Art and Optics

Lesson Plan

ART INSTITVTE CHICAGO

LESSON OVERVIEW

Grades: 6–12 **Duration:** 80–125 minutes

The **RLC Presents: Art + Science** video series and related curriculum supports middle and high school students in exploring science concepts and careers in museum conservation. This material is based upon work supported by the National Science Foundation under Grant No. OISE 1743748.

In the Lab: Art + Optics

In this video, photography conservator Jim Iska of the Art Institute of Chicago and associate professor Pablo Garcia of the School of the Art Institute of Chicago discuss their work in STEAM and demonstrate the science of optics to show how cameras and the human eye "see." Artists have used this science to depict three-dimensional space and spark wonder for hundreds of years. Students watch the video and respond to a brief set of reflection questions.

Art and Optics Lesson Plan Summary

Take a deep dive into the science of optics. Through modeling, inquiry stations, and reflection, students investigate optics and the structures and functions of the human eye to begin to understand how we see. Optional activities invite students to explore related concepts through the museum's collection and draw using linear perspective. Use all of the activities provided or select the ones that are most relevant to your teaching.

Driving Question:

How are we able to see?

Anchoring Phenomenon:

Students observe an object and use that experience to help them determine how they are able to actually see it.

Lesson Objectives

Students will:

- Reflect on careers in art and science
- Make observations and inferences
- Ask questions
- Create models based on observed phenomena, experience, and prior knowledge
- Complete inquiry stations to learn optics vocabulary, collect data, create diagrams, explain a visual phenomenon, and learn the structure and function of the parts of the eye
- Revise their initial models
- Reflect on their learning

Table of Contents

Key Vocabulary

- Optics
- Visible Light
- Reflection
- Refraction
- Transparent
- Translucent
- Opaque
- Converge
- The parts of the eye

Lesson at a Glance

1. **Video Viewing and Reflection (20 minutes)**
   Students reflect on the STEAM-related work of museum conservators.

2. **Opening Activity: "See, Think, Wonder" (10 minutes)**
   Students make observations, inferences, and ask questions about the process of seeing.

3. **Initial Model (10–15 minutes)**
   Students create an initial model of how people are able to see.

4. **Optics Inquiry Stations (40–60 minutes)**
   Students complete four stations focused on optics vocabulary, reflection, refraction, and parts of the human eye.

5. **Model Revisions (10 minutes)**
   Students revise their initial model using their updated knowledge and understanding of optics.

6. **Learning Reflection (10 minutes)**
   Students choose from a variety of questions to reflect on what they learned within the lesson.

7. **Possible Extensions**
   This includes creative response, further study, and exploring the collection.

Next Generation Science Standards

- **MS-PS4** Waves and Their Implications in Technology and Information Transfer (Waves and Electromagnetic Radiation)
  - **MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

- **MS-LS1** From Molecules to Organisms: Structures and Processes
    - **MS-LS1-8**. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

National Core Art Standards

- **Connecting**
    - **Standard 10:** Synthesize and relate knowledge and personal experience to make art. Relating artistic ideas and work with personal meaning and external context.

ART + OPTICS LESSON PLAN

PREPARING THE MATERIALS

Materials

- The following resources are at the end of this document:
    - Optics Vocabulary Cards for Station 1 (1 set per group of four students)
    - Optical Devices Instruction Sheet for Station 3 (2 per group)
    - Parts of the Eye text for Station 4 (1 per student)
- Prism or a picture of a prism (1 per group)
- A picture of the sun or a lamp (1 per group)
- A picture of light going into an eye (1 per group)
- Opaque material (i.e. a piece of cardboard or aluminum foil) (1 per group)
- Translucent material (a piece of wax paper) (1 per group)
- Transparent material (piece of plastic wrap) (1 per group)
- A picture of two lines coming together (converging) (1 per group)
- Flashlights (1–2 per group)
- Small flat mirror (1-2 per group)
- Concave mirror (a make-up or shaving mirror) (1 per group)
- Magnifying glass (1–2 per group)
- Pencil (1 per group)
- Clear glass cup (1 per group)
- Water
- White copy paper (1–2 pieces per group)
- Lamp without a shade (1 per group)

Worksheets

1 Per Student

- Art and Optics Student Resource
    - “See, Think, Wonder” Chart (page 2)
    - Model/Explanation (page 3, 11)
    - Optics Inquiry Stations (page 4–10)
    - Reflection on My Learning (page 12)
- Notebook paper and pencil for reflection

SET UP THE LESSON

Steps to Set-Up Lesson

1. Print the Art and Optics Student Resource for each student or provide them with electronic access.
2. Prepare station materials.

Station 1: Optics Vocabulary

Cut out the optics vocabulary cards. There should ideally be two sets: one with only the terms and another with the definitions. This allows students to match the cards during the activity.

**Tip: If possible, color code the cards so terms are on a card of one color and definitions are on a card of another.*

Vocabulary:

- Optics: The branch of science that deals with light energy
- Visible Light: A form of energy we can see
- Reflection: When light bounces back at the same angle at which it hits a surface
- Refraction: When light bends as it moves through one transparent material to another
- Transparent: (Of a) see-through material that allows light to pass through it
- Translucent: (Of a) material you cannot see through entirely because it only allows some light to pass through it
- Opaque: (Of a) material you cannot see through because no light is able to pass through it
- Converge: To move toward one point and come together

Gather objects or print pictures that match each term to share with students:

- Optics: A picture of light going into an eye
- Visible Light: A lamp or picture of the sun
- Reflection: A mirror or picture of something being reflected in a mirror
- Refraction: A prism or a picture of prism refracting white light into colors
- Transparent: A piece of plastic wrap
- Translucent: A piece of wax paper
- Opaque: A piece of cardboard or aluminum foil
- Converge: A picture of two lines coming together

Station 2: Reflecting and Refracting Light

Gather materials for the station. Each group of 4 students should have:

- Flashlight (1)
- Magnifying glass (1)
- Small flat mirror (1)
- Small concave mirror (a make-up or shaving mirror) (1)
- Pencil (1)
- Small, clear glass filled halfway with water (1)

Station 3: Light Bulb Image

Gather materials for the station. Each group of 4 students should have:

- Optical Devices Instruction Sheets (2)
- Lamp without a shade (1)
- Magnifying glass (1-2)
- White copy paper (1)
- Small concave mirror (a make-up or shaving mirror) (1)

Station 4: Parts of the Eye

Gather materials for the station. Each student should have:

- Parts of the Eye text

FACILITATION INSTRUCTIONS

Video Viewing and Reflection (20 minutes)

1. Ask the students to answer the following question in a whole class discussion, small group, or pairs:
    - Did you know that scientists work in some museums?
    - What do you think they might do?
2. Have students watch the video, *In the Lab: Art and Optics* (runtime: 7 minutes 18 seconds) as a class or individually.
3. Ask students to reflect on the following questions in writing, whole class discussion, or in pairs, sharing with a partner:
    - How do Jim Iska's and Pablo Garcia's work relate to both art *and* science?
    - What did you learn about their career paths? What advice did they offer?
    - What else did you learn that is new or surprising?

Opening Activity: See, Think, Wonder (10 minutes)

1. Review the sections of the "See, Think, Wonder" chart (page 2) as a class.
   **Recommendation: Give students a concrete number of items they need to put in each column.*
2. Provide an object or objects for students to observe.
3. Allow students time to independently observe their object and reflect on how humans are able to see.
   **Opportunity for differentiation: To simplify, complete more examples as a class.*
4. Students look at the image for 3–5 minutes and complete their charts. Student responses vary. Once completed, ask for volunteers to share one thing they noted in their chart.
   **Opportunity for differentiation: To simplify, complete this in pairs or small groups.*
5. Students can share their observations, inferences, and questions from their charts with an elbow partner, small group, or whole class.

Initial Model: How Are We Able to See? (10-15 minutes)

1. As a class, review the instructions for the Initial Model/Explanation (page 3).
2. In pairs or small groups, students infer how they are able to see an object in front of them. Students can use words, pictures, or a combination of both to explain as thoroughly as they can, but ultimately, this is intended to be an educated guess.

   **Opportunity for differentiation: To simplify, begin a model together as a class and let students finish it in smaller groups.*
3. Student groups share their ideas with the class. Models will be revised later.

Optics Inquiry Stations (40-60 minutes)

- **Student Optics Inquiry Stations** (page 4–10)

Station 1: Optics Vocabulary

1. At this station, students have a set of cards with terms and a set of cards with the definitions for each of the terms. There will also be a set of images and/or objects on the table.
2. Students match each term to a definition and to an object or picture.
3. Students then record the definition of a term in the appropriate place on their student document and draw either their own memory clue or the picture/object at the station.

   **Opportunity for differentiation: To simplify, reduce the number of possible choices to pair with select words.*

Station 2: Reflecting and Refracting Light

1. Students begin with a flashlight and flat mirror. They investigate how the light is reflected by the mirror by shining the light onto the flat mirror from different angles.

   **Opportunity for differentiation: To simplify, give specific instructions for different ways to shine the light (i.e. from above, from below, from the side).*
2. Students use knowledge gained during the vocabulary activity to answer a question and draw a simple diagram explaining how the light is moving.

   **Opportunity for differentiation: To simplify, provide the start of the diagram showing the light leaving the flashlight and hitting the flat mirror. Students ready for an additional challenge could do additional reading on the law of reflection.*
3. Students use the flashlight and concave mirror to investigate and explain what happens when the light is reflected off the concave mirror.

   **Opportunity for differentiation: To simplify, give specific instructions for different ways to shine the light (i.e. from above, from below, from the side).*
4. Students use knowledge gained during the vocabulary activity to answer a question and draw a simple diagram explaining how the light is moving.

   **Opportunity for differentiation: To simplify, provide the start of the diagram showing the light leaving the flashlight and hitting the concave mirror.*
5. Students use the flashlight and magnifying glass to investigate and explain what happens to the light when they shine it through the magnifying glass.
6. Students answer a question and draw a simple diagram to explain how the light is moving through a magnifying

glass. **Opportunity for differentiation: To simplify, provide the start of the diagram showing the light leaving the flashlight and hitting the magnifying glass.*

7. Students have a plain glass of water and a pencil. They draw what they see when both objects are separate and sitting on the table.
8. Students put the pencil in the water, draw what they see, and explain what happens to the light that makes the pencil look bent.

   **Opportunity for differentiation: To simplify, provide a sentence frame or give students the vocabulary term they need to use in their explanation. Students ready for an additional challenge could do additional reading on the law of refraction.*
9. Students read about camera obscuras and answer questions on how light moves and creates images.

Station 3: Creating Images with Optical Devices

1. Students recreate the "Magnifying Glass Setup" shown on the Optical Devices Instruction Sheet with a magnifying glass, a lamp, and a sheet of paper.
2. Students experiment with distancing the paper from the magnifying glass until they are able to get the image of the light bulb to appear on the paper.

   **Opportunity for differentiation: To simplify, place pieces of tape on the floor to mark places where students should stand and hold the magnifying glass and paper.*
3. Students answer a few questions and draw a simple diagram explaining what they see.
4. Students recreate the "Concave Mirror Setup" shown on the Optical Devices Instruction Sheet with the mirror, lamp, and sheet of paper.
5. Students experiment with distancing the mirror until they are able to get the image of the light bulb to appear on the paper.

   **Opportunity for differentiation: To simplify, place pieces of tape on the floor to mark places where students should stand and hold the mirror and paper.*
6. Students answer a few questions and draw a simple diagram of the light.

Station 4: Parts of the Eye

1. Students label the diagram of the eye on their student sheets using the Parts of the Eye text as a guide.

   **Opportunity for differentiation: To simplify, provide the diagram already partly labeled.*
2. Using the Parts of the Eye text, students summarize the function of each part of the eye on their graphic organizer.

   **Opportunities for differentiation: Modify the text to a higher or lower lexile level and/or provide one example function for each part of the eye.*
3. Students create a diagram showing how light moves through the eye and answer a few questions using educated guesses.

   **Opportunity for differentiation: To simplify, provide one or two arrows in the already completed diagram.*

Final Model: How Are We Able to See? Final Model (10 minutes)

1. In the same pairs or small groups from the initial model stage, students revise their explanation of how they are

able to see the object in front of them (page 11). Students can use words, pictures, or a combination of both to explain as thoroughly as they can.

**Opportunity for differentiation: Review as a class what was learned in each section of the lesson before students begin their revisions.*

Reflection on My Learning (10 minutes)

1. Students complete a written reflection about their learning, selecting and responding to one question from each column (page 12).

ONGOING LEARNING

About the Conservator

Jim Iska is the Assistant Conservator for Preparation and Framing of photographs, in the department of Conservation & Science. In this role, Iska is responsible for the care of the museum's collection of photographs. This includes preparing and installing photographs for exhibition, shipping, and storage.

During his time working with the Art Institute's Photography Collection, Iska says he has witnessed major changes in the medium of photography, including its radical transformation from primarily silver-based to digital processes. Iska studied photography at the Illinois Institute of Technology's Institute of Design and is also a professional photographer whose work has appeared in a number of exhibitions and publications including *The City in a Garden: A Photographic History of Chicago's Parks* and most recently *Chicago: Classic Photographs*.

Pablo Garcia is an Associate Professor in the Department of Contemporary Practices at the School of the Art Institute of Chicago. Trained as an architect, Garcia is an experienced educator and contemporary artist working in art, architecture, and design. His expertise in the history and technique of drawing technologies has contributed to research at numerous institutions. He is further interested in empowering regular people to learn how to draw. In 2017, Garcia and a partner started a Kickstarter campaign to create and produce a modern camera lucida, a 19th century optical device used as an aid to drawing, called the NeoLucida. Learn more about this project and product at neolucida.com.

Possible Extensions

Creative Expression

- In the fifteenth century, artists invented drawing with linear perspective to realistically render three dimensional space in a two dimensional work. Find simple instructions online for drawing using one point linear perspective. Ask students to sketch a room that is important to them using perspective. What are the sights, sounds and memories they associate with that place? What should they include in their drawing to communicate those qualities to others?

For Further Study

- Optics Engineering Challenge: More advanced students could expand on the concepts explored in this lesson plan by designing a camera obscura or other optical devices.

Explore the Collection

Explore the artworks featured in this lesson by clicking on the titles below. Access the museum's full collection by browsing the collections page at https://www.artic.edu/collection.

Abelardo Morell is a contemporary artist who demonstrates and plays with fundamentals of optics to create his imaginative photographic works. Learn more about Abelardo Morell in this video.

- Abelardo Morell, *Light Bulb*, 1991
- Abelardo Morell, *Camera Obscura: Brookline View in Brady's Room*, 1992

László Moholy-Nagy played with perspective to create the illusion of three dimensional space in this work.

- László Moholy-Nagy, *Berlin Radio Tower*, 1928

Conservator Jim Iska shared this photograph from the museum's collection for the historic importance of its subject, Frederick Douglass, and the beauty and power of this portrait.

- Samuel J. Miller, *Frederick Douglass*, 1847-52

This 16th century drawing shows an artist using linear perspective to realistically render three dimensional space in a two dimensional design.

- Nicoletto da Modena, *The Nativity and the Adoration of the Shepherds*, c. 1512

Gustave Caillebotte is believed to have used an optical device to render perspective in this work.

- Gustave Caillebotte, *Paris Street, Rainy Day*, 1877

Video Viewing and Reflection

1. Ask the students to answer the following question in a whole class discussion, small group, or pairs:
    - Did you know that scientists work in some museums? *Answers vary*
    - What do you think they might do? *Answers vary*
2. *N/a*
3. Ask students to reflect on the following questions in writing, whole class discussion, or in pairs, sharing with a partner.
    - How do Jim Iska's and Pablo Garcia's work relate to both art *and* science? *Answers vary but may include: Jim and Pablo use their knowledge of optics and optical devices to create art.*
    - What did you learn about their career paths? What advice did they offer? *Answers vary*
    - What else did you learn that is new or surprising? *Answers vary*

See, Think, Wonder Opening Activity

Answers vary

Initial Model: How Are We Able to See?

Answers will vary as this is intended to be an educated guess. Answers will be revised later.

Station 1: Optics Vocabulary

See preparation notes for Station 1.

Station 2: Reflecting and Refracting Light

1.
    - What do you notice happening when you shine the light at the flat mirror? *This mirror is reflecting back a pool of light.*
    - *Diagram should show light reflecting, bouncing back, widely from the mirror.*
2.
    - What do you notice happening when you shine the light at the concave mirror? *The concave mirror is reflecting back a beam of light.*
    - How is this different from what happens when you shine the light on the flat mirror? *The light is being gathered to a point that can be aimed by a concave mirror whereas with the flat mirror the light that is reflected back is more hazy, as a pool of light.*
    - *Diagram should show light reflecting, bouncing back, as a beam from the mirror.*
3.
    - What do you notice happening when you shine the light at different angles at the magnifying glass? *The light is being refracted through the magnifying glass.*

- *Diagram should show light going through the magnifying glass, but refracting (bending) in a slightly different direction.*

4.

- *The drawings should show a standard pencil on the table and a pencil that looks bent in the water.*
- Using your optics vocabulary from Station 1 and your experimenting from Station 2, what do you think is happening with the light that changes the look of the pencil? *The light is being refracted through the water, making the pencil look bent.*

5.

- Draw arrows along the edges of the light to show what direction the light is traveling in. *Arrows should be drawn on the edges of the light through the pinhole towards the back of the chamber, revealing that the light is traveling in straight lines.*
- Why do the images on the wall inside the chamber appear upside down and reversed? *The light is traveling in a straight line to the back of the chamber, which makes the image appear upside down and reversed.*

Station 3: Light Bulb Image

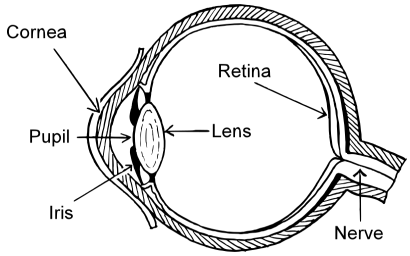
1.

- What image did you create on the paper? What do you notice about the image? *The image is an upside down lightbulb.*
- Based on what you have learned, what is the magnifying glass doing with the light from the light bulb to make the image appear? *The magnifying glass is converging the light to a point and then refracting and flipping it upside down.*
- *Diagram should include light moving in a straight line, converging to a point on the magnifying glass and coming out to the paper. The light is moving similarly to how it moves in a Camera Obscura.*

2.

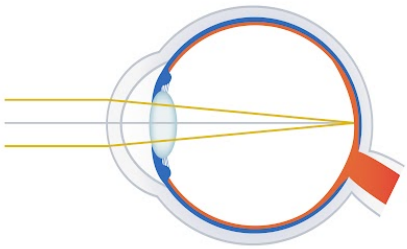
- What type of material is the sheet of paper that it allows the light to pass through? (Look at your vocabulary from Station 1) *The paper is translucent.*
- What image is visible on the paper? *An upside down lightbulb.*
- What is the mirror doing with the light to help create the image? *The mirror is reflecting and flipping/bending the light back to the paper.*
- *Diagram should include light moving through the translucent paper and converging to the mirror, then reflecting back to the paper.*
- If the white piece of paper in this setup was replaced with a piece of cardboard, how would that change the image created? Explain why this change would happen? *There wouldn't be an image created. The light wouldn't pass through the cardboard because it is opaque.*

Station 4: Parts of the Eye

1. 

2. *Answers may vary slightly:*
    - Cornea - *refracts light that enters the eye*
    - Iris - *muscles in the iris control the pupil*
    - Pupil - *controls the amount of light that enters the eye, expands for more light, contracts for less*
    - Lens - *focuses light from pupil to back of the eye*
    - Retina - *collects the light and then converts it to electrical impulses for brain to process*
    - Optic Nerve - *sends electrical impulses to the brain which processes to create a clear image*

3. *Diagram should show light entering through the cornea, through the pupil and lens, to the retina. Similar to diagram below:*



- What do you think would happen to your vision if your cornea became cloudy instead of completely transparent? *Less light would be let in, making it harder to see.*
- What do you think would happen to your vision if a person was born with a cornea that was not curved, but flat? *The light wouldn't refract as it comes into the eye, so our vision would be blurry.*
- If our brain didn't process the image, how would we see the world? *The world would look upside down.*

  **Note: The previous three questions are intended to be answered with students' educated guesses based on knowledge gained through these activities. Depending on the students' level of understanding, the teacher can determine how thorough their answer should be.*

Final Model: How Are We Able to See?

Revisions may vary but should include a diagram or words explaining how the light enters the eye and that our brain then processes and flips that information to create an image.

Reflection on My Learning

Answers vary

ADDITIONAL TERMS FROM THE VIDEO

Camera Lucida: A portable optical device that uses a prism or a special mirror to project the scene in front of you onto your paper, allowing you to trace what you see.

Camera Obscura: from Latin, meaning “dark room.” Light passing from a small aperture, or pin hole, into a dark chamber will project an upside down, reversed image of the scene outside.

Horizon line: An imaginary line drawn across the picture that represents the eye-level of the viewer.

Linear perspective: A technique used in art to create the illusion of depth and realism on a flat surface. This is done by creating vanishing points on a horizon line and drawing the scene with converging orthogonal lines that mimic the way objects appear to get smaller as they recede into the distance.

Orthogonal lines: Diagonal lines that are parallel to the ground plane and recede to a vanishing point. They are used in linear perspective drawing to help the artist create realistic views of objects and scenes.

Vanishing point: A specific point on the horizon line where parallel lines appear to converge. It is a key element in linear perspective that allows an artist to create a 3-dimensional look.

Visible Light	**A form of energy we can see**
Reflection	**When light bounces back at the same angle at which it hits a surface**
Refraction	**When light bends as it moves through one transparent material to another**
Transparent	**(Of a) see-through material that allows light to pass through it**
Translucent	**(Of a) material you cannot see through entirely because it only allows some light to pass through it**
Opaque	**(Of a) material you cannot see through because no light is able to pass through it**
Converge	**To move toward one point and come together.**
Optics	**The branch of science that deals with light energy.**

OPTICAL DEVICES INSTRUCTION SHEET

Optics is the branch of science that deals with light energy. For thousands of years, optical devices have been made and used for entertainment, by scientists to study optics, and by artists as an aid to drawing until it became possible to chemically capture the image formed in a camera with the invention of photography in the 1800s.

Magnifying Glass Set Up

Magnifying glass: A magnifying glass is a convex lens that can be used to gather and bend or refract rays of light and converge that light to a point. This is where an image is formed on an image plane.

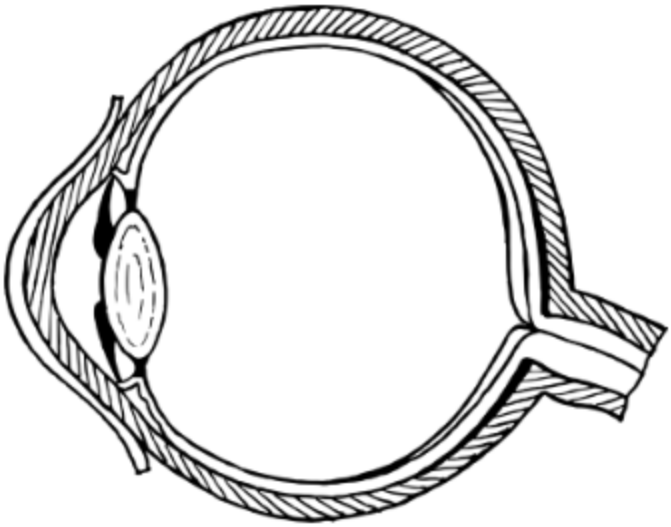
To Do: Hold a magnifying glass in front of the light source and stand a few feet from the light. Hold a piece of paper across from the magnifying glass and move it in and out until you see a clear image form.

Concave Mirror Set Up

Concave Mirror: A concave mirror can be used to gather and reflect rays of light and converge that light to a point. This is where an image can be formed on an image plane.

To Do: Hold the mirror close to and facing the light source. Hold a piece of paper between the light source and the mirror and move it in and out until you see a clear image form. The image appears upside down because the light rays were bent during reflection.

PARTS OF THE EYE TEXT



The eyes are the organs in the body that allow us to see. Even though eyes are small, they contain multiple parts that all have a specific job to help us see.

- The transparent outer layer on the front of the eye is called the **cornea**. Light from the environment enters the cornea. The curve of the cornea refracts (bends) the light that enters the eye.
- The cornea covers the colored part of our eye called the **iris**. There are muscles in our iris that control the pupil.
- The **pupil** is the dark center of our eye. It is responsible for controlling the amount of light that enters our eye. It expands to let more light in and contracts or gets smaller to let less light in.
- Behind the iris and pupil is the **lens**. The lens focuses the light coming from the pupil to the back of the eye.
- The **retina** is located at the back of the eye. It is responsible for collecting the light in our eye and converting it to electrical impulses for the brain to process.
- The **optic nerve** connects the eye to the brain. The optic nerve takes the electrical impulses from the retina and sends them to a specific part of the brain for processing. Our brain receives the information from both or our eyes and creates a clear image.