Overview

Perhaps you have had visual loss yourself, or your child or family member has lost vision. Or maybe you work with individuals who are visually impaired, whether children or adults. You're probably curious about how the human eye works. The human eye, which operates much like a camcorder, is hooked up to the brain (i.e., the television screen) by the optic nerve (i.e., a cable). Seeing is taking pictures, or the mechanical transmission of light. Vision is the developing, processing, and interpreting that gives meaning to what is transmitted. This course will enable you to describe the basic anatomy, routine examination procedures, and some common conditions of the human eye.

The intent of this course is to provide a basic understanding of how the eye functions and of some common conditions related to the eye. Important: the information in this course does NOT replace professional medical advice. If you have concerns about the health of your eyes, please consult an eye-care professional.
This course includes five lessons. The first lesson describes the structure and function of the eye. The second and third lessons explain how eyes are examined. The fourth lesson describes how the eye sees, and the last lesson discusses corrective lenses and prescriptions.

Each lesson has special features. A list of key terms begins each lesson. The section reviews contain practical applications to help you connect what you have learned to everyday life. The section reviews in each lesson are for your personal development only. Complete the section review before going on to a new section of the course. Students who routinely do the section reviews perform significantly better on assignments. Do not send your responses to your Hadley instructor. Rather, check your comprehension by comparing your answers with those provided. You can always contact your instructor, however, to clarify concepts.

To complete the course, you are required to submit five assignments, one at the end of each lesson. These assignments enable your instructor to measure your
understanding of the material presented in the lessons. Refer to the Getting Started instructions for information about submitting assignments.

If you wish to explore the eye further upon completion of this course, consider enrolling in the Hadley course "Human Eye 2." That course examines each part of the eye and describes conditions associated with each eye structure.

The Hadley School for the Blind wishes to express its appreciation to Kay Alicyn Ferrell, Ph.D., and Naomi Tuttle, B.S.N., R.N., who wrote the original version of this course. Hadley would also like to thank Dr. Thomas Chalkley, an ophthalmologist and author of the original 1982 book *Your Eyes*, upon which these lessons are based. Hadley also appreciates the thoughtful review of the manuscript by Dr. Steven V. L. Brown, Dr. Richard Fiscella, and Dr. Deborah Fishman.

If you are ready to explore the human eye, proceed to Lesson 1: Exploring the Eye.
Lesson 1: Exploring the Eye

The human eye operates much like the camcorder from the 1980s, a VHS video camera that used film. The eye is hooked up to the brain, which is like the television screen, by the optic nerve, which functions as the cable. The lens of the eye receives an image, and this image then forms on the retina, which is like the video camera's film. The image on the retina is relayed to the brain by an electronic impulse sent along the optic nerve. Visual information then travels through the brain via several pathways, which act like relay cables. Finally, the image reaches the visual cortex in the back of the brain. There in the visual cortex, the picture is formed, viewed, and understood. Presto! There is vision.

You can also compare the eye to a 35-mm camera. You may recall how camera film needs to be developed. Likewise, the brain records, reviews, and interprets the visual images. Seeing is taking the picture, or the mechanical transmission of light. Vision
is the developing, processing, and interpreting that give meaning to what is transmitted.

This lesson introduces you to the human eye and its parts. It examines the wall of the eye and the role of the eyelids and tears. It describes the parts that allow light to enter the eye: the cornea, iris, and pupil. It then explores the inside of the eye: the lens, ciliary body, and vitreous humor. Finally, it discusses how the eye and brain work together to achieve vision. Knowledge of these structures will enable you to describe the basic anatomy of the human eye.

Note that these eye parts are discussed very briefly. The course "Human Eye 2" explores each part of the eye in more depth, together with conditions related to them.

Objectives

After completing this lesson, you will be able to
a. describe the wall of the eye
b. discuss the role of the eyelids, conjunctiva, and tears
c. describe the cornea, iris, and pupil
d. discuss the lens, ciliary body, and vitreous humor
e. explain the role of the brain in vision

Key Terms

The following terms appear in this lesson. Familiarize yourself with their meanings so you can use them in your course work.

angle: place where the sclera, the front of the iris, and the back of the cornea meet; here, aqueous humor drains out of the eye

anterior segment: the front part of the eye, between the cornea and the lens; divided into the anterior and posterior chambers; contains aqueous humor

aqueous humor: clear, watery fluid that fills the anterior and posterior chambers; nourishes eye tissue and provides pressure to help maintain the shape of the eye

choroid: layer of blood vessels between the retina and the sclera; nourishes the retina

ciliary body: tissue located between the iris and the choroid; contains the ciliary processes that produce aqueous humor, and the ciliary muscle that allows the lens to change shape for accommodation
**conjunctiva**: clear mucous membrane that covers the outside of the eyeball, except for the cornea, and the inner surface of the eyelids

**cornea**: clear tissue covering the front of the eye through which rays of light enter the eye

**iris**: colored part of the eye; made of two muscles that control how much light enters the eye by adjusting the size of the pupil

**lateral geniculate (jen-IK-yoo-lit) nucleus (plural, nuclei)**: way stations in the brain for transmitting electrical impulses

**lens**: sometimes called crystalline lens; a transparent, biconvex (thicker in center than at edges) tissue; bends light rays and focuses them on the retina

**optic nerve**: bundle of nerve fibers at the back of the eye; carries visual impulses from the retina to the brain

**orbit**: bony, hollow socket that holds the eyeball in the skull

**posterior segment**: large back area of the eye, stretching from the lens to the retina

**pupil**: adjustable hole at the center of the iris that allows light to enter the eye; looks like a black dot
retina: innermost layer of the back of the eye; composed of light-sensitive cells (rods and cones) that turn light into impulses, which are then sent to the brain through the optic nerve
sclera: known as the white of the eye; the tough, white, opaque, outer layer that forms a protective covering and gives the wall of the eye durability and resistance
vitreous humor: transparent, jellylike substance that fills the back part of the eyeball; helps the eyeball keep its shape

The Wall of the Eye

The eye is shaped like a goldfish bowl tilted on its side. The wall of the eye, which is like the glass of the goldfish bowl, is made up of three basic layers, one inside the other: the sclera, the choroid, and the retina.

The Sclera

You probably know the sclera (SKLEH-ruh) as the white of the eye. If the eye works like a camcorder, think of the sclera as the camcorder's case, as the sclera is a thin yet tough shell that surrounds and protects the delicate parts of the eye. As the eye's outer layer, the
sclera is made of tough, firm, fibrous connective tissue, and it covers most of the eye. The sclera makes the wall of the eye durable and strong and helps the eye keep its shape. The sclera covers the entire eyeball except for the very front, which is the clear cornea. Another section will discuss the cornea in depth.

The Choroid

Just inside the sclera is a delicate layer, the choroid (KOR-oyd), composed of many tiny blood vessels. The blood cells of the choroid bring nutrients to the retina, which is the innermost, tissue-thin layer at the back of the eye. The choroid contains pigment cells, too, that absorb any stray light, helping the ultimate visual image to be clear.

The Retina

You may recall the film used in 35-mm and disposable cameras. In such cameras, the film is a special plastic sheet coated with a mixture of liquids and salts that when exposed to light form an invisible image. A chemical process called developing makes the invisible image become visible.
Think of the retina as the camera film: it receives light rays that fall on it from the outside world. Composed of nerve tissue, the retina turns the light into electrical impulses. Two types of light-sensitive cells do the work: the rods and cones. The cone cells permit central vision, detailed work like reading, and color vision. The rod cells allow for vision in dim light and peripheral vision. At the very center of the retina is the macula, which is made up almost exclusively of cones. At the center of the macula is a depression or pit called the fovea, which contains only cones. The fovea allows for the highest degree of visual acuity. Rods are located mostly outside of the center of the retina.

The rods and cones transmit these electrical impulses to the optic nerve. These impulses then travel to the visual pathways of the brain and into the visual cortex. Here, the images are interpreted and vision happens.

Inside the Wall

Just as a goldfish bowl holds water, the interior of the eye is filled with fluid. The front of the eye, the anterior segment, is filled with a watery fluid called the aqueous humor. This front section is divided into two parts, the
anterio chamber in the very front and the posterior chamber right behind it. (The word anterior means front, and the word posterior means back.)

The large back of the eye, the posterior segment, contains a clear, jellylike substance called the vitreous humor. The posterior segment is large, taking up two-thirds of the eyeball, stretching from the lens to the retina. The vitreous humor holds the retina against the choroid. This is a critical job, as the blood vessels of the choroid nourish the retina; without nourishment from the choroid, the retina will die.

Both the aqueous humor and the vitreous humor help the eye to keep its goldfish-bowl shape. Think of the inside of the eye as a series of fluid-filled compartments. Going from front to back, you have the anterior and posterior chambers of the anterior segment. These front compartments are filled with the watery aqueous humor. Then you have the large posterior segment in the back of the eye, filled with the jellylike vitreous humor.

Figure 1-1 indicates where specific parts of the eye are located. As you read further, you may want to refer to
this diagram again to locate the other eye parts discussed in this lesson.

Figure 1-1: Cross Section of the Eye
The Orbit

The delicate eyeball is embedded in a cushion of fatty tissue that is surrounded by a bony socket. This socket, known as the orbit, is formed by several bones of the skull. The fat protects the eye from any injury that might be caused by the hard bones of the orbit. These same hard bones of the orbit, however, protect the eyeball from injury. For example, in case of trauma, the orbit absorbs most of the blow. A hole in the very back of the orbit lets the optic nerve pass through to the brain.

Extraocular Muscles

Eyes gaze about in many directions, from looking up at the stars to glancing down at blades of grass. Three pairs of muscles allow the eyeball to move. These muscles are attached via tendons to the orbit and the outside of the sclera. Each extraocular muscle has a special role in moving the eyes up, down, or sideways. And each muscle is stimulated by one of three cranial nerves. These nerves emerge directly from the brain through the skull, or cranium. The following are the six
extraocular muscles and the direction they move the eye:

- medial rectus: look toward the nose
- lateral rectus: look away from the nose
- superior rectus: look upward
- inferior rectus: look downward
- superior oblique: rotate
- inferior oblique: rotate

**Section Review**

Select the best item to answer each of the following multiple-choice questions.

1. What is the tough, outer layer of the eyeball called?
   a. retina
   b. sclera
   c. choroid

   The correct answer is (b). The sclera is the tough, outer layer of the eyeball.
2. What is the main role of the choroid?
   a. to send electrical impulses to the brain
   b. to help the eye keep its shape
   c. to nourish the retina

   The correct answer is (c). The main role of the choroid is to nourish the retina.

3. Which layer of the eye is like the film of a camera?
   a. retina
   b. sclera
   c. choroid

   The correct answer is (a). The retina is like the film of a camera.

4. Which substance fills the large back area of the eyeball?
   a. aqueous humor
   b. vitreous humor
   c. the macula

   The correct answer is (b). The jellylike vitreous humor fills the large back area of the eye.
5. What is the role of the orbit?
   a. to nourish the retina
   b. to keep the eye moist
   c. to protect the eye from injury

   The correct answer is (c). The role of the orbit is to protect the eye from injury.

6. What is the role of the extraocular muscles?
   a. to allow the eyeball to move in the orbit
   b. to absorb blows in case of trauma
   c. to transmit light impulses

   The correct answer is (a). The extraocular muscles allow the eyeball to move in the orbit.

**Practical Application**

7. Identify each of the three layers of the eye in Figure 1-1. Or describe where each of the three layers of the eye is located.

   The three layers of the eye are the sclera, the choroid, and the retina. The sclera is the tough outermost layer, and the choroid is the next layer,
right next to the sclera. The retina is the innermost layer.

This section examined the wall of the eye: the outer sclera, the middle layer of the choroid, and the innermost retinal layer. The next section will explore how eyelids and tears protect the eye.

**Eyelids and Tears**

The eye is a delicate organ, but many structures and substances work together to protect it. Eyelids keep out invading particles, and tears, far from a sign of weakness, keep the eye healthy. The conjunctiva adds further protection.

**The Eyelids**

Eyelids have layers. Each lid has an outer layer of skin, some deeper muscle fibers that enable the eyelid to close and open, and a dense, fibrous tissue layer called the tarsus. Both the upper and lower eyelids protect the front of the eye. People generally blink every three or four seconds, as well as whenever a threat to the eye is perceived. Blinking thus helps protect the eye against danger, be it a too-bright light or a ball veering.
too close. The eyelashes along the edge of the eyelids provide more protection by helping filter out dirt. In addition, the eyelids have an important role in keeping the eyes lubricated. With every blink, the eyelids push tears across the cornea. These tears wash away bacteria and other foreign matter.

**The Conjunctiva**

Lining the inside of both eyelids is a thin, clear mucous membrane known as the conjunctiva (kahn-junk-TY-vuh). The conjunctiva contains blood vessels and makes mucus that lubricates the eye. Besides lining the eyelids, the conjunctiva also covers the outside surface of the sclera.

The conjunctiva that lines the inner surface of the eyelids is called the palpebral conjunctiva. The conjunctiva that lines the sclera is the bulbar conjunctiva.

**Tears**

You cannot tell by look or touch, but a teardrop has three layers: oil, water, and mucus. Tiny cells in the conjunctiva produce the bottom layer of mucus. This is
the layer that directly touches the eye, and it helps the eye have a smooth surface.

The next layer is the water that makes up most of the tear. This fluid is produced by the lacrimal glands, which are located just above the outer part of the upper eyelids, right below the eyebrows. The lacrimal glands work around the clock, continually producing this watery layer that brings nutrients and oxygen to the cornea.

The top layer is the oil produced by the meibomian glands, which are tiny glands that line the edges of the eyelids, just behind the eyelashes. This oily layer makes sure that tears do not evaporate quickly, as eyes need to be moist to be healthy. This layer also helps the surface of the eye to be smooth.

Tears cleanse away any stray particles in the front of the eye and keep the eye moist, making clear vision possible. Tears wet the surface of the eye and are spread evenly when the eyelids open and close. The tears form a film that not only protects the eye but also helps keep the cornea transparent. In addition, tears contain an enzyme called lysozyme (LY-soh-zime),
which restricts the growth of bacteria on the surface of the eye.

When a teardrop leaves the eye, it journeys through a full-fledged irrigation system. The corner of each eye is called a canthus, and the one near the nose is called the nasal canthus. Tears collect in the nasal canthus, which has tiny drains called puncti (singular, *punctum*). The tears travel from the puncti to the lacrimal canal, a tube in the eyelid. Tears travel onward into the lacrimal sac, a hollow pouch located below the corner of the eye. The lacrimal sac is the top end of the nasolacrimal duct. Also known as the tear duct, the nasolacrimal duct is a tube that stretches from the eye to the nasal cavity, a canal at the back of the nostril. The tears proceed from the nasolacrimal duct into the nasal cavity, reaching the end of their journey, draining into the nose and leaving the body. Figure 1-2 shows the parts of the eye related to this system for producing tears and draining them.
This irrigation system lubricates and irrigates the eye, helping it fight infection. If any part of this drainage system is overwhelmed in moments of crying or excessive tearing, the tears spill over onto the cheeks.
Usually you do not notice this irrigation system; the amount of tears flowing into the nose is minimal. But from time to time this drainage system may become overwhelmed from crying or excessive tearing, be it from a broken heart or slicing an onion. The tears then spill over onto the cheeks, also causing a runny nose. If the tear drainage system becomes blocked by a foreign body or disease and tears just sit there without draining, infection may occur.

**Section Review**

Indicate whether the following statements are true or false. If the statement is false, reword it to make it true.

1. Eyelids protect the eye by blinking, which pushes tears across the front of the eye.
   
   True

2. Eyelashes are only decorative and have no practical function.

   False. Eyelashes protect the eye by filtering out dirt.
3. The conjunctiva lines only the inside of the eyelids.
   False. The conjunctiva lines not only the inside of the eyelids but also the outside of the sclera.

4. The conjunctiva makes mucus that lubricates the eye.
   True

5. Tears contain an enzyme that helps prevent bacterial growth.
   True

6. Tears are secreted by the nasolacrimal duct, also known as the tear duct.
   False. Tears are produced by the lacrimal gland. When leaving the eye, tears travel through the nasolacrimal duct to the nose and then out of the body.

Practical Application

7. Where does a tear go after it leaves the eye?
   Identify the parts of the tear irrigation system on
Figure 1-2. Or describe where each part is located and how the parts are connected.

After a tear leaves the eye, it goes through the lacrimal puncti, which are tiny drains at the corner of the eye. The tear then goes into the lacrimal canal, a tube in the eyelid. From there, the tear goes into the lacrimal sac, a little pouch at the top of the nasolacrimal, or tear, duct. The nasolacrimal duct is a tube that stretches from the eye to the nasal cavity, which is right behind the nostril. The tear goes into the tear duct and then the nasal cavity. Finally, the tear leaves the body through the nose.

This section showed how eyelids protect the eye from stray particles. Tears lubricate the eye and protect against infection, and the conjunctiva keeps the eye lubricated as well. The next section explores the window of the eye that lets in light.

**The Window of the Eye**

For vision to occur, light must enter the eye. Light first enters the window of the cornea, but before it goes
any farther, the curtain of the iris screens how much enters the pupil. The watery aqueous fluid circulates throughout this front chamber of the eye, exiting at a place called the angle. Read on to discover how these intricate parts work together.

**The Cornea**

This is the clear cover in the front of the eye, right over the colored part of the eye. A perfectly clear, watch-glass structure, the cornea serves as the window of the eye. It bulges out a bit from the rest of the eyeball. Again, if you compare the eye to a goldfish bowl, the cornea is a bulging clear cover over the bowl's opening. If you wear contact lenses, you insert the contact lens so that it rests on top of your cornea.

The cornea is curved, so light rays start to bend here as they begin their journey toward the retina. In fact, the cornea bends light much more than the lens does.

The cornea has five layers. The top, outer layer is the epithelium, which protects the eye from injury. This layer can usually regenerate or grow again quickly in case of injury. This is not so with deeper layers of the
cornea, such as the Bowman's membrane, the stroma, and the endothelium. The Bowman's membrane, just beneath the epithelium, is made up of collagen that gives the cornea its strength, flexibility, and shape. The stroma, the next layer, makes up most of the cornea. Its pattern of connective tissue cells allows the cornea to be transparent. The next layer, Descemet's membrane, supports the cornea and acts as a barrier against infection and injuries, and it can regenerate after injury. The last, innermost layer is the endothelium, which is responsible for pumping fluid out of the cornea. If the endothelium is damaged, it cannot regenerate or grow new tissue.

The cornea contains pain-sensing nerves that send messages to the brain. Indeed, the cornea has a higher concentration of these nerves than any other place on the body, so a tiny scratch is very painful.

A thin layer of tears coats and moisturizes the outside of the cornea, and behind the cornea is another fluid. Just beyond the cornea is a compartment known as the anterior chamber, which is filled with the clear aqueous (AY-kwee-us) humor. The aqueous humor circulates
throughout the front part of the eye and helps keep the eyeball round and firm. It also helps the eye maintain a consistent pressure. Both the tears and the aqueous humor nourish the cornea.

The cornea connects to the sclera, and the place where they join is called the limbus. The cornea does not have blood vessels itself, but the limbus does. So the limbus also nourishes the cornea.

**The Iris**

If the cornea is the window of the eye, the iris is a curtain that determines how much light comes in. Shaped like a disk, the iris is the colored part of the eye, and it is located directly behind the cornea. The iris contains pigment cells that determine whether it is blue, brown, gray, or green. Many pigment cells make the iris brown; fewer pigment cells make it blue, green, or gray.

The space in the center of the iris is the pupil, which looks like a black dot. The iris is made of two muscles that control the size of the pupil, which is an adjustable opening. The dilator muscle, which resembles spokes
on a wheel, opens the pupil. The circular sphincter muscle closes the pupil. The size of the pupil is controlled by the autonomic nervous system, which is the part of the nervous system in charge of involuntary actions such as heartbeats.

Like a curtain, the iris opens and closes to allow the right amount of light to enter. For example, on a bright sunny day, the iris constricts the pupil, or makes it smaller, letting in less light. On a dark and stormy night, the iris dilates, or widens, the pupil, allowing all possible light to reach the inside of the eye. When the pupil dilates in dim light, less of the iris is visible. In contrast, when the pupil constricts in bright light, more of the iris is visible. You can also compare the iris to the shutter of a camera, opening and closing to allow the right amount of light into the eye. Note that the pupil also changes size in response to looking at close-up objects, to different emotional states, and to various kinds of medications and eye drops.

Not only is the iris the eye's curtain, it also is a room divider, separating the front anterior segment of the
eye into the anterior chamber and the posterior chamber.

Recall that the front part of the eye, from the cornea to the lens, is the anterior segment, which contains the aqueous humor. The area from the cornea to the iris is the anterior chamber, and the area from the iris to the lens is the posterior chamber. Behind the lens is the large posterior segment, the back part of the eye that contains the vitreous humor.

The Angle

This is the point where the cornea, iris, and sclera meet. The angle is made up of a tissue called the trabecular meshwork, which has many tiny openings. These openings allow the aqueous humor to drain away from the eye. The trabecular meshwork connects to the canal of Schlemm, a tubelike structure that links to capillaries, or small blood vessels. The aqueous humor drains from the trabecular network into the canal of Schlemm, which acts like a pipe and carries the fluid away from the eye into the blood. As you will discover in "Human Eye 2," any problem with the angle or this
drainage system causes huge problems for the eye and vision.

Section Review

Select the best item to answer each of the following multiple-choice questions.

1. What is the clear cover of the eye that bends light rays?
   a. cornea
   b. iris
   c. pupil

   The correct answer is (a). The cornea is the clear cover of the eye that bends light rays.

2. Which structure has blood vessels and nourishes the cornea?
   a. iris
   b. pupil
   c. limbus

   The correct answer is (c). The limbus, which is the place where the cornea connects to the sclera, has blood vessels and nourishes the cornea.
3. What is the aqueous humor?
   a. a layer of a teardrop
   b. fluid that circulates in the anterior segment of the eye
   c. fluid that circulates in the posterior segment of the eye

   The correct answer is (b). The aqueous humor is the fluid that circulates in the anterior segment of the eye.

4. Which structure controls the amount of light that enters the eye?
   a. cornea
   b. iris
   c. trabecular meshwork

   The correct answer is (b). The iris is the structure that controls the amount of light that enters the eye.

5. Which muscle opens the pupil?
   a. dilator muscle
   b. sphincter muscle
   c. vitreous
The correct answer is (a). The dilator muscle opens the pupil.

6. What happens in a brightly lit room?
   a. The dilator muscle of the iris opens the pupil.
   b. The sphincter muscle of the iris closes the pupil.
   c. The sphincter muscle of the iris dilates the pupil.

   The correct answer is (b). In a brightly lit room, the sphincter muscle of the iris closes the pupil.

7. What part of the eye extends from the cornea to the iris?
   a. anterior chamber
   b. posterior chamber
   c. posterior segment

   The correct answer is (a). The anterior chamber extends from the cornea to the iris.
8. Where do the cornea, sclera, and iris meet?
   a. angle
   b. dilator muscle
   c. pupil

   The correct answer is (a). The cornea, sclera, and iris meet at the angle.

9. What is the purpose of the trabecular meshwork?
   a. It helps the eye stay round and firm.
   b. It controls how much light enters the eye.
   c. Its tiny openings allow the aqueous humor to drain from the eye.

   The correct answer is (c). The tiny openings of the trabecular meshwork let the aqueous humor drain from the eye.

**Practical Application**

10. Think of the pupil and how the iris controls its size, depending upon the amount of light.
   a. List two real-life occasions when the pupil will become smaller.
Answers will vary. Sample answer: The pupil becomes smaller when you go from a dimly lit house into bright sunlight. The pupil becomes smaller when you turn on an overhead electric light in a pitch-dark room.

b. List two real-life occasions when the pupil will become larger.

Answers will vary. Sample answer: The pupil becomes larger when you go from a brightly lit room into a dark closet. The pupil becomes larger when you go from a house with all the lights on out into the dark night.

This section discussed how light enters the cornea. The iris then determines how much light enters the inside of the eye by controlling the size of the pupil. Aqueous humor circulates throughout the front of the eye, leaving at the angle. The next section explores the interior of the eyeball.

Inside the Eyeball

You've examined the walls of the eye and its window. You're probably wondering what's inside! This section
journeys further inside the eyeball and describes the lens, the ciliary body, and the vitreous humor.

The Lens

Just behind the iris and pupil is the lens, sometimes called the crystalline lens. The lens is a transparent disk made of firm but extremely flexible tissue. It can change its shape to allow the eye to focus on near as well as far objects. Acting like the lens of a camera, it focuses light onto the retina.

The lens is enclosed in a transparent capsule that is connected to a network of tiny, taut bungee-like ligaments, the zonules of Zinn. These zonules are attached to the ciliary body, and they hold the lens in place. The muscle in the ciliary body controls how much the zonules pull on the lens, allowing the lens to change its shape.

The Ciliary Body

This structure is a little bulge in the choroid layer, and it is located at the base of the iris. The ciliary body contains the ciliary muscle and the ciliary processes, each of which has a specific job.
Ciliary Muscle

A ring of muscular fibers, the ciliary muscle connects to the zonules of Zinn, which are attached to the lens. The ciliary muscle pulls on the zonules, and they pull on the lens, making it change its shape. The way that the ciliary muscle works is counterintuitive, or not quite what you would expect! When the ciliary muscle is flexed, or contracted, the zonules relax, and the lens, because it is elastic, becomes thicker and rounder in shape. This allows the lens to bulge at the center and bend light more, permitting the close vision needed for activities such as reading a book. When the ciliary muscle is relaxed, the zonules are tensed, and the lens flattens out. This allows the distance vision needed for activities like reading a store sign across the street.

Why not think of a puppet controlled by a puppeteer pulling its strings? The ciliary muscle, like a puppeteer, controls the zonules, which are like puppet strings, that make the lens, like a puppet, change shape.

This ability to change the shape of the lens from flatter to rounder, or thicker, and back again is called accommodation. This process allows the eye to focus.
on objects regardless of how close or far away they are from the eye. Figure 1-3 shows the ciliary muscle flexing, causing the zonules to relax and the lens to become thicker and rounder.

Figure 1-3: Ciliary Muscle, the Lens, and Accommodation

Illustration courtesy of bouldereyesurgeons.com
Ciliary Processes

The ciliary body contains folds of tissue called ciliary processes, and these structures produce the aqueous humor. Recall that this fluid circulates between the anterior and posterior chambers of the anterior segment in the front of the eye. The ciliary body secretes this fluid nonstop. The aqueous humor first flows into the posterior chamber, which is the space between the iris and the lens. The aqueous humor then passes through the pupil and into the anterior chamber, which is the space between the cornea and the iris. (It may help to remember that **anterior** means front, and **posterior** means back.) The aqueous humor nourishes eye tissue and provides pressure to help maintain the shape of the eye. The aqueous humor exits through the trabecular meshwork and enters the bloodstream.

Note that some of the aqueous humor leaves the eye via the uveoscleral outflow pathway. This path consists of the spaces between cells in the ciliary muscle and space between the sclera and the choroid. The aqueous then leaves either through the sclera or veins. In young people, more aqueous humor leaves through the
uveoscleral outflow pathway; as a person gets older, more flows through the trabecular network. Many glaucoma medications help the aqueous fluid leave the eye through the uveoscleral pathway.

**Vitreous Humor**

Behind the lens is the section known as the posterior segment, and this area is filled with a jellylike substance known as the vitreous. The vitreous helps the eye keep its round shape. The vitreous must remain clear for vision to be sharp; any inflammation or blood inside the eye will blur vision. Notice how the aqueous is continually being produced, circulated about the eye, and drained. On the contrary, the vitreous has a more stable existence and stays in one place.

Recall that the very back inner wall of the eye is the retina, which contains the light-sensitive cells that send messages to the brain. Recall too that the retina is nourished by the choroid, a layer of blood vessels. The vitreous holds the retina against the choroid. If the retina separates from the choroid, the retina has no nourishment and dies, causing loss of vision. At birth, the vitreous is actually attached to the retina, but with
age, parts of the vitreous may separate from it. Sometimes, especially with age, little pieces of debris from within the eye may drift about in the vitreous. These are called floaters, which may become an annoyance, especially when they float into the area of central vision. As will be discussed in "Human Eye 2," although floaters usually are nothing to worry about, sometimes they may signal an emergency.

Note that the choroid, iris, and ciliary body are sometimes called the uvea. You can think of the eye as a ball with three layers that go all the way around it. The choroid, iris, and ciliary body are part of the same middle layer that winds all the way around the eye. In other words, the iris and ciliary body are really part of the choroid layer. These structures all have blood vessels that supply the eye with blood.

You have now learned the parts of the eye. Figure 1-4 is a diagram of the eye that shows these parts. But the eye alone does not produce vision. The next section will discuss the parts of the brain.
Figure 1-4: Eye Diagram

Adapted from illustration NEA08, courtesy of National Eye Institute, National Institutes of Health
Section Review

Indicate whether the following statements are true or false. If the statement is false, reword it to make it true.

1. The lens is clear and flexible and is enclosed in a capsule.
   True

2. The ciliary body has one job: to allow the lens to accommodate.
   False. The ciliary body has two jobs: to allow the lens to accommodate, and also to secrete aqueous humor.

3. The ciliary muscle pulls the zonules, causing the lens to change shape.
   True

4. The flattening of the lens permits near vision.
   False. A flat lens allows for distance vision.
5. Aqueous humor nourishes eye tissue and maintains eye pressure.

True

6. The vitreous humor is constantly being produced, circulated, and drained.

False. The vitreous humor remains in the posterior segment of the eye.

7. The vitreous humor holds the choroid against the retina.

True

8. The choroid, the iris, and the ciliary body make up the uvea.

True

**Practical Application**

9. Think of how the lens accommodates to allow for near and far vision.
   
a. Give two examples of real-life activities for which the lens would become flat and thin.
Answers will vary. Sample answer: If you are sighted, the lens becomes flat and thin when you look at a performer while sitting at the very back of an auditorium. The lens also becomes flat and thin when you're looking down from the viewing deck of a tall building like the Willis Tower.

b. Give two examples of activities for which the lens would become rounder and thicker.

Answers will vary. Sample answer: The lens becomes round and thick when you read the fine print of a book. The lens becomes round and thick when you read your friend's handwriting on a birthday card.

This section discussed structures and substances inside the eye: the lens, the ciliary body, and the vitreous humor. The next section describes parts of the brain that work together with the eye to cause vision.

The Brain Connection

As you can see, the visual system is very complex. The brain devotes more territory to vision than to all the
other senses combined. This massive processing space and the ways it is wired together allow the brain to analyze many pieces of visual information at once. If you are sighted, you see an object and know what it is, where it is in 3-D space, its direction and speed, and what to do about it almost instantly. This visual system is simply amazing.

The optic nerve connects the retina to the brain. From the optic nerve, electrical impulses carrying visual information change directions at the optic chiasm and the lateral geniculate nuclei (LGN). These impulses finally reach the visual cortex and then separate into different streams, journeying to yet other lobes of the brain.

The Optic Nerve

Recall that the retina is the "film" at the back of the eye that contains light-sensitive cells. All the nerve endings in the retina, more than a million of them, come together in a bundle at the back of the eye. This bundle forms the optic nerve, which acts like a cable, connecting the eye to the brain. Electrical signals travel
from the retina to the optic nerve, and the optic nerve acts as a messenger, relaying information to the brain.

The point where the optic nerve and retina meet is the optic disk. This is a "blind spot" as far as vision is concerned, as the optic disk contains no rods or cones. People are usually not aware of this blind spot, as each eye compensates for the blind spot of the other. The center of the optic disk is a depressed area called the cup.

After leaving the eye, the optic nerve cuts through the back of the sclera, runs through a hole in the bony socket, and then proceeds back into the brain. The optic nerve fibers then journey through the brain.

**The Optic Chiasm**

Remember that each eye has its very own optic nerve, with nerve fibers going back into the brain. About one-third of the way back in the brain is a point called the optic chiasm (a crossing or intersection). Here, the two sets of nerve fibers meet, with some fibers crossing sides. Optic nerve fibers from one half of each retina cross to the opposite side of the brain. Fibers from the
other half of each retina remain on the same side of the brain. This is necessary because for each eye, the right field of vision falls on the left side of the retina, and the left field of vision focuses on the right side of the retina. To make sense, these images need to merge.

**Lateral Geniculate Nuclei (LGN)**

The journey through the brain is far from over! After leaving the optic chiasm, nerve fibers continue along the optic tract to the lateral geniculate (jen-IK-yoo-lit) nuclei (LGN). The LGN are small egg-shaped neural structures in the middle of the brain, one on each side. The LGN are way stations for transmitting electrical impulses. Like a train station sending passengers on different routes, the LGN send different types of information on different paths. Some visual information from the eye goes directly to the brain stem for simple survival kinds of tasks, like jumping out of the way of a moving car so you don’t get hit. Most of the information, however, is sent to the visual cortex for more careful processing. Nerve fibers run from the LGN to the optic radiations, a fan-shaped network of paths connecting to the visual cortex.
The Visual Cortex

The visual cortex takes up most of the space in the occipital lobe, which is one of four brain lobes, or sections of the brain. The visual cortex is the brain's main visual processing center. Here, the electrical signals from the retina are interpreted as a visual image. Here, vision happens.

The visual pathway connections are complex. The left visual cortex receives all the visual impulses coming from the left side of each retina. Likewise, the right visual cortex receives those coming from the right side of each retina. But because the retina is curved, not flat, the right side of each retina sees things to the left and vice versa. So injury to the right visual cortex or the area just in front of it on the right side of the brain affects the left visual field, and the person becomes unable to see objects on the left. (The visual field is the entire area you see while looking straight ahead, including what is seen with peripheral vision.)

These structures are shown in Figure 1-5, which helps you trace the path of the optic fibers from the retina to the back of the brain.
Figure 1-5: Visual Pathways in the Brain

- LEFT EYE
- RIGHT EYE
- OPTIC NERVE
- OPTIC CHIASM
- OPTIC TRACT
- LATERAL GENICULATE BODIES
- OPTIC RADIATIONS
- OCCIPITAL LOBE
Lobes and Streams

The visual cortex in the occipital lobe is the primary visual processing area. But the process doesn’t stop there. Other lobes besides the occipital lobe are involved. When visual information leaves the visual cortex, it separates into two streams, each carrying different types of information onward to different brain lobes.

Lobes

The outer portion of the brain is divided into four main parts, called lobes, that resemble cauliflower stalks with their many ridges. These lobes are the frontal, parietal, temporal, and occipital, and each has specific main functions. The frontal lobe is at the front, and it handles higher level thinking. The parietal lobe is in the middle of the brain, right behind the frontal lobe, and it handles body awareness and movement. The two temporal lobes, which primarily deal with hearing and speech, are toward the bottom, located on each side of the brain at ear level. The occipital lobe, which has vision as its main function, is at the very back of the brain. All these lobes work with the visual system. At
the same time, the brain is divided into two halves, the right and left hemispheres, and the right hemisphere is more involved with vision. Figure 1-6 shows the brain and its parts.

**Figure 1-6: The Brain**

![The Brain](image)

Illustration courtesy of SKI-HI Institute, 2005

Visual information analyzed in the visual cortex is sent in two directions. Some information travels along the ventral stream toward the right temporal lobe. Other information goes along the dorsal stream toward the
right parietal lobe. (Remember, the right hemisphere is more involved with vision.)

*The Dorsal Stream*

This stream tells you where things are. The dorsal stream gathers visual information so you can decide where an object is. The dorsal stream has a map of the visual field and can detect motion. This permits the following visual functions: orientation in 3-D space, eye-hand and eye-foot coordination, and perception of movement. The dorsal stream also lets you detect object speed and the direction of motion, and it lets you direct eye movements to follow visual targets. This stream is also known as the "how" or "action" stream, as it tells you what to do, letting you interact with the object now that you realize its location. For example, the dorsal stream guides actions such as reaching.

*The Ventral Stream*

This stream tells you what you see. The ventral stream allows you to recognize objects and more. It allows you to recognize faces, facial expressions, color and shape, letters and words, animals, and objects. Routes are
also stored there so you can remember visual landmarks that help you get around.

Note that some experts believe that the dorsal and ventral streams are extremely interconnected. They believe that the separation into the "what" and "where" streams is too simplistic.

**Section Review**

Select the best item to answer each of the following multiple-choice questions.

1. Where do all the nerve endings in the retina meet?
   a. optic nerve
   b. optic chiasm
   c. frontal lobe

   The correct answer is (a). All the nerve endings in the retina meet at the optic nerve.

2. Which structure is a messenger, connecting the eye with the brain?
   a. optic chiasm
   b. optic pathway
   c. optic nerve
The correct answer is (c). The optic nerve is a messenger, connecting the eye with the brain.

3. Where do the optic nerve and retina meet?
   a. optic disk
   b. optic chiasm
   c. optic pathway

   The correct answer is (a). The optic nerve and the retina meet at the optic disk.

4. What happens at the optic chiasm?
   a. The optic nerve and retina meet.
   b. Half of the optic nerve fibers cross to the opposite side of brain.
   c. No rods or cones exist at the optic chiasm.

   The correct answer is (b). At the optic chiasm, half the optic nerve fibers cross to the opposite side of the brain.
5. Which of the following are way stations in the brain that transmit electrical impulses?
   a. lateral geniculate nuclei
   b. optic radiations
   c. optic disk

   The correct answer is (a). The lateral geniculate nuclei are way stations in the brain that transmit electrical impulses.

6. What is the main processing center for vision in the brain?
   a. visual cortex
   b. retina
   c. optic chiasm

   The correct answer is (a). The main processing center for vision in the brain is the visual cortex.

7. Which structure receives the impulses from the left side of each retina?
   a. left visual cortex
   b. right visual cortex
   c. right side of the retina
The correct answer is (a). The left visual cortex receives the impulses from the left side of each retina.

8. What will happen if the right side of the visual cortex is injured?
   a. The person won't see objects to his or her right.
   b. The person won't see objects to his or her left.
   c. The person will become totally blind.

   The correct answer is (b). If the right side of the visual cortex is injured, the person won't see objects to his or her left.

9. Which part of the brain tells you where you see things?
   a. ventral stream
   b. visual cortex
   c. dorsal stream

   The correct answer is (c). The dorsal stream tells you where the visual objects are.
Practical Application

10. Describe the path of visual information after it leaves the retina, using Figure 1-5. Or describe this path, identifying specific parts of the brain.

After an electrical impulse leaves the retina, it travels to the optic nerve, which is the bundle of nerves at the back of the retina. From the optic nerve, the impulse travels into the brain and reaches the optic chiasm. There, it may cross over to the opposite side of the brain. It travels along the optic tract to one of the lateral geniculate nuclei. It travels along the optic radiations to the visual cortex, which is in the occipital lobe. From there, the impulse travels along the ventral stream to the temporal lobe if it gives "what" information, or along the dorsal stream to the parietal lobe if it gives "where" information.

This section discussed the journey of visual information in the brain, from the optic nerve to the optic chiasm, the lateral geniculate nuclei, the visual cortex in the occipital lobe, and then yet other lobes of the brain.
You have now explored the basic structures of the eye and brain that help produce vision.

**Summary**

This lesson introduced the basic parts of the eye. It described the wall of the eye as well as the eyelids, tears, cornea, iris, pupil, lens, ciliary body, and vitreous humor. Finally, it presented the parts of the brain that transform light impulses into visual images. The human eye may seem to be built very simply, but the task it performs is extremely complex. As you progress in this course, you will learn just how complex this task can be.
Assignment 1

For general instructions on completing assignments, refer to the Getting Started instructions. Then start this assignment by giving your full name, address, and phone number. Also list the name of this course, Assignment 1, your instructor’s name, and the date. Be sure to include the question number along with each answer. This assignment is worth 100 points.

Multiple Choice

Select the best item to answer each of the following questions. (30 points total, 3 points each)

1. Which of the following nourishes the retina?
   a. the sclera
   b. the choroid
   c. the aqueous humor

2. Which of the following changes light into electrical impulses?
   a. sclera
   b. retina
   c. choroid
3. The conjunctiva does which of the following?
   a. makes mucus that lubricates the eye
   b. secretes aqueous humor that lubricates the eye
   c. protects the eye by filtering out dirt

4. What are the tiny drains through which tears leave the eye?
   a. lacrimal sacs
   b. puncti
   c. trabecular meshwork

5. What is the cornea?
   a. the clear cover in front of the eye that bends light rays
   b. the muscle that determines how much light enters the eye
   c. the opening through which light enters the eye

6. What is the anterior chamber of the eye?
   a. the back part of the eye
   b. the very front part of the eye, from the cornea to the iris
   c. the front part of the eye, from the cornea to the lens
7. Which part of the eye focuses light onto the retina?
   a. iris
   b. lens
   c. pupil

8. Which part of the eye produces aqueous humor?
   a. cornea
   b. optic nerve
   c. ciliary body

9. What is the optic nerve?
   a. where the retina connects with the brain
   b. a way station for visual impulses inside the brain
   c. the main processing center for vision

10. Which visual pathway lets you know what an object is?
    a. optic chiasm
    b. dorsal stream
    c. ventral stream
Short Answer

Answer the following questions in a brief paragraph or list. (60 points total)

11. Why are you taking this course, and what do you expect to learn from it?

12. Describe the three layers of the wall of the eye. Explain the function of each layer.

13. What substance fills the anterior segment of the eye?

14. What substance fills the posterior segment of the eye?

15. How are the pupil and iris related to each other?

16. Describe the structures of the eye and surrounding area that help protect the eye from injury.

17. How do the eyelids protect the eyes?

18. Give four ways that tears are important for the eye's health.
19. Describe where the aqueous humor is made and how it circulates in the eye.

20. What happens when the eye changes focus from reading a book to watching television? What is this process called?

21. Explain why injury to one side of the brain can cause decreased vision in both eyes.

**Practical Application**

Answer the following question in a brief paragraph or list. (10 points total)

22. For each of the following eye parts, tell where it is located in the eye or brain and what it does.
   - lens
   - retina
   - cornea
   - conjunctiva
   - visual cortex

When you have completed this assignment, proceed to Lesson 2: The Routine Eye Exam, Part 1.