MODULE 5

Fruit fly mutation!

FACILITATOR'S GUIDE

GENETICS FOR KIDS

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Fruit fly mutation!

Introduction

Mutations are changes in an organism's cellular DNA. The word "mutation" is often associated with harm or damage to an organism, but that is not always the case. Mutations can be harmful, neutral, or beneficial.

For more than 100 years, scientists have used the fruit fly, *Drosophila melanogaster*, as a model organism to learn more about mutations and human genetics. During the 1900's, Thomas Hunt Morgan, a famous biologist, identified fruit flies as organisms with similar genes to humans. Because fruit flies have a similar genetic makeup to humans, fruit flies can be used to examine human genetic diseases. The advantage of using fruit flies is that while they have a similar genetic makeup to humans, they have fewer chromosomes, which makes them a lot easier to study. In the fruit fly genome, there is a match for 75 percent of human disease genes. Fruit flies also have very short life cycles and it is easy to differentiate between males and females. Fruit flies play a critical role in human medical research and are used as a genetic model to study Parkinson's, Huntington's, Alzheimer's, diabetes, cancer, and drug abuse.

In this module, students will learn about mutations. Students will be introduced to the fruit fly, *Drosophila melanogaster*, an organism commonly used by scientists to study mutations. Students will also learn about the life cycle of the fruit fly to understand when mutations can occur, how scientists name the mutations they discover, and how some specific mutations affect fruit flies.

Learning Objectives

- ✓ **Recognize that a mutation is a change in an organism's DNA**
- ✓ **Understand that a change (mutation) in DNA may cause problems in an organism's functioning, increase an organism's chance of survival, or have no noticeable effects**

Prior Knowledge

To complete this module, students should already be able to:

- ✓ **Understand the basic function of DNA**
- ✓ **Recognize that genes are composed of DNA and influence the functioning of an organism**

Relevant Standards of Learning

National Science Education Standards
Life Science, Content Standard C

Structure and function in living systems

- All organisms are composed of cells – the fundamental units of life. Most organisms are single cells; other organisms, including humans, are multicellular.

Reproduction and heredity

- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to the next.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

New York State Intermediate Science Standards (Grades 5 - 8)
Standard 4: The Living Environment

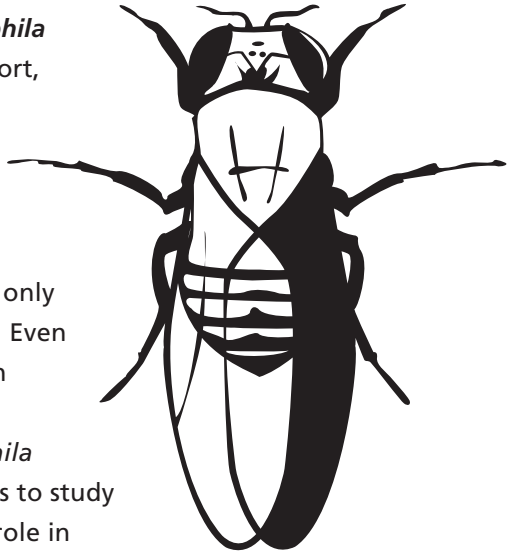
Major Understandings

- 2.1a: Hereditary information is contained in genes. Genes are composed of DNA that makes up the chromosomes of cells.
- 2.1b: Each gene carries a single unit of information. A single inherited trait of an individual can be determined by one pair or by many pairs of genes. A human cell contains thousands of different genes.

Background

Genetic **mutations** are changes to an organism's **DNA**, but not every genetic mutation is harmful for the organism. Mutations may be harmful, neutral, or beneficial to the organism. The outcome of mutations depends very strongly on the environment in which the organism lives.

Fruit flies are good **model organisms** for scientists to study the effects of genetic mutations. Fruit fly mutations yield valuable information about human genes because many fruit fly genes function in ways that are similar to human **genes**. Some genetic mutations occur naturally, and scientists can also create mutations in the laboratory. Students may be surprised to learn that human genes share behavioral characteristics with the genes of these tiny, winged creatures, but much has been learned about human health by looking at the effects of fruit fly gene mutations. Scientists have learned about sex-linked diseases, embryo development, organ and tissue formation, Alzheimer's disease, and Parkinson's disease by using fruit flies as a model organism.



There are over 500 different kinds of fruit flies in the world, but ***Drosophila melanogaste***r is most frequently used by scientists. The fruit fly has a short, 14-day life cycle. They can reproduce as soon as eight hours after coming out of the puparium, the outer shell that forms around the pupae. Fruit flies also produce many offspring (one female can lay 400 eggs at a time!), and have genes that are similar to humans.

Fruit fly genes are easier to study than human genes because they have only eight chromosomes rather than the 46 chromosomes that humans have. Even though fruit flies have fewer chromosomes, they share many genes with humans. An estimated 7,164 of the fly's 14,892 genes share a common origin with human genes. That is almost half! For example, the *Drosophila* version of gene p53 is similar to the human gene p53, allowing scientists to study the p53 gene. In humans, p53 helps repair damage to DNA and plays a role in cancer prevention.

The first scientist to study fruit fly mutations was a Nobel Prize winning biologist named Thomas Hunt Morgan. He studied fruit flies for two years before he saw his first mutation, a fruit fly with white eyes, in 1910.

Fruit flies undergo a life cycle similar to butterflies: egg, larva, pupa, and then adult. The change from larva to adult is called metamorphosis.

The DNA of the fruit fly has instructions for every stage of development and controls how the fly will become an adult. If there are changes in those instructions (mutations), the fruit fly might develop differently. Some examples of mutations are white eyes, curly wings, and longer life spans. To recognize a mutation, you have to know what is normal in fruit fly development *(see Images 1-4 for the life cycle of a fruit fly)*.

Vocabulary

1. **DNA (deoxyribonucleic acid)**: A double-stranded nucleic acid that contains the genetic information for cell growth, division, and function.
2. ***Drosophila melanogaster***: Scientific name (Genus and species) of a kind of fruit fly commonly studied by scientists. A fruit fly is small fly with larvae that feed on decaying fruit and plant matter.
3. **Gene**: A DNA sequence that is transcribed to produce a functional product.
4. **Model organism**: A non-human organism used by scientists in experiments to learn about biological processes, including genetics. Information from the model organism can provide insight about other organisms, including humans.
5. **Mutation**: A change in the sequence of an organism's DNA.

Materials List

Before you begin, ensure that you have all of the items necessary to complete the module.

- ✓ **Student Handout**
- ✓ **One game set per team of two students**
  - ✏ **Game board**
  - ✏ **Card placemat**
  - ✏ **Cards**
- ✓ **Dice**
- ✓ **Two game board place markers per team of two students**
  - ✏ **Place markers can be any small item, such as paper clips and bottle caps.**

Procedure

Day of the Lesson

1. Seat students in pairs.

   Inform students that in today's module, they will learn about mutations to DNA, which can be harmful, neutral, or beneficial. Explain that students will learn about fruit flies, an organism studies by scientists to learn more about human genetics. Inform students to pay close attention to the information in **Part I** and **Part II** because the information will be needed to play "The Mutation Game."

2. Distribute a **Student Handout** to each student.
3. Instruct students to read **Part I: Introduction**.

   Students will use a reflective reading strategy to go through **Part I** of the **Student Handout**. Remind the students that the information from **Part I** and **Part II** will be used again in **Part III: Activities**.

   Explain reflective reading to the students. In one form of reflective or reciprocal reading, one partner reads aloud a section of text while the second partner listens. The listening partner will then ask the reading partner at least two questions based on the text the reading partner read. The students will then switch roles for the next section of text.

Circulate around the room as students read. Redirect students with questions, and check for comprehension as needed.

4. Emphasize key points from **Part I: Introduction**.

   When students finish reading, address any questions they may have about mutations. Emphasize the following key points:

   - A mutation is a change in the DNA sequence.
   - A mutation can be harmful, neutral, or beneficial. The outcome of a mutation may depend on the environment in which an organism lives.
   - Fruit flies are a model organism used by scientists to learn more about human genes.

5. Check students' understanding of **Part I: Introduction**.

   After you have emphasized the key points of the introduction, ask students the following questions:

   - What is a mutation?
   - Name the stages of fruit fly development.
   - What is an example of a beneficial mutation?
   - What is an example of a harmful mutation?

   After discussing the above questions, allow students a few moments to record the answers in **Part II** in the "Check your understanding" box. If you have supplemental materials, such as a vial of real fruit flies *(see Sources for Materials)*, exhibit them at this time.

   Allow students to observe the fruit flies and the differences between humans and flies. Emphasize that although fruit flies look nothing like humans, the fruit flies share many similar genes with humans, therefore, studying mutations in the fruit fly can lead to beneficial discoveries in human health.

6. Instruct students that they will play "The Mutation Game" with their reading partner.

   Inform students that they will play "The Mutation Game."

   As a class, read though the rules of the game on the **Student Handout**. Use a complete game set to show the different game pieces, including the game board, card types, and where the cards go on the card placemat.

   Remind your students that they will use the information from both **Part I** and **Part II** to play "The Mutation Game."

7. Distribute a complete game set to each pair of students.

8. Inform students that they may begin playing "The Mutation Game."

   When the students are ready, they may begin playing the game. Once students begin the game they may not look at **Part I** or **Part II** of the **Student Handout**. If students get stuck, each player is allowed one pass to search for an answer in the **Student Handout**.

   As students play the game, circulate around the room to monitor behavior and answer questions. The game takes about 15 to 20 minutes to complete.

9. Provide alternative activities for students that finish more quickly than the others.

   If a pair of students finish the game early, offer alternative activities. Tell the students they may play the game again.

   For an enrichment activity, your students can use a microscope with a slide of a fruit fly to examine the anatomy *(see Sources for Materials)*. If you do not have access to a microscope and slides of fruit flies, you can provide photos showing details of fruit fly anatomy *(see Additional Resources)*. You can also provide information about scientific discoveries for human health by using fruit flies and photos of fruit fly mutations *(see Additional Resources 2 and 3)*.

10. Lead a closing class discussion about the module's activities.

    Bring the class together as a group and conduct a brief wrap-up discussion after students have had a chance to play at least one round of the game. Ask prompting questions, such as:

    - Can you identify the three possible outcomes of mutations in organisms?

      Harmful, neutral, or beneficial to survival.

    - Can you identify a beneficial/neutral/detrimental mutation of *D. melanogaster*?

      The answer to this question will vary for each student.

    Reinforce the following concepts:

    - Not all mutations hurt the survival of the fruit fly, and the effect on survival depends on the environment.
    - Mutations are changes in the DNA of an organism that can cause changes in how an organism looks or acts. Mutations can be harmful, neutral, or beneficial.

    If you have a few extra minutes, ask students to name their favorite mutations or what they would name a mutation if they were given the opportunity *(see Teacher Notes 1 and 2)*.

Extension Lesson

Culture a Fruit Fly

Students may develop an interest in further investigation with real fruit flies. Since fruit flies are an easy organism to culture, students can design simple experiments to observe the fly life cycle or document basic fly behavior (if you culture the fruit flies in your classroom).

To culture fruit flies, create holes in the top quarter of a plastic soda bottle. Place a bit of fruit into the bottle opening, and put on the lid. You can culture flies for a few months in this arrangement as long as you occasionally drop in some food.

Once the fruit fly culture is established, assign students to research behavioral mutations. Then, examine behaviors in the flies to determine whether the flies exhibit any mutations. To ensure that students are able to observe mutations in the fruit flies, purchase live samples of fruit flies with known mutations. For example, some fruit flies may cover large areas in search of food while others cover a small area. The fruit fly variants, Rover, which covers a large area, and Sitter, which covers a small area, have different metabolisms that affect their food searching strategies. The Sitter has a lower level of mitochondrial activity, which can cause the fly to tire easily.

Research suggests that fruit flies have memories and can be trained. Consider assigning students to set up an experiment to train flies over a few weeks' time to perform a behavior.

Teacher Notes

1. Many students do not think mutations can be beneficial, but there are examples of beneficial mutations in human populations. In some geographic areas people with the sickle trait have an advantage over people with normal red blood cells. In areas of high malaria incidence, the sickle cell trait can protect people from contracting the disease.

2. Similarly, in the plant world, many plants exhibit polyploidy, or multiples of entire sets of chromosomes. For example, commercial potatoes in the United States have four sets of 12 chromosomes, compared to the wild type of potato that only has one set of 12 chromosomes. Often these polyploid plants are bigger and more vigorous than the original, wild types of plants.

Sources for Materials

1. Carolina Biologicals. You can purchase winged and wingless flies and supplies from this website. http://www.carolina.com/category/living+organisms/animals/drosophila+%28fruitfly%29.do

Additional Resources

1. *Drosophila melanogaster*. Lesson plans and photos for using fruit flies in the classroom. http://biology.arizona.edu/sciconn/lessons2/Geiger/prelude.htm

2. Model Organism: Fruit flies. This website provides actual photos of fruit flies with various mutations. http://www.exploratorium.edu/imaging_station/gallery.php?Category=%20Fruit%20flies&Section=Model%20Organisms.

3. Mutant fruit flies. This website provides drawings and information on fruit flies with various mutations. http://www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html

4. NASA, *Flies in Space: Drosophila: Animated Life Cycle*. This links to an animated video that walks through the life cycle of the fruit fly, *Drosophila*. http://quest.nasa.gov/projects/flies/cycleAnim.html

5. The WWW Virtual Library: *Drosophila*. This website provides additional background on *Drosophila melanogaster*, including the Drosophila Genome Project, Drosophila labs on the web, and a host of online resources. http://ceolas.org/VL/fly/index.html

Part I: Introduction

Mutations are changes to the **DNA** in an organism's cells. Sometimes mutations cause problems in the cell (a harmful mutation). Sometimes there is no effect (a neutral mutation) because the change does not affect the instructions that are given to the cell. Sometimes the change even helps the organism to survive better (a beneficial mutation). Often, the outcome of a mutation depends very strongly on the environment in which an organism lives. Scientists often study mutations in humans using model organisms. A model organism has a genetic makeup similar to humans, but is easier to study. One common model organism is the fruit fly. Fruit fly mutations occur both naturally and artificially. Mutations for many **genes** can be produced artificially in the laboratory by exposing flies to radiation or giving them food that contains chemicals that cause mutations in the flies.

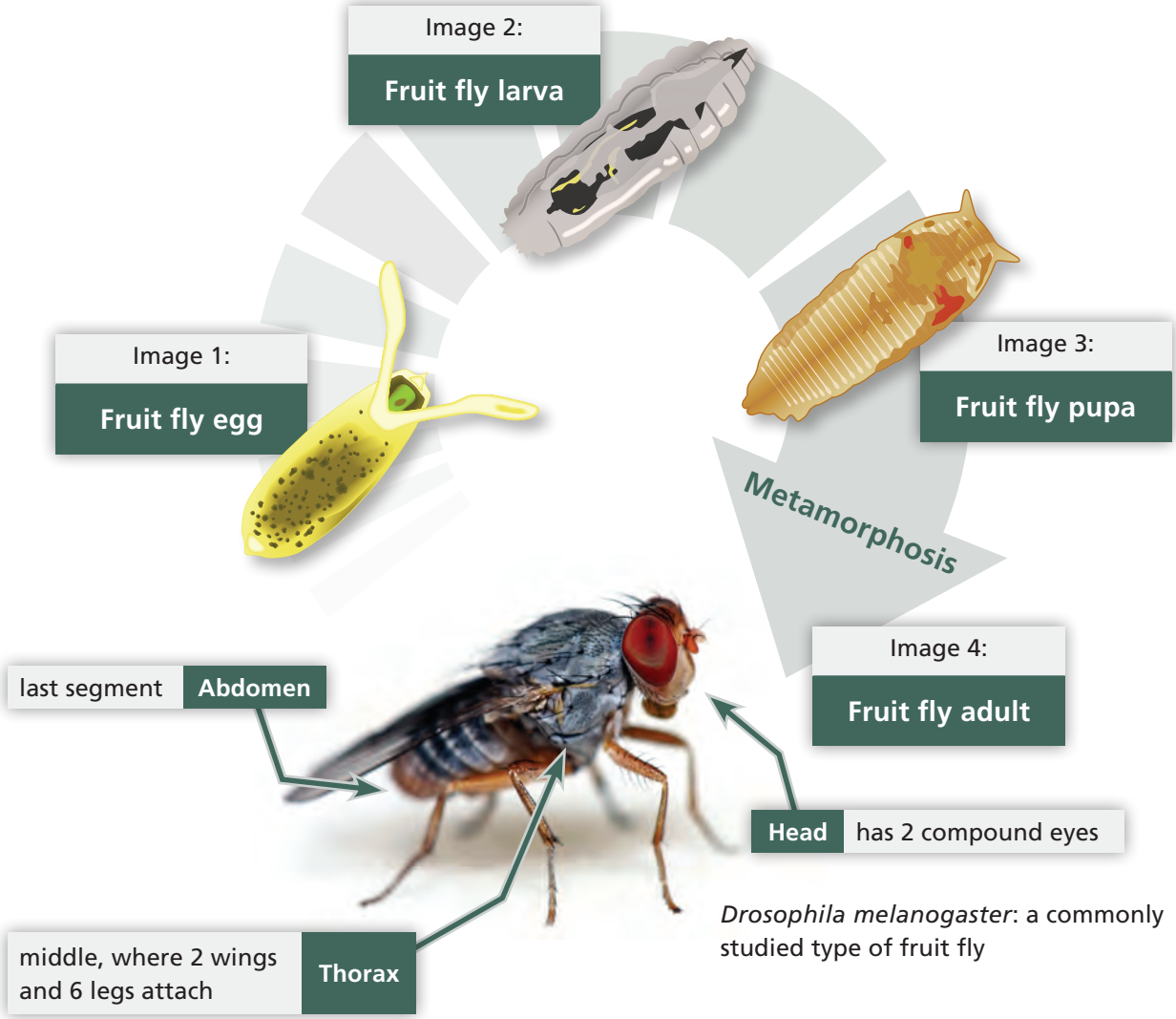
There are over 500 different kinds of fruit flies in the world, but ***Drosophila melanogaster*** is frequently used as a model organism for humans because its genes are very similar to humans. The fruit fly has a short, 14-day life cycle. It can reproduce as soon as eight hours after it is born. The Drosophila melanogaster fruit fly can also produce many offspring–one female can lay 400 eggs at a time!

Fruit fly genes are easier to study than human genes because they have only eight chromosomes rather than the 46 chromosomes that humans have. Even though fruit flies have fewer chromosomes, they share many genes with humans. An estimated 7,164 of the fly's 14,892 genes share a common origin with human genes. That is almost half!

Fruit flies undergo a life cycle similar to butterflies: egg, larva, pupa, and then adult. The change from larva to adult is called metamorphosis. The DNA of the fruit fly has instructions for every stage of development and controls how the fly will become an adult. If there are changes in those instructions (mutations), the fly might develop differently. A few examples of mutations are white eyes, curly wings, and longer life spans.

One example of a harmful mutation in fruit flies is a mutation that causes the fruit fly's nerves to grow in the wrong place during larval development, therefore, the brain does not develop properly. A neutral mutation is a mutation that may or may not be visible and that does not affect the survival of the fruit fly. For example, a mutation that causes fruit fly eyes to be white instead of red does not reduce the survival of the fruit fly. An example of a beneficial mutation may be a mutation that doubles the lifespan of the fly. To recognize a mutation, you have to know what is normal in fruit fly development *(see Images 1-4 for the life cycle of a fruit fly)*.

Fruit fly life cycle



Drosophila melanogaster: a commonly studied type of fruit fly

You can see some mutations, such as the white-eyed fruit fly *(Image 5)*. Others you cannot see, like the INDY gene mutation that causes the flies to live much longer than normal. Fruit fly scientists who discover or create new mutations get to name them. Traditionally, creative names are sought for these new mutations. For example "INDY" stands for "I'm Not Dead Yet" after a scene in a Monty Python movie. Another name is "fushi tatazu" (Japanese for "segment of bamboo" and "not enough") for a mutation that causes the larva to develop fewer body segments than normal.

Image 5: (left) normal adult fruit fly with red eyes, (right) adult fruit fly with mutation for white eyes

Part II: Vocabulary

1. **DNA (deoxyribonucleic acid)**: A double-stranded nucleic acid that contains the genetic information for cell growth, division, and function.
2. ***Drosophila melanogaster***: Scientific name (Genus and species) of a kind of fruit fly commonly studied by scientists. A fruit fly is a small fly with larvae that feeds on decaying fruit and plant matter.
3. **Gene**: A DNA sequence that is transcribed to produce a functional product.
4. **Model organism**: A non-human organism used by scientists in experiments to learn about biological processes, including genetics. Information from the model organism can provide insight about other organisms, including humans.
5. **Mutation**: A change in the sequence of an organism's DNA.

Check your understanding:

1. What is a mutation? _____

   _____

2. Name the stages of fruit fly development: _____
3. Describe a beneficial mutation: _____

   _____

4. Describe a harmful mutation: _____

   _____

Part III: Activities

Activity 1: Play the Mutation Game

Hope you paid very close attention to the information in Part I and Part II because now you and a partner are going to play The Mutation Game!

1. Collect your materials for the game. You will need the following:
   - Game board
   - Card placemat
   - Knowledge (K) cards
   - LIFE! cards
   - Mutation cards
   - Fruit fly (FF) cards
   - Place markers
   - One six-sided die
2. The objective of the game is to collect the most **fruit fly (FF)** cards. To begin, put your marker and your partner's marker on the **EGG HATCHING** circle on the game board. Put all the cards on the card placemat. The youngest player should go first. Roll the die, and move the number of places indicated. If you:
   a. Land on a **K** space, **your partner** should draw one **Knowledge (K)** card and read the question to you. If you answer correctly, draw two **fruit fly (FF)** cards from the stack on the card placemat. If you give an incorrect answer, give your partner two **FF** cards from the stack on the card placemat. Put the **K** card you used in the discard pile on the card placemat.
   b. Land on a **LIFE!** space, draw one **LIFE!** card. Read and follow the instructions on the card. Put the used card in the discard pile on the card placemat.
   c. Land on a **Mutation** space, draw one **Mutation** card. Read and follow the instructions on the card. Put the used card in the discard pile on the card placemat.
   d. Land on a picture of a fruit fly, draw one **FF** card.
   e. Land on a space already occupied by your partner, give your partner two **FF** cards.
   f. Use all the **LIFE!**, **Mutation**, or **K** cards before the game ends, shuffle the cards and use them again.
   g. Land on a "go back" or "move ahead" square, follow the arrow but do not take another card.
3. The game ends when one person reaches the **TIME'S UP!** space. You do not need to roll the exact number on the die in order to reach the **TIME'S UP!** space on the game board. For example, if you are one space away from the **TIME'S UP!**space and roll a three on the die, you may move to the **TIME'S UP!** space and end the game. Whoever has the most **FF** cards wins! **FF** cards represent offspring. In the life of a fruit fly, the winners are the fruit flies that pass on the most copies of their genes.

Part IV: Conclusion questions

Take some time to think about today's discussion and activity.

1. What is a mutation and how does one occur?

2. How can mutations affect organisms such as fruit flies?

3. Can you think of any reasons why it is important to study mutations? Explain your answer.

4. Write a summary statement about what you have learned from today's lesson.

Part V: Notes

Part I: Introduction

Mutations are changes to the **DNA** in an organism's cells. Sometimes mutations cause problems in the cell (a harmful mutation). Sometimes there is no effect (a neutral mutation) because the change does not affect the instructions that are given to the cell. Sometimes the change even helps the organism to survive better (a beneficial mutation). Often, the outcome of a mutation depends very strongly on the environment in which an organism lives. Scientists often study mutations in humans using model organisms. A model organism has a genetic makeup similar to humans, but is easier to study. One common model organism is the fruit fly. Fruit fly mutations occur both naturally and artificially. Mutations for many **genes** can be produced artificially in the laboratory by exposing flies to radiation or giving them food that contains chemicals that cause mutations in the flies.

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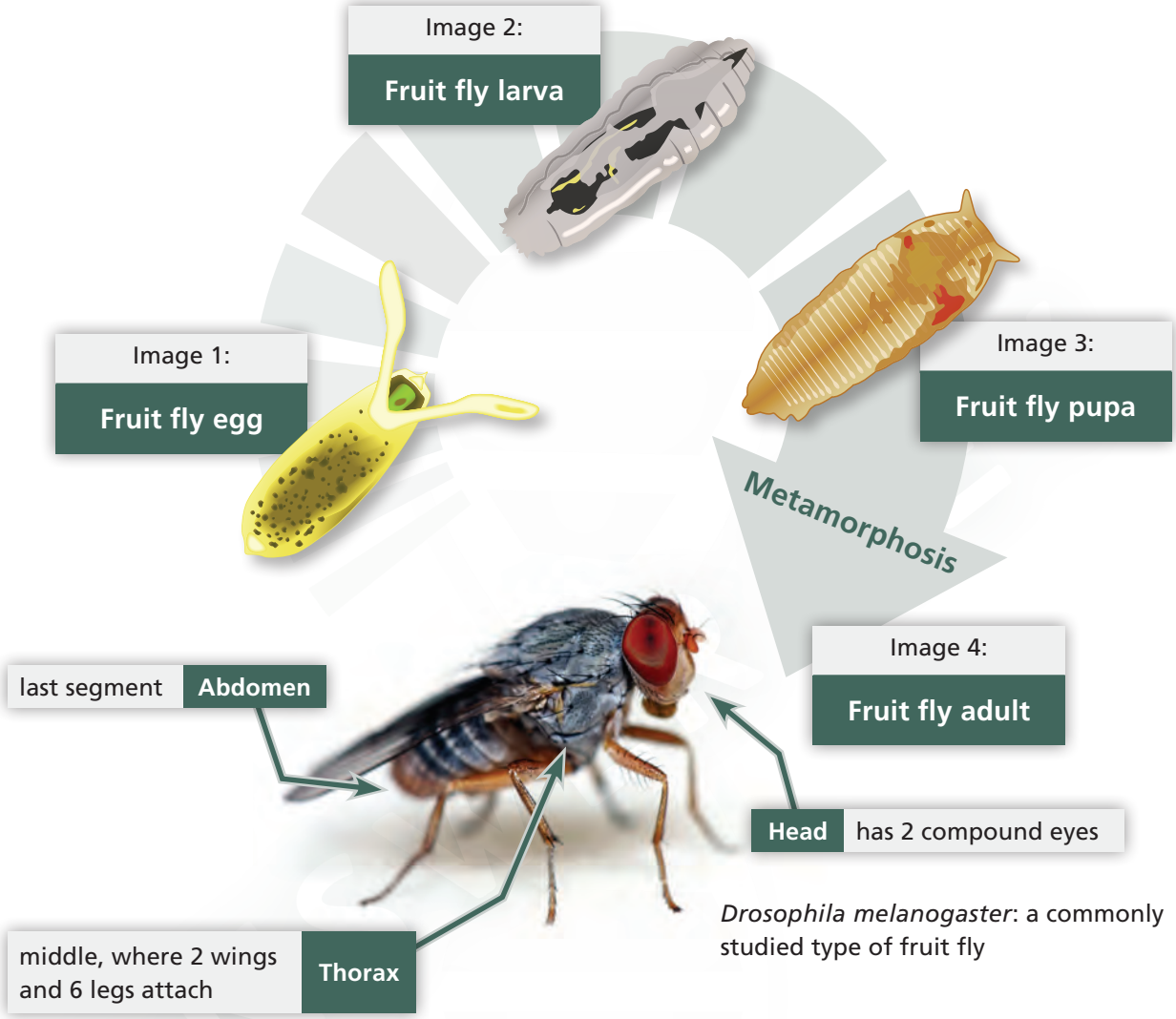

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Image 5: (left) normal adult fruit fly with red eyes, (right) adult fruit fly with mutation for white eyes

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5. **Mutation**: A change in the sequence of an organism's DNA.

Check your understanding:

1. What is a mutation?

A mutation is change in the sequence of an organism's DNA.

2. Name the stages of fruit fly development:

The stages of fruit fly development are egg, larva, pupa, and adult.

3. Describe a beneficial mutation:

A gene that increases the lifespan.

4. Describe a harmful mutation:

A gene that prevents the brain from developing correctly.

Part III: Activities

Activity 1: Play the Mutation Game

Hope you paid very close attention to the information in Part I and Part II because now you and a partner are going to play The Mutation Game!

1. Collect your materials for the game. You will need the following:
   - Game board
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   - Place markers
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   b. Land on a **LIFE!** space, draw one **LIFE!** card. Read and follow the instructions on the card. Put the used card in the discard pile on the card placemat.
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Part IV: Conclusion questions

Take some time to think about today's discussion and activity.

1. What is a mutation and how does one occur?

A mutation is a change in the sequence of an organism's DNA. A mutation can occur randomly or can be created in a lab.

2. How can mutations affect organisms such as fruit flies?

Mutations can be harmful, neutral, or beneficial to a fruit fly.

3. Can you think of any reasons why it is important to study mutations? Explain your answer.

Studying mutations can provide useful information about human health. For example, scientists study mutations in fruit flies to learn more about genetic diseases in humans.

4. Write a summary statement about what you have learned from today's lesson.

The answer to this question will vary for each student, but they should address the importance of mutations.

Part V: Notes

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Fruit fly mutation!

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