Model Science – The Human Eye

I. Competition Overview
   a. Review competition rules
   b. Discuss possible choices of materials for construction of model
   c. Emphasize model specifications, including size, freestanding, clearly labeled, hand drawn diagram, and materials table
   d. Emphasize required structures of the model

II. Overview of the Human Eye
    a. Discuss basic anatomy of human eye
    b. Activity 1 – Layers of the Human Eye
    c. Discuss physiology
    d. Activity 2 – Focusing Images
    e. Activity 3 – Building a Magnifying Glass Refracting Telescope

III. Review Functions of External Structures
     a. Review location and function of eyelid, eyelashes, tear and fat glands, extraocular muscles and conjunctiva.
     b. Activity 4: Basic Anatomy of the Eye Video

IV. Review Functions of Internal Structures
    a. Review location and function of cornea, sclera, iris, ciliary body, choroid, and retina.
    b. Review location and function of lens, aqueous humor, vitreous humor, optic nerve and retinal blood vessels.
    c. Activity 5: How Absolutely Blind is Your Blind Spot?
    d. Activity 6: Structures of the Eye
    e. Activity 7: Dissecting a Sheep Eye
    f. Activity 8: Internet Interactive Study Aids

V. Review Disorders and Diseases
    a. Review common disorders and diseases including astigmatism, cataracts, conjunctivitis, dry eye, glaucoma, myopia, hyperopia, and presbyopia
    b. Activity 9: Eye Disorder Crossword Puzzle
VII. Building the Model  
   a. Form 2-person student teams  
   b. Review dimensions of the model  
   c. Review materials needed for model  
   d. Encourage students to obtain materials found around the house or school – discourage purchasing materials. Suggestions include papier-mâché, straws, rubber tubing, saran wrap, aluminum foil, toothpaste, beans, cardboard, plastic containers, dried pasta, etc.  
   e. Review required structures of the model  
   f. Remind students to clearly label the required structures of the model

VIII. Building the Display  
   a. Review dimensions of the display  
   b. Remind students of the hand-drawn diagram  
   c. Remind students to attach materials list

IX. Questions  
   a. Duplicate questions  
   b. Have student teams scan curriculum materials for answers to competition questions  
   c. Set-up mock competition sessions where students draw questions and provide answers
Section II: Overview of the Human Eye

The Human Eye

The human eye is a significant sense organ which allows for the sense of sight and allows us to observe and learn more about the surrounding environment. We use our eyes in almost every activity we perform such as reading, writing, walking, riding a bike, watching television and in countless other ways. The eye allows us to see and interpret the colors, shapes and depths of objects in the world by processing the light they reflect or emit. The eye is able to detect bright light or dim light, but it cannot sense objects in the absence of light.

Basic Anatomy

The human eye is a spheroid structure with an average diameter of 24mm, about 2/3 the size of a ping-pong ball, that rests in a bony cavity (socket, or orbit) called the bulbus oculi on the frontal surface of the skull. The eye takes up less than one-third of the total space and is surrounded by pads of fat and muscles, which accounts for the remaining two-thirds. The bony cavity is made up of 7 pieces of bone and has a volume of ~ 30ml while the eye's volume is 7ml. The bony cavity is a protective structure because its rim extends beyond the plane of our eye, decreasing the damage done by direct impact if an object hits on our face.

External Structures

- Eyelids
- Eyelashes
- Tears and Fat Glands
- Extrinsic / Extraocular muscles
- Conjunctiva

Internal Structures

- Cornea, Sclera
- Iris, Ciliary Body, Choroid
- Retina
- Lens
- Aqueous Humor, Vitreous Humor
- Optic Nerve

The eye is filled, for the most part, with a jellylike transparent substance called vitreous humor. The thick wall of the eyeball contains three covering layers: the sclera, the choroid, and the retina. None of these three layers encircle the entire eyeball; they all leave space at the front.

- The sclera is the outermost layer of eye tissue; part of it is visible as the "white" of the eye. In the center of the visible sclera and projecting slightly, in the manner of a crystal raised above the surface of a watch, is the cornea, a transparent membrane that acts as the...
window of the eye. A delicate membrane, the *conjunctiva*, covers the visible portion of the sclera.

- Underneath the sclera is the second layer of tissue, the **choroid**, composed of a dense pigment and blood vessels that nourish the tissues. Near the center of the visible portion of the eye, the choroid layer forms the *ciliary body*, which contains the muscles used to change the shape of the lens (that is, to focus). The ciliary body in turn merges with the **iris**, a diaphragm that regulates the size of the pupil. The iris is the area of the eye where the pigmentation of the choroid layer, usually brown or blue, is visible because it is not covered by the sclera. The pupil is the round opening in the center of the iris; it is dilated and contracted by muscular action of the iris, thus regulating the amount of light that enters the eye. Behind the iris is the **lens**, a transparent, elastic, but solid ellipsoid body that focuses the light on the retina, the third and innermost layer of tissue.

- The **retina** is the inner layer of the eye and is a network of nerve cells, notably the rods and cones, and nerve fibers that fan out over the choroid from the optic nerve as it enters the rear of the eyeball from the brain. Unlike the two outer layers of the eye, the retina does not extend to the front of the eyeball. Between the cornea and iris and between the iris and lens are small spaces filled with aqueous humor, a thin, watery fluid. The large spheroid space in back of the lens (the center of the eyeball) is filled with vitreous humor, a jellylike substance.

Accessory structures of the eye are the lacrimal gland and its ducts in the upper lid, which bathe the eye with tears keeping the cornea moist, clean, and brilliant, and drainage ducts that carry the excess moisture to the interior of the nose. The eye is protected from dust and dirt by the eyelashes, eyelid, and eyebrows. Six muscles extend from the eye socket to the eyeball, enabling it to move in various directions.

**Activity 1: Layers of the Human Eye**

**Directions:** Label the layers of the human eye.
**Activity 1: Layers of the Human Eye Solution**

![Eye Diagram]

**Physiology**

The eye has many functions. It can distinguish light and dark, shape, color, brightness and distance.

Light is electromagnetic radiation at wavelengths which the human eye can see. **Visible light is the very narrow band of wavelengths located to the right of infrared and to the left of ultraviolet waves.** Visible radiation is emitted by everything from fireflies to light bulbs to stars, and also by fast-moving particles hitting other particles. A typical human eye can see wavelengths from about 380 to 750 nm (nanometers) and in terms of frequency this corresponds to a band of about 790 – 400 terahertz.

Light waves from an object (such as a tree) enter the eye first through the cornea, the clear dome at the front of the eye. The light then progresses through the pupil, the circular opening in the center of the colored iris.

Fluctuations in incoming light change the size of the eye’s pupil. When the light entering the eye is bright enough, the pupil will constrict (get smaller), due to the pupillary light response.

Initially, the light waves are bent or converged first by the cornea, and then further by the crystalline lens (located immediately behind the iris and the pupil), to a nodal point (N) located immediately behind the back surface of the lens. At that point, the image becomes reversed (turned backwards) and inverted (turned upside-down).

Source: NASA
The lens is a biconvex structure which causes rays of light to come to focus. The curved surfaces allow the light rays to be refracted so that they converge to form an image. The nodal point (N) in the diagram is the focal point where the nearly straight rays of light meet after passing through the biconvex lens.

The light continues through the vitreous humor, the clear gel that makes up about 80% of the eye’s volume, and then, ideally, back to a clear focus on the retina, behind the vitreous humor. The small central area of the retina is the macula, which provides the best vision of any location in the retina. If the eye is considered to be a type of camera, the retina is equivalent to the film inside of the camera, registering the tiny photons of light interacting with it.

Within the layers of the retina, light impulses are changed into electrical signals. Then they are sent through the optic nerve, along the visual pathway, to the occipital cortex at the posterior (back) of the brain. Here, the electrical signals are interpreted or “seen” by the brain as a visual image.

Actually, then, we do not “see” with our eyes but, rather, with our brains. Our eyes merely are the beginnings of the visual process.

**Activity 2: Focusing Images**

**Purpose:** To understand how images can be focused at one point.

**Materials:** Index card
Push pin

**Directions:**

1. Take an index card and make a hole in the center of the card with the push pin.
2. Place aside.
3. Look at a word on the wall.
4. Close your left eye and place your thumb of your right hand in front of your right eye about 6 inches away and focus your right eye on your thumb. (The word on the wall should be out of focus.)
5. With your left hand, now place the index card immediately in front of your right eye and look through the hole at both your thumb and the word on the wall. (Both your thumb and the word on the wall should be in focus.)
Activity 3: Building a magnifying glass refracting telescope

Purpose: To understand that lenses cause rays of light to come to focus by building a refracting telescope.

Materials for each group
- 2 standard magnifying glasses (40mm diameter)
- PVC pipe
- 1.5 L water bottle
- Ruler

Shared Tools
- Glue Gun
- Glue Sticks
- Flashlight
- Xacto knife
- PVC pipe cutter

1. Hold a flashlight about 3m away from a wall.
2. Using one of the magnifying glasses, focus the beam on the wall.
3. Using a ruler, measure the distance from the magnifying glass to the wall. This is the “focal length” of a magnifying glass at infinity. Document on the table to left.
4. Examine a sheet of paper with typed words on a flat table with the other magnifying glass. Move the glass away from the words until the words are as large as they can be without being blurry.
5. Using a ruler, measure the distance from the magnifying glass to the table. This is the other focal length of the magnifying glass. Document on the table above.
6. Remember, the first lens of a telescope focuses an image from far away to a focal point, and the second lens enlarges that image at its focal point.
7. Add the two lengths together to get the length of the telescope tube (see table above).

<table>
<thead>
<tr>
<th>Location</th>
<th>Focal Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnifying glass to wall</td>
<td></td>
</tr>
<tr>
<td>Magnifying glass to table</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
For the standard (40mm diameter) magnifying glass, the focal length to the wall should be about 8cm.
For the standard (40mm diameter) magnifying glass, the focal length to the table should be about 3.2cm.
The PVC pipe should be 11.2cm.
8. Cut the PVC pipe to the total focal length above; this is the telescope tube.
9. Unscrew the cap from the rim of water bottle and cut a hole in the center of the cap with Xacto knife.
10. Cut the top rim off of the 1.5L water bottle with Xacto knife.

11. Insert the PVC into the top part of the water bottle rim that was just cut off. Insert until the end of the PVC is flush with the top of the rim and then glue into place.

12. Glue the back of the cap of the bottle to the center of one magnifying glass.

13. Glue the other end of the PVC to the center of the second magnifying glass.
14. Screw the magnifying glass and cap on to the PVC.

15. This will focus your telescope.
Section III: Review Functions of the External Structures

Eyelids

The upper and lower eyelids are movable lids of skin and muscle that can be closed over the eyeball. The junction of the upper and lower eyelids is called lateral & medical canthus. The eyelids provide the eyeball with protection by preventing entry of excessive light and foreign particles.

The eyelids through blinking (the rapid opening and closure of eyelids at approximately 6 seconds, maybe voluntary or reflex) lubricate the eye surface by distributing tears over the cornea. The eyelids are closed by the orbicularis oculi muscles and are opened by the levator palpebrae muscles.

Eyelashes

Eyelashes, together with eyebrows, stop dust and sweat from running into the eyes.

Tear and Fat Glands

Coating the outer surface of the cornea is a “pre-corneal tear film”. Tears are important in that they:

1. Keep the cornea moist, thereby preventing it from being damaged due to dryness,
2. Wash foreign bodies out,
3. Create a smooth optical surface on the front of the microscopically irregular corneal surface,
4. Act as the main supplier of oxygen and other nutrients to the cornea, and
5. Contain an enzyme called lysozyme to kill bacteria and prevent the growth of microcysts on the cornea.

The tear film resting on the corneal surface has three layers, from front to back:

- lipid or oil layer,
- lacrimal or aqueous layer, and
- mucoid or mucin layer

The most external layer of the tear film is the lipid or oil layer. This layer prevents the lacrimal layer beneath it from evaporating. It also prevents the tears from flowing over the edge of the lower eyelid. The lipid component of the tear film is produced by sebaceous (fat) glands known as “Meibomian” glands and the glands of “Zeis”.

Beneath the lipid layer is located the lacrimal or aqueous layer of the tear film. This middle layer is the thickest of the three tear layers, and it is formed primarily by the glands of “Krause” and “Wolfring” and secondarily by the lacrimal gland, all of which are located in the eyelids.
Lacrimal fluid contains salts, proteins and lysozyme. The lacrimal gland is the major producer of tears when one is crying or due to foreign body irritation.

The lacrimal gland of each eye secretes lacrimal fluid which flows through the main excretory ducts into the space between the eyeball and eyelids. When the eyes blink, the lacrimal fluid is spread across the surface of the eye. The lacrimal fluid is then drawn into the puncta lacrimalia, also known as the punctum, by capillary action, then flows through the lacrimal ducts at the inner corner of the eyelids entering the lacrimal sac, then on to the nasolacrimal duct, and finally into the nasal cavity.

The epithelial surface of the cornea is naturally “hydrophobic” (water-repelling). Therefore, for a tear layer to be able to remain on the corneal surface without rolling off, the “hydrophilic” (water-attracting) mucoid or mucin layer of the tear film is laid down onto the surface of the cornea by “goblet cells,” which are present in the bulbar conjunctiva. In turn, the lacrimal layer of the tear film, located above the mucoid layer, can defy gravity and remain on the front of the eye.

**Extrinsic / Extraocular Muscles**

There are six extraocular muscles which act to turn or rotate the eye about its vertical, horizontal, and antero-posterior axes. These 3 pairs of muscles are called extrinsic because they are external to the eye, in contrast to the ciliary muscles inside the eye. The 3 pairs are:

- Medial rectus (MR) – horizontal
- Lateral rectus (LR) – horizontal
- Superior rectus (SR) – vertical
- Inferior rectus (LR) – vertical
- Superior oblique (SO) – torsion / twisting movements
- Inferior oblique (IO) – torsion / twisting movements
The extraocular muscles can be under voluntary control, but more often, they perform automatic movements. The three nerves responsible are the oculomotor, trochlear and abducens nerves. The muscles anchor the eye to the bony socket, change shape of eyeball for change of focus, move the eyeball independently of the head, and keep movements of both eyes in synchronization.

In the above picture, the trochlea is a ring-like tendon that functions as a pulley, through which the superior oblique muscle passes before it attaches to the eye. And the annulus of Zinn is a cone-shaped structure, behind the eyeball, composed of five extraocular muscles (medial rectus, lateral rectus, superior rectus, inferior rectus, and superior oblique), within which runs the optic nerve, the ophthalmic artery, and the ophthalmic vein.

**Conjunctiva**

The *conjunctiva* is a clear mucous membrane that lines the inner surfaces of the eyelids and continues on to cover the front surface of the eyeball, except for the central clear portion of the outer eye (the *cornea*). The entire conjunctiva is transparent.

The conjunctiva is composed of 3 sections:

1. **palpebral conjunctiva** (covers the posterior surface of the eyelids),
2. **bulbar conjunctiva** (coats the anterior portion of the eyeball), and
3. **fornix** (the transition portion, forming the junction between the posterior eyelid and the eyeball).

Although the palpebral conjunctiva is moderately thick, the bulbar conjunctiva is very thin. The latter also is very movable, easily sliding back and forth over the front of the eyeball it covers. Since it is clear, blood vessels are easily visible underneath it.

Within the bulbar conjunctiva are “goblet cells,” which secrete “mucin.” This is an important component of the pre-corneal tear layer that protects and nourishes the cornea.

The corneal limbus is the border of the cornea and the sclera.
Activity 4: Basic Anatomy of the Eye Video

Purpose: Review basic anatomy of the human eye.
Materials: Computer and Internet
Time: 25 minutes
Website: http://www.ophthobook.com/videos/anatomy-of-the-eye-video

Notes:
Make notes as you watch the Anatomy of the Eye video.

Conjunctiva

Eyelid Muscles

Lacrimal System

The Globe
  Cornea

Chambers of the Eye

Iris and Ciliary Body

Lens

Retina

Eye Muscles
Section IV: Review Functions of the Internal Structures

Fibrous Coat

The outer layer of the eye is called the tunic fibrosa or fibrous tunic and is composed of the cornea and the sclera. The anterior one-sixth of this outer layer bulges forward as the cornea, the transparent dome which serves as the outer window of the eye. The cornea is the primary (most powerful) structure focusing light entering the eye (along with the secondary focusing structure, the crystalline lens).

The cornea is composed, for the most part, of connective tissue with a thin layer of epithelium on the surface. Epithelium is the type of tissue that covers all free body surfaces.

The cornea is composed of 5 layers, from the front to the back:

1. epithelium,
2. Bowman’s (anterior limiting) membrane,
3. stroma (substantia propria),
4. Descemet’s (posterior limiting) membrane, and
5. endothelium (posterior epithelium).

The transparency of the cornea is due to the fact that it contains hardly any cells and no blood vessels. However, blood vessels can creep in from around it, if it is constantly irritated or infected, which can interfere with vision.

On the other hand, the cornea contains the highest concentration of nerve fibers of any body structure, making it extremely sensitive to pain. The nerve fibers enter on the margins of the cornea and radiate toward the center. These fibers are associated with numerous pain receptors that have a very low threshold. Cold receptors also are abundant in the cornea, although heat and touch receptors seem to be lacking.

Along its circumference, the cornea is continuous with the sclera: the white, opaque portion of the eye. The sclera makes up the back five-sixths (posterior) of the eye’s outer layer. It provides protection to the delicate structures within, serves as an attachment for the extraocular muscles, and helps maintain the shape of the eyeball. The sclera is enveloped by the connective-tissue capsule known as the bulbar sheath.

Vascular Coat

The vascular coat (also known as the uvea, tunica vasculosa or vascular tunic) consists of the iris, ciliary body, and choroid and lies between the fibrous coat and the retina.

The iris, visible through the transparent cornea as the colored disc inside of the eye, is a thin diaphragm composed mostly of connective tissue and smooth muscle fibers. It is located between the cornea and the crystalline lens. The color(s), texture, and patterns of each person’s iris are as unique as a fingerprint.
The iris is composed of 3 layers, from the front to the back:

1. **endothelium**,  
2. **stroma**, and  
3. **epithelium**.

The iris divides the *anterior compartment*, the space separating the cornea and the lens, into 2 chambers: the larger *anterior chamber* (between the cornea and the iris), and the smaller *posterior chamber* (between the iris and the lens).

**Eye Color**

The color of the iris, established genetically, is determined by the amount of pigment present in the iris structure. No pigment at all (in the case of an albino) results in a pink iris. Some pigment causes the iris to appear blue. Increasing amounts of iris pigment produce green, hazel, and brown irises (or irides).

There actually are two pigments, **melanin** and **lipochrome**, which determine eye color. Melanin (brown) deposition is controlled by a gene on chromosome 15. Lipochrome (yellowish-brown) deposition is controlled by a gene on chromosome 19.

Rarely, one iris can be a different color than the other iris. This is known as “heterochromia irides” and is determined genetically. Also, a section of one iris may be a different color from the rest of that iris; this is known as “sectoral heterochromia iridis.” Usually, if one of these conditions is present, it is noticeable at birth, although various ocular pathologies can cause any of these conditions to be present.

Unlike what commonly is believed, the iris does **not** change colors in an adult (except in the case of certain pathologies, such as pigment dispersion syndrome). Iris color may **appear** to change, depending upon the color of clothing a person is wearing on a particular day. However, this presumed color change does not actually take place; it is a misperception by the observer, often due to variations in lighting.

**Pupil**

The iris acts like the shutter of a camera. In the middle of a normal iris is the **pupil**, typically a circular hole, comparable to the aperture of a camera. The pupil regulates the amount of light passing through to the **retina**, which is at the back of the eye.

As the amount of light entering the eye diminishes (such as in a dark room or at night), the iris dilator muscle (which runs radially through the iris like spokes on a wheel) pulls away from the center, causing the pupil to “dilate.” This allows more light to reach the retina. When too much light is entering the eye, the iris sphincter muscle (which encircles
the pupil) pulls toward the center, causing the pupil to “constrict” and allowing less light to reach the retina.

Constriction of the pupil also occurs when the crystalline lens accommodates (changes focus) so that the eye can view something at a near distance. This reaction is known as the “near reflex.” Sometimes the pupil does not react properly, due to cranial nerve or muscle problems.

Watching television in a dark room gives some people eye aches or headaches. This is because as the brightness of the television screen fluctuates considerably every few seconds. This causes the dilator and sphincter iris muscles controlling the pupil to have to work overtime, constantly adjusting the ever-changing levels of light entering the eye.

Therefore, it is recommended that a uniform background light source is present in the room while watching television. This will cause the pupils to be slightly constricted, thus causing less variance in the size of the pupil as the television illumination changes. As a result, the muscles controlling the pupil size should become less tired.

The **ciliary body** is an annular (ring-like) structure on the inner surface of the anterior wall of the eyeball and is made up of ciliary muscles and ciliary processes. The **ciliary muscles** are the thickenings around the edge of the choroid and are a band of smooth muscle fibers serving as the chief agent in eye accommodation (how the eye sees objects at different distances from us) when it contracts by drawing the ciliary processes centripetally and relaxing the suspensory ligament of the crystalline lens, permitting the lens to become more convex. The **ciliary processes** are short vascular folds on the inner surface of the ciliary body that give attachment to the suspensory ligaments (zonules) of the crystalline lens.

![Schematic cross section of the human eye](image-url)
The **ora serrata** is the serrated junction between the retina and the ciliary body. This junction marks the transition from the simple non-photosensitive area of the retina to the complex, multi-layered photosensitive region.

The **choroid** is sandwiched between the sclera and retina. This vascular membrane contains large branched pigment cells of melanin to absorb excessive light; else internal reflection would form multiple images on the retina. The choroid contains a network of blood vessels to supply oxygen and food to other parts of the eye, especially to the retina.

**Retina**

The **retina** is the innermost layer of the eye (the *tunica intima* or *internal tunic*) and is comparable to the film inside of a camera. It is composed of nerve tissue which senses the light entering the eye.

This complex system of nerves sends impulses through the **optic nerve** back to the brain, which translates these messages into images that we see. That is, we “see” with our brains; our eyes merely collect the information to do so.

The retina is composed of 10 layers, from the outside (nearest the blood vessel enriched choroid) to the inside (nearest the gelatinous vitreous humour):

1. **pigmented epithelium**,
2. **photoreceptors; bacillary layer** (outer and inner segments of cone and rod photoreceptors),
3. **external (outer) limiting membrane**,
4. **outer nuclear** (cell bodies of cones and rods),
5. **outer plexiform** (cone and rod axons, horizontal cell dendrites, bipolar dendrites),
6. **inner nuclear** (nuclei of horizontal cells, bipolar cells, amacrine cells, and Müller cells),
7. **inner plexiform** (axons of bipolar cells and amacrine cells, dendrites of ganglion cells),
8. **ganglion cells** (nuclei of ganglion cells and displaced amacrine cells),
9. **nerve fiber layer** (axons from ganglion cells traversing the retina to leave the eye at the optic disc), and
10. **internal limiting membrane** (separates the retina from the vitreous).
Light entering the eye is converged first by the cornea, then by the crystalline lens. This focusing system is so powerful that the light rays intersect at a point just behind the lens (inside the vitreous humor) and diverge from that point back to the retina.

This diverging light passes through 9 (clear) layers of the retina and, ideally, is brought into focus in an upside-down image on the first (outermost) retinal layer (pigmented epithelium). Then, amazingly, the image is reflected back onto the adjacent second layer, where the rods and cones are located.

**Photoreceptors (Cones and Rods)**

Four kinds of light-sensitive receptors are found in the retina:

- **Rods**
- Three kinds of cones, each “tuned” to absorb light from a portion of the spectrum of visible light
  - Cones that absorb long-wavelength light (red)
  - Cones that absorb middle-wavelength light (green)
  - Cones that absorb short-wavelength light (blue)

Rods and cones actually face *away* from incoming light, which passes by these photoreceptors before being reflected back onto them. Light causes a chemical reaction with “iodopsin” in cones (activated in photopic or bright conditions) and with “rhodopsin” in rods (activated in scotopic or dark conditions), beginning the visual process.

Activated photoreceptors stimulate bipolar cells, which in turn stimulate ganglion cells. The impulses continue into the axons of the ganglion cells, through the optic nerve, and to the visual center at the back of the brain, where the image is perceived as right-side up. The brain actually can detect one photon of light (the smallest packet of energy available) being absorbed by a photoreceptor.
There are about 6.5 to 7 million cones in each eye, and they are sensitive to bright light and to color. **The highest concentration of cones is in the macula.** The macula is the small, yellowish central portion of the retina. It is the area providing the clearest, most distinct vision. Not uncommonly an eye’s best visual acuity is 20/15, that eye can perceive the same detail at 20 feet that a 20/20 eye must move up to 15 feet to see as distinctly. Some people are even capable of 20/10 acuity, which is twice as good as 20/20. Vision this sharp may be due to there being more cones per square millimeter of the macula than in the average eye, enabling that eye to distinguish much greater detail than normal.

**The fovea centralis (fovea), at the center of the macula, contains only cones and no rods.** Because the fovea has no rods, small dim objects in the dark cannot be seen if you look directly at them. For instance, to detect faint stars in the sky, you must look just to one side of them so that their light falls on a retinal area, containing numerous rods, outside of the macular zone. Rods detect dim light, as well as movement.

There are 3 types of cone pigments; each one is most sensitive to a certain wavelength of light: short (430 to 440 nm), medium (535 to 540 nm), and long (560 to 565 nm). The wavelength of light perceived as brightest to the human eye is 555 nm, a greenish-yellow. (A “nanometer”—nm—is one billionth of a meter, which is one millionth of a millimeter.) Once a cone pigment is bleached by light, it takes about 6 minutes to regenerate.

There are about 120 to 130 million rods in each eye, and they are sensitive to dim light, to movement, and to shapes. The highest concentration of rods is in the peripheral retina, decreasing in density up to the macula.

Rods do not detect color, which is the main reason it is difficult to tell the color of an object at night or in the dark. The rod pigment is most sensitive to the light wavelength of 500 nm. Once a rod pigment is bleached by light, it takes about 30 minutes to regenerate. **Defective or damaged cones result in color deficiency; whereas, defective or damaged rods result in problems seeing in the dark and at night.**
**Lens**

The *lens* is a transparent crystalline biconvex structure located immediately behind the iris. The lens is composed of fibers that come from epithelial (hormone-producing) cells. In fact, the cytoplasm of these cells make up the transparent substance of the lens.

The crystalline lens is composed of 4 layers, from the surface to the center:

1. **capsule,**
2. **subcapsular epithelium,**
3. **cortex,** and
4. **nucleus.**

The lens is a clear, membrane-like structure that is quite elastic, a quality that keeps it under constant tension. As a result, the lens naturally tends towards a rounder or more globular configuration, a shape it must assume for the eye to focus at a near distance.

The lens is suspended from the ciliary body by threadlike ligaments called *zonules or zonules of Zinn.* These slender but very strong suspensory ligaments attach at one end to the lens capsule and at the other end to the ciliary processes of the circular ciliary body, around the inside of the eye. These thin ligaments or zonules hold the lens in place.

When the eye is viewing an object at a *far distance* (such that parallel rays of light are entering the eye), the ciliary muscle within the ciliary body relaxes. The ciliary processes pull on the suspensory ligaments (or zonules), which in turn pull on the lens capsule around its equator. This causes the entire lens to flatten or to become less convex, enabling the lens to focus light from the far-away object.

Conversely, when the eye views an object at a *near distance,* an “accommodative demand” is created. As a result, the ciliary muscle works or contracts, causing tension to be released on the suspensory ligaments and, subsequently, on the lens capsule. This causes both (front and back) lens surfaces to become more convex and the eye to be able to focus at near.

This adjustment in lens shape, to focus at various distances, is referred to as “*accommodation*” or the “accommodative process” and is associated with a concurrent constriction (decrease in size) of the *pupil.* The animated diagram above illustrates the change in stance of the ciliary body, crystalline lens, and pupil as the eye looks back and forth between far and near.
**Aqueous Humor and Vitreous Humor**

**Aqueous humor** is the transparent fluid occupying the anterior compartment (the space between the cornea and crystalline lens) of the eye. The fluid is a solution of mineral salts, sugars and proteins produced by ciliary epithelium, and is circulated into the posterior chamber (between the iris and the crystalline lens), through the pupil, into the anterior chamber (between the cornea and the iris), and out of the eye through the trabecular meshwork and canal of Schlemm. The fluid nourishes the lens and the epithelial cells.

The **vitreous humor**, also known as the **vitreous body**, is a clear gel which occupies the posterior compartment, the vitreous chamber, of the eye, located between the crystalline lens and the retina and occupies about 80% of the volume of the eyeball. Light initially entering through the cornea, pupil, and lens, is transmitted through the vitreous body to the retina. Vitreous humor has the following composition:

1. water (99%)
2. a network of collagen fibrils,
3. large molecules of hyaluronic acid,
4. peripheral cells (hyalocytes),
5. inorganic salts,
6. sugar, and
7. ascorbic acid.

The **hyaloid canal** exists in the vitreous body, linking the optic nerve with the lens. This minute canal contained in foetus development a prolongation of the central artery of the retina, the hyaloid artery. The hyaloid artery grows, in the fetus, outward from the optic cup of the optic nerve into the vitreous cavity. It extends forward to the crystalline lens to aid its development. The hyaloid artery regresses during the last trimester of fetal formation, leaving behind the hyaloids canal, also known as the “Cloquet’s canal”. Sometimes, the hyaloid artery remains after birth and is viewable by a doctor looking into the eye as a “persistent hyaloid artery,” but it rarely is noticeable to the person who has it.

Both the aqueous humor and the vitreous humor are transparent, so they help refract light onto the retina. They are also important in providing **intraocular pressure** to maintain the shape of the eye.
Optic Nerve

The optic nerve (also known as cranial nerve II) transmits electrical impulses from the retina to the brain. It connects to the back of the eye near the macula. The outer layer of the optic nerve that fuses with the sclera where the optic nerve enters the eye is called the dura mater.

The optic nerve is a continuation of the axons of the ganglion cells in the retina. The optic disc or optic nerve head is the location where the ganglion cell axons exit the eye to form the optic nerve. There are approximately 1.1 million nerve cells in each optic nerve. The optic nerve, which acts like a cable connecting the eye with the brain, actually is more like brain tissue than it is nerve tissue.

Visual Pathway

As the optic nerve leaves the back of the eye, it travels to the optic chiasm, located just below and in front of the pituitary gland (which is why a tumor on the pituitary gland, pressing on the optic chiasm, can cause vision problems). In the optic chiasm, the optic nerve fibers emanating from the nasal half of each retina cross over to the other side; but the nerve fibers originating in the temporal retina do not cross over.

From there, the nerve fibers become the optic tract, passing through the thalamus and turning into the optic radiation until they reach the visual cortex in the occipital lobe at the back of the brain. This is where the visual center of the brain is located.

The visual cortex ultimately interprets the electrical signals produced by light stimulation of the retina, via the optic nerve, as visual images.

Blind spot

The beginning of the optic nerve in the retina is called the optic nerve head or optic disc. Since there are no photoreceptors (cones and rods) in the optic nerve head, this area of the retina cannot respond to light stimulation. As a result, it is known as the “blind spot,” and everybody has one in each eye.

The reason we normally do not notice our blind spots is because, when both eyes are open, the blind spot of one eye corresponds to retina that is seeing properly in the other eye.
Activity 5: How Absolutely Blind is Your Blind Spot?

Follow these viewing instructions:

1. Place this paper on a wall and stand about an arm’s length away.
2. Completely cover your left eye (without closing or pressing on it), using your hand or other flat object.
3. With your right eye, stare directly at the ◇ above. In your periphery, you will notice the ◇ to the right.
4. Slowly move closer to the wall, continuing to stare at the ◇.
5. At about 16-18 inches from the wall, the ◇ should disappear completely, because it has been imaged onto the blind spot of your right eye. (Resist the temptation to move your right eye while the ◇ is gone, or else it will reappear. Keep staring at the ◇.)
6. As you continue to look at the ◇, keep moving forward a few more inches, and the ◇ will come back into view.
7. There will be an interval where you will be able to move a few inches backward and forward, and the ◇ will be gone. This will demonstrate to you the extent of your blind spot.
8. You can try the same thing again, except this time with your right eye covered stare at the ◇ with your left eye, move in closer, and the ◇ will disappear.

If you really want to be amazed at the total sightlessness of your blind spot, do a similar test outside at night when there is a full moon. Cover your left eye, looking at the full moon with your right eye. Gradually move your right eye to the left (and maybe slightly up or down). Before long, all you will be able to see is the large halo around the full moon; the entire moon itself will seem to have disappeared.
Retinal Blood Vessels

Blood vessels transport oxygen and nutrients to the eye. Retinal veins are salmon to orange in color. Retinal arteries are salmon to red in color and are about 1 1/3 to 2 times the diameter of retinal veins.

The central retinal artery is a branch of the ophthalmic artery that enters the retina from the middle of the optic nerve and branches to form the arterioles of the retina. The central retinal artery supplies all the nerve fibers that form the optic nerve. The fovea centralis and a small area surrounding it are not supplied by the central artery or its branches, but instead by the choroid.

The central retinal vein is formed by the union of the veins draining the retina and which passes into the middle of the optic nerve. The central retinal vein empties into the superior ophthalmic vein.

The vorticose vein is formed by branches from the back surface of the eye and the ciliary body. This vein empties into the ophthalmic veins.
Activity 6: Structures of the Human Eye

Image courtesy of Wikimedia Commons, Wikipedia.
**Activity 6: Structures of the Human Eye Solution**

<table>
<thead>
<tr>
<th>Number</th>
<th>Structure</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>posterior compartment</td>
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<tr>
<td>2.</td>
<td>ora serrata</td>
</tr>
<tr>
<td>3.</td>
<td>ciliary muscle</td>
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<tr>
<td>4.</td>
<td>ciliary zonules</td>
</tr>
<tr>
<td>5.</td>
<td>canal of Schlemm</td>
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<tr>
<td>6.</td>
<td>pupil</td>
</tr>
<tr>
<td>7.</td>
<td>anterior chamber</td>
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<tr>
<td>8.</td>
<td>cornea</td>
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<tr>
<td>9.</td>
<td>iris</td>
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<tr>
<td>10.</td>
<td>lens cortex</td>
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<td>11.</td>
<td>lens nucleus</td>
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<tr>
<td>12.</td>
<td>ciliary process</td>
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<tr>
<td>13.</td>
<td>conjunctiva</td>
</tr>
<tr>
<td>14.</td>
<td>inferior oblique muscle</td>
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<tr>
<td>15.</td>
<td>inferior rectus muscle</td>
</tr>
<tr>
<td>16.</td>
<td>medial rectus muscle</td>
</tr>
<tr>
<td>17.</td>
<td>retinal arteries and veins</td>
</tr>
<tr>
<td>18.</td>
<td>optic disc</td>
</tr>
<tr>
<td>19.</td>
<td>dura mater</td>
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<tr>
<td>20.</td>
<td>central retinal artery</td>
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<tr>
<td>21.</td>
<td>central retinal vein</td>
</tr>
<tr>
<td>22.</td>
<td>optical nerve</td>
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<tr>
<td>23.</td>
<td>vorticose vein</td>
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<tr>
<td>24.</td>
<td>bulbar sheath</td>
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<tr>
<td>25.</td>
<td>macula</td>
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<tr>
<td>26.</td>
<td>fovea</td>
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<tr>
<td>27.</td>
<td>sclera</td>
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<tr>
<td>28.</td>
<td>choroid</td>
</tr>
<tr>
<td>29.</td>
<td>superior rectus muscle</td>
</tr>
<tr>
<td>30.</td>
<td>retina</td>
</tr>
</tbody>
</table>

Image courtesy of Wikimedia Commons, Wikipedia.
Activity 7: Dissecting a Sheep Eye

Purpose: To examine and understand the external and internal structures of the eye by dissecting a sheep eye.

Materials:

1 sheep / cow eye
1 dissecting probe
1 pair of dissecting scissors
1 pair of gloves

Use Laboratory Procedures and Precautions.

Resources:

Dissection of a Sheep’s Eye
http://www.geocities.com/centennial3d/sheep_eye.html

Biological Supply Companies:

Ward’s Natural Science
PO Box 92912
Rochester, NY 14692-9012
1-800-962-2660
http://wardsci.com
Item # 69 V 7192 (Sheep Eyes, Preserved, Jar of 10)

Frey Scientific
80 Northwest Blvd
Nashua, NH 03063
1-800-225-3739
http://www.freyscientific.com
Item #: 596874016 (Sheep Eyes, Pack of 10)

Fisher Scientific
2000 Park Lane Drive
Pittsburg, PA 15275
1-800-766-7000
http://www.fishersci.com
Catalog Number: S9224S (Sheep Eyes, Pack of 10)

Connecticut Valley Biological Supply Company
82 Valley Road
PO box 326
Southampton, MA 01073
1-800-628-7748
http://www.connecticutvalleybiological.com
Model: P 9650
Activity 8: Internet Interactive Study Aids

Go to the following website, WebAnatomy – University of Minnesota at the following link:
http://www.msjensen.gen.umn.edu/webanatomy/

1. Select “Nervous” from the left column.
   a. Take the “Eye 1” interactive self-test.
      __________  Number correct out of 5
   b. Take the “Eye 2” interactive self-test.
      __________  Number correct out of 10
   c. Take the “Eye 3” interactive self-test.
      __________  Number correct out of 8
   d. Take the “Eye 4” interactive self-test.
      __________  Number correct out of 10

   a. Take the “Eye” timed-test (under “Senses). Note: There are a total of 7 timed-tests; click on the small images at the top to load its larger image.
      __________  Number correct out of 6
      __________  Number correct out of 7
      __________  Number correct out of 7
      __________  Number correct out of 5
      __________  Number correct out of 6
      __________  Number correct out of 4
      __________  Number correct out of 7
Section V: Human Eye Common Disorders and Diseases

Astigmatism

Astigmatism is a defect of an ocular structure (most commonly the cornea or the crystalline lens) causing rays from a point to fail to meet in a single focal point, resulting in an imperfect blurred or smeared image.

Astigmatism may be corrected with eyeglasses, contact lenses, or refractive surgery. Various considerations involving ocular health, refractive status, and lifestyle frequently determine whether one option may be better than another.

Cataract

Normally, all the layers of the crystalline lens are clear, and light passes through it unobstructed. However, with age or due to certain systemic diseases, as well as with a cumulative absorption of ultraviolet radiation over many years, the lens material can become cloudy, yellow, brown, and even opaque. A clouding of the lens that affects vision is referred to as a cataract. More than 50% of people over the age of 60 have some form of a cataract. It has been said that if one lives long enough, he/she will develop a cataract. Even some infants are born with a “congenital” cataract which, if left untreated, can cause permanent visual impairment or blindness, even if the cataract is removed years later.

It is not possible to remove a primary cataract without irreparably damaging the crystalline lens within which the cataract is contained. A laser cannot be used successfully to remove a cataract, except as described later (in the case of a secondary cataract). Therefore, cataract surgery involves removing most or all of the lens of the eye and replacing it with an artificial “intraocular lens” or “lens implant,” made of a hard plastic (polymethyl methacrylate or PMMA), silicone, acrylic, or hydrogel material.

An “extracapsular” cataract extraction (ECCE) is the routine type of cataract removal. In an ECCE procedure, an opening is made in the front of the lens capsule. Through this opening, the lens nucleus is removed, either as a whole or by dissolving it into tiny pieces and vacuuming out the pieces, a procedure called “phacoemulsification.” Next, the lens cortex also is sucked out, leaving the lens capsule in place, and into the lens capsule is inserted the artificial lens implant. Prior to the 1980’s, the entire crystalline lens was removed in a cataract surgery, called an “intracapsular” cataract extraction (ICCE). Usually, this was performed using “cryoextraction,” where a cryoprobe froze the entire lens, permitting its complete removal. Now, in the unusual case of an intracapsular lens extraction, or ICCE, the implant lens is placed in front of the iris.
rather than behind it, because there is no lens capsule to hold the implant in place. Rarely is this procedure done anymore.

Naturally occurring carotenoids in the crystalline lens—lutein and zeaxanthin (molecular cousins of beta carotene and vitamin A)—have been shown to reduce the risk of cataracts. These pigments act as antioxidants within the lens, inhibiting the formation of free radicals, which can damage lenticular material and contribute to the development of cataracts.

Thus, it may be that the greater the amount of antioxidants such as lutein and zeaxanthin in the system, the less the risk of cataract formation. These two antioxidants are found particularly in yellow fruits and in green leafy vegetables (especially xanthophyll-rich vegetables such as spinach, kale, collard greens, and broccoli), in eggs, and as nutritional supplements.

**Secondary Cataract**

Not uncommonly, following an “extracapsular” cataract extraction (ECCE), a few cells of the crystalline lens cortex remain adhered to the inner surface of the posterior lens capsule. After a few weeks or months, these cells can become opaque, resulting in a secondary cataract. Fortunately, the eye does not have to be reopened for this simple cataract to be removed. Rather, a YAG (yttrium aluminum garnet) laser is used, in a procedure taking only a few minutes, to fire through the clear cornea and pupil and to obliterate the secondary cataract (and a small portion of the capsule behind it). This enables light to pass into the eye again, unobstructed. If this laser procedure is successful, a cataract never again should pose a problem for that eye.

**Color Blindness**

Color blindness, a color vision deficiency, is a condition in which certain colors cannot be distinguished. It is most commonly due to an inherited condition, but may also occur because of eye, nerve, or brain damage, or due to exposure to certain chemicals. Red/Green color blindness is by far the most common form and causes problems distinguishing reds and greens.

There is no treatment for color blindness, nor is it usually the cause of any significant disability. However, it can be very frustrating for individuals affected by it. Those who are not color blind seem to have the misconception that color blindness means that a color blind person sees only in black and white or shades of gray. While this sort of condition is possible, it is extremely rare. Being color blind does keep one from performing certain jobs and makes others difficult.

Color blindness can be inherited genetically. It is most commonly inherited from mutations on the X chromosome. Inherited color blindness can be congenital (from birth), or it can commence in childhood or adulthood. Depending on the mutation, it can be stationary, that is, remain the same throughout a person’s lifetime, or progressive. As progressive phenotypes involve deterioration of the retina and other parts of the eye, certain forms of color blindness can progress to legal blindness, i.e. an acuity of 6/60 or worse, and often leave a person with complete blindness.

Color blindness always pertains to the cone photoreceptors in the retinas as the cones are capable of detecting the color frequencies of light.
About 5 to 8 percent of males, but less than 1 percent of females, are color blind in some way or another, whether it be one color, a color combination, or another mutation. The reason males are at a greater risk of inheriting an X linked mutation is because males only have one X chromosome (XY, with the Y chromosome being significantly shorter than the X chromosome), and females have two (XX). If women inherit a normal X chromosome in addition to the one which carries the mutation, they will not display the mutation, while men have no “spare” normal chromosome to override the chromosome which carries the mutation.

**Conjunctivitis (pink eye)**

Bacterial or viral *conjunctivitis* (or “pink eye”) is an inflammation of irritated or infected conjunctiva. Someone with such a conjunctivitis must be careful not to touch the infected eye. If that occurs, it is imperative to wash the hands well, because the infection easily can be transferred to the other eye and/or to the eyes of other people.

An allergic reaction to something can cause conjunctival redness, extreme itching, and excessive ocular mucous production. The reaction, called “allergic conjunctivitis” or “vernal conjunctivitis,” can occur due to seasonal allergies (usually in the Spring and Fall of the year).

Not uncommonly, allergic conjunctivitis can result from a reaction to proteins deposited on the surface of contact lenses, most commonly daily wear soft lenses. The latter can result in “giant papillary conjunctivitis” (GPC), mostly evidenced by the appearance of large “papillae” on the superior conjunctival tarsal plate (underneath the upper eyelid). Each papilla is a collection of lymphocytes and plasma cells.

Elimination of conjunctival papillae often is not easy. Obtaining new contact lenses, with reduced wearing time and with regular enzymatic cleaning of the lenses, is recommended. Sometimes it is best to be refit with disposable soft lenses or with rigid gas permeable (RGP) lenses. With these lenses, protein build-up is not as much of a problem as it is with daily wear lenses, though it still can occur.

Many people develop callous-like thickenings of the conjunctiva on the front of the eye, usually located on the nasal portion of the conjunctiva. Such eyes are susceptible to irritation caused by dry climates (especially with windy conditions), as well as toxic vapors, salt water spray, excessive exposure to the sun (ultraviolet radiation), and even inadequate natural lubrication of the eye (tears).

**Subconjunctival Hemorrhage**

A somewhat common condition, caused by direct or indirect trauma to the eye, is a subconjunctival hemorrhage. This manifests as a spot or pool of blood underneath the clear conjunctiva. It can be seen in distinct contrast to the *sclera* or white part of the eye.
The hemorrhage may be present on only one side or on both sides of the cornea, and it almost always is on only one eye, unless the trauma has affected both eyes.

The trauma causing the hemorrhage may be due to a blunt hit, hard coughing, pushing, straining, heavy lifting, or even hypertension. Any of these things can cause a small blood vessel to break and to leak blood underneath the conjunctiva. A subconjunctival hemorrhage is one of the worst looking things that is harmless and will not affect vision. No treatment is necessary. The blood should reabsorb and disappear in 1-2 weeks, depending on the extent of the bleeding.

**Dry Eye**

A deficiency of any of the three layers of the tear film can lead to a **dry eye** condition, causing anything from mild eye irritation to severe pain. Interestingly, in some cases, excessive tearing or watering of the eyes can be a symptom of a dry eye condition. This is because when, for whatever reason, there is an inadequate normal tear layer on the eye, irritation results; this causes an overproduction of the lacrimal gland and a flooding of lacrimal fluid into the eye (“reflex tearing”).

Besides excessive tearing, symptoms associated with dry eyes can include the following:

- eye irritation, scratchiness, grittiness, or pain;
- redness of the eye(s);
- a burning sensation in the eye(s);
- a feeling of something in the eye(s);
- eyes that feel “glued shut” after sleeping;
- blurred vision; and
- eye discomfort with contact lens wear.

There can be multiple causes of a dry eye condition, and these are some of the possibilities:

- lid or blinking problems (for instance, an injury or stroke affecting one of the nerves which helps us blink);
- reading or working at a computer screen for long periods of time;
- medications like antihistamines, oral contraceptives, beta blockers, diuretics, tranquilizers, pain relievers, or antidepressants;
- a dry climate (including heating and air conditioning in a home, airplane, or motel room), wind, UV radiation, tobacco smoke, and dust;
- diseases such as rheumatoid arthritis, Sjogren’s syndrome, keratoconjunctivitis sicca, xerophthalmia, lupus erythematosus, Grave’s disease, diabetes, or scleroderma;
- hormonal changes accompanying menopause;
- chemical, radiation, or thermal burns to the eye;
- vitamin A deficiency;
- aging, since the tear glands produce fewer tears as we age; and
- idiopathic (unknown) causes.
A dry eye problem often can be relieved with the use of over-the-counter eyedrops which behave as “artificial tears” on the eyes. These types of drops can soothe the eyes, moisturize dry spots, supplement tears, and protect eyes from further irritation. Some drops are formulated to match the pH of human tears for added comfort. Special ocular lubricant ointments, applied to the eyes for overnight use, also are available.

Artificial tears may be preserved or unpreserved. Bottle contamination is less likely with preserved drops; however, an allergic reaction to the preservatives can occur. If unpreserved eyedrops are used, care must be taken not to contaminate the bottle by touching the tip to any surface, including the eyeball.

Some eyedrops contain “vasoconstrictors” (chemicals such as tetrahydrozaline or naphazoline), which constrict the conjunctival blood vessels, thereby reducing the amount of redness on the surface of the eyes. These drops may or may not contain a tear substitute component for red eyes. Overuse of such drops can cause eyes to become even more red (“rebound hyperemia”), due to a weakening of the muscles persistently constricting the blood vessels.

In certain cases, artificial tear drops do not relieve the discomfort due to dry eyes. In such cases, if the discomfort is severe enough, other options are available. The most common of these involves closing the tear ducts (which act as “drains” for the tears). Using either a silicone plug or scarring the tear duct closed by cautery (“hot poker”) decreases or stops the passage of the tears into the tear ducts. That way, any tears naturally produced, or artificially placed into eyes, will remain longer (until they evaporate). It can be a very successful way to make irritated eyes with a chronic dry eye syndrome feel more comfortable.

**Glaucoma**

Glaucoma is an insidious disease which damages the optic nerve, typically because the *intraocular pressure (IOP)* is higher than the retinal ganglion cells can tolerate. This eventually results in the death of the ganglion cells and their axons, which comprise the optic nerve. Thus, less visual impulses are able to reach the brain.

In advanced glaucoma, the visual field in the peripheral retina is decreased or lost, leaving vision in the central retina (macular area) intact. This results in “tunnel vision.” Elevated eye pressure occurs when too much aqueous fluid enters the eye and not enough of the aqueous fluid is leaving the eye. Eye pressure can be measured by performing a “tonometry” test.

Normally, fluid enters the eye by seeping out of the blood vessels in the *ciliary body*. This fluid eventually makes its way past the *crystalline lens*, through the *pupil* (the central opening in the *iris*), and into the *irido-corneal angle*, the anatomical angle formed where the iris and the cornea come together. Then the fluid passes through the *trabecular meshwork* in the angle and leaves the eye, via the *canal of Schlemm*.

If the rate of aqueous fluid is entering the eye is too great, or if the trabecular meshwork “drain” gets clogged (for instance, with debris or cells) so that the fluid is not leaving the eye quickly enough, the pressure builds up in what is known as “open angle glaucoma.” It is more common with increasing age.
Open angle glaucoma, which tends to be a chronic and painless condition, also can be caused when the posterior portion of the iris, surrounding the pupil, somehow adheres to the anterior surface of the lens (creating a “pupillary block”). This can prevent intraocular fluid from passing through the pupil into the anterior chamber.

On the other hand, if the angle between and iris and the cornea is too narrow, or is even closed, then the fluid backs up because it cannot flow out of the eye properly. This causes an increased intraocular pressure in what is known as “closed angle glaucoma.” Typically, there is an acute (sudden), painful onset. It can be accompanied by the appearance of rainbow-colored rings around white lights.

An internal pressure more than that which the eye can tolerate can deform the lamina cribrosa, the small cartilaginous section of the sclera at the back of the eye through which the optic nerve passes. A deformed lamina cribrosa seems to “pinch” nerve fibers passing through it, eventually causing axon death. Untreated glaucoma eventually leads to optic atrophy and blindness.

Eye pressure is measured by using a “tonometer” (with the test being called “tonometry”), and the standard tonometer generally is considered to be the “Goldmann tonometer.” The normal range of intraocular pressure (IOP) is 10 mm Hg to 21 mm Hg, with an average of about 16 mm Hg. Typically, eyes with intraocular pressure measurements of 21 mm Hg or higher, using a Goldmann tonometer, are considered to be “ocular hypertensive” and are suspect for glaucoma.

However, although glaucoma typically is associated with elevated IOP, the amount of pressure which will cause glaucoma varies from eye to eye and person to person. Many people with glaucoma actually have IOP’s in the normal range (“low tension” glaucoma), possibly indicating that their lamina cribrosas are too weak to withstand even normal amounts of pressure. Conversely, many people with IOP’s which would be considered high have no evidence of glaucomatous damage.

The modern goals of glaucoma management are to avoid glaucomatous damage, preserve visual field and total quality of life for patients with minimal side effects. Glaucoma management requires appropriate diagnostic techniques and follow up examinations and judicious selection of treatment for individual patients. Intraocular pressure can be lowered with medication, usually eye drops. Both laser and conventional surgeries are performed to treat glaucoma. Generally, these operations are a temporary solution, as there is not yet a cure for glaucoma.
Hyperopia (Farsightedness)

Hyperopia is a condition in which visual images come to a focus behind the retina of the eye and vision is better for distant than for near objects. The causes of hyperopia are typically genetic and involve one eye that is too short or a cornea that is too flat, so that images focus at a point behind the retina. People with hyperopia can usually see distant objects well, but have trouble focusing on nearby objects.

Minor amounts of hyperopia are sometimes left uncorrected, however, larger amounts may be corrected with convex lenses in eyeglasses or contact lenses or by refractive surgery.

Iritis / Uveitis / Chorioretinitis

It is not uncommon for the iris, the entire uvea, and/or the choroid/retina complex to become inflammed. Here are types of inflammation of the uveal tract:

- iritis: inflammation of the iris alone,
- iridocyclitis: inflammation of the iris and ciliary body,
- choroiditis: inflammation of the choroid alone,
- chorioretinitis: inflammation of the choroid and retina, and
- uveitis: inflammation of the entire uveal tract

Although the exact cause of an iritis or uveitis often is unknown, in many cases the inflammation is related to a disease or infection in another part of the body (that is, a systemic problem). Sometimes these (and other) diseases can cause uveal inflammation: arthritis, tuberculosis, syphilis, ankylosing spondylitis, Reiter’s syndrome, toxoplasmosis, histoplasmosis, cytomegalovirus (CMV), sarcoidosis, and toxocariasis. Infection of some parts of the body (tonsils, sinus, kidney, gallbladder, and teeth) also can cause inflammation of the iris or of the entire uveal tract.

The symptoms of iritis usually appear suddenly and develop rapidly over a few hours or days. Iritis commonly causes pain, tearing, light sensitivity, and blurred vision. A red eye, usually with inflammed blood vessels around the limbus (the junction of the cornea and sclera), often is present when there is an iritis. Some people may see floaters, which appear as small specks or dots moving in the field of vision. In addition, the pupil may become smaller in the eye affected by iritis.

Caught in the early stages, an iritis or uveitis usually is readily treated with corticosteroids and/or antibiotics. However, without treatment, or with chronic occurrences of the inflammation, there can be a permanent decrease in vision or, in rare cases, even blindness.
A case of iritis usually lasts 6 to 8 weeks. During this time, a person should be observed carefully (by an optometrist or ophthalmologist) to monitor potential side effects from medications and any complications which may occur. Cataracts, glaucoma, corneal changes, and secondary inflammation of the retina may develop as a result of iritis and/or the medications used to treat the disorder.

**Macular degeneration**

Certain conditions can affect the macula and, in turn, one’s central vision. Probably the most common is *macular degeneration*, a hereditary ocular disease. Age-related macular degeneration (ARMD) is the leading cause of irreversible blindness among Americans 65 and older.

*“Dry” macular degeneration* generally is caused by a thinning of the macula’s layers, and vision loss typically is gradual. However, tiny, fragile blood vessels can develop underneath the macula.

*“Wet” macular degeneration* can result when these blood vessels hemorrhage, and blood and other fluid further can destroy macular tissue, even causing scarring. In this case, vision loss can be rapid—over months or even weeks—as well as very devastating.

Macular tissue destroyed by either dry or wet macular degeneration cannot be repaired. In the case of the wet form, a special laser can be used to seal the leaking blood vessels in the retina. However, 1) the tiny spots where the laser burns the retina will lose vision permanently, and 2) other blood vessels may leak in the future, requiring further laser treatment.

The earliest symptom of macular degeneration usually is persistently blurred vision. As more cells of the macula are destroyed, objects become distorted (for instance, straight lines become crooked). Eventually, a small area of no vision, in the central visual field, can develop and grow in size. This can progress to the point of “doughnut” vision, where people’s faces are unrecognizable when looking directly at them, yet peripheral vision remains unaffected.

Naturally occurring carotenoids in the macula, *lutein* and *zeaxanthin* (molecular cousins of beta carotene and vitamin A), have been shown to be effective protectants against degeneration of the macula. These pigments essentially act built-in macular “sunglasses” by absorbing, and filtering out, near-to-blue ultraviolet radiation, which potentially is the most damaging electromagnetic radiation reaching the macula.

Thus, the greater the amount of macular pigment there is, the less the risk is for developing macular degeneration. Lutein and zeaxanthin are found particularly in yellow fruits and in green leafy vegetables (especially xanthophyll-rich vegetables such as spinach, kale, collard greens, and broccoli), in eggs, and as nutritional supplements.
Myopia (Nearsightedness)

Myopis is a condition in which visual images come to a focus in front of the retina of the eye and vision is better for near than for far objects. This may be due to the surface(s) of the cornea and/or crystalline lens having excessive (too steep) curvature, an eyeball which is too long, and/or an index of refraction of one of the ocular media that is too high.

Eyeglasses, contact lenses, and refractive surgery are the primary options to treat the visual symptoms of those with myopia.

Presbyopia

Presbyopia is a condition which becomes apparent most often during the age span 40 to 45 in which loss of elasticity of the crystalline lens causes reduced accommodation and the inability to focus sharply at a near distance.

Since presbyopia is a natural part of the human aging process, it is not routinely curable. Treatment for presbyopia has advanced significantly in recent years, thanks in no small part to the ready availability of inexpensive over-the-counter reading glasses with corrective lenses that cover a wide range of magnification level. Contact lenses have also been used to correct the focusing loss that comes along with presbyopia. Some people choose to correct the focus problems with bifocals, giving them a wider range of vision without having to use a second set of glasses. As the focusing loss increases, prescription changes become more frequent.
Activity 9: Eye Disorder Crossword Puzzle

CLUES

Across
1  Deficiency of the tear film (2 words)
3  Common name of conjunctiva inflammation or infection (2 words)
6  A clouding of the lens that affects vision
8  Condition where visual images come to focus in front of the retina
10 Disease damaging the optic nerve

Down
2  Condition where visual images come to focus behind the retina
4  Inflammation of iris
5  Diminished ability to focus on near objects with age
7  Condition where rays from point fail to meet in a single focal point
9  Inflammation of entire uveal tract
Activity 9: Eye Disorder Crossword Puzzle Solution

2 H 9 U
1 D R Y E Y E V
5 P 8 R
3 P 4 I N K E Y E 6 C 7 A T A R A C T T
6 C 7 A T A R A C T T

3 R S S O I
3 R S S O I
3 R S S O I
3 R S S O I

10 G L A U C O M A
10 G L A U C O M A
10 G L A U C O M A
10 G L A U C O M A

10 G L A U C O M A
10 G L A U C O M A
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10 G L A U C O M A

These materials are for the internal use of MESA staff and teachers only and should not be forwarded or used outside of MESA.
**References**

Information for this curriculum was taken from the following websites:


- The Eye-Opener, Oracle ThinkQuest Education Foundation. Thinkquest entry number 28030. [http://library.thinkquest.org/28030/index.htm](http://library.thinkquest.org/28030/index.htm)


