

# PhUn Day



# Welcome to Physiology Day!

Welcome to Physiology Understanding (PhUn) Day! We're glad you're here and are excited to explore the world of physiology with you today. We'll be participating in a number of activities and experiments designed to give you an overview of some physiological systems and the scientific method.

Please do not hesitate to ask any questions, as scientists we love questions and are happy to help you find the answers. Ask anything related to the particular activities or science in general.. We're here to help!

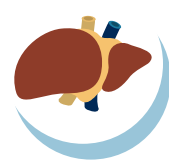
**#PhUnDay**

## Schedule

9:00 – 9:15 am	Event Check-in
9:15 – 9:30 am	Pre - Evaluation
9:30 – 10:00 am	Station 1
10:00 – 10:30 am	Station 2
10:30 – 11:00 am	Station 3
11:00 – 11:30 am	Station 4
11:30 – 12:00 pm	Station 5
12:00 – 12:30 pm	Lunch
12:30 – 1:00 pm	Station 6
1:00 – 1:30 pm	Station 7
1:00 – 1:45 pm	Teacher and Chaperone Session
1:30 – 2:00 pm	Station 8
2:00 – 2:30 pm	Station 9
2:30 – 2:45 pm	Post - Evaluation
2:45 – 3:00 pm	Large Group Photo

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# Introduction to Physiology

**Physiology** is the study of how living things work and how all the parts or systems of a living organism interact with one another to keep the organism healthy. Oftentimes physiology is taught with **anatomy**, which is the study of the structures that make up an organism. Anatomy and physiology are closely related as the structure of a cell, tissue, or organ (anatomy) are important in determining its function (physiology).

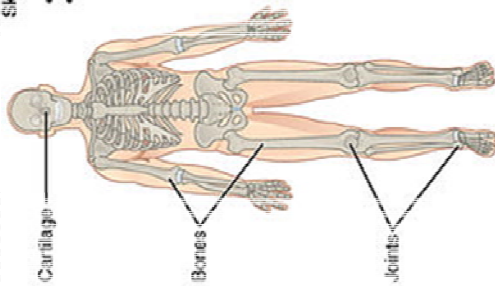
Physiology and medicine are intimately connected. Without an understanding of physiology, doctors and nurses would not be able to treat patients with disease. **Physiologists** are scientists who study physiology. They research different diseases and look for new ways to treat or cure them. We know a lot about how the body works, but there is still a lot we don't know. Many physiologists study how our bodies do certain functions, this is called basic research.

It's easy to think of physiology in terms of systems. Each system carries out a particular job, which allows our bodies to perform certain tasks. For instance, the musculoskeletal system is responsible for moving our body around in space and allows us to get from one place to another, handle tools, and interact with our environment. Our cardiovascular system on the other hand, is more of a shipping company that takes oxygen and nutrients throughout the body to where they are needed and removes carbon dioxide and other waste from the tissues that make them. Overall, each of these systems need to work together with one another to keep us in good health and balance. We often call this balance **homeostasis** (*homeo*-same, *stasis*-keeping still).

Today, we'll be exploring various physiological systems by doing activities that investigate how particular systems work.

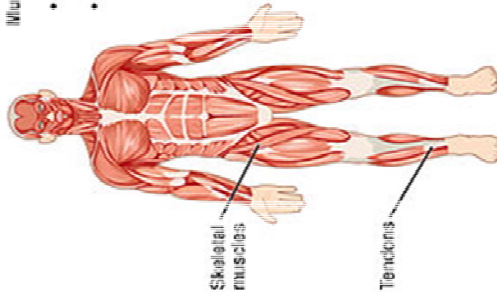
### Skeletal System

- Supports the body
- Enables movement (with muscular system)



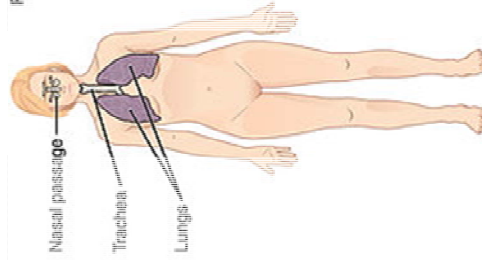
### Muscular System

- Enables movement (with skeletal system)
- Helps maintain body temperature



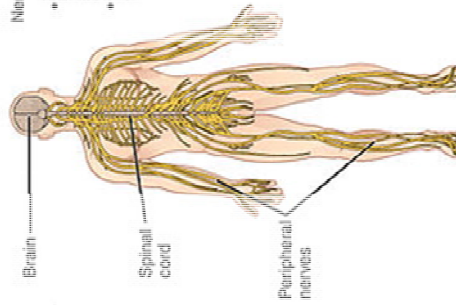
### Respiratory System

- Removes carbon dioxide from the body
- Delivers oxygen to blood



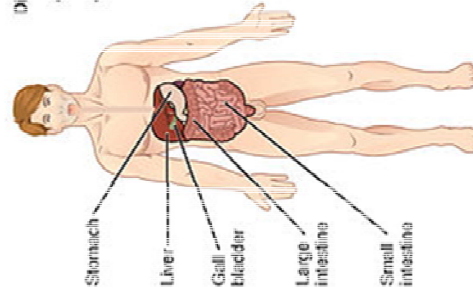
### Nervous System

- Detects and processes sensory information
- Activates bodily responses



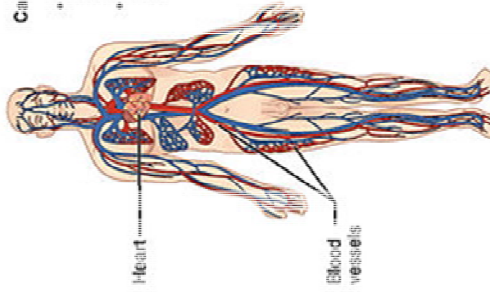
### Digestive System

- Processes food for use by the body
- Removes wastes from (and gastric) food



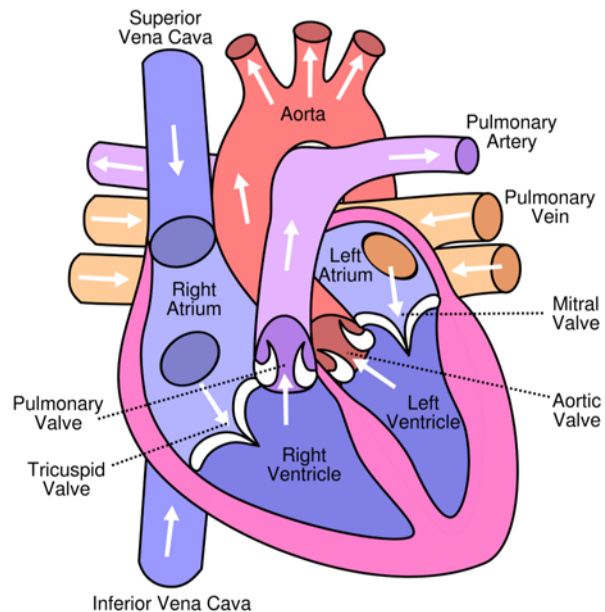
### Cardiovascular System

- Delivers oxygen and nutrients to tissues
- Equalizes temperature in the body



## Activity 1a - Heart Rate Changes

Your heart is responsible for pumping blood through the body. Each time it contracts (beats) it pushes a certain amount of blood to your lungs (**pulmonary circulation**) and the rest of your body (**systemic circulation**). Our blood gets moved around by blood vessels, and the pressure that the blood exerts on those vessels is what is called **blood pressure**. The amount of blood the heart moves is referred to as **cardiac output**, which is determined by the size each contraction (**stroke volume**) and the number of contractions (**heart rate**).



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The quickest way your heart changes the amount of blood being pumped is by changing the heart rate. Faster heart rates pump more blood during times when your body is doing activities that require more metabolism such as exercising or standing up. When resting, your heart rate slows to match the lower metabolic needs of your body. Heart rates also change in response to changes in blood pressure. When your blood pressure goes down as you stand up, your heart rate compensates for this decrease by activating the **baroreflex**. The baroreflex is one of the body's ways to keep blood pressure level.

We usually record heart rate as beats per minute (**bpm**) and measure it by feeling for the **pulse** made by the pressure created in your arteries during the heart's contraction. This can most easily be felt by putting your fingers on your wrist or neck as your activity leader will demonstrate for you.

**For this activity, you will measure your heart rate by feeling your pulse before and after doing various activities. Record your values in the table below for each activity.**

<b>Activity</b>	<b>Before</b>	<b>After</b>
Running		
Laying Down		
Laying Down (Before) Standing (After)		
20 Jumping Jacks		

**Why did your heart rate change like it did for each activity?**

**How would you expect your heart rate to change if you went to sleep?**

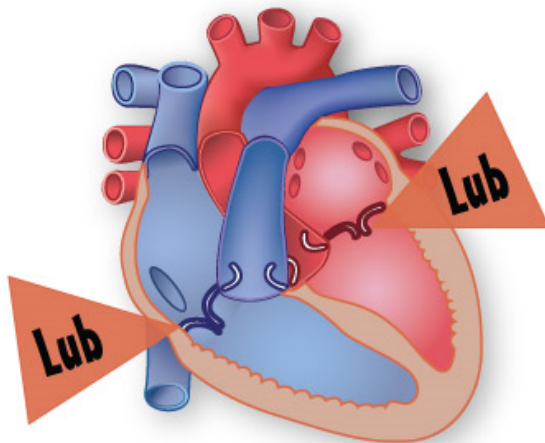




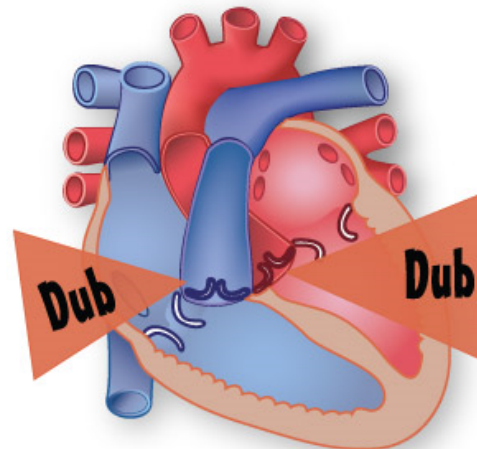
## Activity 1b - Heart Sounds

As your heart contracts it pushes blood from one chamber to the next and out of the heart into the circulation. When it pushes the blood it causes **valves** within your heart to snap shut to prevent the blood from moving backwards. The heart sounds you hear through a stethoscope come from the snapping, drum-like noise these valves make as they close. The first sound (**lub**) happens at the beginning of the period called **systole**, which is when the large chambers of your heart (the **ventricles**) begin to contract and push blood out of the heart. The second sound (**dub**) happens when systole is over and the ventricles begin to relax again in order to fill with more blood, which marks the beginning of the period called **diastole**.

**Normal Heart "Lub"**



**Normal Heart "Dub"**



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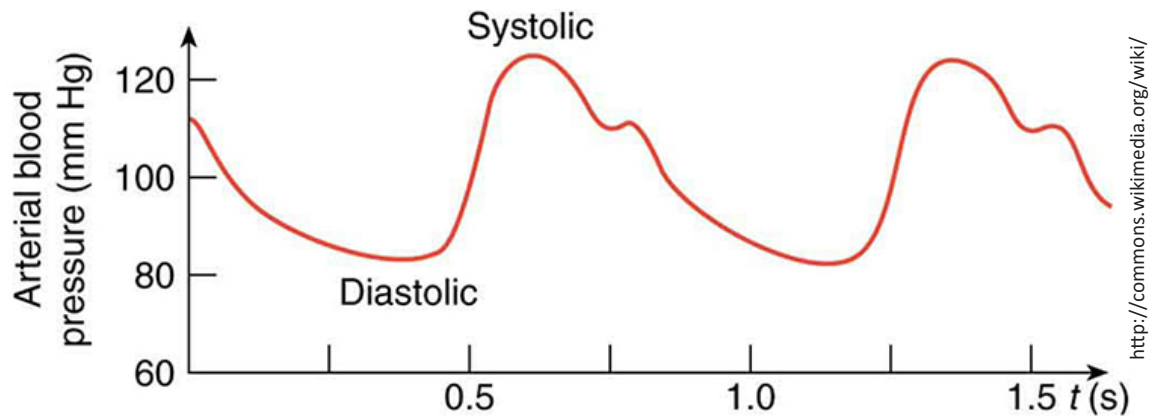
**With the help of your activity leader, use the computer and speakers to watch a contracting heart and listen for the lub, dub sounds.**

**Use the stethoscopes to listen to your own and a willing partner's heart sounds.**



## Activity 1c - Blood Pressure

Each heart contraction and relaxation (systole and diastole) create waves of pressure that move throughout the vessels in your body that lead away from your heart, called arteries. These waves have high and low points that match the pressure made inside your heart during systole and diastole.



We measure blood pressure by using a blood pressure cuff and computer or stethoscope. The numbers recorded are systole/diastole (usually around 120/80) millimeters of mercury (mm Hg), which is a unit of measurement for pressure.

**Use the provided equipment (Vernier, blood pressure cuff, stethoscope, etc.) to measure your own blood pressure and record it below.**

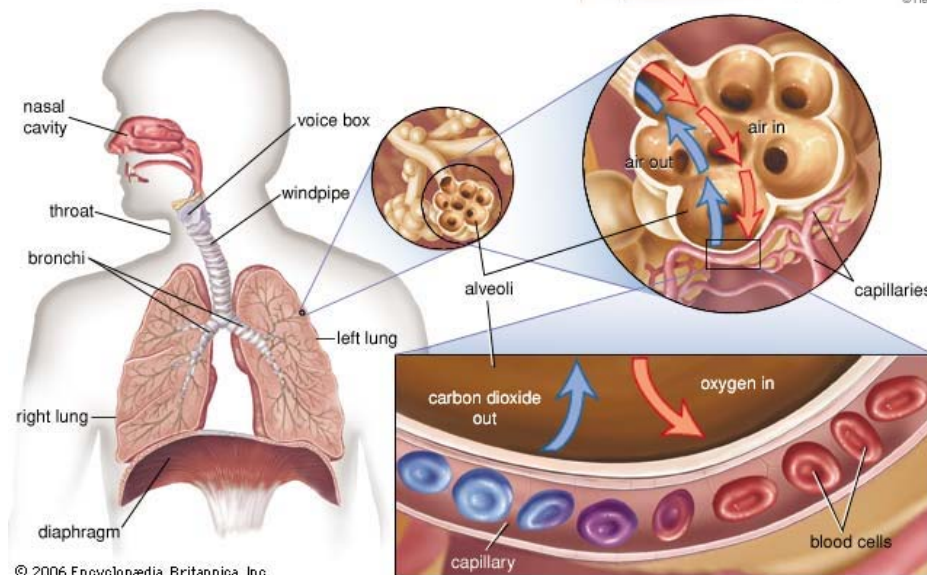
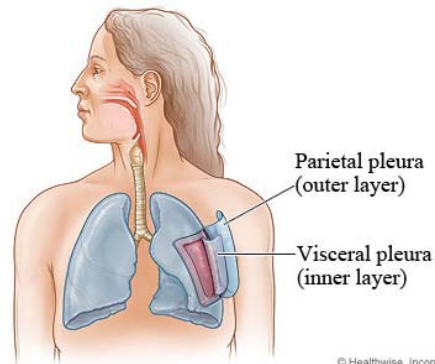
\_\_\_\_\_ / \_\_\_\_\_ mm Hg



## Activity 2a - Lung Anatomy

The lungs are a very important organ system and help us keep oxygen in our blood. Your windpipe (or **trachea**) branches into smaller segments known as **bronchi** as it gets closer to your lungs. The lungs are composed of many very tiny sacks of tissue called **alveoli**. When air travels down your trachea and eventually into the alveoli, they are able to expand. There are also **capillaries** or very tiny blood vessels next to the alveoli that allow **oxygen** to get into the blood. **Carbon dioxide** can also pass through these capillaries and then into the alveoli. When you exhale, this carbon dioxide then travels back up through your windpipe (trachea) and is exhaled when you breathe.

The lungs also expand and contract a lot when you breathe in and out. In order for the lungs to be able to do this smoothly, they are covered in a smooth, bag-like structure called the **pleura**.



***In this activity, you will get to touch and try to inflate a real set of lungs!***

**What do the lungs feel like? Are they soft or hard?**

**Did you expect them to feel this way?**

**Can you see the areas where the alveoli are collapsed and where they start to inflate?**

**If you had a collapsed lung, why is it difficult to get the alveoli to expand (re-inflate)?**

**Find and identify all of the vocabulary words listed, on the real lung:**

**Trachea:**

**Bronchi:**

**Alveoli:**

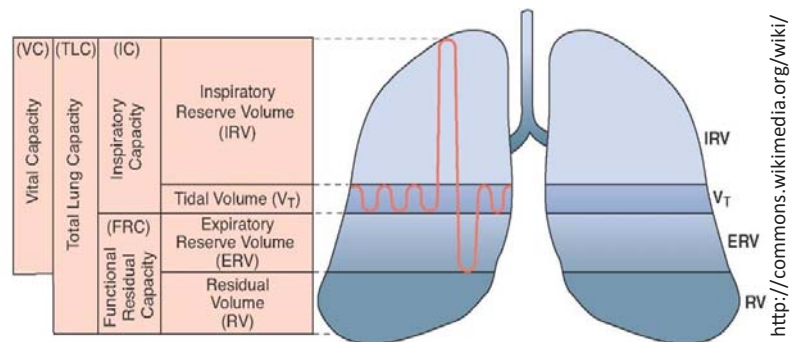
**Capillaries:**

**Pleura:**



## Activity 2b - Lung Capacity and Respiration

Your lungs are about the size of footballs and are located behind your rib cage. The total amount of air that is in your lungs is composed of several volume subsets. When you take a normal breath this is called the **tidal volume**. The largest volume that you are able to exhale from your lungs is called the **expiratory reserve**. When you are exercising very heavily and inhale more air than normal, this is referred to as the **vital capacity**. In this activity, you will use a balloon to calculate how much air is in your lungs for various subsets.



### Part A—Tidal Volume

- Take in a normal breath. Exhale into the balloon *only* as much air as you would normally exhale. DO NOT force your breathing.
- Place the balloon next to a metric ruler. Determine the diameter of the balloon by measuring across the top of the balloon to the ruler.
- Record the diameter of the balloon in centimeters in column A.
- Deflate the balloon.

*Repeat the previous four steps three more times.*

### Part B—Expiratory Reserve

- Exhale normally
- Then, exhale into the balloon as much air as possible.
- Measure and record the diameter of the balloon in column B.

*Run three more trials. Record the diameter of the balloon in the data table.*

### Part C—Vital Capacity

- Take as deep a breath as possible. Then exhale all the air you can into the balloon.
- Measure and record the diameter of the balloon in column C.

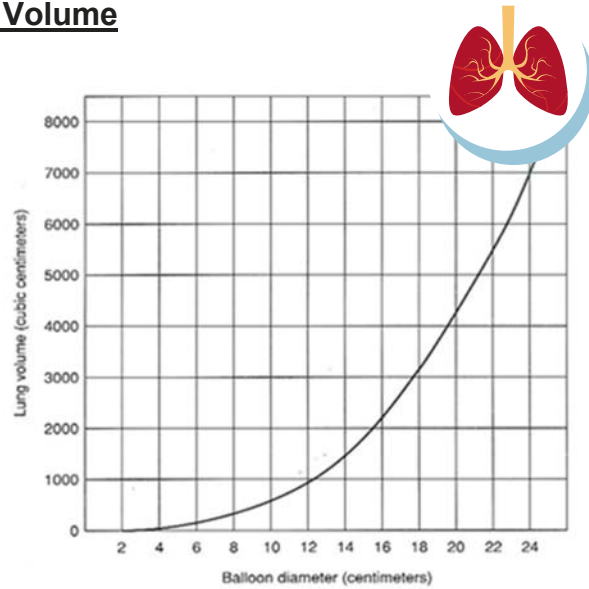
*Run three more trials. Record the diameter for each trial in the data table.*

**Part D—Conversion of Diameters to Volume**

Lung volume is expressed in cubic centimeter units (cm<sup>3</sup>). (1,000 cm<sup>3</sup> is slightly more than one quart.)

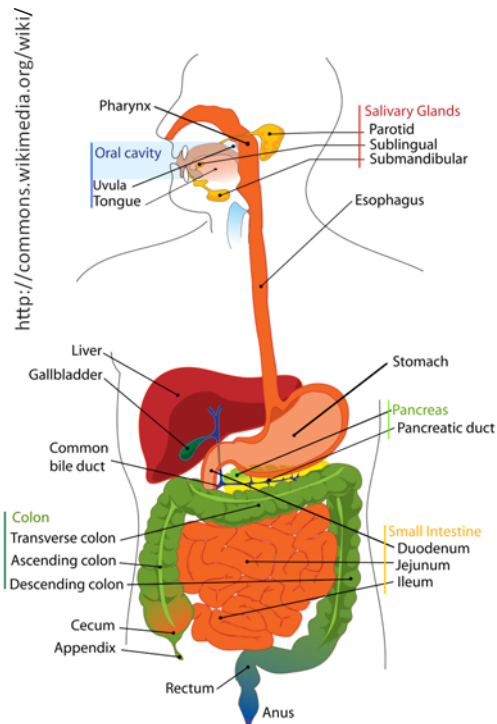
To convert from balloon diameter to volume, locate the balloon diameter on the horizontal axis of the graph. Follow this number up to the heavy line, then move across to locate the corresponding volume.

For example, if your balloon diameter is 12 cm, then the corresponding lung volume is 1000 cm<sup>3</sup>.



Trial	Balloon Diameter (cm)			Lung Volume (cubic centimeters)		
	A Tidal Volume	B Expiratory Reserve	C Vital Capacity	D Tidal Volume	D Expiratory Reserve	D Vital Capacity
1						
2						
3						
			Total			
			Average			

## Activity 3a - Digestion



Your digestive system takes all of the food you eat, breaks it down into smaller parts, absorbs what your body needs, and disposes of whatever is left along with some waste. The main actions your digestive system accomplishes are called **catabolism**, **absorption**, and **secretion**.

Catabolism is when large things are broken down into smaller parts. Think of it like when you take a big Lego construction and remove the pieces from it so that you are only left with smaller pieces. The opposite of this is called anabolism, where small pieces are put together into larger structures.

Your digestive system starts with your mouth, goes through the esophagus, stomach, small intestine, and large intestine.

These organs are responsible for pushing things through your digestive tract in a squeezing process called **peristalsis**, for mixing things around, and for absorbing the nutrients into your body. Other organs such as your liver, gallbladder, and pancreas also participate in digestion. The pancreas makes and secretes **enzymes**, special proteins that catabolize materials. Think of enzymes like scissors, they cut up big things into smaller pieces. The liver makes and the gallbladder stores something called **bile**, which is responsible for a process called **emulsification**.

Different animals' digestive systems have differing anatomy and chemical abilities. This allows different animals to have diets best suited to their particular environments. For instance as humans, we can't break down the cellulose in grass thus we get no nutritional benefit from eating it. Cows however, have



digestive systems with multiple stomachs and a regurgitation process that allows them to break down and absorb the nutrients found in grass and other plants. The science of comparing the physiology of animals with one another is called **Comparative Physiology**.

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**Since different animals' digestive systems are organized differently from one another and are unique for each specie's particular diet, we can identify which fecal material (poop) came from particular animals.**

**Match the petri dish containing a fecal sample with the animal it came from.**

Animal	Poop Description



## Activity 3b - Digestion

If you've ever mixed together oil and water, you know that they tend to stay separate from one another. That's because water, as a polar molecule, doesn't interact well with non-polar molecules like oils. This is hard for digestion because oils would make big droplets with very small surface area, which doesn't allow for very good catabolism or absorption.

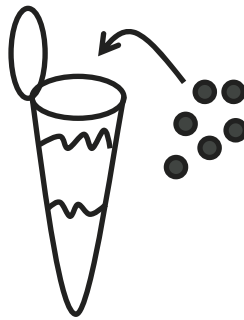
In order to mix oil and water, you need to create an **emulsification**. In order to do this, you need special molecules that have both polar and non-polar segments. These are called emulsifying agents. The albumin in egg is a good example of an emulsifying agent and is how mayonnaise can mix large amounts of oil with water into a cream.

The bile made by your liver is another emulsifying agent. It breaks down the oil and fats in your food into smaller droplets to ease catabolism and absorption.

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**Take 1 ml of water and 1 ml of oil and put them both into your test tube.**

**Can you get them to mix evenly?**



**Now add a pinch of “bile salts” into the test tube.**

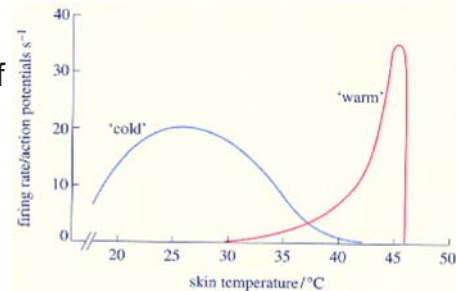
**Now can you get the oil and water to mix evenly?**



## Activity 4a - Temperature Sensing

Your body is constantly sensing the environment around it using special sensors in your body. Each of these sensors, or sensory receptors, can detect a certain kind of stimulus. We'll go more in depth into sensory physiology in the Special Senses lab, but here we'll discuss one particular type of sense, how it works, and how it relates to muscle physiology.

**Thermoreceptors** are the sensory receptors that can detect temperature and changes in temperature. Mostly distributed throughout your skin, these receptors respond to both cold and warm stimuli. Cold exposure increases the activity of "cold" thermoreceptors and inhibits the activity of "warm" thermoreceptors. Exposure to warm temperatures or objects does the opposite. Your brain then decodes this activity into the sensation of "warm" or "cold."



**For this activity, place one hand into a container filled with warm water and the other hand into a container filled with cold water. After 2 minutes, take both hands and put them both into a container containing room-temperature water.**

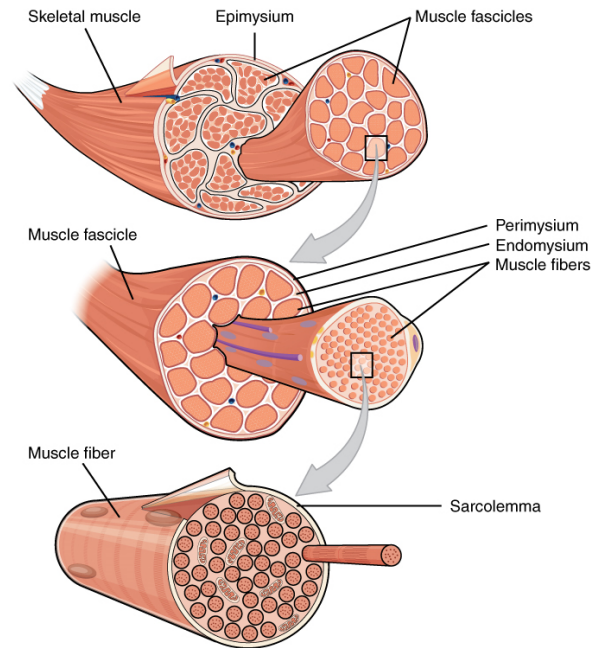
**What sensation occurred immediately after placing your hands into each of the first containers?**

**What happened toward the end of the 2 minutes? Did the temperature sensation stay the same as the beginning?**

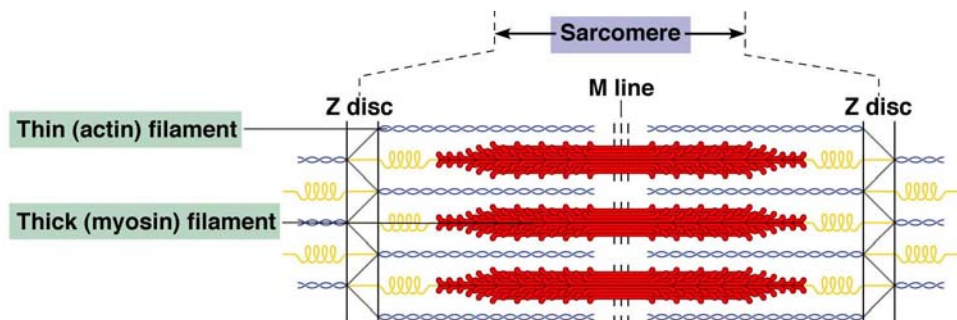
**How did the room-temperature water feel on each of your hands?**

## Activity 4b - Muscle Action and Fatigue

**Muscles** are organs that contract to move your skeleton around. Muscles move you around your environment. Muscles allow you to grasp and handle objects. Muscles are made up of individual fibers that contain the functional unit called a **sarcomere**. The sarcomere is made up of intertwined fibers of protein called **actin** and **myosin**. There are lever-like molecular motors on the myosin that in essence walk down the chains of actin by using energy in the form of **ATP** (adenosine triphosphate). This movement makes the sarcomere shorter and is what causes the contraction of the muscle.



Since muscles are made of protein motors and use ATP there are a number of things that can affect the ability of muscles to contract fully. Temperature can change how fast reactions occur, and lots of activity can change the availability of ATP. The activities you'll be doing at this station investigate how temperature and activity can change muscle function.



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**1. Count the number of times you can make a fist in 20 seconds. Start with your hand completely outstretched and make a tight fist each time. Do it as rapidly as you can. Record the number in the table below.**

**2. Now submerge your hand in ice water. Leave your hand in the ice water for one full minute.**

**3. Remove your hand and immediately count how many forceful fists you can make in 20 seconds. Record this in the table below**

Temperature	Number of Fists
Normal	
Ice Water	

**1. Count how many times you can tightly squeeze a rubber ball in your hand in 20 seconds. Record in the table below.**

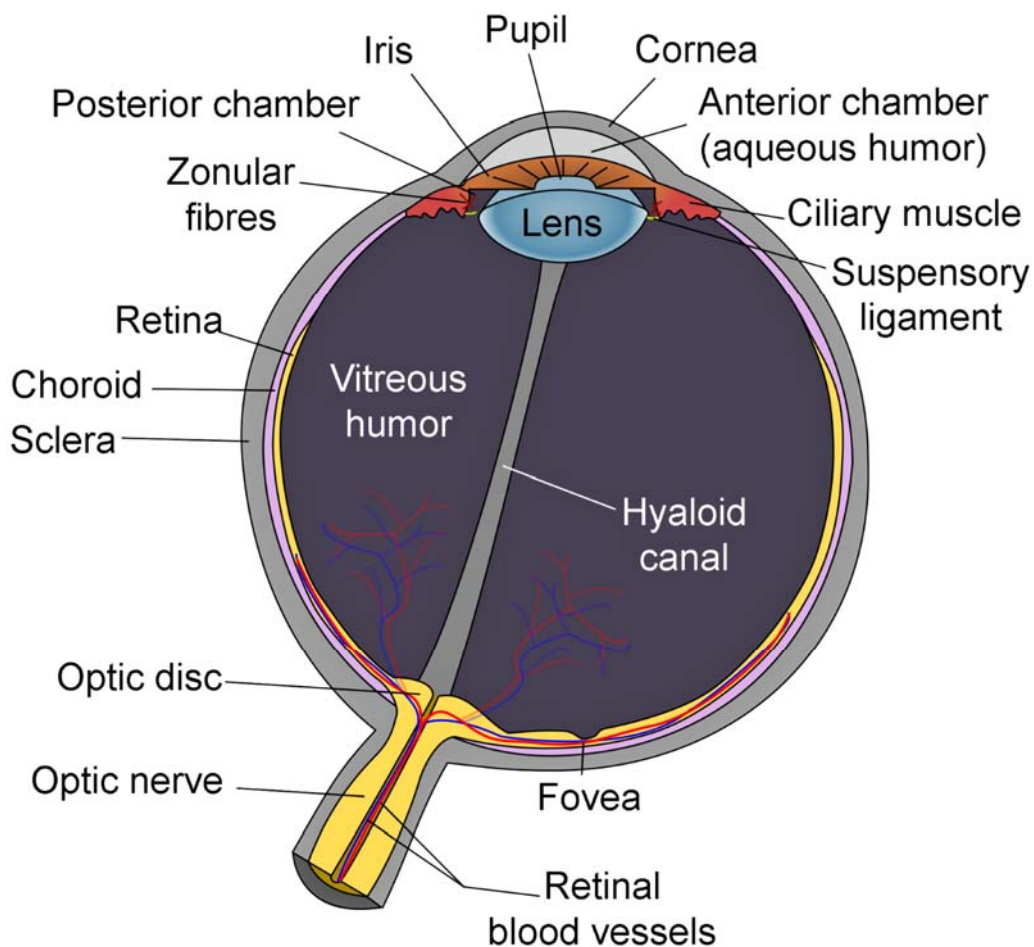
**2. Repeat the squeezing nine more times and record results. Do not rest between trials.**

**(An alternative procedure which works well is to open and close a clothespin with the thumb and index finger while the other fingers are held out straight.)**

Trial	# of Squeezes in 20 seconds	9 More times
1		
2		
3		

## Activity 5 - Eye Dissection

Your eyes are the organs that sense light and turn that light signal (**stimulus**) into information that your brain can interpret and give you a visual image of your environment. We'll talk more about the neurological processes involved in sight during the Special Senses lab, but here we'll be discussing the anatomical structure and physiological function of the various parts of the eye.



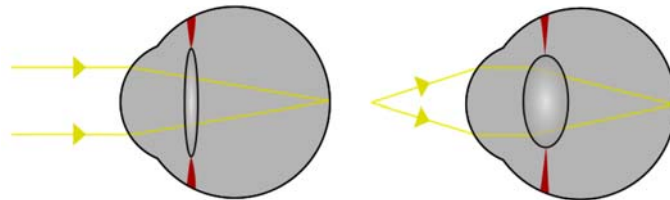
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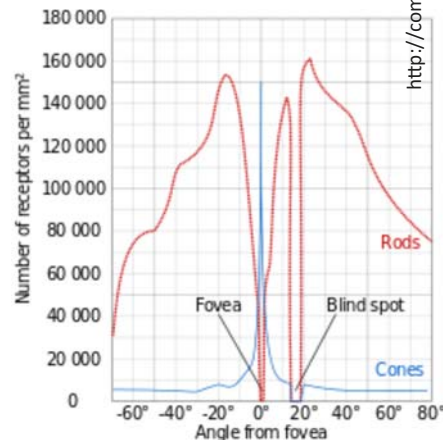


The major function of the anatomical structure of the eye is to focus light onto the **retina**, which is the sensory receptor part of the eye. The receptors in the retina will sense the light stimuli and convey this information to the brain.

As light first enters the eye, it passes through the **cornea**, which **refracts**, or bends, the light. Your **iris** is the colored part of your eye. By constricting or dilating, it can decrease or increase the size of the pupil, which is the black spot of your eye and is really just a hole. Next, the light hits the **lens**, which is the major powerhouse of refraction within your eye. The **ciliary muscles** and **suspensory ligaments** hold the lens in place and can change its thickness in a process called **accommodation**. Accommodation is what allows you to focus on objects that are close to you or objects that are far away. If you focus on something nearby, your ciliary muscles contract, which loosens the suspensory ligaments, and the lens gets thicker. This thick lens has more refractory power (it bends the light more) and focuses the light from the nearby object onto your retina. The opposite occurs when looking at an object far away (ciliary muscles relax, suspensory ligaments get tight, lens flattens out and has low refractory power).

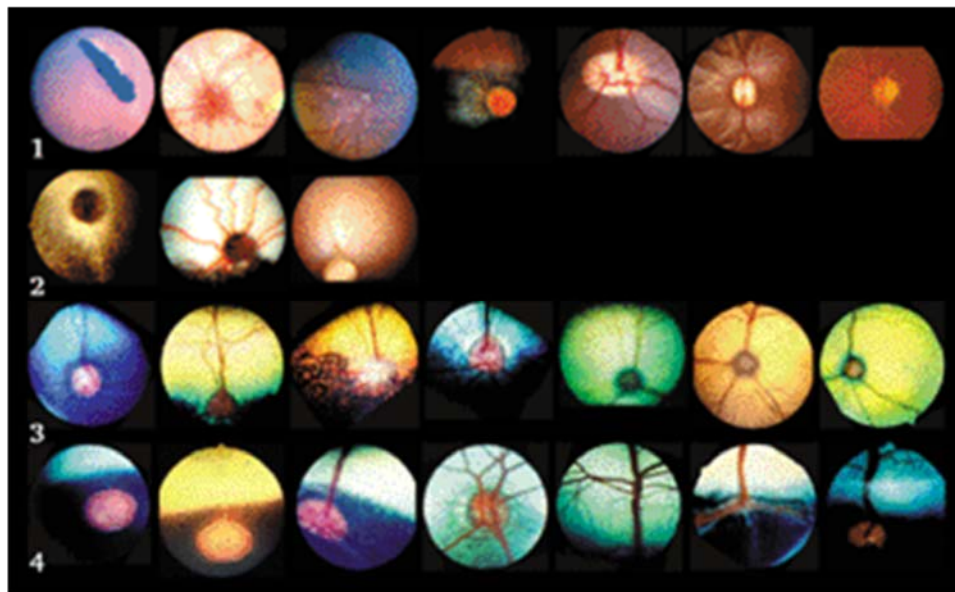


All this bending of light focuses it onto your **fovea**, a specialized area of your retina consisting of a high density of color sensitive receptors called **cones**. The fovea is responsible for the high acuity (resolution/high definition) of your central vision. The rest of the receptors throughout the retina are mainly **rods** that detect light but don't distinguish color and make up your peripheral vision.



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Behind human retinas there is a layer of pigmented cells that absorbs any light that has not been absorbed by the retina. This prevents the light from reflecting back onto the retina and causing abnormal visual signals. The down-side to this is that humans have rather poor low-light vision. Some animals have specialized structures behind their retinas that do reflect light back onto the retina, which aids in low-light vision. This structure is called the **tapetum lucidum** (lucid/bright tapestry) and is why some animals eyes “glow” when a light is shined toward them at night.



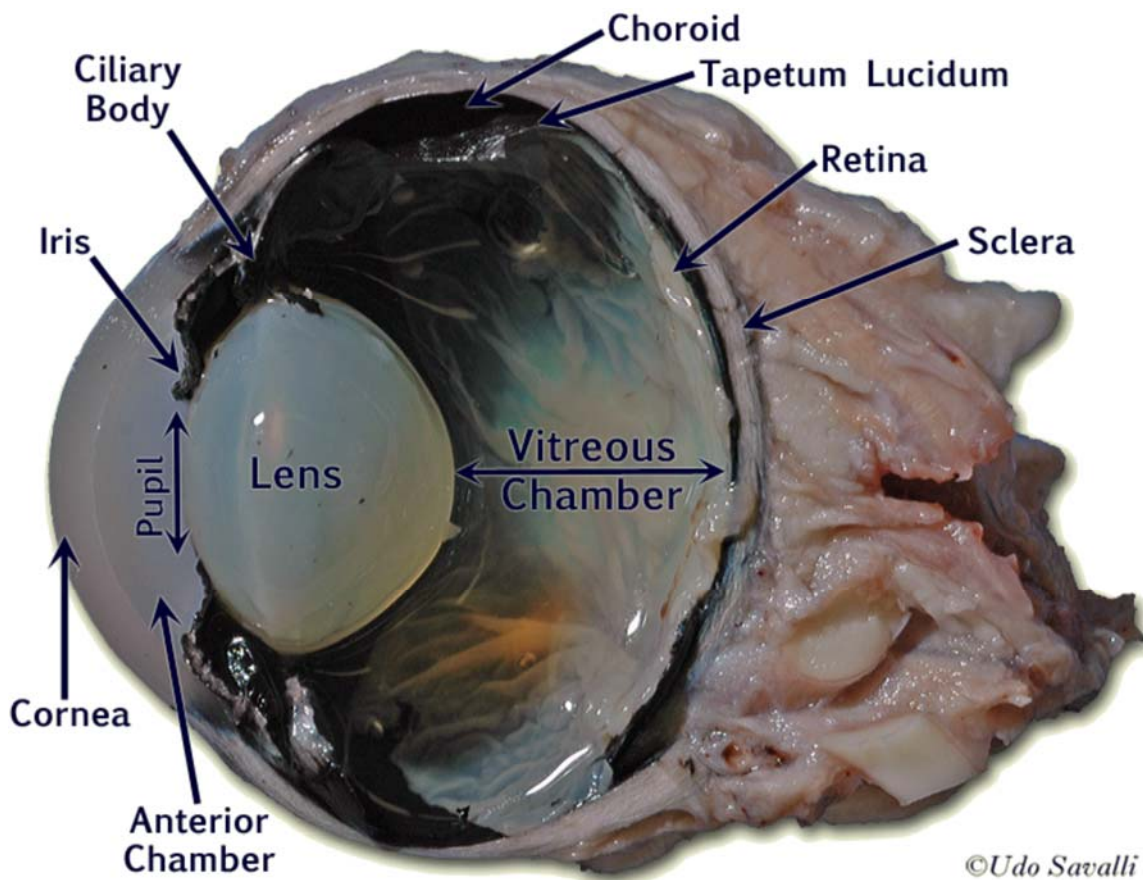
Ocular fundus of various species showing the absence or the presence a tapetum lucidum that can exhibit various colors. From right to left: Lane 1: absence of tapetum: bird, albinos rat, hooded rat, red kangaroo, pig, rhesus monkey, human. Lane 2: retinal tapeta: alligator, possum, fruit bat. Lane 3: Choroidal tapeta cellulosa: puppy, dog (3), cat, jaguar, leopard. Lane 4: choroidal tapeta fibrosa: foal, horse, sheep, goat, cow, deer, mouflon.

Ollivier, F. J., Samuelson, D. A., Brooks, D. E., Lewis, P. A., Kallberg, M. E. and Komáromy, A. M. (2004), Comparative morphology of the tapetum lucidum (among selected species). *Veterinary Ophthalmology*, 7: 11–22. doi: 10.1111/j.1463-5224.2004.00318.x



For this lab you will dissect a sheep eye.

Identify as many of the structures as you can from the image below and discuss with your station leader and group partners



## Activity 6 - Diving Reflex

Blood pressure and heart rate are discussed more in depth in Activity 1. Here we will be investigating one particular example of reflexive cardiovascular control, the mammalian diving reflex. Lots of things can affect blood pressure and heart rate – such as body position, exercise, and diet. Since mammals need to breathe in air rich in oxygen and expel carbon dioxide (discussed more in Activity 2), some interesting changes occur to cardiovascular control when mammals dive underwater. When mammals are under the water, inhalation and exhalation is not possible so it is important to conserve oxygen. Thus, when we first submerge our faces in water, we activate the **mammalian diving reflex**, which leads to an immediate change in heart rate.

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**What do you predict will happen to heart rate when a mammal dives underwater (will heart rate increase or decrease)? Why do you think this happens?**

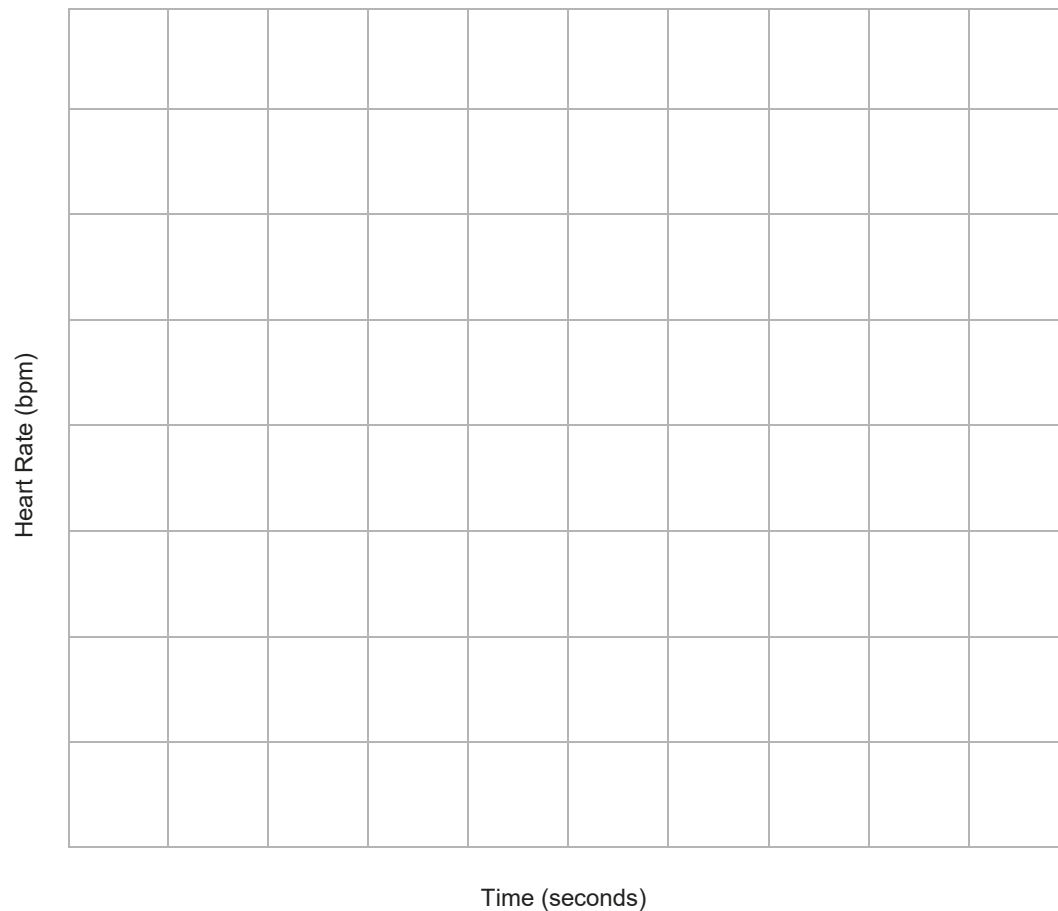
**What do you predict would happen to your heart rate when you submerge your elbow or hand into the water?**



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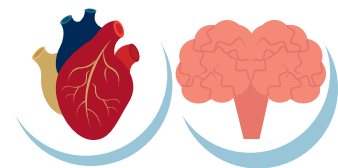
Using the Vernier system, measure your heart rate until you get a stable baseline. After a few seconds of baseline, submerge your face into the cold water. Record your results onto the grid below.

Do the same experiment, only now submerge your elbow instead of your face and record the results using a different color or dashed lines on the grid below.



**Did your results match your predictions?**

**Why or why not?**



## Activity 7 - Owl Pellet Dissection

Owls are a type of bird called a raptor. They have large claws, a hooked beak, and swallow their food whole. They eat mainly small rodents such as mice and shrews. Owls also have a large mouth that stretches to accommodate a larger food source. Other large birds such as eagles tear their food into small pieces before eating it. Owls also have weaker stomach acids than other raptors and therefore, can not fully digest all of the material it swallows, such as fur and bones. This material is compacted by the owl's stomach muscles into a "pellet" and is **regurgitated** on a regular basis.

Owl pellets are also a mini ecosystem and may be a home for beetles, fungi or a place for moths to produce larvae. The small pellets you see may be the droppings from caterpillars that have hatched. Don't worry— after the owl pellets were collected, they were fumigated (sterilized) and are safe to touch.



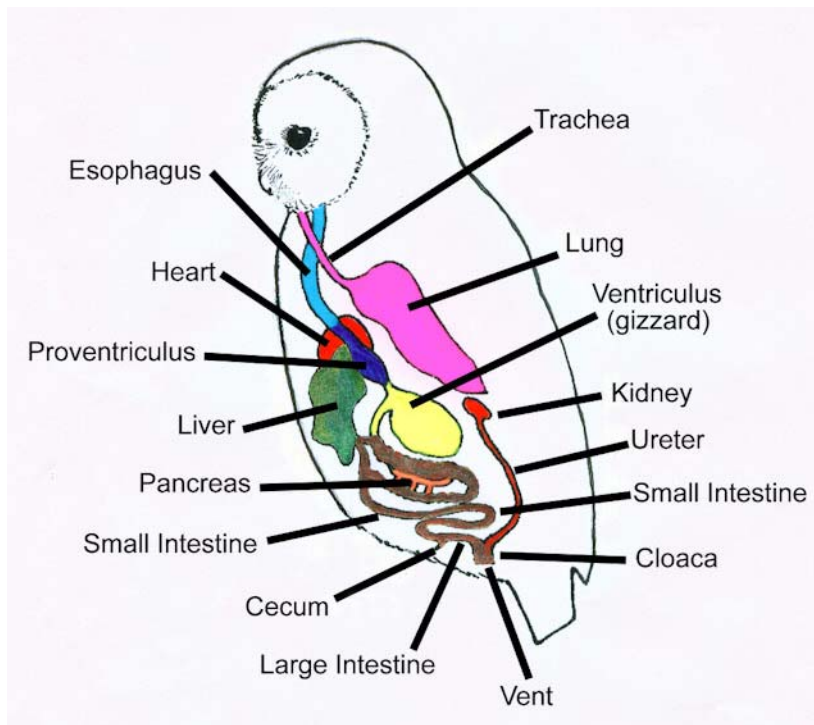
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**What do you know about the owl's digestive system based upon the pellets?**


















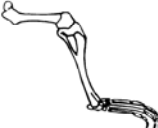

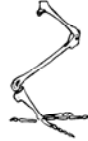












**What other types of “animals” did you find in your owl pellet?**

**Other types of birds (such as eagles ) produce pellets, too. What would you expect them to look like?**



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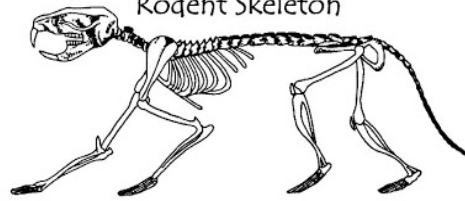


Owl Pellet Bone Chart				
	Rodent	Shrew	Mole	Bird
Skull				
Jaw				
Scapula				
Forelimb				
Hindlimb				
Pelvic Bone				
Rib				
Vertebrae				

CB280780000

**Carolina Biological Supply Company** 2700 York Road,  
Burlington, North Carolina 27215

Rodent Skeleton



**After you have sorted the contents of your owl pellet using the chart on the left use the space below to try and construct a skeleton by gluing the bones to this page. Feel free to draw in any missing parts of the skeleton, or make more than one if you have several animals in your pellet.**

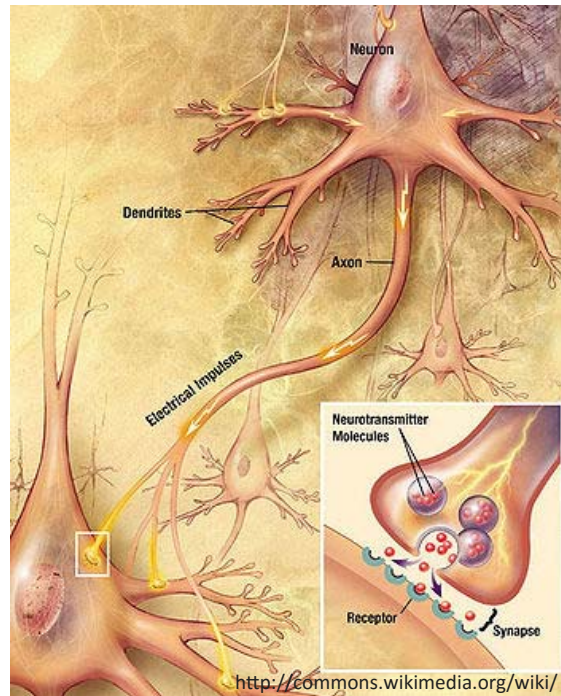


## Activity 8 - Nerves and Reflexes

**Nerves** are one way the parts of the body communicate with one another. The “language” nerves use to communicate are electrical signals called **action potentials**. Nerves carry action potentials from sensory receptors to your **central nervous system** (brain and spinal cord) or from the central nervous system to organs such as muscles for movement.

Your nervous system is an elaborate network of connected neurons. **Neuron** to neuron communication happens over junctions called **synapses**. One neuron releases **neurotransmitters** into the synapse to be received by the connected neuron. Depending on the type of neurotransmitter, this second neuron is either activated or inhibited. The coordinated action of the network of neurons in your central and **peripheral** (non brain and spinal cord neurons) systems is how you think, sense your environment, and move. Although synapses are necessary to create this elaborate network, they slow down the speed of a signal down a nervous pathway because they require the physical movement of neurotransmitters from one neuron to another.

A **reflex** occurs when your nervous system creates a response to a stimulus without the need for you to “think” about the reaction. If you put your hand on a hot stovetop, your body will immediately withdraw your hand before you’re even aware of pain from the stove. Reflexes are a type of preprogrammed response the body has to protect itself from harmful stimuli. Reflexes use as few synapses as possible to ensure a very quick response.



**Break up into two groups with one group having 3 or 4 more people in it than the other. Line up and hold hands.**

You are now a neuronal network pathway. When you get the signal to start, the people on the end of each line will start sending an “action potential” down the pathway by squeezing the hand of the person next to them. This person will then squeeze the hand of the person next to them, until the “action potential” reaches the end of the line.

**Which group had the faster signal?**

**Why was this group faster?**

*With the help of your activity supervisor, test the patellar and ocular reflexes as partners or in small groups.*

**Why does the leg kick when the patellar tendon is hit with the reflex hammer?**

**What is the benefit of the iris changing size when a light is shone into the eye?**

**One of the volunteers will spin around in a chair. Watch their eyes when they stop spinning. The movement is called **nystagmus**. What is the benefit of this reflex?**

**Why do the eyes continue to flicker even after the spinning has stopped?**



## Activity 9 - Special Senses

Since all organisms live within an environment, it is important for the organism to be able to sense and respond to changes from that environment. Each organism has special sense capabilities that best suit the environment in which its kind live. For humans, we use the five special senses of touch, sight, smell, taste, and hearing. There is another “sense” called the vestibular system, which is used to orient the organism within space. It’s how you tell what is up vs. down and directional movement. The following table lists the human senses with a short description for each.

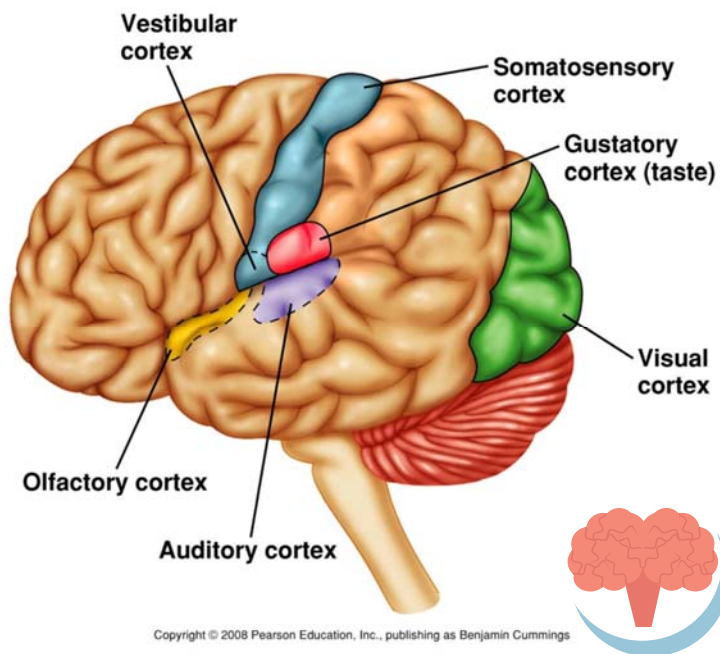
<b>Common Sense Name</b>	<b>Scientific Name</b>	<b>Description</b>
Touch	Touch	Receptors in the skin sense mechanical stimuli, temperature, and pain.
Sight	Vision	Receptors in the retina sense light stimuli.
Smell	Olfaction	Receptors in the nose sense chemicals in the air.
Taste	Gustation	Receptors on the tongue sense chemicals from food.
Hearing	Audition	Hair cell receptors in the ear sense vibrations from sound waves.
Vestibular	Vestibular	Hair cell receptors in the vestibular labyrinth sense gravity and angular momentum.

All sense systems work in a similar manner where a specialized receptor is sensitive to a certain type of **stimulus** (light, touch, etc.) and converts (**transduces**) that stimulus into a nerve impulse. That nerve impulse then travels up nerves into the central nervous system (CNS, spinal cord and brain).



Stimulus	Sensory Receptors <b>Transduce</b> signal	Sensory Neurons Transport signal	CNS Processes Action Potentials
<ul style="list-style-type: none"> <li>- light</li> <li>- sound</li> <li>- chemical</li> <li>- pressure</li> <li>- heat</li> <li>- etc.</li> </ul>	<ul style="list-style-type: none"> <li>- eye/retina cells</li> <li>- ear/hair cells</li> <li>- taste buds</li> <li>- etc.</li> </ul>	<ul style="list-style-type: none"> <li>- to CNS in a coded series of action potentials</li> </ul>	<ul style="list-style-type: none"> <li>- perception of stimulus</li> </ul>

Each sense has a special location of the brain that is responsible for responding to a particular sense. This location-based sense perception is called the **labeled-line principle**.

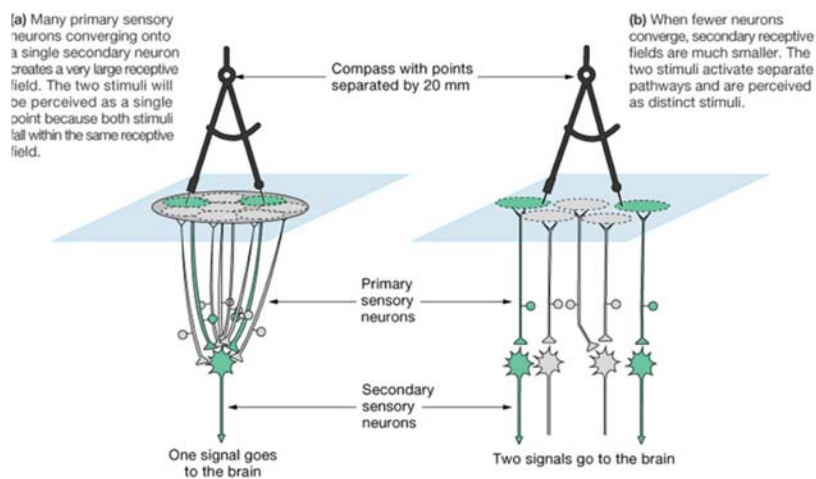


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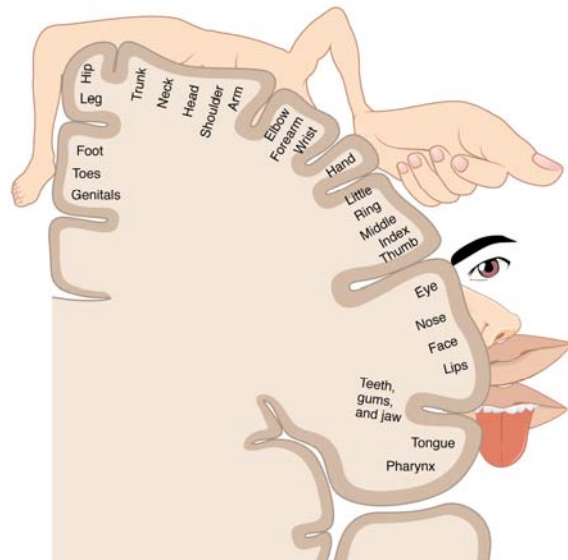
## Touch

The ability to distinguish between two separate stimuli is due to **receptive fields**. Similar to the labeled-line principle, receptor fields are the areas that are covered by individual neurons that go to the CNS. If two separate stimuli, like 2 different pin points, each touch separate receptive fields your brain will distinguish two separate points of touch. On the other hand if both points touch the same receptive field, your brain will only distinguish and perceive one point of touch.



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Receptive fields on your skin are called **dermatomes**. Dermatomes map to particular parts of your brain at the **somatosensory cortex**. You have a high density of small dermatomes on parts of your body that require fine touch (your palm) and larger, low-density dermatomes are on parts of your body that don't need fine point distinguishing (your back). The association points of specific dermatomes to specific areas of your somatosensory cortex are called **homunculi**.

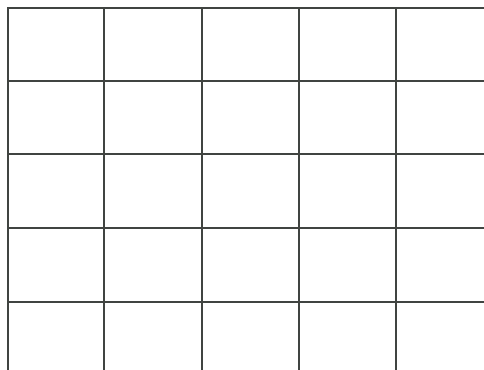


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### ***Dermatome Mapping***

In this experiment, you will attempt to map a dermatome. Work in pairs.

- 1. First, you will need to draw a small grid on your forearm that is approximately 3" X 3". Keep your head turned so you can't see your lab partner or the tools that they will stimulate the nerves in your skin with.**
- 2. Have your partner test the sensitivity of your skin by gently tapping your skin with a room temperature probe to determine a minimal level of pressure which can adequately be perceived by you.**
- 3. Begin the experiment with your partner picking one location in the square as a reference point to be used with each turn. Have your lab partner put a small magic marker spot at that point. Each time afterwards, your partner will touch that reference point first and then gently touch another spot within that same square. You will then be asked to say if it felt like the same spot was touched again or if it felt like a new location was stimulated. If the second stimulus felt like it was the same as the reference point, then your lab partner should mark it with the same color marker as the reference point. If the spot felt as though it was a different location, then your lab partner should mark that spot with a different color marker. Ultimately, you should have a grid that has different colors in two defined places on your skin, identifying a boundary between two distinct dermatomes. Copy this map onto the grid below for your records.**



## Sight

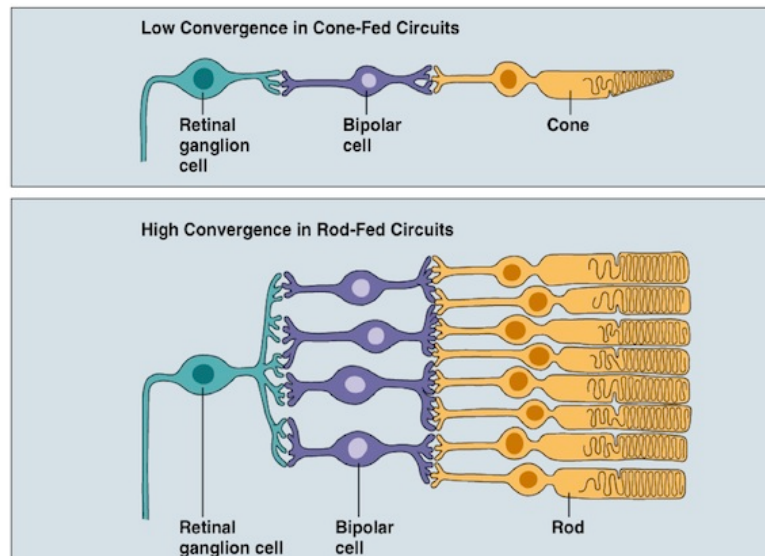
The anatomy of the eye is discussed in Activity 5 (middle schoolers can read this section at home if you wish). Here we will look at the receptors and physiology of perceiving vision.

**Rods** are receptors that respond to all light but doesn't distinguish between colors. **Cones** only respond to certain wavelengths of light and are sensitive to one of three colors. You have rods that only sense blue, red, or green. The way you see colors other than these three is by activation of multiple cones that combine their signals so your brain perceives the full range of colors along the spectrum.

Some people have a genetic trait that causes an inability to tell between certain colors. Red/Green **colorblindness** is the most common of the color blindness because it is an X-linked gene, which also means it's more common in males than females. Color blindness is tested using Ishihara tests.. These tests use multiple colored dots with two or more different numbers arranged by the dots. A person with normal vision will see one number while someone with colorblindness will see a different number.

Rods and cones also have receptive fields, cones have a one to one connection with second order neurons that take the signal to the visual cortex of the brain. This gives your color vision very high **acuity** (high density and resolution). Your color vision makes up your **central vision**.

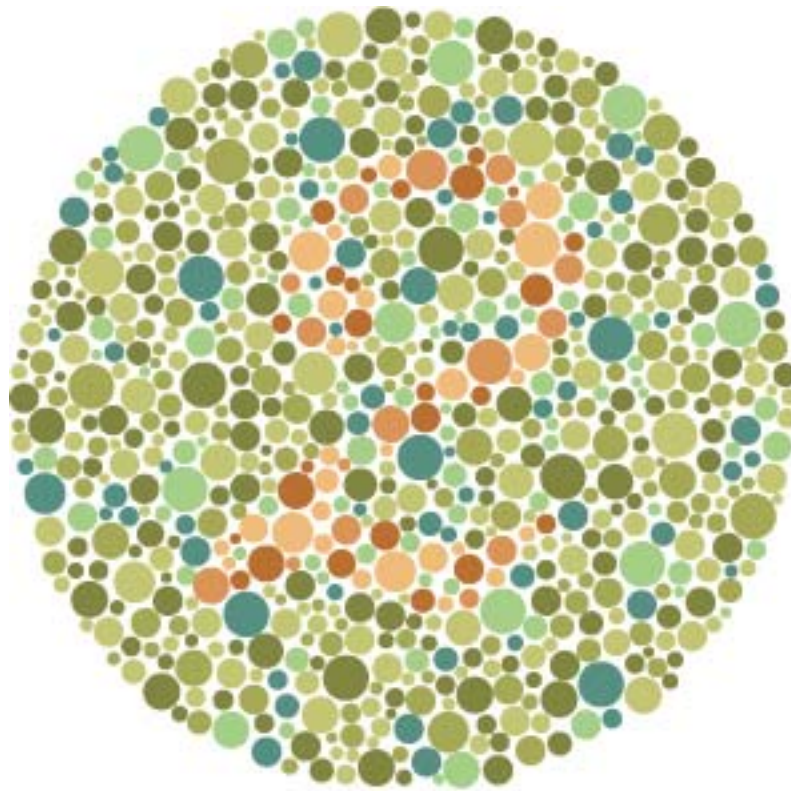
► Convergence of Cones and Rods



Conversely, there are many rods for each second order neuron. This gives your non-color vision very large receptive fields and low resolution. Your non-color vision makes up your **peripheral vision**, which has less of a need for high resolution vision and more of a need to simply detect movement.

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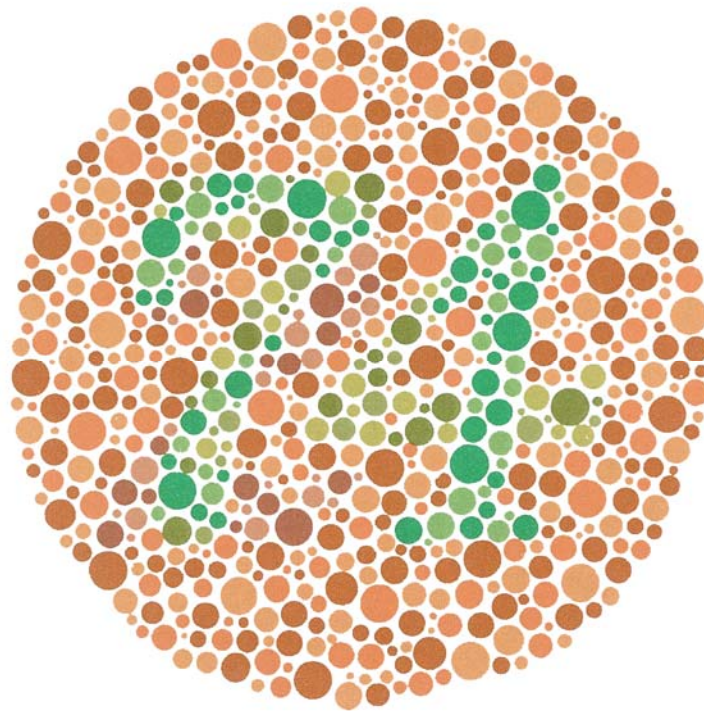
**What number do you see in the following Ishihara tests?**



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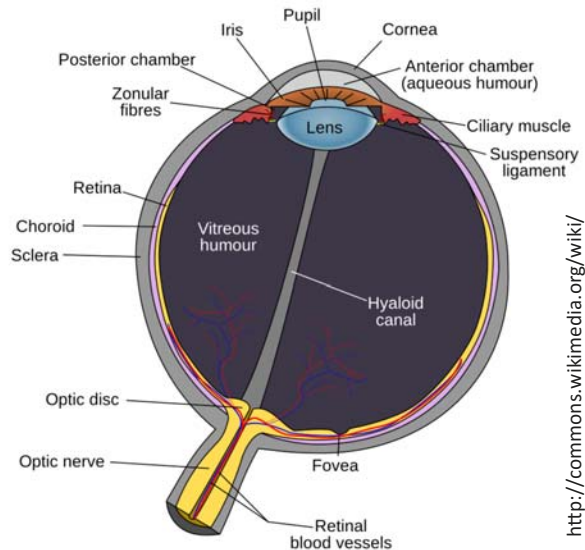
What number do you see here?



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The way the eye is organized has the **optic nerve** and blood vessels leaving the eye through a portion of the back of the eye called the **optic disc**. Since this section is just nerve axons and blood vessels, there aren't any receptors on that portion of the retina. Without receptors there isn't any way to detect light, therefore this is a **blind spot** in our vision. Normally, we don't notice this blind spot because our brain "fills in" this area with color from surrounding areas. You can find the blind spot by doing the following test.



Hold the booklet about a foot away from your face and focus on either the cross with your right eye or the circle with your left eye. Slowly move the booklet toward your face until the other shape disappears. This is the focal length at which the shape is projected onto your optic disc.

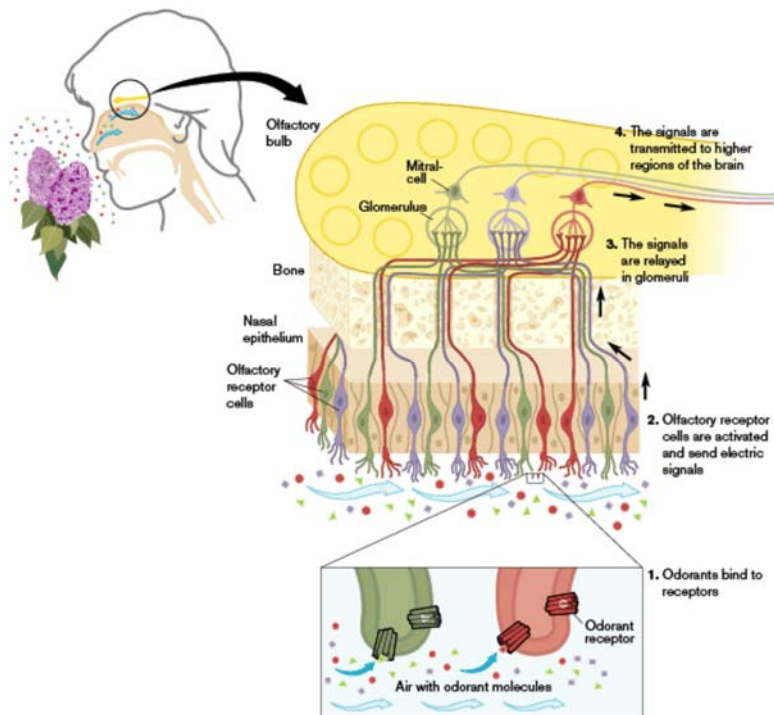




## Smell (Olfaction) and Taste (Gustation)

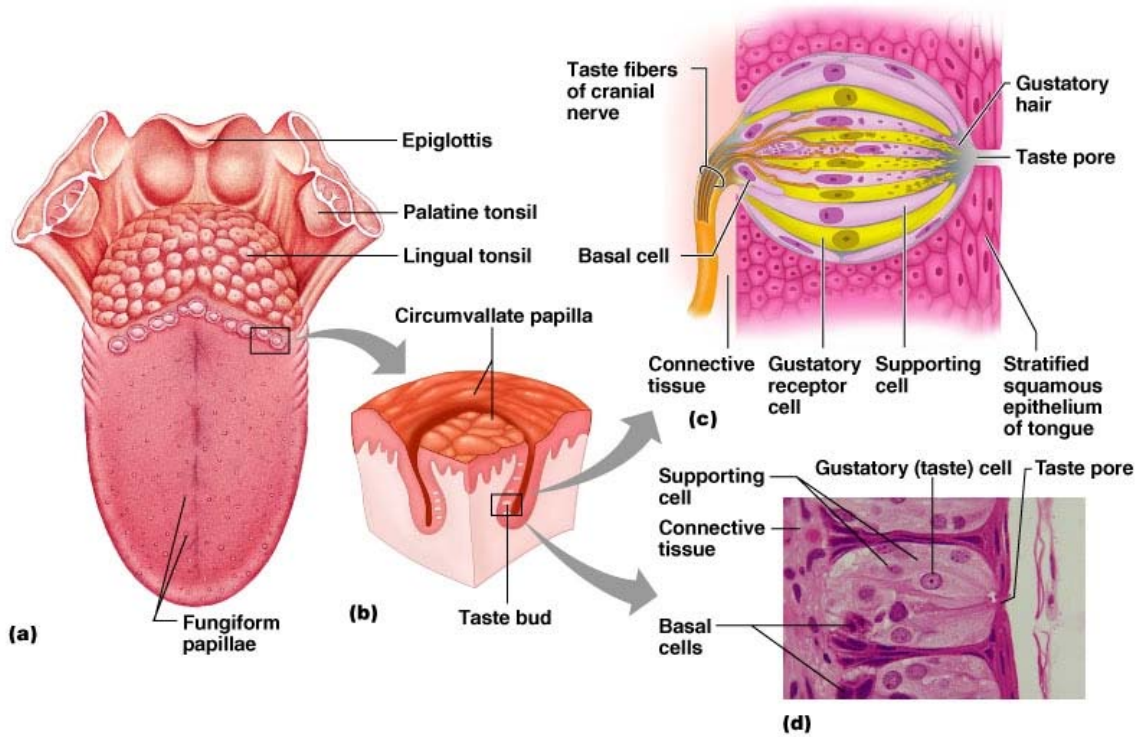
Just like the other senses, olfaction and gustation use specialized receptors that detect certain stimuli. In olfaction these receptors detect **odorants**, or chemicals that are floating in the air. Odorants bind to receptors that recognize that type of odorant, kind of like a key fits into a particular lock. This causes those receptors to activate their associated neurons either by initiating a sequence of chemical processes or by opening ion channels. These signals then travel into the olfactory bulb where your brain perceives the sense of that particular smell. Humans have a decent sense of smell, but we have a limited number of olfactory receptors and brain area dedicated to olfaction compared to other animals that have more of a need for accurate smelling.

Taste is very similar to smell in that chemicals from food bind to receptors on the tongue and are then communicated by nerve impulses to the gustatory cortex. You may have heard taste explained before by concentrating certain “tastes” in certain areas of the tongue (such as a bitter taste center). We now think that all types of basic tastes are evenly distributed throughout the tongue (bitter and sweet are intermixed throughout the tongue, not localized in specific areas). We have five basic “tastes” that interact with one another to produce the complex flavors we experience. These are sweet, sour, salt, bitter, and savory (umami).



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**Have you ever wondered why your nose is located above your mouth? What do you think is the advantage to this particular anatomical arrangement?**

**For this activity, a partner will pick various smell or taste samples and you will try to identify them. See how many you can correctly identify.**

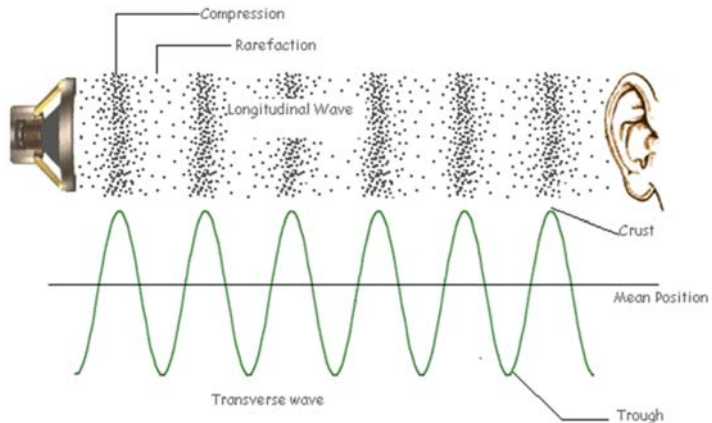
**Correct Identification**

**Taste** \_\_\_\_\_ / \_\_\_\_\_ **Smell** \_\_\_\_\_ / \_\_\_\_\_



## Hearing (Audition)

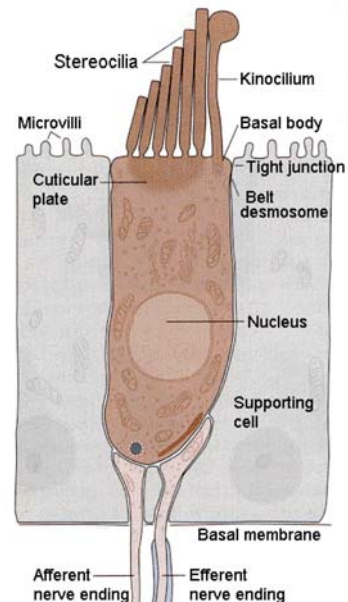
Sound travels through waves of vibrating matter such as air. **Pitch** is determined by the wavelength of the sound wave. High frequency, short wavelength sound waves are high pitch, while low frequency, long wavelength sound waves are low pitch sounds. The height of the wave, or **amplitude**, determines the volume of the sound.

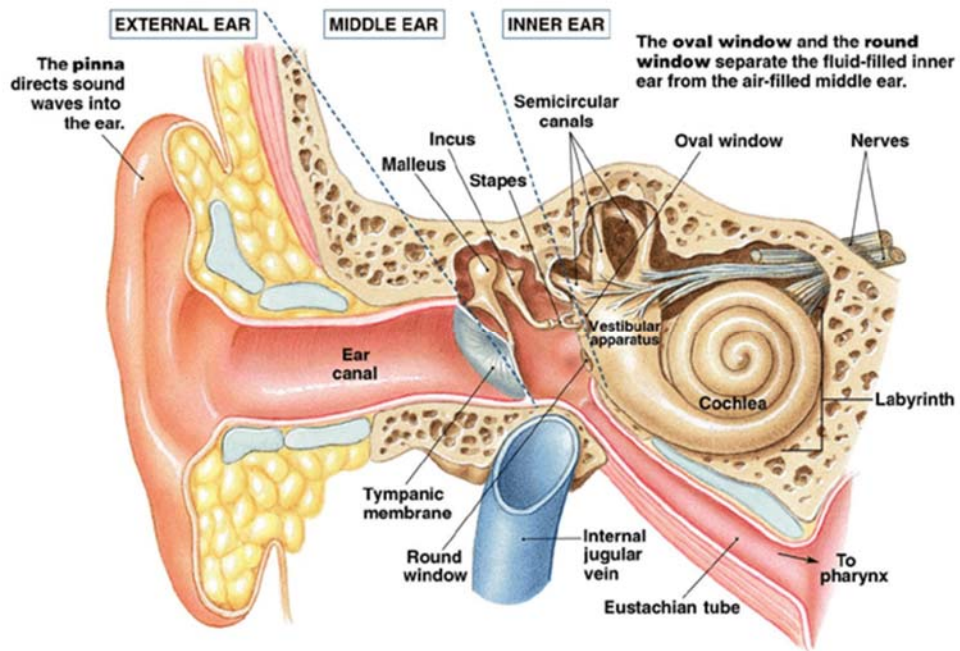


Sound waves travel into your ear through your ear canal where it then hits the **tympanic membrane** (ear drum). This causes the tympanic membrane to vibrate and pushes the bones of the **middle ear** (malleus, incus, and stapes). This vibration pushes on the the oval window of the **cochlea**, which causes a wave to be sent down the cochlea. Within the cochlea are the hair cells that are the receptors for the auditory system. When the wave passes over these hair cells, it bends the cilia (hairs) and causes them to either be activated or deactivated. This activation is then sent to the auditory cortex where the perception of the sound is interpreted.

## Vestibular System

The vestibular system is made up of the **semicircular canals** and utricles, which are all within the vestibular apparatus. Hair cells similar to those in the cochlea sense movement of the fluid that is held within the semicircular canals, and sense gravity. When you spin, or accelerate, your vestibular system keeps your eyes focused on a particular spot so you don't lose balance. *This activity will be done in the station on reflexes.*





You'll be given a couple tuning forks, use them and see what the different pitches sound like.

Place the end of a tuning fork on your forehead or on the bone behind your ear, does it sound different than if you listen to the fork over the air?

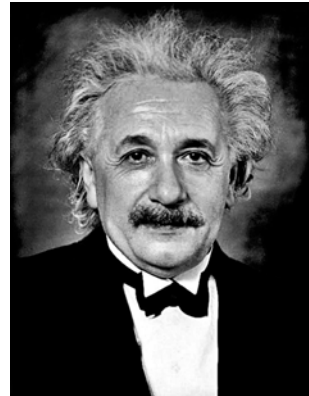


# What Does a Scientist Look Like?

Have you ever noticed that many times scientists are pictured with white hair, bowties and look kind of weird?



Random Cartoon Scientist



Albert Einstein,  
famous German-born scientist

**In reality, scientists are a very diverse group of people!**

Please take a moment today to notice all of the people volunteering at the booths.  
They are student and career scientists!



**Anna McGowan**  
Scientist at NASA



**Dr. Bruce Jackson**  
co-founder of the African  
American Roots Project



**Marie Curie**  
the first woman to  
win a Nobel Prize



**You?**



# #PhUnDay



**For this activity, we would like you to have some “PhUn” and to also get to know the people are joining you! You will be assisted by students that are studying science and medicine, as well as professors who are career scientists. Please feel free to ask them questions about their jobs, how they decided that was what they wanted to do and also what their schooling was like.**

**Here are a few examples questions to ask if you can’t think of any:**

1. What do you think a scientists typical day is like?
2. What are some of the different areas scientists study?
3. How long do you usually have to go to school to be a scientist?
4. Do scientists and Doctors go to school together?

## **Now for the PhUn Part!**

Use the clothes and props provided to “dress up” the skeleton (or yourself and your friends!)

Snap a picture and show everyone that did not get to come today “What a Scientists Looks Like” to you.

Feel free to tag the picture on any social medial site or for Twitter use #PhUnDay

# Glossary

**Absorption** – the process by which molecules or chemicals enter an organ

**Accommodation** - the reflex by which the lens shape is changed by the ciliary muscle to focus on near or far objects (lens is thick for near objects, and thin for far objects)

**Actin** – a protein in muscle fibers that forms microfilaments and is essential for muscle contraction

**Action Potential**— the electrical signal sent down the length of a neuron

**Acuity**—resolution (high density, small receptive fields allow for greater distinction between two separate stimuli)

**Alveoli** – small sacs or cavities in the lungs that enable air exchange between in the blood

**Amplitude** – the sum of the increase and decrease of a wave form

**Anatomy** – the study of the physical structure of organisms

**ATP** – adenosine triphosphate; an important source of energy for cells

**Baroreflex** – a reflex in which a decrease in blood pressure will cause an increase in heart rate

**Bile** – a green/yellow fluid produced in the gall bladder that is important for digesting lipids (fats)

**Blind Spot**—the area of the retina where the optic nerve and blood vessels exit the eye. Being without photoreceptors, any light that hits here will not be detected

**Blood Pressure** – the force within arteries created by contractions of the heart.

**BPM** – Beats Per Minute = the number of times your heart contracts every minute

**Bronchi** – the several large tubes that air enters into the lungs through

**Capillaries** – the smallest vessels that carry blood in the body

**Carbon Dioxide** – a metabolic waste product. This type of gas is exhaled from the body

**Cardiac Output** – the amount of blood your heart is able to push out to the



body in one beat

**Catabolism** – the building of metabolic products

**Central Nervous System**—brain and spinal cord

**Central Vision**—the focus of your vision (i.e. what you are directly looking at)

**Ciliary Muscle**—muscle connected to the suspensory ligaments holding the lens of the eye. By contracting or relaxing it changes the thickness of the lens in accommodation

**Cochlea** – part of the inner ear that is important for hearing

**Colorblindness** – not being able to tell the difference between certain (or all) colors

**Comparative Physiology** – describing similarities in physiology between species

**Cones** – the cells in the eye that are important for color vision

**Cornea** – the transparent front part of the eye

**Dermatomes** – an area of the skin that a single nerve senses

**Diastole** – part of the cardiac cycle when the heart is filling with blood (relaxed)

**Emulsification** – to allow the mixing of unlike substances (i.e. oil and water)

**Enzymes** – proteins that increase the rate of a chemical reaction

**Expiratory Reserve** – the amount of air left in your lungs after a normal breath out

**Fovea** – high acuity area of the retina, where central vision is focused, consisting of mostly cones

**Heart Rate** – the amount of times your heart beats for a certain period of time

**Homeostasis** – maintaining balance within an organism

**Homunculi**—the particular areas of the sensory cortex that correspond to particular receptive fields of your body. For instance, touch on your index finger will go to a particular location (homunculi) of your sensory cortex.

**Iris** – the structure of the eye responsible for controlling the pupil size, or the amount of light

**Labeled-line Principle**—the concept that nerve activity from certain sense receptors will terminate in a specific location in the brain. Certain locations of the



brain are responsible for certain senses. For instance, nerve signals from photoreceptors end in the visual cortex, not the olfactory cortex. This segregation of “sense centers” allows for the different perception of differing stimuli

**Lens** – part of the eye that can change shape and enables you to focus on objects

**Lub/Dub** – sounds representing the opening and closing of valves inside the heart while it is beating

**Mammalian Diving Reflex** – a reduction in heart rate caused by cold water on the face to conserve oxygen when diving

**Middle Ear** – transfer sound energy to the cochlea to enable hearing

**Muscles** – soft tissue composed of actin and myosin that enables movement

**Myosin** – a protein found in muscle that is essential for contraction

**Nerve**—a bundle of neurons

**Neuron**—the cell that carries electrical signals in the form of action potentials throughout your body.

**Neurotransmitter**—any substance that is released into a synapse by one neuron that has an effect on the activity of the connected neuron

**Odorants** – the chemicals that react with receptors in the nose

**Optic Disc** – area with no rods and no cones where the optic nerve travels through

**Optic Nerve** – the nerve that sends visual information to from the retina to the brain

**Oxygen** – the gas required by all tissues to perform basic metabolic processes

**Pellet** – a compacted ball of indigestible matter (hair, fur, bones) from a bird’s food

**Peripheral Nervous System**—any nerves outside of the central nervous system

**Peripheral Vision** – vision that is outside the directly forward vision

**Peristalsis** – the movement of muscles in the intestines intended to move food through

**Physiologists** – scientists who study physiology

**Physiology** – the study of how living things function and how systems within

organisms integrate with one another

**Pitch** – a certain frequency or tone of sound (high pitch (treble) waves have high frequency waves, low pitch (bass) have low frequency)

**Pleura** – the smooth membrane that surrounds the lungs

**Pulmonary Circulation** – blood vessels that go between the heart and the lungs

**Pulse** – the increase in pressure observed in all arteries from the contraction of the heart

**Receptive Fields**—the area of sense receptors that converge onto one second order neuron (if receptive fields are large, two stimuli that fall within the same receptive field will only be distinguished by the brain as one point)

**Receptors** – molecular structures that chemicals bind to

**Reflex**—an automatic response to a stimuli (e.g. your iris constricting to light)

**Refraction** – the change in direction of a wave

**Regurgitated** – “throwing up” or moving a substance from inside the stomach to the outside

**Retina** – light sensitive layer of tissue in the eye

**Rods** – receptors on the retina that only respond to light/dark and are not sensitive to particular colors like cones

**Sarcomere** – a “unit” of muscle (composed of actin and myosin)

**Secretion** – the process of a substance traveling to the outside of a tissue

**Semicircular Canals** – tubes in the inner ear that are important for maintaining balance

**Somatosensory Cortex** – the part of the brain that is responsible for processing senses, such as touch

**Stimulus** – something that induces a feeling or sensation

**Stroke Volume** – the volume of blood pumped from one ventricle of the heart in one beat

**Suspensory Ligaments** – a structure that holds a body part in place, usually an organ

**Synapse**—the connection between two neurons

**Systemic Circulation** – blood vessels that transport blood throughout the body.

**Systole** – the part of the cardiac cycle where the heart is contracting

**Tapetum Lucidum** – layer of tissue behind the retina responsible for reflecting light

**Thermoreceptors** – receptors that can sense temperature

**Tidal Volume** – the volume of air inhaled and exhaled during a normal breath

**Trachea** – the “windpipe” or the tube that air travels down from the mouth to the lungs

**Transduction** – translating one type of “signal” into another type

**Tympanic Membrane** – separates the middle from the external ear and is important for detecting sound waves

**Valves** – part of the heart that allows blood to only flow one direction; the valves open and close

**Ventricles** – the two large chambers of the heart

**Vital Capacity** – the amount of air that you can exhale after a very large

## Sources & Additional Resources

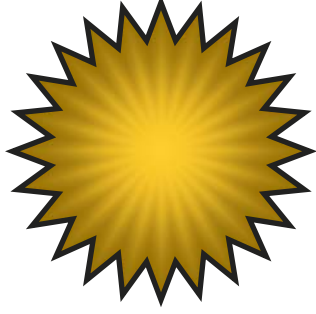
- All content created by Bryan Becker and Alicia Schiller with assistance from NPS and APS PhUn Week resources.
- Nebraska Physiological Society (NPS) - <http://unmc.edu/physiology/nps/>
- American Physiological Society (APS) - <http://www.the-aps.org/>
- Physiology Info: <http://www.physiologyinfo.org/>
- Physiology Online: <http://physiologyonline.physiology.org/>

# Certificate of Completion

Awarded To

\_\_\_\_\_

For the successful completion of activities on  
Physiology Understanding Day



\_\_\_\_\_

Date

\_\_\_\_\_

Signature

## This PhUn Day Activity Booklet Belongs To:

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This event is part of the **American Physiological Society's Physiology Understanding (PhUn) Week**, an annual outreach program bringing scientists to K-12 school classrooms to promote understanding of science and interest in science careers. For more information, see [www.phunweek.org](http://www.phunweek.org).

"Building Bridges: Health Science Education in Native American Communities" is supported by a Science Education Partnership Award (SEPA) from the National Institutes of Health. This project was funded by the National Center for Research Resources (RR032178) and is currently supported by the Office of Research Infrastructure Programs (OD011071).



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