapters 11 and 12, you explored how target cells utilize a "lock and key" method of detecting specific hormones and/or other molecules. This is due to the fact that target cells have special receptors (locks) on their outer membranes that fit specific "keys" located on individual hormones/molecules. This is going to help you out as you explore the topic of…

Blood types

All red blood cells contain specific "locks" on their outer surface which are referred to as **antigens**. Your blood type is determined by the presence or absence of three different surface antigens which are labeled as A, B, and Rh.



Based upon the presence of the A and B surface antigens, every individual has only one of four possible blood types:

<u>Type A</u> blood has surface antigen A only,

<u>Type B</u> has surface antigen B only,

<u>Type AB</u> has both A and B,

and <u>Type O</u> has neither A nor B.

In regards to the Rh surface antigen, the term Rh positive (Rh+) indicates the presence of the Rh surface antigen, also known as the **Rh factor**. The absence of this antigen is indicated as Rh negative (Rh–). When an individual's blood type is recorded, the term Rh is usually omitted, and a positive or negative sign is used in its place. For example, a person with Type A blood and a positive Rh factor, their blood type is recorded as A positive (A+).

Bad things may happen if you receive blood with the wrong antigens!

If you recall, you have antibodies (globulins) that are floating around your plasma and attacking foreign invaders that enter your blood stream. If you have Type A blood, your plasma contains anti-B antibodies which will attach to and attack Type B surface antigens.

This occurs as the antibodies, acting as "keys", attach themselves to the specific "locks" found on the antigens.

And, if you have Type B blood, your plasma contains anti-A antibodies which will attack Type A surface antigens. Therefore, if you receive the wrong type of blood, your body's antibodies will destroy all of the red blood cells from the donated blood!

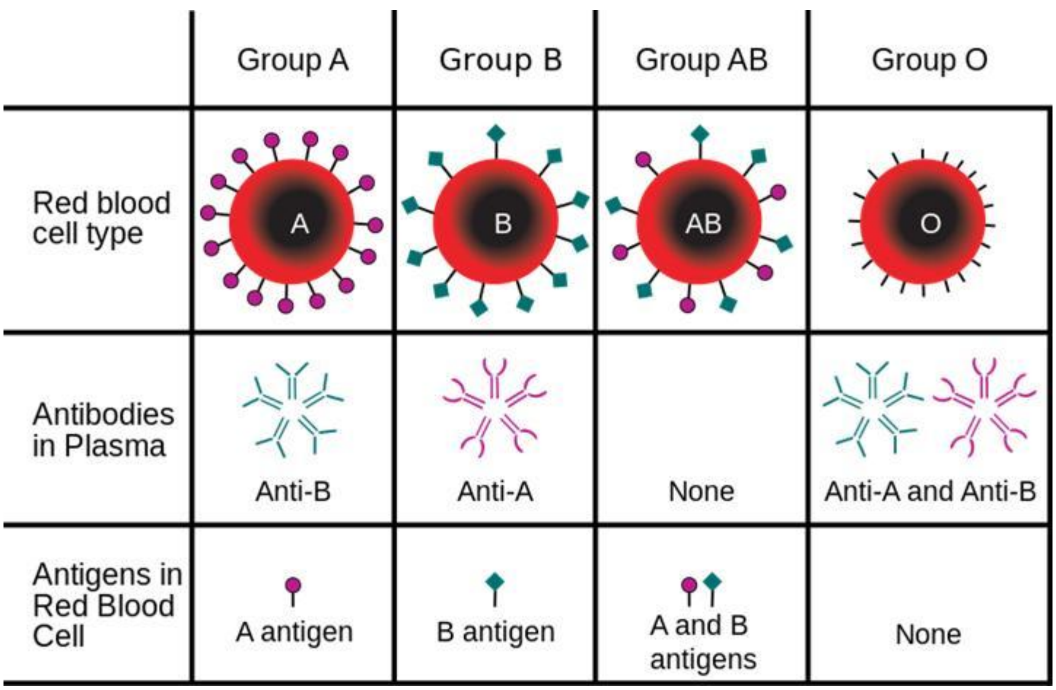
Tests can be performed to determine the blood type from an unknown sample by administering an **antiserum**. Antisera (plural form) is blood serum containing specific antibodies against specific antigens. For example, an antiserum that is "Anti-B" would contain B antigens. If Anti-B antisera comes into contact with B antigens within the unknown sample, the blood would begin to clump together as the antibody binds with the antigen.

What about a difference in Rh factors?

The plasma of an Rh-negative individual does not contain anti-Rh antibodies. However, if a pregnant woman is found to be Rh-negative, the father's blood type is also determined as parents with mismatched Rh factors can have babies with deadly blood problems.

Individuals who have Type O blood are known as **universal donors** because they are capable of donating their blood to any recipient.

If you look at the following table, you will see that Type O blood contains no surface antigens on their red blood cells. Without these antigens, the antibodies within the recipients of their blood cannot attack any of the newly introduced red blood cells. Therefore, Type O blood can be safely received by all patients.



All of this blood is worthless without a way to transport it throughout the body. In the next two chapters, we will be exploring how this life-giving fluid is transported through a study of...

The Cardiovascular System

Match the following vocabulary terms with their correct definition:

albumins	**globulins**	**solutes**
antibodies	**hypertonic**	**solution**
antigens	**hypotonic**	**solvent**
blood type	**osmotic pressure**	**transport globulins**
fibrin	**Rh factor**	**universal donors**
fibrinogen	**serum**	**viscosity**

1)	______________	a mixture of solute(s) and solvent(s)
2)	______________	a type of globulin which is responsible for attacking foreign invaders within the bloodstream
3)	______________	blood plasma which contains no fibrinogen
4)	______________	chemical "taxis" of the blood; bind to important compounds that may otherwise be flushed out of the body
5)	______________	individuals who have type O blood
6)	______________	long strands of fibrinogen proteins which assemble around the "plug" of platelets within a blood clot
7)	______________	one of four different types of blood which is characterized by the absence or presence of three different surface antigens (A, B, and Rh)
8)	______________	plasma protein; largest by volume; act to regulate the osmotic pressure of the blood
9)	______________	plasma protein; works with the platelets in the blood to help with the formation of a blood clot

10)	______________	resistance of a fluid to flow
11)	______________	second most abundant type of plasma proteins; functions include protection and transport of molecules
12)	______________	solutions containing fewer solutes as compared to another fluid
13)	______________	solutions containing more solutes as compared to another fluid
14)	______________	specific molecular "locks" on the outer surface of cells that can only be opened by specific molecular "keys"
15)	______________	substances that are dissolved in a solution by solvents
16)	______________	substances which dissolve solutes to form a solution
17)	______________	surface antigen within blood that identifies an individual's blood type as either positive or negative
18)	______________	the pressure needed to keep water from moving through a porous substance (like the blood vessels)

Choose the correct answer from the following questions:

1) The AB blood type are based on the presence of:

A) A antigens
B) B antigens
C) O antigens
D) A, B, and O antigens
E) A and B antigens

2) The universal donor has blood type:

A) A
B) B
C) AB
D) ABO
E) O

3) Which blood type(s) can a person with blood type O receive?

A) blood type A
B) blood types A, B, AB, or O
C) blood type B
D) blood type O
E) blood type AB

4) Which of these blood types carries no antigens?

A) blood types A, B, and AB
B) blood type A
C) blood type O
D) blood type B
E) blood type AB

5) **Which antigen(s) does type AB blood contain?**
   A) sometimes A antigens, other times B antigens
   B) B antigen
   C) A antigen
   D) A and B antigens

6) **True or false:** Rh-related problems occur in pregnant Rh- women carrying a baby from an Rh- father.

7) **True or false:** Normal blood volume in healthy males is 5-6 liters.

Application Question:

A runner wanted to improve his performance in an upcoming marathon race. About 6 weeks before the race, 500 mL of blood was removed from his body, and its solid components were separated from the plasma. These components were frozen, and the plasma was placed back into his body. Just before the competition, the frozen components were thawed and injected into his body. Explain why this procedure, called blood doping, would help his performance in the marathon. Can you suggest any possible bad effects?

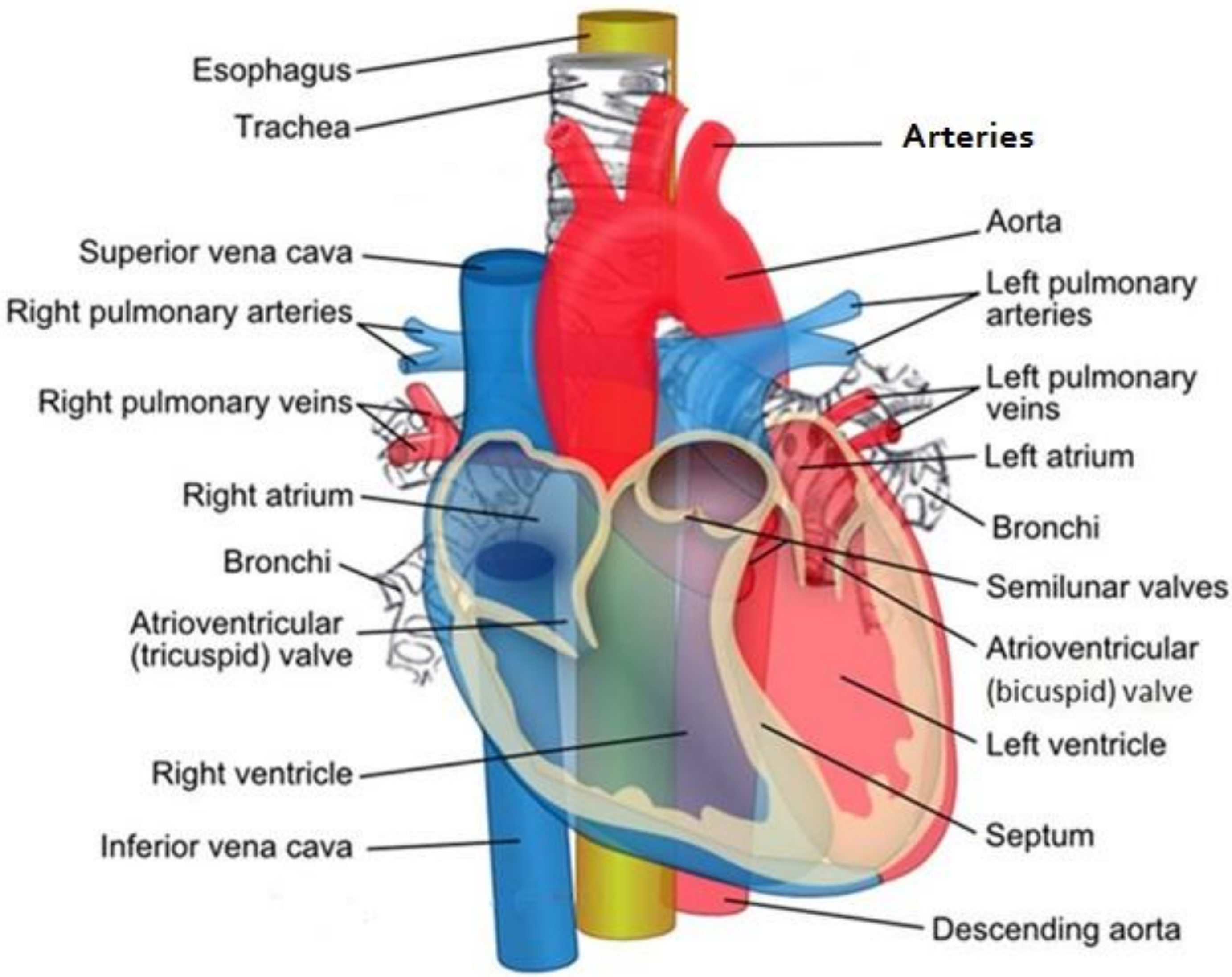
Chapter 17

Cardiovascular System – Part I

In the next two chapters we will be dealing with the main transport system of the blood within our body:

The Cardiovascular System

The **heart** is, by far, the main character in this week's reading as it provides the driving force for the circulation of blood. Although the size of this organ varies with its owner, it is approximately the size of one's fist and is located within the protective ribcage of our chest.



The heart is divided into four separate chambers. The two upper chambers are known as **atria** and the two lower chambers are called **ventricles**.

Atria

The left atrium and right atrium are the upper chambers of the heart where blood is delivered into the heart through large blood vessels called **veins**.

Ventricles

The left and right ventricles are responsible for pumping blood out of the heart with the assistance of another type of blood vessel called **arteries**. These two chambers force blood to different areas of the body. Of the two ventricles, the left chamber is reinforced with thicker walls which make it larger in size than its partner. This extra girth is vital for the left ventricle as it has the added challenge of forcing blood throughout the <u>entire</u> body, unlike the right ventricle which only pumps blood towards the lungs.

Let's take a look at how blood is directed through the chambers of the heart.

When it is functioning correctly, blood flows in one direction through the four chambers of the heart and the body as well. Any backflow of blood is prevented by the presence of two different structures:

Atrioventricular valves and the Semilunar valves

In plumbing terms, **valves** are devices which control the passage of fluid through a pipe or a tube. Typically, a valve will allow fluids to travel in one direction; and, when backflow happens, the force of the fluid moving in the opposite direction pushes against the valve itself which closes the pathway. This is how the valves of the heart work as well. The valves we will be exploring are located between the four chambers of the heart and on the areas where blood is pumped out of the heart from the ventricles.

The **atrioventricular valves (AV)** are located between the right atrium and right ventricle (**tricuspid valve**) and left atrium and left ventricle (**bicuspid valve**).

The **semilunar valves (SV)** close after blood has exited the right ventricle (**pulmonary semilunar valve**) and left ventricle (**aortic semilunar valve**).

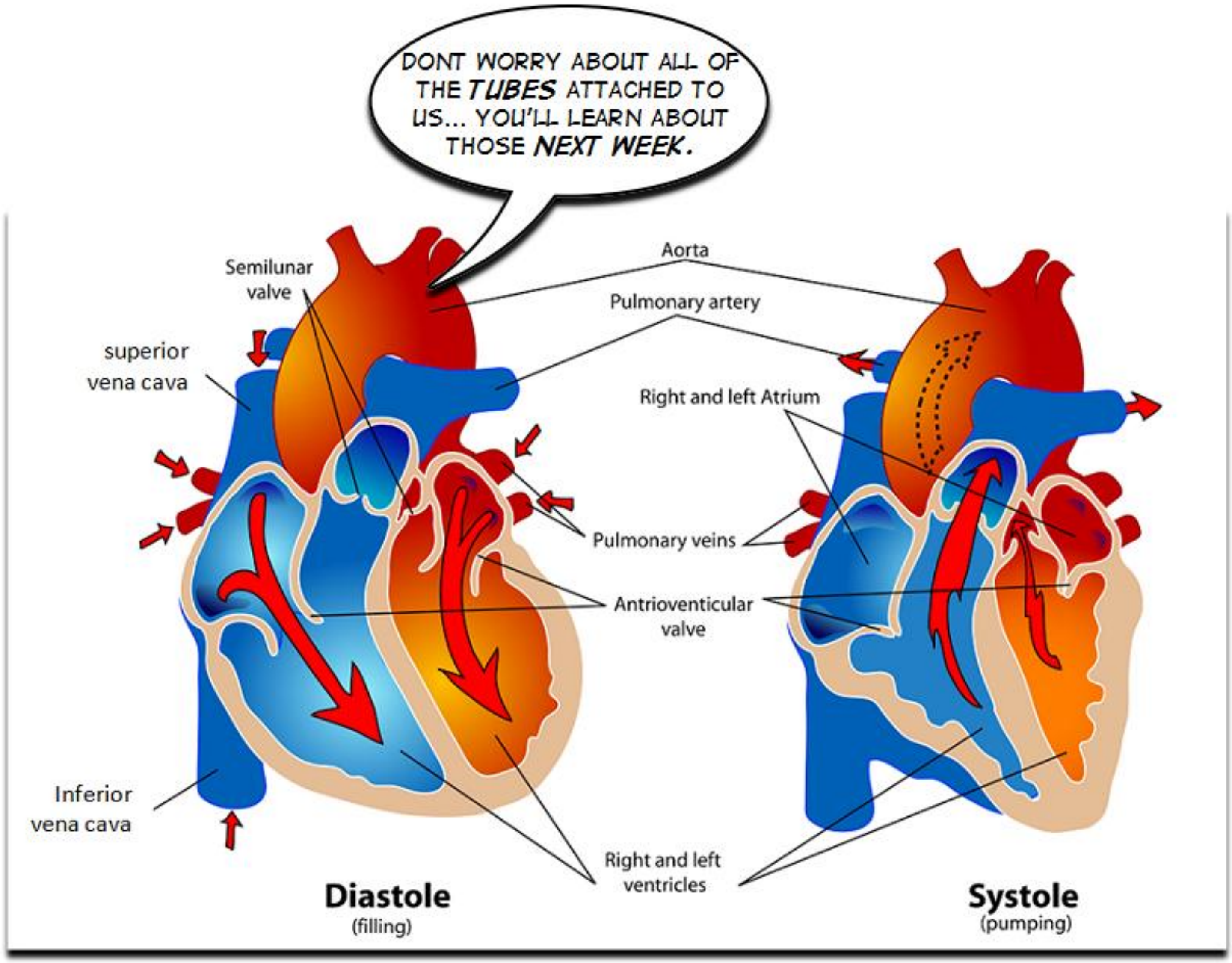
A very important "dance" occurs between these two different types of valves:

When the ventricles are relaxed and not pumping blood away from the heart, the atrioventricular valves are open and the semilunar valves are closed. To put it simply, a door opens and forces blood into the ventricles without any possibility of escape throughout the body as the exit door is closed.

When the ventricles contract and begin forcing blood throughout the body, the atrioventricular valves close and the semilunar valves open. In this sequence, the door which allowed blood to rush into the ventricles is closed as its exit doors are opened. Once the semilunar valves open, blood is forced out of the heart through the arteries.

You can hear these valves opening and closing all day long!

The opening and closing of your heart valves make a characteristic "lub-dub" sound. The first sound, the "lub" is the sound of your atrioventricular valves closing. This marks the beginning of **systole**, or the phase of the cardiac cycle where blood is forced out of the heart and into the arteries. The second "dub" sound is caused by the closing of the semilunar valves and begins a period of **diastole**. This period of time within the cardiac cycle is when the heart refills with blood after systole.



Back in Chapter 6, you briefly looked at the structure and function of cardiac muscle and how it is different from skeletal and smooth muscle tissues. You also learned that cardiac tissue can only be found within the structure of the heart. Its cells are striated in appearance due to the presence of sarcomeres and, unlike the long cylindrical skeletal muscle cells, cardiac muscle is branched much like that of a tree. Most importantly, these cells do not require a connection with the nervous system to create a nerve impulse. Cardiac muscle involuntarily contracts due to its ability to be self-stimulated through the presence of **pacemaker cells** within the heart tissue.

The pacemaker cells are located within the right atrium and generate a rhythmical flow of nerve impulses throughout all of the cardiac muscle tissue.

Although these nerve impulses resemble those found within skeletal and smooth muscle tissue, the contraction of cardiac muscle lasts nearly 10 times longer. The periodic resting periods between each "beat" of the heart allow these tissues to relax and they rarely become exhausted.

Your doctor can monitor the nerve impulses of your heart through specialized equipment as well.

An **electrocardiogram** is a device used by medical professionals to detect the electrical impulses generated by your cardiac muscle. This device is sensitive enough to detect any abnormal electrical impulse that may be generated by the contraction of your heart. These irregular patterns in nerve impulses are known as **arrhythmias** and can be potentially dangerous.

The following list will give you an overview of the pathway of the blood we have explored so far:

1. Right atrium
2. Tricuspid valve
3. Right ventricle
4. Pulmonary semilunar valve
5. *(Blood travels to the lungs)*
6. Left atrium
7. Bicuspid valve
8. Left ventricle
9. Aortic semilunar valve
10. *(Blood travels to the tissues/organs in the body)*
11. Right atrium (…and the process begins again!)

We'll fill in the gaps for #5 and #10 in the next chapter. For now, let's look at a few amazing facts about the heart…

If I asked you to place your hand over your heart, you would likely put your hand on the left side of your chest, correct? This is not entirely true as your heart is actually located in the center of the chest.

Within the course of one day, your heart beats about 100,000 times. This adds up to roughly 2.5 billion times in an average lifetime.

Approximately 2,000 gallons (7,571 liters) of blood is forced through your body daily.

Your body contains approximately 5.6 liters (6 quarts) of blood. This volume of blood circulates through the body every 20-60 seconds.

The heart pumps around 55,000,000 gallons (~207,000,000 liters) in an average lifetime. This would fill approximately 900,000 average-sized bathtubs.

In the next chapter, you will be exploring the pathway of the blood throughout the entire body. Stay tuned!

Match the following vocabulary terms with their correct definition:

aortic semilunar valve	**pacemaker cells**
arrhythmias	**pulmonary semilunar valve**
arteries	**semilunar valves**
atria	**systole**
atrioventricular valves	**tricuspid valve**
diastole	**valves**
electrocardiogram	**veins**
heart	**ventricles**

1)	______________	a device used to detect the electrical impulses generated by cardiac muscle
2)	______________	atrioventricular valve located between the right atrium and right ventricle
3)	______________	device which control the passage of fluid in one direction
4)	______________	irregular patterns in nerve impulses caused by pacemaker cells
5)	______________	large blood vessels responsible for carrying blood away from the heart and towards the various tissues of the body
6)	______________	large blood vessels which deliver blood into the left atrium and right atrium of the heart
7)	______________	located within the right atrium; generate a rhythmical flow of nerve impulses throughout all of the cardiac muscle tissue causing muscular contraction
8)	______________	main organ of the cardiovascular system; responsible

		for pumping all bodily fluids throughout each system
9)	_____________	one of two valves which close after blood has exited the right ventricle (pulmonary semilunar valve) and left ventricle (aortic semilunar valve)
10)	_____________	semilunar valve which closes after blood has exited the left ventricle
11)	_____________	semilunar valve which closes after blood has exited the right ventricle
12)	_____________	two lower chambers within the heart
13)	_____________	two upper chambers within the heart
14)	_____________	two valves located between the right atrium and right ventricle (tricuspid valve) and left atrium and left ventricle (bicuspid valve)
15)	_____________	phase of the cardiac cycle where the heart refills with blood after systole
16)	_____________	phase of the cardiac cycle where blood is forced out of the heart and into the arteries

Choose the correct answer from the following questions:

1) **The right atrioventricular valve is known as the:**
   A) pulmonary semilunar valve
   B) aortic semilunar valve
   C) tricuspid valve
   D) bicuspid valve
   E) mitral valve

2) **When the ventricles contract, the bicuspid valve prevents blood from flowing from the:**
   A) left ventricle to the left atrium
   B) right ventricle to the right atrium
   C) right atrium to the left atrium
   D) left atrium to the right atrium
   E) left ventricle to the right ventricle

3) **The tricuspid valve is located between the:**
   A) right ventricle and the pulmonary trunk
   B) left ventricle and pulmonary artery
   C) right atrium and right ventricle
   D) right atrium and left atrium
   E) left ventricle and aorta

4) **Which one of the following is true concerning the lub-dub sounds of the heart:**
   A) the first sound is caused by the closing of the atrioventricular valves; the second sound is caused by closure of the semilunar valves
   B) the first sound is caused by closure of the tricuspid valve; the second sound is caused by closure of the mitral valve
   C) the first sound is caused by closure of the tricuspid valve; the second sound is caused by closure of the mitral valve
   D) the first sound is caused by closure of the semilunar valves; the second sound is caused by closure of the atrioventricular valves

5) **The bicuspid valve is normally closed:**
   A) when the ventricle is in diastole
   B) when the atrium is contracting
   C) when the ventricle is contracting
   D) when the ventricle is in systole
   E) by the movement of blood from the atrium to the ventricle

6) **True or False:** Systole occurs during the contraction of the ventricles.

7) **True or False:** During diastole, the bicuspid and tricuspid valves are closed.

Application Question:

Don has a heart murmur (an unusual sound during a heartbeat) in his left ventricle that produces a loud "gurgling" sound at the beginning of systole. Which valve is probably faulty? Describe what you believe is causing this sound.

Chapter 18

Cardiovascular System – Part II

This chapter is devoted to the pathway of blood as it travels to and from the heart. As you learned in the last chapter, the two upper chambers (atria) of the heart are fed by large blood vessels known as veins. After blood flows from the upper chambers to the lower chambers (ventricles), it is pumped throughout the body within other types of blood vessels known as arteries. This entire pathway is a closed system, with blood filling up every blood vessel and chamber of the heart. Bubbles are not something you want circulating within your blood! They take up space that is typically reserved for your blood and can restrict the flow of red blood cells (and oxygen) to vital areas of your body.

The following device can be used to remember the pathway of blood through the heart and body:

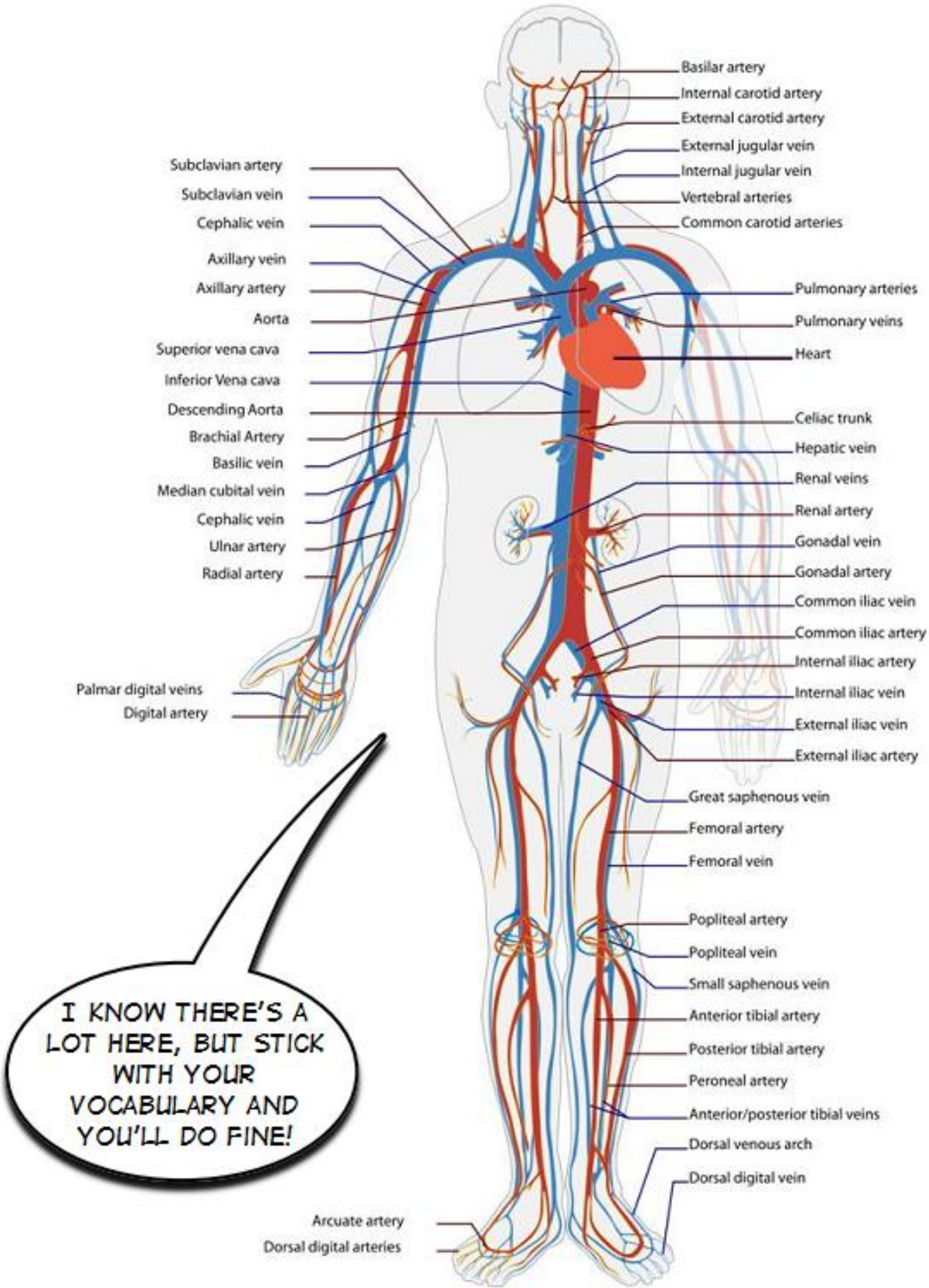
RA → RV → Artery → Vein → LA → LV → Artery → Vein → RA

In this pathway, the term "RA" refers to the right atrium and "RV" is the right ventricle. You can use the same abbreviations for "LA" and "LV". Take a closer look at this pathway and you will find another pattern that may help you out a great deal...

The pathway of blood always follows a pattern with alternating "A's" and "V's"

Atria → **V**entricle → **A**rtery → **V**ein → **A**tria → **V**entricle → and so on...

If you can trace the path of the "A's" and "V's", most of your job is done. The image on the next page will give you a thorough list of the arteries and veins within the human body.


Basilar artery
Internal carotid artery
External carotid artery
External jugular vein
Internal jugular vein
Vertebral arteries
Common carotid arteries
Subclavian artery
Subclavian vein
Cephalic vein
Axillary vein
Axillary artery
Aorta
Superior vena cava
Inferior Vena cava
Descending Aorta
Brachial Artery
Basilic vein
Median cubital vein
Cephalic vein
Ulnar artery
Radial artery
Pulmonary arteries
Pulmonary veins
Heart
Celiac trunk
Hepatic vein
Renal veins
Renal artery
Gonadal vein
Gonadal artery
Common iliac vein
Common iliac artery
Internal iliac artery
Internal iliac vein
External iliac vein
External iliac artery
Palmar digital veins
Digital artery
Great saphenous vein
Femoral artery
Femoral vein
Popliteal artery
Popliteal vein
Small saphenous vein
Anterior tibial artery
Posterior tibial artery
Peroneal artery
Anterior/posterior tibial veins
Dorsal venous arch
Dorsal digital vein
Arcuate artery
Dorsal digital arteries
I KNOW THERE'S A LOT HERE, BUT STICK WITH YOUR VOCABULARY AND YOU'LL DO FINE!

Arteries and veins have a similar anatomical structure with one very important difference. Both have three tissue layers which make up an inner lining of cells (**endothelial cells** or **endothelium**), a middle layer made of smooth muscle, and an outer layer made of connective tissue. However, since the arteries are responsible for pumping blood out the heart, its walls are much thicker because of the increased pressure it must maintain. In fact, blood leaves the left ventricle through the aortic semilunar valve and into a single large artery known as the **aorta**. The aorta is the largest artery in the human body and extends into the abdominal area with branches that carry blood to <u>nearly</u> all of the body's tissues.

Let's follow a drop of blood from the aorta to the rest of the body!

The blood within the aorta is full of oxygen gas which is used by the tissues of our body for all vital functions. The aorta carries blood away from the heart under high pressure and branches off towards all of the tissues/organs of the body <u>with the exception of the lungs</u>. These branches become smaller in diameter where they are known as **arterioles**. The walls of the arterioles continually become much thinner than the wall of the aorta. This fact is very important as the arterioles are attached to a web of very small blood vessels known as:

Capillaries

In the simplest definition, **capillaries** are the tiniest blood vessels in the human body with diameters as small as a single red blood cell. These vessels surround the organs and tissues of the body in tiny linkages of web-like "nets."

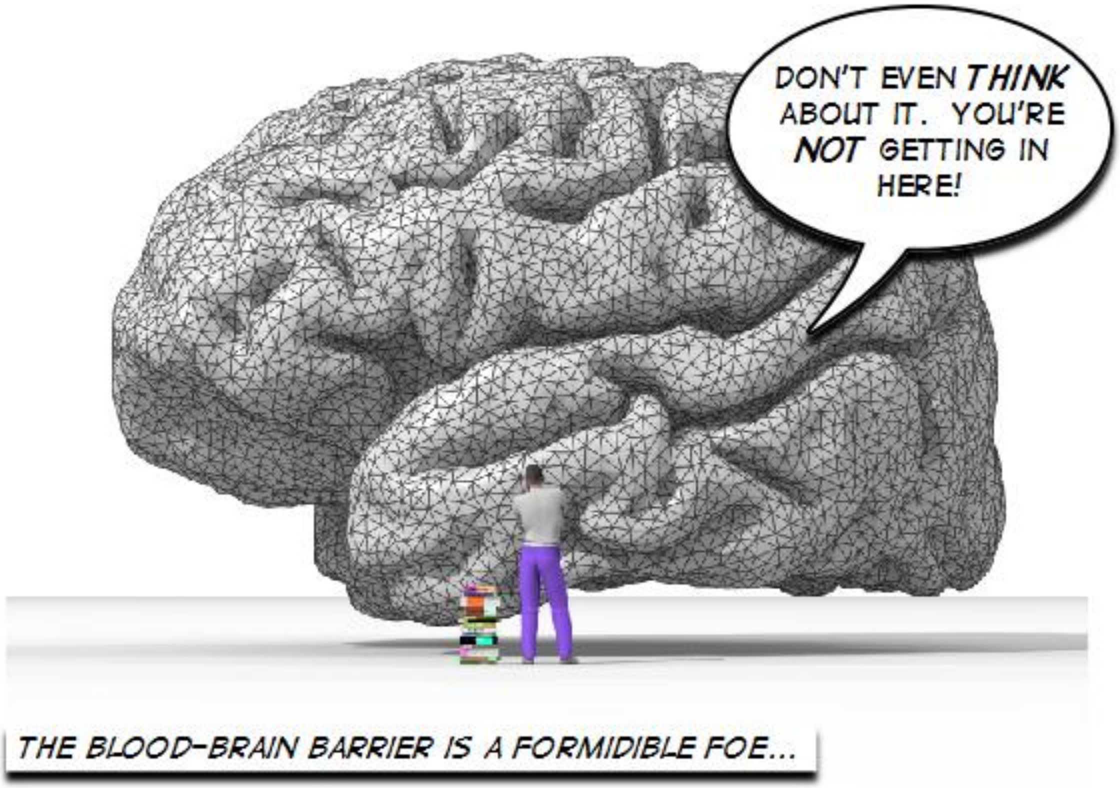
Because of their tiny size, you should be able to assume that the walls of capillaries are equally tiny as well. And you would be correct!

In fact, the walls of capillaries are so thin they allow gases to diffuse between the blood and the fluids which surround body tissues. You learned about this back in Chapter 2 when you first explored the concept of diffusion:

Diffusion is simply the movement of any substance from an area of high concentration to an area of low concentration.

The high concentration of oxygen within the blood from the aorta diffuses out of the network of capillaries and into the body tissues which they surround. As this is occurring, the body tissues have already used up their oxygen supply and have a surplus of the waste product - carbon dioxide gas (CO_2). The high concentration of CO_2 is then diffused out of the body tissues and into the capillaries. In addition to oxygen and carbon dioxide, the capillaries are responsible for transporting nutrients, hormones, and dozens of other molecules between the body tissues/organs and the cardiovascular system.

*This network of capillaries works differently within the brain and CNS. The layers of endothelial cells within the capillaries surrounding these areas fit very tightly together. Because of the closeness of these cells, only the smallest of materials can diffuse through the vessel walls (i.e. oxygen, carbon dioxide, etc.). Large molecules such as fats and other foreign particles cannot pass through the vessel walls. This is known as the **blood-brain barrier** and provides a very efficient level of protection for the organs of the central nervous system.*



After the exchange of oxygen for waste products from the body tissues, the capillaries leave the organs and begin to increase in diameter. As they grow into larger blood vessels, they are referred to as **venules**. Both the diameter and the wall thickness of the venules increase in size as they move away from the capillaries and towards the even larger veins.

You can easily find the veins in your body. Look for the "blue" blood vessels under your skin!

Many people believe that the blood in our veins is actually blue in color. This is absolutely false! Blood within the veins do not contain a high concentration of oxygen and, therefore, does not appear to be bright red in color, but a much darker red hue. Blood within arteries, however, do contain a high level of oxygen and therefore display a red color. The "blue" color of venous blood is actually caused by the way in which light is absorbed by the skin and the darker colored venous blood. Remember - none of your blood vessels are blue in color!

As the larger venules branch outwards from the capillaries and towards the larger veins, you might be wondering about one thing:

Where does the force needed to move the blood come from after passing through the capillaries?

This is a very good question, and to answer this we have to look at another system we discussed earlier - the muscular system. Whenever our body makes some form of movement, our muscles contract and relax back to their normal position. When a muscle contracts, it pushes against the veins which then helps to drive the blood towards the heart. Since the walls of the veins are thinner, they are able to be "squeezed" rather easily by its surrounding skeletal muscles. There's no need to be concerned about our muscles pushing the blood in the opposite direction - several tiny valves are present within the veins to prevent this from happening! In fact, muscular contraction is the primary method for pushing venous blood back towards the heart.

Now back to the pathway of blood...

It is important to note here that the path of the blood at this stage can be split in two separate sections of the human body – the upper and lower halves. Why is this important? Because both halves of the human body utilize its own large vein to deliver blood into the right atrium of the heart:

Inferior Vena Cava and the Superior Vena Cava

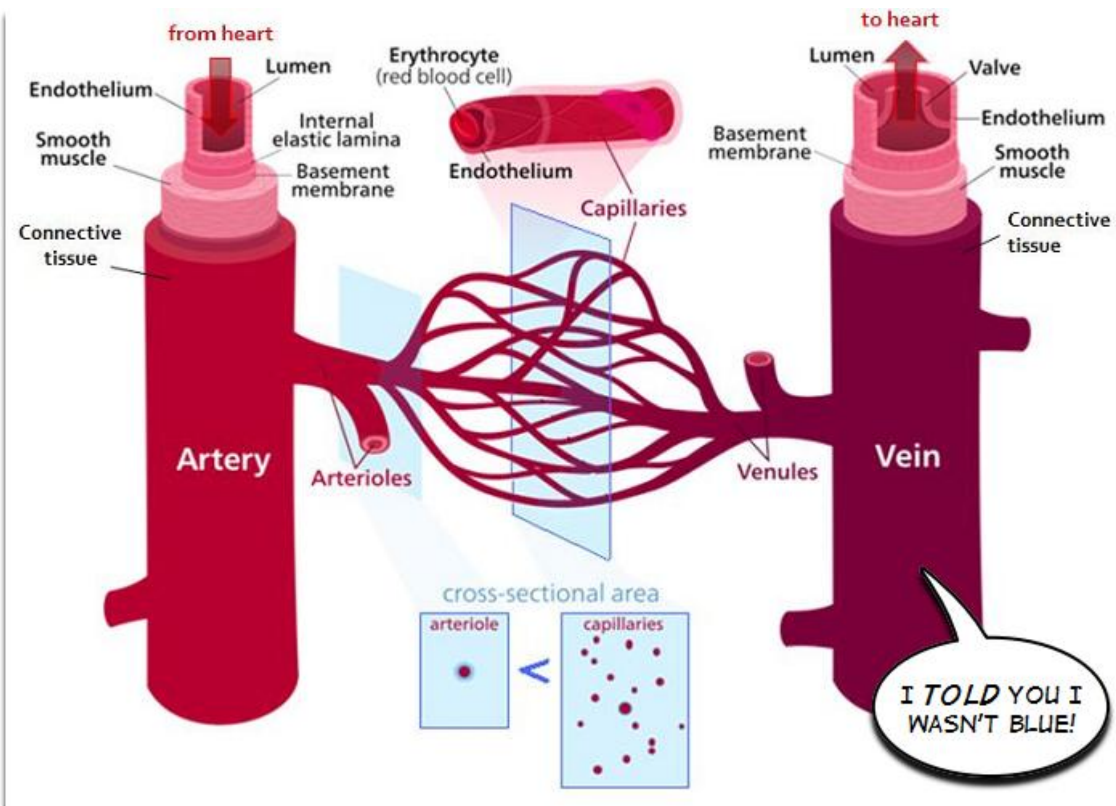
The **inferior vena cava** is a large vein that carries blood from the lower half of the body into the heart. Its colleague is the **superior vena cava** which delivers blood to the heart from the upper half of the body. Both of these large veins deliver its oxygen-poor blood into the right atrium of the heart. Its flow is controlled by the opening and closing of the tricuspid valve before it reaches the right ventricle of the heart.

Once blood reaches the right ventricle, it passes through the pulmonary semilunar valve before reaching the large **pulmonary artery**. Here it runs through the same pathway as the oxygen-rich blood you just learned. From the pulmonary artery, blood travels through smaller arterioles until they reach the web-like capillary network which surrounds the lungs.

The pulmonary artery only transports blood to the lungs and NOT the rest of the body!

As blood reaches the lungs, the high concentration of CO_2 diffuses out of the blood and into the lungs while the lungs' high concentration of oxygen diffuses into the blood. This transfer of CO_2 is aided by the increased blood pressure within the arteries (as compared to the veins). We will be focusing on this process in greater detail during our discussion on the respiratory system. For now, the pathway of our blood is of much more importance.

The now oxygen-rich blood travels out of the capillaries and moves through the larger venules before branching into four separate **pulmonary veins** (two from each lung). These veins carry blood back into the left atrium of the heart, through the biscupid valve, and into the left ventricle where we originally began this story!



Need a shortcut for this pathway? How about this:

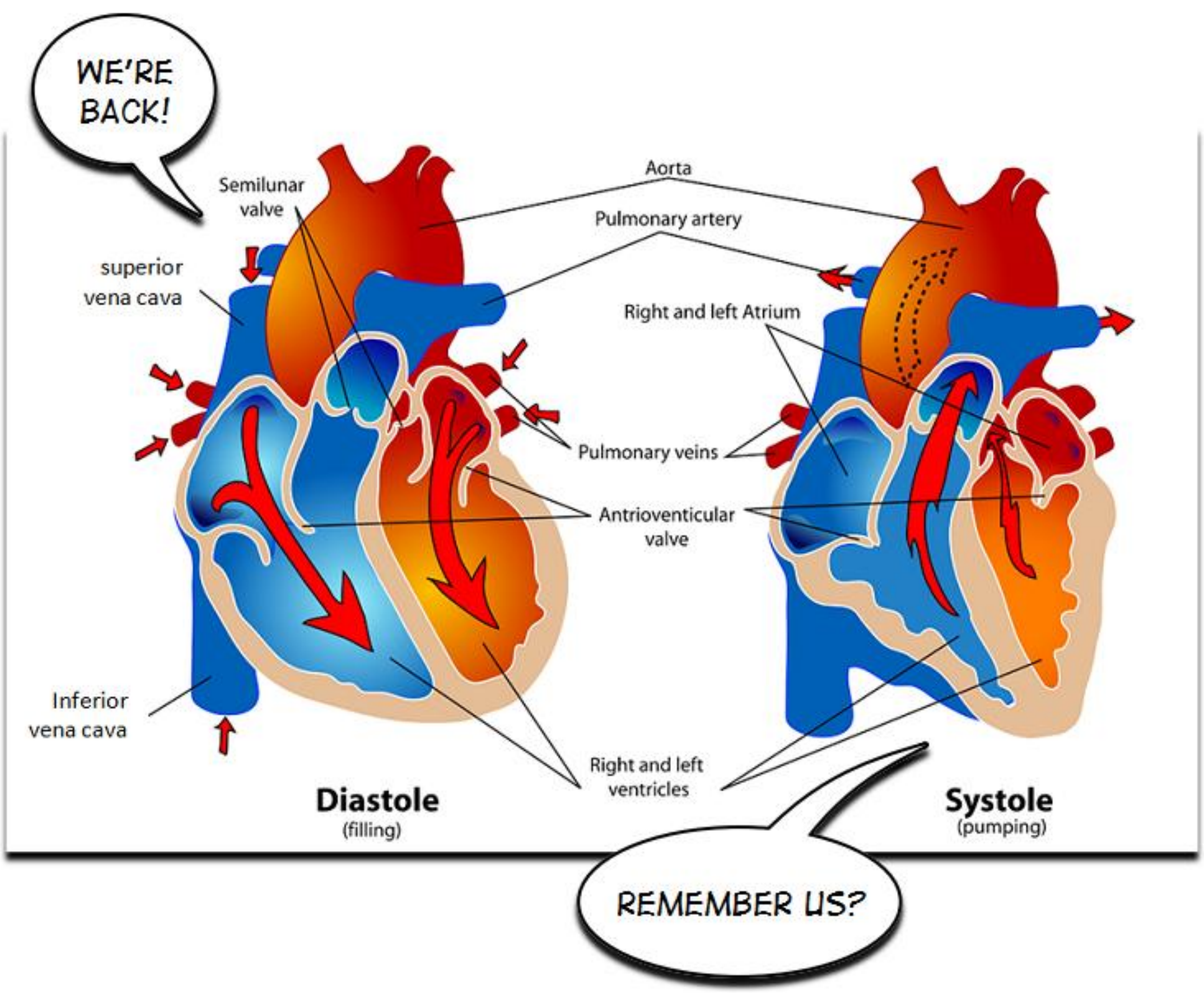
1. Left atrium
2. Bicuspid valve
3. Left ventricle
4. Aortic semilunar valve
5. Aorta
6. Arterioles
7. Capillaries throughout the body tissues/organs
8. Venules
9. Veins (Superior vena cava and Inferior vena cava)
10. Right atrium
11. Tricuspid valve
12. Right ventricle
13. Pulmonary semilunar valve
14. Pulmonary artery
15. Arterioles
16. Capillaries surrounding the lungs
17. Venules
18. Pulmonary veins (four of them)
19. Back to the left atrium (and the process begins again!)

We have a couple more concepts to briefly go through before our study of the cardiovascular system is over.

If you spend any time within the doctor's office, the attending nurse has likely taken two different readings about your body:

Blood pressure and Pulse

Blood pressure is a measured force of the blood pushing against the inner walls of the arteries near the heart. During each heartbeat, the blood pressure reaches a maximum amount (**systolic pressure**) and a minimum amount (**diastolic pressure**). In order to accurately measure one's blood pressure, both measurements must be recorded. The systolic pressure measures the pressure in the arteries when the heart muscles contract and blood is forced from the heart. The diastolic pressure measures the pressure that exists between heartbeats, when the heart is resting and filling with blood. If your blood pressure becomes too high (as during vasoconstriction), the heart rate will slow down as a reduced amount of blood flowing through the vessels will (hopefully) lower the pressure as well. The opposite is true when your blood pressure becomes too low as when the inner diameter of blood vessels become dilated as during vasodilation. This noticeable change undoubtedly affects our next topic of discussion…



Pulse is the rhythmical throbbing of arteries that can be felt through the skin as blood is forced through these vessels. This sensation is much like the feeling of water rushing through a hose after it has been partially blocked. The hose pulsates as the increased pressure within the hose is finally released and water rushes forward.

Let's wrap up this chapter with a look at a few more amazing heart facts!

If you could place all the capillaries end-to-end from one human body, its length would be approximately 25,000 miles (46,325 kilometers). This would easily reach across the equator of the Earth.

The length of **all** the blood vessels in the cardiovascular system is approximately 60,000 miles (96,500 kilometers).

The pressure produced by the human heart when it is beating is capable of pumping blood nearly thirty feet. (But let's keep our blood inside our bodies, okay?)

Anatomy & Physiology - Connections

How the following body systems affect the cardiovascular system		How the cardiovascular system affects the following body systems	
Integumentary	Vasodilation and vasoconstriction control the flow of blood through the skin	Delivery of immune cells to sites of injury; removal of waste products; provides warmth to tissues	**Integumentary**
Skeletal	Provides calcium needed for muscle contraction and bone marrow as site for red blood cell synthesis	Transportation of calcium, phosphorus, PTH, and CT for ossification	**Skeletal**
Muscular	Skeletal muscle contractions help to move blood through veins	Delivery of oxygen and nutrients to body tissues and removal of wastes	**Muscular**
Nervous	Regulation of heart rate and blood pressure	Endothelial cells protect the CNS via the blood-brain barrier	**Nervous**
Endocrine	Erythropoietin increases RBC production; epinephrine increases heart rate	Transports hormones throughout the body	**Endocrine**

Match the following vocabulary terms with their correct definition:

aorta	**diastolic pressure**	**pulse**
arterioles	**endothelial cells**	**superior vena cava**
blood pressure	**inferior vena cava**	**systolic pressure**
blood-brain barrier	**pulmonary artery**	**venules**
capillaries	**pulmonary veins**	

1)	______________	a large vein that carries blood from the lower half of the body into the right atrium of the heart
2)	______________	a measured force of the blood pushing against the inner walls of the arteries near the heart
3)	______________	branches of arteries whose diameters are smaller than that of the aorta
4)	______________	delivers blood to the heart from the upper half of the body
5)	______________	four veins which carry blood back into the left atrium of the heart, through the bicuspid valve, and into the left ventricle
6)	______________	innermost lining of cells within both arteries and veins; surrounded by layers of smooth muscle and connective tissue
7)	______________	large artery which carries all of the blood out of the left ventricle
8)	______________	large artery which carries blood from the right ventricle after it passes through the pulmonary semilunar valve
9)	______________	layer of endothelial cells within the capillaries surrounding the brain and CNS which fit very tightly together, allowing only the smallest of materials to diffuse through the vessel walls (i.e. oxygen, carbon dioxide, etc.)

10)	______________	the maximum blood pressure achieved during each heartbeat
11)	______________	the minimum blood pressure achieved during each heartbeat
12)	______________	the rhythmical throbbing of arteries that can be felt through the skin
13)	______________	the tiniest blood vessels in the human body
14)	______________	vessels attached to both the capillaries and veins; the diameter and the wall thickness of these vessels increase in size from the capillaries and towards the veins

Choose the correct answer from the following questions:

1) **The path of blood through all of the vessels is:**
   A) arterioles, arteries, capillaries, veins, venules
   B) arterioles, arteries, capillaries, venules, veins
   C) arteries, arterioles, capillaries, veins, venules
   D) arterioles, arteries, venules, veins, capillaries
   E) arteries, arterioles, capillaries, venules, veins

2) **In which one of the following blood vessels is blood pressure the highest:**
   A) arterioles
   B) arteries
   C) vena cava
   D) capillaries
   E) veins

3) **Substances tend to leave the bloodstream from the arteries to the capillaries because:**
   A) blood pressure is higher at the arterial end of the capillary
   B) the osmotic pressure of the blood is higher as it leaves the capillary and moves towards the veins
   C) blood pressure is higher from the capillaries to the veins
   D) the osmotic pressure of the blood is higher as it leaves the capillary and moves towards the arteries

4) **Veins:**
   A) carry blood away from the heart
   B) do not transport oxygen-rich blood
   C) branch into smaller vessels called arterioles
   D) operate under high pressure
   E) have valves to prevent the backflow of blood

5) Pulmonary veins:

A) split off the pulmonary trunk
B) transport oxygenated blood to the heart
C) return blood to the right atrium of the heart
D) transport oxygenated blood to the lungs
E) transport blood rich in carbon dioxide to the lungs

6) Which of the following reduces heart rate:

A) increased body temperature
B) exercise
C) high blood pressure
D) epinephrine

Application Question:

The following observations were made on a patient who had suffered a bullet wound: Heart rate was elevated and rising. Blood pressure was very low and dropping. After bleeding was stopped and a *blood transfusion* (the introduction of new blood from a donor) was given, blood pressure increased. Which of the following statements is consistent with these observations concerning blood pressure? Defend your answer.

a) Negative-feedback mechanisms are occasionally inadequate without medical intervention.
b) The transfusion interrupted a negative-feedback mechanism.
c) The transfusion was not necessary.

Chapter 19

Immune System – Part I (Lymphatic System)

Our body contains several ways to protect us from internal and external threats to our health. Historically, these methods have been categorized into a single organ system known as:

The Immune System

Over the years, however, our knowledge of the body has increased and the "**immune system**" cannot stand by itself as a single system. The immune system actually consists of several **immune responses** carried out by systems within the body as we have already discussed. For example, the integumentary system is part of the immune system as it provides a line of defense for our bodies against infections within the skin. Immune responses exist within the respiratory system as well. Every breath we take places unwanted pathogens on the surfaces of our cells and our organ systems have developed many different ways to protect us from infection. To put it simply, the physiology of our immune system is to provide some form of immune response towards all potentially damaging invaders to our body. Its anatomy, however, is spread out throughout the body.

This chapter will deal with the anatomy and physiology of a particular subsection of the immune system known as the...

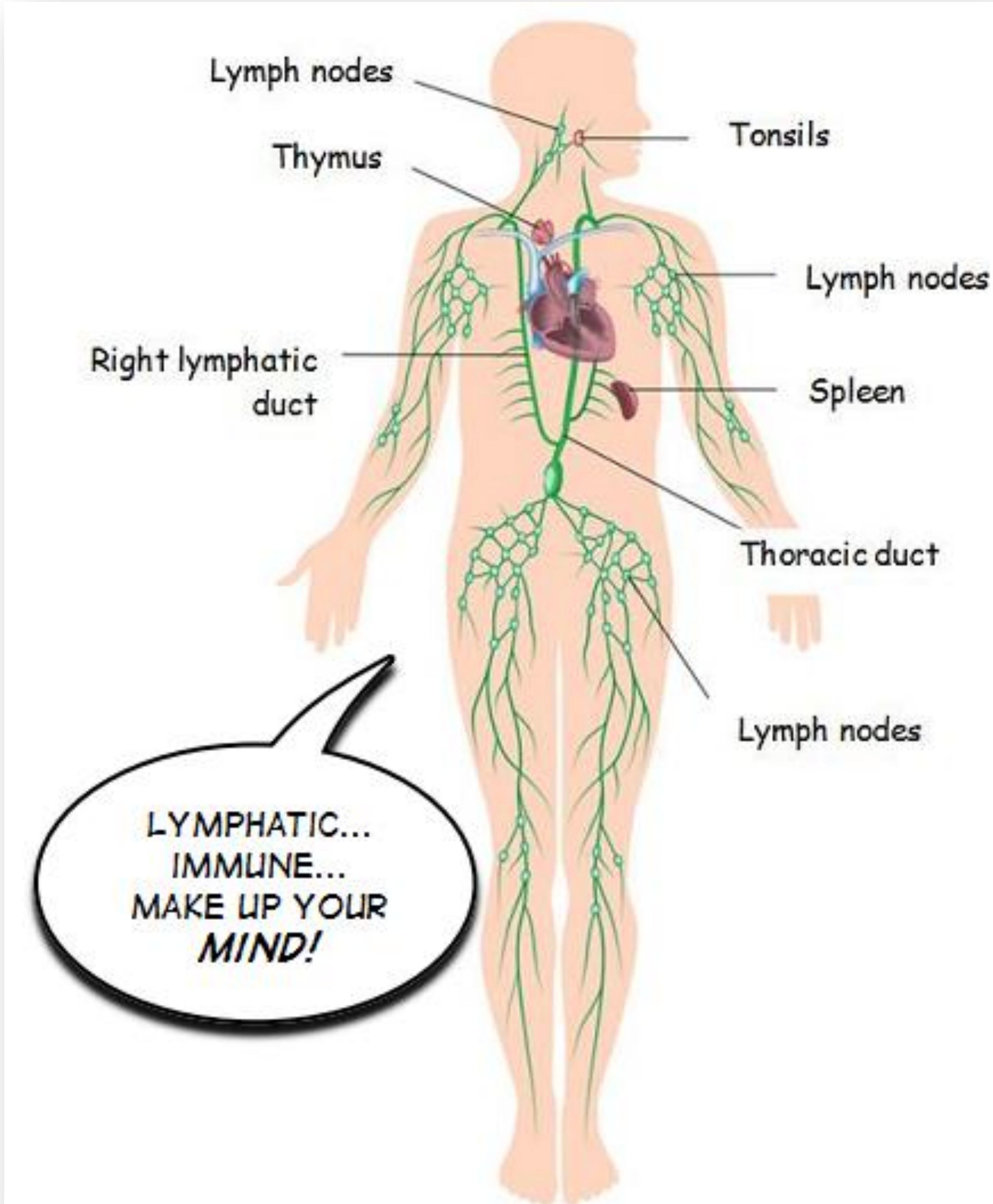
Lymphatic System

...and the next chapter will deal more specifically with the actions at the battle sites of infections, otherwise known as the immune response.

The lymphatic system has two main functions within the human body:

Immunity and Regulation of Blood Volume

We will explore how the lymphatic system maintains a constant volume of blood shortly. First, let's look at the topic of **immunity** - the ability of the body to resist infection and disease. Our immunity can be broken down into two independent types which are known as **innate (nonspecific) immunity** and **adaptive (specific) immunity**.



All bodily actions which prevent the spread of infection or disease, regardless of the damaging agent, are carried out by our *innate immunity*. This type of immunity does not identify the specific threat that is invading the body. Our *adaptive immunity*, on the other hand, involves defenders who identify each invading pathogen (such as bacteria or viruses), unhealthy body cells (such as cancer cells), and other foreign particles before they begin their attack.

Several different structures play an important role within the lymphatic system as it maintains our immunity and regulates the volume of blood:

Lymph, Lymphatic vessels, Lymphocytes, and Lymphatic tissues/organs

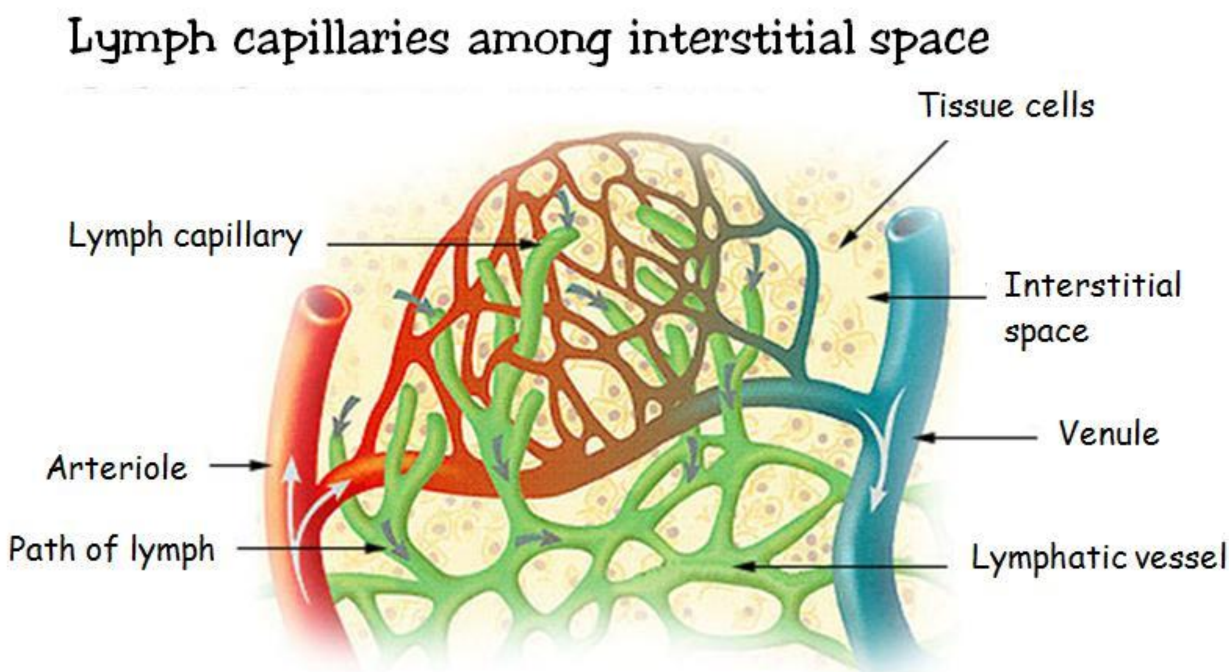
Lymph

Up to three quarts (three liters) of **lymph** exists within our bodies and is primarily made up of recycled plasma from the blood. This fluid passes through the lymphatic system and carries with it white blood cells, water, and other dissolved substances. Movement of this fluid is partially caused by the contractions of surrounding muscles which push the lymph along its pathways much like the venous blood of the cardiovascular system. Red blood cells and most proteins are typically not found in the lymph as their large size prevents them from moving into the "pathways" of the lymphatic system, also known as...

Lymphatic vessels

Lymphatic vessels act very much like the blood vessels of the cardiovascular system. Although somewhat different in appearance, a network of these thin-walled vessels surrounds the same general areas as the capillaries throughout all of the vascular tissues of the body. As gases, nutrients, and wastes are being exchanged by the capillaries and the various tissues, it is normal for excess fluid to "pool" in the spaces between tissues and capillaries. This **interstitial fluid** is collected and drained back into the blood by the lymphatic vessels which act much like rain gutters on homes. Once this fluid enters the lymphatic vessels, it is collectively known as lymph.

These last statements are very important! The lymphatic system regulates the volume of blood by returning excess fluids back into the blood stream and towards the heart.



Excess fluids (approximately three liters per day) are picked up by the lymphatic "capillaries" and are carried through a series of larger vessels which end in two large tubes known as the **right lymphatic duct** and the **thoracic duct**. Both of these ducts drain their fluids into the **right and left subclavian veins**, respectively, which flow quickly into the heart.

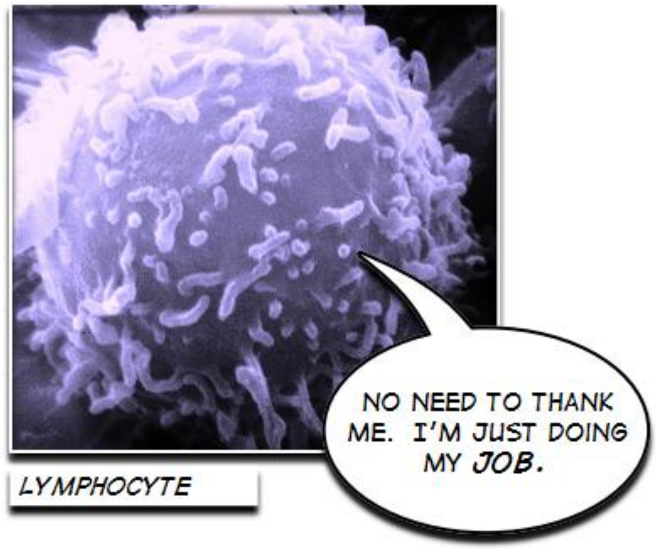
The right lymphatic duct is the smaller of the two vessels and contains lymph from the right side of the head, right upper limb, shoulder and lung, and the right side of the heart.

The thoracic duct receives lymph from 75% of the body including the left side of the head, neck, chest, the left upper limb, and the entire body below the ribs.

Both the lymph and the lymphatic vessels are responsible for the regulation of blood volume within the body. However, it is the lymphocytes and lymphatic tissues/organs within the lymphatic system that provide us with our immunity!

Lymphocytes

The primary cells involved with our immunity are known as **lymphocytes**. Lymphocytes are a specific type of white blood cells (leukocytes) whose function is to identify and/or eliminate all potentially damaging substances from our body. Much like the red blood cells, lymphocytes are produced primarily within the red bone marrow.



LYMPHOCYTE

A couple of facts about these tiny protectors...

There are close to 10 trillion lymphocytes in your body right now and have a collective weight of over 2.2 pounds (1 kilogram). Their life span is equally impressive as most lymphocytes can remain floating throughout the lymphatic system and blood for up to 20 years!

There are three types of lymphocytes:

T cells, B cells, and NK (natural killer) cells

T cells make up over three quarters of all lymphocytes and mature within the thymus of the endocrine system after being created by the red bone marrow. The T cells are the primary agent of cellular defense within our body and are part of our adaptive immune system.

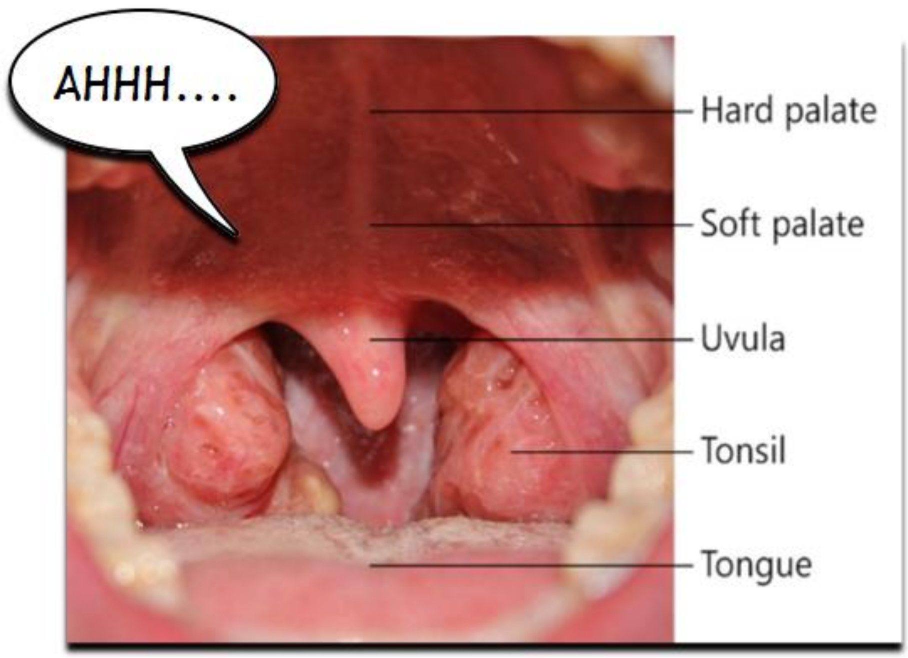
B cells are also created by the red bone marrow and are one of the primary agents within our adaptive immune system. These cells get their name from the location of their origin – the bone marrow. The immune response generated by the T and B cells will be a topic of discussion in the next chapter. Stay tuned...

Unlike the T and B cells, the **NK cells** are part of our innate immune system and provide an early line of defense against abnormal cells within the body. These cells are particularly good at removing cancerous cells from the body!

Lymphatic tissues and organs

Lymph nodules are specialized lymphatic tissues found beneath the epithelial layers of the digestive, respiratory, and urinary system. Areas such as these are typically exposed to high amounts of pathogens; and, as you will learn next week, the lymph nodules are important warehouses for the functioning of B cells during an immune response.

Another specialized tissue within the lymphatic system are the **tonsils.** The tonsils are a collection of lymph nodules found in the back of the throat and are responsible for the storage of large numbers of lymphocytes. These tissues are one of the first defenders against pathogens that enter the nose or throat.



Lymphatic tissues such as the lymph nodules and tonsils tend to be smaller than the lymphatic tissues which we will be discussing now. In addition, they are typically not protected by a layer of connective tissue and are not attached to any vessels of the lymphatic system.

The three most important lymphatic organs includes:

Lymph nodes, the Spleen, and the Thymus

The **lymph nodes** are inch-long (2.5 cm) oval-shaped organs which are found throughout the body and are connected to the lymphatic vessels. Hundreds of these organs trap pathogens found within the lymph and are filled with protective lymphocytes and other white blood cells. As these organs are filled with disease-fighting lymphocytes, these areas act as filters of lymphatic fluid and are very active sites for the destruction of invading pathogens.

You already read about the second major organ of the lymphatic system - the *thymus*. This organ is anterior to the heart and posterior to the sternum within the chest. The function of this organ, as you read previously, is to help with the maturation of the T cells. Simply put, the thymus is an organ which "programs" the T cells to attack specific pathogens. How this programming takes place is well beyond the scope of this book; however, the preparation of T cells by the thymus is vital to the functioning of our adaptive immunity.

The **spleen** is the largest lymphatic organ located in the upper left portion of the abdomen. Measuring approximately 5 inches (12 centimeters) long and 5.6 ounces (160 grams), the spleen removes old red blood cells and recycles its iron for the bone marrow's generation of new blood cells. The spleen is one of the first organs to identify the presence of foreign particles in the blood as it acts as a filter for the blood. Furthermore, an immune response is typically generated within the spleen in response to the detection of these pathogens.

You have begun to explore the anatomy and physiology of the lymphatic system - but you are not done yet! In the next chapter, you will be exploring the specifics of the lymphatic system as it provides us with the life-saving...

Immune response

Match the following vocabulary terms with their correct definition:

adaptive (specific) immunity	lymphatic vessels
B cells	lymphocytes
immune response	NK cells
immune system	right and left subclavian veins
immunity	right lymphatic duct
innate (nonspecific) immunity	spleen
interstitial fluid	T cells
lymph	thoracic duct
lymph nodes	tonsils
lymph nodules	

1)	______________	a specific type of white blood cells (leukocytes) whose function is to eliminate all potentially damaging substances from our body
2)	______________	all actions involved with the identification and removal of foreign invaders by the immune system
3)	______________	all defensive actions our bodies undergo to prevent the spread of infection or disease, regardless of the damaging agent
4)	______________	created by the red bone marrow and are one of the primary agents within our adaptive immune system
5)	______________	directs lymphatic fluid from the right lymphatic duct and the thoracic duct towards the heart
6)	______________	excess fluid which "pools" in areas where capillaries exchange nutrients and wastes
7)	______________	inch-long (2.5 cm) oval-shaped organs connected to the lymphatic vessels and are filled with protective lymphocytes ;act as traps for pathogens

8)	______________	larger of two ducts which carries lymph from the left side of the head, neck, chest, the left upper limb, and the entire body below the ribs
9)	______________	largest lymphoid organ located in the upper left portion of the abdomen; removes old red blood cells and recycles iron for use by the bone marrow
10)	______________	make up over three quarters of all lymphocytes; mature within the thymus of the lymphatic system after being created by the red bone marrow; primary agent of cellular defense within the adaptive immune system
11)	______________	one of two different types of immunity; identifies each invading pathogen (such as bacteria or viruses), unhealthy body cells (such as cancer cells), and other foreign particles
12)	______________	part of the innate immune system; indiscriminately attacks every foreign invader considered to be a threat
13)	______________	recycled plasma from the blood
14)	______________	smaller of two ducts which carries lymph from the right side of the head, right upper limb, shoulder and lung, and the right side of the heart
15)	______________	specialized lymphatic tissues which are found between the epithelial and connective tissue layers of the digestive, respiratory, and urinary system
16)	______________	specialized tissues within the lymphatic system responsible for the storage of large numbers of lymphocytes; found in the oral cavity
17)	______________	the ability of the body to resist infection and disease

18)	____________	the body's defense mechanism; a general term used to describe the collective anatomy/physiology of several systems within the body to remove foreign invaders
19)	____________	thin-walled vessels surrounding vascular tissues which carries "pooled" interstitial fluid back into the cardiovascular system

Choose the correct answer from the following questions:

1) Which lymphatic organ acts to recycle old red blood cells?
- A) tonsils
- B) thymus gland
- C) lymph nodes
- D) spleen

2) Which lymph nodules trap and remove bacteria entering the throat?
- A) lymph nodes
- B) tonsils
- C) right lymphatic duct
- D) thymus gland

3) Excess fluid that pools in the spaces between capillaries and various tissues is known as:
- A) venous blood
- B) arterial blood
- C) plasma
- D) lymph
- E) interstitial fluid

4) Which one of the following is NOT true of lymph nodes:
- A) they are attached to lymphatic vessels
- B) they act as filters along the lymphatic vessels
- C) they remove foreign materials from the lymph fluid
- D) they are involved with the functioning of the B cells during an immune response
- E) they contain lymphocytes

5) **The lymph organ that programs T cells and functions at peak levels only during youth is the:**
   A) lymph nodes
   B) thymus
   C) spleen
   D) lymph nodules
   E) tonsils

6) **Lymph flows:**
   A) toward the heart only
   B) in a circular pattern within the tissues
   C) away from the heart only
   D) both toward and away from the heart

Application Question:

If the thymus of an animal is removed immediately after its birth, the animal tends to be more vulnerable to infections and has decreased numbers of lymphocytes in lymphatic tissue. How can you explain these observations?

Chapter 20

Immune System – Part II (Immune Response)

In the last chapter, you explored the lymphatic system and how it provides immunity to our body. If you recall, there are two different types of immunity: innate (nonspecific) immunity and adaptive (specific) immunity.

Our innate immunity has been with us since birth and is made up of defense mechanisms which do not identify one type of threat from another. Adaptive defenses utilize multiple immune cells which target and attack specific pathogens.

One question you may be asking is...

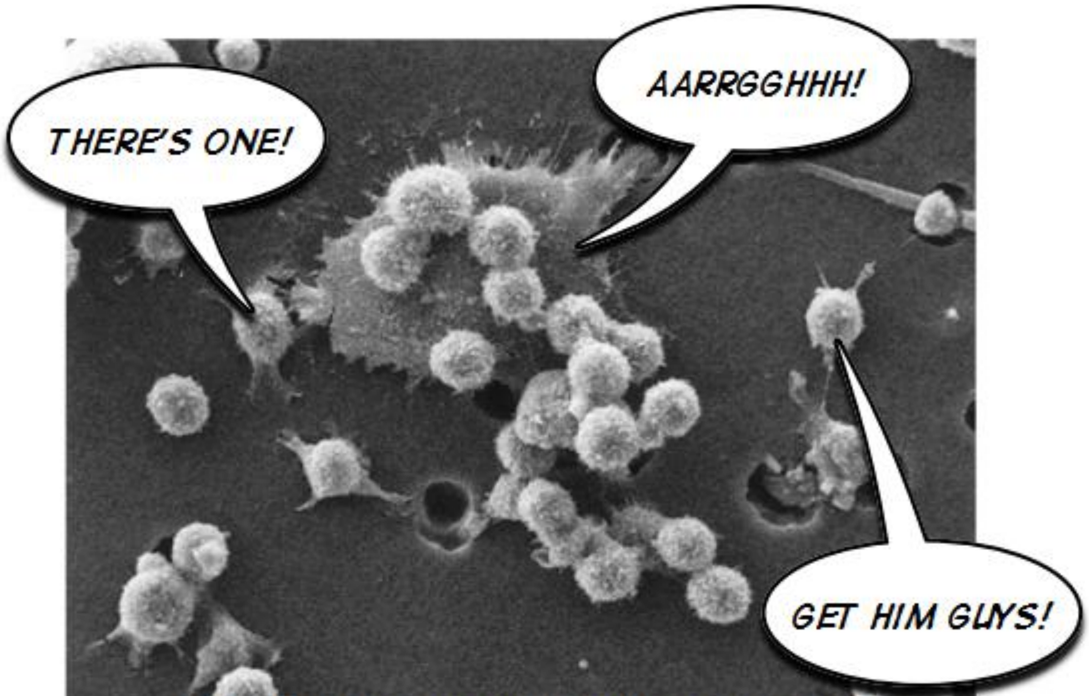
How do cells attack and destroy their targets?

This is a very good question whose answers could fill volumes of books. For the purpose of this textbook however, we will simplify this down to three of our most popular attackers: T cells, NK cells, and **macrophages**.

- NK cells utilize chemicals to break down the cell membrane of abnormal cells within the body. These cells are very good at identifying and destroying cancerous cells in many different ways!

- T cells also utilize chemical weaponry to attack cells that have been marked for death. Several different types of compounds can be secreted by "killer" T cells once they have been programmed to attack a specific target within the thymus.

- <u>Macrophages</u> are unique cells which work within both the innate immunity and the adaptive immunity. Their primary role is to consume pathogens or cellular fragments within the blood and lymph. You first learned about phagocytic cells back in Chapter 15 as "tiny protectors…which literally mean 'cells that eat.'"



MACROPHAGES HUNTING DOWN CANCER CELLS

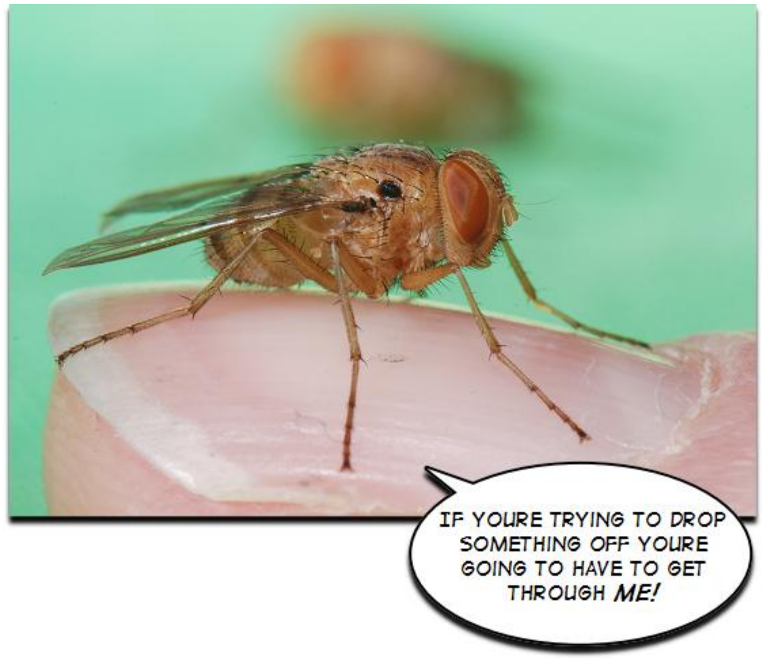
Now let's take a deeper look into our innate and adaptive immunities. Our first stop...

Innate (nonspecific) Immunity

Our innate immunity has seven different defensive tools in its arsenal:

Physical barriers
Phagocytic cells
Immunological surveillance
Interferons
Complement
Inflammation
and Fever

Physical barriers



Physical barriers such as hair and fingernails keep dangerous organisms and materials from entering the body. For example, a bacterium that lands on your finger is unlikely to enter your body as it cannot penetrate your fingernail.

Immunological surveillance

Immunological surveillance is a defense mechanism utilized in large part by the natural killer (NK) cells. NK cells recognize and destroy abnormal cells found within our bodies. The way these cells recognize abnormal cells is very similar to a process you learned back in Chapter 16 about red blood cells and the specific "locks" on their outer surface known as antigens. Abnormal cells (such as cancer cells) contain antigens on their outer surface that are detected by the "keys" of the natural killer cells. Once any of these abnormal cells have been recognized, NK cells rapidly attack and destroy its target.

Interferons

Interferons are proteins which are released by lymphocytes and cells which are infected with viruses. These proteins have two functions: 1) bind to the surface of healthy cells neighboring the infected cells and instruct them to produce their own protective proteins. These proteins are a defense mechanism to prepare the cell should the virus find a way inside its membrane; and, 2) interferons floating throughout the body tend to flag NK cells and macrophages towards the area of infection. With more defenders in the area of infection, there is a greater chance that any pathogens in the area will be identified and attacked.

Complement

Complement is a group of proteins circulating through the blood and lymph which assists or "complements" the actions of our adaptive (specific) immunity. Generally speaking, complementary proteins help to "mark" pathogens by attaching themselves to the foreign invader.

As more and more complement proteins attach themselves to a pathogen, a series of steps (which we do not have the time to discuss here) take place which can either destroy the cell membrane of the pathogen, allow it to be attacked by NK cells and macrophages more easily, or trigger the release of a chemical known as **histamines** which help to trigger inflammation and increased blood flow towards the infected area.

Inflammation

Inflammation is a topic you first learned about in Chapter 7. Inflammation involves swelling, redness, excessive warmth, and pain in the area that contains the damaged tissues. These actions produce an environment which is not favorable for bacteria and viruses to grow and reproduce thus keeping the pathogens within the area of infection from spreading further.

Fever

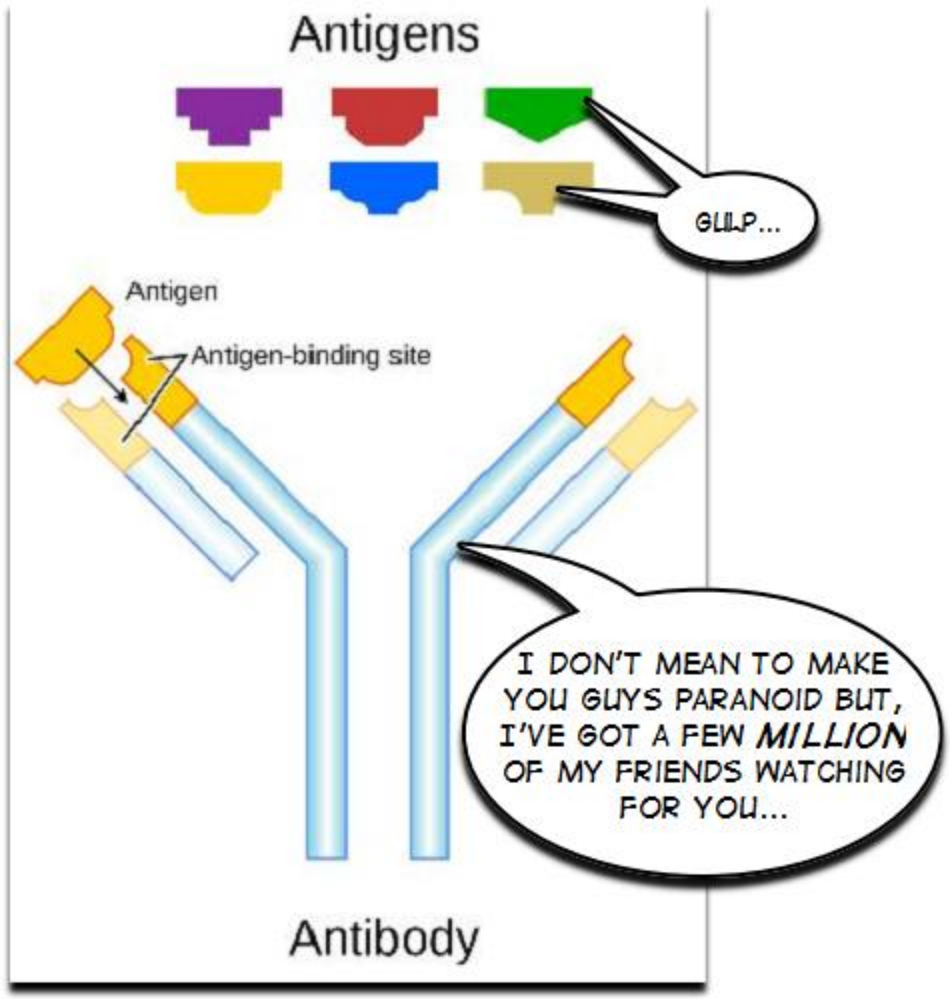
Fever is a condition in which the body temperature is increased above 37.2°C (99°F). A fever can be helpful to the immune system as the increased temperature decreases the growth of some bacteria and viruses. In addition, cellular motion and chemical reactions tend to speed up in warmer environments which, in turn, increase the speed of the immune system to repair infected areas.

Remember, all of these defenses have been present since the day you were born and act the same regardless of the type of pathogen. In this next section, we will look at another type of immune system which responds to specific threats to our health.

Adaptive (specific) Immunity

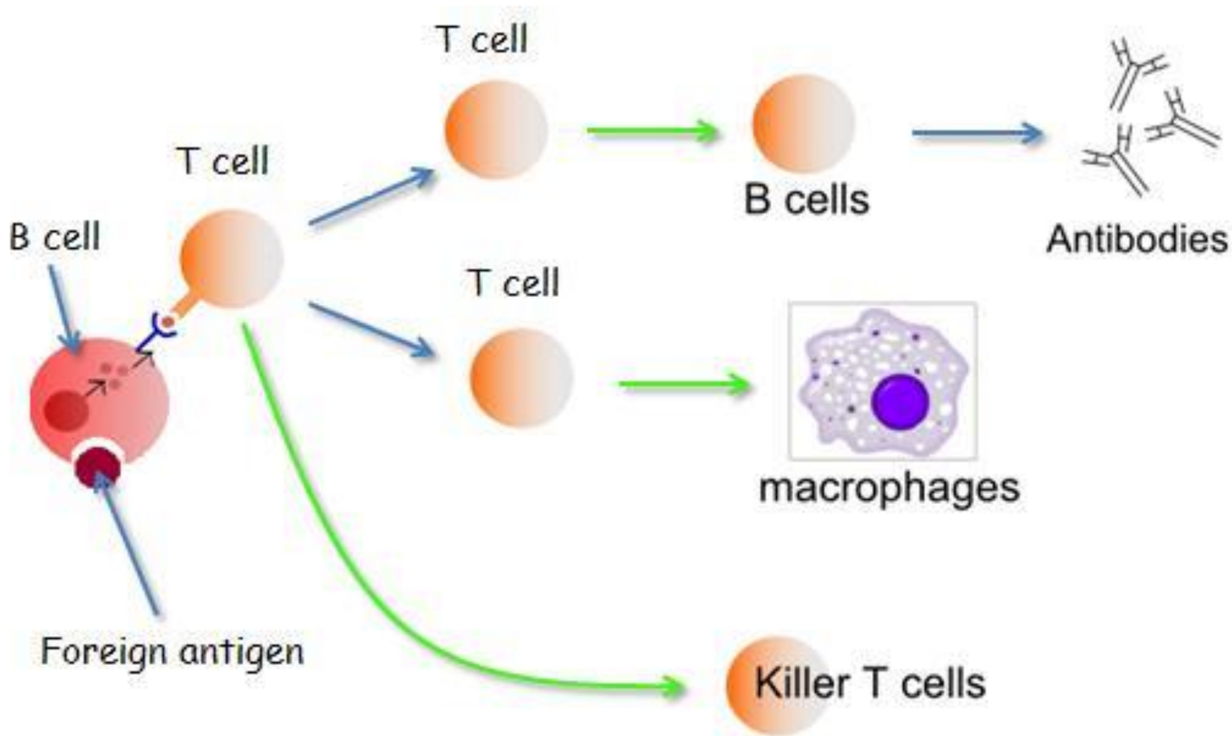
Our adaptive immunity is not present within us at the time of our birth. Instead, we acquire this type of immunity after we are exposed to particular surface antigens of pathogens or if we receive particular antibodies from another source.

Antibodies are large Y-shaped proteins produced by the B cells which can identify and attach themselves to the foreign invaders within the body. Although the general structure of antibodies is the same, a small area at their tip contains unique chemical "keys" which can only bind with specific antigens (locks) on the surface of pathogens. This allows millions of different antibodies to exist within the body, all prepared to attach themselves to unique pathogens.



Antibodies work with the complement proteins of our innate immunity to help mark specific pathogens for attack.

Once attached, the pathogen is marked for attack by various cells of the immune system. During an infection, B cells will congregate within areas such as the lymph nodules where they can concentrate their production of specific antibodies. The following image will help you understand the various roles of the B cell within our immune response:



B cells are triggered when they encounter a matching antigen. The B cell engulfs the antigen and digests it, allowing fragments of the digested material outside on its surface. These fragments are identified by a mature T cell. This activates the T cell to produce chemicals known as cytokines (simulated by the green arrows in the diagram) that further stimulate the activity of macrophages, killer T cells and B cells, the latter producing antibodies.

Our adaptive immunity can be broken down into two separate sections:

Active Immunity and Passive Immunity

Active Immunity

Our **active immunity** develops when our body produces its own antibodies in response to the presence of a foreign antigen. As you just read, the body is capable of housing millions of different antibodies, each designed to mark an individual antigen. However, this defense mechanism is only activated **after** an antigen is detected. Our active immunity can be further broken down into two subsections:

Naturally acquired active immunity

and

Artificially acquired active immunity

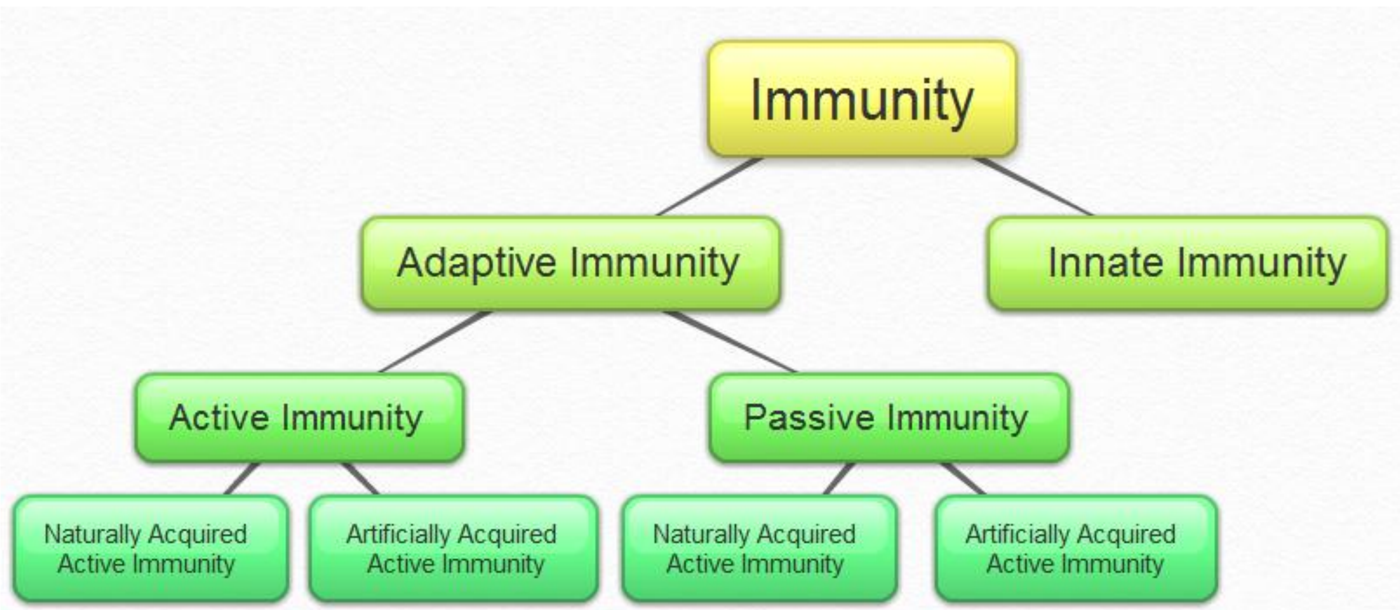
A **naturally acquired active immunity** develops from birth and continues throughout a person's lifetime. In essence, every foreign antigen triggers the development of a new antibody which can patrol the body for years.

An **artificially acquired active immunity**, much like the use of a **vaccine**, stimulates the body to produce antibodies under safe conditions. With the production and distribution of these antibodies within the body, future exposure to the same pathogen can more readily be identified and destroyed. A vaccine is a solution containing dead or inactive pathogens along with their unique antigens. The presence of these antigens within the body will trigger the production of specific antibodies; however, as these pathogens are either dead or inactive, they are unable to cause a patient to become ill.

Passive Immunity

Our **passive immunity** can be either naturally or artificially acquired as well. This type of immunity is produced by transferring antibodies from another source. For example, a **naturally acquired passive immunity** is generated within a baby as she received antibodies from her mother through breast milk. Antibodies can also be placed within our bodies, as when we receive an injection following a rabid dog bite. This injection contains the antibodies needed to attack the rabies virus and is an example of an **artificially acquired passive immunity**.

The following chart will help you separate the individual levels of our immune system:



Let's take a moment to explore what we have learned so far.

Foreign pathogens are initially repelled by the body through <u>*physical barriers*</u> *such as hair and nails. However, if these particles find their way into the body, a series of activities within our* <u>*innate immunity*</u> *work to stop them from spreading. Abnormal (cancerous) cells are also identified and destroyed by the* <u>*NK cells*</u> *of our innate immunity.*

Our <u>adaptive immunity</u> works to identify pathogens by reading the unique antigens their surfaces. This is accomplished through the work of the <u>B cell</u> lymphocyte. B cells engulf and display fragments of antigens on their surface which are read by the T cells. Once attached, T cells release cytokines which stimulate activity of killer T cells, macrophages, or additional B cells which can generate large numbers of <u>antibodies</u> into the blood. These antibodies will continue to fasten themselves to the surface antigens of the pathogen throughout the body. These antibodies act as "flags" for attack by other cells such as macrophages or <u>"killer" T cells</u> which have been programmed to identify these individualized antibodies during their maturation process within the <u>thymus</u>.

Since your immune system must be prepared to identify any antigen at any time, multiple copies **(clones)** of lymphocytes are produced when they come into contact with a specific antigen. Each of these clones is able to identify the same type of antigen. This is very important as it takes a massive amount of lymphocytes to overcome the rapid growth and spread of many pathogens. Two different types of clones are produced after connecting with a surface antigen. One type actively works to destroy the invading pathogen; the other becomes an army of **memory cells**.

These types of cells remain inactive and flow throughout the body. Once these memory cells encounter the same antigens in future infections, they may be quickly activated to generate a faster immune response than compared to the first infection. At any given time, the human body contains an army of memory T and B cells flowing through its blood and lymph in addition to a wealth of antibodies pre-programmed to mark future pathogens for attack as well. This explains how unlikely it is to contract the same disease (such as chicken pox or measles) twice in your life.

The molecular actions of our adaptive immunity are remarkable! Researchers are discovering new activities of our immune system every day. You will not be disappointed by spending a little time studying the innovative details of our amazing immune system beyond this textbook.

In the next chapter, we will be exploring some of the common problems that occur within the fluids, transport systems, and immune responses of our body.

Anatomy & Physiology - Connections

How the following body systems affect the immune system		How the immune system affects the following body systems	
Integumentary	Skin provides protective barrier against incoming pathogens	Secretes antibodies into tissues of integumentary system	**Integumentary**
Skeletal	Hematopoiesis creates white blood cells within red bone marrow	Helps to repair damaged bone tissues	**Skeletal**
Muscular	Contractions of skeletal muscles push lymph through lymphatic vessels	Helps to repair damaged muscle tissues	**Muscular**
Nervous	Production of antigens trigger active immunity	Production of hormones which induce the hypothalmus to secrete several hormones as well	**Nervous**
Endocrine	Production of several hormones which reduce inflammation, produce/mature lymphocytes, etc.	Production of T cells by thymus; secretion of various hormones assist cells throughout body	**Endocrine**
Cardiovascular	Distributes lymphocytes, antibodies, and proteins needed for blood clots	Defends organs against infection; lymphatic vessels return fluids back into the blood	**Cardiovascular**

Match the following vocabulary terms with their correct definition:

active immunity	**inflammation**
artificially acquired active immunity	**interferons**
artificially acquired passive immunity	**macrophage**
clones	**memory cells**
complement	**naturally acquired active immunity**
fever	**naturally acquired passive immunity**
histamines	**passive immunity**
immunological surveillance	**physical barriers**
	vaccine

1)	_______________	a condition in which the body temperature is increased above 37.2°C (99°F)
2)	_______________	a group of proteins which help to "mark" pathogens by attaching themselves to the foreign invader
3)	_______________	a solution of dead or inactive pathogens containing their unique antigens; common source for a person's artificially acquired active immunity
4)	_______________	a type of immunity which is produced by transferring antibodies from another source
5)	_______________	a type of white blood cell which sweeps through the blood and consumes pathogens and cellular fragments
6)	_______________	any one of the many identical copies of specific lymphocytes
7)	_______________	chemical which helps to trigger inflammation and increases blood flow towards the infected area

8)	______________	clones which remain inactive and flow throughout the body after an infection; can be quickly activated to generate a faster immune response during future infections
9)	______________	defense mechanism utilized by the natural killer (NK) cells to identify surface antigens on foreign cells before destroying the invader
10)	______________	initial barrier of the body's innate immunity; external structures such as hair and fingernails keep dangerous organisms and materials from entering the body
11)	______________	proteins released by lymphocytes and/or cells which are infected with viruses; tags the infected cells for attack by the immune system or instructs healthy cells to prepare for the impending spread of infection
12)	______________	symptoms such as swelling, redness, excessive warmth, and pain in an area that contains damaged tissues
13)	______________	type of active immunity which develops from birth and continues throughout a person's lifetime
14)	______________	type of active immunity which stimulates the body to produce antibodies under safe conditions
15)	______________	type of immunity which develops after the body produces its own antibodies in response to the presence of a foreign antigen
16)	______________	type of passive immunity in which antibodies are transferred into another individual through artificial means (i.e. as through a tetanus or rabies shot)
17)	______________	type of passive immunity in which antibodies are transferred into another individual without any artificial means (i.e. via breast milk)

Choose the correct answer from the following questions:

1) **Tissues invaded by viruses may secrete proteins called __________ to protect nearby cells from becoming infected.**
   A) histamine
   B) memory cells
   C) complement
   D) interferon

2) **What specific type of acquired immunity do vaccines provide:**
   A) naturally acquired artificial immunity
   B) naturally acquired passive immunity
   C) artificially acquired passive immunity
   D) artificially acquired active immunity
   E) naturally acquired active immunity

3) **Which one of the following is NOT one of the four most common indicators of the inflammation:**
   A) redness
   B) heat
   C) swelling
   D) pain
   E) fever

4) **The body's first line of defense against the invasion of pathogens is:**
   A) phagocytes
   B) skin
   C) natural killer cells
   D) fever
   E) inflammation

5) **True or false:** Natural killers are unique phagocytic defense cells that can kill cancer cells well before the immune system is activated.

6) **True or false:** Artificially acquired passive immunity is administered to a person when one receives “anti-venom” after being bit by a poisonous snake.

Application Question:

You learned in Chapter 11 that the cornea and lens of the eye both refract (bend) light as it enters the eye. What you may not have known is that both of these structures are completely lacking in capillaries. How do you believe this fact is related to the high success of transplants of corneas from donors?

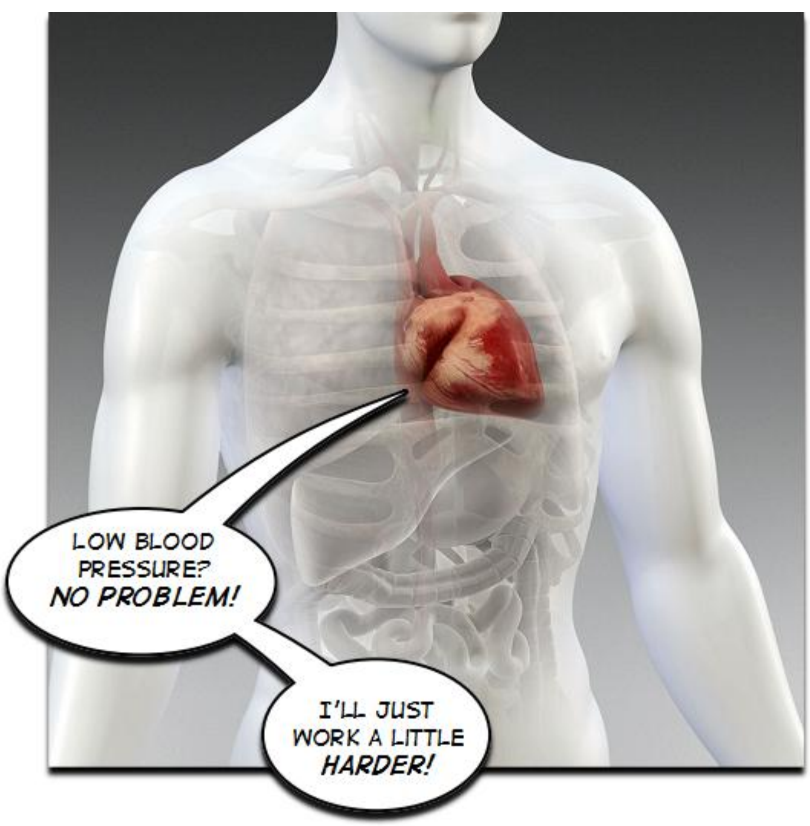
Chapter 21

Fluid Transportation: What can go wrong?

We've spent the last six chapters looking at the anatomy and physiology of the blood, the cardiovascular system, and the lymphatic/immune systems. Now it's time to look at a few of the problems that commonly occur within these areas of our body. As you have read previously in Chapters 7 and 14, this is by no means a complete list of the diseases, disorders, and common problems that exist within the human race. You are only going to explore the most common troubles that exist within the cardiovascular and immune systems. So let's begin with...

Disorders of the Cardiovascular System

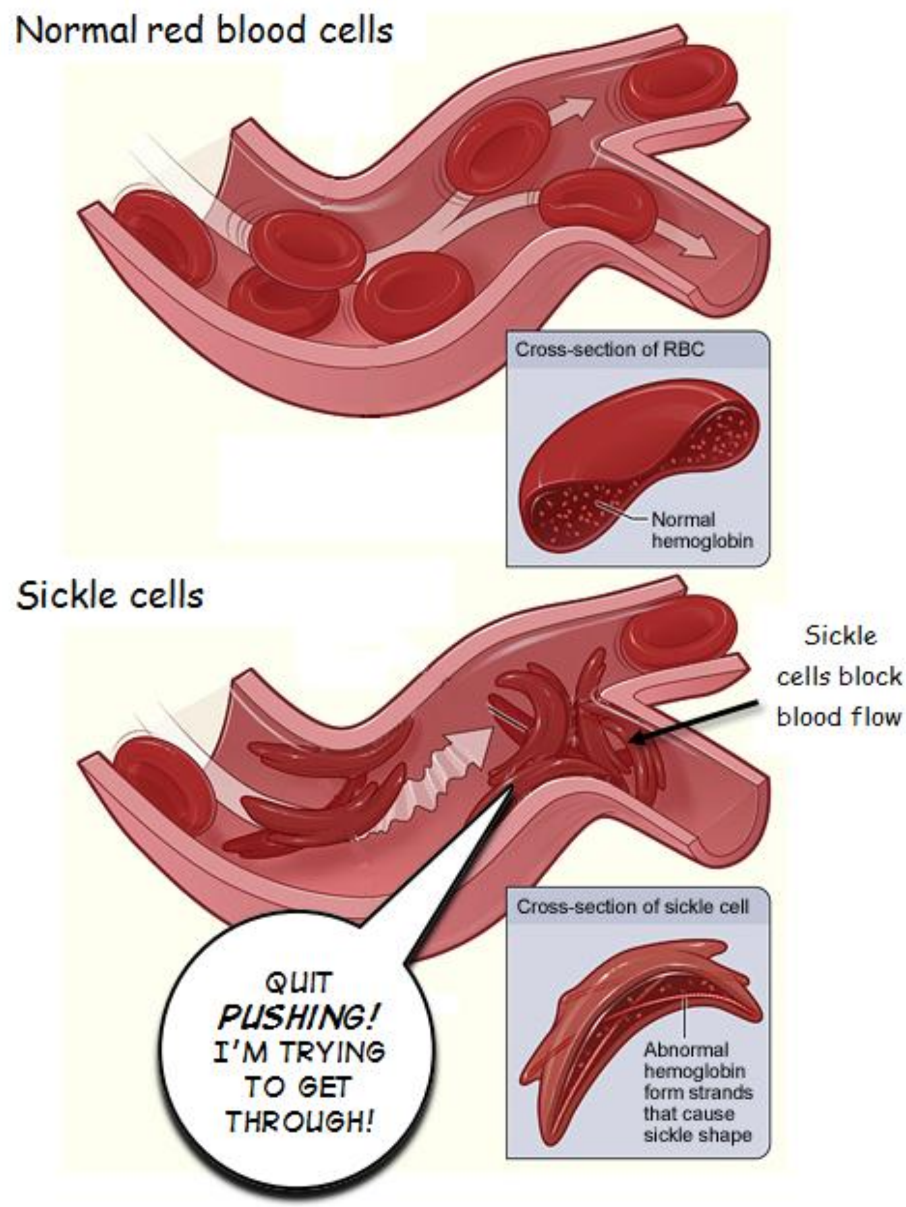
The #1 type of disorder which affects red blood cells is anemia. As you learned back in Chapter 15, anemia is a condition in which the blood can only transport limited amounts of oxygen to the rest of the body due to a lowered amount of red blood cells. This disorder can be caused by diseases of the skeletal system which can lower the amount of red blood cell development or hemoglobin levels. Additionally, travelers to high altitudes may have felt the effects of this disorder as the lowered oxygen levels within these areas can induce symptoms which include fatigue and loss of energy, rapid heartbeat, shortness of breath and headaches. In addition to traveling in high altitudes, an extreme loss of blood known as a hemorrhage may also induce symptoms of anemia.



<u>The body responds to a hemorrhage by increasing the heart rate in order to raise the decreasing blood pressure.</u>

The body also responds to a hemorrhage by narrowing the arterioles, causing an increase in blood pressure as the blood is allowed to flow faster (due to a series of actions caused by a complex molecule known as **ACE** produced by the lungs).

Sickle cell anemia



At times when the blood oxygen levels are decreased, red blood cells can abnormally fold themselves into shapes resembling stiff crescent-shaped rods. This only occurs among individuals containing an inherited genetic disorder known as **sickle cell anemia**.

These "sickle-shaped" red blood cells are not as durable as healthy cells and easily break apart. These fragments form clots within the smaller blood vessels and the reduced number of red blood cells further lowers the volume of oxygen to very dangerous levels.

Angina

When the heart is deprived of oxygen, an individual may suffer from extreme chest pain in a condition known as **angina**. Although a blood disorder may not be the only cause of angina, this symptom is a clear warning sign that blood oxygen levels are dangerously low.

High blood pressure

You learned back in Chapter 18 that our blood pressure is a measured force of blood pushing against the inner walls of the arteries near the heart. At times, our blood pressure may become too high which is a condition known as **hypertension.** Although a definite cause for this disorder is not entirely known, it is widely accepted that poor diet, lack of exercise, and smoking contribute directly to an increased blood pressure.

To understand this disorder a little better, imagine a garden hose that is transporting a steady stream of water. What would happen if we pinched part of the hose?

The water would spray out of the hose much faster!

This increased velocity of water is caused by a buildup of water pressure of it attempts to pass through the pinched area of the hose. The flow of water being forced through the hose is traveling with an equal amount of force from the spigot; however, pressure builds up because the water molecules are slamming into the sides of the hose with more frequency than before.

This is what happens within our blood vessels as well.

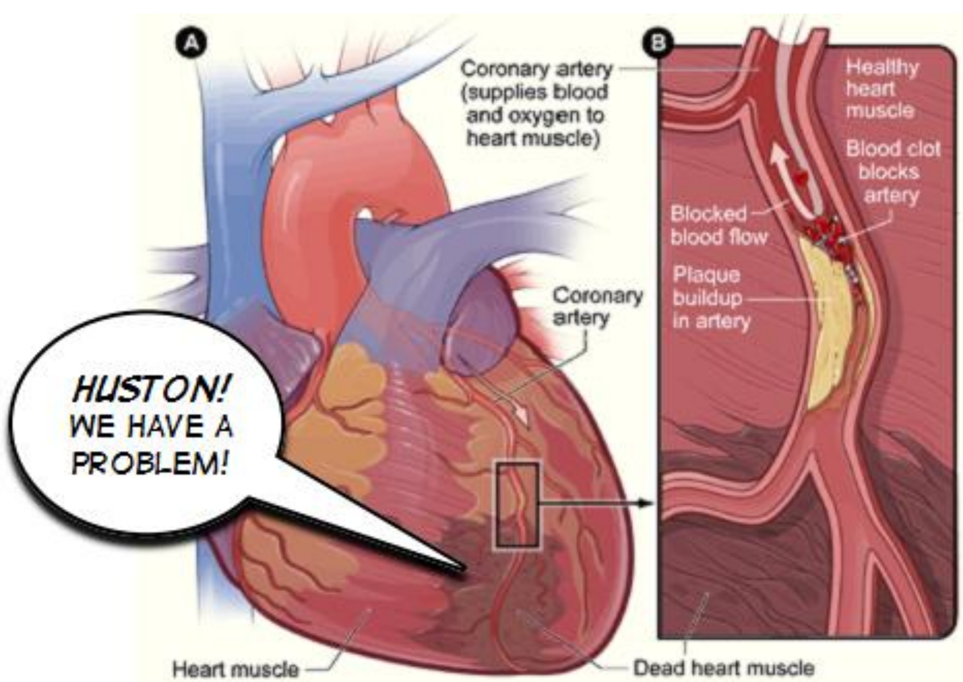
Whenever blood cannot flow through the vessels at a normal rate, the heart has to pump harder. Why? Unlike the hose, our cells and tissues require an equal amount of oxygenized blood at all times. When the blood vessels become "pinched" and do not allow as much blood to flow, it is the heart which has to push a little harder to move the same volume of blood throughout the body.

So what causes this "pinching" within the blood vessels?

The restricted area within the blood vessels actually occurs <u>inside</u> the vessel walls rather than by an actual "pinching" of their outer structure. This “pinching” is actually occurs when arteries become clogged when their walls become thickened by deposits of hardened calcium (**arteriosclerosis**). Additionally, arteries can become clogged by a particular fat known as **cholesterol** (also known as **plaque**) in a condition known as **atherosclerosis**. Poor diet, smoking, and lack of exercise are again the leading cause of these disorders.

What if an artery becomes completely blocked?

If the flow of blood within a **coronary artery** (one of two arteries which supply the heart with blood) are completely restricted, the heart muscle begins to be damaged without its necessary blood and oxygen supply. This damaging process is known as a **heart attack**.



Symptoms of a heart attack begin slowly, with the individual experiencing mild pain. Several minutes of chest pain or other areas of the upper body may develop, as well as shortness of breath, nausea, or lightheadedness. It is important to note that any of these symptoms may not exist prior to a heart attack. Nevertheless, it is vital for an individual to seek medical advice should any of these symptoms persist as damage to the heart muscle can cause severe complications and could be fatal.

Don't forget!

The heart must continue to provide an equal amount of blood to all our tissues. So, because of the "hardening of an artery" from the actions of arteriosclerosis and atherosclerosis, the heart must pump <u>harder</u> to drive the flow of blood in equal volumes.

What if the vessels cannot withstand the increased pressure coming from the heart?

If we were to go back to the hose analogy, imagine what would happen if we pinched the hose completely (don't do this at home!) If you guessed that the bulge would eventually form within the hose before it split apart you would be correct. And, the rupture would likely occur where the hose attaches to the spigot itself as the seal between the both items is the weakest area of the hose. This can occur within the aorta of the heart or the large arteries within the brain and is known as an **aneurysm**. Both of these conditions are equally life-threatening as an aneurysm in the brain will likely cause a stroke in the victim and the rupture of the aorta will cause a massive internal hemorrhage resulting in the victim's death.

Hemophilia

Although larger ruptures within our blood vessels are life-threatening, minor damage to blood vessels are easily fixed by the formation of a blood clot. As you learned in Chapters 15 and 16, these plugs of platelets help to reduce the loss of blood as the vessel is being repaired. As the vessel is being plugged up, specialized proteins called **clotting factors** work to transform another protein in our blood (fibrinogen) into long strands of fibrin which, in turn, provides structural support for the accumulating platelets.

Unfortunately, a genetic disorder exists which reduces the amount of clotting factors. This disorder, called **hemophilia,** actively slows down the formation of fibrin depending upon the volume of clotting factors within the blood. Basically, an individual with hemophilia is either unable to produce a scab or produces one so slowly that an excessive amount of blood may be lost. In extreme cases, this disorder can be fatal especially with damage to major blood vessels.

How can you help prevent the effects of cardiovascular disease?

Most medical professionals would agree that an individual who does not undergo some form of moderate-to-vigorous exercise several times a week is in risk of developing some form of cardiovascular disease. These forms of exercise, such as running, jogging, or even brisk walking do not have to be extended over long periods of time...

...only 30 minutes a day!

Regular exercise increases the heart's ability to pump blood more efficiently throughout the body. This efficiency can be measured in the amount of times the heart must beat in order to pump your blood. Every time you exercise, you are training your heart to pump more blood with every beat! This means your heart doesn't have to work as hard when you are at rest to deliver blood throughout the body. And we could spend days talking about how increased blood flow can control the levels of fats and cholesterol in your blood stream as well as your blood pressure!

Disorders of the Lymphatic System

The most widely known group of diseases which involve the lymphatic system are **cancers**. Nearly all cells undergo some form of reproduction during their life cycle. However, the rate in which these cells make copies of themselves is regulated to prevent large groups of unwanted cells from developing and accumulating within the body.

Cancers are the uncontrolled growth of individual cells within the body. As more and more of these unwanted cells continue to be produced, they form a mass of cells known as a **tumor**. The continual growth of tumors may invade and cause trouble for nearby organs/tissues of the body. These types of tumors are classified as being **malignant**. In addition, malignant cancerous cells may also spread to other areas of the body throughout the lymphatic system or through the blood stream. One type of these mobile cancers is known as **lymphomas.**

Lymphomas are particular types of cancers affecting lymphocytes which are transported easily through the lymphatic system. Luckily, not all tumors are malignant. **Benign tumors** do not spread or invade neighboring tissues.

Another mass of tissues within our bodies is worth mentioning here...

Humans have a pair of soft tissues at the rear of the throat known as tonsils which actively work to remove pathogens from the body. Because of their location, the tonsils are in the first line of defense against all inhaled or ingested pathogens. Should the tonsils become infected, physicians may suggest a removal of these tissues known as a **tonsillectomy**. The removal of these tissues does not appear to have any effect on our ability to fight off invading pathogens.

The Immune System and Common Illnesses

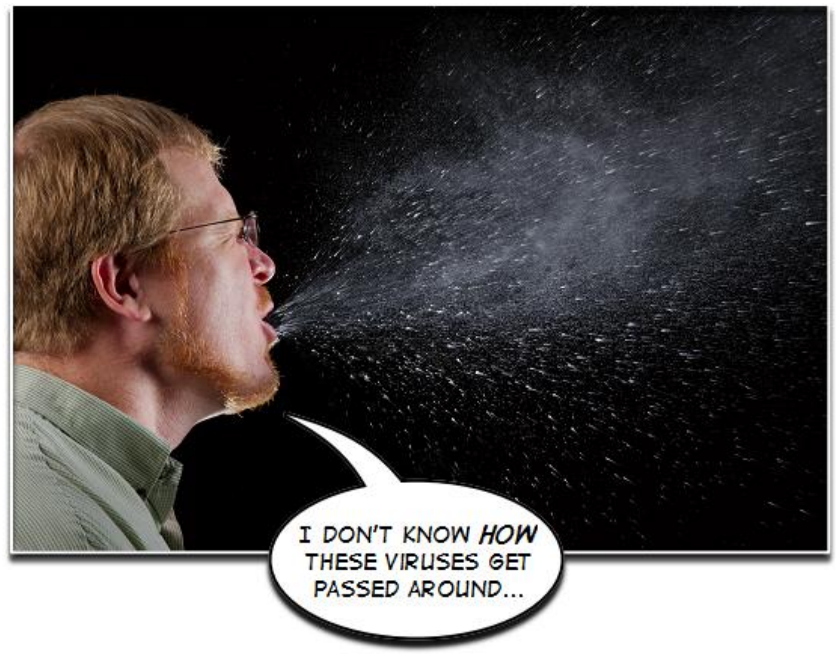
Let's look at a couple common events that all of us have likely encountered:

Colds and Flu's

It is a very good guess that most if not all of us has had a cold or flu at one time in our lives. What you may not have known is that both of these diseases are caused by a viral infection. The cold can be caused by many different types of viruses. This is the reason why it is almost impossible to prevent the spread of a cold.

With so many different pathogens causing this disease, our immune system is incapable of building up a defense until well after the virus has entered the body and has begun to spread. And, because of the nature of viruses, most medications are ineffective at preventing their spread throughout the body.

This is much different than the flu which is caused by only a handful of influenza viruses. The reduced amount of pathogens causing the flu has enabled medical researchers to develop an annual vaccine for the common flu viruses that have been identified each year. As you learned in Chapter 20, a vaccine stimulates the body to produce antibodies that will identify and attack specific pathogens. Each year, flu vaccinations contain different solutions of dead or inactive strains of viruses that have been recently found throughout a particular area of the world. This is why people are asked receive a new flu vaccine each year.



Another common illness that affects millions of people each year is allergies. An **allergy** is a reaction caused by the immune system against normally harmless substances we encounter every day (known as **allergens**). Food products, medications, household pets, dust, and molds are just a few of the items that may trigger an allergic reaction in some individuals. Within the body, antibodies will attach themselves to specialized cells that can produce histamines after being exposed to an allergen for the first time. (You learned about histamines in Chapter 16 as chemicals which induce an inflammatory response.) When the individual is exposed to the same allergens at a later time, the antibodies trigger the release of histamines into the blood stream which causes symptoms such as sneezing, itchy and watery eyes, and an increase in mucus production.

As stated before, a year-long curriculum could be devoted solely to the study of disorders of the cardiovascular, lymphatic, and immune systems. I highly recommend looking into these fascinating and vitally important fields of study. Our future depends upon the bright and energetic minds within these medical fields.

Match the following vocabulary terms with their correct definition:

ACE	benign tumors	hypertension
allergens	cancer	lymphomas
allergy	cholesterol	malignant tumor
aneurysm	clotting factors	sickle cell anemia
angina	coronary artery	tonsillectomy
arteriosclerosis	heart attack	tumor
atherosclerosis	hemophilia	

1)	______________	the uncontrollable growth of individual cells within the body
2)	______________	rupture of the aorta of the heart or the large arteries within the brain
3)	______________	high blood pressure
4)	______________	a reaction caused by the immune system against normally harmless substances encountered daily
5)	______________	clogging of arteries by cholesterol deposits
6)	______________	proteins which assist in the formation of fibrin from fibrinogen
7)	______________	complex molecule produced by the lungs which is responsible for narrowing the diameter of arterioles, allowing blood to flow faster
8)	______________	one of two arteries which supply the heart with blood
9)	______________	type of fat; excess amounts within the blood can cause deposits to form within arteries which may lead to atherosclerosis

10)	______________	cancerous cells which do not invade neighboring tissues or cells
11)	______________	a genetic disorder in which the the formation of fibrin is slowed down considerably due to a decreased volume of clotting factors within the blood
12)	______________	restriction of blood flow through either of the coronary arteries; immediate damage to the heart muscle begins without a supply of blood and oxygen
13)	______________	deposits of hardened calcium within the arteries
14)	______________	extreme chest pain
15)	______________	normally harmless substances encountered every day which may induce an allergic response
16)	______________	inherited genetic disorder causing red blood cells to abnormally fold themselves into shapes resembling stiff crescent-shaped rods
17)	______________	malignant cancerous cells which spread to other areas of the body via the lymphatic system or blood stream
18)	______________	procedure involving the removal of the tonsils due to infection
19)	______________	a mass of cancerous cells
20)	______________	a tumor that has invaded and caused trouble for nearby organs/tissues of the body

Three of the following statements are incorrect. Identify them and place the correct word in the underlined area.

1) <u>Benign</u> cancers do not spread or invade neighboring tissues.

2) An aneurysm in the <u>aorta</u> will likely cause a stroke within a person.

3) The severity of hemophilia depends upon the volume of <u>fibrin</u> in the blood.

4) The clogging of arteries by hardened calcium deposits is known as <u>arteriosclerosis</u>.

5) <u>Angina</u> is one possible symptom for a person about to suffer a <u>heart attack</u>.

6) Colds and flus are caused by <u>bacterial</u> infections.

7) The body responds to a hemorrhage by <u>increasing</u> the heart rate in response to a <u>lowered</u> blood pressure.

Application Question:

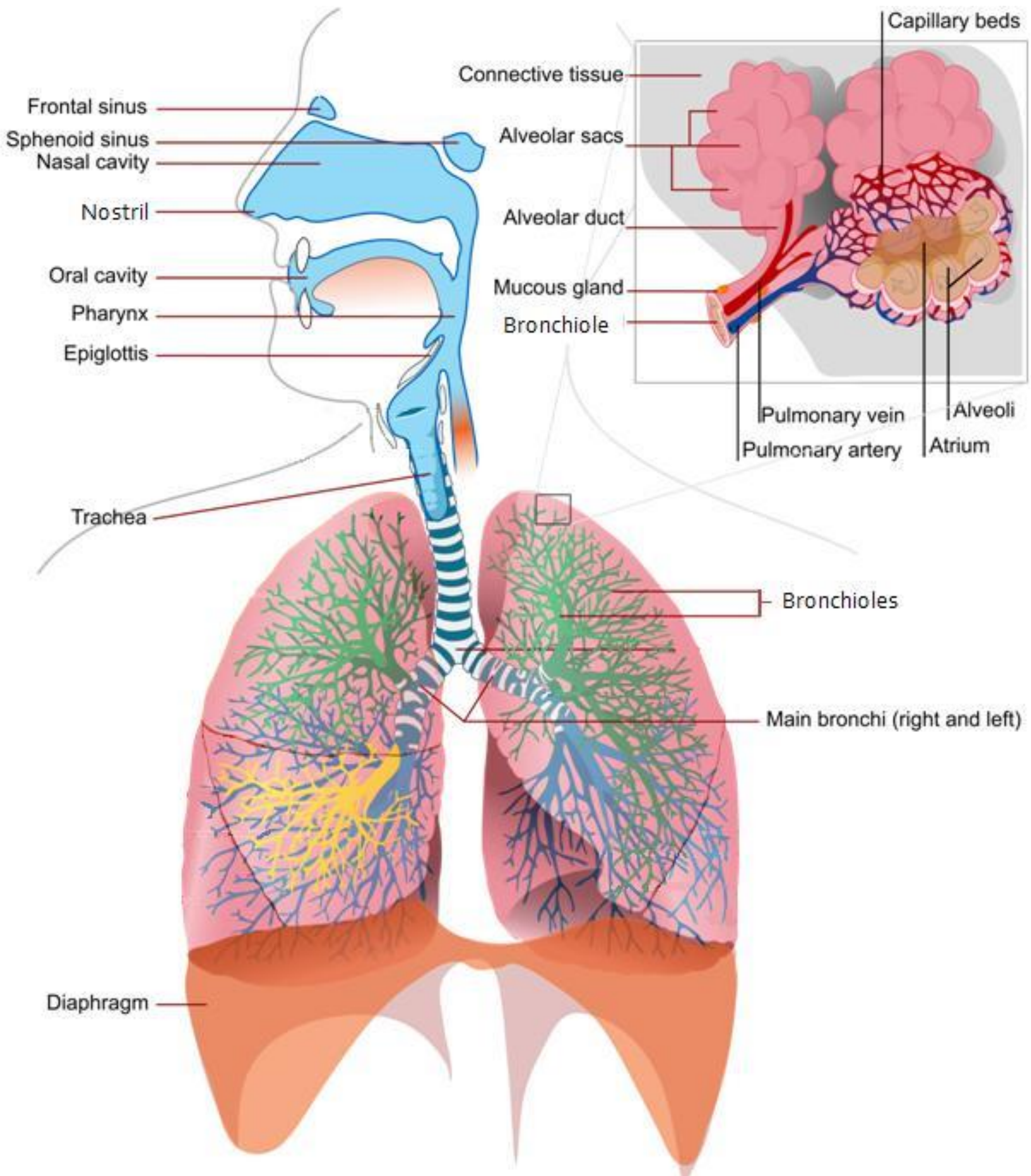
During the virus-induced disease mononucleosis ("mono"), the spleen enlarges because of increased numbers of phagocytic cells which are attacking the virus. Common signs and symptoms of this disease include a pale complexion, tired feeling, and a lack of energy sometimes to the point of not being able to get out of bed. Using your knowledge of the functions of the spleen, what might cause these signs and symptoms?

Chapter 22

Respiratory System – Part I

Two of the most vital functions we must perform to ensure our existence are the ability to inhale oxygen gas and remove the gaseous waste product known as carbon dioxide. The next two chapters will focus on the anatomy and physiology of the system that is responsible for these functions...

the Respiratory System



Our ability to breathe is a complex system of muscles which contract and expand, allowing air to freely enter and be forced out of our body. Before we begin looking at the anatomy of this system, let's explore its primary functions. It is important to mention that the five functions mentioned below almost entirely touch upon concepts we have explored in previous chapters:

Respiration, Immunity, Olfaction (our sense of smell), **Regulation of blood pH,**

and...

Each of these functions is equally important to our survival and will be the topics of discussion for the next two chapters. Let's begin this journey with the first two (and possibly most important) items from this list.

Respiration and Immunity

The technical definition of **respiration** is the exchange of gases between two or more structures. Within the human body, three different types of respiration exist:

External respiration, Internal respiration, and **Cellular respiration**

External respiration is the exchange of gases between the air and the blood; **internal respiration** occurs between the blood and the cells; and, **cellular respiration** involves the use of oxygen by the cells for its functioning and the release of carbon dioxide gas as waste.

As you have learned previously, the collaborative efforts of the cardiovascular and respiratory systems are very important in every type of respiration.

Several steps exist throughout the process of external respiration, as the oxygen gas within the air (O_2) flows into our blood and carbon dioxide (CO_2) is removed from the blood. As the muscles within the respiratory system contract, air is forced into our bodies in the following order:

Nose, Pharynx, Larynx, Trachea, Bronchi, Bronchioles, and Alveoli

Let's start this amazing pathway by taking a closer look at...

the Nose

The nose is much more than just a place to rest your glasses. It is the primary access point for all air entering the respiratory system. It is ironic that the life-giving function of our external respiration and the tunnel-like anatomy of nose put us in harm's way during every breath. Every time we inhale, unwanted pathogens are drawn into our bodies through the two external openings of our nose which are known as the **nostrils.**
The nostrils open up to a large, mucus-filled area behind the nose which is known as the **nasal cavity**. The tissues that line all of the organs of the respiratory system, including the nasal cavity, produce a significant amount of mucus which protects these tissues in a couple of ways.

First, mucus prevents these tissues from drying out as air constantly passes over them; and secondly, the sticky nature of mucus traps pathogens that are passed through the air. Mucus acts as a form of flypaper to trap foreign pathogens before they have a chance to reproduce and grow within our bodies. In addition, a large amount of hair protrudes from the inner surface of the nasal cavity. These hairs act as filters to capture unwanted particles within the air as well.

Large blood vessels are found within the **sinuses** (hollow areas in the bones of the skull which open into the nasal cavity) which provide the necessary warmth to heat the incoming air. The additional warmth prevents the mucus from drying out or possibly freezing in colder environments. The sinuses also redirect the flow of air in and out of the respiratory system causing **resonance** (deepness) to the voice.

Let's take a look at the next stop within the respiratory system…

the Pharynx

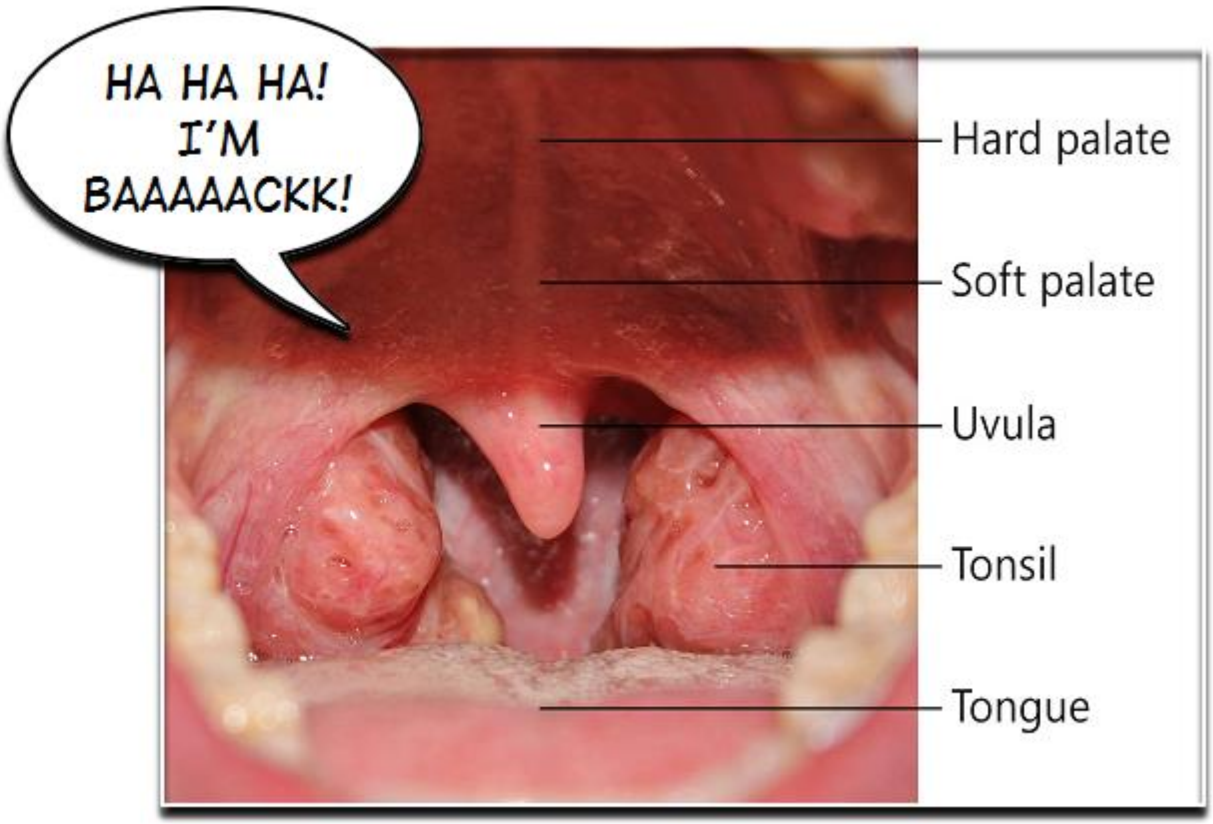
Some of the pathogen-filled mucus within the nose eventually dries out. This material is expelled from the body as a **booger**. This is one way our body removes unwanted invaders from entering the body. However, most of our mucus is sent to the **pharynx** (otherwise known as the throat), which is attached to the nasal cavity and is divided into three separate areas: the **nasopharnynx**, the **oropharynx**, and the **laryngopharnx**.

Nasopharynx

The **nasopharynx** is the most superior portion of the pharynx and, unlike the two remaining inferior portions, it always remains open. The nasopharynx is wedged between the nasal cavity and an inferior section of the pharynx known as the **oropharynx**.

Oropharynx

This portion of the pharynx includes the area between the **soft palate** of the throat and the top of the **epiglottis**. The soft palate of your mouth can be found in the posterior area of the roof of your mouth. The **hard palate,** located adjacent to and anterior to the soft palate, contains a layer of bone under its tissues unlike the soft palate.



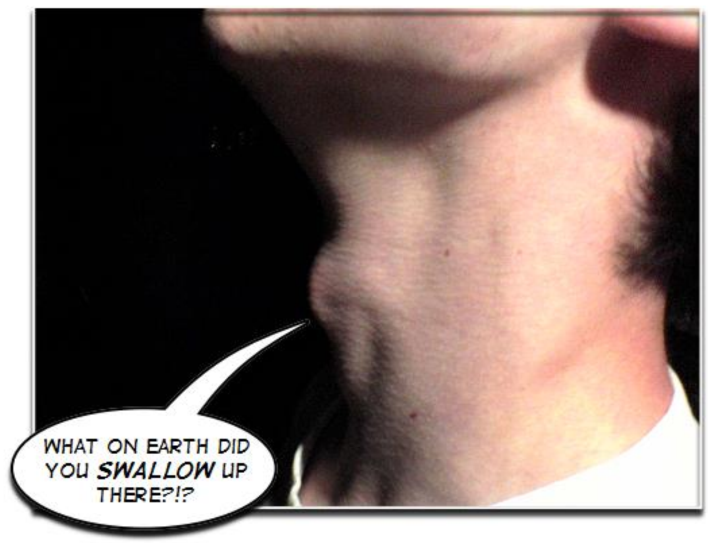
The epiglottis is a flap of connective tissue that moves back and forth to cover the lowest area of the pharynx, the **laryngopharynx**, when food is being swallowed. The function of the epiglottis prevents food from entering the respiratory system and guides it towards the organs of the digestive system.

Laryngopharynx

Both food and air pass through the laryngopharynx, which lies at the most inferior position of the pharynx. This opening is closed off by the epiglottis during swallowing and is attached to the next pathway of the respiratory system:

the Larynx

The area connecting the laryngopharynx with the larynx is an opening known as the **glottis**. This opening is covered up by the actions of the epiglottis which prevent food from passing into the remaining organs of the respiratory system. Within the larynx the **vocal cords** can be found. These "cords" are actually two pairs of tissues which are stretched horizontally across the larynx. As air is passed through the larynx, the vocal cords vibrate which is responsible for the **pitch** (highness and lowness) and volume of our voice. In addition, the male larynx is larger than the female larynx which results in an obvious bulge known as the **Adam's apple**.



When solid or liquids mistakenly pass through the glottis, they have a chance of being drawn into the lungs. When this happens, the larynx triggers a reflex known as a **cough** to rapidly remove the foreign items from the respiratory system before it reaches the lungs.

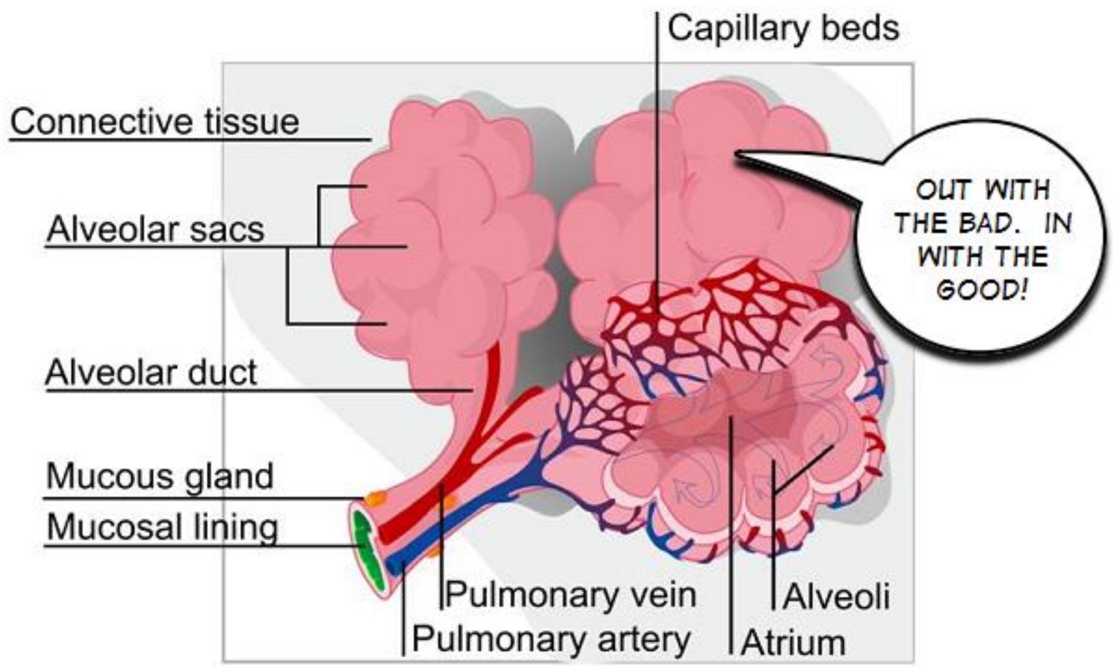
The larynx is connected to the next organ of the respiratory system...

the Trachea

The **trachea**, also known as the windpipe, allows the passage of air from the larynx to the lungs. The internal walls of this 5 inch (12.5 cm) long tube is coated with a layer of mucus which traps inhaled foreign particles much like the larynx, pharynx, and nasal cavity. Should particles find their way this far into the respiratory system, the pathogen-filled mucus is expelled upwards into the pharynx once again where it can be directed towards the stomach or through the mouth as **phlegm**.

The trachea ends by dividing into two separate branches much like that of a tree. These two branches are known as the **right and left bronchi** and continue to decrease in diameter, the smallest being known as the **bronchioles.** These tiny tubes and are capped off by microscopic "balloons" of tissue known as **alveoli**.

It is within the 700 million alveoli of our lungs that oxygen and carbon dioxide are exchanged.



The **lungs** are two cone-shaped organs of the respiratory system, each weighing around one pound (2.2 kilograms). The millions of alveoli which make up its structure, if stretched out, could cover the surface of a tennis court. This is a massive amount of surface area which is vital to their primary function:

Gas exchange

As you learned back in Chapter 18:

The high concentration of oxygen within the blood from the aorta while under increased arterial pressure diffuses out of the network of capillaries and into the body tissues which they surround. As this is occurring, the body tissues have already used up their oxygen supply and have a surplus of the waste product - carbon dioxide gas (CO_2). The high concentration of CO_2 is then diffused out of the body tissues and into the capillaries. In addition to oxygen and carbon dioxide, the capillaries are responsible for transporting nutrients, hormones, and dozens of other molecules between the body tissues/organs and the cardiovascular system.

Within 60 seconds, the heart pumps all of its blood around the body to ensure as much gas exchange as possible.

But what would happen if this gas exchange did not occur as efficiently as it should? What is the result of an excess amount of carbon dioxide within our blood? These questions can be answered by one of the five primary functions of the respiratory system you read about at the beginning of this chapter - the regulation of the blood pH.

Regulation of blood pH

It should be fairly evident that the more frequently you exhale, the more carbon dioxide gas is expelled from your body, right?

This is a very important function of the human body because the majority of the carbon dioxide that is dissolved into our blood combines with water to form a different chemical known as **carbonic acid (H_2CO_3)** before quickly breaking apart once more to form **bicarbonate ions (HCO_3^-)** and hydrogen ions (H^+). Therefore, the majority of the carbon dioxide we inhale travels through our blood as bicarbonate ions.

The following reversible chemical formula describes the formation of carbonic acid (H_2CO_3) from the reaction of carbon dioxide (CO_2) and water in the forward direction; and, from the reaction between bicarbonate ions and hydrogen ions in the reverse direction:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

Therefore, if your breathing becomes slower or shallower, the amount of carbon dioxide remaining in your body increases and the reaction moves in the forward direction. This causes an excess buildup of carbonic acid within your blood which is a condition known as **respiratory acidosis**.

Why does this buildup occur?

If the amount of CO_2 is increased, the forward direction will more likely occur as an excess amount of reactants (CO_2 and H_2O) will be more likely to react than the remaining reactants (HCO_3^- and H^+).

If you take the CO_2 out of the above reaction, there will be nothing to react with water. Therefore, the bicarbonate and hydrogen ions will continue to make carbonic acid as they complete the reverse reaction.

Respiratory acidosis can cause blood pH to fall to potentially dangerous levels. In order to make the blood less acidic, your respiration rate must increase. The more the body exhales, the more carbon dioxide gas is removed from the blood and the higher its pH level increases to safe levels.

The relationship between the cardiovascular and the respiratory system is vital to our survival. The constant removal of the waste product, carbon dioxide, coupled with the continual intake of oxygen gas involves a series of secondary organs and tissues which we will learn about in the next chapter as we explore the physical act of breathing.

Match the following vocabulary terms with their correct definition:

Adam's apple	**internal respiration**	**pitch**
alveoli	**laryngopharnx**	**resonance**
booger	**larynx**	**respiration**
bronchioles	**lungs**	**respiratory acidosis**
carbonic acid	**nasal cavity**	**right and left bronchi**
cellular respiration	**nasopharnynx**	**sinuses**
cough	**nose**	**soft palate**
epiglottis	**nostrils**	**trachea (windpipe)**
external respiration	**oropharynx**	**vocal cords**
glottis	**pharynx**	
hard palate	**phlegm**	

1)	____________	5 inch (12.5 cm) long tube; attached to the larynx; allows the passage of air from the larynx to the lungs
2)	____________	a flap of connective tissue that moves back and forth to cover the laryngopharynx when food is being swallowed
3)	____________	a large, mucus-filled area behind the nose
4)	____________	acid created from carbon dioxide that is dissolved in the blood
5)	____________	cone-shaped organs of the respiratory system made up of millions of alveoli
6)	____________	deepness (of the voice)
7)	____________	dried mucus, potentially filled with pathogens, which is expelled from the body
8)	____________	exchange of gases between two or more structures
9)	____________	found in the back of the roof of the mouth; does not contain a layer of bone under its tissues

10)	________________	found in the front section of the roof of the mouth; contains a layer of bone under its tissues
11)	________________	highness and lowness (of the voice)
12)	________________	hollow areas in the bones of the skull which open into the nasal cavity
13)	________________	lowest section of the pharynx; connected to the larynx; allows both food and air to pass through until it is closed by the epiglottis during swallowing
14)	________________	microscopic "balloons" of tissue which cap off each bronchiole
15)	________________	middle section of the pharynx; located between the soft palate of the throat and the top of the epiglottis
16)	________________	organ of the respiratory system; contains the vocal cords; blocks the passage of food through the actions of the glottis
17)	________________	pathogen-filled mucus which is expelled through the mouth
18)	________________	potentially dangerous condition in which a buildup of carbonic acid exists within the blood
19)	________________	reflex triggered by the larynx; used to rapidly remove the foreign items from the respiratory system before it reaches the lungs
20)	________________	the exchange of gases between the air and the blood
21)	________________	the exchange of gases between the blood and the cells
22)	________________	the larynx of males; the larger size of this organ in males produces an observable bulge within the neck
23)	________________	the opening between the laryngopharynx and the larynx
24)	________________	the primary access point for all air entering the respiratory system
25)	________________	the smallest air passageways leading into the lungs; capped off by microscopic alveoli

26)	______________	the use of oxygen by the cells for its functioning and their release of carbon dioxide gas as waste
27)	______________	throat; attached to the nasal cavity and divided into three separate areas
28)	______________	two branches directly attached to the trachea which direct air movement eventually into both lungs
29)	______________	two external openings of the nose
30)	______________	two pairs of tissues which are stretched horizontally across the larynx; vibrations of these cords create the pitch and volume of the voice
31)	______________	upper section of the pharynx; always remains open unlike the remaining sections of the pharynx

Choose the correct answer from the following questions:

1) **The nasal cavity is separated from the tongue by:**
   A) the sinuses
   B) both the hard and soft palate
   C) the hard palate
   D) both the sinuses and hard palate
   E) the soft palate

2) **Exchange of both oxygen and carbon dioxide through the alveoli occurs by:**
   A) active transport
   B) diffusion
   C) facilitated diffusion
   D) osmosis

3) **After passing through the trachea during inhalation, air travels next through the:**
   A) larynx
   B) bronchi
   C) bronchioles
   D) pharynx
   E) alveoli

4) **Respiratory acidosis is typically caused by which of the following actions?**
   A) extremely slow breathing
   B) extremely fast breathing
   C) extremely deep breathing
   D) irregular breathing

5) **The flap of elastic cartilage that protects food from entering the larynx when swallowing is the:**
   A) thyroid cartilage
   B) Adam's apple
   C) epiglottis
   D) glottis
   E) trachea

6) **What is the role of mucus in the nasal cavity:**
   A) trap incoming bacteria and other foreign debris
   B) lighten the skull
   C) act as a resonance chamber for speech
   D) increase olfaction

Application Question:

During hyperventilation, a person breathes either faster or deeper than normal. This action rapidly removes a large amount of carbon dioxide from the blood. A side effect from hyperventilating for long periods of time is dizziness and/or fainting due to a decreased volume of oxygen reaching the nervous system. Would you expect the pH of the blood from a hyperventilating person to be increased or decreased? What effect do you believe this pH level has on the diameter of blood vessels to the brain at it relates to the symptoms of hyperventilation?

Chapter 23

Respiratory System – Part II

In the previous chapter, you learned that the alveoli were "balloon-like" in structure. Elastic fibers within the alveoli allow them to stretch outward during inhalation, much like a balloon. During exhalation, these air-filled containers stretch back to their normal size. This motion is one of the central concepts we will explore in this chapter which will focus primarily on the mechanics of...

Breathing

As you should already know by now, the act of breathing involves the movement of air into and out of the respiratory system. You learned about the major organs and tissues involved with this process in the last chapter. However, air does not simply move in and out of the body. It requires some energy to get the job done!

If you were to measure the amount of air that you inhale with every breath, it would have a volume of ~500 mL which is a little more than one US pint. This volume is known as the **tidal volume** and it is inhaled and exhaled around 12-18 times each minute...

...this adds up to hundreds of millions of breaths in an average lifetime!

This number is based upon an average human adult male who has a **lung capacity** of around six liters (~1.5 gallons) of air which is the maximum amount of gas the body can hold within its alveoli. This number is smaller for adult women who have a lung capacity of around 4 liters (~1 gallon).

Even if you attempted to exhale all of the air of your lungs after your deepest breath possible (a volume known as the **vital capacity**), you would still have approximately 20% of your total lung capacity remaining within your lungs. This remaining volume is known as your **residual volume**.

The figures you just read about are only averages within the human population. Several factors can influence our breathing in addition to those associated with our gender:

Individuals with larger lung capacities

Tall people, non-smokers, non-obese, and living in higher altitudes

Individuals with smaller lung capacities

Shorter people, smokers, obese, and living in lower altitudes

Taller people, simply put, tend to have larger lungs than shorter people. Therefore, it is to be expected that these individuals have larger lung capacities. The damage caused by smoking to alveoli prevents these inflatable tissues from functioning properly. The high temperatures and chemicals found within the smoke easily destroys or prevents alveoli from receiving air from the bronchioles. An increased amount of **adipose tissue**, otherwise known as fat, surrounds and compresses the lungs which prevent them from inflating to their maximum levels. This lowers the lung capacity of the individual as they are forced to breathe more quickly and shallowly to obtain enough oxygen for their body. However, these actions cause another problem you learned about in the last chapter –high carbon dioxide levels in the blood.

What does altitude have to do with lung capacity?

This is a good question that requires a little more explanation about the presence of oxygen within the atmosphere. The higher in altitude you travel, the "thinner" the air becomes. Although there is no real "thinness" to the air, this phrase is used to describe a reduction in the amount of air molecules in higher altitudes. This reduction also includes the amount of oxygen as well!

Individuals who live in higher altitudes tend to develop larger lung capacities to compensate for the lack of oxygen in their environment. This increased lung capacity allows them to process more air (and more oxygen) than individuals at lower altitudes.

It's time to look at an organ which is directly involved with the process of breathing...

the Diaphragm

The **diaphragm** is a dome-shaped plate of skeletal muscle that extends across the bottom of the ribs. Both the heart and lungs rest upon the top of this muscular dome. The diaphragm contracts (flattens) during the process of inhalation. This action allows the lungs to be lowered into the chest as more room is being provided. As the diaphragm contracts, several groups of **external intercostal muscles** between the ribs contract as well. The movement of these muscles causes the ribs to expand, thereby allowing the lungs to expand in size as well.

Contraction of both the intercostal muscles AND the diaphragm provide more room for the lungs to expand within the chest!

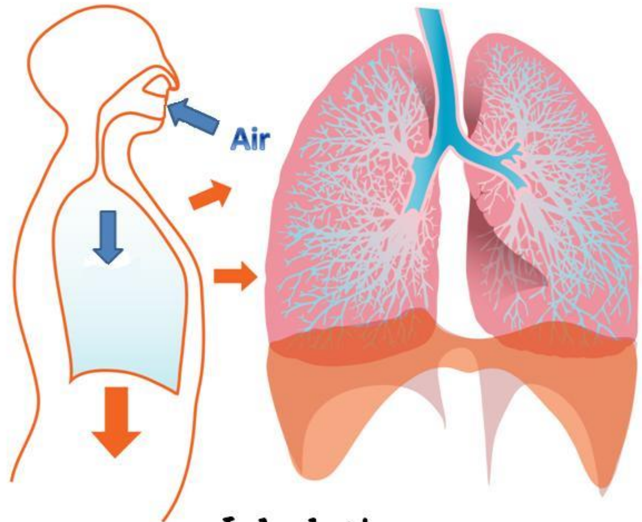
Since external intercostal muscles act to expand the ribs, another group of muscles, the **internal intercostal muscles**, must counteract this action. When the internal intercostal muscles contract, the ribs are brought closer together which compresses the lungs and reduces the amount of space within the chest. This action correlates with the relaxing of the diaphragm which pushes the lungs upwards into the chest. Both of these actions take place during the process of exhalation.

So how is air moved in and out of the lungs throughout all this movement?

To answer this question, we need to look once again at the atmosphere. At any given time your body is being bombarded by fast moving molecules in the air. Every time one of these molecules slams into you (or into anything for that matter) a small amount of pressure is generated. This is known as **air pressure** and has an average value of around 14.7 pounds per square inch.

What does this have to do with how air gets in and out of your lungs?

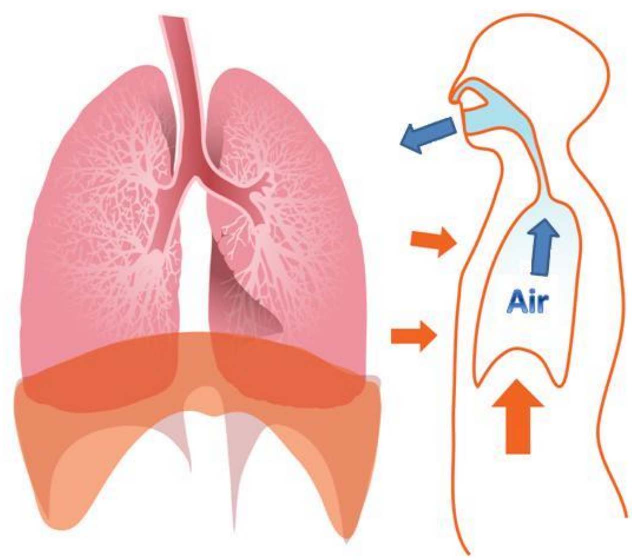
Well... during inhalation your diaphragm and external intercostal muscles both contract, creating more space for your lungs to expand. But what forces the lungs to expand? Since the air pressure outside of your body is greater than the reduced air pressure within your chest, air is forced into your lungs from the atmosphere, therefore, causing your lungs to expand.



Inhalation

If you recall from your activity in the last chapter, there is an inverse relationship between the volume and pressure of a gas. An increase in the volume of your lungs during inhalation causes a decrease in air pressure within the lungs.

When you exhale, the diaphragm relaxes and the internal intercostal muscles contract which decreases the size of your chest. This decreased volume within your chest increases the air pressure within your lungs to a level that is slightly greater than the air pressure of the atmosphere. When this occurs, the air within the lungs is forced out of the lungs and back into the atmosphere.



Exhalation

The decrease in the volume of your lungs during exhalation causes an increase in air pressure within the lungs.

As you learned back in Chapter 9, the central nervous system plays a key role in regulating all of the functions within the human body. More specifically, it is the medulla oblongata and the pons of the brain which stimulate the contraction of the diaphragm and intercostal muscles to induce inhalation and exhalation. More specifically, groups of neurons within the oblongata known as the **dorsal and ventral respiratory groups** initiate the contraction of the diaphragm and intercostals, respectively. A different group of neurons within the pons – the **pontine respiratory group**, regulates the tidal volume of air during each inhalation. The pontine group signals for the process of exhalation to begin when it detects a maximum tidal volume has been reached.

The respiratory system is responsible for two more functions which are vital to our survival. The first of these functions we have explored in a previous chapter:

Olfaction

Olfaction is the scientific term which describes our ability to smell. You learned back in Chapter 11 that specialized neurons called chemoreceptors are responsible for our ability to detect different odors in the environment. Each chemoreceptor resembles a finger-like projection which lines the nasal cavity and contains one of nearly 4000 molecular "locks". These locks can only be opened by specific molecular "keys" found on the surface of substances which are inhaled.

The last function of the respiratory system we will be exploring allows us the capability of communication:

Voice production

The length, tension, and thickness of the vocal cords within the larynx all are responsible for the sounds one can make. Simply put, the air that moves through the larynx causes the vocal cords to vibrate. These vibrations cause the unique sounds that come out of our larynx in a process known as **phonation**. This is only one step in our production of sound which also requires the *adjustment* of sounds as air is passed through the pharynx, nasal cavity, and sinuses. Both phonation AND the adjustment of sounds through phonation gives the voice a distinctive pitch and sound.

Here is something else that is pretty cool about your voice that you may not have known about...

What you believe to be the sound of your own voice is really not the sound that anyone else truly hears. What do I mean by this? Well, have you ever heard your own voice on a recording? I would be willing to guess that the voice you heard sounded a little different than what you are used to hearing when you speak, right? This difference is not because of a faulty recording device. It is because whenever you speak, the vibrations caused by your vocal cords cause all of your bones and teeth to vibrate as well. And, since your sense of hearing is caused by the vibrations received by your middle and inner ear, the sound you "hear" coming out of your voice is really a mixture of the sounds you are producing AND the vibrations which exist within your body. These extra vibrations do not exist when you are listening to your recorded voice or when other people hear your voice. Therefore, what you perceive to be the sound of your voice can only be heard by yourself. Weird, huh?

Okay, let's get back to the anatomy and physiology of your voice…

It is without doubt that you have noticed the differences in pitch between the voices made by younger and older people as well as between the sexes. The pitch of one's voice explains how high or low it sounds. The reason for this difference is due to a difference in vocal cord length. Typically, vocal cords are longer in men than in women. Male vocal cords are approximately 1 in (2.5 cm) in length which is considerably larger to average length of 0.17 inches (0.4 cm) in women. This increased length results in a much lower pitch in the male voice. Children also maintain a higher pitch in their voice as their vocal cords are still developing. As they mature, their vocal cords lengthen which deepens the sound of their voice.

In the next two chapters, you are going to study a different pathway after you pass through the mouth and throat. It's time to explore the…

Digestive System

Anatomy & Physiology - Connections

How the following body systems affect the respiratory system		How the respiratory system affects the following body systems	
Integumentary	Protects the upper respiratory tract which is exposed to the environment; hair within nasal cavity filters incoming air	Provides oxygen and removes carbon dioxide from tissues	**Integumentary**
Skeletal	Protection for lungs; movement of ribs assists in breathing	Provides oxygen and removes carbon dioxide from tissues	**Skeletal**
Muscular	Muscles release carbon dioxide gas to be removed; intercostal muscles responsible for movement of ribs	Provides oxygen and removes carbon dioxide from muscular tissues	**Muscular**
Nervous	Groups of neurons regulate the process of inhalation and exhalation	Provides oxygen and removes carbon dioxide from nerve cells	**Nervous**
Endocrine	Epinephrine opens air passages widely to increase intake of oxygen	Production and secretion of ACE which increases blood pressure	**Endocrine**

Cardiovascular	Transports gases via red blood cells between lungs and body tissues	Production and secretion of ACE which increases blood pressure; bicarbonate ions can act as a buffer to raise blood pH	**Cardiovascular**
Immune	Tonsils and lymph nodules trap and destroy foreign pathogens as they enter the digestive system	Layers of mucus within upper respiratory organs trap invading pathogens as they enter the body	**Immune**

Match the following vocabulary terms with their correct definition:

adipose tissue
air pressure
diaphragm
dorsal/ventral respiratory groups
external intercostal muscles
internal intercostal muscles
lung capacity
olfaction
phonation
pontine respiratory group
residual volume
tidal volume
vital capacity

1)	______________	a dome-shaped plate of skeletal muscle that extends across the bottom of the ribs; contraction/relaxation is the cause for inhalation/exhalation
2)	______________	approximately 20% of the remaining air within the lungs after the vital capacity has been exhaled
3)	______________	fat
4)	______________	group of neurons within the pons which regulate the tidal volume of air during each inhalation
5)	______________	groups of muscles between the ribs which allow the ribs to expand during inhalation
6)	______________	groups of muscles between the ribs which compresses the ribs, allowing for the process of exhalation
7)	______________	groups of neurons within the oblongata; initiate the contraction of the diaphragm and intercostal muscles
8)	______________	maximum volume of air exhaled after taking the deepest breath possible

9)	______________	pressure generated when air molecules slam into a structure; average air pressure is ~14.7 pounds per square inch
10)	______________	production of unique sounds from the vibration of vocal cords
11)	______________	term which describes the ability to smell
12)	______________	the amount of air inhaled with every breath
13)	______________	the maximum amount of gas the body can hold within its alveoli; six liters (~1.5 gallons) of air is normal for an average adult male

Choose the correct answer from the following questions:

1) In order to exhale:
- A) the internal intercostal muscles must contract
- B) both the internal intercostal muscles and the diaphragm must contract
- C) the external intercostal muscles must contract
- D) the diaphragm contracts

2) The pitch and volume of our voice is caused by the vibration of:
- A) trachea
- B) vocal cords
- C) glottis
- D) epiglottis

3) The air that moves in and out of the lungs during normal, quiet breathing is called
- A) Tidal volume
- B) Inspiratory reserve
- C) Vital capacity
- D) Lung capacity

4) Lung capacity is:
- A) vital capacity minus the residual volume
- B) residual volume minus tidal volume
- C) vital capacity plus the residual volume
- D) tidal volume plus residual volume

5) **True or false:** Inspiration results when the diaphragm and external intercostal muscles relax.

6) **True or false:** The amount of air that can be forcibly exhaled after a normal expiration is the residual volume.

Application Question:

Every time you inhale, the gases within the air diffuse into your blood. Most of the oxygen gas is picked up by the hemoglobin on your red blood cells while a little is left dissolved in the plasma. As this gas is being transported through your cardiovascular system, chemoreceptors in the walls of the large arteries monitor oxygen concentration in the blood. A lowered amount of inhaled oxygen from the air, therefore, will trigger a response to breathe faster and deeper than normal. However, people with anemia do not generally exhibit an increase in respiratory rate or tidal volume despite a lack of oxygen being transported to the necessary tissues of the body. Why do you believe this phenomenon occurs?

Chapter 24

Digestive System – Part I

It's a good guess that you have never heard a person claim that he hates the practice of eating. Right? Now you may have heard of a person's hatred for the smell or taste of broccoli, spinach, fish, or other types of foods; and, you likely have heard someone complain about the process of cooking or cleaning up afterwards. But you rarely ever hear of someone complaining about how much of a burden the physical act of eating can be.

This week is all about what happens to that slice of pizza after you first put it in your mouth – and what happens to it when you see it once again (ewww...) as it travels through your...

Digestive System

You have approximately 30 feet of "plumbing" in your body from the opening of your mouth to your **anus** (the final opening at the end of your digestive system). Your pizza travels through a series of steps all along the digestive system:

Ingestion, Peristalsis, Digestion, Absorption, and Defecation

All of these steps are vital to the central functions of the digestive system:

1) Break down the compounds within your food into smaller molecules.
2) Absorb these molecules into the bloodstream for use by cells for growth and reproduction.
3) Remove the excess and/or unneeded particles from the body.

This first main function - the breaking down of food into smaller molecules - will be the first stop in our study of the digestive system.

As your pizza is broken down into tiny molecules, it goes through three separate steps: **Ingestion** (the physical act of eating), **peristalsis** (slow, involuntary movements of smooth muscles which push food through the digestive tract), and **digestion** (conversion of large compounds into smaller, more usable molecules).

The organs which are responsible for these functions include the

Oral cavity, Esophagus, and Stomach

Together, these organs make up a division of the digestive system known as:

the Upper Gastrointestinal Track

The **oral cavity** (also known as the **buccal cavity**) includes the teeth, lips, tongue, **salivary glands**, and cheeks. Each of these structures provides a valuable role in the digestive process of our food.

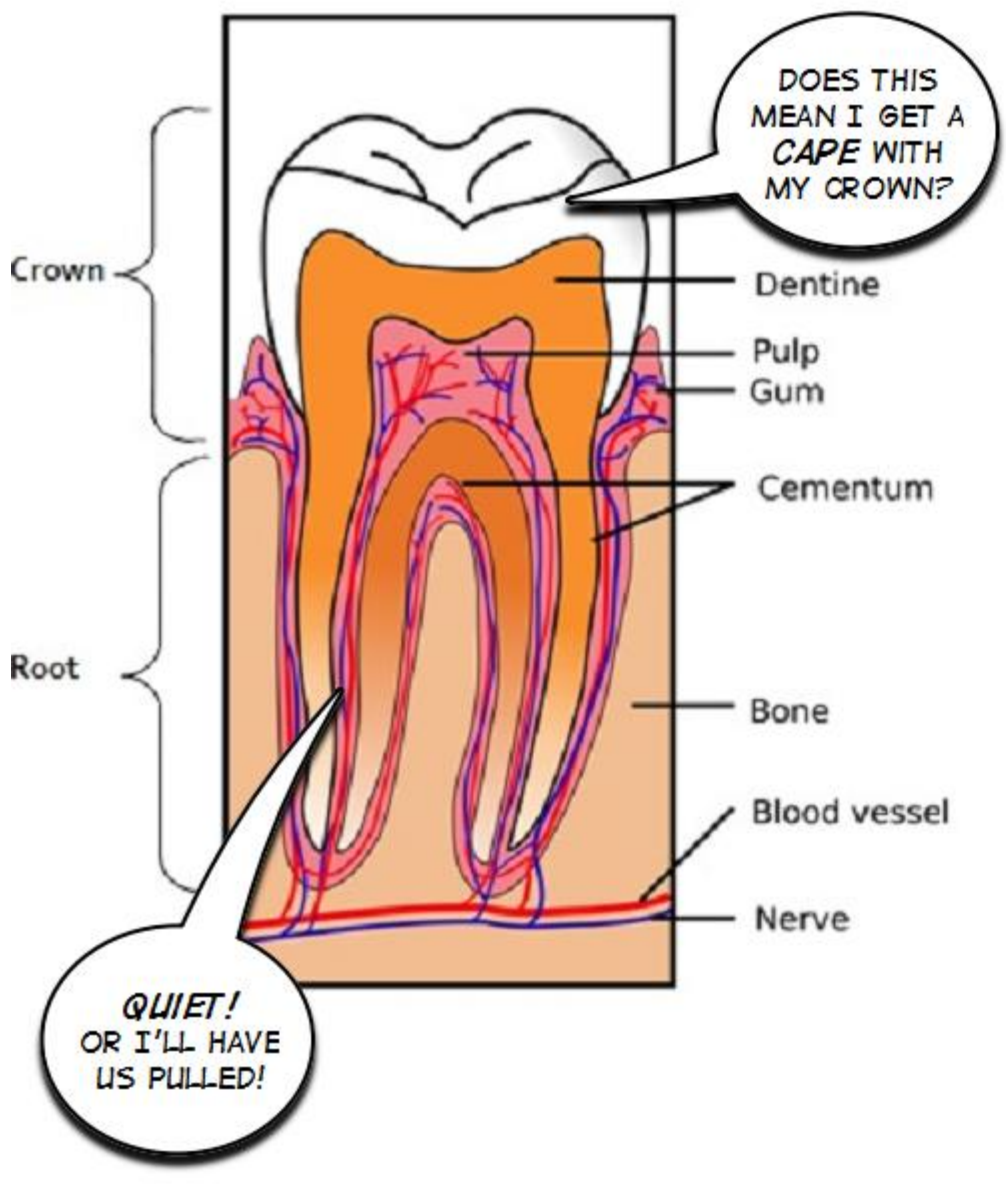
Teeth

All of your teeth are made up of two different parts – the **crown** and the **root**. The crown is the visible white part of the tooth that you (hopefully) brush a couple of times a day. The root is found under your gums and acts as an anchor to the bones of the skull.

There are a total of three different types of teeth within your mouth:

Incisors, Cuspids (canines), and Molars

Each of these different types of teeth has a different shape and performs different functions. The **incisors** are the eight teeth in the front of your mouth (four on top and four on bottom) and have a wedge-shape. This design is perfect for cutting through food. The **canines** are the four sharpest teeth in your mouth and are located on either side of your incisors. These teeth are used to shred or tear food apart. Finally, the largest group of teeth in your mouth, the **molars**, consists of 20 teeth (ten upper and ten lower) which have flattened crowns. These teeth are used to crush and grind our food into a pulp. The entire act of chewing is also known as **mastication**.



Tongue, Salivary glands, and Cheeks

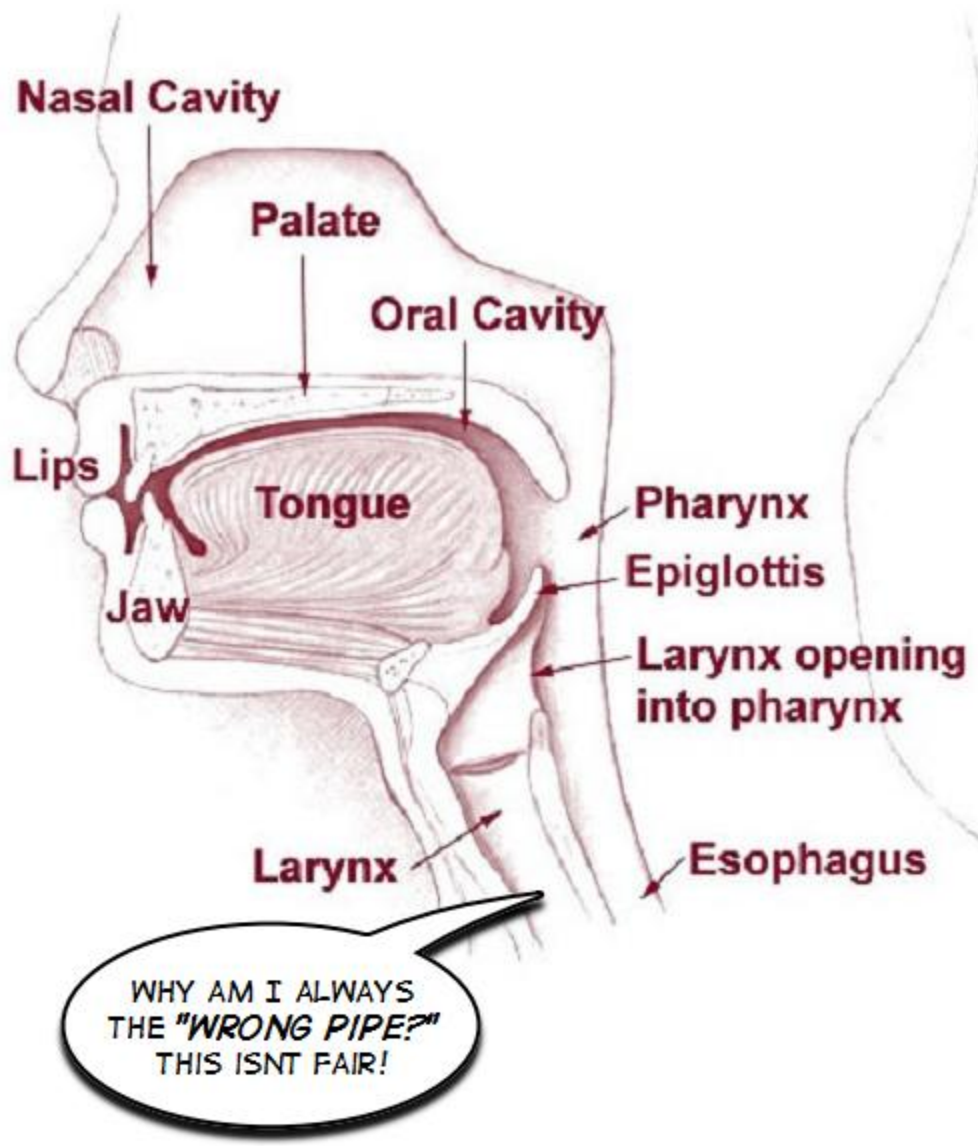
As you learned back in Chapter 11, your tongue is loaded with bundles of specialized cells called taste buds which are responsible for detecting the thousands of individual flavors which exist in the world. The skeletal muscles which make up the tongue along with the cheeks direct the food in our mouth onto the surface of the molars. During this time, the salivary glands secrete a solution of **saliva** into mashed food to keep it moist. This pulverized mixture is then rolled into a round mass known as a **bolus** by the tongue.

Your body produces an average of two cups (500 mL) of saliva per day. This solution is composed of dissolved ions (atoms which have lost or gained electrons), mucus, antibodies, and **enzymes**. Enzymes are large molecules that trigger thousands of chemical processes within the human body. The most important enzyme found within saliva that assists the digestive system is **amylase**. Most of the carbohydrates we eat are very large and difficult to digest. An example of this type of complex carbohydrate is <u>starch</u> which is commonly found in flour, rice, cereal, and potatoes. The enzyme amylase breaks down these complex carbs into smaller molecules that can be later absorbed by the digestive track.

Once the bolus is formed, it is ready to be moved into the throat!

The chewing of our food is completely voluntary and is the first step in the act of swallowing. You have full control over what happens to your food as you are chewing it. This is a good defense if you taste something bad within your food such as spoiled dairy products (again – ewww…) However, once the bolus enters the pharynx (throat), the act of swallowing your food is controlled by involuntary muscle contractions which move your food through the digestive system. We'll come back to this involuntary motion in a short while…

After the bolus passes through the pharynx, the epiglottis covers the top of the larynx to prevent the food from entering the trachea. If you have ever had your food "go down the wrong pipe", your epiglottis was unsuccessful in closing off the trachea in time. The best prevention for this is to slow down when chewing your food and to keep your mouth closed. Yep! Your parents may not have known the science behind this dinnertime rule, but the incomplete chewing of food is the main cause of choking. Laughing and talking with your mouth full of food is an easy way to inadvertently swallow your food too quickly and have it lodged in your trachea.



Two other actions take place as the bolus begins its journey through the throat, and both cut off the available escape routes for your food.

First, your tongue moves to the roof of your mouth which closes off the throat from the oral cavity; and, second, the piece of tissue that dangles in the back of your throat (the **uvula**) moves upward to block your food from traveling upwards into the nasal cavity.

After passing over the epiglottis (and bypassing the larynx), the bolus will enter the next organ within the digestive system...

the Esophagus

You first learned about the esophagus back in Chapter 2 when we explored the involuntary contractions of smooth muscle. More specifically, you learned that the esophagus is a muscular tube that carries your food to the stomach. This 10 inch (25 cm) long pathway continues to secrete mucus along its length, further lubricating the bolus as it is pushed towards the stomach.

Yep! Your food is PUSHED towards the stomach!

The involuntary contraction of smooth muscle within the esophagus is known as **peristalsis** and produces a wave-like motion within the smooth muscle. This motion pushes the bolus towards the stomach at a rate of 1.6in/sec (4cm/sec).

Much like the tongue and uvula protect food from moving in a backward direction, the esophagus contains structures that perform this same function. Two valves (also known as **sphincters**) trap all food and liquids within its walls and guarantees the movement of all substances towards the stomach. All food and liquids enter the esophagus through the **pharyngoesophageal sphincter** and exits through the **gastroesophageal sphincter** before entering the next stop within the digestive system:

the Stomach

The **stomach** is a J-shaped muscular organ which lies against the diaphragm, and can reach up to 10 inches (25 cm) in length and 6 inches (15 cm) in width.

The stomach is much more than simply a storehouse of food as it performs four other vital functions:

1) The stomach provides a hazardous environment for any foreign pathogens within our food.
2) Continues to breaks down food into molecular-sized portions.
3) Facilitates the chemical breakdown of compounds with the use of acid and enzymes.
4) Produces the protein known as **intrinsic factor**.

After passing through the esophagus and the gastroesophageal sphincter, the bolus is immersed in a sea of chemicals within the stomach, each maintaining a specific function in the digestive process.

One family of chemicals that are secreted by the stomach are called **proteases**. Proteases are enzymes which break down the large organic molecules of protein within our food.

You have heard a lot about proteins throughout this book. Proteins are very large molecules that make up significant portions of all living cells and carry out many of their functions as well. Because of their massive size, the intestines are unable to absorb them into our bloodstream. Therefore, proteases break down these large molecules into smaller pieces that can be more easily absorbed and used by our body.

One of these proteases, **pepsin**, can only begin digesting protein in a very acidic environment. Once activated by an acid, pepsin attacks many different proteins within our food to break them into smaller pieces.

Where does this acidic environment come from?

Each day the stomach produces approximately 6 cups (1.4 L) of a clear fluid called **gastric juice** which is a solution of hydrochloric acid, pepsin, mucus, and intrinsic factor. The acidity of gastric juice destroys most pathogens that enter the stomach and efficiently breaks down proteins as well!

Peristalsis continues within the stomach as its smooth muscle-lined walls continue its wave-like motion. This constant movement churns the bolus within the gastric juice and continues to break it down into smaller and smaller particles. Within one to several hours, the food has been pulverized into a thickened "soup" of material which is now called **chyme**. Up to four cups (~1 L) of chyme may exist within a human stomach during the digestive process.

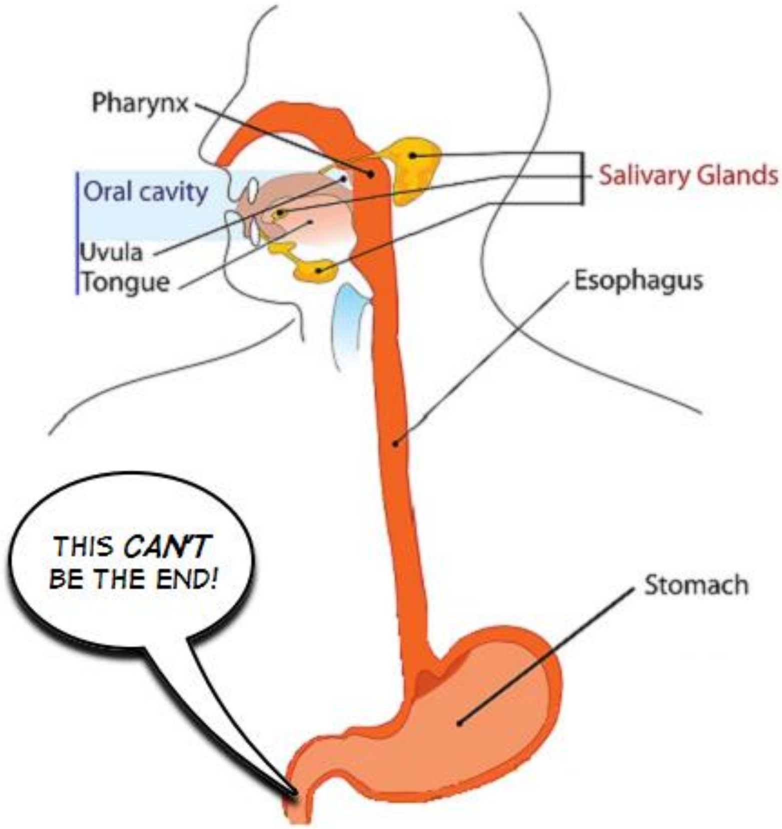
So what about this "intrinsic factor"?

Intrinsic factor is a protein secreted by the stomach that helps the body to absorb vitamin B12 from our food. This vitamin is a very large and complex molecule that is normally involved with the chemical reactions taking place within every living cell of the human body. Its main focus rests within the functioning of the central nervous system and the formation of red blood cells. Vitamin B12 cannot be absorbed by the digestive system without being bound to the intrinsic factor protein.

Since the stomach is filled with a very strong acid, it has to be protected from being destroyed by its own gastric juice!

This is where our mucus comes back into the story. The inner walls of the stomach are lined with a protective layer of mucus that has an alkaline pH. This protective layer prevents the acid from coming in contact with the stomach tissue itself. And, since we are on the topic of stomach tissue, this organ is also very effective at recycling and creating new cells (several hundreds of thousands per minute) to constantly replenish old tissues.

At this rate, your body could produce a new stomach every three days.



Much like the oral cavity and the esophagus, the stomach also utilizes special structures to prevent its contents from being forced backwards through the digestive system. The gastroesophageal sphincter, located at the top of the stomach, prevents acid from entering the esophagus and damaging its lining. Another valve exists at its base which is known as the **pyloric sphincter.** This valve is a little different from other valves we have studied so far as the pyloric sphincter is never completely closed. Water and a small amount of the highly acidic chyme can pass through this valve continually into the next organ within the digestive system...

the Small Intestine

...but you are going to have to wait until next week to see what happens next!

Match the following vocabulary terms with their correct definition:

oral cavity (buccal cavity)	**crown**
gastroesophageal sphincter	**digestion**
pharyngoesophageal sphincter	**mastication**
pyloric sphincter	**enzymes**
salivary glands	**molars**
gastric juice	**pepsin**
incisors	**peristalsis**
ingestion	**proteases**
intrinsic factor	**root**
amylase	**saliva**
anus	**sphincter**
bolus	**stomach**
canines	**uvula**
chyme	

1)	______________	a clear solution of hydrochloric acid, pepsin, mucus, and intrinsic factor within the stomach
2)	______________	a protease which can only digest protein in a very acidic environment
3)	______________	a protein secreted by the stomach that helps the body to absorb vitamin B12 from food
4)	______________	a solution produced by the salivary glands; made of water, dissolved ions, mucus, antibodies, and enzymes
5)	______________	a valve
6)	______________	conversion of large compounds into smaller, more usable molecules
7)	______________	enzyme which breaks down complex carbs to be later absorbed by the digestive track
8)	______________	enzymes which break down the large organic molecules of protein within food

9)	______________	found under the gums and acts as an anchor to the bones of the skull
10)	______________	glands within the oral cavity which secrete a solution of saliva into mashed food to keep it moist
11)	______________	J-shaped muscular organ responsible for preventing the spread of harmful pathogens, digestion of food, chemical breakdown of compounds, and production of intrinsic factor
12)	______________	large molecules that trigger thousands of chemical processes within the human body
13)	______________	part of the upper gastrointestinal track; includes the teeth, lips, tongue, salivary glands, and cheeks
14)	______________	piece of tissue that dangles in the back of the throat; moves upward to block food from traveling upwards into the nasal cavity
15)	______________	pulverized mass of food with a consistency of thickened "soup"
16)	______________	round mass of pulverized food created during mastication
17)	______________	slow, involuntary movements of smooth muscles which push food through the digestive tract
18)	______________	the act of chewing
19)	______________	the eight teeth in the front of the mouth (four on top and four on bottom) and have a wedge-shape
20)	______________	the final opening at the end of the digestive system
21)	______________	the four sharpest teeth in the mouth and are located on either side of the incisors
22)	______________	the largest group of teeth in the mouth; consists of at least 20 teeth (ten upper and ten lower) with flattened crowns; used to crush and grind food into a pulp
23)	______________	the physical act of eating

24)	_______________	the visible white part of the tooth
25)	_______________	valve in which food and liquids pass through before entering the esophagus
26)	_______________	valve in which food and liquids pass through before entering the stomach
27)	_______________	valve located at the base of the stomach; never entirely closed; allows water and chyme to pass through into the small intestine continually

Choose the correct answer from the following questions:

1) The release of food from the esophagus into the stomach is regulated by the:

A) pharyngoesophageal sphincter
B) hepatopancreatic ampulla
C) buccal cavity
D) gastroesophageal sphincter

2) Which one of the following represents the correct order through which food passes in the upper gastrointestinal track?

A) pharynx, mouth, esophagus, stomach
B) pharynx, mouth, stomach, esophagus
C) mouth, stomach, esophagus, pharynx
D) mouth, esophagus, pharynx, stomach
E) mouth, pharynx, esophagus, stomach

3) Which one of the following is NOT involved in the act of swallowing:

A) pharynx
B) tongue
C) soft palate
D) larynx
E) esophagus

4) The number of permanent teeth within a full set of adult teeth is:

A) 36
B) 20
C) 28
D) 32
E) 24

5) Intrinsic factor is a protein secreted by the stomach needed to absorb ___________ from our food.

A) vitamin K
B) vitamin B12
C) vitamin C
D) vitamin A
E) vitamin D

6) Amylase is an enzyme that is only able to digest:

A) starch
B) minerals
C) vitamins
D) fat
E) protein

Application Question:

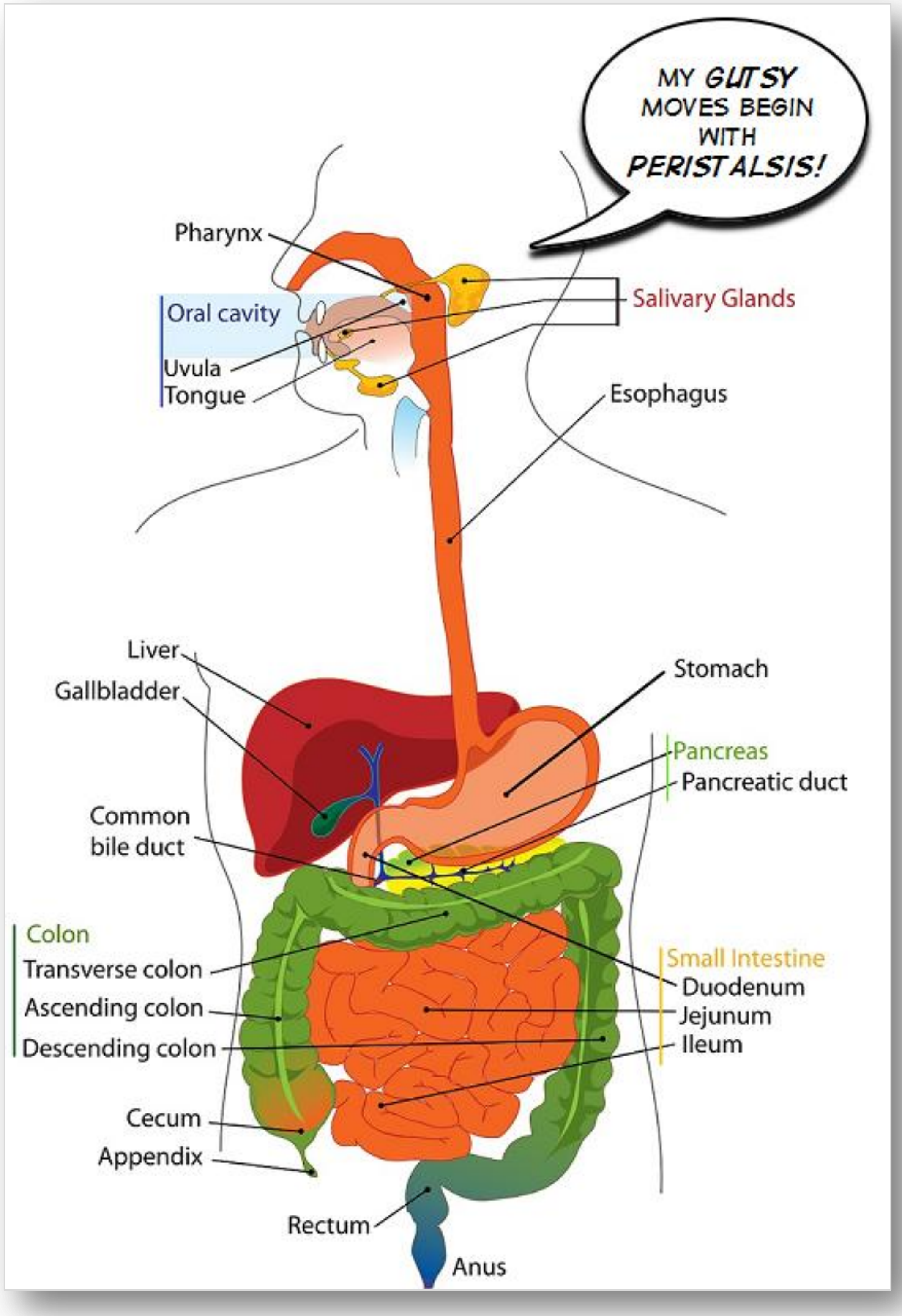
Achlorhydria is a condition in which the stomach stops producing hydrochloric acid and other secretions. What effect would achlorhydria have on the digestive process? On red blood cell count?

Chapter 25

Digestive System – Part II

In the last chapter, you explored the first three steps of your food's journey through the digestive system - ingestion, peristalsis, and digestion. You also learned how the upper gastrointestinal tract, consisting of the oral cavity, esophagus, and stomach, accomplishes these vital tasks.

This week, you will complete your study of the digestive system by looking at the **lower gastrointestinal tract (GI)** and how it allows for the functions of **absorption** (movement of water and nutrients from the chyme into the bloodstream) and **defecation** (removal of waste products.)



The two organs of the lower gastrointestinal tract are the **small intestine** and **large intestine**. The pancreas, **gall bladder**, and **liver** are all organs which assist the digestive system even though they are not found within the digestive system's "plumbing." These three organs will appear throughout our discussion of the lower GI track which will begin with a study of the...

Small Intestine

The 22 foot-long (7 meters) small intestine is attached to the stomach through the pyloric sphincter and can be divided into three segments:

Duodenum, Jejunum, and Ileum

Duodenum

At 10 inches long (25 cm), the **duodenum** is the smallest section of the small intestine. As chyme passes through the stomach, the duodenum is the final area where food is prepared for absorption by the remaining two sections of the small intestine. Peristaltic contractions along the walls of the small intestines continue to propel the chyme forward as well as churning it with other chemicals that are introduced into this area. Where do these "extra" chemicals come from? Well...

It is within the duodenum where the digestive systems' secondary organs (pancreas, gall bladder, and liver) come into play...

You've heard of a couple of these organs already. In Chapter 16 you explored how the liver produces the main plasma proteins which regulate the level of water within the blood, antibodies which play a key role within the immune system, transport proteins which attach to and carry necessary chemicals around the body, and proteins needed for the protective clotting of our blood.

And, in Chapter 13, you learned how the pancreas produces the chemicals insulin and glucagon which are used to stimulate the liver to regulate the control of glucose within the blood.

The role of the liver and gall bladder in the digestive system

The liver is the second largest organ in the human body and weighs approximately 3 pounds (1.4 kilograms) in adults. In addition to the hundreds of functions performed by this organ, the liver's main contribution to the digestive system is in the development and secretion of **bile** into the duodenum. Bile is an alkaline solution that has the main function of breaking down large fat molecules into smaller molecules known as **fatty acids** which can be absorbed by the small intestine.

Bile is released by the liver and travels through tubes known as **bile ducts** towards the **gall bladder** which acts as a storehouse for bile. When needed, the gall bladder delivers its bile into the duodenum through the **common bile duct**. The alkaline nature of this fluid neutralizes the acidic chyme, making it able to travel through the rest of the small intestine.

The role of the pancreas in the digestive system

Every day, nearly 6.4 cups (1.5 liters) of highly alkaline **pancreatic juice** flows from the **pancreatic duct** until it merges with the common bile duct which eventually empties into the duodenum. Pancreatic juice contain a variety of digestive enzymes which are able to breakdown all categories of food - fats, carbohydrates, proteins, etc. within the chyme. Much like bile, these enzymes act like tiny "molecular scissors" which separate large molecules within the chyme into more readily absorbed nutrients.

After these "molecular scissors" are finished with the chyme, large carbohydrates are broken down into smaller sugars called **monosaccharides**; proteins are split into smaller molecules known as **amino acids**; and, as you have already learned, fats are reduced into fatty acids. All three of these smaller substances along with vitamins, minerals, salts, and water are tiny enough to be absorbed by the walls of the villi and into the adjacent capillaries where they can be pumped throughout the rest of the body by the circulatory system!

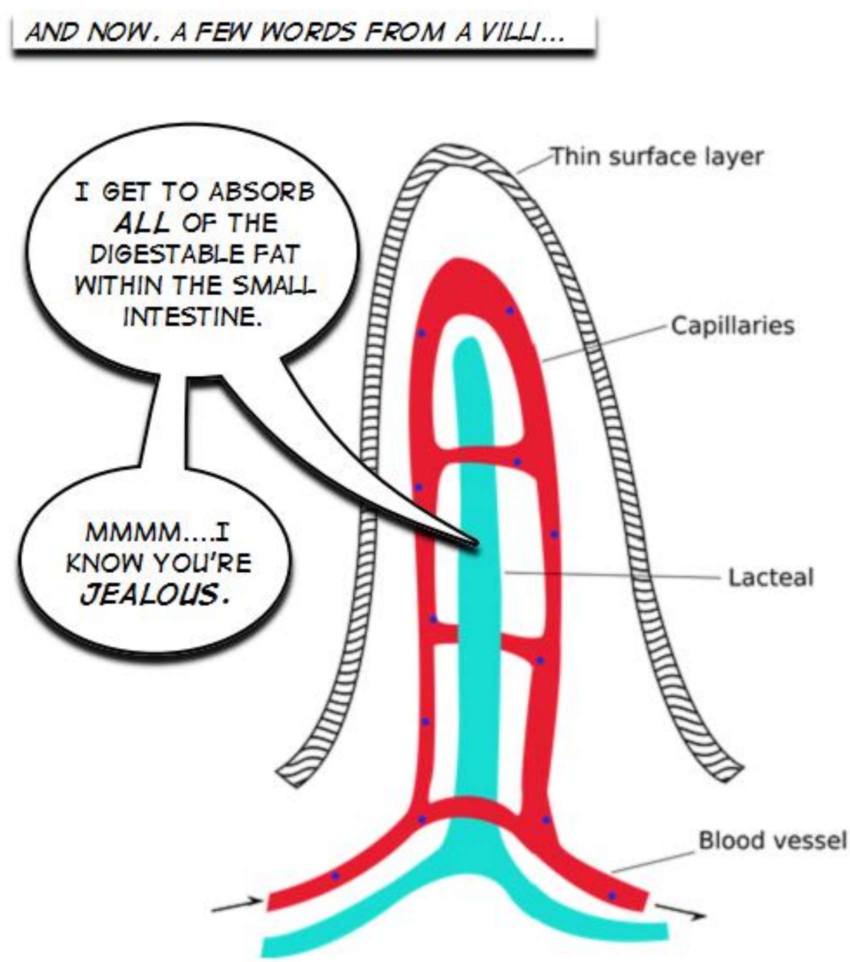
With all of these secondary organs assisting the duodenum, it may be easy to forget that you still have two more sections of the small intestine to explore! In fact, the final two sections of the small intestines are where most of the absorption of water and nutrients into the bloodstream and lymphatic system takes place. Nearly all of the water we ingest is absorbed by the next two sections of the small intestine beginning with the...

Jejunum

The **jejunum** is approximately 8 feet (2.5 meters) long and its inner walls are covered with tiny, finger-like projections called **villi**. Villi provide almost four times the amount of surface area within the jejunum, which increases the ability for the small intestine to absorb water and nutrients from the chyme.

How do these finger-like structures increase the surface area of the jejunum?

Imagine laying a paper ruler on the table and marking the length of the ruler on the table (don't do this at home or your parents will likely become angry!) This line represents the length of a section of small intestine within your body. Let's assume it measures 10 inches (25.4 cm) in length. Now imagine sliding one side of the paper ruler towards the other side, creating at first a dome and then a finger-like shape. The length of the ruler is still the same, right? However, this finger-shaped ruler cannot cover the 25.4cm length anymore, right? It would several of these bent rulers to cover the same length. This is identical to how villi increase the surface area within the jejunum (and ileum). Their finger-like shape line the inner walls of the jejunum and ileum which maximizes the amount of absorption that can take place.



Ileum

This last section of the small intestine is nearly 12 feet (3.5 meters) long and continues the work done by the jejunum by absorbing any remaining particles that happened to be missed. Within three to six hours will have passed from the time your food enters the small intestine until it reaches the **ileocecal valve** which is the gateway into the next organ of the digestive system:

the Large Intestine

You may think that the **large intestine** is much longer than the smaller intestine; however, this is not true. The names given to the small and large intestine refer to the diameter of these organs. Even though the large intestine is only 20% as long as the small intestine (5 feet or 1.5 meters), it is nearly three times as large in diameter. The small intestine is typically one inch (2.5 centimeters) in diameter as compared to the large intestine whose diameter is approximately three inches (7.5 centimeters).

Since the majority of water and nutrients are absorbed from the chyme by the small intestines, the large intestines are primarily a 12-36 hour storage area for materials that are not digested.

The large intestine is segmented into four parts:

Cecum, Colon, Rectum, and Anal canal

The **cecum** is a pouch-like structure which is attached to the small intestine via the ileocecal valve and receives the leftover chyme from the small intestine.

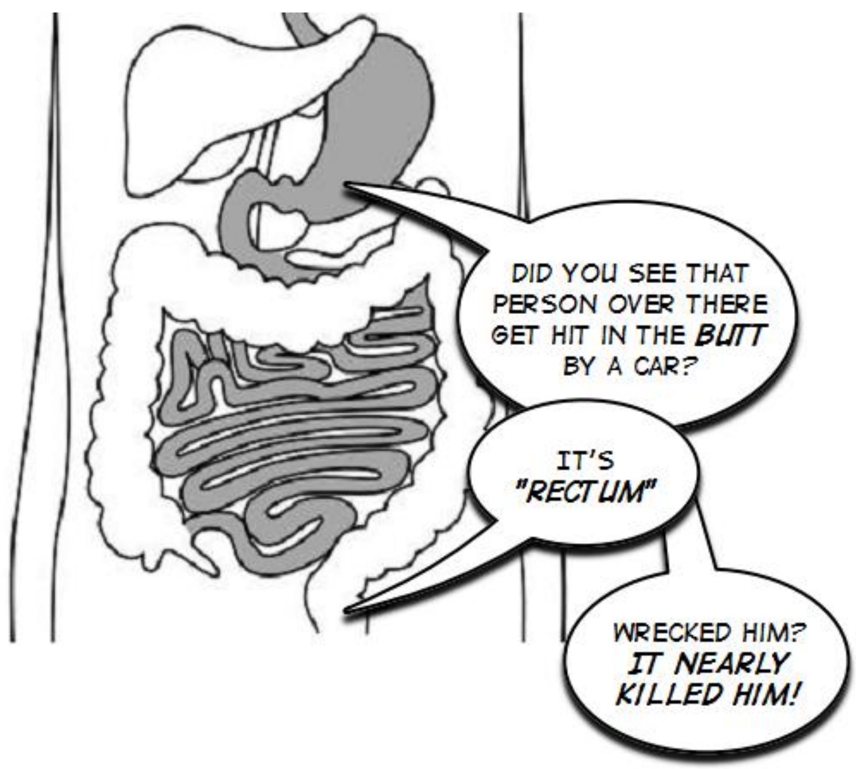
The **colon** is the longest area of the large intestine measuring up to four feet (1.2m) in length. Within the colon, leftover water, salt, and vitamins are absorbed through its walls.

Unlike the small intestine, no villi are found within the large intestine!

The remaining undigested materials are mixed with mucus and bacteria (**gut flora**) and are known as **fecal matter** (**feces**). Many bacteria such as *E. coli* and *Clostridium* are typically found within the colon as they can contribute to the final digestion of large sugar molecules into monosaccharides. During this process, bacteria release waste products as well, the most common being **flatus**, or intestinal gas. Each day, an average human produces 1 pint (473 milliliters) of flatus from the digestive action of intestinal gut flora.

The **rectum** is a temporary storage site for feces. Measuring approximately 4.7 inches (12cm) in length, this area expands with an increasing volume of waste matter. Upon the expansion of the rectum, a nerve impulse is sent to the central nervous system triggering the desire to defecate or expel the fecal matter from the body.

The **anal canal** is the final section of the large intestine and serves as a passageway for feces during defecation. This 1 - 1.5 inch (2.5 - 4cm) canal is surrounded by a muscular sphincter system which tightly traps the fecal matter inside the body before defecation through the opening at the end of the large intestine known as the anus.



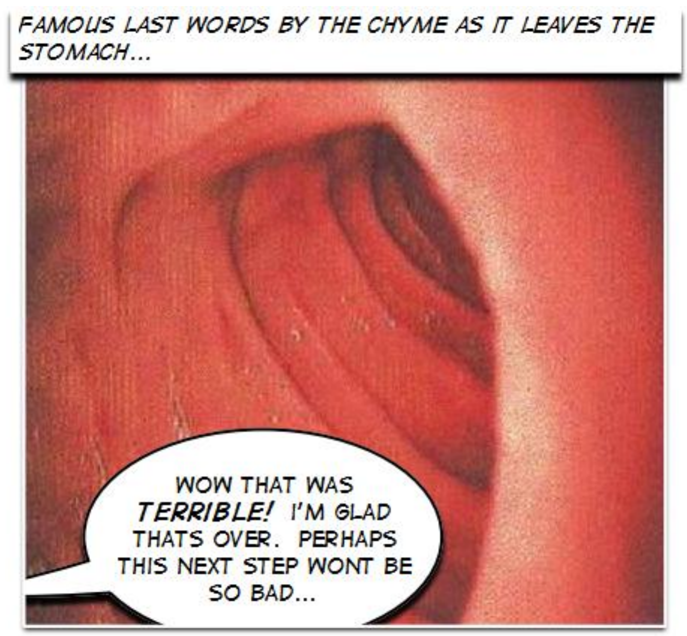
Approximately 5 ounces (150g) of feces are produced each day. Its characteristic brown color is caused by the presence of a waste product from the digestion of old red blood cells known as **bilirubin**.

As we end look at the small and large intestines, it is vital that you understand an additional role of the liver within the digestive system:

Every drop of blood that passes through the small and large intestines is filtered through the liver before returning to the heart!

Why is this important? Besides the liver producing and secreting bile, this vital organ is the biochemical control center for the entire body. Everything we eat and drink must be "checked" by the liver before it can be allowed to pass throughout the rest of the body. Liver cells remove nutrients for use by the body and store them if they are in excess quantities. It removes toxins from the blood and/or chemically alters them to become useful nutrients by our tissues. It also triggers the release of stored reserves of nutrients, such as sugar, if it detects a deficiency within the blood. It even produces the vitally important plasma proteins you explored in Chapter 16 which serve as enzymes, transport mechanisms, and as key components within the immune system.

These are just a few of its physiological traits that work to maintain homeostasis within our body. It is easily the most complex organ next to the brain! I hope you will take the time at some point to explore more about this amazing organ. A detailed explanation for all of its functions would easily fill most of this textbook alone...



That wraps up our exploration of the digestive system. Next week, we will be taking a look at how we expel the majority of our waste fluids through the urinary system!

Anatomy & Physiology - Connections

How the following body systems affect the digestive system		How the digestive system affects the following body systems	
Integumentary	Provides vitamin D which causes the absorption of calcium and phosphorus	Absorbs fat from food to be stored within the skin	**Integumentary**
Skeletal	Protection of all vital organs within digestive system; Mastication of food by the teeth	Absorbs calcium and phosphorus for use by bones; absorbs fat to be stored by the yellow bone marrow	**Skeletal**
Muscular	Smooth muscle tissue provides peristalsis for movement of food; skeletal muscles within tongue assist in mastication	Regulation of blood sugar and levels of fatty acids by the liver	**Muscular**
Nervous	Control over hunger and satiation; regulation of peristalsis throughout digestive system	Absorption of amino acids from food needed for production of neurotransmitters	**Nervous**

Endocrine	Production of epinephrine constricts sphincters within digestive system	Digestive enzymes insulin and glucagon secreted by the pancreas and regulates blood sugar levels	**Endocrine**
Cardiovascular	Transports nutrients and water from areas where they are absorbed into the liver for filtration	Regulates blood volume by absorbing fluids	**Cardiovascular**
Immune	Tonsils and lymph nodules trap and destroy foreign pathogens as they enter the digestive system	Gastric juice provide unfavorable environment for invading pathogens	**Immune**
Respiratory	Provides oxygen for functions of digestive organs	Absorption of carbohydrates and fats provide chemical energy for use during inhalation and exhalation	**Respiratory**

Match the following vocabulary terms with their correct definition:

absorption	**duodenum**	**liver**
amino acids	**fatty acids**	***lower gastrointestinal tract***
anal canal	**fecal matter (feces)**	**monosaccharides**
bile	**flatus**	**pancreatic duct**
bile ducts	**gall bladder**	**pancreatic juice**
bilirubin	**gut flora**	**rectum**
cecum	**ileocecal valve**	**small intestine**
colon	**ileum**	**villi**
common bile duct	**jejunum**	
defecation	**large intestine**	

1)	______________	~5 feet (1.5 meters) long organ characterized by a much larger diameter than the small intestine; storehouse for materials that are not digested although some leftover water and salts are absorbed in this organ before defecation
2)	______________	~8 foot (2.5 meters) long section of the small intestine; lined millions of villi; responsible for the absorption of the majority of nutrients from the chyme
3)	______________	22 foot-long (7 meters) organ; attached to the stomach through the pyloric sphincter and is responsible for most absorption of water and nutrients within the chyme
4)	______________	a pouch-like structure which is attached to the small intestine via the ileocecal valve and receives the leftover chyme from the small intestine
5)	______________	a storehouse for bile

6)	______________	alkaline solution produced by the liver; breaks down large fat molecules into fatty acids which can be absorbed by the small intestine
7)	______________	area of the digestive system below the stomach including the large and small intestines as well as secondary organs including the pancreas, gall bladder, and liver
8)	______________	final section of the large intestine and serves as a passageway for feces during defecation
9)	______________	gateway between the small and large intestine
10)	______________	highly alkaline fluid created by the pancreas; contains a variety of digestive enzymes which are able to breakdown all categories of food - fats, carbohydrates, proteins, etc.
11)	______________	intestinal gas released as waste products from gut flora
12)	______________	last section of the ileum; continues to absorb water and nutrients missed by the jejunum
13)	______________	longest area of the large intestine; leftover water, salt, and vitamins are absorbed through its walls without the use of villi
14)	______________	mixture of undigested materials in the colon including the gut flora
15)	______________	movement of water and nutrients from the chyme into the bloodstream
16)	______________	mucus and bacteria found within the undigested materials of the colon
17)	______________	passageway for pancreatic juice from the pancreas into the common bile duct
18)	______________	removal of waste products from the body
19)	______________	second largest organ in the human body ; contributes to the digestive system through the development and secretion of bile

20)	______________	small molecules of fat; can be created through the breakdown of larger fat molecules by bile
21)	______________	small sections/pieces of proteins; absorbed by the small intestine
22)	______________	small sugars created from larger carbohydrates
23)	______________	smallest section of the small intestine; final area where food is prepared for absorption
24)	______________	temporary storage site for feces
25)	______________	tiny, finger-like projections which provide additional surface area within the small intestine for nutrient absorption
26)	______________	tube which carries bile from the gall bladder into the duodenum
27)	______________	tubes between the liver and gall bladder which carry bile
28)	______________	waste product from the digestion of old red blood cells; gives feces its characteristic brown color

Choose the correct answer from the following questions:

1) The opening of the large intestine to the environment is called the:
- A) cecum
- B) colon
- C) anus
- D) ileum
- E) rectum

2) Which one of the following is the middle section of the small intestine:
- A) descending colon
- B) duodenum
- C) ascending colon
- D) ileum
- E) jejunum

3) Which one of the following is NOT a subdivision of the large intestine:
- A) anal canal
- B) colon
- C) cecum
- D) duodenum
- E) rectum

4) Which one of the following is NOT absorbed by the large intestine:
- A) vitamin K
- B) water
- C) salt
- D) some of the B vitamins
- E) protein

5) **The journey of chyme through the small intestine takes:**
   A) 10-12 hours
   B) 8-10 hours
   C) 6-8 hours
   D) 2-4 hours
   E) 3-6 hours

6) **Transport of digested products from the lower gastrointestinal tract into the bloodstream is called:**
   A) ingestion
   B) defecation
   C) digestion
   D) absorption

Application Question:

The colon occasionally can become impacted (blocked by feces.) Given what you know about the functions of the colon and the role of osmosis along the colon wall, predict the effect of this condition on the contents of the colon above (closer to the small intestine) the point of impaction.

Chapter 26

Urinary System – Part I

You ended the last chapter learning how excess waste products are expelled from the digestive system through the process of defecation. Although nearly 75% of your feces is made up of water (the rest is a mixture of undigested solids and bacteria), this volume of water does not make up **all** of the leftover/excess water in your body. Much of the water you ingest is absorbed by the intestines and is spread throughout your body through the cardiovascular system.

But how is all that water filtered while it is mixed within your blood? And how does the body know how much water to retain and how much to expel? These are questions that can be answered by exploring our next system:

the Urinary (Renal) system

The **urinary system** regulates and filters the volume and chemical contents of the blood and expels waste products from the body. In order to accomplish this last function, the urinary system has the vital task of producing, storing, and expelling a solution known as **urine**.

Urine from a healthy individual is non-toxic and sterile, meaning it contains no bacteria. In fact, you could extract drinkable water from your urine in emergency situations

(I'm not going to tell you how for obvious reasons. Ewww...)

Urine is a solution of nearly 95% water and several other dissolved solutes. These include a large volume of the element nitrogen and a variety of other substances which are not usable by the body. The color, odor, and daily volume of urine vary according to the **hydration** (amount of water within the blood stream), diet, and health of the individual. On average, the volume produced by a person ranges between 1 to 2 liters (~4 to 8 cups) per day.

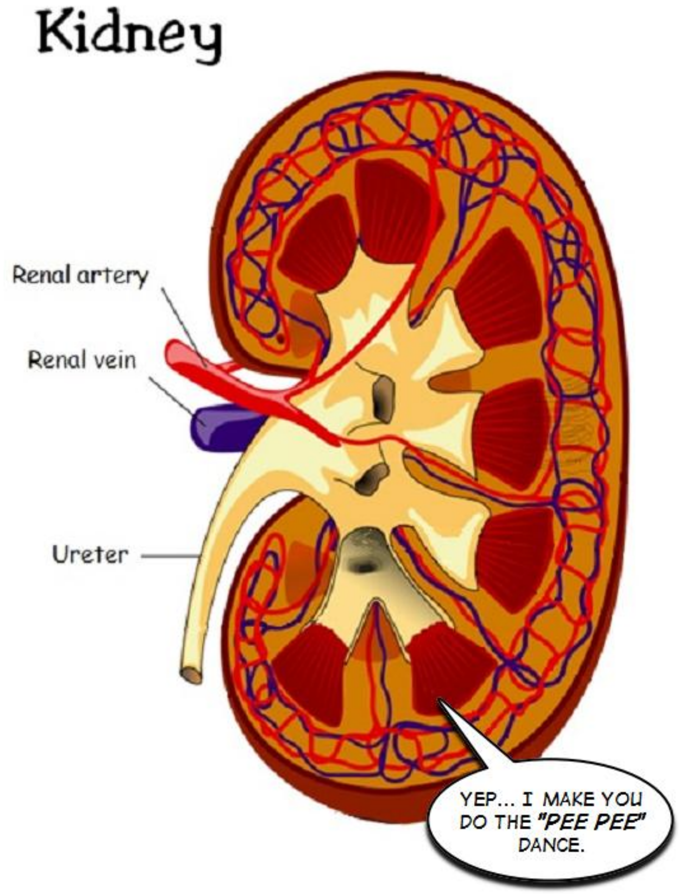
If we lose that much fluid each day, how much do we really need to put into our bodies every day?

An average adult requires 1-3 liters (~4-16 cups) of water every day. Most people would say that the majority of this water comes directly from some form of fluid that we drink. This is a correct statement; however, we do have other sources of water if we are following a well-balanced diet. For example, the food we eat contributes ~0.5-1 L (~2-4 cups) of water into our daily diet; and, the digestion of protein, fat, and carbohydrates by our digestive system produces another ~0.25-0.4 L of water per day as well. This means we require somewhere between 0.25-1.6 L (1-8 cups) of drinkable water in our daily diet each day if we are following a well-balanced diet. (Do you see a pattern here?)

By far, the major organs within the urinary system are known as the...

Kidneys

In the lower part of your back, inferior to the ribcage and on both sides of the spinal column are two fist-sized organs responsible for the production of urine. These bean-shaped organs, the **kidneys**, weigh about 5 ounces (150 grams) each and are connected to the cardiovascular system by **renal arteries** which enter the organs and **renal veins** which exit each kidney.



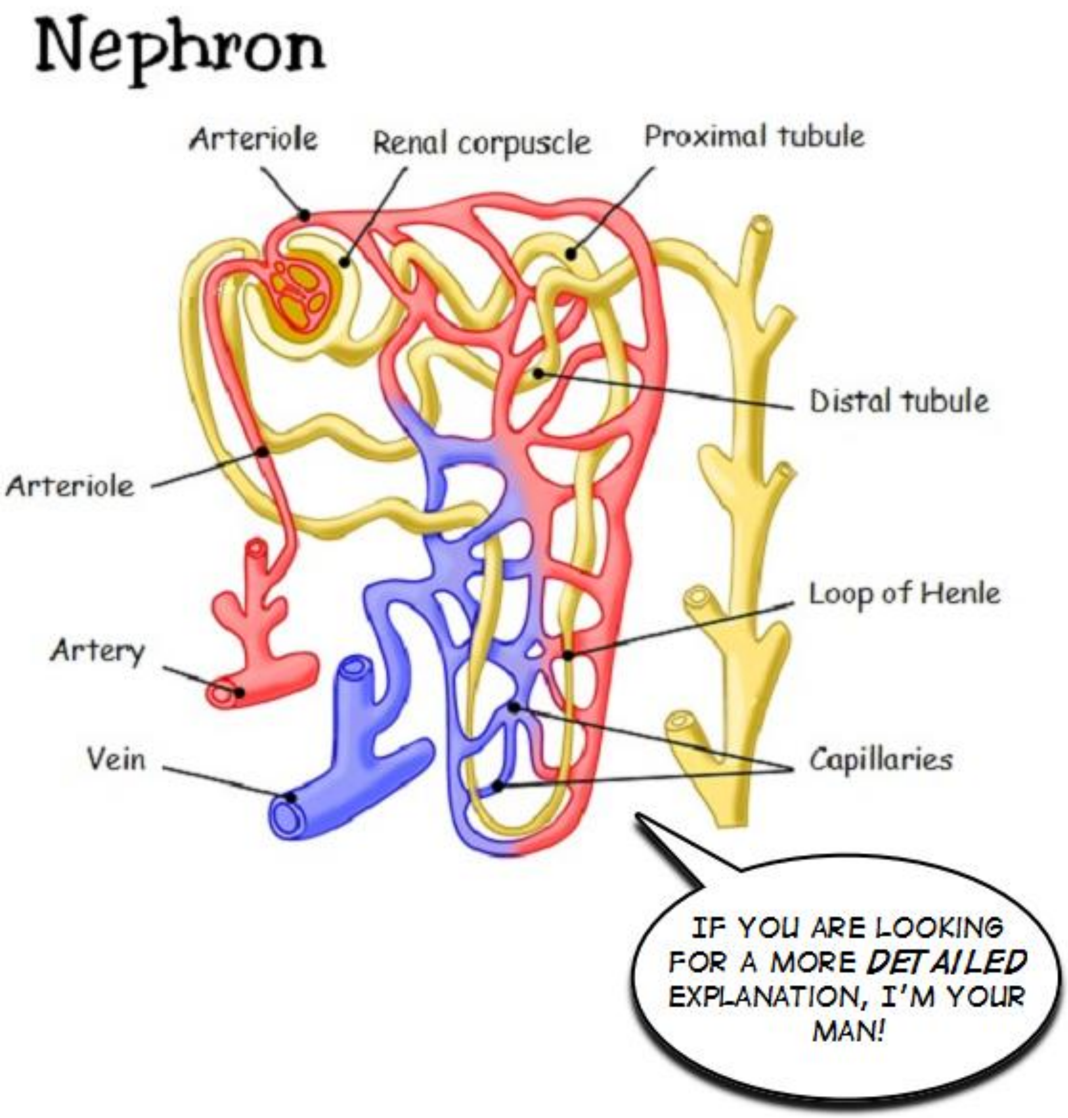
Between the renal arteries and veins a network of capillaries can be found. These vessels surround nearly one million specialized filters within each kidney known as the...

Nephrons

To put it very simply, arterioles from the cardiovascular system pass through the end of one of nearly a million **nephrons** within each kidney. A fraction of the fluid within the blood is filtered through the semipermeable walls of the nephron itself. As this fluid travels through the nephron, water and necessary nutrients within the blood are allowed to be **reabsorbed*** back into the blood leaving behind a solution of waste products and excess compounds in the nephron. This remaining solution (urine) travels through the rest of the urinary system until it is expelled from the body.

**Throughout this chapter, a fluid that is "reabsorbed" or undergoes the process of "reabsorption" refers to any substance that is moved into the bloodstream.*

This is just a simple explanation. A more detailed description is a lot more interesting. Let's begin this exploration with the first step in urine production - within the renal corpuscle.



The renal artery carries blood into the kidney. As it passes through one of its arterioles, the blood is directed into the head of a nephron and makes a tiny U-turn within a bulb-like area before continuing throughout the cardiovascular system. This entire "bulb" at the beginning of a nephron is known as the **renal corpuscle** and is the site where a portion of the water and solutes are filtered out of the blood and into the nephron itself.

Approximately 20% of the plasma which travels through the arterioles passing through the renal corpuscle is filtered into the nephron. The remainder continues to be pumped through the cardiovascular system to be filtered at a later time.

The fluid that passes into the nephron is collectively known as a **filtrate** (a fluid that has been passed through a filter.) Dissolved compounds within the filtrate and within the blood continually pass back and forth throughout the length of the nephron. This is accomplished by a web of capillaries which surround the length of each nephron in a manner very similar to the exchange of gases within the alveoli of the lungs.

One thing needs to be remembered about the physiology of the nephron:

More compounds (~99%) will be reabsorbed back into the blood along its journey through the nephron than added to the nephron.

The filtrate which enters the renal corpuscle is a solution of water and the following solutes: sodium chloride (table salt), potassium ions (K^+; atoms of potassium which have lost one of their electrons), bicarbonate (HCO_3^-; a compound formed from the breakdown of carbonic acid in the blood), glucose, amino acids, **creatinine**, and **urea**.

Creatinine

Creatinine is a nitrogen-containing compound produced from the breakdown of another chemical called **creatine** found in muscle cells. Creatine is a compound used during a muscular contraction. After each contraction, a small amount of creatinine is produced and is eventually delivered into the kidney for excretion. Doctors will test for creatinine levels in the blood to determine how well your kidneys are functioning. Increased creatinine levels mean that the kidneys are not able to filter this waste product from the blood at a normal level.

Urea

As you read previously, our urine contains a large volume of the element nitrogen. This nitrogen is primarily found within the compound **ammonia (NH_3)** which is a waste product formed during the digestion of proteins. As ammonia enters the blood, it combines with carbon dioxide to form urea. This compound is produced in greater volumes than all other toxins expelled by the kidneys. Nearly 0.75 ounces (21 grams) of urea are created each day!

The proximal tubule is the next stop for the filtrate

After the filtrate is removed from the blood within the renal corpuscle, it travels through a small tube known as the **proximal tubule**. In this area, the filtrate reabsorbs all of its amino acids and glucose back into the surrounding capillaries. Why? Because, amino acids and glucose are essential compounds for most processes in our bodies! Excreting these compounds through the urine would not be beneficial to the individual. In addition, much of the salt, water, and potassium ions (~65%) as well as much of the bicarbonate ions (80-90%) are reabsorbed as well. The bicarbonate ions react chemically within the filtrate to keep its pH from becoming too acidic.

As this is occurring, the proximal tubule is receiving additional waste products from the surrounding capillaries. This process is known as **secretion**. One of the waste products that are secreted at this time is known as **uric acid** which is an additional nitrogen-containing compound.

The filtrate will now travel through the Loop of Henle

The **loop of Henle** is a U-shaped tube attached to the proximal tubule whose primary function is to concentrate the waste product by removing two compounds - water and salt. The loop of Henle contains a descending loop and an ascending loop. Within the descending loop, only water is allowed to be reabsorbed; while in the ascending loop, 25% of the remaining sodium chloride within the filtrate is allowed to be reabsorbed. This results in a higher concentration of waste products within the filtrate.

The next stop is the distal tubule

Before we begin our study of the **distal tubule**, it may be best to look at the nephron in the following manner:

The proximal tubule does most of the reabsorption and secretion of the filtrate; the loop of Henle concentrates the filtrate; and, the distal tubule is the fine-tuning device for the final production of urine.

By "fine-tuning" we are referring to a stimulus/response mechanism for maintaining homeostasis within the body. For example, if the body is in need of additional sodium, water, or calcium, the body will respond by secreting the proper hormones to ensure the reabsorption of these substances back into the blood.

An additional 5% of sodium, water, and calcium can be reabsorbed by this "fine-tuning" device as the filtrate travels through the distal tubule. The volumes of these three substances are actually regulated by the hormones aldosterone, calcitonin, parathyroid hormone, and antidiuretic hormone.

The regulation of sodium reabsorption by aldosterone was first explored back in Chapter 13 during your study of the endocrine system:

Aldosterone is a hormone produced by the adrenal glands and is responsible for increasing the amount of sodium (and water) into the blood by removing it from the urine. In addition, aldosterone also helps to <u>*remove*</u> *the element potassium from the blood into the urine when its concentration is too high.*

- and -

The thyroid gland secretes the hormone calcitonin into the blood when the concentration of calcium within the blood is too high. The presence of calcitonin stimulates the secretion of calcium back into the nephron for expulsion. The opposite is true if the parathyroid hormone is present within the blood - reabsorption of calcium back into the blood stream is triggered in the presence of this hormone.

- and -

When the level of water in the blood is too low or if the blood contains a high concentration of ions, antidiuretic hormone triggers the kidneys to reabsorb more water back into the blood.

In addition to "fine-tuning" the levels of calcium, sodium chloride, and water, the distal tubule also regulates the pH level of the filtrate by reabsorbing or secreting bicarbonate ions and hydrogen ions (H^+). It is a fact that any fluid with an excess of hydrogen ions decreases the pH of the fluid by making it more acidic. Although an individual's pH will vary depending upon many factors, an average range between 4.6 and 8 is considered normal. If the body produces an unusually acidic filtrate (below 4.6), additional bicarbonate ions will be secreted into the solution to neutralize the excessive hydrogen ions and bring the pH level to a more neutral level.

The reabsorption of bicarbonate ions can also help in the buffering of blood pH when the blood becomes too acidic. Once introduced back into the blood stream from the filtrate, bicarbonate ions can help to bring the pH of the blood back to a normal level!

As you first learned in Chapter 22, the following reversible chemical formula describes the formation of carbonic acid (H_2CO_3) from the reaction of carbon dioxide (CO_2) and water in the forward direction and from bicarbonate ions (HCO_3^-) and hydrogen ions (H^+) in the reverse direction:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

That ends our study of the nephron. The final pathway for the filtrate will be the topic of discussion next week. Nope… we're not done yet! Hang in there!

Match the following vocabulary terms with their correct definition:

ammonia (NH_3)	**hydration**	**renal corpuscle**
bicarbonate ion (HCO^{-1})	**kidneys**	**renal veins**
creatine	**loop of Henle**	**secretion**
creatinine	**nephrons**	**urea**
distal tubule	**proximal tubule**	**uric acid**
filtrate	**reabsorption**	**urinary (renal) system**
	renal arteries	**urine**

1)	______________	"bulb" at the head of a nephron; site where water and solutes are filtered out of the blood and into the nephron itself
2)	______________	a fluid that has been passed through a filter
3)	______________	a nitrogen-containing compound produced from the breakdown of creatine during a muscular contraction
4)	______________	amount of water within the blood stream
5)	______________	arteries which supply the kidneys with blood
6)	______________	compound used by muscles during a contraction
7)	______________	final section of nephron where the concentration of water and nutrients within urine is fine-tuned
8)	______________	nitrogen-containing compound secreted into the nephron for excretion
9)	______________	non-toxic and sterile fluid excreted by the urinary system containing nearly 95% water and several other dissolved solutes

10)	________________	process by which water and nutrients are released from the nephron into the surrounding capillaries
11)	________________	reacts chemically within the filtrate to keep its pH from becoming too acidic
12)	________________	semipermeable tube responsible for the filtration and/or reabsorption of water and nutrients from the blood; ~1 million of these structures are found within each kidney
13)	________________	small tube attached to the renal corpuscle of a nephron; site of filtrate reabsorption where amino acids and glucose are released from the filtrate back into the surrounding capillaries
14)	________________	system responsible for regulating the volume and chemical contents of plasma and filters the blood to expel waste products
15)	________________	the process of receiving additional waste products from the surrounding capillaries into the nephron
16)	________________	two bean-shaped organs responsible for the filtration and reabsorption of water and nutrients from the blood
17)	________________	U-shaped tube attached to the proximal tubule whose primary function is to concentrate the waste product by removing water and salt
18)	________________	veins which exit each kidney
19)	________________	waste product created from the reaction between ammonia and carbon dioxide; produced in greater volume than all other toxins expelled by the kidneys
20)	________________	waste product from the digestion of proteins; combines with carbon dioxide to form urea

Choose the correct answer from the following questions:

1) **Each kidney contains approximately:**
   A) 100,000 nephrons
   B) 2 million nephrons
   C) 500,000 nephrons
   D) 1 million nephrons
   E) 3 million nephrons

2) **Which of the following is NOT found within the filtrate which enters the renal corpuscle:**
   A) urea
   B) bicarbonate ions
   C) glucose
   D) hemoglobin
   E) amino acids

3) **Approximately __________ of the plasma which travels through the arterioles passing through the renal corpuscle is filtered into the nephron.**
   A) 99%
   B) 95%
   C) 30%
   D) 25%
   E) 20%

4) **Which of the following is NOT true:**
   A) creatinine is a byproduct of a muscular contraction
   B) the digestion of protein produces ammonia
   C) creatine is converted into creatinine
   D) ammonia is formed from the contraction of muscles

5) **The percentage of filtrate eventually reabsorbed into the bloodstream is closest to:**
   A) 20%
   B) 99%
   C) 10%
   D) 80%
   E) 25%

6) **Which one of the following is NOT a function of the kidneys:**
   A) production of hormones which assist in digestion
   B) formation of urine
   C) disposal of metabolic waste products
   D) regulation of the volume of blood

Application Question:

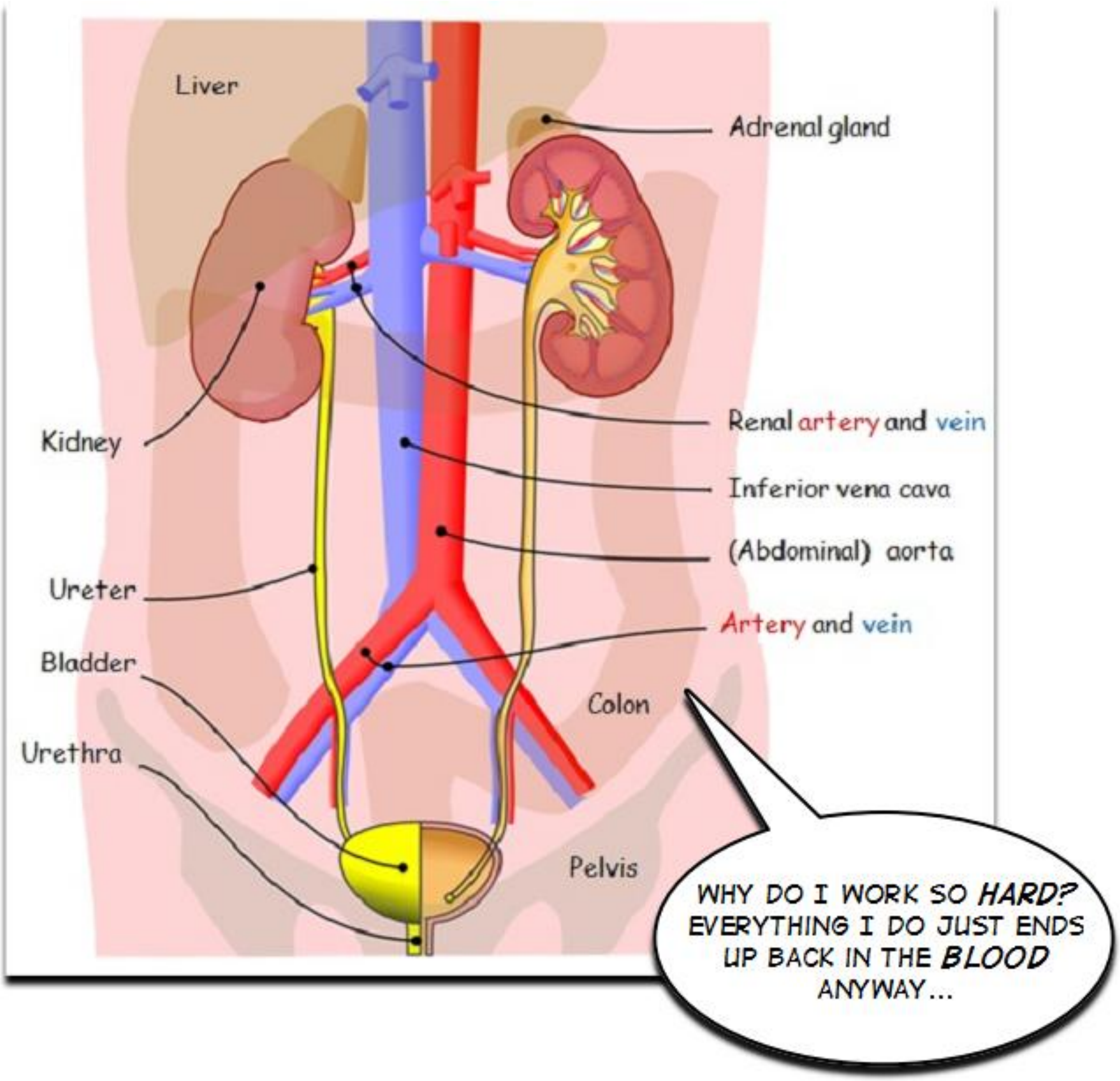
A patient suffered from kidney failure a few days after he was exposed to a toxic chemical. A biopsy of his kidney indicated that many of the thousands of cuboidal epithelial cells that normally line this organ were damaged, although the basement membranes appeared to be mostly intact. Predict how likely this person is to fully recover.

Chapter 27

Urinary System – Part II

Last week, you explored the anatomy and physiology of the kidneys and how they filter your blood. The kidneys are only the first organs within the urinary system to process waste products from the blood. Three additional organs within the urinary system are responsible for preparing the filtrate for excretion:

Bladder, Ureters, and the Urethra

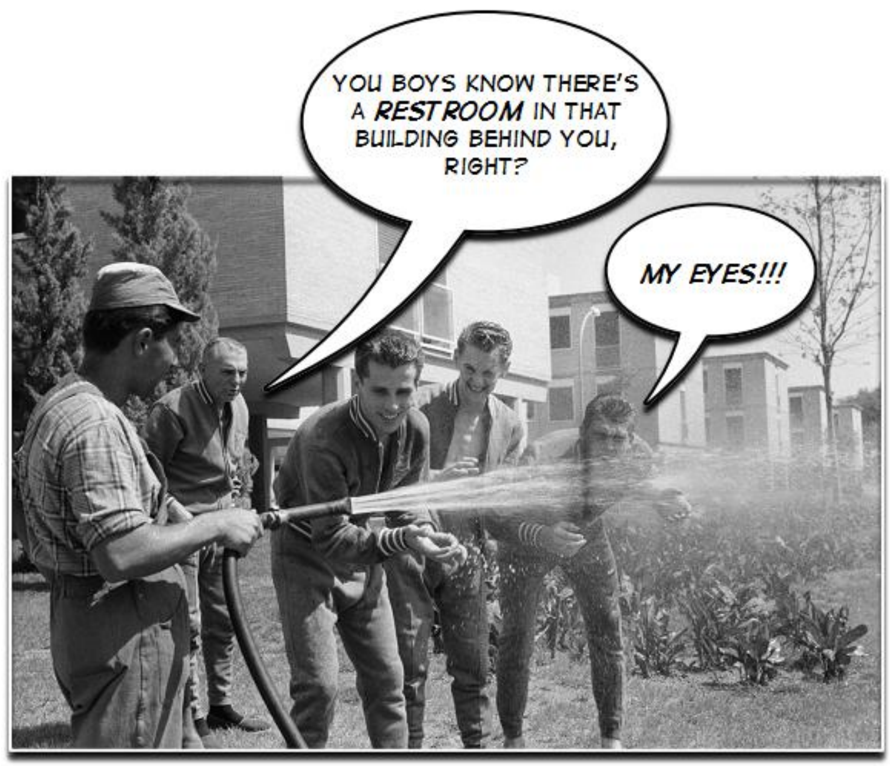


As you recall, waste products are filtered through the blood within the nephrons of the kidneys. As this filtrate passes through the renal corpuscle, proximal tubule, loop of Henle, and distal tubule the waste products are collected, filtered, concentrated, and fine-tuned. This process allows for nearly 99% of the collected filtrate to be reabsorbed back into the bloodstream and the remaining 1% to be directed into one of several **collecting ducts** before it can be excreted from the body.

This system of collecting ducts exists within both kidneys and acts as a pathway between all of the nephrons and the ***ureters*** *- two main tubes which drains the collected urine from each kidney through the urinary system.*

Collecting ducts, much like the distal tubule, also fine-tunes the concentration of the filtrate through the processes of reabsorption and secretion. Although this "fine-tuning" involves the regulation of potassium ions, bicarbonate ions, and hydrogen ions, it is the management of sodium, chloride, and water that is the most important in this area of urine production.

Under normal conditions the collecting ducts are **impermeable** (not allowing fluid to pass through) to water. However, there are times in which water is needed by the body such as when an individual is dehydrated or is hemorrhaging. During these times, the collecting ducts respond to the presence of antidiurectic hormone (ADH) in the blood.



As you learned in Chapter 12, ADH is secreted by the posterior lobe of the pituitary gland and is released at times when water is needed by the body. In the presence of ADH, the collecting ducts allow water to be reabsorbed back into the blood stream. This action inhibits **diuresis** (urine production).

Through all this processing, it is important to note that the filtrate has yet to leave the kidneys! This system of collecting ducts must pass through an impressive protective covering before urine may pass into the ureters.

Both kidneys are protected by three layers of connective tissue. This first layer of protection is a tough fibrous tissue known as the **renal capsule**, which is then surrounded by a layer of adipose tissue (fat), and finally another layer of dense connective tissue, the **renal fascia**, surrounds each kidney and anchors the organs to surrounding tissues within the lower back.

Why do the kidneys need so much protection?

The kidneys must remain anchored to the lower back to protect these organs from moving into the abdominal area which can be very dangerous. If the kidneys are allowed to move freely a condition known as **nephroptosis** or "floating kidney" may occur. This involves the twisting of the ureters by the moving kidney which causes the flow of urine to be blocked. The buildup of excess urine can eventually damage the kidney.

The anatomy of the ureter is fairly simple, each being 10 to 12 inches (25 to 30 centimeters) long and made of smooth muscle fibers which move urine by peristalsis. Both ureters move urine into a single, elastic, and muscular organ called the **bladder**.

On average, the human bladder is nearly 5 in (12 cm) in length and can hold approximately 1.7 cups (~400 mL) of urine. However, it is possible for the bladder to expand in order to hold twice this much urine if necessary.

The walls of the bladder have three layers:

An innermost layer of epithelial tissue holds the urine which is covered by layers of connective tissue and muscle, the latter of which is known as the **detrusor** muscle. It is when the detrusor muscle contracts that the bladder is compressed and urine is forced out of this collecting area. The pathway in which urine travels out of the bladder is known as the **urethra**.

The urethra is a thin, muscular tube that connects the bladder to the outside environment. In males, the urethra has an average length of 8 inches (20 cm) and has a dual function as it carries not only urine but also **seminal fluid** from the reproductive system. Seminal fluid carries with it the male sex cells needed for reproduction. We will learn more about these cells in Chapter 29. In females, the urethra is much smaller as it is only 1.5 inches (3 to 4cm) in length and is not responsible for any functions within the reproductive system.

So what is the final product (urine) really made of?

Approximately 95% of urine is made up of water. The remaining 5% is comprised of various dissolved substances:

The majority of dissolved substances which make up the remaining 5% of urine are compounds containing the element nitrogen. In fact, you learned about three of these compounds in the last chapter...

Urea makes up the majority of these dissolved substances with nearly 0.75 ounces (21 grams) per day. Creatinine is the second highest with 0.06 ounces (1.8 grams). Two other nitrogen-based compounds top this list with ammonia (NH_3) at 0.02 ounces (0.7 grams) and uric acid with 0.018 ounces (0.5 grams).

Varying amounts other compounds are excreted daily as well. Some of these include carbohydrates (~0.1 grams), fats (~0.02 grams), amino acids (~2.3 grams), red blood cells (130,000 per day), white blood cells (650,000 per day), along with ions of sodium (~4 grams), potassium (~2 grams), chloride (~6.4 grams), and calcium (~0.2 grams).

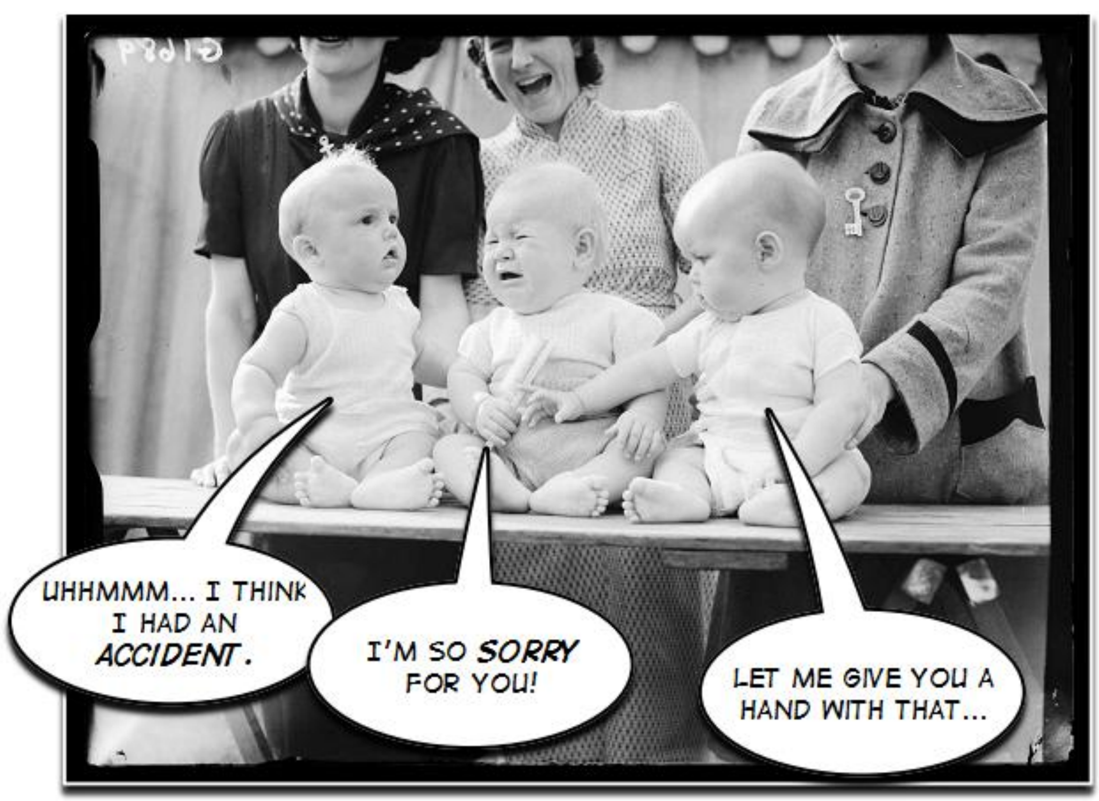
The volumes of all these substances is largely based upon a variety of factors: weight, age, diet, hydration levels, and relative health of the individual. As you learned in the previous chapter, to determine how well your kidneys are functioning, physicians look at one of these compounds - creatinine, within your blood and urine. Why is this done?

Because creatinine is neither reabsorbed nor secreted throughout the entire urinary system after entering the renal corpuscle!

As stated in the last chapter, increased creatinine levels in the blood mean that the kidneys are not able to filter this waste product from the blood into the kidneys at a normal level. Therefore, doctors will study the levels of blood creatinine and urine creatinine simultaneously to ensure a proper amount of this compound is passing through your kidneys.

Here are a few more facts about the kidneys:

In an average day, your kidneys will filter approximately 48 gallons (182L) of blood and produce approximately 45 gallons (170L) of filtrate. And nearly all of this volume is reabsorbed back into the body leaving behind approximately 6-8 cups (1.4-1.9L) of urine which is expelled from the body each day.



It may seem like 45 gallons of filtrate is a large volume - and it is! But remember...

More compounds are removed from the filtrate along its journey through the nephron than added to it; and, most of the fluid within the filtrate is reabsorbed back into the blood.

The kidneys also help control the production of red blood cells by producing the hormone erythropoietin. You first learned about this hormone back in Chapter 15 as a chemical messenger for the skeletal system which is used to increase the production of red blood cells in times of low oxygen levels.

In addition to its properties concerning red blood cell development, erythropoietin causes blood vessels to **constrict** (become narrower) which increases the overall blood pressure of the body. This action is very much like shooting water out of a hose by pinching one of its ends.

The kidneys produce another hormone other than erythropoietin in response to a lowering of the blood pressure – **renin.** This hormone triggers a series of events involving the constriction of blood vessels, secretion of both ADH and aldosterone, and several other processes as well.

One more thing about the kidneys...

The kidneys also convert vitamin D within the blood into a more active hormone called **calcitrol**. This hormone promotes the absorption of calcium into the blood within the digestive system. Calcitrol is vital for bones to absorb the correct amount of calcium for growth. This hormone also inhibits the release of the hormone calcitonin produced by the thyroid. You learned about the role of calcitonin in Chapter 13 as a hormone which reduces the amount of calcium within the blood. <u>Yet another example of homeostasis at work!</u>

These last six chapters have dealt with the organ systems associated with various ways in which particles are absorbed or excreted from the body. In the next chapter, you will explore a few of the common disorders that may exist within the respiratory, digestive, and urinary systems.

Anatomy & Physiology - Connections

How the following body systems affect the urinary system		How the urinary system affects the following body systems	
Integumentary	Sweat glands remove excess water from body; keratin can prevent excess loss of water; vitamin D production allows for the production of calcitrol	Elimination of wastes and balancing of fluids, acids/bases, and electrolytes used to maintain the skin	**Integumentary**
Skeletal	Protection for all major organs of the urinary system	Reabsorption of calcium and phosphorus for bone growth and cellular membrane construction	**Skeletal**
Muscular	Movement of urine through peristalsis and muscular contractions	Removal of waste products from muscles; regulates levels of calcium and phosphorus	**Muscular**
Nervous	Control over urination	Elimination of wastes and balancing of fluids, acids/bases, and electrolytes used for nerve impulses	**Nervous**

Endocrine	Regulation of sodium chloride reabsorption by aldosterone and water by ADH	Secretion of renin and erythropoietin in response to low blood pressure and oxygen levels	**Endocrine**
Cardiovascular	Accepts the fluids and solutes reabsorbed during the production of urine	Secretion of renin to increase blood pressure and erythropoietin to increase red blood cell production	**Cardiovascular**
Immune	Antibiotic defenses provide protection against infection	Acidic pH of urine provides defense against infection	**Immune**
Respiratory	Expulsion of carbon dioxide regulates pH of body fluids	Reabsorbs or secretes bicarbonate to regulate pH of urine	**Respiratory**
Digestive	Secretion of excess water into filtrate for urine production	Excretion of waste products secreted by the intestines; production of calcitrol to enhance calcium and phosphate reabsorption	**Digestive**

Match the following vocabulary terms with their correct definition:

bladder	**diuresis**	**renin**
calcitrol	**impermeable**	**seminal fluid**
collecting ducts	**nephroptosis**	**ureters**
constrict	**renal capsule**	**urethra**
detrusor	**renal fascia**	

1)	______________	"floating kidney"; occurs when the kidneys fail to remain anchored to the lower back and begin moving into the abdominal area
2)	______________	a single, elastic, and muscular organ used to store urine before excretion
3)	______________	a tough fibrous tissue which is the first layer of protection for each kidney
4)	______________	become narrower
5)	______________	chemical secreted by the kidneys when the blood pressure is too low; acts to constrict blood vessels and triggers the secretion of ADH and aldosterone
6)	______________	dense connective tissue which is the outermost protective layer around each kidney; anchors the organs to surrounding tissues within the lower back
7)	______________	fluid which carries the male sex cells needed for reproduction
8)	______________	hormone produced from vitamin D by the kidneys; promotes the absorption of calcium into the blood within the digestive system
9)	______________	layer of muscle surrounding the bladder; during contraction, the bladder is compressed and urine is forced outwards

10)	______________	not allowing fluid to pass through
11)	______________	pathway in which urine travels out of the bladder
12)	______________	system of pathways for the passage of urine between each nephron and the ureters
13)	______________	two main tubes which drains the collected urine from each kidney through the urinary system
14)	______________	urine production

Choose the correct answer from the following questions:

1) **Antidiuretic hormone prevents excessive water loss by promoting water reabsorption in the:**
   A) distal convoluted tubule
   B) collecting duct
   C) glomerulus
   D) proximal convoluted tubule
   E) bladder

2) **Urine is transported from the bladder to the outside of the body by the:**
   A) prostate gland
   B) ureter
   C) urethra
   D) collecting duct

3) **The average adult bladder is moderately full when it contains ___________ of urine.**
   A) ~2 liters
   B) ~1 gallon
   C) ~1 liter
   D) ~100 mL
   E) ~400 mL

4) **Which of the following is NOT an organ found in the urinary system:**
   A) ureter
   B) urethra
   C) pancreas
   D) kidney
   E) urinary bladder

5) **The average output of urine for a normal healthy adult is:**
   A) ~6-8 cups/day
   B) ~4-6 cups /day
   C) ~8-10 cups /day
   D) ~2-4 cups /day

6) **True or false:** Antidiuretic hormone (ADH) causes increased water loss through the urine.

7) **True or false:** Urine moves down the ureters into the bladder due to gravitational pull alone.

Application Question:

A man eats a full bag of salty potato chips. What effect does this have on urine concentration and volume? Explain the mechanisms involved.

Chapter 28

Absorption and Excretion: What can go wrong?

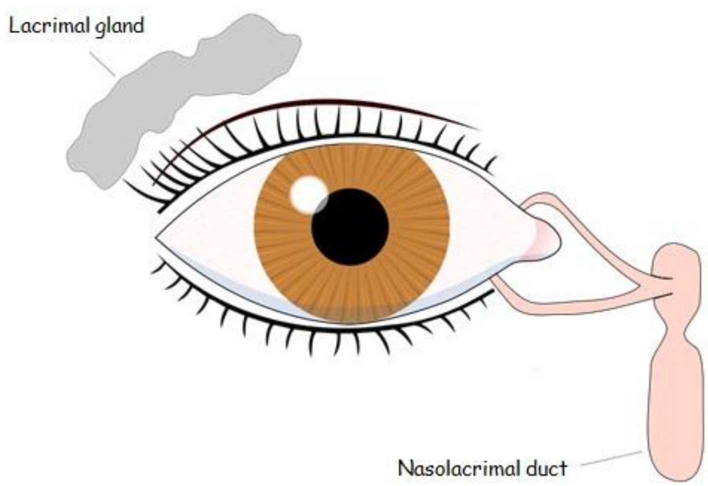
Throughout this chapter you will be exploring a few of the common disorders and ailments existing within the respiratory, digestive, and urinary systems. As you have been told previously, this chapter is by no means an exhaustive list of all the maladies that may occur. It is only a brief exploration. So let's get started with our look into...

Disorders of the Respiratory System

It is a good assumption that you have already experienced the first few issues we will explore in your lifetime. For example, if you have ever noticed a large amount of blood within a tissue after blowing your nose, the sight was probably a little unnerving. **Epistaxis** (**nosebleeds**) are rarely dangerous but can be uncomforting at first sight. Nosebleeds are caused by the rupture of a blood vessel within the nose, causing a hemorrhage to occur as blood drains from the nostril. Another common cause of epistaxis is a sharp blow to the nose such as when one is punched. Nosebleeds will normally stop once the immune response forms a blood clot over the ruptured vessel. This can be sped up by pinching the nose firmly for five to twenty minutes. By the way, you may want to tilt your head forward as well. The old suggestion of tilting your head backwards may cause excess blood to travel into your stomach which can make you nauseous!

Have you ever noticed that you normally have to blow your nose after you have been crying?

The eyes are flushed with tears from the **lacrimal glands** which are located above each eye. This excessive fluid can easily cascade over the eyelid causing a noticeable tear; however, much of this fluid is directed into a specialized tube called the **nasolacrimal ducts** (also known as the "**tear ducts**") which drains into the nasal cavity. Therefore, your tears flow through your nasal cavity causing your "nose to run." This same incident occurs when a person's eyes become watery due to an allergic reaction.



Since we are on the topic of the nasal cavity...

Back in Chapter 22, you learned that the nasal cavity is lined with a protective layer of hair and mucus which traps foreign particles as they enter the respiratory system. You also learned that some of these particles can be expelled from the body as they become trapped in a dried volume of mucus (a booger). However, there are times when these trapped particles trigger sensory receptors within the nasal cavity to speed up the removal of these invaders through a **sneeze**. A sneeze is a sudden explosion of forced air traveling at nearly 100 miles (161 kilometers) per hour from the lungs. This force is typically sufficient to expel the foreign element from the nasal cavity.

These next few disorders are commonly caused by some form of infection or ingestion of damaging compounds...

Sore throats can be caused by a variety of conditions, and viral/bacterial infections are the most common culprits. However, if the tissues within the larynx become inflamed, a condition known as **laryngitis** can occur. Much like sore throats, laryngitis can be caused not only by invading viruses or bacteria, but also through the ingestion of damaging chemicals such as those found in tobacco products. This disorder can cause an individual to have a hoarse voice or possibly lose their voice altogether for a small period of time.

Tobacco smoking is also linked to lung cancer, the most common cause of cancer death in the world.

The extreme heat and dangerous levels of toxins within tobacco products can cause significant damage to the tissues of the respiratory system. Its use has been linked to **emphysema**, which is a progressive destruction of the alveoli. The reduction in surface area due to this disorder significantly lowers the body's ability to exchange gases within the lungs.

Bronchitis is another disorder of the respiratory system which is characterized by the swelling of the internal walls of the bronchi combined with an increased level of mucus production. A persistent cough lasting a few weeks is a tell-tale sign of bronchitis as the lungs continually attempt to expel the excess mucus from the body. Typically, bronchitis is caused by viral infections of the bronchi.

One final disease that probably should be mentioned...

Any condition causing inflammation of the lungs (more specifically the alveoli) is generally considered to be a form of **pneumonia**. These types of infections tend to cause excess fluids to build up within the lung tissues. Although both bronchitis and pneumonia both produce long-lasting symptoms involving the expelling of fluid from the lungs, a patient with pneumonia tends to have a moderately high fever as opposed to an individual with bronchitis. Pneumonia is considerably more dangerous than bronchitis as complications from pneumonia claims nearly four million lives per year worldwide. As the inflammation spreads throughout the lungs, alveoli fill with fluid/mucus, systematically depriving the body of needed oxygen in a relatively short period of time.

Disorders of the Digestive System

Don't forget that a small container of highly corrosive acid can be found within our bodies. You would be correct if you would guess that if any of our organs supporting this fluid are not functioning properly, a painful amount of damage can be created!

The pyloric sphincter has the important job of protecting the esophagus from the dangerous effects of the highly acidic gastric juice. When this valve does not close completely, a medical condition known as **gastroesophageal reflux disease (GERD)** can occur. When stomach acid is allowed to leak into the esophagus (**reflux**), it causes a burning sensation in the chest/throat which is commonly known as **heartburn**.

Acid indigestion is another term used to describe one of the symptoms of heartburn and occurs when the stomach contents can be tasted within the mouth.

In the not so distant past, most doctors believed that a person under considerable stress or a person who eats spicy foods can develop what is known as a **stomach ulcer**. An ulcer is an open sore on surface of a tissue. When this occurs within the stomach lining, it becomes a very painful condition. In the 1980's, however, researchers discovered that a stomach ulcer is caused by a bacterium known as **Heliobacter pylori**. Constant inflammation in the stomach tissue caused by the spread of these bacteria (a condition known as **gastritis**) allows for the gastric juices to cause a burning sensation within the stomach wall where the open sore exists.

Let's move through the stomach and into the lower gastrointestinal tract...

A diet containing far too much cholesterol can cause the bile created by the liver to become hardened masses known as **gallstones**. Most people who have gallstones simply pass them through their digestive system without ever knowing about their presence. However, if one of these gallstones happens to block a bile duct, surgical removal is usually required. And since we are on the topic of bile...

The gallbladder is not an essential organ for our survival!

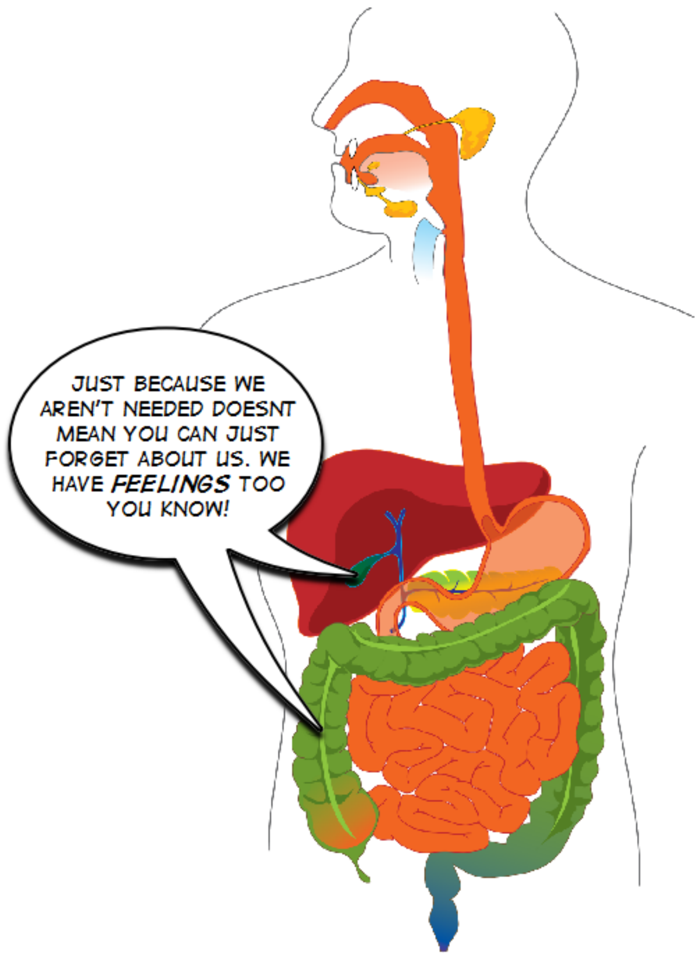
As a mere storehouse for bile, this organ can be removed if it is infected or impaired in any way. Without this organ, bile flows from the liver directly into the duodenum without any problems whatsoever. If any excess bile is produced, it is simply stored within the bile ducts.

Here's a more common ailment that involves our intestines...

Diarrhea is a condition in which an individual has three or more loose and watery bowel movements per day. This may be caused by either bacterial or viral infections or other disorders of the intestines. Although the immune system is capable of killing the pathogens that cause most cases of diarrhea, it still remains one of the most common causes of infant death worldwide. The rapid excretion of water carries with it vital ions and other nutrients which are necessary to maintain homeostasis. Without the replacement of fluids and ions in a timely fashion, a patient may eventually die.

Much like your gallbladder....

You may not have realized this, but the primary function of your large intestines is to serve as a storage area for your feces. Much like your gallbladder, <u>you do not need your large intestine to live!</u> Diseases such as colon cancer which are isolated within the large intestines can be relieved through the surgical removal of the large intestine itself. The small intestines may simply be attached to the anal canal for the final excretion of feces.



Disorders of the Urinary System

As was briefly mentioned back in Chapter 26, the color of urine can change with the diet and health of the individual. Under normal circumstances, urine is nearly colorless unless it has a very concentrated amount of filtrate in which it can appear a deep yellow color. Natural and artificial dyes within our food can alter the color of urine to red, green, blue, black, and brown. However, damage to the muscular system or specific cancers can cause urine to appear brown, black, or red. An infection of the urinary tract can cause urine to appear cloudy due to the presence of **pus** (a thick yellow liquid produced by infected tissues.)

Much like the large intestine and the gall bladder, one of the two kidneys may be removed from the body without significant problems to the individual. Although complications may arise slowly as the person gets older, urinary functions tend to occur naturally when a single kidney is removed.

Uric acid and salts within the filtrate may bind together to form large crystals inside the kidneys, ureter, and/or bladder. These large crystals, known as **kidney stones**, can cause intense pain for individuals as they pass through the urinary system. If these stones are particularly large or cause some form of blockage, doctors can shatter them into smaller crystals using sound waves in a procedure called **lithotripsy**.

What happens to the kidneys and bladder as we age?

As we age, the number of nephrons within the kidneys decreases as does the overall amount of kidney tissue. In addition, the blood vessels which allow for reabsorption and secretion surrounding the nephrons can become hardened as well. All of these factors cause a much slower rate of filtration among older individuals.

The interior wall of the bladder can become less elastic with age and a decrease in the amount of detrusor muscle within the bladder wall can reduce its ability to compress all of its urine out of the body during urination.

Despite these changes, a healthy older individual can expect normal kidney function despite the fact that these functions may occur more slowly than those found within a younger individual.

On a more serious note…

Life-threatening medical conditions can occur if the kidneys are not functioning properly or at all. Artificial filtration of the blood can be administered to patients experiencing this problem through a procedure called **kidney dialysis** (**hemodialysis**). Several times a week a patient will have his blood filtered through **permeable tubing** (tubing which allows specific compounds to pass through) that is immersed in a solution which mimics the actions of the nephrons and its surrounding capillaries. As the patient's blood is moved through the dialysis machine, desired nutrients and water are retained within the blood while wastes such as urea are removed throughout the six-hour procedure.

That takes care of some common problems associated with the respiratory, digestive, and urinary systems. We only have one more system to explore - the reproductive system. Until then, you may want to start preparing for your assessment on these three systems. Good luck!

Match the following vocabulary terms with their correct definition:

acid indigestion	**kidney stones**
bronchitis	**lacrimal glands**
diarrhea	**laryngitis**
emphysema	**lithotripsy**
epistaxis (nosebleeds)	**nasolacrimal ducts (tear ducts)**
gallstones	**permeable tubing**
gastritis	**pneumonia**
gastroesophageal reflux disease	**pus**
heartburn	**reflux**
Heliobacter pylori	**sneeze**
kidney dialysis (hemodialysis)	**stomach ulcer**

1)	______________	a condition in which an individual has three or more loose and watery bowel movements per day
2)	______________	a progressive destruction of the alveoli caused by extreme heat and/or toxins
3)	______________	a sudden explosion of forced air traveling at nearly 100 miles (161 kilometers) per hour from the lungs
4)	______________	a thick yellow liquid produced by infected tissues
5)	______________	an open sore on surface of the stomach lining; caused by the H. pylori bacterium
6)	______________	artificial filtration of the blood administered to patients with kidney failure
7)	______________	bacteria which may induce a stomach ulcer
8)	______________	burning sensation in the chest/throat caused by reflux

9)	______________	caused by the rupture of a blood vessel within the nose, causing a hemorrhage to occur as blood drains from the nostril
10)	______________	condition in which the pyloric sphincter does not close completely allowing gastric juice to leak back into the esophagus
11)	______________	constant inflammation of the stomach tissue caused by the spread of H. pylori
12)	______________	disorder of the respiratory system characterized by the swelling of the internal walls of the bronchi combined with an increased level of mucus production
13)	______________	generalized term used to identify any condition involving the inflammation of the lungs
14)	______________	glands which are located above each eye; responsible for the production of tears
15)	______________	hardened masses of bile caused by the ingestion of excessive cholesterol
16)	______________	hoarseness or the loss of one's voice due to an inflammation of the larynx
17)	______________	large crystals of uric acid and salts formed inside the kidneys, ureter, and/or bladder
18)	______________	procedure in which doctors shatter kidney stones into smaller crystals using sound waves
19)	______________	specialized tubes which drain tears from the eyes into the nasal cavity
20)	______________	symptom of heartburn; characterized by the tasting of one's stomach contents within the mouth
21)	______________	the leaking of stomach acid into the esophagus
22)	______________	tubing which allows specific compounds to pass through

Choose the correct answer from the following questions:

1) Which of the following organs are not necessary for our survival:

A) liver
B) gallbladder
C) small intestine
D) pancreas
E) stomach

2) Excess fluid from the _______________are drained into the nasal cavity via the __________________.

A) nasolacrimal ducts; lacrimal glands
B) alveoli: nasolacrimal ducts
C) lacrimal glands: tear ducts
D) lacrimal glands: alveoli

3) Artificial filtration of the blood can be administered to patients through a procedure known as:

A) hemoglobin
B) hemophilia
C) hemodialysis
D) hemopoietin

4) GERD is caused by:

A) a faulty valve
B) overproduction of stomach acid
C) gastritis
D) Heliobacter pylori
E) acid indigestion

5) A diet containing too much ________________ can cause the ________________ created by the liver to become hardened masses known as ________________.

A) Heliobacter pylori:bile:stomach ulcers
B) bile:cholesterol:gallstones
C) fat:insulin:gallstones
D) cholesterol:bile:gallstones

6) One of the most common causes of infant deaths worldwide is:

A) stomach ulcers
B) gastritis
C) bronchitis
D) diarrhea
E) gastroesophageal reflux disease

Application Question:

A dialysis membrane is semipermeable, and substances smaller than proteins are able to pass through it. If you wanted to use a dialysis machine to remove only urea (a small molecule) from blood, what could you use for the dialysis fluid? Defend your answer.

a) a solution that is isotonic and contains only large molecules, such as protein
b) a solution that is isotonic and contains the same concentration all substances except that it has no urea
c) distilled water, which contains no ions or dissolved molecules
d) blood, which is isotonic and contains the same concentration of all substances, including urea

Chapter 29

Male Reproductive System

The first three units you explored in this textbook centered around the core concepts of protection, support, and movement within the skin, muscles, and bones of the body; the next three focused on the topics of integration and regulation within the nervous and endocrine systems; transport was the main concept within the following three units through your exploration of the cardiovascular and immune systems; and finally, the last three units explored the topics of absorption and excretion within the respiratory, digestive, and urinary systems.

This last unit is the smallest in length with only two chapters; however, without the proper functioning of this system, the animal kingdom would certainly cease to exist. In these next two weeks we will be taking a close look at the anatomy and physiology of...

The Reproductive System

This first week will focus primarily on the male reproductive system. Before we begin our exploration on this topic, let's look at some of the general characteristics of this vitally important system.

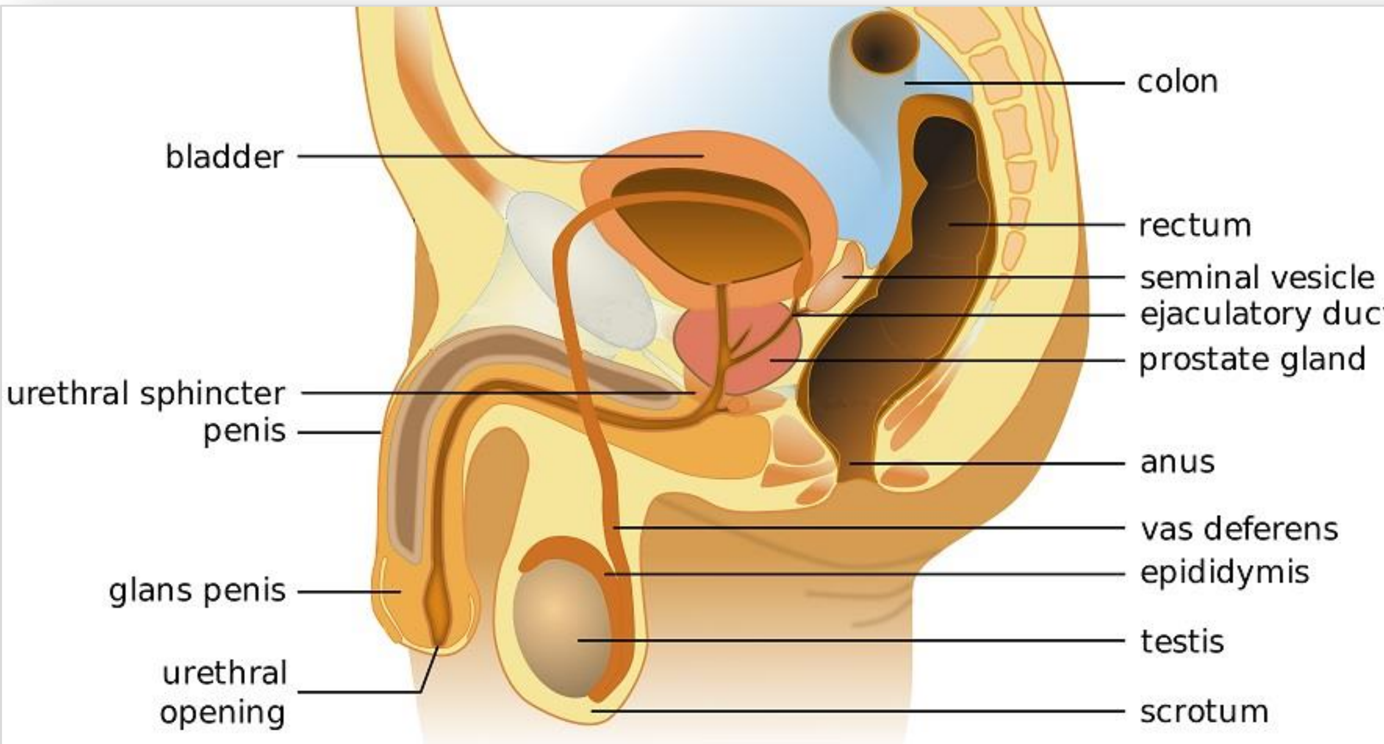
The ability to reproduce is essential for all living organisms to survive. Without some mechanism for reproduction, all life would surely end. Although there are many different ways in which organisms accomplish this task, we will continue to focus on the organs and functions of the human body.

All of the organ systems within the human body are nearly identical with variances mainly in size according to gender, height, weight, and the overall health of the individual. However...

The organs of the reproductive system are not the same between men and women!

Naturally, there are some similarities between the male and female reproductive systems but their intended purpose, the creation of a new child, cannot be performed without **both** the male and female systems working cooperatively. Unlike any other system, a man or a woman can survive to a very old age without a properly functioning reproductive system.

The Male Reproductive System



The main organs within the male reproductive system include the following:

Testes, Epididymis, Vas deferens, Seminal Vesicles, Prostate Gland, and the Penis

The testes (also known as **gonads**) are the locations where the male reproductive cells (**sperm**) are created. The testes are located within the **scrotum** which is a small pouch made of both loose skin and muscle tissue which hangs outside of the body. The scrotum is divided into two separate chambers by a wall of tissue known as a **septum**. Each half of the scrotum contains a single testis (singular form of testes).

As you learned back in Chapters 12 and 13, the testes are part of the endrocrine system as well as the reproductive system. These organs are triggered to produce sperm in the presence of follicle-stimulating hormone (FSH) which is secreted by the anterior lobe of the pituitary gland. In addition, the testes produce the chemicals testosterone and inhibin when triggered by the luteinizing hormone (LH) which is also produced by the pituitary gland.

Testosterone stimulates the growth of male reproductive tissues, bones, muscles, and body hair. Testosterone also acts to enlarge the larynx (voice box) which causes a deepening of the voice during puberty. Inhibin regulates the volume of FSH secreted into the bloodstream by lowering its production from the pituitary gland.

Meanwhile, back in the anatomy of the male reproductive system...

The location of the scrotum outside of the body is necessary for the development and protection of the sperm. The male sex cells can be damaged if exposed to the temperatures typically found within the body. On average the scrotum is 2–3°F (1.1–1.6°C) lower than the normal body temperature. Regulation of the scrotum's temperature is partially controlled by a muscle which covers the testes called the **cremaster muscle**. This muscle raises and lowers the testes in response to various environmental stimuli.

For example, if the environmental temperature is particularly cold, the cremaster muscle will contract, thereby raising the testes closer to the body and reducing its surface area.

The reduced surface area also reduces the amount of heat that can be lost to the environment. In times when the scrotum's environment is warmer, this muscle will relax, allowing the testes to cool off within its enlarged surface area in a location farther away from the body.

Let's take a closer look into the anatomy of sperm.

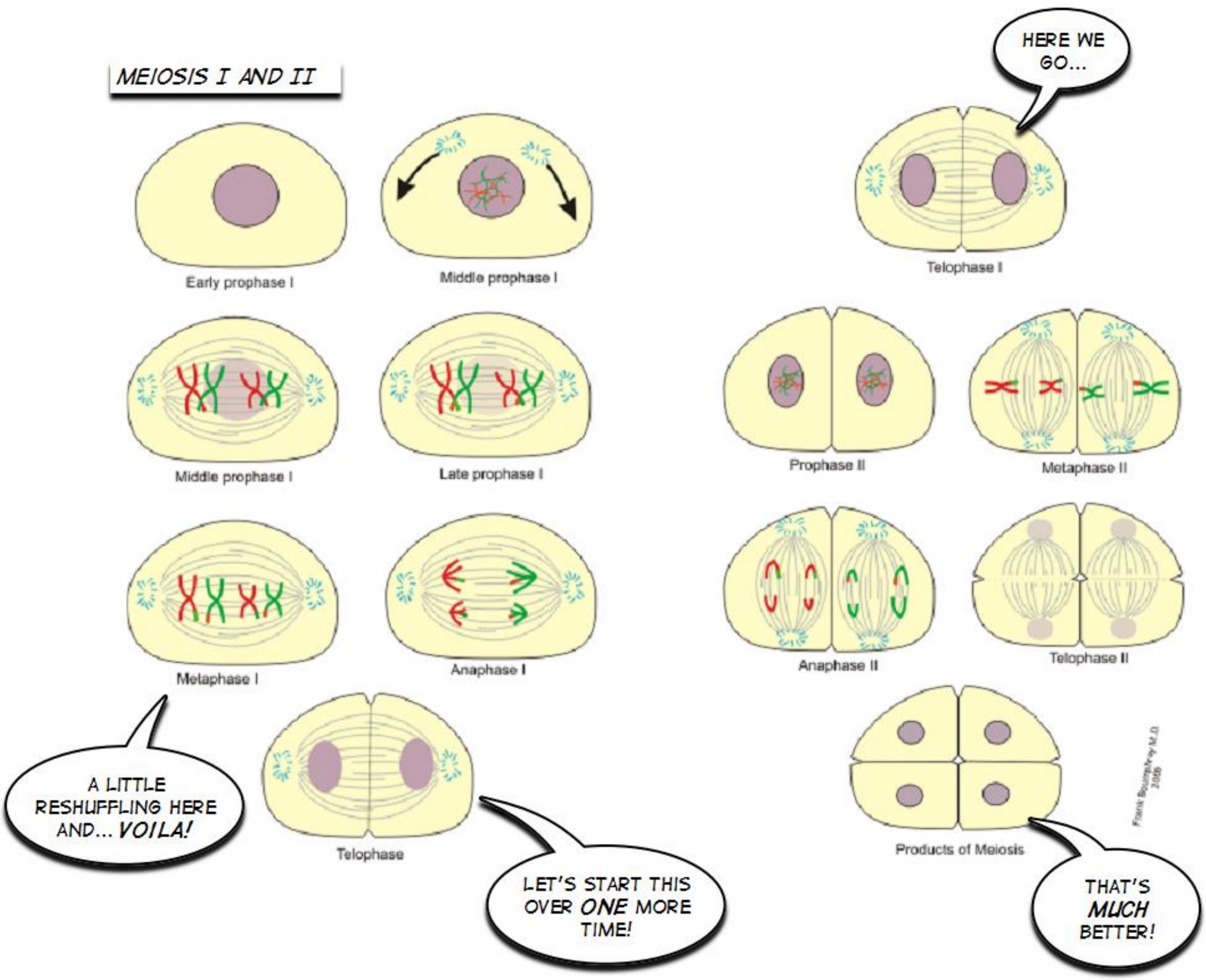
The production of sperm is known as **spermatogenesis** and takes place within each of the nearly 800 small, tightly coiled tubes known as **seminiferous tubules** within each testis. There are three steps which take place during spermatogenesis:

Meiosis I, Meiosis II, and Spermiogenesis

The process of **meiosis I** is a special form of cell division in which the chromosomes go through a "shuffling" procedure ending in different genetic combinations of DNA within each cell. The products of meiosis I include two cells with exactly one-half the number of chromosomes than can be found in the regular body cells. In humans, each cell will contain exactly 23 chromosomes after undergoing meiosis I.

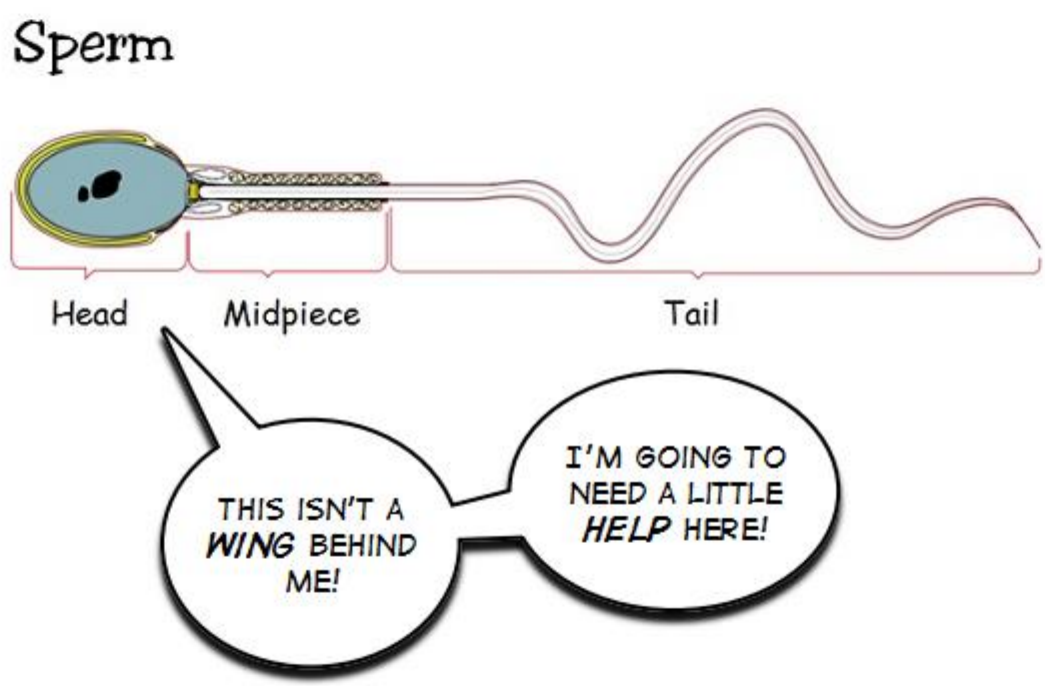
Meiosis II involves the further division of the two cells produced from meiosis I. Therefore, the products of meiosis II are four cells, each with 23 chromosomes and each containing a unique pattern of DNA due to the "shuffling" procedure within meiosis I. Each of these cells are known as **spermatids** and require one further step towards their maturity into adult sperm...

Spermiogenesis is the process by which the spermatids develop a head and tail and become an adult sperm cell or **spermatozoa**. The head of the sperm contains the chromosomes created within meiosis II. Even though the sperm contain a tail (**flagellum**) at this time, they are not yet able to move on their own.



Before we explore the next organ of the reproductive system, it will be helpful to understand the fluid in which the young sperm will be traveling in.

Seminal fluid (also known as **semen**) is primarily generated by the **seminal vesicles** and surrounds the sperm. This alkaline fluid additionally provides nutrients needed by the sperm for energy and mobility. The alkaline nature of this fluid helps to balance the naturally acidic environment of the sperm. An additional 30% of the semen is produced by the **prostrate gland**, a walnut-sized gland found in front of the rectum and under the bladder. The fluid produced by this gland is often milky-white in appearance and slightly acidic in nature. This acidity helps to balance the overwhelming majority of alkaline fluid produced by the seminal vesicles. In addition, the fluid produced by the prostrate gland contains a protein known as **seminalplasmin** which functions similarly to antibodies which help males fight bacterial infections within their urethra.



All of this fluid is transported and stored within the next organ of the reproductive system along with the spermatozoa which are moved by peristalsis (check back in Chapters 24 and 25 for a review of this process) into a specialized tube known as...

the Epididymis

The **epididymis** is a coiled tube which has a length of approximately 20 to 23 feet (6 to 7 meters) long if uncoiled. This impressive length provides a large area to store the maturing sperm. During the 10-14 day maturation process, the sperm gain the ability to use their flagella to propel themselves through the seminal fluid. If mature sperm are not removed from the epididymis within a period of thirty days, they are chemically broken down and recycled by the reproductive system to create new sperm cells.

The mature sperm cells are then moved (via peristalsis yet again) into the next duct within the reproductive system:

the vas deferens

The **vas deferens** are shorter yet wider tubes which carry the semen down its 12 inch (30 cm) length towards a much shorter tube [approximately 1 inch (2.5 centimeters) in length] known as the **ejaculatory duct** which then ejects the semen into the urethra. If you recall from Chapter 27, the male urethra is responsible for expelling both urine <u>and</u> sex cells from the body. The ejection of semen from the urethra is known as **ejaculation**.

Approximately 300 million sperm can be found within the 0.5 to 1 teaspoons (2 to 5 milliliters) of semen that is ejaculated.

In fact, as soon as a male reaches the ages of 11 to 14, the testes are able to produce sperm at a rate which averages approximately 12 billion per month!

The external organ of the male reproductive system is the **penis**. The penis is made up of three individual parts:

Root, Shaft, and the **Glans**

The **root** is simply the part of the penis which is attached to the abdomen. The shape of the penis **shaft** is cylindrical and contains mechanoreceptors whose nerve impulses induce a series of functions that cause the shaft to fill with blood and become erect (also known as an **erection**.) The **glans** of the penis is the head or tip and contains significantly more mechanoreceptors.

As you read in the beginning of this chapter…

The ability to reproduce is essential for all living organisms to survive.

- and -

The creation of a new child cannot be performed without **both** the male and female systems working cooperatively.

In the next chapter, you will learn about the organs of the female reproductive system and how the process of fertilization can produce a new child.

Match the following vocabulary terms with their correct definition:

cremaster muscle	**penis**	**shaft**
ejaculation	**prostate gland**	**sperm**
ejaculatory duct	**root (penis)**	**spermatids**
epididymis	**scrotum**	**spermatogenesis**
flagellum	**semen**	**spermatozoa**
glans	**seminal vesicles**	**spermiogenesis**
gonads	**seminalplasmin**	**vas deferens**
meiosis I	**seminiferous tubules**	
meiosis II	**septum**	

1)	_______________	~12 inch (30 cm) long tubes which carry semen towards the ejaculatory duct
2)	_______________	~20-23 foot (6 to 7 meters) long coiled tube which stores the maturing sperm
3)	_______________	~800 tightly coiled tubes within each testis; site of spermatogenesis
4)	_______________	a small pouch made of loose skin and muscle tissue which hangs outside of the body and contains the male testes
5)	_______________	a walnut-sized gland found in front of the rectum and under the bladder; produces 30% of all seminal fluid which is often milky-white in appearance and slightly acidic
6)	_______________	an adult sperm cell
7)	_______________	cylindrically-shaped structure of the penis; contains tissue filled with mechanoreceptors that trigger nerve impulses when stimulated

8)	______________	immature sperm; products of meiosis II (four cells), each with a unique pattern of 23 chromosomes due to the "shuffling" procedure within meiosis I
9)	______________	involves the further division of the two cells produced from meiosis I
10)	______________	male reproductive cells
11)	______________	muscle which covers the testes; regulates the scrotum's temperature
12)	______________	process by which the spermatids develop a head and tail and become a spermatozoa
13)	______________	production of sperm
14)	______________	antibacterial protein found within the male urethra
15)	______________	responsible for generating the majority of seminal fluid
16)	______________	seminal fluid; alkaline fluid generated by seminal vesicles which provide nutrition for sperm and a medium by which it can be mobile
17)	______________	special form of cell division in which the chromosomes go through a "shuffling" procedure ending in different genetic combinations of DNA within each cell
18)	______________	storage vessel which ejects the semen into the urethra.
19)	______________	tail which propels an adult sperm cell
20)	______________	testes; location where sperm are created
21)	______________	the ejection of semen from the urethra
22)	______________	the external organ of the male reproductive system

23)	______________	the head or tip of the penis; contains a significant amount of mechanoreceptors
24)	______________	the part of the penis which is attached to the abdomen
25)	______________	wall of tissue which divides the scrotum into two chambers and separates the testes

Choose the correct answer from the following questions:

1) **The final outcome of meiosis II among males is:**
   A) four cells with 23 pairs of chromosomes
   B) two cells with 23 chromosomes
   C) four cells with 23 chromosomes
   D) two cells with 23 pairs of chromosomes

2) **Which of the following compounds help males fight bacterial infections within the urethra:**
   A) semen
   B) seminal fluid
   C) seminalplasmin
   D) spermatids

3) **The majority of seminal fluid is produced by the:**
   A) ejaculatory duct
   B) vas deferens
   C) prostate gland
   D) seminal vesicles

4) **The enlarged tip of the penis is referred to as the:**
   A) scrotum
   B) glans
   C) shaft
   D) root
   E) vas deferens

5) **The male gonads produce both sperm and testosterone and are also called:**
   A) ovaries
   B) gametes
   C) testes
   D) ovum
   E) sperm

6) **The process in which sperm develop a head and tail is called:**
   A) meiosis II
   B) spermatids
   C) spermiogenesis
   D) spermatozoa

Application Question:

In some cultures of the past eunuchs were responsible for guarding harems, which were the collective wives of one male. Eunuchs were males who, as boys, were castrated. Castration removes the testes, the major site of testosterone production in males. Because testosterone is responsible for the sex drive in males, the reason for castration is obvious. As a side effect of this procedure, the eunuchs grew to above-normal heights. Can you explain why?

Chapter 30

Female Reproductive System

Last week you looked at the anatomy and physiology of the male reproductive system which, as you will learn in this chapter, have many similarities and differences when compared to the organs within the female reproductive system. More importantly, you explored two important concepts involving the reproductive systems of our species:

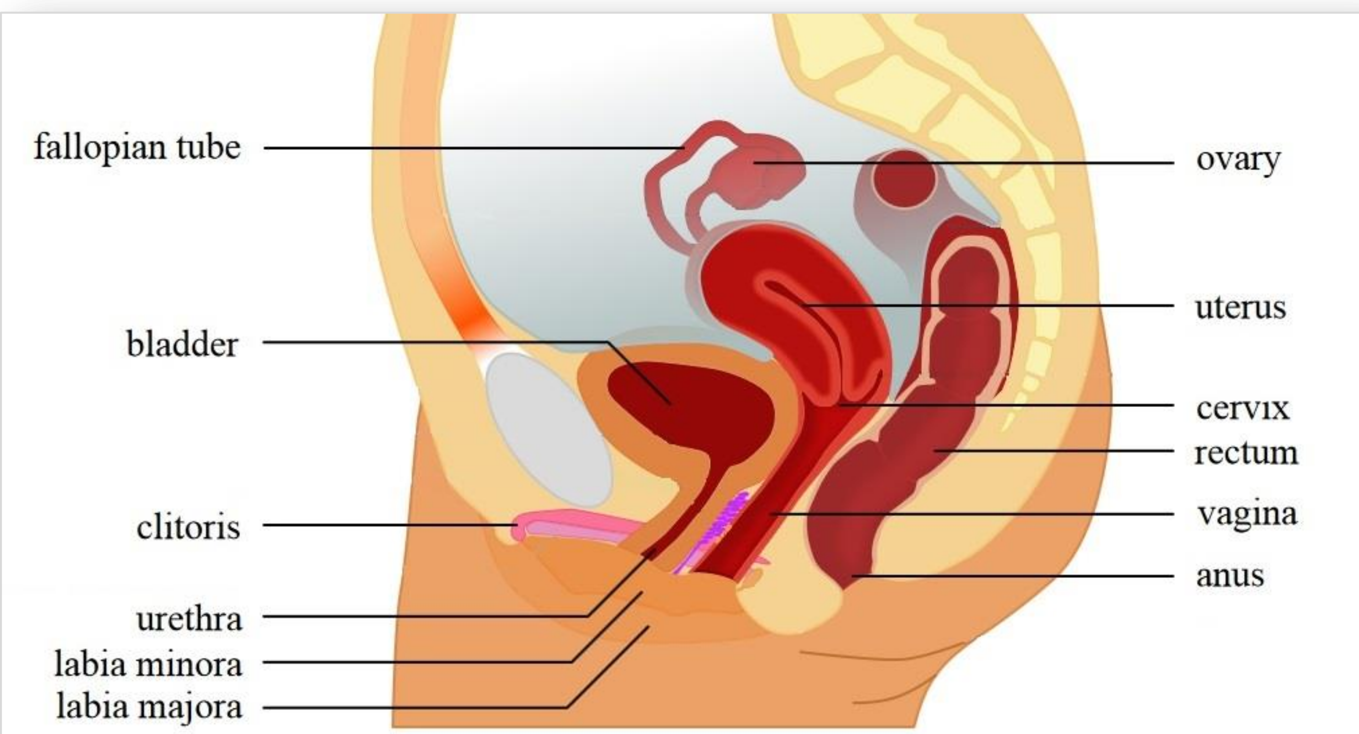
The ability to reproduce is essential for all living organisms to survive.

- and -

The creation of a new child cannot be performed without both the male and female systems working cooperatively.

Keep these two concepts in mind this week as we explore the following main organs functions of the female reproductive system:

Ovaries, Uterine tubes, Uterus, Vagina, Vulva, and the **Mammary glands**



The female reproductive system contains gonads (areas in which the reproductive cells are created) which are also known as ovaries. Each ovary is approximately the size of an unshelled almond - 1 to 2 inches (2.5 to 5.0 cm) long and 0.6 to 1.2 inches (1.5 to 3.0 cm) wide. Within each ovary contains the female sex cells known as eggs.

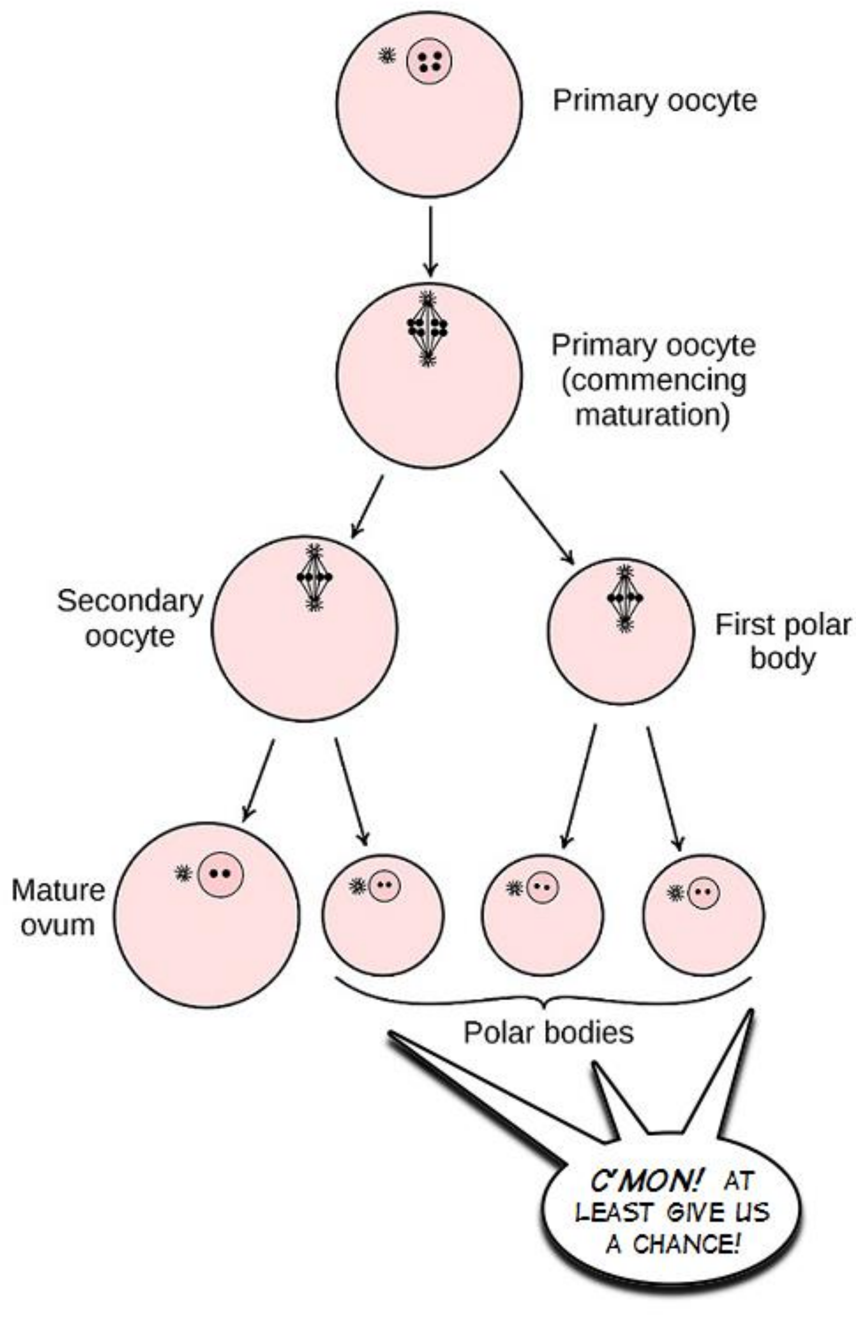
Much like the testes of the reproductive system, the ovaries are also members of the endocrine system as you learned back in Chapters 12 and 13. Ovaries are triggered to produce eggs while in the presence of a pituitary gland secretion called follicle-stimulating hormone (FSH) and luteinizing hormone (LH). Once the ovaries detect LH, these organs will begin to produce the chemicals progesterone and estrogen. The primary functions of these chemicals in women involve the preparation and maintenance of their bodies before and during pregnancy.

Once stimulated by FSH, the ovaries begin to produce eggs through a process known as **oogenesis**. This process begins as the female is still a **fetus** (a developing mammal still within the mother's reproductive system).

Oogenesis involves the production of sex cells for females just as spermatogenesis produces sex cells for males; however, the mechanism for this process has a couple of differences:

First, only one <u>mature</u> sex cell is produced from meiosis I and II during oogenesis, unlike the four sperm produced by spermatogenesis. To be honest, a total of four sex cells are actually created; however, the three female sex cells that do not mature (known as **polar bodies**) are much smaller than the fourth and are quickly broken down within the ovary.

Second, unlike spermatogenesis, oogenesis begins during fetal development of the female child. To be more specific, meiosis I takes place before birth and produces nearly two million immature sex cells known as **primary oocytes**. These cells do not progress or mature any further until meiosis II is activated when the child reaches approximately age twelve. When meiosis II begins in females, only 300,000 to 400,000 primary oocytes remain, the rest having degenerated over time. Meiosis II allows for the primary oocyte to be divided into two separate cells. One of these cells (the secondary oocyte) is much larger than the other and eventually matures into an egg (**ovum**) within the ovary. This maturation process (known as the **ovarian cycle**) takes place each month within the female until a mature egg is released through another process known as **ovulation**.



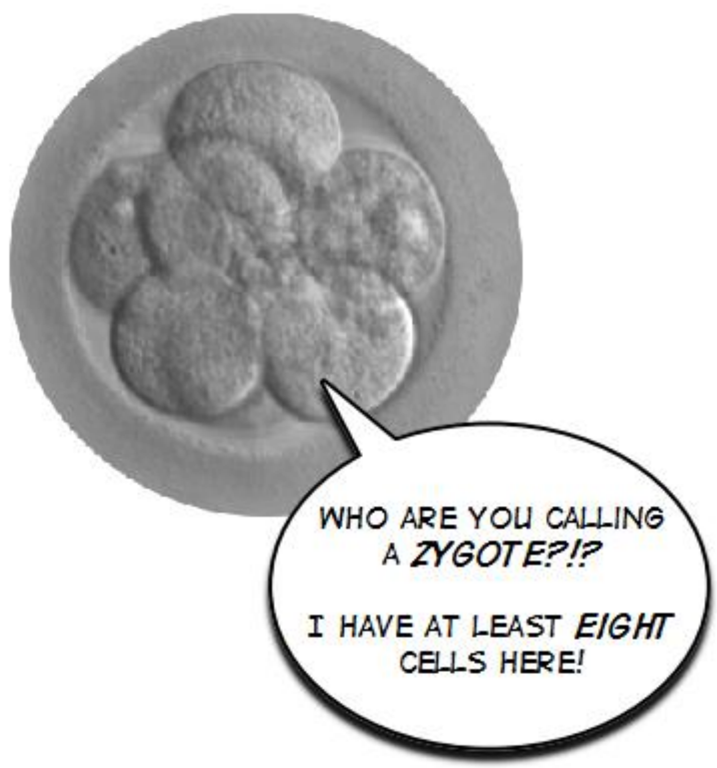
Out of the hundreds of thousands of primary oocytes within the ovaries, only a few hundred (~400) develop into eggs and go through the process of ovulation in a woman's lifetime.

As the process of ovulation takes place, a single mature egg travels down one of two **uterine tubes** (also known as **Fallopian tubes**). It is within the uterine tubes that the mature egg can bond with a single incoming sperm from the male in a process known as **fertilization**. Although millions of sperm may be present within the uterine tube, and several sperm may reach the egg, only one sperm may penetrate its protective covering and begin the process of fertilization.

Upon reaching the egg, the sperm releases an enzyme within its head that removes part of the egg's outer wall. The sperm then enters the egg where their combined DNA strands bind with each other. Once this process is complete, the opening created by the sperm is closed off as the outer wall of the now fertilized egg begins to thicken, preventing further sperm from entering the egg.

Once fertilization has taken place, the fertilized egg is then known as a **zygote** and can travel up to seven days within the Fallopian tubes towards a pear-shaped organ between the bladder and the rectum called the uterus (**womb**). You first learned about the uterus back in Chapter 12 as the target for the hormone oxytocin – a chemical which stimulates the smooth muscles of the uterus to contract which helps to push the child out during childbirth. In addition, oxytocin assists in the release of breast milk among nursing women.

Upon entering the uterus, the zygote begins to undergo several cell divisions where it is referred to as an **embryo**. The embryo can then be anchored into wall of the uterus where the developing fetus receives nutrients and protection throughout the remainder of its development.



Prior to fertilization, the female uterus is approximately 3 inches (7.5 cm) long, 2 inches (5 cm) wide, and weighs 1 to 1.4 ounces (30 to 40 grams). During pregnancy these figures are much higher as the total weight of the developing fetus and uterus is approximately 22 pounds (10 kg)

Before we explore the remaining structures of the female reproductive system, let's take a look at a very important timeline for all of the processes you just learned...

The Menstrual Cycle

The **menstrual cycle** (**menses**) identifies all of the physiological changes that take place within a female to prepare her for sexual reproduction. Although each individual is unique, the average length of a menstrual cycle is approximately 28 days. The menstrual cycle is commonly confused with similar phases involving the ovarian cycle. For the purposes of this book, the menstrual cycle will contain all of the phases which involve the organs of the female reproductive system.

Menstrual phase (Menstruation)

The **menstrual phase** lasts an average of 4 days during which ~1.2 to 1.7 ounces (35 to 50 milliliters) of menstrual fluid is lost. This fluid is a mixture of blood, mucus, inner lining of the uterine wall, and the unfertilized egg. This phase is triggered by a reduced concentration of the hormones estrogen and progesterone in the blood. How this occurs you will soon find out...

Proliferative phase/Follicular phase

This phase involves the growth of a new inner lining for the uterus wall (proliferative phase). In addition, the pituitary glands begin to secrete large volumes of follicle-stimulating hormone (FSH) and luteinizing hormone (LH). The latter of which causes the ovaries to produce large amounts of estrogen (triggering the completion of meiosis I and II.)

This generates the ovarian cycle to complete its maturation and preparation for an egg to be released into the Fallopian tube. This entire process takes approximately eight days to complete.

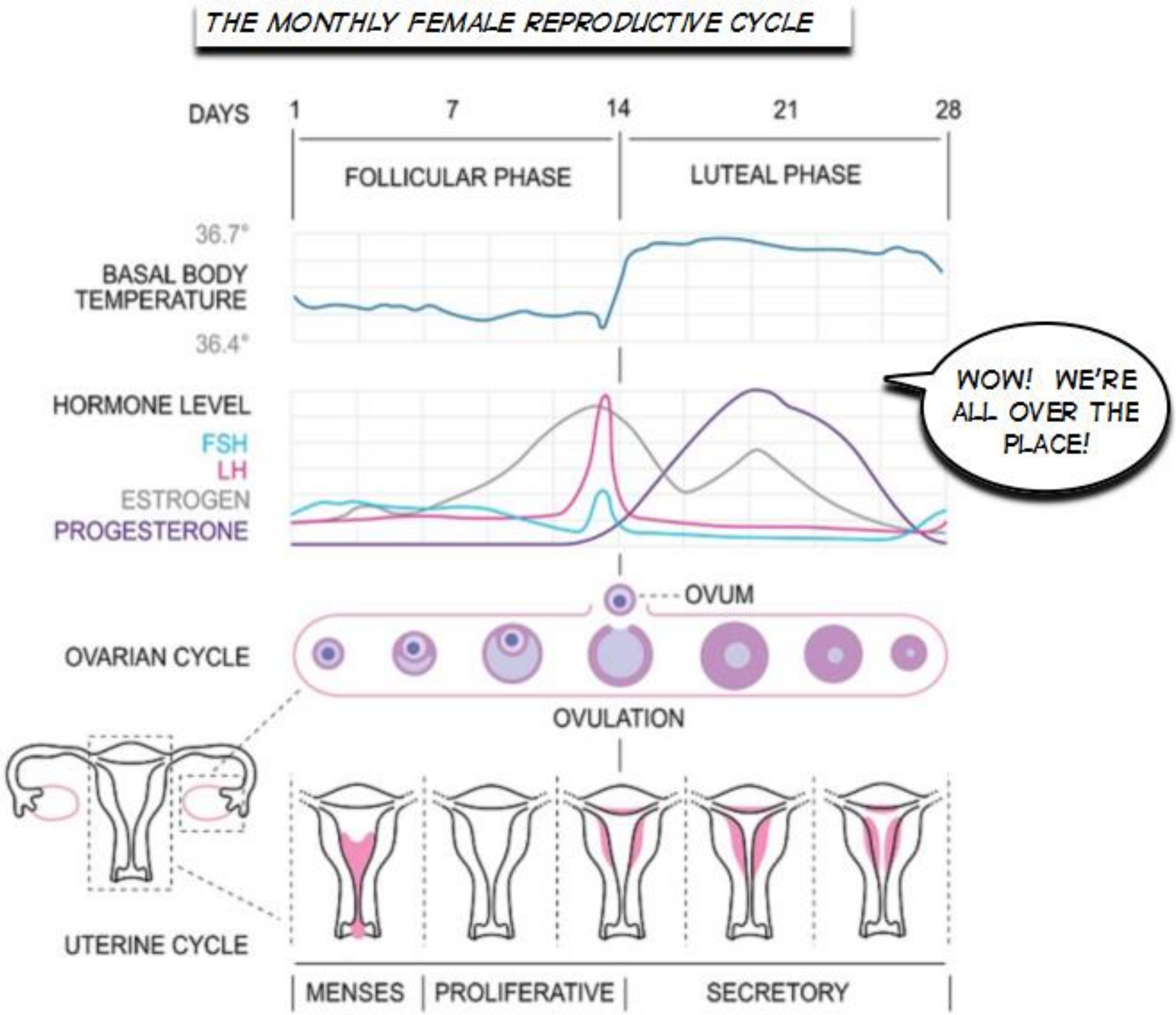
Ovulation

As stated previously, ovulation involves the release of an egg through a Fallopian tube. The egg is actually released from a protective covering known as the **corpus luteum** which remains within the ovary during ovulation. This structure plays an important role in the next stages of the menstrual cycle. The journey of the egg through the uterine tube lasts approximately 3-4 days.

Secretory phase/Luteal phase

If it does not become fertilized, the egg only survives for 24 hours after ovulation. However, the corpus luteum begins to secrete large amounts of the hormones estrogen and progesterone. These hormones prepare the inner lining of the uterine to be implanted with an embryo and act to inhibit the release of FSH and LH by the pituitary gland. If an embryo is not developed within approximately 11 days, the corpus luteum degenerates within the ovary and the levels of progesterone and estrogen are decreased significantly.

The reduced presence of these two hormones triggers the process of menstruation to begin once again.



The lower portion of the uterus (**cervix**) is attached to a muscular tube that extends to the outside structures collectively known as...

the Vagina

The **vagina** allows fluids to escape into the outside environment in addition to providing passageways for both the penis to enter during sexual intercourse and for the fetus to exit during childbirth.

The vagina's acidic environment protects the female reproductive system from the growth of many pathogens. The vagina is also protected by a series of external structures which is commonly referred to as the **vulva**. The structures of the vulva include the following:

Labia majora

The **labia majora** are the outer two large folds of tissue which cover the sides of the vaginal opening.

Labia minora

The **labia minora** are two soft folds of tissue within the lining of the labia majora which also helps to cover the opening to the vagina as well as to cover the clitoris. The main function of the labia minora is to secrete lubricating fluids to keep the skin around the vulva moist. Compounds within this fluid actively destroy invading pathogens as well.

Clitoris

The **clitoris** is located at the top of the vulva and is covered by the labia minora. This organ contains a large volume of blood vessels and nerve cells (mechanoreceptors) which trigger nerve impulses when stimulated. These actions are similar to those found within the shaft and glans of the penis.

Vaginal vestibule

The **vaginal vestibule** ("entrance") can only be seen when the labia minora and majora are parted. This area contains the vaginal opening and two small glands which provide lubricating fluid to the vulva as well.

Urethral meatus

The **urethral meatus** is the external opening of the ureter. As you recall, the ureter is only used for expelling urine within females (unlike males which use the ureter to transport both seminal fluid and urine.) The urethral meatus in females is located below the clitoris and above the vaginal opening (vaginal vestibule.)

Perineal body

The **perineal body** (also known as the **perineum**) is located at the bottom of the vulva, between the opening of the vagina and the anus. This area of the vulva is made of very strong and flexible tissues which allow for the vulva to be widely stretched during childbirth.

Hormonal changes during pregnancy can induce other changes within the endocrine system as well. The most noticeable change involve the...

Mammary glands

Mammary glands, as you learned back in Chapter 12, are organs in female mammals that produce milk to feed young offspring. These glands are triggered by the hormone prolactin which has another important role within the female reproductive system:

Prolactin helps to maintain the corpus luteum within the ovary

Although the biochemistry of how prolactin helps the corpus luteum is beyond the purpose of this book, it is important to note that prolactin levels increase progressively throughout pregnancy, thereby triggering the mammary glands to produce milk.

This is not an exhaustive list of the anatomy and physiology of the male and female reproductive systems. However, it does contain all of the main components of how our species continues to survive through sexual reproduction. In the next chapter, we will explore some of the conditions that complicate this entire process.

Anatomy & Physiology - Connections

How the following body systems affect the reproductive system		How the reproductive system affects the following body systems	
Integumentary	Covers external sex organs; mammary glands provide milk for newborns	Hormones secreted by reproductive system affect body hair growth	**Integumentary**
Skeletal	Pelvis protects organs for both male and female reproductive systems	Hormones trigger growth and development of bones	**Skeletal**
Muscular	Contractions eject semen from male reproductive tract	Hormones trigger growth and development of skeletal muscles	**Muscular**
Nervous	Controls sexual functions	Mechanoreceptors trigger the CNS to produce a sexual response	**Nervous**
Endocrine	Hormones from hypothalmus and pituitary regulate growth and development of reproductive system	Hormone (inhibin) regulates the volume of FSH in bloodstream	**Endocrine**

Cardiovascular	Distribution of reproductive hormones; provides nutrients, oxygen, and waste removal for unborn child	Estrogen may help in the maintaining healthy blood vessels	**Cardiovascular**
Immune	Helps to prevent infection and repairs damaged tissues	Female secretions from vagina provide bacterial immunity	**Immune**
Respiratory	Provides gas exchange within tissues of reproductive system	Sexual response can alter rate of respiration	**Respiratory**
Digestive	Provision of nutrients for production of sex cells and fetal development	Increased appetite caused by developing fetus	**Digestive**
Urinary	Transportation of semen through urethra in males; excretion of fetal waste products by kidneys in females	Secretions from prostate may contain anti-bacterial properties	**Urinary**

Match the following vocabulary terms with their correct definition:

cervix	**ovulation**
clitoris	**perineal body (perineum)**
corpus luteum	**polar bodies**
embryo	**primary oocytes**
fertilization	**proliferative phase/follicular phase**
fetus	**urethral meatus**
labia majora	**uterine tubes (Fallopian tubes)**
labia minora	**vagina**
menstrual cycle (menses)	**vaginal vestibule**
menstrual phase	**vulva**
oogenesis	**womb**
ovarian cycle	**zygote**

1)	_______________	~2 million immature sex cells produced during meiosis I
2)	_______________	a developing mammal still within the mother's reproductive system
3)	_______________	a fertilized egg
4)	_______________	a series of external structures which protect the vagina
5)	_______________	all of the physiological changes that take place within a female to prepare her for sexual reproduction
6)	_______________	allows fluids to escape into the outside environment in addition to providing passageways for both the penis to enter during sexual intercourse and for the fetus to exit during childbirth
7)	_______________	bonding of a mature egg with a single sperm

8)	______________	first stage of the menstrual cycle; lasts an average of 4 days during which approximately 1.2 to 1.7 ounces (35 to 50 milliliters) of menstrual fluid is lost
9)	______________	lower section of the uterus
10)	______________	maturation process of a single egg from the division of a primary oocyte into two separate cells
11)	______________	passageway for mature egg to travel from the ovary towards the uterus; site of potential fertilization
12)	______________	protective covering which remains within the ovary during ovulation; site where an egg is released into the Fallopian tube
13)	______________	second stage of the menstrual cycle; involves the growth of a new inner lining for the uterus wall, the secretion of LH and estrogen and the maturation and preparation of the egg to be released into the Fallopian tube
14)	______________	series of events involving the traveling of a mature egg down the Fallopian tubes and potentially becoming fertilized by sperm
15)	______________	structure of the vulva; contains the vaginal opening and two small glands which provide lubricating fluid to the vulva as well
16)	______________	structure of the vulva; external opening of the ureter
17)	______________	structure of the vulva; identifies the outer two large folds of tissue which cover the sides of the vagina opening
18)	______________	structure of the vulva; identifies the two soft folds of tissue within the lining of the labia majora which also helps to cover the opening to the vagina and clitoris
19)	______________	structure of the vulva; located at the bottom of the vulva; made of very strong and flexible tissues which allow for the vulva to be widely stretched during childbirth

20)	______________	structure of the vulva; located at the top of the vulva and is covered by the labia minora; contains a large volume of blood vessels and nerve cells (mechanoreceptors) which trigger nerve impulses when stimulated
21)	______________	the process of producing eggs
22)	______________	three of the four immature eggs produced through the process of meiosis I and II which are much smaller than the fourth and are quickly broken down within the ovary
23)	______________	uterus; pear-shaped organ between the bladder and the rectum; site of developing zygote into an embryo
24)	______________	zygote that has undergone several cellular divisions; anchored into the wall of the uterus

Choose the correct answer from the following questions:

1) **A fertilized egg is known as a:**
   A) morula
   B) zygote
   C) secondary oocyte
   D) blastocyte
   E) primary oocyte

2) **Specific glands that produce milk when a woman is pregnant are called:**
   A) mammary glands
   B) lactiferous ducts
   C) fallopian glands
   D) lactating glands

3) **Which one of the following is NOT true of the proliferative stage of the menstrual cycle:**
   A) estrogen levels rise
   B) a new inner lining of the uterus wall is created
   C) an egg is prepared to be released by the Fallopian tube
   D) ~1.2-1.7 ounces of menstrual fluid is lost

4) **The corpus luteum covers the ovaries and produces:**
   A) estrogen
   B) testosterone
   C) luteinizing hormone
   D) luteinizing hormone
   E) progesterone and estrogen

5) **True or False:** The external genitalia of a female is also called the vulva.

6) **True or False:** Ovulation usually occurs on or about day 13 of the menstrual cycle.

Application Question:

A study of two groups (A and B) of healthy adult females contains females who have been sexually active for at least 2 years and are not pregnant at the beginning of the experiment. Group A women receive a a sugar pill (placebo) each morning during their menstrual cycles. Group B women receive a pill containing estrogen and progesterone each morning of their menstrual cycles. Then plasma LH levels are measured before, during, and after ovulation. The results are as follows:

Group	4 Days Before Ovulation	The Day of Ovulation	4 Days After Ovulation
A	18 mg/100 mL	300 mg/100 mL	17 mg/100 mL
B	21 mg/100 mL	157 mg/100 mL	15 mg/100 mL

The number of pregnancies in Group A was 37/100 females/year.
The number of pregnancies in Group B was 1.5/100 females/year.

What conclusion(s) can you reach on the basis of these data? Defend your answer.

Chapter 31

Reproductive Systems: What can go wrong?

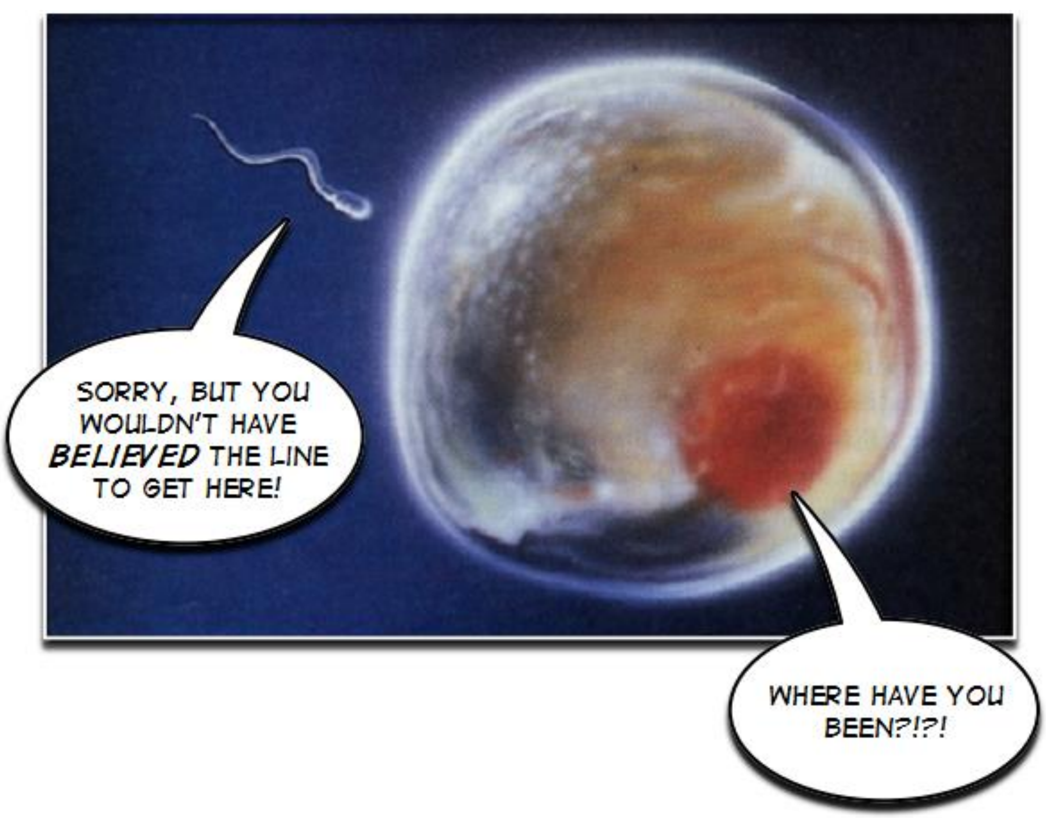
In this final chapter we will explore some of the medical disorders that are associated with the human reproductive system. As with all of the previous chapters that have been devoted to the identification of disorders and conditions of the various body systems we have explored, this chapter will not provide an exhaustive list – only a small portion of the most common conditions that may be witnessed in our daily lives.

Disorders and conditions involving the male reproductive system

The first condition we will explore is known as **sterility**. A man is considered to be sterile when the number of sperm he produces falls below 20 million per milliliter (0.03 ounces). Although it may not seem like this is a small number, when compared to the nearly 300 million sperm per milliliter found in average volume of semen discharged during ejaculation, this number is really quite small. With only 20 million sperm entering the female reproductive system, it is unlikely many will survive long enough to have the ability to fertilize an egg.

This next condition is not a disorder in any way, but it is a normal condition that affects all males:

The inability to urinate and ejaculate at the same time



Back in Chapter 27, you learned about the elastic bladder which is squeezed by its muscular walls to empty its urine through a tube called the urethra. A sphincter exists between these two structures which closes the urethra just prior to ejaculation. This action prevents urine from mixing with the semen and to keep semen from flowing into the bladder.

Endocrine glands can also cause problems for a man's reproductive system!

As you have learned previously, the prostate gland is responsible for producing approximately 30% of the semen that is ejaculated by men. When this gland becomes inflamed, a patient tends to suffer through a painful condition called **prostatitis**. Although bacterial infection can cause the symptoms of prostatitis to develop, the majority of cases involve the absence of foreign pathogens. Lower back pain, frequent and painful urination, and fever are common symptoms of prostatitis.

A potentially more serious condition involving the prostate are slow-growing cancers.

Prostate cancer is the second leading cause of cancer-related death in men within the United States. Many individuals with an early stage of prostate cancer are **asymptomatic** meaning they do not show any visible symptoms of the disease. However, as the cancer continues to grow it may cause pain, difficulty with urination, and **erectile dysfunction** - a condition in which the man is unable to achieve or maintain an erection during sexual intercourse.

Prostate cancer is not the only cause of erectile dysfunction. A long list of possible reasons may also cause this condition in men. Some of these include the use of tobacco and anti-depressants, neurological disorders such as spinal cord, brain and nerve cell injuries, kidney failure, diabetes, aging, and various psychological conditions.

Disorders and conditions involving the female reproductive system

Much like sterility which can occur in males, females can also be incapable of becoming pregnant (**infertility**). A woman is considered infertile if she is unable to become pregnant after one year of unsuccessful attempts. Most problems begin within the stages of ovulation as the egg fails to fully mature or be released from the ovary. However, blocked Fallopian tubes as well as chemical and/or tissue imbalances within the uterus may also cause infertility within women.

Unlike men who can produce viable sperm for most of their adult lives, women have a finite amount of eggs that can be released during their monthly cycles. When the supply of oocytes within the ovaries is depleted, ovulation and menstruation cease to occur. This condition is known as **menopause** and occurs in women between the ages of 45 and 55 or after a woman has not gone through menstruation for at least a year.

The absence of menstruation can be induced in other ways...

Amenorrhea is a condition in which a woman fails to menstruate before the age of 16. Many causes may bring about this condition including genetic and developmental disorders as well as disorders of the endocrine system. It is possible for a woman to go six months or longer without menstruating – despite being pre-menopausal and not pregnant. This condition, known as **secondary amenorrhea**, may be caused by emotional problems such as depression or grief, and can be induced through excessive weight loss.

A general series of diseases known as pelvic inflammatory disease (PID) within the female reproductive system can lead to infertility as well.

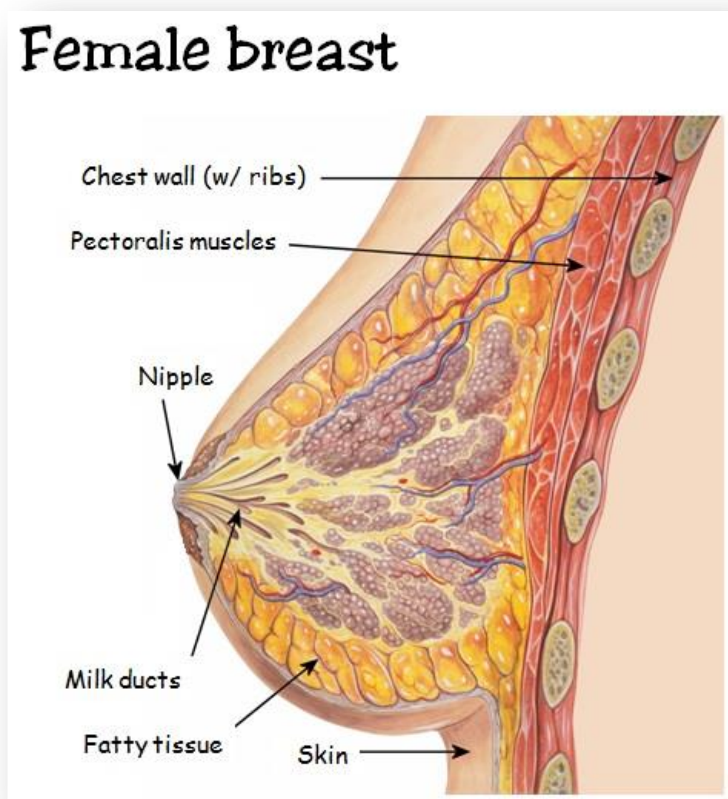
Pelvic inflammatory disease (PID) is a broad term describing an inflammation of the uterus, Fallopian tubes, and/or the ovaries which can be caused by a number of different pathogens. One complication of PID is the formation of **adhesions** within the lower abdomen. Adhesions are fibrous bands of tissue that can connect organs together which typically are not connected at all. This condition can be painful as the internal organs can become twisted or pulled from their normal locations. Lower abdominal pain is the most common symptom of pelvic inflammatory disease. Due to the wide range of PID infections, most physicians will diagnose this disease according to the organs that are affected, the duration of the infection, and the type of pathogen that has caused the disease. If left untreated, adhesions can block the uterine tubes. This blockage may cause infertility or, should a fertilized egg be blocked within the uterine tube, an **ectopic pregnancy** may occur. This type of pregnancy is life-threatening to the mother as the developing embryo embeds itself within the uterine tubes. If the embryo grows too large, it can rupture the uterine tube, causing a very serious internal hemorrhage.

Another cause for adhesions exists within a condition known as **endometriosis**. This condition takes place when the inner lining of the uterus spreads outward and connects to the ovaries, vagina, small intestine, and other tissues within the abdomen. Much like PID, adhesions from endometriosis can cause lower abdominal pain and infertility.

At times, physicians will perform a surgical removal of the uterus (**hysterectomy**) to end the spread of endometriosis or the growth of uterine **fibroids** (abnormal growths of smooth muscle tissue found within the uterine wall). Both of these conditions can induce large amounts of pain for the female. The most common hysterectomy that is performed removes both the cervix and uterus together. However, part of the vagina and supporting tissues can also be removed in cases where cancer is present.

And since we are on the topic of cancer…

Nearly 23% of all cancers which affect women are a form of breast cancer. As you read in previous chapters, mammary glands secrete milk in response to pregnancy. This milk must travel from the glands through **milk ducts** which lead eventually to the tip of the **nipple** where the milk is released to feed a newborn child. It is in the rapid and uncontrollable growth of cells within the milk ducts that most breast cancers originate. In most cases, breast cancer is detected by a visible lump of tissue under the breast. And as with all cancers - the earlier it is detected, the more likely the individual can have it removed and live a long healthy life.



This last brief section pertains to the spread of sexually transmitted diseases...

Sexually transmitted diseases (STDs) are caused by the spread of bacteria or viruses between two individuals involved in any form of sexual contact or between a mother and her baby during childbirth. In recent years "sexually transmitted diseases" has been more widely termed "sexually transmitted infections" (STIs) as an infected individual may not have the full-blown symptoms of the disease when he or she infects another individual. Individuals who harbor such pathogens within their bodies but are asymptomatic are known as **carriers** of the disease. We could have spent this entire year looking at the various types of diseases that can be sexually transmitted and still have several more years to go before we end our studies!

This ends our exploration of the anatomy and physiology of the human body. You have learned many of the main concepts that surround this continually growing field of study. We need students like you to use this information and continue to search for deeper understandings of the amazing processes of the human body. There is true art in healing and it requires a team of capable researchers, care givers, and physicians who are dedicated to the craft. I hope this text has inspired some of you to consider this as your calling in life.

"Let the young know they will never find a more interesting, more instructive book than the patient himself."

Giorgio Baglivi
Italian physician and scientist
1668-1707

Match the following vocabulary terms with their correct definition:

adhesions	**fibroids**	**disease (PID)**
amenorrhea	**hysterectomy**	**prostatitis**
asymptomatic	**infertility**	**secondary amenorrhea**
carriers	**menopause**	**sterility**
ectopic pregnancy	**milk ducts**	***sexually transmitted***
endometriosis	**nipple**	***diseases (STDs)***
erectile dysfunction	**pelvic inflammatory**	

1)	______________	a broad term describing an inflammation of the uterus, Fallopian tubes, and/or the ovaries which can be caused by a number of different pathogens
2)	______________	a condition in which a woman fails to menstruate before the age of 16
3)	______________	a condition in which the man is unable to achieve or maintain an erection during sexual intercourse
4)	______________	a surgical removal of the uterus
5)	______________	abnormal growths of smooth muscle tissue found within the uterine wall
6)	______________	area within the breast where milk is secreted
7)	______________	caused by the spread of bacteria or viruses between two individuals involved in any form of sexual contact or between a mother and her baby during childbirth
8)	______________	condition in which a woman goes six months or longer without menstruating, despite being pre-menopausal and not pregnant

9)	______________	condition when the number of sperm a man produces falls below 20 million per milliliter (0.03 ounces)
10)	______________	condition which takes place when the inner lining of the uterus spreads outward and connects to the ovaries, vagina, small intestine, and other tissues within the abdomen
11)	______________	fibrous bands of tissue that can connect organs together which typically are not connected at all
12)	______________	individuals who harbor pathogens within their bodies but do not have any of the visible symptoms of the disease
13)	______________	not showing any visible symptoms of a disease one has contracted
14)	______________	painful inflammation of the prostate gland
15)	______________	passageways for milk from the mammary glands to the nipple
16)	______________	situation in which a fertilized egg is blocked within the uterine tube
17)	______________	the act of being incapable of becoming pregnant
18)	______________	the lack of ovulation and menstruation occurring when the supply of oocytes within the ovaries is depleted

Choose the correct answer from the following questions:

1) **Pregnancy is generally improbable with a sperm count:**
   A) under 50 million per milliliter
   B) under 30 million per milliliter
   C) under 20 million per milliliter
   D) under 100 million per milliliter

2) **Menopause, which ends the ability to produce a child, is considered to have occurred when a woman:**
   A) turns 50
   B) misses two periods in a row
   C) has gone a year without menstruation
   D) misses her first period

3) **The ovary is part of which of the following two systems:**
   A) digestive and respiratory systems
   B) reproductive and endocrine systems
   C) digestive and endocrine systems
   D) reproductive and respiratory systems
   E) endocrine and respiratory systems

4) **True or false:** Menopause generally occurs between ages 10 and 15 in females.

5) **True or false:** An average number of sperm within the semen discharged during ejaculation is 40 million per milliliter.

6) **True or false:** An ectopic pregnancy is life-threatening to the mother as the developing embryo embeds itself within the uterine tubes.

7) **True or false:** Asymptomatic carriers of pathogens cannot infect other individuals.

Application Question:

Julie is pregnant but is not receiving care from a physician. She has a poor diet consisting mostly of fast food with no vegetables and she drinks no milk. How would this diet affect Julie's level of parathyroid hormone? (You may have to look back in previous chapters for this one!)

Glossary

abducens nerve	cranial nerve; responsible for the abduction of the eye
abduction	movement away from the midline of the body
absorption	movement of water and nutrients from the chyme into the bloodstream
ACE	molecule produced by the lungs which is responsible for narrowing the diameter of arterioles, allowing blood to flow faster
acetylcholine	chemical released by muscle fibers to diffuse calcium ions into myofibrils thereby causing a muscle contraction
acid indigestion	symptom of heartburn; characterized by the tasting of one's stomach contents within the mouth
actin	long thin strands of protein attached to the walls of each sarcomere that are pulled by myosin to cause the contraction of muscle tissue
action potential	a series of actions during a nerve impulse in which a large amount of sodium ions enter the cell after the dendrites receive a stimulus
active immunity	type of immunity which develops after the body produces its own antibodies in response to the presence of a foreign antigen
active transport	a pump which drives particles in and out of the cell against the normal flow of diffusion
Adam's apple	the larynx of males; the larger size of this organ in males produces an observable bulge within the neck
adaptive (specific) immunity	one of two different types of immunity; identifies each invading pathogen (such as bacteria or viruses), unhealthy body cells (such as cancer cells), and other foreign particles
adduction	movement toward the midline of the body
adhesions	fibrous bands of tissue that can connect organs together which typically are not connected at all

adipose tissue	fat
adrenal cortex	comprises ~90% of the adrenal gland; secretes 2+ dozen corticosteroid hormones
adrenal gland s	two glands which sit on top of each kidney and separated into two sections known as the medulla and the cortex
adrenal medulla	small section of the adrenal gland responsible for producing the hormones epinephrine (also known as adrenaline) and norepinephrine
adrenocorticotropic hormone (ACTH)	hormone which acts on the adrenal cortex gland to produce the hormones cortisol and aldosterone
aerobic respiration	conversion of sugar to ATP at times when oxygen is in abundance
air pressure	pressure generated when air molecules slam into a structure; average air pressure is ~14.7 pounds per square inch
albumins	plasma protein; largest by volume; act to regulate the osmotic pressure of the blood
aldosterone	a mineralocorticoid hormone secreted by the adrenal cortex; responsible for increasing the amount of sodium (and water) into the blood and to remove potassium from the blood into the urine
alkaline	non-acidic compounds
allergens	normally harmless substances encountered every day which may induce an allergic response
allergy	a reaction caused by the immune system against normally harmless substances encountered daily
alveoli	microscopic "balloons" of tissue which cap off each bronchiole
Alzheimer's disease	a disease in which changes within neurons cause the death of a large number of cells within the brain
amenorrhea	a condition in which a woman fails to menstruate before the age of 16
amino acids	small sections/pieces of proteins; absorbed by the small intestine

ammonia (NH_3)	waste product from the digestion of proteins; combines with carbon dioxide to form urea
amnesia	the loss of memory that may be caused by a blow to the head
amylase	enzyme which breaks down complex carbs into smaller molecules that can be later absorbed by the digestive track
anal canal	final section of the large intestine and serves as a passageway for feces during defecation
anaerobic respiration	conversion of sugar to ATP at times when oxygen is limited
anatomy	the study of the body's physical structures
anemia	a dangerous condition occurring when a person has a low level of red blood cells or hemoglobin
aneurysm	rupture of the aorta of the heart or the large arteries within the brain
angina	extreme chest pain
anterior (ventral)	directional term meaning "toward the front"
anterior lobe	one of two lobes within the pituitary gland; produces thyroid-stimulating hormone and adrenocorticotropic hormone
antibodies (immunoglobulins)	a type of globulin which is responsible for attacking foreign invaders within the bloodstream
antidiurectic hormone (ADH)	hormone which targets the kidney cells to balance the volume of fluids within the body
antigens	specific molecular "locks" on the outer surface of cells that can only be opened by specific molecular "keys"
antisera	blood serum containing specific antibodies against specific antigens
anus	the final opening at the end of the digestive system
aorta	large artery which carries all of the blood out of the left ventricle
aortic semilunar valve	semilunar valve which closes after blood has exited the left ventricle

appendicular skeleton	the lower skeleton containing the pelvis and all of the extremities
arbor vitae	tree of life; name given to the anatomy of the cerebellum
arrector pili muscles	small bundles of smooth muscles attached to the bulb and root of a hair follicle
arrhythmias	irregular patterns in nerve impulses caused by pacemaker cells
arteries	large blood vessels responsible for carrying blood away from the heart and towards the various tissues of the body
arterioles	branches of arteries whose diameters are smaller than that of the aorta
arteriosclerosis	deposits of hardened calcium within the arteries
arthritis	a group of disorders which affect synovial joints
articulation	joints; an area in the human body that holds two bones together
artificially acquired active immunity	type of active immunity which stimulates the body to produce antibodies under safe conditions
artificially acquired passive immunity	type of passive immunity in which antibodies are transferred into another individual through artificial means (i.e. as through a tetanus or rabies shot)
asymptomatic	not showing any visible symptoms of a disease one has contracted
atherosclerosis	clogging of arteries by cholesterol deposits
ATP (adenosine triphosphate)	compound created by cells which acts as the main chemical fuel for all bodily processes
atria	two upper chambers within the heart
atrioventricular valves	two valves located between the right atrium and right ventricle (tricuspid valve) and left atrium and left ventricle (bicuspid valve)
auditory canal	a 1 inch (2.5 cm) tube within the pinna of the external ear
auditory occicles	three small bones within the tympanic cavity known as the malleus (hammer), the incus (anvil), and stapes (stirrup); vibrations from these bones induce vibrations within the cochlea

autoimmune disease	a condition where the body attacks its own healthy cells
autonomic nervous system	responsible for all of the involuntary activity in the body
avascular	not being supplied with nutrients from the blood
axial skeleton	bones which are responsible for protecting the head, neck, and trunk of the body
axons	special structures within a nerve cell which move nerve impulses towards the CNS
B cells	created by the red bone marrow and are one of the primary agents within our adaptive immune system
basement membrane	connective tissue which attaches the stratum basale to the dermis
benign tumors	cancerous cells which do not invade neighboring tissues or cells
bicarbonate ion (HCO^{-1})	compound created from the breakdown of carbonic acid; storehouse for most carbon dioxide within the blood; reacts chemically within the filtrate to keep its pH from becoming too acidic
biceps	muscles which attached to both the shoulder and elbow joints within our upper arm; responsible for the act of lifting objects
bile	alkaline solution produced by the liver; breaks down large fat molecules into fatty acids which can be absorbed by the small intestine
bile ducts	tubes between the liver and gall bladder which carry bile
bilirubin	waste product from the digestion of old red blood cells; gives feces its characteristic brown color
bladder	a single, elastic, and muscular organ used to store urine before excretion
blisters	fluid-filled pocket between the epidermis and the dermis/hypodermis; caused by burning or friction
blood clot	a "plug" of platelets within a damaged blood vessel
blood pressure	a measured force of the blood pushing against the inner walls of the arteries near the heart

blood type	one of four different types of blood which is characterized by the absence or presence of three different surface antigens (A, B, and Rh)
blood-brain barrier	layer of endothelial cells within the capillaries surrounding the brain and CNS which fit very tightly together, allowing only the smallest of materials to diffuse through the vessel walls (i.e. oxygen, carbon dioxide, etc.)
body cavity	any space in the body between the skin and the outermost tissues of the internal organs
bolus	round mass of pulverized food created during mastication
booger	dried mucus, potentially filled with pathogens, which is expelled from the body
brain	one of two main organs of the CNS; control center for most neural activity throughout the body
bronchioles	the smallest air passageways leading into the lungs; capped off by microscopic alveoli
bronchitis	disorder of the respiratory system characterized by the swelling of the internal walls of the bronchi combined with an increased level of mucus production
bulb	enlarged base at the end of a single hair which contains its root
calcitonin	hormone produced by the thyroid gland which stimulates bone growth and helps to regulate the amount of calcium found in the blood
calcitrol	hormone produced from vitamin D by the kidneys; promotes the absorption of calcium into the blood within the digestive system
calcium ions	a particle of calcium which has lost two of its electrons
cancer	the uncontrollable growth of individual cells within the body
canines	the four sharpest teeth in the mouth and are located on either side of the incisors
capillaries	the tiniest blood vessels in the human body

carbonic acid	acid created from carbon dioxide that is dissolved in the blood
cardiac muscle	an involuntary tissue making up most of the heart's mass which is primarily responsible for pumping blood
carriers	individuals who harbor pathogens within their bodies but do not have any of the visible symptoms of the disease
cartilage	type of connective tissue responsible for protection of bones and flexibility of joints; not as rigid as bone tissue but less flexible than muscle tissue
cartilaginous joints	joints which are made up of either hyaline cartilage or fibro-cartilage and provide little if any movement
cauda equina	extension of thin nerves below the vertebrate column resembling the shape of horse's tail
cecum	a pouch-like structure which is attached to the small intestine via the ileocecal valve and receives the leftover chyme from the small intestine
cell membrane	protective covering which surrounds a cell
cellular respiration	the use of oxygen by the cells for its functioning and their release of carbon dioxide gas as waste
Central Nervous System (CNS)	control center of the nervous system; consisting of the brain and spinal cord
cerebellum	second-largest area of the brain; found above the medulla oblongata; responsible for movements, balance, equilibrium, and posture
cerebral cortex	wrinkly mass surrounding the right/left cerebral hemispheres
cerebrospinal fluid (CSF)	a specialized fluid located in the space between the meninges and the organs
cerebrum	makes up the majority of the brain's mass; separated into right and left hemispheres
cervical (neck) curvature	top section of the spinal cord which contains seven vertebrae within the neck
cervical nerves	spinal nerve; responsible for functions pertaining to the head, neck, and shoulders

cervix	lower section of the uterus
chemoreceptors	sensory receptor which responds to chemical compounds such as odor molecules
cholesterol	type of fat; excess amounts within the blood can cause deposits to form within arteries which may lead to atherosclerosis
chyme	pulverized mass of food with a consistency of thickened "soup"
cilia	branches of fingerlike projections from the cell body of dendrites; responsible for identifying specific chemicals
circadian rhythm	sleep-wake cycle of humans; controlled by the hormone melatonin secreted by the pineal gland
clitoris	structure of the vulva; located at the top of the vulva and is covered by the labia minora; contains a large volume of blood vessels and nerve cells (mechanoreceptors) which trigger nerve impulses when stimulated
clones	any one of the many identical copies of specific lymphocytes
clotting factors	proteins which assist in the formation of fibrin from fibrinogen
coccyx	tailbones; four fused vertebrae found within the pelvic curvature
cochlea	spiral-shaped fluid-filled chamber within the inner ear whose mechanoreceptors transmit nerve impulses to the CNS concerning our sense of hearing
cold receptors	nerve endings within the skin that are are sensitive to temperatures that fall under 50°F (10°C)
collagen	group of proteins making up ~30% of all connective tissues; easily and widely converted into gelatin for industrial uses
collecting ducts	system of pathways for the passage of urine between each nephron and the ureters
colon	longest area of the large intestine; leftover water, salt, and vitamins are absorbed through its walls without the use of villi

color blindness	the inability to perceive one or more colors
columnar	skin cells which are much taller than they are wide
common bile duct	tube which carries bile from the gall bladder into the duodenum
compact bone tissue	hard outer layer of bones
complement	a group of proteins which help to "mark" pathogens by attaching themselves to the foreign invader
concave lenses	lens which bends light outwards; its structure is thinnest in the center
concussion	a general name given to any minor injury to the brain that is caused by a blow to the head
conduction deafness	a form of deafness; caused by damage within the middle ear which prevents a nerve impulse from being created
cones	photoreceptors in the retina; specialized for vision in bright light and can detect color
connective tissue	most widespread tissue; acts as "cellular glue" forming the framework and support structures for all body tissues and organs
connective tissue proper	type of connective tissue which includes tendons, ligaments and fat tissue; strong and flexible tissue which allows the body to hold onto fluids, absorb waste material, and stores fat
constrict	become narrower
contracts	to shorten
convex lenses	lens which bends light inwards; its structure is thickest in its center
cornea	refracts (bends) and focuses light rays (much like the lens of a camera or telescope) into the pupil
coronal (frontal) plane	plane of reference which divides the body into anterior and posterior portions
coronary artery	one of two arteries which supply the heart with blood
corpus luteum	protective covering remaining within the ovary during ovulation; site where egg is released into the Fallopian tube

corticosteroid	one of 2+ dozen hormones secreted by the adrenal cortex
cortisol	a glucocorticoid hormone secreted by the adrenal cortex responsible for increasing the level of sugar within the blood
cough	reflex triggered by the larynx; used to rapidly remove the foreign items from the respiratory system before it reaches the lungs
cranial nerves	12 pairs of nerves attached to the brain which spread throughout the body
creatine	compound used by muscles during a contraction
creatinine	a nitrogen-containing compound produced from the breakdown of creatine during a muscular contraction
cremaster muscle	muscle which covers the testes and regulates the scrotum's temperature
crown	the visible white part of the tooth
cuboidal	cube-shaped skin cell
cytoplasm	fluid within a cell which acts as a storage area for gases, food, wastes, etc.
defecation	removal of waste products from the body
deltoids	a group of muscles on your shoulders ; responsible for abduction, horizontal abduction and adduction; flexion/extension, and medial/lateral rotation
dendrites	special structures extending from the surface of nerve cells which receive a stimulus
depolarization	period of time during a nerve impulse when waves of positively-charged sodium ions enters the neuron; this causes the neuron to become more positively charged
dermis/hypodermis	internal layer of skin; interior to the epidermis
detrusor	layer of muscle surrounding the bladder; during contraction, the bladder is compressed and urine is forced outwards
diabetes	a medical condition which is caused by the inability of the pancreas to produce or utilize the hormone insulin

diaphragm	a dome-shaped plate of skeletal muscle that extends across the bottom of the ribs; contraction/relaxation is the cause for inhalation/exhalation
diaphysis	long shaft of a long bone
diarrhea	a condition in which an individual has three or more loose and watery bowel movements per day
diastole	phase of the cardiac cycle where the heart refills with blood after systole
diastolic pressure	the minimum blood pressure achieved during each heartbeat
diencephalon	region between the midbrain and the cerebrum; contains the thalamus and hypothalamus
diffusion	the movement of any substance from an area of high concentration to an area of low concentration
digestion	conversion of large compounds into smaller, more usable molecules
distal	away from the trunk of the body
distal tubule	final section of nephron where the concentration of water and nutrients within urine is fine-tuned
diuresis	urine production
dorsal and ventral respiratory groups	groups of neurons within the oblongata; initiate the contraction of the diaphragm and intercostal muscles
duodenum	smallest section of the small intestine; final area where food is prepared for absorption
eardrum (tympanic membrane)	divides the external ear from the middle ear; vibrations from this membrane induce the mechanical act of hearing
ectopic pregnancy	situation in which a fertilized egg is blocked within the uterine tube
edema	swelling of tissues; caused by a buildup of fluid within areas that are inflamed
eggs	female reproductive cells
ejaculation	the ejection of semen from the urethra
ejaculatory duct	storage vessel which ejects the semen into the urethra.

electrocardiogram	a device used to detect the electrical impulses generated by cardiac muscle
electrochemical process	method of communication between neurons in which chemicals are released thereby triggering a nerve impulse
electron	negatively-charged particle within an atom; 1800+ times smaller than a proton
embryo	zygote that has undergone several cellular divisions; anchored into the wall of the uterus
emphysema	a progressive destruction of the alveoli caused by extreme heat and/or toxins
endometriosis	condition which takes place when the inner lining of the uterus spreads outward and connects to the ovaries, vagina, small intestine, and other tissues within the abdomen
endomysium	a protective connective tissue surrounding each muscle fiber
endothelial cells	innermost lining of cells within both arteries and veins; surrounded by layers of smooth muscle and connective tissue
enteric nervous system	localized solely within the smooth muscle tissue of the digestive system
enzymes	large molecules that trigger thousands of chemical processes within the human body
epidermis	the outermost and visible layer of skin
epididymis	~20-23 foot (6 to 7 meters) long coiled tube which stores the maturing sperm
epiglottis	a flap of connective tissue that moves back and forth to cover the laryngopharynx when food is being swallowed
epilepsy	disorder of the brain; characterized by nerve impulses within the brain traveling much faster than normal
epimysium	layer of connective tissue covering an individual skeletal muscle
epinephrine (adrenaline)	hormone secreted by the adrenal medulla; works with norepinephrine to regulate the fight or flight response in humans during times of stress

epiphyseal plates (growth plates)	two cartilage plates found where the diaphysis meets the epiphyses on both of its ends; areas where new cells continue to grow thereby lengthening the long bones
epiphysis	enlarged rounded end of a long bone
epistaxis (nosebleeds)	caused by the rupture of a blood vessel within the nose, causing a hemorrhage to occur as blood drains from the nostril
epithelial	tissue which covers the outside of the body, outer surfaces of organs, body cavities, and various glands
erectile dysfunction	a condition in which the man is unable to achieve or maintain an erection during sexual intercourse
erection	condition in which the penis shaft and glans fills with blood
erector spinae	a group of muscles located on each side of the spinal column along the lumbar, thoracic, and cervical regions; extends the back to a straightened position
erythropoietin	hormone which is released into the blood and signals the skeletal system to increase the rate of red blood cell production
esophagus	the muscular tube which carries your food to the stomach
estrogen	chemical which helps to maintain bone mass and regulates the organs and tissues within the female reproductive system
estrogen	hormone secreted by the ovaries which works along with progesterone to prepare and maintain women before and during pregnancy
eustachian tube	tube which connects the middle ear to the throat and maintains air pressure between both sides of the eardrum
extension	increasing the angle between two bones
external (superficial)	toward the surface of the body
external ear	the visible part of the ear
external intercostal muscles	groups of muscles between the ribs which allow the ribs to expand during inhalation

external respiration	the exchange of gases between the air and the blood
extremities	arms and legs
facial nerve	cranial nerve; responsible for the function of facial expressions, taste, secretion of tears and saliva
facilitated diffusion	"gates" or "revolving doors" within cell membranes which allow certain types of particles to pass through
false ribs	8th-10th pairs of ribs which are attached to the seventh pair of ribs
fascicle	bundles of 10-100 muscle fibers (cells) within each skeletal muscle
fatty acids	small molecules of fat; can be created through the breakdown of larger fat molecules by bile
fecal matter (feces)	mixture of undigested materials in the colon including the gut flora
fertilization	bonding of a mature egg with a single sperm
fetus	a developing mammal still within the mother's reproductive system
fever	a condition in which the body temperature is increased above 37.2°C (99°F)
fibrin	long strands of fibrinogen proteins which assemble around the "plug" of platelets within a blood clot
fibrinogen	plasma protein; works with the platelets in the blood to help with the formation of a blood clot
fibroids	abnormal growths of smooth muscle tissue found within the uterine wall
fibrous joints	joints which do not allow any movement to exist at all between the two bones
fight or flight response	hormonal response to emergency situations; regulated by epinephrine which elevates the heart rate, thereby increasing both blood and oxygen flow throughout the body
filtrate	a fluid that has been passed through a filter
first-degree burns	burns which damage only the epidermis
flagellum	tail which propels an adult sperm cell

flat bones	flattened bones found in the skull and pelvis which typically protect softer tissues/organs
flatus	intestinal gas released as waste products from gut flora
flexion	decreasing the angle between two bones
floating ribs	last two pairs of ribs which are unattached to any other structures
frontal lobe	lobe of the cerebral cortex which is responsible for intelligence, memory, and idea association
gall bladder	a storehouse for bile
gallstones	hardened masses of bile caused by the ingestion of excessive cholesterol
gap junctions	areas between synapses in which an electrochemical system can jump from one neuron to another
gastric juice	a clear solution of hydrochloric acid, pepsin, mucus, and intrinsic factor within the stomach
gastritis	constant inflammation of the stomach tissue caused by the spread of H. pylori
gastrocnemius	calf muscle; assists the hamstrings to flex the knees
gastroesophageal reflux disease (GERD)	condition in which the pyloric sphincter does not close completely allowing gastric juice to leak back into the esophagus
gastroesophageal sphincter	valve in which food and liquids pass through before entering the stomach
gelatin	compound formed from processed collagen; used for a variety of industrial products
general senses	senses that can generally be found throughout our body as they are associated with the skin
genitalia	sex organs
gigantism	condition caused by an abnormally large amount of growth hormone being produced during and beyond adolescence
glands	organs responsible for creating and releasing specific chemicals throughout the body
glans	the head or tip of the penis; contains a significant amount of mechanoreceptors

globulins	second most abundant type of plasma proteins; functions include protection and transport of molecules
glossopharyngeal nerve	cranial nerve; responsible for the function of taste, swallowing and secretion of saliva
glottis	the opening between the laryngopharynx and the larynx
glucagon	hormone secreted by the pancreas which stimulates the liver to produce an increased amount of glucose to be released into the bloodstream
glucocorticoids	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being cortisol
glucose	a simple sugar created from glycogen within the liver; used as fuel for most cellular functions within the body
gluteals	buttocks; a group of three muscles which move the hip joints and are responsible for the lateral rotation of the hip
glycogen	a complex sugar stored by the liver for use when blood sugar levels increase or decrease
goiter	condition in which the thyroid has grown very large; can be caused by hyper- or hypothyroidism
gonads	testes; location where sperm are created
goosebumps	pockets of warm air trapped between hair follicles within the epidermis of the skin
gray matter	neurons and unmyelinated dendrites and axons and is grayish in color within the brain
growth hormone (GH)	hormone which acts on many different tissues within the body to stimulate their growth
gut flora	mucus and bacteria found within the undigested materials of the colon
hamstrings	group of muscles in the posterior side of the upper leg; responsible for extension of the hip and flexion of knee joints
hard palate	found in the front section of the roof of the mouth; contains a layer of bone under its tissues

heart	main organ of the cardiovascular system; responsible for pumping all bodily fluids throughout each system
heart attack	restriction of blood flow through either of the coronary arteries; immediate damage to the heart muscle begins without a supply of blood and oxygen
heartburn	burning sensation in the chest/throat caused by reflux
Heliobacter pylori	bacteria which may induce a stomach ulcer
hematopoiesis	the process of blood formation
heme	iron-containing molecule found within hemoglobin
hemoglobin	protein within red blood cells consisting of heme which binds to a single oxygen gas molecule
hemophilia	a genetic disorder in which the the formation of fibrin is slowed down considerably due to a decreased volume of clotting factors within the blood
hemorrhage	the loss of a large amount of blood
histamines	chemical which helps to trigger inflammation and increases blood flow towards the infected area
homeostasis	the property which regulates our internal environment to create a stable and constant set of properties
hormones	chemical messengers which travel throughout the body and help to maintain homeostasis
hyaline	form of connective tissue which is very smooth and allows tissues to move/slide over each easily
hydration	amount of water within the blood stream
hyperopia (farsightedness)	the ability to see objects far away, but not near to you
hyperextension	extension of a joint beyond its normal range of motion
hyperpolarized	period of time after repolarization when an excess of potassium ions have left the neuron causing it to become more negative
hypertension	high blood pressure
hyperthyroidism	condition caused by the overproduction of the hormones thyroxine (T_3) and triiodothyronine (T_4)

hypertonic	solutions containing more solutes as compared to another fluid when separated by a permeable membrane
hypoglossal nerve	cranial nerve; responsible for the movement of tongue during speech and swallowing
hypothalamus	a gland in our brain which acts like a thermostat for the body
hypothyroidism	condition caused by the underproduction of the hormones thyroxine (T_3) and triiodothyronine (T_4)
hypotonic	solutions containing fewer solutes as compared to another fluid when separated by a permeable membrane
hysterectomy	a surgical removal of the uterus
ileocecal valve	gateway between the small and large intestine
ileum	last section of the ileum; continues to absorb water and nutrients missed by the jejunum
immune response	all actions involved with the identification and removal of foreign invaders by the immune system
immune system	the body's defense mechanism; a general term used to describe the collective anatomy/physiology of several systems within the body to remove foreign invaders
immunity	the ability of the body to resist infection and disease
immunological surveillance	defense mechanism utilized by the natural killer (NK) cells to identify surface antigens on foreign cells before destroying the invader
impermeable	not allowing fluid to pass through
incisors	the eight teeth in the front of the mouth (four on top and four on bottom) and have a wedge-shape
incus	one of three small bones in the ear known as the "anvil" within the middle ear that induces the sensation of hearing through its vibration
inferior (caudal)	directional term meaning "toward the bottom"
inferior vena cava	a large vein that carries blood from the lower half of the body into the right atrium of the heart
infertility	the act of being incapable of becoming pregnant

inflammation	first stage of tissue repair; identified by swelling, redness, excessive warmth, and pain in the area that contains the damaged tissues
inflammation	symptoms such as swelling, redness, excessive warmth, and pain in an area that contains damaged tissues
ingestion	the physical act of eating
inhibin	hormone responsible for lowering the amount of follicle stimulating hormone within the blood stream
innate (nonspecific) immunity	all defensive actions our bodies undergo to prevent the spread of infection or disease, regardless of the damaging agent
inner ear	contains the cochlea; site where vibrations from middle ear are transferred into nerve impulses involving the sense of hearing
insulin	hormone secreted by the pancreas which helps cells to absorb sugar from the bloodstream
integration	the sorting and directing of signals to other areas of the body
integumentary system	a system consisting of the skin, hair, nails, and glands within the skin
interferons	proteins released by lymphocytes and/or cells which are infected with viruses; tags the infected cells for attack by the immune system or instructs healthy cells to prepare for the impending spread of infection
interior	away from the surface of the body
internal and external obliques	muscles within the abdomen responsible for the flexion of the spine and allows the body to bend from side to side
internal intercostal muscles	groups of muscles between the ribs which compresses the ribs, allowing for the process of exhalation
internal respiration	the exchange of gases between the blood and the cells
interstitial fluid	excess fluid which "pools" in areas where capillaries exchange nutrients and wastes
intrinsic factor	a protein secreted by the stomach that helps the body to absorb vitamin B12 from food

involuntary	actions which are not controlled by the brain
ion	an element which has lost or gained one or more electrons
iris	changes the size of the pupil thereby regulating the amount of incoming light; colorful part of the eye
irregular bones	bones having many different shapes; examples include the jawbone and kneecap
isotonic	solutions which are separated by a permeable membrane which contain equal concentrations of solutes
jejunum	~8 foot (2.5 meters) long section of the small intestine; lined millions of villi; responsible for the absorption of the majority of nutrients from the chyme
keratin	protein produced and used by the epidermis of the skin which provides a protective barrier against infection
kidney dialysis (hemodialysis)	artificial filtration of the blood administered to patients with kidney failure
kidney stones	large crystals of uric acid and salts formed inside the kidneys, ureter, and/or bladder
kidneys	two bean-shaped organs responsible for the filtration and reabsorption of water and nutrients from the blood
labia majora	structure of the vulva; identifies the outer two large folds of tissue which cover the sides of the vagina opening
labia minora	structure of the vulva; identifies the two soft folds of tissue within the lining of the labia majora which also helps to cover the opening to the vagina and clitoris
lacrimal glands	glands which are located above each eye; responsible for the production of tears
lactation	process by which women produce milk from their mammary glands
lactic acid	produced by muscle fibers during exercise which interfere with the ability of calcium ions to produce muscle contraction

large intestine	~5 feet (1.5 meters) long organ characterized by a much larger diameter than the small intestine; storehouse for materials that are not digested although some leftover water and salts are absorbed in this organ before defecation
laryngitis	hoarseness or the loss of one's voice due to an inflammation of the larynx
laryngopharynx	lowest section of the pharynx; connected to the larynx; allows both food and air to pass through until it is closed by the epiglottis during swallowing
larynx	organ of the respiratory system; contains the vocal cords; blocks the passage of food through the actions of the glottis
lateral	away from the midline of the body
latissimus dorsi (lat)	a large muscle located on the back; responsible for extension, adduction, and medial rotation at shoulder joint
lens	refracts (bends) incoming light as well; focuses light onto the retina
lidocaine	local anesthetic used to numb the surface of the skin
ligaments	a type of connective tissue proper which connects bones to other bones
lipid	fat
lithotripsy	procedure in which doctors shatter kidney stones into smaller crystals using sound waves
liver	second largest organ in the human body ; contributes to the digestive system through the development and secretion of bile
lobes	specialized areas of the cerebral cortex which is responsible for specific functions in the body
local anesthetics	numbing agents which block the sensation of pain by keeping sodium ions from entering and leaving the cell membranes of neurons
long bones	those which are typically found within the arms and legs

loop of Henle	U-shaped tube attached to the proximal tubule whose primary function is to concentrate the waste product by removing water and salt
lower gastrointestinal tract (GI)	area of the digestive system below the stomach including the large and small intestines as well as secondary organs including the pancreas, gall bladder, and liver
lumbar curvature (small of the back)	a section of the spinal cord which contains five vertebrae and carries most of the weight of the human body
lumbar nerves	spinal nerve; responsible for functions pertaining to tissues found within the lower abdomen and all lower extremities
lumen	the inside spaces of a tubular structures such as the esophagus
lung capacity	the maximum amount of gas the body can hold within its alveoli; six liters (~1.5 gallons) of air is normal for an average adult male
lungs	cone-shaped organs of the respiratory system made up of millions of alveoli
luteinizing hormone (LH)	hormone which targets ovaries and testes; stimulates the production of hormones utilized by the reproductive system
lymph	recycled plasma from the blood
lymph nodes	inch-long (2.5 cm) oval-shaped organs connected to the lymphatic vessels and are filled with protective lymphocytes ;act as traps for pathogens
lymph nodules	specialized lymphatic tissues which are found between the epithelial and connective tissue layers of the digestive, respiratory, and urinary system
lymphatic vessels	thin-walled vessels surrounding vascular tissues which carries "pooled" interstitial fluid back into the cardiovascular system
lymphocytes	a specific type of white blood cells (leukocytes) whose function is to eliminate all potentially damaging substances from our body
lymphomas	malignant cancerous cells which spread to other areas of the body via the lymphatic system or blood stream

macrophage	a type of white blood cell which sweeps through the blood and consumes pathogens and cellular fragments
malignant tumor	a tumor that has invaded and caused trouble for nearby organs/tissues of the body
malleus	one of three small bones in the ear known as the "hammer" within the middle ear that induces the sensation of hearing through its vibration
mammary glands	glands which produce and secrete milk in females
mandible	jawbone
mastication	the act of chewing
matrix	a combination of fluid and fibers of various strengths which makes up connective tissue
mechanoreceptors	sensory receptor which responds to changes in pressure or movement
medial	toward the midline of the body
medulla oblongata	area of the brain which connects the spinal cord to the brain; together with the pons, this area of the brain makes up the brainstem
meiosis I	special form of cell division in which the chromosomes go through a "shuffling" procedure ending in different genetic combinations of DNA within each cell
meiosis II	involves the further division of the two cells produced from meiosis I
melanin	a brown-black pigment responsible for absorbing harmful ultraviolet light within the skin
melatonin	hormone secreted by the pineal gland; regulates the circadian rhythm of humans
memory cells	clones which remain inactive and flow throughout the body after an infection; can be quickly activated to generate a faster immune response during future infections
meninges	three fiber-like layers of tissue that cradles the brain and spinal cord within the skull and vertebral column
menopause	the lack of ovulation and menstruation when the supply of oocytes within the ovaries is depleted

menstrual cycle (menses)	all of the physiological changes that take place within a female to prepare her for sexual reproduction
menstrual phase	first stage of the menstrual cycle; lasts an average of 4 days during which approximately 1.2 to 1.7 ounces (35 to 50 milliliters) of menstrual fluid is lost
middle ear (tympanic cavity)	a small, air-filled space within the skull which contains the tympanic membrane and three small bones (auditory ossicles)
milk ducts	passageways for milk from the mammary glands to the nipple
mineralocorticoid	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being aldosterone
molars	the largest group of teeth in the mouth; consists of at least 20 teeth (ten upper and ten lower) with flattened crowns; used to crush and grind food into a pulp
monosaccharides	small sugars created from larger carbohydrates
motion sickness	minor condition caused when the body undergoes rapid changes in speed and/or direction
motor (efferent) nerves	send information AWAY from the central nervous system to the effectors (e.g. muscles or glands)
mucus	a thick, slippery solution that is produced in several areas of the body; its functions are varied and plays an important role in several body systems
multiple sclerosis (MS)	disease in which a neuron's myelin is destroyed or lost; causes serious problems within the muscular system by slowing down or completely blocking the ability of muscles to function
muscle cramp	situation in which a muscle contracts with such force it stays contracted and no other muscle acts to stretch it back into place
muscle fibers	very long and threadlike cells which make up skeletal muscle
muscle spasms	a strong and painful involuntary contraction of muscles

muscle tissues	a collection of elongated cells which contract (shorten) to enable locomotion of the organism or movement of the internal organs
myelin	a lipid which covers parts of the neurons and is vital for the promotion of nerve impulses
myofibrils	hundreds of long protein chains found within muscle fibers (cells)
myopia (nearsightedness)	the ability to see objects near you, but not far away
myosin	long thick strands of protein resting between strands of actin within the center of a sarcomere; responsible for pulling actin strands together during a contraction
nasal cavity	a large, mucus-filled area behind the nose
nasolacrimal ducts (tear ducts)	specialized tubes which drain tears from the eyes into the nasal cavity
nasopharnynx	upper section of the pharynx; always remains open unlike the remaining sections of the pharynx
naturally acquired active immunity	type of active immunity which develops from birth and continues throughout a person’s lifetime
naturally acquired passive immunity	type of passive immunity in which antibodies are transferred into another individual without any artificial means (i.e. via breast milk)
negative feedback	occurs when the response to a stimulus (feedback) results in a reversal of the direction of change
nephrons	semipermeable tube responsible for the filtration and/or reabsorption of water and nutrients from the blood; ~1 million of these structures are found within each kidney
nephroptosis	"floating kidney"; occurs when the kidneys fail to remain anchored to the lower back and begin moving into the abdominal area
nerve cell (neuron)	the building block for the nervous system and is responsible for sending electrochemical signals throughout the body
nerve impulse	a wave-like signal that moves through the body by an electric current

nerves	a long cable-like bundle of nerve cells
nervous tissue	responsible for creating and sending nerve impulses throughout the body
neuroglia	supporting cells: help to support the neurons throughout the body
neurons (nerve cells)	responsible for sending the nerve impulses throughout the body
neurotransmitters	chemical which allow for neurons to communicate with other neurons
nipple	area within the breast where milk is secreted
NK cells	part of the innate immune system; indiscriminately attacks every foreign invader considered to be a threat
norepinephrine	hormone secreted by the adrenal medulla; works with epinephrine to regulate the fight or flight response in humans during times of stress
nose	the primary access point for all air entering the respiratory system
nostrils	two external openings of the nose
novocain	local anesthetic used for tooth pain
occipital lobe	lobe of the cerebral cortex which is responsible for the perception of vision
oculomotor nerve	cranial nerve; responsible for the movements of the eye, eyelid, pupil, and lens
olfaction	term which describes the ability to smell
olfactory nerve	cranial nerve; responsible for the function of smell
oogenesis	the process of producing eggs
optic nerve	cranial nerve; responsible for the function of vision
optic nerve	transmits nerve impulses to the brain
oral cavity (buccal cavity)	part of the upper gastrointestinal track; includes the teeth, lips, tongue, salivary glands, and cheeks
organelles	specialized structures within a cell
oropharynx	middle section of the pharynx; located between the soft palate of the throat and the top of the epiglottis

osmosis	a special type of diffusion in which only water is being transported through the membrane
osmotic pressure	the pressure needed to keep water from moving through a porous substance (like the blood vessels)
ossification	process of bone development
osteoarthritis	a type of arthritis commonly affects the larger, well-worn joints such as the hips and knees
osteoblasts	the main bone-building cells during human development
osteoclasts	cells found within the center of a bone which secrete proteins that destroy bone tissue
osteocytes	mature osetoblasts; assist in the maintenance and support of growing skeletal tissue
osteoporosis	condition in which bones become abnormally thin and brittle; caused by the excessive activity of osteoclasts
ovarian cycle	maturation process of a single egg from the division of a primary oocyte into two separate cells
ovaries	female reproductive organs
ovulation	series of events involving the traveling of a mature egg down the Fallopian tubes and potentially becoming fertilized by sperm
ovum	mature female egg
oxytocin	hormone which stimulates the smooth muscles of the uterus to contract during childbirth
pacemaker cells	located within the right atrium; generate a rhythmical flow of nerve impulses throughout all of the cardiac muscle tissue causing muscular contraction
pain receptors	sensory receptor which responds to stimuli that result in the sensation of pain
pancreas	an elongated organ 6in (15+cm) found between the stomach and small intestine; responsible for producing several hormones, the most important being insulin and glucagon
pancreatic duct	passageway for pancreatic juice from the pancreas into the common bile duct

pancreatic juice	highly alkaline fluid created b the pancreas; contains a variety of digestive enzymes which are able to breakdown all categories of food - fats, carbohydrates, proteins, etc.
papillae	visible mushroom-shaped projections on your tongue which contain taste buds
parasympathetic nervous system	helps the body to conserve energy and tends to slow the heart rate
parathyroid glands	four glands found on each side of the back(posterior) surface of the thyroid gland ; responsible for producing the hormone parathyroid hormone (PTH)
parathyroid hormone (PTH)	hormone released from the parathyroid glands; responsible for increasing the levels of calcium (for bones) and phosphorus (for cell membranes) found within the blood
parietal lobe	lobe of the cerebral cortex which is responsible for sensations of temperature, touch, and sense of position and movement as well as the perception of size, shape, and weight
passive immunity	a type of immunity which is produced by transferring antibodies from another source
patella	kneecap
pathogens	harmful agents that invade the body
pectoralis major	muscles found in your upper chest ; responsible for adduction, horizontal adduction, flexion/extension, and medial rotation at the shoulder joint
pelvic curvature	the lowest section of the spinal cord which contains the sacrum, pelvis, and coccyx
pelvic inflammatory disease (PID)	a broad term describing an inflammation of the uterus, Fallopian tubes, and/or the ovaries which can be caused by a number of different pathogens
pelvis	hipbones
penis	the external organ of the male reproductive system
pepsin	a protease which can only digest protein in a very acidic environment

perception	the receiving of signals concerning what is going on inside and outside the body
perimysium	a protective connective tissue surrounding the fascicle
perineal body (perineum)	structure of the vulva; located at the bottom of the vulva; made of very strong and flexible tissues which allow for the vulva to be widely stretched during childbirth
periosteum	permeable covering over bones which allows for nutrient/waste transfer and sites for attachment by tendons
peristalsis	slow, involuntary movements of smooth muscles which push food through the digestive tract
permeable tubing	tubing which allows specific compounds to pass through
phagocytic cells	"cells that eat"
pharyngoesophageal sphincter	valve in which food and liquids pass through before entering the esophagus
pharynx	throat; attached to the nasal cavity and divided into three separate areas
phlegm	pathogen-filled mucus which is expelled through the mouth
phonation	production of unique sounds from the vibration of vocal cords
phosphate	a chemical made of one atom of phosphorus and four oxygen atoms
phospholipids	large molecule made up of a phosphate and two long "tails" of lipids; found in doubled layers as the main component of cell membranes
photoreceptors	sensory receptor which responds to light
physical barriers	initial barrier within the body's innate immunity; external structures such as hair and fingernails keep dangerous organisms and materials from entering the body
physiology	the study of the body's functions
pineal gland	gland found near the center of the brain; regulates the sleep-wake cycle of humans through the secretion of the hormone melatonin

pinna	funnel-shaped structure within the center of the visible, external ear
pitch	highness and lowness (of the voice)
pituitary glands	two glands located within the skull; responsible for the majority of hormone production
planes of reference	a set of three planes (imaginary flat surfaces) passing through the body used to identify specific locations in, on, and around the body
plasma	fluid portion of blood
platelets	short-lived packets of cytoplasm and dissolved molecules within the blood; assist in the immune response to the vessels of the cardiovascular system
pneumonia	generalized term used to identify any condition involving the inflammation of the lungs
polar bodies	three of the four immature eggs produced through the process of meiosis I and II which are much smaller than the fourth and are quickly broken down within the ovary
polarization	stage of a neuron in which the electrical charge on the outside of the neuron is positive while the electrical charge on the inside of the membrane is negative
pons	connects the various areas of the brain into one single organ; located above the medulla oblongata, below the midbrain and anterior (towards the front) to the cerebellum; together with the medulla oblongata, this area of the brain makes up the brainstem
pontine respiratory group	group of neurons within the pons which regulate the tidal volume of air during each inhalation
positive feedback	occurs when the feedback results in an increase of the change
posterior (dorsal)	directional term meaning "toward the back"
posterior lobe	one of two lobes within the pituitary gland; receives and transports antidiuretic hormone and oxytocin which are produced by the hypothalamus

postsynaptic neuron	the cell that receives the message from the presynaptic neuron
presynaptic neuron	the cell which sends a message
primary oocytes	~two million immature sex cells produced during meiosis I
progesterone	hormone secreted by the ovaries which works along with estrogen to prepare and maintain women before and during pregnancy
prolactin (PRL)	hormone which helps women to produce milk from their mammary glands
proliferative phase/follicular phase	second stage of the menstrual cycle; involves the growth of a new inner lining for the uterus wall, the secretion of LH and estrogen and the maturation and preparation of the egg to be released into the Fallopian tube
prostate gland	a walnut-sized gland found in front of the rectum and under the bladder; produces 30% of all seminal fluid which is often milky-white in appearance and slightly acidic
prostatitis	painful inflammation of the prostate gland
proteases	enzymes which break down the large organic molecules of protein within food
proteins	large organic molecules each possessing a unique function)
proton	proton-charged particle within an atom
proximal	toward the trunk of the body
proximal tubule	small tube attached to the renal corpuscle of a nephron; site of filtrate reabsorption where amino acids and glucose are released from the filtrate back into the surrounding capillaries
puberty	a series of physical changes in which a child's body matures into an adult body
pulmonary artery	large artery which carries blood from the right ventricle after it passes through the pulmonary semilunar valve
pulmonary semilunar valve	semilunar valve which closes after blood has exited the right ventricle

pulmonary veins	four veins which carry blood back into the left atrium of the heart, through the biscupid valve, and into the left ventricle
pulse	the rhythmical throbbing of arteries that can be felt through the skin
pupil	black part of the eye which allows light to enter the eyeball
pus	a thick yellow liquid produced by infected tissues
pyloric sphincter	valve located at the base of the stomach; never entirely closed; allows water and chyme to pass through into the small intestine continually
quadriceps	a group of four muscles in the anterior side of the upper leg; responsible for extension of the knee joint and flexion of hip
reabsorption	process by which water and nutrients are released from the nephron into the surrounding capillaries
rectum	temporary storage site for feces
rectus abdominus	one of several muscles found in the abdomen; anterior to the spine and responsible for its flexion
red blood cells (erythrocytes)	major component of blood; responsible for transport of oxygen and carbon dioxide gases throughout the body
red bone marrow	found within spongy bone tissue of long bones; site of blood cell production
reflux	the leaking of stomach acid into the esophagus
refractory period	period of time during a nerve impulse in which a neuron can no longer send any more signals along its neuron before its resting potential is reached once again
regeneration	second stage of tissue repair in which the body attempts to restore homeostasis be replacing/repairing damaged tissues back to their normal functions
renal arteries	arteries which supply the kidneys with blood
renal capsule	a tough fibrous tissue which is the first layer of protection for each kidney

renal corpuscle	"bulb" at the head of a nephron; site where water and solutes are filtered out of the blood and into the nephron itself
renal fascia	dense connective tissue which is the outermost protective layer around each kidney; anchors the organs to surrounding tissues within the lower back
renal veins	veins which exit each kidney
renin	chemical secreted by the kidneys when the blood pressure is too low; acts to constrict blood vessels and triggers the secretion of ADH and aldosterone
repolarization	stage within a nerve impulse when the movement of positively-charged ions from the inside of the cell begins to lower the positively-charged cell back to a more negative charge
residual volume	approximately 20% of the remaining air within the lungs after the vital capacity has been exhaled
resonance	deepness (of the voice)
respiration	exchange of gases between two or more structures
respiratory acidosis	potentially dangerous condition in which a buildup of carbonic acid exists within the blood
resting potential	electrically negative charge of all neurons
retina	absorbs light; forms nerve impulses which are transmitted to brain
Rh factor	surface antigen within blood that identifies an individual's blood type as either positive or negative
rheumatoid arthritis	a type of arthritis caused by the inflammation of tissues within the synovial joints
rib cage	twelve pairs of ribs attach to the thoracic curvature of the spine
right and left bronchi	two branches directly attached to the trachea which direct air movement eventually into both lungs
right and left cerebral hemispheres	two halves of the cerebrum

right and left subclavian veins	directs lymphatic fluid from the right lymphatic duct and the thoracic duct towards the heart
right lymphatic duct	smaller of two ducts which carries lymph from the right side of the head, right upper limb, shoulder and lung, and the right side of the heart
rods	photoreceptors in the retina; specialized for vision in dim light and cannot detect color
root	a vascular "anchor" for an individual hair follicle
root	found under the gums and acts as an anchor to the bones of the skull
root (penis)	the part of the penis which is attached to the abdomen
rotation	turning around an axis
sacral and coccygeal nerves	spinal nerve; responsible for functions pertaining to the hips, tail bone, buttocks, rectum, anus, and sex organs
sacrum	five vertebrae which are fused together forming one part of the pelvic curvature
sagittal plane	plane of reference which divides the body into right and left sides
saliva	a solution produced by the salivary glands; made of water, dissolved ions, mucus, antibodies, and enzymes
salivary glands	glands within the oral cavity which secrete a solution of saliva into mashed food to keep it moist
sarcomeres	small segments along a myofibril that are responsible for the contraction of a muscle
scapula	shoulder blades
scars	a large amount of connective tissue that replaces cut layers of epidermis resulting from a cut into the lower dermis/hypodermis layer
sclera	white part of the eye; maintains the eye's shape
scoliosis	disorder causing abnormal curvature of the spine and lateral (side) bending of the backbone
scrotum	a small pouch made of loose skin and muscle tissue which hangs outside of the body and contains the male testes
sebaceous glands	oil-producing glands

sebum	acidic chemical secreted by sebaceous glands near hair follicles to the surface of the skin; used to protect, lubricate, and waterproof the skin
secondary amenorrhea	condition in which a woman goes six months or longer without menstruating, despite being pre-menopausal and not pregnant
second-degree burns	burns which damage the epidermis and the upper region of the dermis
secretion	the process of receiving additional waste products from the surrounding capillaries into the nephron
semen	seminal fluid; alkaline fluid generated by seminal vesicles which provide nutrition for sperm and a medium by which it can be mobile
semilunar valves	one of two valves which close after blood has exited the right ventricle (pulmonary semilunar valve) and left ventricle (aortic semilunar valve)
seminal fluid	fluid which carries the male sex cells needed for reproduction
seminal vesicles	responsible for generating the majority of seminal fluid
seminalplasmin	protein which help males fight bacterial infections within the urethra
seminiferous tubules	~800 tightly coiled tubes within each testis; site of spermatogenesis
semipermeable	property of the cell membrane which regulates the substances allowed in and out of the cell
sensorineural deafness	a form of deafness in which an injury occurs within or beyond the inner ear; a nerve impulse may be generated, but the damage prevents the signal from reaching the central nervous system
sensory (afferent) nerves	send information from sensory receivers (e.g., in skin, eyes, nose, tongue, ears) TOWARD the central nervous system
sensory receptors	receptors within the skin that respond to various stimuli such as touch, pressure, temperature, and pain
septum	wall of tissue which divides the scrotum into two chambers and separates the testes

serum	blood plasma which contains no fibrinogen
sexually transmitted diseases (STDs)	caused by the spread of bacteria or viruses between two individuals involved in any form of sexual contact or between a mother and her baby during childbirth
shaft	visible portion of the hair
shaft	cylindrically-shaped structure of the penis; contains tissue filled with mechanoreceptors that trigger nerve impulses when stimulated
short bones	found in wrists and ankles; allows the body to move more freely
sickle cell anemia	inherited genetic disorder causing red blood cells to abnormally fold themselves into shapes resembling stiff crescent-shaped rods
simple epithelial tissue	epithelial tissue made of a single layer
sinuses	hollow areas in the bones of the skull which open into the nasal cavity
skeletal muscle	voluntary tissue which is responsible for movement
skull	collection of fused irregular bones which protect the brain
sliding filament theory	the shortening of the sarcomere and the subsequent contraction of the entire muscle fiber
small intestine	22 foot-long (7 meters) organ; attached to the stomach through the pyloric sphincter and is responsible for most absorption of water and nutrients within the chyme
smooth muscle	responsible for slow, involuntary movements of the internal organs
sneeze	a sudden explosion of forced air traveling at nearly 100 miles (161 kilometers) per hour from the lungs
sodium/potassium pumps	active transport system which uses energy to move three sodium ions out of the neuron for every two potassium ions it allows in
soft palate	found in the back of the roof of the mouth; does not contain a layer of bone under its tissues
solutes	substances that are dissolved in a solution by solvents

solution	a mixture of solute(s) and solvent(s)
solvent	substances which dissolve solutes to form a solution
soma	cell body of a nerve cell
somatic nervous system	nerves which connect the brain and spinal cord to structures such as the skin and the skeletal muscles; works with voluntary muscles only
special senses	senses produced by very specific organs found only in certain areas of the body; includes the senses of smell, hearing, vision, taste, and balance
sperm	male reproductive cells
spermatids	immature sperm; products of meiosis II (four cells), each with a unique pattern of 23 chromosomes due to the "shuffling" procedure within meiosis I
spermatogenesis	production of sperm
spermatozoa	an adult sperm cell
spermiogenesis	process by which the spermatids develop a head and tail and become a spermatozoa
sphincter	a valve
spinal accessory nerve	cranial nerve; responsible for the function of voice production; movement of head and shoulders
spinal cord	a large bundle of nerve fibers protected within the vertebral column
spinal nerves	31 pairs which are attached to the sides of the spinal cord
spleen	largest lymphoid organ located in the upper left portion of the abdomen; removes old red blood cells and recycles iron for use by the bone marrow
spongy bone tissue	porous, highly vascular inner portion of bones
squamous	a thin, flat skin cell
stapes	one of three small bones in the ear known as the "stirrup" within the middle ear that induces the sensation of hearing through its vibration
sterility	condition when the number of sperm a man produces falls below 20 million per milliliter (0.03 ounces)

sternocleidomastoid (SCM)	two muscles located on the side of the neck responsible for rotation, flexion, and lateral flexion of head/neck
sternum	breastbone; attaches the first seven pairs of ribs
stomach	J-shaped muscular organ responsible for preventing the spread of harmful pathogens, digestion of food, chemical breakdown of compounds, and production of intrinsic factor
stomach ulcer	an open sore on surface of the stomach lining; caused by the H. pylori bacterium
stratified epithelial tissue	epithelial tissue made of several layers
stratum basale	sub-layer of tissue attached to the dermis with the help of the basement membrane
striated tissue	tissues which contain visual stripes on its surface when viewed under a microscope
stroke	a condition in which a vessel that supplies blood to the brain becomes blocked, inducing a series of potentially life-threatening symptoms
sudoiferous glands	sweat-producing glands
superior	directional term meaning "toward the top"
superior vena cava	delivers blood to the heart from the upper half of the body
sympathetic nervous system	known as the "fight or flight" system because it usually increases the alertness and generally prepares the body to deal with emergencies
synapses	the location where two nerve cells meet and transmit signals to each other
synovial fluid	fluid found within a sealed pocket containing a synovial joint; helps to lubricate the fibro-cartilage between the bones
synovial joints	all freely moving joints in the human body such as those found in the shoulders, knees, elbows, wrists, etc.
systole	phase of the cardiac cycle where blood is forced out of the heart and into the arteries

systolic pressure	the maximum blood pressure achieved during each heartbeat
T cells	immune cells which attack foreign substances as they enter our body
T cells	make up over three quarters of all lymphocytes; mature within the thymus of the lymphatic system after being created by the red bone marrow; primary agent of cellular defense within the adaptive immune system
target cells	cells identified for specific chemical reactions by individual hormones
taste buds	bundles of specialized cells located on the surface of the tongue, the roof of the mouth, and within the throat
taste hairs	specialized structures on the surface of taste buds which identify specific molecules
temporal lobe	lobe of the cerebral cortex which is responsible for the perception of hearing
tendons	a type of connective tissue proper which connects muscles to bones
testes	male reproductive organs
testosterone	hormone which stimulates the growth of male reproductive tissues, bones, muscles, body hair, and the deepening of one's voice
thalamus	a relay and processing center for most sensory information received into the brain
the pyramids	two large bundles of afferent and efferent nerves within the medulla oblongata; responsible for right/left sides of the brain controlling opposite sides of the body
thermoreceptors	sensory receptor which responds to changes in temperature
third-degree burns	heat from these burns destroys all layers of the skin, including blood vessels and nerve endings
thoracic (chest) curvature	a section of the spinal cord which contains twelve vertebrae and is attached to the ribs

thoracic duct	larger of two ducts which carries lymph from the left side of the head, neck, chest, the left upper limb, and the entire body below the ribs
thoracic nerves	spinal nerve; responsible for functions pertaining to tissues found between the shoulders and small intestines
thymosins	hormones produced by the thymus gland
thymus gland	gland found directly between the lungs; secretes thymosin hormones which help the immune system produce T cells
thyroid gland	a gland which is located in the neck and is in front of (anterior) to the trachea ; secretes the hormones thyroxine, triiodothyronine, and calcitonin
thyroid-stimulating hormone (TSH)	hormone which targets the thyroid gland to control the production of thyroxine (T_4) and triiodothyronine (T_3)
thyroxine (T_4)	hormone secreted by the thyroid gland which contains three atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
tidal volume	the amount of air inhaled with every breath
tonsillectomy	procedure involving the removal of the tonsils due to infection
tonsils	specialized tissues within the lymphatic system responsible for the storage of large numbers of lymphocytes; found in the oral cavity
trachea (windpipe)	5 inch (12.5 cm) long tube; attached to the larynx; allows the passage of air from the larynx to the lungs
transport globulins	chemical "taxis" of the blood; bind to important compounds that may otherwise be flushed out of the body
transverse plane	plane of reference which divides the body into inferior and superior portions
trapezius	muscles found towards the upper posterior area of neck and are connected to the scapula; responsible for rotation, extension and lateral flexion of head/neck
triceps	muscles in the upper arm which allow us to lower objects through the motions of the elbow and/or shoulders
trichosiderin	iron-containing pigment within red-haired individuals

tricuspid valve	atrioventricular valve located between the right atrium and right ventricle
trigeminal nerve	cranial nerve; responsible for the sensations to the face and regulates the act of chewing
triiodothyronine (T_3)	hormone secreted by the thyroid gland which contains four atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
trochlear nerve	cranial nerve; responsible for the rotation of the eye
tumor	a mass of cancerous cells
umami	a flavor associated with a particular chemical called monosodium glutamate (MSG)
universal donors	individuals who have type O blood
urea	waste product created from the reaction between ammonia and carbon dioxide; produced in greater volume than all other toxins expelled by the kidneys
ureters	two main tubes which drains the collected urine from each kidney through the urinary system
urethra	pathway in which urine travels out of the bladder
urethral meatus	structure of the vulva; external opening of the ureter
uric acid	nitrogen-containing compound secreted into the nephron for excretion
urinary (renal) system	system responsible for regulating the volume and chemical contents of plasma and filters the blood to expel waste products
urine	non-toxic and sterile fluid excreted by the urinary system containing nearly 95% water and several other dissolved solutes
uterine tubes (Fallopian tubes)	passageway for mature egg to travel from the ovary towards the uterus; site of potential fertilization
uterus	organ where offspring are grown during pregnancy
uvula	piece of tissue that dangles in the back of the throat; moves upward to block food from traveling upwards into the nasal cavity

vaccine	a solution of dead or inactive pathogens containing their unique antigens; common source for a person's artificially acquired active immunity
vagina	allows fluids to escape into the outside environment in addition to providing passageways for both the penis to enter during sexual intercourse and for the fetus to exit during childbirth
vaginal vestibule	structure of the vulva; contains the vaginal opening and two small glands which provide lubricating fluid to the vulva as well
vagus nerve	cranial nerve; responsible for the function of swallowing, coughing, and voice production; also monitors blood pressure and oxygen and carbon dioxide levels in blood
valves	device which control the passage of fluid in one direction
vas deferens	~12 inch (30 cm) long tubes which carry semen towards the ejaculatory duct
vascular	being regularly supplied with nutrients from the blood
vasoconstriction	thickening of blood vessel walls
vasodilation	widening the internal walls of blood vessels
veins	large blood vessels which deliver blood into the left atrium and right atrium of the heart
ventricles	two lower chambers within the heart
venules	vessels attached to both the capillaries and veins; the diameter and the wall thickness of these vessels increase in size from the capillaries and towards the veins
vertebrae	small bones of the backbone
vertebral column	the backbone or spine
vestibulocochlear nerve	cranial nerve; responsible for the function of hearing and balance of the body
villi	tiny, finger-like projections which provide additional surface area within the small intestine for nutrient absorption
viscosity	resistance of a fluid to flow

vital capacity	maximum volume of air exhaled after taking the deepest breath possible
vitamin D	chemical created within the stratum basale through exposure to the sun; responsible for the absorption of calcium and phosphorus
vocal cords	two pairs of tissues which are stretched horizontally across the larynx; vibrations of these cords create the pitch and volume of the voice
vulva	a series of external structures which protect the vagina
warm receptors	nerve endings within the skin that are sensitive to temperatures above 113°F (45°C)
white blood cells (leukocytes)	phagocytic cells within the blood ; major component of the immune system
white matter	thousands of myelinated nerve fibers that send nerve impulses up and down the cord
womb	uterus; pear-shaped organ between the bladder and the rectum; site of developing zygote into an embryo
yellow bone marrow	storehouse for fat; found in the long hollow area within the diaphysis of long bones
zygote	a fertilized egg

Credits

Chapter	Image Description	Illustrator (Wikicommons)
1	Body directions	Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist
	Body planes	YassineMrabet
	Aquarium	Ks.mini
	Kitten	Nicolas Suzor
	Fish	Tim Regan
2	Bilayer phospholipids	Dhatfield (talk)
	Diffusion	LadyofHats Mariana Ruiz Villarreal
	Facilitated diffusion	LadyofHats Mariana Ruiz Villarreal
	Active transport	LadyofHats Mariana Ruiz Villarreal
	Epithelium	USGov
	Jello	mattbuck
	Blood	Longhair
3	Skin	Daniel de Souza Telles
	Redheads	Bartr
	Sweating	Dogbertio 14
	Vasodilation	Mwanner
4	Skeleton	LadyofHats Mariana Ruiz Villarreal
	Skull	LadyofHats Mariana Ruiz Villarreal
	Long bone	U.S. military
	Spinal column	vsion
	Ribs	LadyofHats Mariana Ruiz Villarreal

4	Joint	Madhero88
5	Muscle types	Mdunning13
	All drawn muscle groups	Användare:Chrizz
6	Muscle layers	Jeremykemp at en.wikipedia
	Digging well	Vaikoovery
	Spaghetti	Nationaal Archief, Den Haag, Rijksfotoarchief: Fotocollectie Algemeen Nederlands Fotopersbureau (ANEFO)
	Flex	U.S. military
7	Flames	Calforester
	Ski	William Notman and Son HS85/10/16097
	Scoliosis	FaceMePLS
	Horse	bianditz
8	Signals	U.S. military
	Cell	U.S. military
	Polar	Ansgar Walk
	Sodium potassium	LadyofHats Mariana Ruiz Villarreal
	Neuron	LadyofHats Mariana Ruiz Villarreal
	Hallway	Sampsonchen
	Impulse speed	Velocidad perruna xD
9	Brain sections	John A Beal, PhD. Dep't. of Cellular Biology & Anatomy, Louisiana State University Health Sciences Center Shreveport
	Brain lobes	(see above)
	Brain and spinal	Grm wnr
	Air bag	Cete
	Gray hair	Bernd B

10	CNS and PNS	Persian Poet Gal
	Cranial nerves	Patrick J. Lynch, medical illustrator
	Spinal nerves	Gray's Anatomy
	Brain and Cord	U.S. military
11	Ear	Chittka L, Brockmann
	Taste bud	NEUROtiker
	Eye	Rhcastilhos
	Smell	Smckellygarthwait
	Fly eye	Richard Bartz
12	Pituitary and hypothalamus	LadyofHats Mariana Ruiz Villarreal
	Speed	http://www.gutenberg.org/etext/19994
	Keys	Jorge Royan http://www.royan.com.ar
	Pituitary	BodyParts3D
13	Thyroid and pineal	LadyofHats
	Parathyroid	LadyofHats Mariana Ruiz Villarreal
	Ovaries and testes	LadyofHats Mariana Ruiz Villarreal
	Liver kidney adrenal	LadyofHats Mariana Ruiz Villarreal
14	Myopia	U.S. military
	Hyperopia	U.S. military
	Correction of myopia and hyperopia	A. Baris Toprak MD
	Dentist	http://www.offutt.af.mil/shared/media/photodb/photos/050426-F-9999Z-001.jpg US Air Force photo
	Caesar	Alfred von Domaszewski
	Snot	Gerrynobody
	Nasa	Great Images in NASA

15	Blood cells	U.S. federal government
	Blood tubes	JHeuser
	Glove	Kevin Hutchinson
	Car	S-8500
	Holes	jlrsousa
16	Blood types	InvictaHOG
	antigen antibody	Anna Bauer
	Plasma	Bugboy52.4
	Fibers	Steve F
17	Heart model	Mikael Häggström
	Dancing	Morten Rask
	Systole diastole	LLadyofHats Mariana Ruiz Villarreal
	Slam	U.S. federal government
	Tub	Yannick Trottier
18	Blood vessels	Kelvinsong
	Systole diastole	LadyofHats Mariana Ruiz Villarreal
	Pulse	National Cancer Institute
	Bloodbrain	Nicolas Rougier
	Circulatory	LadyofHats Mariana Ruiz Villarreal
19	Lymph capillaries	U.S. federal government
	Duct	Vincent de Groot
	Lymphocyte	U.S. federal government
	Tonsils	Klem
20	B t macrophage	Mikael Häggström
	Antibody	Fvasconcellos
	Macrophage vs cancer	National Cancer Institute
	Nail	Jpaur
	Clones	Evelyn Simak
21	Sickle cell	U.S. federal government
	Heart attack	U.S. federal government
	Hemorr	GustavoHCL

21	Exercise	Lorenz kerscher
21	Sneeze	U.S. federal government
22	Alveoli	LadyofHats Mariana Ruiz Villarreal
	Respiratory	LadyofHats Mariana Ruiz Villarreal
	Nostril	Vladimir gubanov
	Voice	U.S. federal government
	Palate	Klem
	Adams apple	Ian T. McFarland
23	Breathing	Jean-Romain PAC
	Altitude	Andy Beecroft
	Pancakes	Hmundol
	Inhalation	LadyofHats Mariana Ruiz Villarreal
	Exhalation	LadyofHats Mariana Ruiz Villarreal
	Sound	Tamorlan
24	Gluttony	Gabriel S. Delgado C.
	Pushing	Catherine Scott
	Upper GI	LadyofHats Mariana Ruiz Villarreal
	Digest head	Arcadian
	Tooth	Indolences
	Acid	Walkerma
25	Digestive system	LadyofHats Mariana Ruiz Villarreal
	Duodenum	Someguy1221
	Scissors	Sertion
	Villi	Snow93
	Rectum	Lozzaaa
26	Kidney	Piotr Michał Jaworski; PioM
	Nephron	Burton Radons
	Toilet	Jim

26	Urea	Rijksdienst voor het Cultureel Erfgoed
	Balance	Leandro Inocencio
27	Urinary full	Jordi March i Nogué [1]
	Protection	U.S. Navy
	Diaper	National Media Museum
	Hose	Nationaal Archief, Den Haag, Rijksfotoarchief: Fotocollectie Algemeen Nederlands Fotopersbureau (ANEFO)
28	Tears	User:Erin_Silversmith
	nosebleed	Tibor Végh
	Larynx	Indi Samarajiva
	GERD	U.S. federal government
	Sound	TeresaLynnE
	Large gall	LadyofHats Mariana Ruiz Villarreal
29	Male reproductive	Tsaitgaist
	Sperm	Mariana Ruiz Villarreal
	Cold	U.S. Navy
	Meiosis I and II	Boumphreyfr
30	Female reprod	Tsaitgaist
	Menstrual cycle	Isometrik
	Oogenesis	Mysid
	Embryo	ekem
31	Breast	Patrick J. Lynch, medical illustrator
	Fertilization	ScienceGenetics
	Sterile	Candida Performa
	Carrier	U.S. federal government