Structure and Anatomy of the Eye

Learning Objectives

Through examining images from the Memento Mütter exhibit (memento.muttermuseum.org) and hands-on activities, students will

• Understand the basic structure and function of the human eye.
• Understand how the photoreceptors, specialized cells in the retina, allow the eye to process light.

Note: This lesson can serve as an introduction to The College of Physicians of Philadelphia’s lesson Eye Diseases: Diagnosis and Detection. It can also provide contextual information for a cow eye dissection.

Time Required for Lesson: Approximately 30-40 minutes

Answers to Student Worksheets: Email info@collegeofphysicians.org

Class Preparation

Print out the attached images of the Hardy-Rand-Rittler Pseudoisochromatic Plates.

This lesson will make use of a camera obscura to demonstrate how light passes through the eye. Depending on resources and availability of space, the camera obscura can be made as a handheld “pinhole camera” that can be passed around during class. Alternatively, an entire room can be converted into a camera obscura for an impressive visual display!

How to make a camera obscura/pinhole camera

Note: Depending on the size of your class, you may want to make several handheld pinhole cameras to pass around.

Supplies needed:

A Pringles tube
Aluminum foil
Waxed paper
Masking, electrical, or duct tape
A straight pin or push pin
Ruler
Marker
Hobby knife, box cutter or scissors

Directions

http://www.hometrainingtools.com/a/pinhole-camera-science-project

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Step 1: Use the marker to make a line around the circumference of the tube two inches above the bottom.

Step 2: Cut the tube along the line you made, separating the tube into a long and short piece.

Step 3: Using the straight pin, carefully make a small hole in the center of the metal end.

Step 4: Cut a circle of waxed paper and use it to cover it to the end of the short piece of the tube (opposite the metal end).

Step 4: Tape the end with the waxed paper to the longer cardboard piece, making sure that no light passes through the ends but covering the point at which they connect with tape.

Step 6: Cut a piece of aluminum foil the length of the cardboard tube and wrap the foil around the tube. Secure the foil with tape so that no light can pass through it without covering the ends. The only points where light can enter the tube should be at the ends.

_How to turn a room into a camera obscura_

_Note: Ideally, this method works best if the classroom has windows on one wall and a white wall or projection screen on the wall opposite the window(s)._ 

**Supplies needed:**

Black poster board (enough to cover all the windows in the room)

Black Tape

A hobby knife or scissors

Optional: White sheet or projection screen

Step 1: Use the black poster board to cover the windows in the room. Secure them with the tape. Make sure no light can pass through.

Step 2: Cut a small, circular hole in the center of the poster board. This hole will serve as the “pupil” of the eye.

Step 3: Hang the white sheet on the wall directly opposite the hole in the poster board. This will serve as the “retina.”

**Optional:** Print out the attached _Eye Anatomy Assessment_ and _Eye Comparison Assignment_ sheets.

**Academic Standards (Lesson, Activities, and Assignments)**

Next Generation Science Standards: HS-LS1-2, HS-LS1-3

Common Core Standards: CCSS.ELA-Literacy.9-10.4, CCSS.ELA-Literacy.11-12.4

**Key Terms**

_Aqueous Humor:_ A clear fluid at the front of the eyeball that nourishes the eye and helps maintain its shape.

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Blind Spot: Portion on the retina where there are no photoreceptors.

Color Vision Deficiency: The inability to distinguish certain colors. Also known as color blindness.

Cones: Photoreceptors responsible for processing colors. Located primarily in the fovea.

Cornea: A clear covering around the front of the eye that serves as protection for the pupil and iris.

Fovea: An indented part of the retina at the center point of the macula. Contains a high concentration of cones.

Iris: The colored part at the front of the eye. Regulates the size of the pupil, contracting or dilating it based on the amount of light to which the eye is exposed.

Lens: Located between the iris and pupil, the lens is used to focus on objects and projects an image onto the retina. Adjusts based on the distance of objects.

Macula: A central point in the retina upon which light passing through the eye is focused. Responsible for central (focused) vision.

Optic Nerve: A collection of nerves connected to the retina that serve as a pathway through which optical signals travel from the eye to the brain.

Photoreceptors: Cells within the retina that process light into information and send the image to the optic nerve. Photoreceptors come in two varieties: rods and cones.

Pupil: The opening at the front of the eye through which light passes. Its size is regulated by the iris.

Retina: The lining of the inside surface of the eye which converts light into electrical impulses. The impulses are sent to the brain through the optic nerve.

Rod: Photoreceptors responsible for processing light. Located mostly on the periphery of the retina.

Sclera: The fibrous outer layer of tissue surrounding the eye that maintains the eye’s shape. The “white of the eye.”

Visual Cortex: The section of the brain responsible for vision.

Vitreous Gel (also known as Vitreous Humor): A jelly-like substance in the back of the eye that keeps the retina in place.

Overview:

We live in a society based strongly on visual stimuli. Movies, television, Internet videos, video games and the like rely on our ability to perceive images. All of this is possible through the use of our eyes. The human eye is a product of millions of years of complex evolution. Our eyes have developed to take in light and process it into images our brains can interpret.

Lecture Materials:

Part 1: The Parts of the Eye

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The eye is a complex organ, with many intricate parts which when working together allow us to see.

Figure 1. Drawing of the Eye. Source: National Eye Institute, National Institutes of Health. Used under Creative Common license 2.0. No changes have been made.

Figure 2. Papier-mâché Eyeball Model, with labeled parts, Accession No. F1993.701

Visual Demonstration:

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Bring up the image of the Papier-mâché Eyeball Model on Memento.MutterMuseum.org

Teacher’s Note: Click on the Explore button to rotate the online model to demonstrate the parts of the eye. Use the model to demonstrate the various parts of the eye to the class, using the above diagram (Fig.1 ) as a guide.

**Key Parts of the Eye and their Use:**

- **Cornea:** A clear covering around the front of the eye that serves as protection for the pupil and iris.

- **Pupil:** The opening at the front of the eye through which light passes. Its size is regulated by the iris.

- **Iris:** The colored part at the front of the eye. Regulates the size of the pupil, contracting or dilating it based on the amount of light to which the eye is exposed.

- **Sclera:** The fibrous outer layer of tissue surrounding the eye that maintains the eye's shape. The “white of the eye.”

- **Vitreous Gel (Also known as the Vitreous Humor):** A jelly-like substance in the back of the eye that keeps the retina in place.

- **Retina:** The lining of the inside surface of the eye which converts light into electrical impulses.

- **Fovea:** An indented part of the retina at the center point of the macula. Contains a high concentration of cones.

- **Macula:** A central point in the retina upon which light passing through the eye is focused. Responsible for central (focused) vision.

- **Optic Nerve:** A collection of nerves connected to the retina that serve as a pathway through which optical signals travel from the eye to the brain.

**A Brief Introduction to The Mechanics of Sight, or How Does the Eye Work?**

Light makes contact with the cornea and passes through the pupil. The amount of light entering through the pupil is regulated by the iris, which expands or contracts the pupil to allow for more or less light. When there is little to no light, the iris expands (dilates) the pupil to allow the eye to take in as much light as possible. When exposed to excess light, the iris contracts the pupil to protect the eye and minimize the amount of light it receives.

Like the lens of a camera, the eye’s lens adjusts to focus on images and allow for clear vision. The lens can expand or contract, becoming thicker or thinner depending on the object’s distance from the eye. The movement of the lens helps to bend, or refract, the light as it enters the eye, allowing for clearer focus.

Once through the lens, the light then passes through the vitreous humor where the light is refracted (bent) on its way to the retina (more on the retina below). The retina contains millions of specialized cells called photoreceptors. The photoreceptors—broken into rods and cones—process the light into information that is then sent to the visual cortex of the brain via the optic nerve.²


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Figure 3. Illustration of light passing through the pupil onto the retina.

**Visual Demonstration: Camera Obscura**

“The Eye is essentially an *optical* instrument, constructed for receiving, *bending* (refracting), and throwing the rays of light on to a screen (the retina) at its back, so that it shall receive a very *minute* and *inverted*, but clear and definite, picture or *image* of the surrounding objects. In fact, in no case do we see the external objects themselves, but a *picture of them focused by the light sent from them*, and *focused on the back of the eye* (the retina), as *just described*. The eye is, in fact, a sort of water *camera obscura*....”—John Angell, *Elements of Animal Physiology, Chiefly Human*.³

In some respects, the eye processes light in a manner similar to modern cameras. Much like a camera, the eye has a lens, which adjusts to allow the eye to focus on objects and allow for clear vision. Damage or deterioration to the lens, as in the case of cataracts, can result in an inability to focus and lead to blurred vision. Also like a camera, light is bent within the eye and projected onto the retina.

A way to visualize how light is received and processed by the eye is by using a device known as a *camera obscura*. Latin for “dark room,” the *camera obscura* is a predecessor to modern cameras. The device is effectively a projector receiving light through a narrow opening at one end and displaying an image on a screen on the opposite end. These “pinhole cameras” can be made as self-contained picture boxes; however, it is possible to convert an entire room into one large *camera obscura*. Numerous scientists from antiquity, including Leonardo da Vinci, Johannes Kepler, and Rene Descartes used *camera obscuras* as a simple way of illustrating how vision worked.

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The room-based camera obscura provides an impressive visual demonstration. However, depending on the complications of setup and time restrictions, it may be easier to use a handheld version.

Have the students observe how the light projects through the camera obscura. Similar to the light passing through the eye, the image projected through the camera obscura is upside-down and reversed. This is because light passes along a straight line, meaning that the top part of an image is projected on the bottom part of the retina and vice versa.

Part 2: Focusing on the Retina:

The rear wall of the eye is lined with a membrane known as the retina. As explained earlier, images that enter the eye through the pupil are projected on the retina. In the camera obscura demonstration, the surface onto which the inverted image is displayed serves the role of the retina.

The retina contains millions of specialized cells called photoreceptors. Photoreceptors process light that comes into the eye into neural impulses that are sent to the brain via the optic nerve.

There are two kinds of photoreceptors: rods and cones. Each is named after their shape, and each processes different kinds of light. Photoreceptors, both rods and cones, are comprised of discs that hold specialized proteins (called Rhodopsin and Photopsin, respectively) that absorb certain kinds of light. The absorption of light by the rods and cones allow humans to perceive different kinds of vision. There is also a spot in the eye that has no photoreceptors whatsoever. This is known as the blind spot, and it is located at the point where the eye connects to the optic nerve.

Rods:

Rods are elongated photoreceptors spread along the periphery of the retina, except around the fovea (where the cones are located). As a result, the human retina has significantly
more rods than cones. Rods are responsible for processing low light vision and allow us to perceive changes in light and darkness. Rods allow the eye to process black and white; however they do not process colors.

**Visual Demonstration of Rods:**

Notice during the *camera obscura* demonstration that as the room darkens, our ability to perceive colors begins to dim. This is because rods are responsible for processing low light but they do not perceive colors. If not using the room *camera obscura*, cover any windows and turn off any lights. Have the students observe how our perception of color changes under less light.

**Cones:**

Cones are conical photoreceptors located primarily in a centralized point on the retina called the fovea. Cones are responsible for processing color vision. There are three different kinds of cones, each processes a different color: red, green, and blue.

**Visual Demonstration of Cones: Hardy-Rand-Rittler (HRR) Test**

This demonstration involves using a method doctors use to measure a subject’s color perception (the kind of vision made possible by the cones) called a pseudoisochromatic test. The patient is shown a series of plates containing dots of varying sizes and hues. Dots of certain colors are arranged to form symbols. The patient’s perception (or lack thereof) of the hidden images is used to determine whether a patient has a color vision deficiency (CVD), or an inability to distinguish between colors (commonly known as “color blindness”). The two most common tests are the Ishihara test and the Hardy-Rand-Rittler (HRR) test. According to the instructions provided by LeGrand H. Hardy, Gertrude Rand, and M. Catherine Rittler, the developers of the test, administration of the HRR test takes place as follows:

Seat the subject about 30 inches from the test book. Present the four demonstration pieces showing that there may be two, one, or no colored symbols (triangle, circle or cross) on a plate and that such symbols may appear in any of the four corners of a plate. Tell him that the test plates may have similar designs in varying intensities of color and that only colored symbols are to be reported. Exhibit the test plates and require the subject to state first the number of colored designs on each plate and, next, the name of each symbol. As each test plate is exposed it is important to obtain an *immediate* response as to the number of designs seen. A good way to enforce this is to ask as each plate is shown: “How many colored designs do you see there?” and then: “What are they?” Revision of opinion regarding the number of designs is not allowed. The names of the reported designs can be recorded quickly on the record form if “^” is used for triangle, “O” for circle, and “X” for cross. Errors are recorded as “—”.5

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Attached are a series of images of Hardy-Rand-Rittler plates test that can be projected. Pass around the images to the students and ask them to observe what they see. Ask students to examine the plates and identify what (if any) images they see.

Figure 5. Plate from the Hardy-Rand-Rittler Test
Eye Anatomy Assessment

Part 1: Identify the parts of the eye:

1. ________________
2. ________________
3. ________________
4. ________________
5. ________________

Part 2: Match the key term with the definition.

1. _____ Blind Spot  
   A. The fibrous outer layer of tissue surrounding the eye that maintains the eye’s shape. The “white of the eye.”

2. _____ Rods  
   B. Cells within the retina that process light into information and send the image to the optic nerve.

3. _____ Fovea  
   C. The section of the brain responsible for vision.

4. _____ Visual Cortex  
   D. The lining of the inside surface of the eye which converts light into electrical impulses.

5. _____ Sclera  
   E. A clear fluid at the front of the eyeball that nourishes the eye and helps maintain its shape.

6. _____ Color Vision Deficiency  
   F. A central point in the retina upon which light passing through the eye is focused.

7. _____ Aqueous Humor  
   G. An indented part of the retina at the center point of the macula.

8. _____ Macula  
   H. The inability to distinguish certain colors. Also known as color blindness.

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9. ______ Retina
   I. Photoreceptors responsible for processing light. Located mostly on the periphery of the retina.

10. ______ Photoreceptors
    J. Portion on the retina where there are no photoreceptors.
Name: ____________________________  Date: __________

Eye Comparison Assignment

1. On a separate sheet of paper, compare and contrast the human eye to that of the eyes of a cow. How is the cow eye similar to a human eye? In what ways are they different? Focus on the anatomy of each, how each eye processes light, the amount of rods versus cones, presence (or absence) of a blind spot.

2. In the box below, draw a diagram of a cow’s eye, indicating the major parts.