HOW TO USE THIS RESOURCE:

The image for this resource, which shows the bloodsucking mouthparts of a mosquito, can serve as a phenomenon to explore the key concepts described below.

The pedagogical practice of using phenomena to provide a context for understanding science concepts and topics is an implementation practice supported by the Next Generation Science Standards (NGSS). Phenomena are observable occurrences that students can use to generate science questions for further investigation or to design solutions to problems that drive learning. In this way, phenomena connect learning with what is happening in the world while providing students with the opportunity to apply knowledge while they are building it.

The "Implementation Suggestions" and "Teaching Tips" sections provide options for incorporating the image into a curriculum or unit of study and can be modified to use as a standalone activity or to supplement an existing lesson. The "Student Handout" includes reproductions of the image and the "Background Information" section.

KEY CONCEPTS

- Many infectious human diseases are caused by microbial pathogens, such as viruses.
- A vector is an organism that transmits pathogens from one host to another. Many infectious diseases are transmitted via animal vectors.
- The biology and life cycles of vectors influence how effective they are at transmitting diseases. Understanding vector biology is important for developing strategies to predict, reduce, or interrupt disease transmission.

BACKGROUND INFORMATION

This image shows the mouthparts of a female mosquito under a powerful microscope. The mosquito uses these mouthparts to drink blood from other animals, called **hosts**. The mouthparts help the mosquito pierce a host's skin and suck out blood, which the mosquito needs to make eggs. The red parts of the image indicate blood cells from the host.

Sometimes, a mosquito drinks blood from a host infected by a **pathogen**: a disease-causing microbe such as a virus, bacterium, or parasite. The pathogen may enter the mosquito and can then be **transmitted**, or passed on, to the mosquito's future hosts.

An organism that transmits pathogens (and the diseases they cause) from one host to another is called a **vector**. Examples of vectors include mosquitoes and other biting arthropods, such as flies, fleas, lice, and ticks. **Vector-borne diseases** are diseases caused by pathogens that are transmitted from one host to another by vectors. Mosquitoes are the main vectors for a variety of vector-borne diseases — including dengue, chikungunya, West Nile fever, and Zika — that lead to the deaths of more than 700,000 people worldwide each year.

Many **emerging diseases**, diseases that are becoming more common or of concern, are transmitted by vectors. Biologists and medical experts work to control the spread of vector-borne diseases by studying vectors, such as mosquitoes. Learning about the biology of a vector — including its life cycle, physiology, and behavior — can help us better understand how diseases spread and how we can develop effective management and control strategies to reduce disease transmission.

IMPLEMENTATION SUGGESTIONS

The following suggestions outline several options for incorporating the image into a unit of study as a phenomenon:

Engagement, establishing prior knowledge, and providing context:

- Begin the lesson by showing the image without any context. Ask students to make observations using the sentence stems "I notice…", "I wonder…", and "It reminds me of…".
- Have students brainstorm ideas and reasoning for what the image could be showing using the sentence stems "It could be… because…". Students should also record any questions that arise from their observations and brainstorming.
- Use a think-pair-share protocol to have students share their observations, ideas, and questions about the image. Have each group report out their main observations, ideas, and questions and draw attention to the range of student-generated responses.
- Explain that the image shows the bloodsucking mouthparts (proboscis) of a female mosquito and was taken using a powerful microscope (scanning electron microscope).
    - The red areas of the image (which were colored in by a computer) indicate blood cells. You may need to circle, describe, or otherwise indicate these areas for colorblind or other visually impaired students.
    - Students may wonder how the mouthparts work and why they are covered in blood. Consider having students discuss where and when they have previously encountered mosquitoes and why mosquitoes need blood. Some students may note that mosquitoes can transmit diseases.
- Have the students read the "Background Information" for the image.
- Transition to the next set of activities by asking students to consider what strategies could be used to control mosquitoes and the diseases they spread.
    - Depending on students' previous experience and knowledge, you can have them work in groups to develop a preliminary series of control strategies. The student strategies could focus on their local environments (neighborhood, school, parks) to incorporate their experiences and develop practical solutions.
    - For students with more limited experience with mosquitoes, it may be helpful for them to focus on and share any questions they might have about mosquitoes, including what additional information about mosquitoes they would like to know in order to develop their control strategies.
        - For example, students may want to know where mosquitoes are found, how and when they feed, what attracts them to food sources, what predators they have, etc.

Exploration/Investigation, Part 1:

- Use a jigsaw approach to help students further explore the role of mosquitoes in spreading diseases and strategies to minimize these diseases. This approach can be implemented following the sequence below.
- Divide students into small groups that will each explore a different aspect of mosquitoes' biology, ecology, or interactions with pathogens.
- For each group, provide specific prompts tied to the questions that students shared earlier in the activity. These prompts should help students develop a broader understanding and context for devising mosquito-control strategies. Potential prompts may include:
    - "What does the image of a female mosquito's mouthparts (proboscis) tell us about the biology and behavior of mosquitoes?"
        - Students can explore this prompt by focusing on the morphology of the mouthparts ("How do the different components work together?"), on physiological processes ("How do mosquitoes move and

process blood from their hosts? Why do female mosquitoes need blood as part of their life cycle?"), or on mosquito feeding behavior ("How do mosquitoes find their hosts or choose their feeding sites?").

- "What is the general ecology of mosquitoes?"
  - Students could explore the life cycle of mosquitoes, the factors that influence when and where mosquitoes are found, or the relationships between mosquitoes and their prey ("Are mosquitoes generalists, or do they specialize on certain prey?") or predators ("What eats mosquitoes? How do predators and pathogens control mosquito populations?").
- "What is the relationship between mosquitoes and the pathogens they spread?"
  - Students may explore how mosquitoes become infected by pathogens, the factors that make some mosquitoes more likely to spread pathogens, or the effects of these pathogens on the mosquitoes themselves.

- Have each group explore external resources to address their prompts, then present their findings to the class.
- Ask each group to use what they have learned from the presentations to develop a strategy (or revise their previously proposed strategy) for controlling diseases spread by mosquitoes.

Exploration/Investigation, Part 2:

- Ask students to diagram what they know about the life cycle of mosquitoes, including the mosquito's life stages. Their diagrams should include predictions for where each stage might be found in the environment and what each stage might be feeding on.
- Have students watch the video *The Mosquito Life Cycle*, which provides an overview of the mosquito's life stages and how mosquitoes can transmit disease. After watching the video, students should revise and annotate their diagrams based on what they learn.
- Have groups of students expand on their understanding based on the video using external sources to address one or more of the following prompts:
  - "Discuss how the requirements of each mosquito life stage (egg, larva, adult) might determine their distributions in space and time. What is required in the environment to support the mosquito's entire life cycle?"
    - Larvae may require stagnant water and food sources such as algae, plankton, bacteria, and other microorganisms. Adults may require nectar and females may require blood.
  - "What adaptations does each mosquito life stage (larva and adult) have to its environment?"
    - Larvae have "breathing tubes" (siphons) for living underwater. Adults have antennae and other receptors to help them locate hosts on land (by detecting CO_2 plumes of their hosts or other odors).
    - Both adults and larvae develop specific mouthparts and other physiological features to match their diet. They also have specific appendages to help them move through their environment (appendages for swimming in larvae, wings for flying in adults).
  - "How might changes in abiotic and biotic factors influence the number of mosquitoes in an environment?"
    - Students could consider the resources required by mosquitoes to develop and feed, and how those resources and other "bottom-up" factors influence mosquito distributions.
    - Students could consider the role that predators and other "top-down" factors play in controlling mosquito populations.
- If you had all groups consider the *same* prompt, have students share out as a class. Reiterate and record student ideas, looking for places of commonality and divergence.

- If you had groups consider *different* prompts, use a gallery walk with feedback to make student thinking visible to their peers. Student explanations can be used to assess their understanding and engagement.

Exploration/Investigation, Part 3:

- Have students use the *Stopping Mosquito-Borne Disease* Click & Learn to apply their understanding of mosquitoes and vectors. This Click & Learn explores different strategies for disrupting the life cycle of *Aedes* mosquitoes, which are vectors for dengue. Students will also examine and interpret data to understand the impact of one mosquito-eradication program carried out in Fortaleza, Brazil.
- Use the Click & Learn to set the stage for further individual reflections or group and classroom discussions. Students can use their knowledge to develop explanatory hypotheses or address new questions. Some suggested questions are as follows:
  - "What factors might make some vectors (such as different mosquito species or different insects) more effective at transmitting diseases than others? Develop a hypothesis regarding these factors."
  - "How is the abundance of mosquitoes influenced by environmental factors? Develop a hypothesis about how an abiotic or biotic factor may influence mosquito population sizes and distributions."
  - "What factors might explain the current global spread of vector-borne diseases? Develop a hypothesis regarding how changing environmental and climatic conditions, as well as human activities, might contribute to the spread of vector-borne diseases."
- Depending on the class and activity, students could also develop predictions that, if true, would support their hypotheses. The students could then design an experiment that would test their hypotheses.
- Students can further develop their thinking by using external sources to address these prompts, inform their ability to develop hypotheses, and help them design experiments to test these hypotheses.

Assessment:

- A number of points for assessment are built into the "Exploration/Investigation" sequences described above. For instance:
  - In Part 1, you could assess the degree to which student understanding improves by comparing their initial control strategy ideas (generated during the "Engagement, establishing prior knowledge, and providing context" sequence) with their modified ideas (based on their group research and jigsaw activity).
  - In Part 2, you could assess student understanding by comparing their initial life cycle diagrams with their revised diagrams following the video.
  - In Part 3, you could use the questions on slides 15–24 of the *Stopping Mosquito-Borne Disease* Click & Learn to assess how students are able to evaluate presented data. If you had students design an experiment to test their hypotheses, you could evaluate their designs for their foundational understanding and ability to apply the scientific method.
  - In all three parts, you could assess the degree to which students can find, evaluate, and incorporate relevant external sources to address different questions. You could also assess the degree to which students are able to verbally communicate their findings and evaluate and incorporate information provided by other groups.

Extension:

- Students can expand their understanding of mosquito biology and vector-borne diseases by exploring one or both of the following resources on West Nile virus (which has multiple hosts as part of its transmission cycle):

  - The Click & Learn *From Birds to People: The West Nile Virus Story* shows that the main hosts of the West Nile virus are birds. Although West Nile virus cannot spread by infecting humans, the virus can still strongly impact human health.
  - The card activity "West Nile Virus: Vectors and Hosts Game" has students take the role of either a vector (mosquito) or one of several hosts to simulate how the West Nile virus spreads. Students can reflect on how the presence of multiple reservoirs for pathogens can influence disease dynamics.
- Use the "Mosquito Life Cycle" activity to have students further develop and test hypotheses regarding how different environmental factors (temperature, light, food availability, etc.) influence the development and survival of mosquitoes. This activity shows how understanding the biology of vectors can inform our understanding of vector-borne diseases, as well as management and public policy decisions. The "Asking Scientific Questions" activity can provide additional classroom support.
  - You can use the "Student Handout" for this activity to guide and assess student learning. For example, the following prompt from the end of the activity can be used to have students synthesize what they have learned: "Using evidence from the data you collected, develop a claim to explain how people in a community could determine whether there is a mosquito problem where they live and how they might slow or prevent the spread of mosquito-borne disease."
- Students can learn about more pathogens transmitted by mosquitoes and other vectors using the following resources:
  - The animations *Malaria: Human Host* and *Malaria: Mosquito Host* show the life cycle of the malaria parasite, including how it is transmitted to humans by mosquitoes.
  - The *Virus Explorer* Click & Learn highlights several viruses transmitted by vectors. It includes 3D models of different viruses, the criteria that scientists use to classify viruses, the characteristics of different viruses, their modes of transmission, and their global prevalence.
- Students can watch the following videos to explore innovative approaches that scientists are developing to control the spread of vector-borne diseases:
  - *Genetically Modified Mosquitoes* describes how scientists are creating and releasing genetically modified mosquitoes to reduce populations of wild mosquitoes.
  - *Mosquitoes Might Save Lives, Thanks to Bacteria* shows how inoculating mosquitoes with bacteria can prevent mosquitoes from transmitting dengue virus to humans.

TEACHING TIPS

- Present students with the image first, before they read the background information.
- Encourage students to draw upon their prior experiences and knowledge to interpret the image and generate questions.
- Provide opportunities for students to explore outside sources to promote their independent explorations and team discussions.
- Background information may be edited to support student proficiency, course sequence, etc.
- The image may be projected in lieu of handouts.
- Printed images can be laminated for use in multiple classes.

CREDITS

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