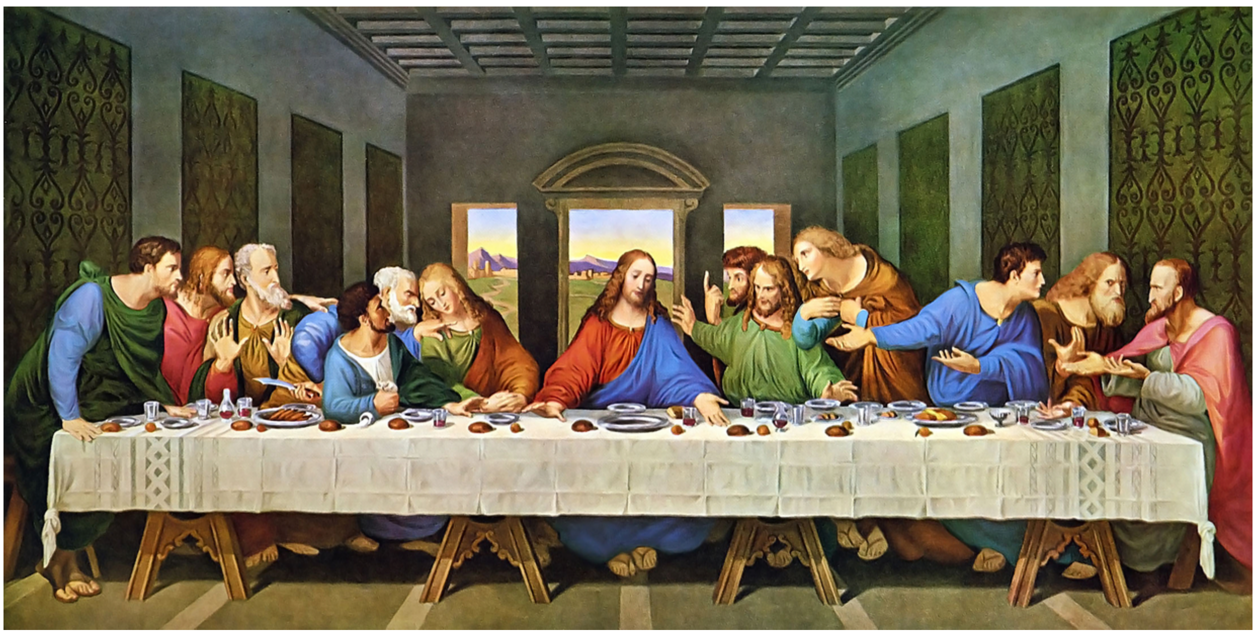
INVESTIGATION 4

Lesson Plan



INVESTIGATION 4

Exploring Symmetry

INVESTIGATION 4

INVESTIGATION FOCUS
Within the CELL, this Investigation is designed to:

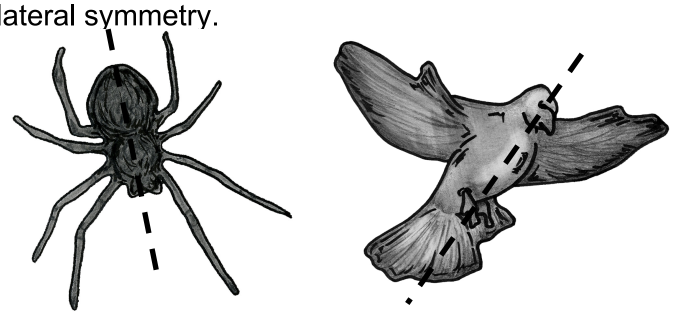
1. introduce students to the concept of symmetry.
2. provide students with an opportunity to investigate two types of symmetry: bilateral and radial.
3. help students understand differences between bilateral and radial symmetry.
4. aid students' understanding of a plane of symmetry.
5. Illustrate how artists use symmetry in their work.
6. provide an opportunity for students to explore differences in how science and art define and describe symmetry.
7. Introduce students to two types of symmetry in art: symmetrical and asymmetrical balance.

RELEVANT BACKGROUND KNOWLEDGE
In Investigations One, Two and Three, students investigated various aspects of perspective, a concept central to art. In Investigation Four, students expand their exploration of art and science by focusing on symmetry.

In the scientific and mathematical fields, symmetry represents one type of pattern. As you can imagine because there are a myriad of scientific as well as mathematical disciplines, there is not just one way in which symmetry is described or studied within these fields. As students progress in their education they are likely to encounter discussions of symmetry at various times and levels. Investigation Four provides an opportunity for students to focus on two types of symmetry within those fields: bilateral symmetry and radial symmetry.

Bilateral and radial symmetry are terms that can be associated with biology and organisms as well as mathematical constructs. To gain a better understanding of bilateral symmetry, think of the human body. Observe the body and you observe two arms, two legs, two hands, and two feet. Observe more closely as you can see that each part of the pair is almost exactly like the other except for slight differences in orientation. The thumbs of each hand do not both point towards the same side of the body. Rather each points inward towards the chest. The same relationship exists for the two legs, feet and arms. A pattern emerges if an imaginary line is drawn down the middle of the body from the head to the feet. What is on one side of the line is the mirror image of what is on the other side of the line. This "line" is referred to as a "plane of symmetry" and "bilateral symmetry" is the specialized term that describes the exterior of the body. Bilateral symmetry refers to the ability to draw a median axis or line through a structure with the result being that two essentially two equal halves are created. Objects that have bilateral symmetry contain only ONE plane of symmetry. A spider and bird are two other examples of organisms that have bilateral symmetry.

Figure 4.1: Examples of organisms with bilateral symmetry.



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Look outside or in a zoo and symmetry becomes readily apparent. Many organisms within our world are exhibit external bilateral symmetry. And yet, that symmetry may fail to maintain its consistency internally. For example, within our bodies, our veins, arteries and skeletal muscles tend to be bilaterally symmetrical. However, our heart, liver, appendix and other organs are not.

In addition to the multitude of organisms that posse bilateral symmetry, there are a number of organisms that exhibit radial symmetry. Organisms or objects that are radially symmetrical have similar parts arranged around a central axis. A starfish is an example of an organism with radial symmetry. Each of the five arms of a starfish extends out from a central axis. Another way to think of radial symmetry is to imagine that the object or organism can be divided into equal halves by a plane passing through the central point or axis at ANY angle. In other words, an object with radial symmetry has MORE THAN ONE plane of symmetry. A pine tree, when viewed from above, a snowflake and a starfish are examples of organisms that have radial symmetry.

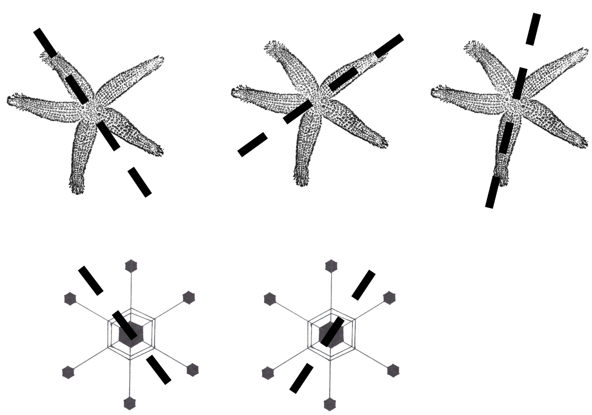

Figure 4.2: Examples of organisms and objects with radial symmetry.

Symmetry also exists in art, whether it be in painting, sculpture, theater or music. Part of this may be because of a focus on the human form. However, part of it may simply come from an almost intrinsic human desire and preference for symmetry. Recent research into human perception has shown that within 0.05 seconds of viewing an object, humans scan the object for symmetrical properties. Regardless of the reasons, for many artists and patrons of art, symmetry in all aspects of illustration creates harmony and consistency. Marcus Vitruvius Pollio, a prominent architectural engineer during the Renaissance, displayed what he considered the beauty of anatomical symmetry when he created the drawing below. Vitruvius believed this beauty and balance carried through all forms of nature, including his architectural drawings. The artist and scientist Leonardo da Vinci also noticed and ascribed great importance to the symmetry of human anatomy. His perhaps more famous drawing is shown below.

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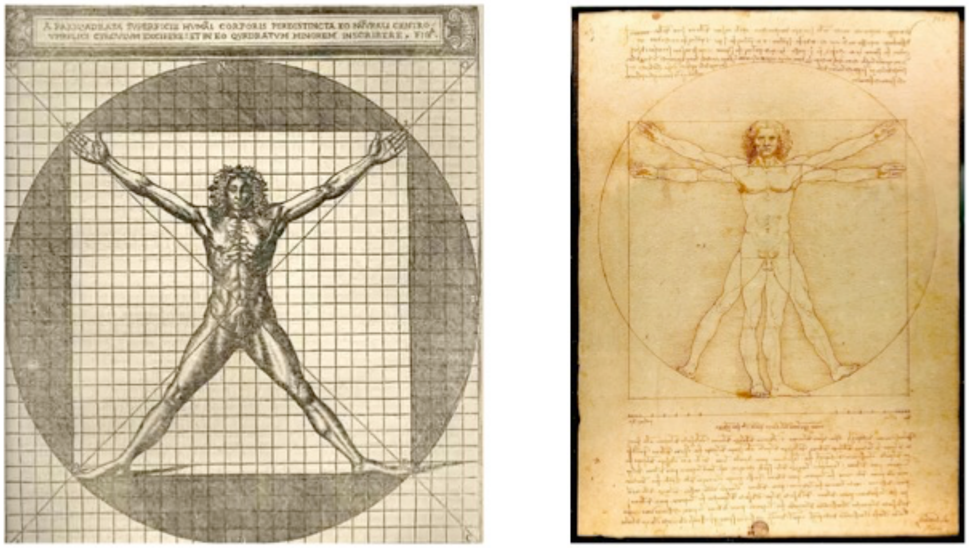

Figure 4.3: Symmetry in human anatomy from Vitruvius (left) and da Vinci (right)

Over the course of history, artists have also manipulated the human desire for symmetry by creating asymmetrical pieces of work. In doing so, they often hoped to elicit drama and heightened emotions as a result of this asymmetry.

In some cases, it is easy to see where art and science overlap with regards to symmetry. Just take Vitruvius's or da Vinci's drawings (above) as an example. Both illustrate the bilateral symmetry of the human form. In other cases, however, the definition of symmetry may become more blurred or inconsistent. Bilateral and radial symmetry as defined by science require the formation of mirror images, something that is not often the focus of art. Discussion of symmetry in art, therefore, often becomes a more lenient comparison of elements within the work of art. In addition, the word balance is often used as a substitute for symmetry. In Investigation Four, students will have the opportunity to explore symmetrical and asymmetrical balance in artwork and compare these descriptions to those of bilateral and radial symmetry. Through their Investigations, they will find that symmetrical balance suggests the ability to find a central focus of a painting and divide the painting into left and right halves with equivalent number and sizes of objects on either side. Art with asymmetrical balance, however, often lacks a central focus around which it can be divided into left and right halves. Many times, art with asymmetrical balance provides a feeling of balance for the overall piece of work but does not rely on the strict equivalence of size and number of objects across left and right halves.

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KEY SCIENCE TERMS AND CONCEPTS

1. **Asymmetry:** The absence of symmetry. Asymmetrical objects cannot be divided into equal parts.
2. **Balance:** A term used in art that describes the way in which lines, shapes, colors and textures are arranged. Art may have symmetrical or asymmetrical balance.
3. **Bilateral symmetry:** One type of symmetry in which an imaginary line or plane divides an object into right and left halves. Each half is a mirror image of the other.
4. **Radial symmetry:** A type of symmetry in which an object can be divided equally around a central axis or point by multiple lines or planes of symmetry. A starfish is an example of an organism that has radial symmetry. A pie cut into equal pieces is also an example of radial symmetry.
5. **Symmetry:** A type of pattern in which an object can be divided into equal divisions or parts. Symmetry can also refer to the idea of balanced proportions or the “beauty” that results from balanced proportions.
6. **Plane of symmetry:** A line that divides an object into equal parts. An object can have one or multiple planes of symmetry.

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PROCEDURAL TOOLBOX

Modeled Tools	New Tools	Previously Used Tools
		Completion of Data Table

COGNITIVE TOOLBOX

Modeled Tools	New Tools	Previously Used Tools
		Apply *Conclusions* *Look For* *Recall*

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PRE-LAB

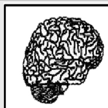
Supplies and Equipment:

Class materials:
1 *Symmetry in Art and Science Presentation*
1 *Preparing for the Lab Transparency*

Individual materials:
1 *Scientist's Glossary*
1 *Scientist Data Record*

Procedure:

A. Begin the Investigation by reviewing what students learned about perspective, point of view and field of view in Investigations One, Two and Three



Tool: **Recall**

Ask students: **What do we do when getting ready to learn something new?**
*Students should realize that the **Recall** tool is appropriate.*

Pose the following questions to prompt student recall about art and perspective.

1. **What do you think of when I say the word "perspective?"**
   Student answers may vary.

2. **Imagine you are looking at a building up close and then later from farther away. Will the building look the same each time? Why or why not?**
   The building will look different depending upon your point of view. The building will look smaller when it is farther away and larger when it is closer because it takes up a different portion of the your field of view. When it is farther away is takes up a smaller portion of your field of view. When it is closer it takes up more of your field of view. Another way to explain this, is that the building forms different visual angles on your retina at different distances. It forms a smaller visual angle when it is farther away. This makes the building appear shorter and narrower when it is farther away.

3. **Complete the following statement: The smaller the visual angle either outside or inside the eye, the ________ the image of an object on the retina.**
   Students should answer: "the smaller the image of an object on the retina."

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B. Continue the review by encouraging students to apply what they have learned thus far by modifying the drawing they created in Investigation Three.

Tool: **Apply**

1. Tell students to locate problem 1 in their *Investigation* ***Three*** *Scientist Data Record.* Remind students that in this problem they used what they had learned about perspective to create a drawing that showed depth.

2. Explain that in this part of the Pre-Lab you would like them to ***apply*** what they learned from Investigation Three to their drawing. You would like them to imagine how their drawing would look from a different perspective.

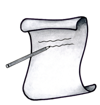
3. Tell students to imagine that they are now standing at the far end of the road they drew and looking back the other direction.

4. Encourage students to create a new drawing from this different perspective in problem 1 in their *Investigation* ***Four*** *Scientist Data Record.*

5. When they are finished students should be able to compare the drawings and see the same objects from two different perspectives.

6. Provide approximately 15 minutes for this activity.

C. Continue the Pre-Lab by explaining that in addition to perspective one of the other key elements of art is its symmetry or lack of symmetry.



1. Introduce the word symmetry by reviewing its definition from the *Scientist's Glossary.*

2. Show students the *Symmetry in Art and Science Presentation.*

3. Use the teacher notes included in the presentation to discuss examples of symmetry in art. This presentation looks at the concept of symmetry in art, math and science and introduces students to different types of symmetry.

D. Conclude the Pre-Lab by providing an opportunity for students to apply and rehearse what they have learned thus far.

1. Continue the discussion of symmetry focusing on three additional terms from the *Scientist Data Record*: *radial symmetry*, *bilateral symmetry,* and *plane of symmetry.* Students should be more familiar with these terms after having seen the *Symmetry in Art and Science Presentation.*

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2. Provide students with an opportunity to explore two different types of symmetry by performing the following activity. As students conduct this activity they should focus on the number and orientation of students rather than the gender, height or dress of students.

   a. Divide students into groups of six.

   b. Provide a meter stick, long piece of tape or other object that can be used to model a line.

   c. Tell each group to place the meter stick on the floor.

   d. Instruct two students to stand on one side of the meter stick and four students to stand on the other side of the meter stick.

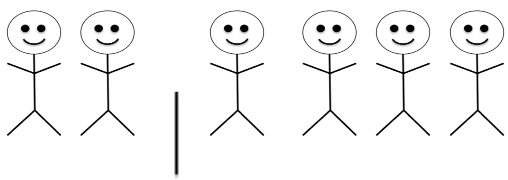

Figure 4.4: Example of role play

   e. Ask students: **Is this pattern bilaterally symmetrical? Why?**
   *Students should indicate that the pattern is **not** bilaterally symmetrical because the meter stick does not divide the students into equal sections that are mirror images of each other. There are two students on one side and four students on the other side of the meter stick.*

   f. Next, instruct one student to orient themselves so that 1 student is on one side of the meter stick and five students are on the other side?

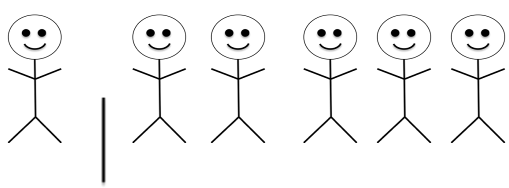

Figure 4.5: Example of the second formation in the role play

   g. Ask students: **Is this pattern bilaterally symmetrical? Why?**
   *Students should indicate that the pattern is **not** bilaterally symmetrical because the meter stick does not divide the students into equal sections that are mirror images of each other. There is one student on one side and five students on the other side of the meter stick.*

   h. Instruct students to move so that three students are on one side the meter stick and three are on the other side.

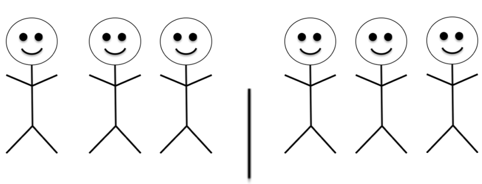

Figure 4.6: Example of bilateral symmetry

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i. Ask students: **Is this pattern bilaterally symmetrical? Why?**
Students should indicate that the pattern is bilaterally symmetrical because the meter stick divides the students into equal sections that are mirror images of each other. There are three students on one side and three students on the other side of the meter stick. Some students may suggest that the two parts are not mirror images of each other because the students on each side differ from one another in appearance. Remind students that at the beginning of the activity there were asked to imagine that each student was the same in appearance.

j. Finally, direct students to form a circle around the meter stick. Tell students that they are now in a pattern that is radially symmetrical because there is more than one plane of symmetry for the circle. Have students illustrate this by rotating the meter stick so that is “cuts” the circle in different places. Each time, the meter stick divides the circle into mirror images.

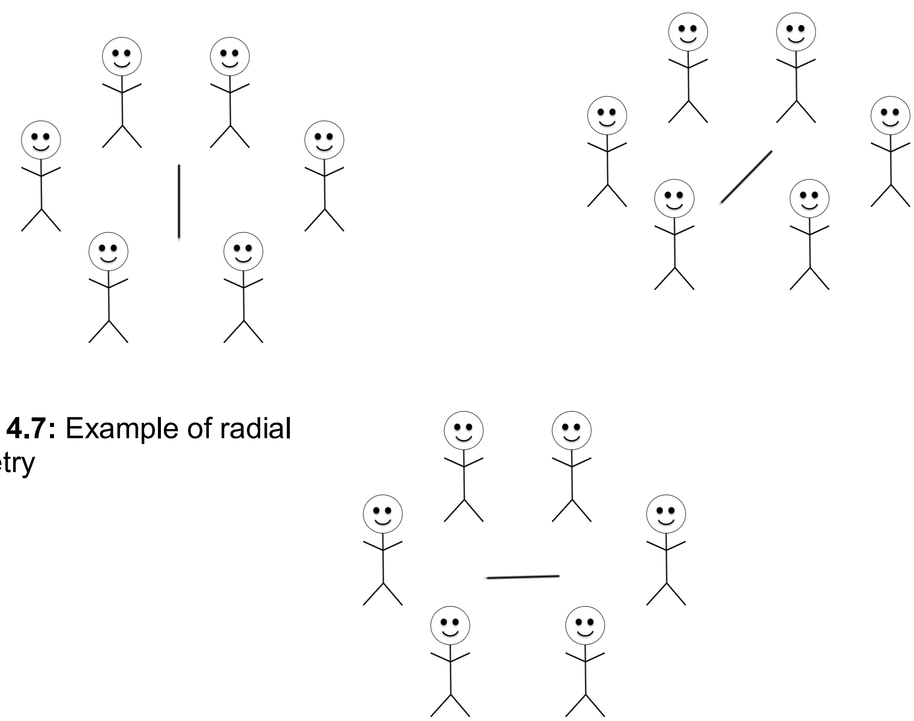

Figure 4.7: Example of radial symmetry

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3. End the Pre-Lab by explaining that students will investigate whether objects have bilateral or radial symmetry in the lab.

    a. Tell students that in order to do this they will use a mirror to find a plane of symmetry. Use the *Preparing for the Lab Transparency* to help orient students to this procedure.

    b. Encourage students to read the information in problem 2 in their *Scientist Glossary.* This selection provides addition information about symmetry that may be helpful to review as they prepare for the lab experiments.

    c. Encourage students to consider the following questions as they prepare for the lab.

    How many planes of symmetry does an object have?

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LAB

Supplies and Equipment:

Group materials:
1 rectangular mirror (or can of vegetables or any cylindrical can)
1 200 g mass
1 stuffed bear (or similar stuffed animal)
1 baseball (or other ball)
1 basketball (or other ball)
1 wood block (or any small rectangular box)
1 100 ml beaker (or plain round drinking glass)

Individual materials:
1 *Scientist Data Record*

Preparation:
1. Organize the required materials at a distribution point.
2. Divide students into five (5) cooperative groups.

Instruction:
1. Direct each student group to obtain the following necessary materials from the distribution point: one (1) rectangular mirror, one(1) 200 g mass, one (1) stuffed bear, one (1) wood block, one (1) ping pong ball, one (1) moon ball, one (1) 100 ml beaker, and one (1) plastic dropper.

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Procedure:

1. The trials in this Investigation focus on how many planes of symmetry exist for certain objects. Students will use a mirror to find planes of symmetry and to determine if the mirror creates an image that makes the object appear similar to its appearance without the mirror. If this occurs, then the plane where the mirror is located is a plane of symmetry. Each trial includes steps that are used to set-up the experiment. In following the directions for set-up, students may be tempted to focus more on the steps of the procedure and less on the observations they will make after the experiment design has been prepared.

Tool: **Look For**

Ask students: **What will you Look For when observing objects in the Investigation?** *Students should indicate that they should observe the whether the location of the mirror creates a plane of symmetry.*

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2. Trial 1: Trial 1 has been designed to illustrate an example of bilateral symmetry to students. Students will determine how many planes of symmetry exist for the human face by placing along different planes that divide the object. The directions in the trial show students how to think about the possible orientations for a plane of symmetry. Students begin by placing the mirror down the middle of face along a longitudinal axis. When students observe the image formed by the image in the mirror and the side of the face, they should see what appears to be a complete human face with a left and right side.

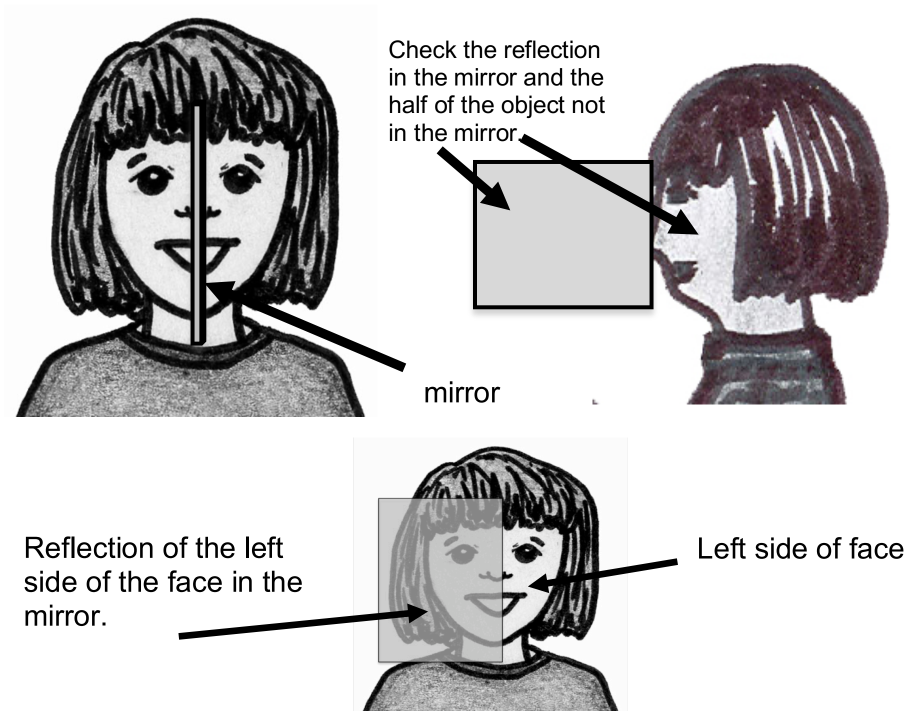

Figure 4.8: Using a mirror to detect a plane of symmetry

The text in their *Scientist Data Record* indicates that the object appears “real” when the mirror is used, then a true plane of symmetry has been established. Students should then recognize that the line from the forehead to the chin down the middle of the face is a plane of symmetry.

Students next test a plane that runs across the latitudinal axis of the face and then two planes that run diagonally across the face. As they observe each image they should see a distorted appearance of a face rather than a “normal” face. Based on these observations, students should discern that these are not planes of symmetry for the human face.

As a result, students should categorize the human face as an example of bilateral rather than radial symmetry since only one plane of symmetry is present. Objects that are radially symmetrical have more than one plane of symmetry.

As students complete this trial, ask them to consider the following question:

Is the human face bilaterally or radially symmetrical?

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3. Trial 2: Trial 2 has been designed to illustrate an example of radial symmetry to students. Students will determine how many planes of symmetry exist for a 200 g mass by using a mirror to find planes of symmetry. The directions in the trial show students how to think about the possible orientations for a plane of symmetry. When students observe the image formed by the image in the mirror and the other portion of the 200 g mass, they should see what appears to be a complete 200 g mass cylinder.

   The text in their *Scientist Data Record* indicates that if the object appears "real" when the mirror is used, then a true plane of symmetry has been established. Students should then recognize that the line from one end of the top of the cylinder to the other is a plane of symmetry.

   Students next test a plane that runs from two other points of the top of the 20g mass across its center. As they observe each image they should see a complete cylinder. Based on these observations, students should discern that these are also planes of symmetry for the 200g mass. Students continue testing different planes, finding each time that the plane produces a "real" image of a cylinder.

   As a result, students should categorize the 200g mass as an example of radial rather than bilateral symmetry since many planes of symmetry are present. Objects that are radially symmetrical have more than one plane of symmetry. Bilaterally symmetrical objects have ONLY ONE plane of symmetry.

   As students complete this trial, ask them to consider the following question:

   Is the 200g mass bilaterally or radially symmetrical?

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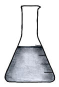
4.  Trial 3: In Trial 3 students apply what they learned in Trials 1 and 2 about how to test for planes of symmetry and how to identify objects with radial and bilateral symmetry. As in Trials 1 and 2, they use a mirror to find planes of symmetry and determine whether six different objects exhibit bilateral or radial symmetry.

   As students complete this trial, ask them to consider the following question:

   How many planes of symmetry do the objects have?
   Are they bilaterally or radially symmetrical?

5. Upon completion of the Investigation, permit enough time to clean up the lab and return the materials and equipment to their assigned locations.

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POST-LAB ANALYSIS

Supplies and Equipment:

Class materials:
1 *Human Face Transparency*
1 *200 g Mass Transparency*
1 *Art CELL Drawing Presentation*

Individual materials:
1 *Scientist Data Record*

A. Begin this part of the Investigation by encouraging students to summarize their activities in the Lab. Prompt student discussion by posing the following questions:

1. **What were the main questions we wanted to investigate in this lab?**
Students should indicate that the questions were: Is the human face bilaterally or radially symmetrical? Is a 200g mass bilaterally or radially symmetrical? How many planes of symmetry do objects have? Are they bilaterally or radially symmetrical? How does your perspective affect the appearance of an object?

2. **How would you summarize the types of experiments that you performed to investigate this question?**
Students should indicate that they performed three trials. In all three trials they used a mirror to find planes of symmetry. In each trial, they placed the mirror along several different planes then looked at the image formed by the reflection in the mirror and the other half of the object. If the image appeared "normal" then the plane was a plane of symmetry. Objects that had many planes of symmetry were classified as radially symmetrical. Objects that had only one plane of symmetry were bilaterally symmetrical.

B. Begin analysis of the experiment by encouraging students to review their data from Trial 1.

1. Tell students to locate problem 3 in their *Scientist Data Record.* Ask students: **Was the human face bilaterally or radially symmetrical? Why?**
Bilaterally symmetrical.

   a. Use the *Human Face Transparency* to walk students through the results from the experiment.

   b. Discuss how only one of the planes tested- from the top of head to the chin- produced an image that looked like the face. This was the only plane of the symmetry.

   c. All of the other planes produced images that were different from a "real" face. Because the face only had one plane of symmetry, it was bilaterally symmetrical.

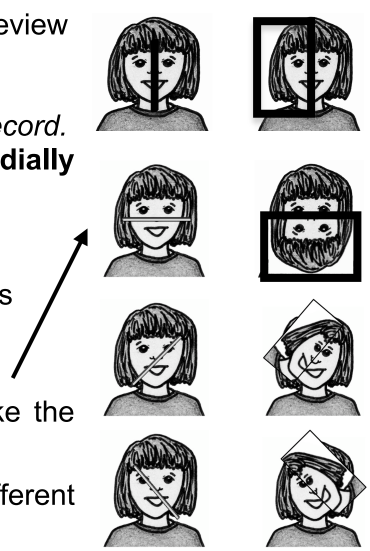

Figure 4.9: Images from the Human Face Transparency

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2. Direct students to locate problem 4 in their *Scientist Data Record.* Ask students: **Was the 200 g mass radially or bilaterally symmetrical? Why?**
   Radially symmetrical.

   a. Use the *200 g Mass Transparency* to walk students through the results from the experiment.

   b. Discuss how each plane tested produced an image that looked like the intact 200 g mass. As a result, the 200 g mass can be classified as an object with radial symmetry.

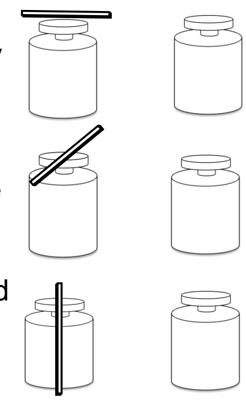

Figure 4.10: Images from the 200 g Mass Transparency

3. Ask students: **How does the number of planes of symmetry determine the type of symmetry?**
   Students should indicate that if an object has more than one plane of symmetry is likely to be radially symmetrical. If it is has ONLY ONE plane of symmetry, it is a bilaterally symmetrical object.

4. Direct students to locate problem 5 in their *Scientist Data Record.* Ask students: **Which objects were radially symmetrical? Which objects were bilaterally symmetrical? Why?** Use the *Symmetry of Different Objects Transparency* during the discussion.

Object	Number of planes of symmetry	Radial or bilateral symmetry?
Baseball	***More than one (many)***	***radial***
Basketball	***More than one (many)***	***radial***
Wood block	***One***	***bilateral***
100 ml beaker	***More than one (many)***	***radial***
Stuffed bear	***one***	***bilateral***

Figure 4.11: Table from the Symmetry of Different Objects Transparency

5. Encourage students to think about their results. Ask students: **Can you think of any features the objects that were radially symmetrical had in common?**
   Students should indicate that all of the objects they tested in the lab that were radially symmetrical were either circular or cylindrical in shape.

   NOTE: Cylindrical and circular objects generally exhibit radial symmetry. However, this conclusion may lead students to believe that ONLY objects that are cylindrical and circular have radially symmetry. Should this question arise, students may be interested to know that objects that have other shapes such as a cube would also be considered radially symmetrical because they possess many planes of symmetry. Therefore, although one can conclude that cylindrical and circular objects are radially symmetrical, one may not conclude that radially symmetrical objects are ONLY cylindrical or circular in shape.

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Tool: **Conclusions**

Direct students to draw some conclusions about their experiments in problem 6 in their *Scientist Data Record.*

Describe your conclusions about objects that have bilateral and radial symmetry. Use the following words or phrases in your description.

Plane of symmetry cylindrical circular

one more than one

Objects that have more than one plane of symmetry are radially symmetrical. These objects are similar in that they are often circular or cylindrical in shape.

Objects that have only ONE plane of symmetry are bilaterally symmetrical. These objects are generally not cylindrical or circular in shape.

C. Provide an opportunity for students to extend what they have learned about symmetry.

1. Encourage students to recall the drawing they completed in the Pre-Lab (problem 1). Ask students: **Does your drawing have symmetry**?
   Student answers will vary depending upon their drawing. Accept all reasonable answers that students can support. For example, some students may indicate that their drawings are not bilaterally or radially symmetrical because even if a plane is placed in the middle of the road, the two halves of the drawings are not mirror images of each other. Other students may suggest that in artwork, symmetry may not be defined as parts of a painting as mirror images, but rather that there is a balance in the number and size of the objects between two halves of a painting. Therefore, they may suggest that their drawing is symmetrical because it contains a house and tree on both sides of the road.

2. Use the *Art CELL Drawing Presentation* to discuss the type of symmetry or lack of symmetry found in students' drawings.

3. Use the presentation as a springboard for comparing the difference between the type of symmetry students explored in the lab and the more loosely defined symmetry that appears in many forms of art. For example, students may not define their drawings as symmetrical because they are not strictly bilaterally symmetrical—what appears on the right side is not a mirror image of what appears on the left side. Many times, this type of drawing is referred to as symmetrical balance because what is on the right side is balanced by what is on the left side. Art with symmetrical balance also tends to have a central focus or central point at which the sides or points can be divided. Another term artists often use is asymmetrical balance to describe art in which the number and size of the objects on the left and right sides do not balance each other, but rather create an overall feeling of balance for the painting.

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4. After the presentation is finished, conclude the Post-Lab by providing time for students to re-visit their drawings. Task them with adding other objects to the drawing with the intent of making their drawings bilaterally symmetrical, symmetrically balanced or asymmetrical balanced.