

BIOL 2210L

Unit 13: Eye and Ear

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Terms to Know for Unit 13

<u>Eye</u>	Neural parts of the eye	<u>Additional Instructor Terms</u>
Accessory structures of the eye	Retina	
Conjunctiva	Photoreceptors	
Lacrimal gland	Optic disc	
Lacrimal sac	Macula lutea	
Extrinsic eye muscles	Fovea centralis	
	Optic nerve	
Wall layers of the eye		
Fibrous tunic	<u>Ear</u>	
Sclera	Outer ear	
Cornea	Pinna	
Vascular tunic	External auditory canal	
Choroid		
Ciliary body	Middle ear	
Ciliary muscles	Tympanic membrane	
Iris	Auditory ossicles	
Pupil	Malleus	
Sensory tunic	Incus	
	Stapes	
Optics of the eye	Auditory tube	
Lens		
Suspensory ligaments	Inner ear	
Anterior segment of eye	Semicircular canals	
Anterior chamber	Crista ampullaris	
Posterior chamber	Vestibule	
Aqueous humor	Cochlea	
Canal of Schlemm	Organ of Corti	
Posterior segment of eye		
Vitreous humor		

Learning Objectives (modified from [HAPS learning outcomes](#))

1. Gross & microscopic anatomy of the eye
 - a. Identify the accessory eye structures, the tunics, the optical components and the neural components of the eye.
2. Roles of specific tissues of the eye in vision

- a. Describe the functions of the accessory structures of the eye.
 - b. Trace the path of light as it passes through the eye to the retina and the path of nerve impulses from the retina to various parts of the brain.
 - c. Describe the structure of the retina and the cells that compose it.
 - d. Compare and contrast the function of rods and cones in vision.
3. General gross & microscopic anatomy of the hearing & accessory structures of the ear
 - a. Identify the hearing structures of the outer, middle and inner ear.
 4. Roles of specific tissues of the ear in hearing
 - a. Describe how the various structures of the outer, middle and inner ear function in hearing.
 - b. Describe the sound conduction pathway from the auricle to the fluids of the inner ear and the path of nerve impulses from the spiral organ to various parts of the brain.
 - c. Describe the structure of the crista ampullaris and its function in dynamic equilibrium.

Explanation of Anatomy

This last unit for the term covers the eye and the ear. We will briefly go over structures that allow us to cry and move our eyeball. Then, we will peel apart the different layers of the eye and learn how each of those layers allow us to see our world. In our study of the ear, we will follow sound waves through the outer and middle ear, and in the inner ear, we will learn how those sound waves are converted to neural signals that are sent to our brain for us to interpret the sounds in our environments.

Think about what is happening when you enter a simulation ride at an amusement park. You experience visual images, hear sounds of a place that is not really there, and your body is moved into different positions to give you the additional sense that you are there. Simulations work so well because they are stimulating special senses that we as a human rely heavily on to assess our environment. We rarely think of balance as one of those special senses, but in a simulation ride, we notice if we start to feel woozy or if we feel a bit unstable after the ride. Sight, hearing, and balance are important senses that we use daily.

Accessory Structures of the Eye

Just like in other units of this lab manual, we discuss eye components as they relate to one eye even though we have two eyes. The eye has many accessory structures, including the conjunctiva, lacrimal gland, lacrimal sac, and extrinsic eye muscles.

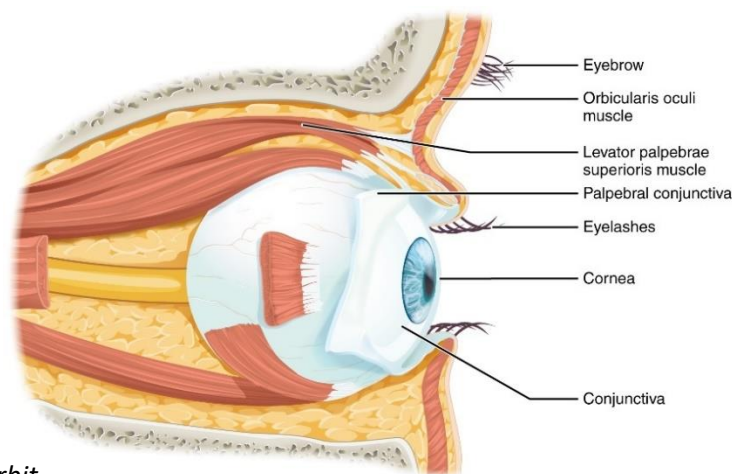


Image 1: Eye in its orbit

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The conjunctiva, lacrimal gland, and lacrimal sac help protect and moisten the eye. The **conjunctiva** is a transparent vascularized mucous membrane that lines the inner surface of the eyelid and anterior surface of the eyeball (see Image 1). It protects the eye from drying out. The **lacrimal gland** also keeps the eye moist as it produces tears that travel across the eye. These tears not only lubricate the eye but also contain antibiotic properties to help prevent infections. Tears drain into the nasal cavity after passing into the **lacrimal sac**, which is nestled within the depression of the lacrimal facial bone of the skull. When we cry, blood vessels dilate in the conjunctiva causing blood shot eyes while tears drain into the nasal cavity, causing us to have a runny nose. Image 2 shows the lacrimal gland and sac.

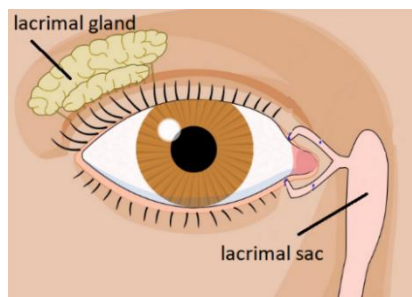
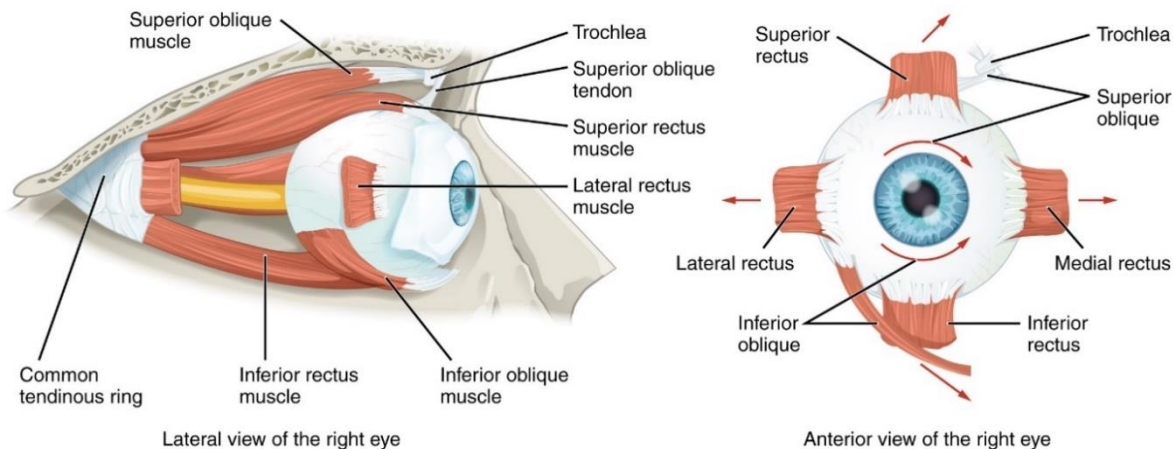


Image 2: Lacrimal gland and sac

Modified [CC BY SA 2.5](#) by [Erin Silversmith](#) URL: [Lacrimal gland and sac](#)

Extrinsic eye muscles are located outside of the eye and allow for the eyeball to move (see Image 3). There are six extrinsic eye muscles total. There are four straight rectus extrinsic eye muscles that cause the eyeball to move up, down, medially, and laterally. The lateral rectus muscle is innervated by the abducens cranial nerve and allows the eye to move away (or laterally) from the midline of the body. The two oblique extrinsic muscles help keep the eye forward and help align the eye when you tilt your head towards your shoulder. The superior of the two oblique eye muscles is innervated by the trochlear cranial nerve named since its tendon attachment to the eyeball is shaped like a pulley system. Remember that trochlea means pulley. The remaining four extrinsic eye muscles, three rectus and one oblique, are innervated by the oculomotor cranial nerve.



Insert 3: Extrinsic eye muscles

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Wall Layers of the Eye

The eye has three main components: wall layers, optics, and neural parts. First, we will explore the layers that make up the eye's wall (see Image 4).

The outermost layer of the eye is called the **fibrous tunic**. The sclera and cornea make up the fibrous tunic. The **sclera** is the white part of the eye that is a connective tissue layer that protects the eye and is the attachment point for the extrinsic eye muscles. The **cornea** is the anterior part of the fibrous tunic that is transparent. Because the cornea is transparent, it allows light to enter the eye and is one of the optical structures of the eye.

The middle layer of the eye is called the **vascular tunic**. The choroid, ciliary body, iris, and pupil make up the vascular tunic. The **choroid** is a vascular layer that provides nutrients to the inner, sensory layer of the eye's wall. Extending from the choroid is the **ciliary body**, a muscle that gives support to the iris and lens of the eye. The **iris** is a smooth muscle that constricts and dilates causing the **pupil**, an opening into the eye, to get smaller or larger. The iris thus influences how much light enters the eye.

The light entering the eye eventually reaches the most inner layer, which is the **sensory tunic**. This sensory tunic is called the **retina** and will be discussed in detail when we discuss the neural components of the eye that allow us to detect and send visual messages to our brain for interpretation.

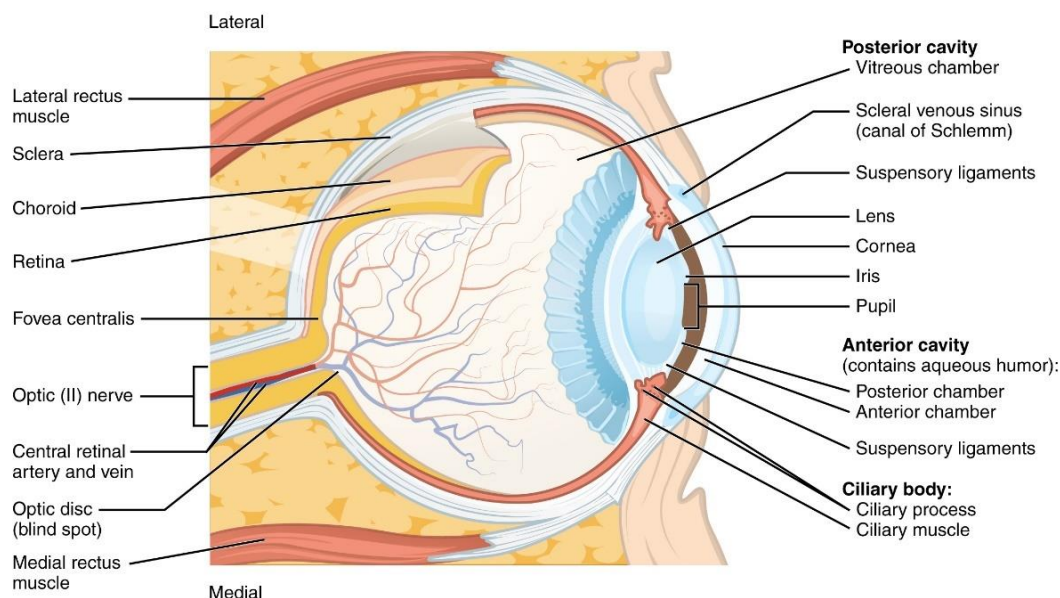


Image 4: Eye structures including wall layers: Sclera and cornea- fibrous tunic, Choroid- vascular tunic, and Retina- sensory tunic

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Optics of the Eye

The optical components of the eye are transparent and allow light to enter the eye. The **cornea** is where light first enters the eye. As the light passes through the cornea, it bends. Have you noticed that when you look at an object that is partially immersed in water it looks bent? That is because light changes its direction and bends as it passes through the water. This is called refraction.

Mini activity: Seeing refraction

Below are two simple activities you can do at home to see refraction.

1. Fill up a clear glass with water and place a pen in the glass. Notice how the pen looks bent because light is traveling through air and water. You're seeing refraction!



Image 5: Pen in water

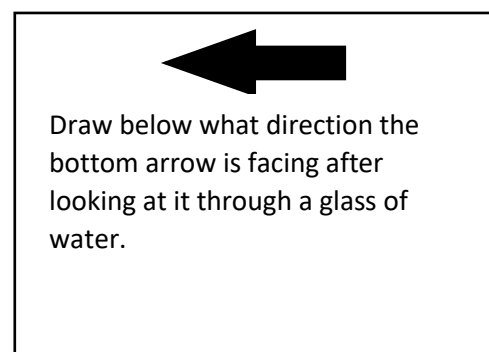
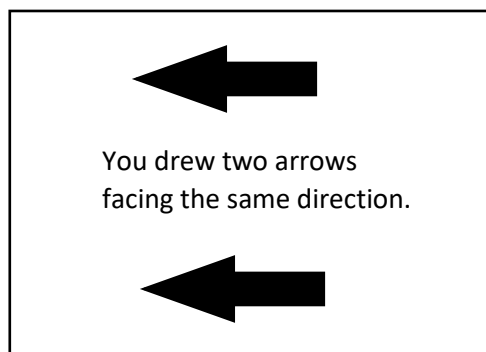
[CC BY-NC 2.0](#) by [Martin LaBar](#) URL: [Pen in water](#)

2. Now draw two arrows on a piece of paper facing the same direction. Make sure to draw the arrows small enough that they can be seen through the same glass of water you used for the mini-activity 1 above. One arrow will be on top of the page, and the other one will be on the bottom of the page.

Either use the same glass of water from mini activity 1 or fill up another clear glass with water.

As you're facing the glass of water, lower the piece of paper on the other side of the glass so you are looking at only the bottom arrow through the glass of water.

For this activity you should see the arrow flip so that it is pointing in the other direction. This happens because light is being refracted. That is what is happening when our corneas bend incoming light into our eyes!



As the light passes through the pupil, it will eventually pass through the lens. The lens does not bend the incoming light as much as the cornea. Instead, the **lens** will focus the light so it converges at a single point. This bending and focusing from the cornea and lens cause the image to invert, be upside down, when the light is absorbed by the sensory tunic (see Image 6).

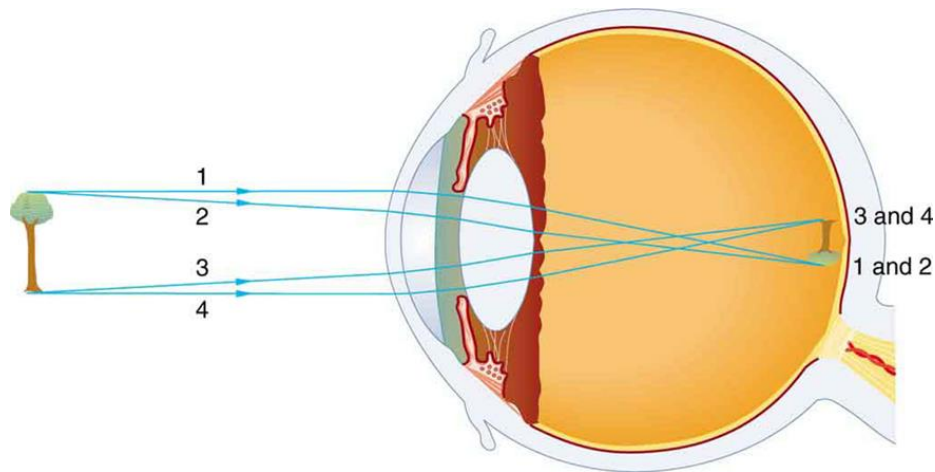


Image 6: Pathway of light through the eye.

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Suspensory ligaments attach to the lens and play a role in the shape of the lens when viewing images from either far away or nearby (see Image 7). Suspensory ligaments are stretched when the ciliary body is relaxed, which causes the lens to flatten, allowing for far vision. When we want to see something up close, the ciliary body contracts, loosening suspensory ligaments and causing the lens to bulge. Using close vision is called accommodation and can result in our eyes becoming tired.

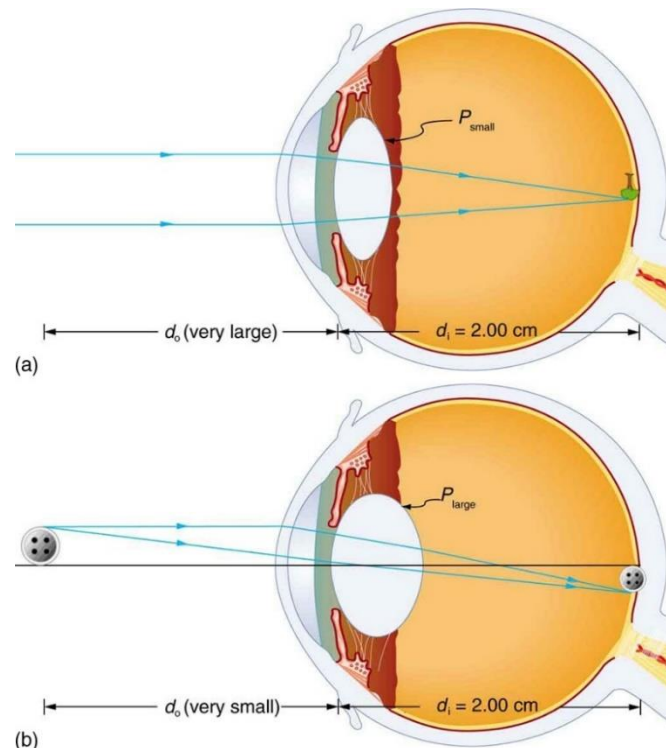


Image 7: Physics of far and close vision. (a) far vision (b) close vision

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In addition to the cornea and lens, the aqueous humor and vitreous humor also are optical components of the eye. Although these two media allow light to pass through the eye, they have other functions. The vascular tunic's ciliary body produces aqueous humor that resides in the **posterior chamber**, which is between the iris and lens, and the **anterior chamber**, which is between the cornea and iris. The **aqueous humor** provides nutrients to the cornea, iris, and lens. The aqueous humor is constantly being made and drained from the anterior chamber. When it cannot be drained, the pressure in the eye increases, causing damage to the retina. This is the eye condition called glaucoma. Behind the lens is a gel-like substance called the **vitreous humor** that maintains pressure so that the retina can snugly press against the choroid from which it receives its nutrients. The vitreous humor is a stagnant media that as we get older can lose its ability to keep the retina pushed against its nutrient supply, leading to loss of vision. Both the aqueous and vitreous humor have important roles in maintaining pressure within the eye so that the retina can function properly (see Image 4).

Neural Parts of the Eye

The retina and the **optic nerve** are the neural parts of the eye. We will first discuss the sensory receptors located within the retina and then end this section talking about the optic nerve. Image 4 shows the neural parts of the eye.

There are two types of **photoreceptors** within the retina: cones and rods. As light reaches the retina, it is focused on a spot called the **macula lutea**. *Lutea* means yellow, and this area of the retina has a high concentration of cones, which makes the macula lutea appear yellow. Only cones are found at the center of the macula lutea, which is called the **fovea centralis**. Cones detect color and allow us to see images when there is a lot of light. Rods work best in low-light situations and send visual messages as gray tones. Rods are more common along the periphery of the retina. If you are outside at night looking at a dim star, try looking at the dim star along its edge rather than directly at it. Because rods are responsible for night vision and are more common along the periphery of the retina, looking at a dim star's edge allows rods to better detect the dim star's glow.

The optic nerve eventually receives visual messages that have been detected from rods and cones. The neurons that make up the optic nerve are the first to have an action potential. Before this though, the rods, cones, and bipolar cells have graded potentials. The orientation of all these different neural cells within the retina are from how ganglion cells of the optic nerve plunge into the eye, causing a blind spot where no rods, cones, or bipolar cells exist. This part of the retina is called the **optic disc**.

Mini Activity: Finding your blind spot

Mark a 3 X 5 inch index card or some other "stiff" piece of paper with a "dot" on one side and an "X" on the other like seen in the image below.



1. Cover your right eye and focus on the X with your left eye.
2. Bring the image about a foot away from your face.
3. Keep focusing on the X and move back and forth and left to right until you no longer see the X.

This is your blind spot: where the light is being focused on the optic disc at the back of the retina.

Most of the retina, however, does have the ability to detect light, and thus starts the process of sending visual information to the brain. The axons of the optic nerve travel through the optic canal to converge at a structure called the **optic chiasm**. Here, the axons cross over to the other side of the body and continue to travel along the **optic tract** ending at the thalamus. The thalamus sorts and edits the incoming information and sends the visual message to the occipital lobe of the brain on the opposite side of the visual field. The left occipital lobe interprets information that is within the right side of our visual field as the right occipital lobe interprets information that is within the left side of our visual field. When damage occurs along this pathway, blindness is the result even if the eye is still healthy and uninjured. Image 8 shows the pathway of nerve impulses from the eye to the brain.

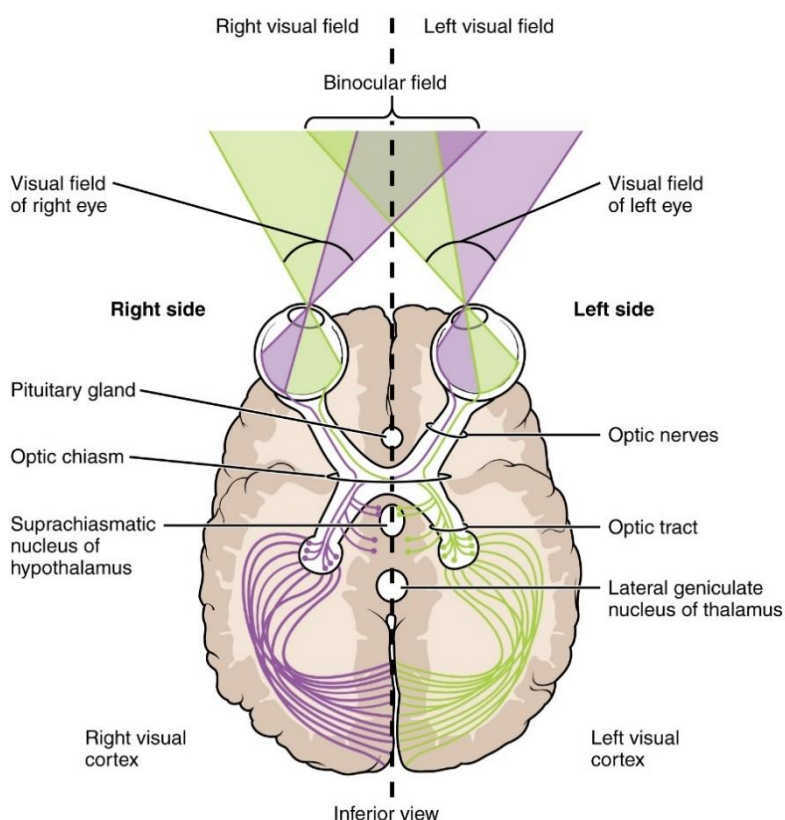


Image 8: Pathway of nerve impulses from the eye to the brain

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Outer Ear

The two important parts of the outer ear are the pinna and the external auditory canal. The **pinna** (auricle) is the fleshy outer part where the superior structure is maintained by elastic cartilage. The ear

lobe of the pinna mainly contains adipose tissue. The pinna funnels sound waves into the **external auditory canal** (ear canal) which then conducts the air vibrations towards the middle ear. The opening of the external auditory canal is supported by cartilage where its length is maintained by the temporal bone. Image 9 shows external ear structures and Image 10 shows sound vibrations traveling through the ear.

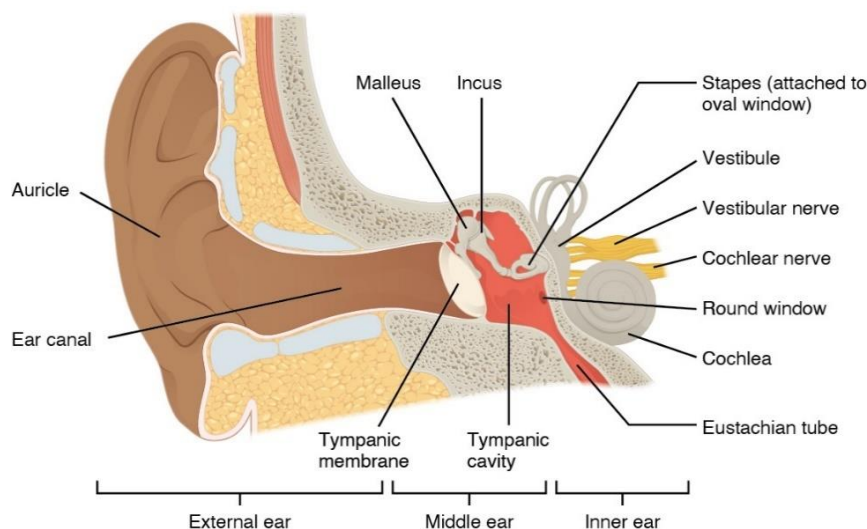


Image 9: External ear, middle ear, and inner ear

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Middle Ear

The **tympanic membrane** (ear drum) separates the outer ear from the middle ear. This membrane is made up of connective tissue lined externally by skin and internally with mucosa and is shaped like a cymbal. The pointed part of the cymbal faces the middle ear. As sound waves travel to the tympanic membrane, it vibrates, causing three tiny bones in the middle ear to vibrate too.

The malleus, incus, and stapes are the smallest bones in the body. The **malleus** directly attaches to the tympanic membrane. The **incus** is intermediate to the malleus and stapes and is connected to both through synovial joints. The **stapes** is the most medial of the **auditory ossicles**.

The **auditory tube** (eustachian tube), not to be confused with the external auditory canal, connects the middle ear to the throat. This connection allows the middle ear to equalize its pressure so that the tympanic membrane can vibrate freely. As the tympanic membrane vibrates, the auditory ossicles vibrate, causing the fluid in the inner ear to move. Image 8 shows middle ear structures.

Mini Activity: Seeing sound

1. Take a piece of plastic wrap and tightly wrap it on top of a bowl. Make the plastic wrap as tight and flat as you can.
2. If you have an appropriately sized rubber band, use it to secure the plastic wrap to the bowl.
3. Sprinkle either some pepper or rice grains on top of the plastic wrap. Make some NOISE!

As you make noise, you should see the pepper or rice “dancing” on the top of the plastic wrap. The NOISE you made sends sound waves in the air that are transmitted to the plastic wrap. The plastic wrap then vibrates, causing the pepper and rice grains to bounce!

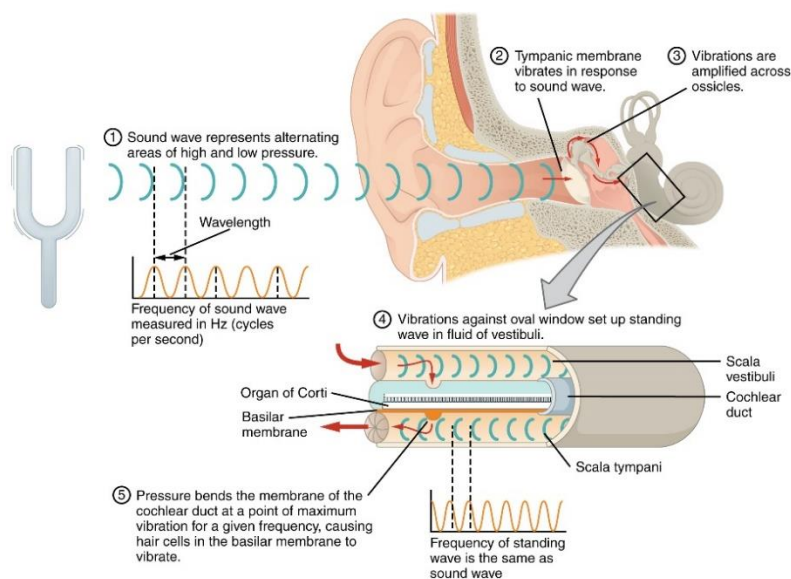


Image 10: Sound vibrations traveling through the ear

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Inner Ear

The **cochlea**, a snail-shaped structure in the inner ear, contains the **organ of Corti** where sound waves are converted to neural signals (see Image 11).

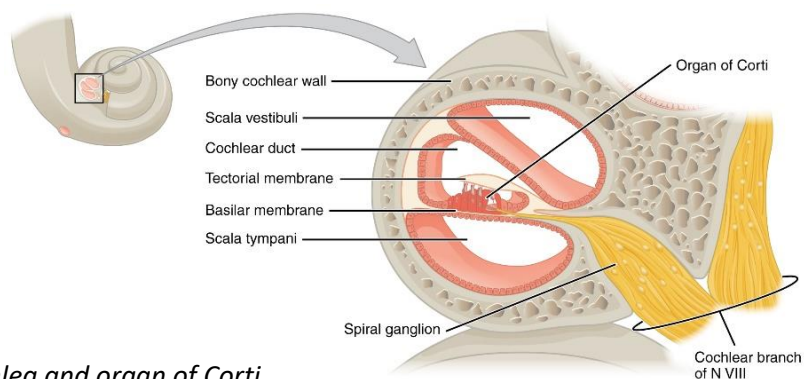


Image 11: Cochlea and organ of Corti

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As the fluid in the inner ear moves within the organ of Corti, mechanoreceptors called hair cells are pushed and pulled. When the tension increases, think of this as pulling, an electrical signal will occur, and if strong enough, it conducts to sensory bipolar neurons of the cochlear branch of the vestibulocochlear nerve. These impulses travel through the brain stem and send the signal to interneurons of the central nervous system. Part of this pathway includes the inferior colliculi, which you might recall is responsible for auditory reflexes. Also, as with other incoming sensory pathways, the

information will be sorted and edited in the thalamus before it reaches the primary auditory cortex within the temporal lobes. Along this pathway there are multiple crossovers so that damage to either the left or right side of the primary auditory cortex does not cause complete hearing loss for either the right or left ear.

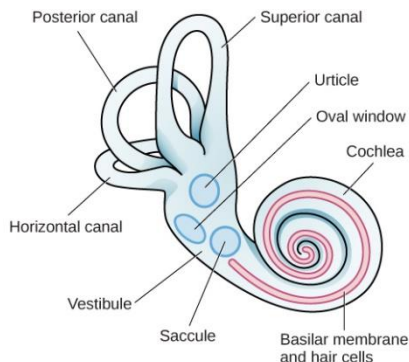


Image 12: Vestibule, semicircular canals (superior, posterior, and horizontal) and cochlea

[Creative Commons Attribution 4.0 International](#) Psychology Openstax URL: [Vestibule, semicircular canals \(superior, posterior, and horizontal\) and cochlea](#)

The inner ear also contains structures that are responsible for our sense of balance. Both the vestibule and the semicircular canals give us our sense of balance (see Image 12). The **vestibule** senses the position of our head. The semicircular canals, however, sense the movement of our head. The **semicircular canals** do this with a structure called the **crista ampullaris** (see Image 13). There are three semicircular canals that each have a crista ampullaris. As we rotate our heads, the fluid within the crista ampullaris bends mechanoreceptors. The combination of all three crista ampullaris at the base of the semicircular canals allows for detection of head movements in a three-dimensional space.

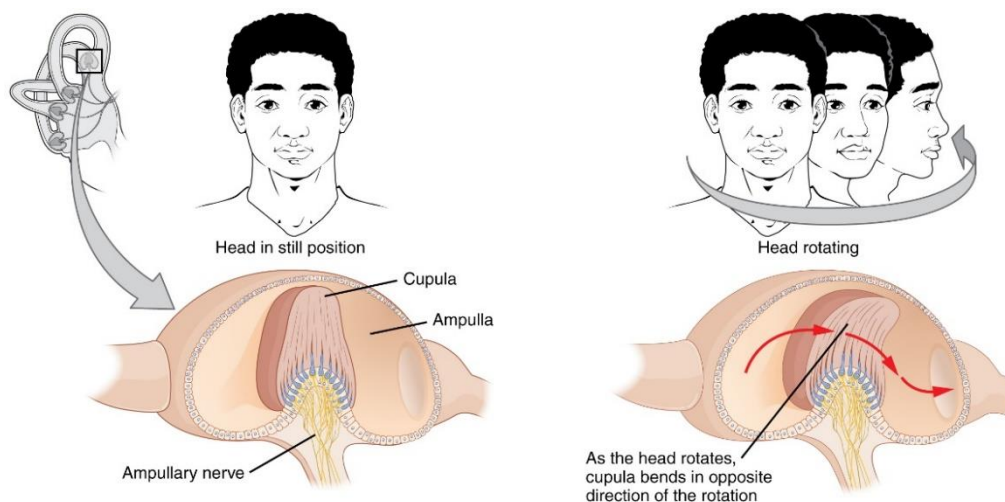


Image 13: How the crista ampullaris works

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Activity 1: Labeling Eye Structures on Models

Part 1 - Referring to the terms on page 1 and Image 4, label eye structures on a laboratory model.

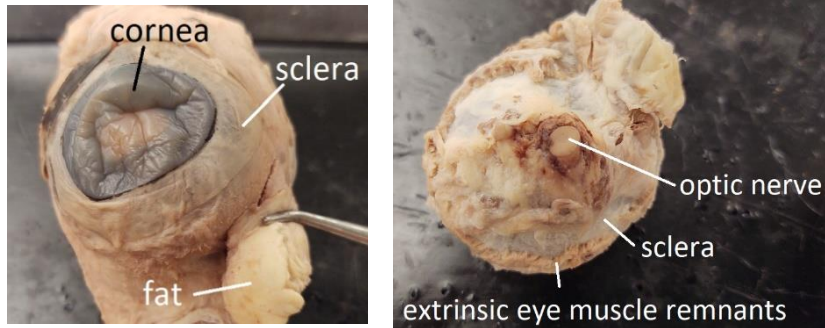
When you encounter a term that you don't know or you are struggling remembering a term, write it below.

Part 2 - Test your knowledge about eye terminology.

1. What tunic does the choroid belong to?
2. What is the name of the transparent part of the fibrous tunic, which allows light to enter the eye?
3. What moves the eyeball?
4. What part of the eye, when it contracts, changes the shape of the lens?
5. Describe, using at least two relevant anatomy terms, what the blind spot is.
6. What part of the retina does the lens focus light on because that is where most cones reside?
7. List all optical components of the eye.
8. Pick three of those optical components and describe them below.

Activity 2: Dissection of Sheep Eye

1. First get a dissecting tray, kit, and gloves.
2. Then get a sheep eye that is stored under the fume hood in the class.
3. Your sheep eye will probably have a lot of fatty tissue that cushions the eye when it is in the orbital. Cut this fat away from the eyeball to expose the eye's fibrous tunic.



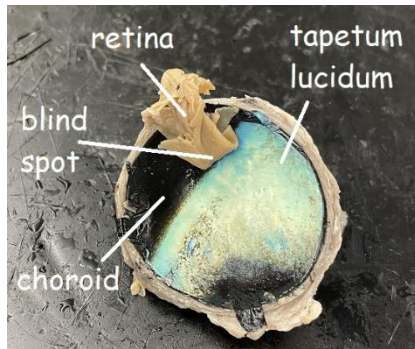
4. Visually inspect the eye at this stage in the dissection. Take note of the sclera and cornea that make up the fibrous tunic.
5. Also note on the posterior side of the eyeball, the optic nerve, and any extrinsic eye muscles.
6. Place the eyeball on the dissecting tray and make a small incision with the kit's scalpel midway between the cornea and optic nerve.



7. Then take scissors and shallowly cut the sclera all around the eye at this mid-point.
8. After cutting around the entire eye, you'll have two "hemispheres." The vitreous humor will be a gelatinous fluid that you can rest in the anterior hemisphere. The posterior "hemisphere" from this dissection should expose the brownish-colored retina.

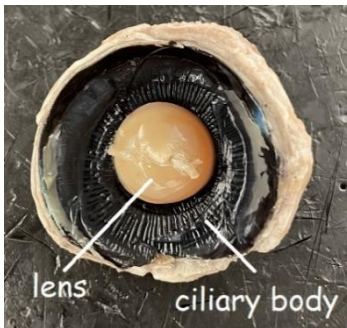


9. Gently peel away the retina. Notice that the retina is attached at one location. That is the blind spot!

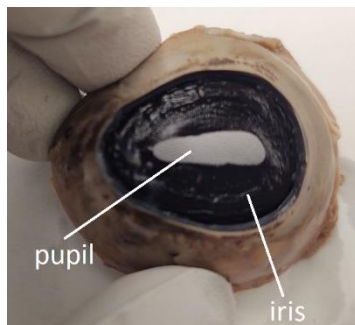


10. The part that is exposed from peeling the retina is the choroid, vascular tunic. You'll also notice a shiny iridescence, which is called the tapetum lucidum. Humans don't have this structure, but nocturnal animals do. This structure reflects any light in a dark environment, thus increasing vision capabilities at night.

11. Gently remove the vitreous humor with tweezers in the other half of the eyeball, taking care not to damage the lens.



12. After removing the vitreous humor, notice the lens and the ciliary body. Using scissors, remove the lens. It will be cloudy from the preservatives used in treating the sheep eye.



13. After removing the lens, you should notice the opening in the eye called the pupil along with the pigmented smooth muscle that makes up the iris.

14. Dispose of all eyeball components in the biohazard bucket, clean dissecting trays and tools in lab sinks, and after the trays and tools are dry, put them back where they are being stored in the lab.

Dissections and photographs of eye by Elisa DiMenna and Terri Koontz

Activity 3: Labeling Ear Structures on Models

Part 1 - Referring to the terms on page 1 and Image 9, label ear structures on a laboratory model.

When you encounter a term that you don't know or you are struggling remembering a term, write it below.

Part 2 - Test your knowledge about ear terminology.

1. What type of joint connects the three tiny bones of the middle ear?
2. List the middle ear bones from the first that is in contact with the tympanic membrane, the bone in the middle, and the final bone that is closest to the inner ear.
3. What is the difference between the external auditory canal and the auditory tube? In your answer include how each of those structures of the ear promote hearing.
4. What inner ear structure detects sound waves?
5. What are the inner ear structures that involve balance?

Activity 5: Research on Problems with Human Balance

Eyes, inner ear, skeletal muscles, and the brain all work together to allow us to keep our balance. Either individually or in small groups, research problems with human balance.

Write below the problem you discovered and describe briefly what causes that problem in human balance. If time permits, share your findings with the lab.