SN EDUCATOR GUIDE

March 18, 2017

Malaria molecule lures mosquitoes

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?

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

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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?

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