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JAMES GATHANY/CDC

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Malaria molecule lures mosquitoes

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

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About this Issue

The article "Malaria molecule lures mosquitoes" (12.9 readability score) reports new clues about how mosquitoes may be preferentially attracted to malaria-infected individuals. Red blood cells with more of a molecule produced by the malaria parasite release more carbon dioxide and more airborne chemicals known to attract mosquitoes. Students can focus on details in the article; find connections to earlier articles about malaria, parasites or other diseases; explore cross-curricular connections to other major science topics; and learn about how diseases affect the blood by comparing malaria-infected blood with healthy blood and other samples under the microscope.

Science News for Students provides another version of this article written at a lower Lexile level (8.0 readability score): "Malaria molecule lures mosquitoes." Power Words are defined at the end of the *Science News for Students* article.

Want to introduce your students to an interesting STEM career related to this article? Check out Cool Jobs: Finding new uses for nature's poisons by *Science News for Students*.

Connections to Curricula

- Public health
- Biochemistry
- Microscopy
- Blood and cells
- Protists
- Viruses
- Molecular structure
- Epidemiology
- Disease

What's in this Guide?

- Article-Based Observation: These questions focus on reading and content comprehension by drawing on information found in the article "Malaria molecule lures mosquitoes." Questions focus on a recent research finding that connects malaria parasites in hosts to a host's attractiveness to mosquitoes.
- Quest Through the Archives: Mosquitoes that carry the Zika virus have received a lot of attention in the last year, but mosquitoes play a big role in the spread of many other diseases. With Internet access and your school's digital access to *Science News*, your students can use this short section to explore the history of diseases carried by mosquitoes as reported by *Science News* since 1922.
- Cross-Curricular Discussion: These questions and extension prompts connect to the article "Malaria molecule lures mosquitoes" and encourage students to think in more detail about scientific areas related to the article. The section is divided roughly by science subdiscipline for educators who would like to focus on one particular topic area. The extension prompts are either more topic specific or more conceptually advanced. **Biological Sciences** questions concern the life cycle of malaria parasites and related organisms. **Chemical and Physical Sciences** questions focus on molecular

structures of biomolecules and the benefits of understanding their properties. **Engineering and Experimental Design** questions cover potential applications of the new research and explore other host-controlling parasites.

- Activity: **Malaria Under the Microscope** gives students the opportunity to explore differences between healthy and infected cells by comparing prepared microscope slides of mosquitoes, human blood, malaria-infected blood and other related samples. Students will also explore the basis of some disease symptoms.

Standards Alignment

Next Generation Science	Common Core
From Molecules to Organisms: Structures and Processes: HS-LS1-2	ELA Standards: Reading Informational Text (RI): 1, 2, 4, 5, 7
Ecosystems: Interactions, Energy and Dynamics: HS-LS2-8, HS-LS2-4, HS-LS2-6, HS-LS2-8	ELA Standards: Writing (W): 1, 2, 3, 4, 6, 7, 9
Biological Evolution: Unity and Diversity: HS-LS4-3, HS-LS4-4, HS-LS4-6	ELA Standards: Speaking and Listening (SL): 1, 2, 4, 6
Earth and Human Activity: HS-ESS3-5, HS-ESS3-6, HS-ESS3-8	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
Engineering Design: HS-ETS1-1, HS-ETS1-2	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 9

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Article-Based Questions

Directions: Read the recent article "Malaria molecule lures mosquitoes" and then answer these questions:

1. **What molecule does *Plasmodium falciparum*, a malaria parasite, produce in blood? When this molecule is present in blood, what effect does it have on malaria-transmitting mosquitoes?**

2. **According to biologist Ingrid Faye, what observation did researchers make while watching mosquitoes sip blood from artificial feeders? What did their observation make them think?**

3. **What is produced from red blood cells containing HMBPP? How does this affect malaria-transmitting mosquitoes?**

4. **Why were the malaria-transmitting mosquitoes *Anopheles gambiae* more attracted to blood that contains HMBPP? Fully explain the relationships stated.**

5. **What might be the evolutionary advantage of the malaria parasite producing HMBPP in blood?**

6. **Given the information in this article, come up with a research question you would use to explore decreasing the spread of malaria by mosquitoes.**

7. **Finished early? Check out this related *Science News* article and answer the question that follows. "In malaria battle, indoor bug spraying has unintended consequence," found at www.sciencenews.org/article/malaria-battle-indoor-bug-spraying-has-unintended-consequence, discusses a possible trend in mosquito evolution, perhaps caused by the use of pesticides. What is the unintended consequence of indoor bug spraying and what implications are noted?**

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Responses to Article-Based Observation

1. **What molecule does *Plasmodium falciparum*, a malaria parasite, produce in blood? When this molecule is present in blood, what effect does it have on malaria-transmitting mosquitoes?**
   Possible student response: Malaria parasite *P. falciparum* produces a molecule called HMBPP or (E)-4-hydroxy-3-methyl-but-2-enyl pyrophosphate that makes parasite-infected blood more attractive to malaria-transmitting mosquitoes.

2. **According to biologist Ingrid Faye, what observation did researchers make while watching mosquitoes sip blood from artificial feeders? What did their observation make them think?** Possible student response: The researchers noticed that mosquitoes ate a lot more blood from the artificial feeding system when HMBPP was in the blood. But when HMBPP was mixed with serum not containing red blood cells, the allure to infected serum was not as great. This observation led the researchers to believe that HMBPP is not directly attracting the mosquitoes but having its effect through other molecules or chemicals.

3. **What is produced from red blood cells containing HMBPP? How does this affect malaria-transmitting mosquitoes?** Possible student response: When HMBPP mixes with red blood cells, more carbon dioxide is released compared with HMBPP-free red blood cells. Also, greater amounts of certain airborne chemicals called aldehydes and monoterpenes are produced. Malaria-transmitting mosquitoes are more attracted to a greater concentration of all of these molecules.

4. **Why were the malaria-transmitting mosquitoes *Anopheles gambiae* more attracted to blood that contains HMBPP? Fully explain the relationships stated.** Possible student response: Blood that contains HMBPP produces more carbon dioxide, aldehydes and monoterpenes. Mosquitoes sense exhaled carbon dioxide and use it to find blood sources, so a greater concentration of the chemical would be more attractive to mosquitoes. Similarly, the aldehydes and monoterpenes produced by infected blood attract mosquitoes. Many nectar-containing plants that mosquitoes feed on produce these molecules. A greater number of mosquitoes should be lured toward a higher concentration of these chemicals.

5. **What might be the evolutionary advantage of the malaria parasite producing HMBPP in blood?**
   Possible student response: If blood infected with the malaria parasite attracts more malaria-transmitting mosquitoes, there is a greater probability that the parasite will spread to more people.

6. **Given the information in this article, come up with a research question you would use to explore decreasing the spread of malaria by mosquitoes.** Possible student response: How does the malaria parasite produce HMBPP? If HMBPP production can be prevented or decreased, then the rate of malaria transmission by mosquitoes would likely decrease.

7. **Finished early? Check out this related *Science News* article and answer the question that follows. "In malaria battle, indoor bug spraying has unintended consequence," found at www.sciencenews.org/article/malaria-battle-indoor-bug-spraying-has-unintended-consequence, discusses a possible trend in mosquito evolution, perhaps caused by the use of pesticides. What is the unintended consequence of indoor bug spraying and what implications are noted?** Possible student response: Indoor spraying to combat four species of malaria-carrying mosquitoes has been effective in eradicating two species on Bioko Island, but the spraying seems to have driven two other species to biting outdoors instead. Researchers consider the possibility that this shift may be caused by genetic changes. If the trend continues, researchers fear that the indoor spraying will no longer be as effective.

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Quest Through the Archives

Directions: After reading the article "Malaria molecule lures mosquitoes" use the archives available at www.sciencenews.org to answer these questions:

1. **Search for an early article about malaria from before the 1950s in the *Science News* archives. Describe the article.**

2. **Search for another article about the malaria parasite and its effect on mosquito behavior. Discuss the research described in the article.**

3. **Search for an article that discusses other diseases carried by mosquitoes. Summarize what you find.**

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Responses to Quest Through the Archives:

1. **Search for an early article about malaria from before the 1950s in the *Science News* archives. Describe the article.** Possible student response: "Starve malaria germs," published 4/10/1948, describes a possible "germ-starvation" treatment for malaria. The article suggests that the malaria parasite cannot grow and reproduce without methionine. Preventing methionine from interacting with the malaria parasite could be a possible treatment for malaria.

2. **Search for another article about the malaria parasite and its effect on mosquito behavior. Discuss the research described in the article.** Possible student response: "People with malaria attract more mosquitoes," published 9/3/2005, discusses an experiment in which researchers studied mosquitoes' attraction to people infected with malaria at different stages in the parasite's life cycle. An experiment arranged three tents with connecting compartments, and a child was placed in each. One child carried the malaria parasite in its full transmissible stage, the second child was infected but did not yet carry the transmissible stage and the third child was not infected. One hundred mosquitoes were released and trapped before they reached the children. Researchers found that roughly twice as many mosquitoes were attracted to the child who carried malaria in its transmissible stage than the other two.

3. **Search for an article that discusses other diseases carried by mosquitoes. Summarize what you find.** Possible student response: "Vaccines may offer defense against dengue, Zika and chikungunya," published 6/25/2016, describes the *Aedes aegypti* mosquito as the most dangerous species on Earth. Its saliva transmits viral particles including those that cause yellow fever, dengue and chikungunya. The article also suggests that vaccines may be the best means for defense against mosquito-borne viruses. A vaccine for yellow fever has been developed, but it is more difficult to produce a vaccine for dengue because four different viruses are responsible for it.

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Cross-Curricular Discussion

After students have had a chance to review the article "Malaria molecule lures mosquitoes," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. Before starting the discussion, you may want to have your students explore some of the additional resources listed below or show the suggested video.

Additional Online Resources

- The Centers for Disease Control and Prevention websites are excellent resources for learning about malaria and its effects on humans. You may want to have your students explore the Biology of malaria and the *Anopheles* Mosquitoes pages before beginning your discussion.
- *Science News* also offers "What a mosquito's immune system can tell us about fighting malaria" and "Malaria parasite drives mosquitoes to human scent."
- *Science News for Students* offers "Will chicken cologne guard you from malaria?" (7.2 readability score), "Gene editing swats at mosquitoes" (7.5 readability score), "Do mosquitoes love you? Blame your parents" (7.5 readability score) and "Grape scents repel mosquitoes" (7.2 readability score).
- The National Institutes of Health describes "How Mosquitoes Detect People."
- Sumanas, Inc. produced a video explaining the life cycle of the malaria parasite called *Plasmodium, The Malaria Parasite*.

BIOLOGICAL SCIENCES

Discussion Questions:

1. How would you classify *Plasmodium*, the genus of parasites that causes malaria? [*Protista, and more specifically single-celled organisms that penetrate host cells called Apicomplexa. During much of their lives, they do not have physical structures such as flagella or cilia to move on their own.*]
2. How do *Plasmodium* parasites reproduce and spread? [Plasmodium *parasites reproduce sexually in certain species of mosquitoes. The asexual forms called sporozoites are injected by mosquitoes into a vertebrate's bloodstream. They travel to the liver, where they infect cells, grow and replicate inside hepatocytes (liver cells), bursting out of the cells once they are done. Parasites can then migrate into red blood cells. There,* Plasmodium *parasites can go through synchronized rounds where they multiply and rupture their red blood cells, go into new cells and repeat the cycle. Others inside red blood cells form gametocytes. When the gametocytes are taken up by a suitable mosquito feeding on a host, the gametocytes reproduce sexually and create a new generation of sporozoites.*]
3. Why does malaria cause waves of fever? [*The replication cycle inside host cells lasts a certain period of*

time, so the Plasmodium *parasites all tend to burst out of human red blood cells in wavelike coordination. While they are inside host cells, the immune system has difficulty detecting them, so there is not much fever. Each time the parasites burst out of the host cells and become detected, though, the immune system kicks into overdrive and triggers a strong inflammatory response and high fever.*]

4. What is a key difference between infections from different species of *Plasmodium*? [*Different species of* Plasmodium *produce different frequencies of fevers, ranging from 36 to 48 hours per round of replication for* P. falciparum *to 48 hours for* P. vivax *to 72 hours for* P. malariae.]
5. What is *Babesia*? How does is compare with *Plasmodium*? [Babesia *is also an Apicomplexan parasite like* Plasmodium. *It also munches on your red blood cells from the inside out. Except,* Babesia *is transported and transmitted to new hosts primarily by* Ixodes *ticks (deer ticks) instead of mosquitoes.*]
6. What protein do *Plasmodium* parasites consume? What is the main job of this protein in the body? [*Hemoglobin is the molecule that carries oxygen and carbon dioxide in red blood cells.*]

Extension Prompts:

7. Hemoglobin breakdown products are toxic, so how do *Plasmodium* parasites avoid poisoning while consuming the hemoglobin? [*The parasites convert the used heme from hemoglobin into hemozoin, which is linked together to form large insoluble crystals rather than soluble toxin.*]
8. How do most antimalarial drugs work? [*Quinine, chloroquine, mefloquine, primaquine and others interact with individual heme molecules and prevent formation of hemozoin clumps.* Plasmodium *parasites consuming heme inside red blood cells cannot convert their waste products into nontoxic hemozoin, so they drown in their own toxic waste.*]
9. In addition to increasing CO_2 and certain other molecules emitted by red blood cells, how else might malaria symptoms attract mosquitoes to infected hosts? [*Malaria causes waves of fever, which can induce sweating. Some research has suggested that warm and moist skin attracts mosquitoes.*]
10. What other parasites can alter their hosts to make them more likely to infect others? [Toxoplasma gondii *needs to be inside a cat to reproduce sexually. Infected rodents appear to lose their fear of cats, causing them to be caught by cats more frequently. Researchers are investigating whether* Toxoplasma gondii *changes mood and behavior in infected humans as well — though the evidence for this is limited.*]

Biological Sciences Question Bank

How would you classify *Plasmodium*, the genus of parasites that causes malaria?

How do *Plasmodium* parasites reproduce and spread?

Why does malaria cause waves of fever?

What is an easy way to tell the difference between infections from different species of *Plasmodium*?

What is *Babesia*? How does it compare with *Plasmodium*?

What protein do *Plasmodium* parasites consume? What is the main purpose of this protein molecule in the body?

Hemoglobin breakdown products are toxic, so how do *Plasmodium* parasites avoid poisoning while consuming the hemoglobin?

How do most antimalarial drugs work?

In addition to increasing CO_2 and certain other molecules emitted by humans, how else might malaria symptoms attract mosquitoes to infected hosts?

What other parasites can alter their hosts to make them more likely to infect others?

CHEMICAL AND PHYSICAL SCIENCES

Discussion Questions:

1. What is the structure of hemoglobin? How does hemoglobin bind and release oxygen? [*See Hemoglobin and the Heme Group: Metal Complexes in the Blood for Oxygen Transport website* from Washington University in St. Louis.]
2. What is the structure of heme, and how can it be converted into linked hemozoin units? [You can find the structures of heme and hemozoin about halfway down *this Tulane University webpage on the Biochemistry of Plasmodium*.]
3. Draw the 2-D Lewis dot structures of carbon dioxide (CO_2), 2-hexenal ($C_6H_{10}O$, an aldehyde that occurs naturally in a variety of fruits and vegetables) and ipsdienol ($C_{10}H_{16}O$, an acyclic monoterpene that is the main attractive component of an orchid). Determine the molecular shape around each central atom and draw the 3-D molecular structure of each molecule. [*Use PubChem to check the molecular drawings.*]
4. How might studying the chemical and physical properties of molecules like carbon dioxide, aldehydes and monoterpenes help prevent the spread of malaria? [*These molecules lure mosquitoes to a host and knowing their chemical properties can help determine how mosquitoes detect them. Mosquito repellents may be developed based on this information.*]

Extension Prompts:

5. Look up the structure for pyrophosphate and use the rules of organic nomenclature to draw the 2-D Lewis dot structure of HMBPP, or (E)-4-hydroxy-3-methyl-but-2-enyl pyrophosphate. Determine the molecular shape around each central atom and draw the 3-D molecular structure of HMBPP. Draw appropriate dipole moments to indicate polar areas of the molecule. [*See PubChem's 2-D and 3-D structures here. Note: Not all lone pair electrons, carbon atoms and hydrogen atoms are included. Largest dipole moment arrows should be drawn between oxygen atoms bonded to a hydrogen atom and should point toward the oxygen atoms.*]
6. How might studying the properties of this molecule help prevent the spread of malaria? [*Scientists must understand its chemical and physical properties to understand how it interacts with blood to produce other mosquito-luring molecules. Its structure might also provide insights into how the malaria parasite produces it.*]

Chemical and Physical Sciences Question Bank

What is the structure of hemoglobin? How does hemoglobin bind and release oxygen?

What is the structure of heme, and how can it be converted into linked hemozoin units?

Draw the 2-D Lewis dot structures of carbon dioxide (CO_2), 2-hexenal ($C_6H_{10}O$, an aldehyde that occurs naturally in a variety of fruits and vegetables) and ipsdienol ($C_{10}H_{16}O$, an acyclic monoterpene that is the main attractive component of an orchid). Determine the molecular shape around each central atom and draw the 3-D molecular structure of each molecule.

Why might studying the chemical and physical properties of molecules like carbon dioxide, aldehydes and monoterpenes help prevent the spread of malaria?

Look up the structure for pyrophosphate and use the rules of organic nomenclature to draw the 2-D Lewis dot structure of HMBPP, or (E)-4-hydroxy-3-methyl-but-2-enyl pyrophosphate. Determine the molecular shape around each central atom and draw the 3-D molecular structure of HMBPP. Draw appropriate dipole moments to indicate polar areas of the molecule.

How might studying the properties of this molecule help prevent the spread of malaria?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. What are some possible practical applications of the fact that mosquitoes are attracted to certain scent molecules? Can you think of any practical applications of the fact that HMBPP increases CO_2 released from red blood cells? [*Build traps emitting those molecules to attract and kill mosquitoes; devise ways to neutralize, mask or collect those molecules emitted from humans; design molecules with the properties to repel mosquitoes; mimic the mosquito sense organ to develop sensors for such molecules.*]

Extension Prompts: Use your imagination combined with your scientific knowledge to be creative in answering these prompts.

2. How could host-controlling parasites be useful for creating a zombie plague? [*Fictional zombie plagues are often attributed in books and movies to strains of some of the known host-controlling pathogens. The zombie ant fungus* Ophiocordyceps unilateralis *is blamed in the zombie movie* The Girl with All the Gifts, *as well as several earlier zombie stories such as "The Last of Us". Rabies virus, or rhabdovirus, gets blamed in several zombie movies, including* The Crazies, REC, Quarantine *and* 28 Days Later.]

3. Research a host-controlling parasite and use it to create your own apocalyptic zombie plague short story. Use the *Science News for Students* article "Zombies are real!" for additional motivation: www.sciencenewsforstudents.org/article/zombies-are-real. Make sure that the symptoms, transmission and biology of your selected host-controlling parasite are thoroughly explained. You want your apocalyptic zombie plague short story to be as true to the scientific details as possible.

Engineering and Experimental Design Question Bank

What are some possible practical applications of the fact that mosquitoes are attracted to certain scent molecules? Can you think of any practical applications of the fact that HMBPP increases CO_2 released from red blood cells?

How could host-controlling parasites be useful for creating a zombie plague?

Research a host-controlling parasite and use it to create your own apocalyptic zombie plague short story. Use the *Science News for Students* article "Zombies are real!" for additional motivation: www.sciencenewsforstudents.org/article/zombies-are-real. Make sure that the symptoms, transmission and biology of your selected host-controlling parasite are thoroughly explained. You want your apocalyptic zombie plague short story to be as true to the scientific details as possible.

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Teacher Guide: Malaria Under the Microscope

Class time: 30-50 minutes

Purpose: Students will observe prepared microscope slides of mosquitoes, human blood, malaria-infected blood and other available samples and describe the differences between healthy and infected cells. Students will communicate their findings by answering guided questions.

Notes to the teacher: This activity can be adapted to incorporate any available blood cell sample slides. If alternative slides are used, adjust the discussion questions accordingly. You will need microscopes for this activity. There should be at least one microscope for every four students, and preferably one microscope for every two students. If you have just a few microscopes or if students are unfamiliar with microscopy, have them use this simulation offered by the University of Delaware (requires Flash) before they begin. Another option is to have half the students read "Malaria molecule lures mosquitoes" and complete another section of this guide while the other half of the class uses the microscopes. Then switch.

Ideally, each microscope station should have one copy of every slide that the students will examine for this lab. If you do not have that many slides, you can distribute slides among the microscope stations and let students rotate slides.

Materials:

- **Microscopes with multiple objectives giving total magnifications between 40x and 400x**
  - Home Advanced LED microscope from Home Science Tools provides a cost-efficient, high-quality option.
- **Bolded prepared microscope slides are needed for the lab activity (ideally one copy of each slide per microscope station)**
  - B&H Photography, Human Pathological Tissues Slide Set 1 contains **one slide of spleen tissue with malaria, one slide of spleen tissue with leukemia, one slide of blood with sleeping sickness** and seven other slides that could be useful for other lab activities.
  - B&H Photography, Human Pathological Tissues Slide Set 2 contains **one slide of blood with malaria** and nine other slides that could be useful for other lab activities.
  - B&H Photography, Normal Human Tissues Slide Set 1 contains **one human blood slide, one slide of red bone marrow, one tonsil slide** (the best available healthy comparison for the diseased spleen slides) and seven other slides that could be useful for other lab activities.
  - Home Science Tools, Complete Elementary Set of 25 slides contains **one normal human blood slide, one frog blood slide, one mosquito slide** and 22 other slides that could be useful for oth-

er lab activities. Or, buy slides separately: Home Science Tools, Human Blood Slide and Home Science Tools, Frog Blood Slide. There are also sets that contain human and frog blood slides: Home Science Tools, Human Anatomy Slide Set and Home Science Tools, Biology Slide Set.

- Home Science Tools, Human Blood Slide, Sickle Cell Anemia contains **one slide with sickle-shaped blood cells**. Or, buy this slide as part of a set: Home Science Tools, Human Pathology Slide Set.
- (Optional) B&H Photography, Normal Human Tissues Slide Set 2 does not contain any slides essential for this lab activity, but it complements Normal Set 1 and contains 10 slides that could be useful for other lab activities.
- (Optional) B&H Photography, Parasites Slide Set, 10 slides contains one blood slide with sleeping sickness, one blood slide with malaria and eight other slides that could be useful for other lab activities.

Directions:

1. Have students observe the microscope slides listed below and on the chart on Blackline Master 3. If you would like students to try to photograph slides, suggest that they capture two slides for comparison. The notes below should help you guide your students in analyzing the slides.
2. When students are finished taking initial observations, have them identify at least six pairs of related slides and create a comparison diagram to compare and contrast the pairs.
3. Students should use their observations and comparisons to answer the accompanying comprehension questions.

Slide Notes:

- Healthy human blood. [*The slide will be dominated by red blood cells, and only a few white blood cells with nuclei that are stained blue or purple will be seen.*]
- Frog blood. [*The red blood cells have nuclei, unlike in human blood. Human red blood cells lose their nuclei when they leave the bone marrow and thus don't possess any genetic material that might mutate and make the cells cancerous.*]
- Sickle cell anemia. [*There are noticeably fewer red blood cells, many have a deformed shape and they tend to clump together. Unhealthy sickle cells cannot transport oxygen throughout your body, which can lead to fatigue. Because of their shape, sickle cells can also get stuck and prevent blood flow, resulting in pain or painful swelling.]*
- Human blood with trypanosomes. [*Some eel-like single-celled parasites can be spotted between the red blood cells.*]
- Human blood with *Plasmodium*. [*Some red blood cells have one or more stained blue or purple dots inside. These are the malaria parasites that are eating the hemoglobin in the cells. Students may also see red blood cells that have been ruptured by multiplying malaria parasites.*]
- Healthy human tonsil. [*A number of white blood cells will be seen, as well as red blood cells and other*

cell types. This makes a good healthy tissue slide for comparison with the diseased spleen slide.]

- Human spleen with leukemia. [*The slide will be dominated by white blood cells, which have multiplied and run amok*.]
- Human spleen with *Plasmodium*. [*There will be more cells with stained blue or purple dots inside than in other slides. These are the malaria parasites that are consuming the healthy cells. Students may also see cells that have been ruptured by multiplying malaria parasites.*]
- Red bone marrow. [*Developing red blood cells will be dominant.*]
- Mosquito. [*Students should note the proboscis. You could also give students a swatter and tell them to collect and mount their own mosquitoes on slides*.]

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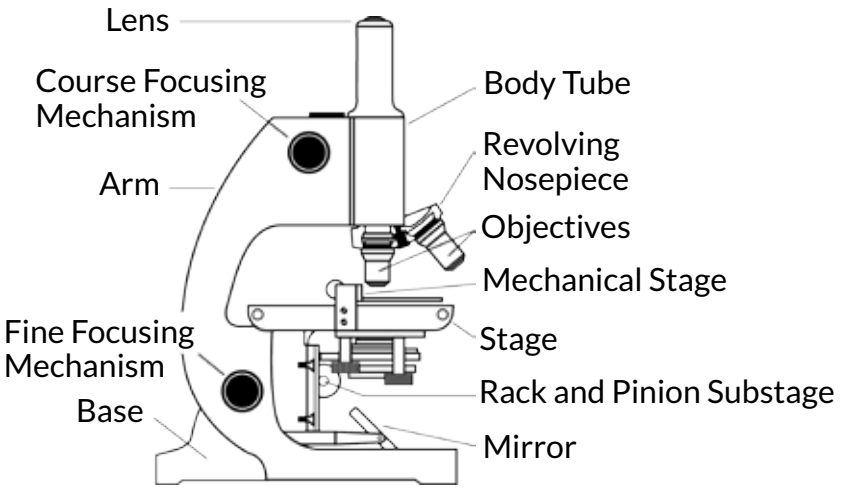
Student Guide: Malaria Under the Microscope

Purpose: To observe prepared microscope slides of mosquitoes, human blood, malaria-infected blood and other available samples of related diseases and to describe the differences between healthy and infected cells.

Directions:

1. Using your microscope, observe each of the following microscope slides (see generic diagram below for names of microscope parts).
    a. Turn on the microscope and align a slide on the stage, the flat platform of the microscope.
    b. Start with the lowest power (4x objective, or 40x total magnification).
    c. Adjust the focus making sure you focus on the blood layer. (You should see red, blue and/or purple stains that were used to make the samples more visible. If you see only black and white spots and lines, you are probably focused on dust or scratches on the top or bottom of the slide.) Please note: Do NOT run the objective into the microscope slide.
    d. Adjust the objective to a higher power and refocus.



2. Using the table provided on the next page, write down a description and provide a sketch of what you see for each slide. For blood slides, note the following:
    a. What do red blood cells, called erythrocytes, look like?
    b. What do while blood cells, called leukocytes, look like?
    c. Are there platelets? What do platelets look like?
3. If your teacher gives you permission and you have a cell phone camera, hold it up to the microscope eye-piece and take photos with the flash off.

Slide Observation Table

Type of slide	Description of what you see under the microscope	Sketch
Healthy human blood		
Healthy frog blood		
Sickle cell anemia blood		
Human blood with trypanosomes (Protists that cause African sleeping sickness and Chagas disease)		
Human blood with *Plasmodium* (Protists that cause malaria)		
Healthy human tonsil (A good substitute for healthy human spleen)		
Human spleen with leukemia		
Human spleen with *Plasmodium* (Protists that cause malaria)		
Red bone marrow		
Mosquito		

4. Identify at least six related pairs of slides (for example, frog blood vs. human blood, or diseased vs. healthy samples). List them here:

5. Using a comparison diagram, such as a Venn diagram, compare each pair of related slides. Make sure your diagram incorporates how they look similar and different. Draw the diagrams below.

6. Answer the following comprehension questions. Use the Centers for Disease Control and Prevention website on Diseases and Conditions for additional information: www.cdc.gov/DiseasesConditions/.

   - Explain how human blood is different than frog blood. Why are the features identified in human blood helpful for human survival (do additional research if necessary)?

   - How does the sickle cell anemia sample compare with healthy human blood? What are some disease symptoms of sickle cell anemia? How might the characteristics you observe contribute to disease symptoms?

   - Locate *Plasmodium* and trypanosomes in the samples. What are the differences in where *Plasmodium* and trypanosomes appear to live in the samples? What are differences in their methods of locomotion?

   - How is spleen tissue affected by malaria? What are the common symptoms of malaria? Based on what you observe in the slides, what might be causing these symptoms?

   - What differences do you see between cells in blood and those in red bone marrow? Explain why these differences might exist.

   - Describe the different parts of the strawlike proboscis of a mosquito. How could this structure benefit a mosquito's ability to draw blood from an animal? Why is the structure of the proboscis beneficial for transmitting malaria?