frontiers | Frontiers for Young Minds

HUMAN HEALTH
Published: 01 February 2024
doi: 10.3389/frym.2024.1305938

MALARIA—WHY DO MOSTLY CHILDREN GET SICK?

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YOUNG REVIEWERS:

FANGYI
AGE: 15

ROSA
AGE: 15

SCUOLA IC PICENTIA
AGES: 12–13

Did you know that micro-organisms can live in blood? *Plasmodium* parasites can infect red blood cells and cause a serious disease called malaria. This disease is mostly seen in young children living in Africa. Sick children have a fever, aches, can feel very tired, and in bad cases, they can even die from malaria. There are medicines that cure malaria, but it is hard to get these to everyone who needs them. Fortunately, as children grow older, they do not feel as sick when they are infected by the malaria-causing parasite. Better yet, adults hardly ever get malaria. The reason for this difference between children and adults has to do with how well the body's defense system can fight off the parasite. Keep reading if you want to learn more about

malaria, the *Plasmodium* parasite and how the immune system fights against it.

WHAT IS MALARIA?

Malaria is a disease caused by a germ or **micro-organism** that can live in blood. This micro-organism is a **parasite** named *Plasmodium*. Humans can get infected with this parasite when they are bitten by a mosquito that carries the *Plasmodium* parasite. The word "malaria" comes from the Italian words "mala aria", which means "bad air". A long time ago, people thought that breathing in the bad air coming from smelly swamps caused this disease. Later, in the late 1800s, scientists learned that it is not something bad in the air that causes malaria, but instead malaria is caused by a parasite [1] that is transmitted from mosquitoes to humans [2, 3]. The standing water of swamps was simply a perfect place for mosquitoes to live. This explains why malaria was seen in areas with standing water.

Parasites are small, living things that need to live on or inside other organisms—called hosts—for food. Parasites are unwanted guests that can make their host very sick. The *Plasmodium* parasite has two hosts—it needs to live inside mosquitoes *and* humans. The life cycle of the *Plasmodium* parasite is complex because it involves two hosts, and different shapes (life stages) of the parasite.

MALARIA

A disease caused by the *Plasmodium* parasite, which is spread by mosquitoes. Malaria patients have a fever, and they can die when not treated. Most patients are children living in Africa.

MICRO-ORGANISM

A living thing so small that it can only be seen under a microscope. Micro means small. Examples of micro-organisms are bacteria, viruses and some small parasites.

PARASITE

A living thing that needs to live on or inside another living being—called the host—to survive. It feeds and multiplies in a way that hurts the host.

HOW DOES THE PARASITE GROW INSIDE HUMANS?

The *Plasmodium* parasite needs to live inside the human body to survive. But where exactly in the body does the parasite live and multiply? When a mosquito "bites" a human, it actually drinks a little bit of blood. Female mosquitoes need blood to make eggs. When the snout of an infected mosquito is in the skin of a human, *Plasmodium* parasites can enter the human body. These parasites first travel to the liver, one of the biggest organs, located just below the heart. The parasites grow in the liver for about a week and undergo an important change: they become able to infect **red blood cells**, which is bad news! Red blood cells carry oxygen from the lungs to all parts of the body.

After a *Plasmodium* parasite has entered or infected a red blood cell, it starts to eat the cell's hemoglobin—the molecule that binds oxygen. Even worse, inside the red blood cell, the parasite grows bigger and multiplies. After about 2 days, there are so many new parasites inside the red blood cell that it bursts open, releasing the parasites and dying in the process. At some point there may not be enough red blood cells left to carry oxygen to the tissues. Furthermore, infected red blood cells can become sticky and block the body's blood vessels [4].

RED BLOOD CELLS

Cells in the blood that carry oxygen from the lungs to all tissues in the body. These cells color blood red.

Blocked blood flow can prevent important organs, like the brain, from receiving enough oxygen.

With infected red blood cells flowing through the blood vessels, the next time a mosquito "bites" an infected human, the mosquito can become infected, too. Now, this newly infected mosquito can bite and infect another person. This completes the circle of the *Plasmodium* parasite life cycle (Figure 1).

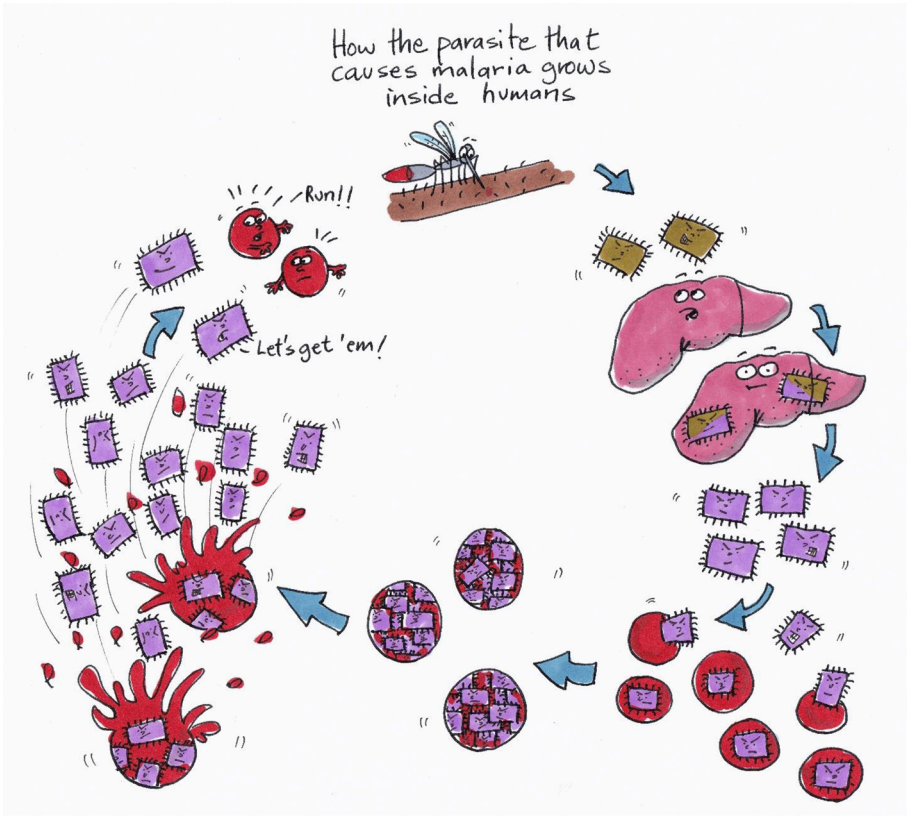

Figure 1

When an infected mosquito bites a human, the parasites (brown squares) move into a blood vessel and travel to the liver (top right). Here, the parasites multiply, and many new parasites leave the liver (purple squares). The parasites can now infect red blood cells (bottom right). Once inside a red blood cell, the parasite divides many times and, after about 2 days, dozens of new parasites burst out of a single red blood cell (left). When this happens, the red blood cell gets destroyed. Every new parasite can now infect a new red blood cell again. Bad news for the red blood cells!

HOW DOES IT FEEL TO HAVE MALARIA?

Most people with malaria have a fever and feel very weak. With a fever, the body is too hot—sometimes malaria fevers can even reach 40°C (104°F), and people sweat a lot. Other symptoms are headaches, chills, aching muscles, feeling extremely tired, and not wanting to eat. When people are very sick, their urine can be the brownish color of cola, which is caused by the presence of destroyed red blood cells in the urine. These symptoms result from the *Plasmodium* parasites living and multiplying in the red blood cells.

Malaria is a serious disease and people with malaria need medicines quickly to make them better. If they are not treated within a couple of days, it is possible that not enough oxygen will reach their

important organs, including the brain. When this happens, people can go into a coma, meaning they become unconscious and cannot wake up. Most malaria patients in a coma will die if they do not receive medicines.

WHO GETS MALARIA?

Malaria is a common disease that kills a lot of people—and some other animals as well. Millions of people get malaria and every minute a young child dies of malaria. Almost all (~95%) malaria patients live in Africa (Figure 2) [5]. Of all the malaria patients in the world who die of this disease, three out of four are young children [5]! Together with diarrhea, malaria is the most common cause of child death in Africa. Compared to the USA or Europe, 15 times more young children die in Africa.

Figure 2

Africa is one of the world's seven continents, and it has more than 50 countries. It is an extremely beautiful and diverse continent with amazing nature, animals, and culture. Most people in Africa live in the tropical (green) region. The tropics are a great place for mosquitoes to live: there is lots of water and it never gets too cold for the mosquitoes. This geographical factor is not the only reason most malaria cases are seen in Africa. In many African countries there is not enough money to protect people against the parasite and prevent malaria.

Unlike any of the other six continents, most of Africa lies in the tropics—areas of the world around the equator where it is warm and wet. This is the climate mosquitoes like best. There are many different types of mosquitoes. The *Anopheles* mosquito that carries the most dangerous *Plasmodium* parasite, *Plasmodium falciparum*, prefers to bite humans more than other animals, and it likes to live in Africa. This is why there are many *Plasmodium* infections in Africa—most of them with the dangerous *Plasmodium falciparum* parasite. On top of that, in many African countries, there is not enough money available to prevent people from getting sick.

Anyone living in the tropical parts of Africa is at high risk of getting malaria, no matter what color their skin is. However, people visiting Africa, including tourists, often do not get malaria, because they have the opportunity to take medicines that will prevent them from getting sick when bitten by an infected mosquito. This type of prevention is called prophylaxis.

WHY DO MOSTLY CHILDREN GET MALARIA?

As we mentioned, 75–80% of the people dying from malaria are young children. Why do so few adults get malaria, while there are many more grownups than children? Most adults who get infected with the *Plasmodium* parasite feel a little sick, but they do not need medicines to get better—they do not get malaria. Why is this?

Most adults living in Africa have been infected with the *Plasmodium* parasite many times in their lives. When they were children, they probably got malaria several times. As they grew older, their bodies learned how to better deal with the parasite. The part of the body that fights parasites and other germs is called the **immune system**. This defense system consists of many different white blood cells, their products (for example **antibodies**), and several organs (for example bone marrow, spleen, and thymus). B cells—produced inside bone—are a small, special group of white blood cells that produce antibodies. Antibodies are proteins that stick to germs (for example *Plasmodium* parasites), thereby preventing them from entering a human cell (for example a red blood cell) and making the person sick (for example getting malaria) (Figure 3).

IMMUNE SYSTEM

All cells, things these cells produce (for example antibodies), and tissues in the body that help protect an animal against disease-causing germs.

ANTIBODIES

Y-shaped proteins, made by a type of white blood cells called B cells, that can stop a micro-organism from making a person sick. B cells and antibodies are part of the immune system.

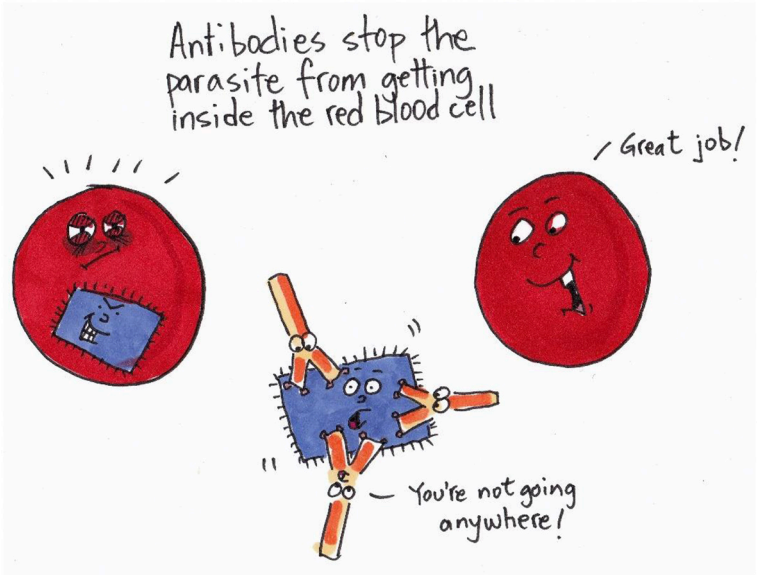

Figure 3

When antibodies (yellow/orange) bind to the parasite (blue), the parasite can no longer invade the red blood cell. When the parasites cannot get inside the red blood cells, the red blood cells stay alive, and the person does not get sick.

Antibodies also help in other ways than blocking the invasion of germs. They can stick to a germ and kill it, or get other cells of the immune system to eat it. An important study done in the early 1960s showed that antibodies found in the blood of grownups who had malaria many times, could be used to cure children with malaria [6]. However, making B cells that can produce strong and enough antibodies takes several years. Every time the immune system sees the malaria-causing parasite, it learns and becomes better at making more and stronger antibodies the next time it sees the same germ. This is probably why mostly young children get malaria—their antibodies are not good enough yet at defending the red blood cells against *Plasmodium* parasites (Figure 4).

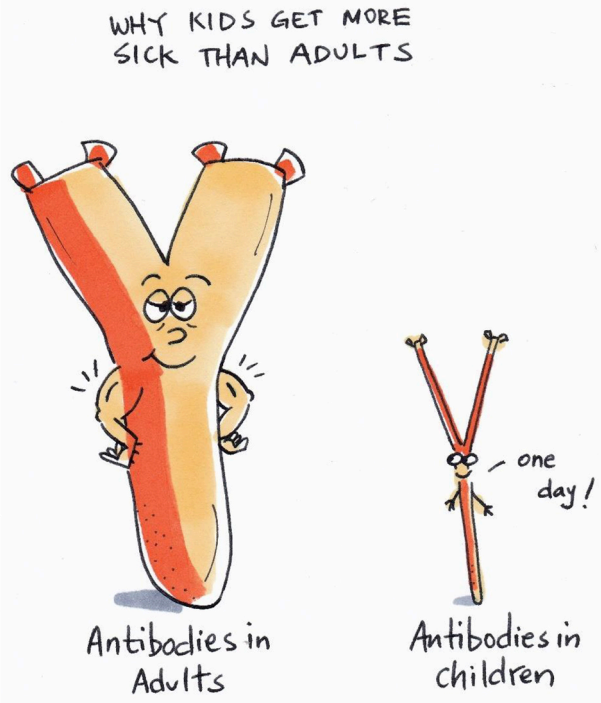

Figure 4

The immune or defense system of a child cannot yet make effective (big and strong) antibodies against *Plasmodium* parasites yet. A child's immune system also does not make as many antibodies as adults do. Not having enough effective antibodies is believed to be the main reason why mostly children get malaria, while adults do not get as sick when they are infected by the parasite. It takes time and many infections for the immune system to grow up and be strong enough to fight off the parasite.

HOW CAN WE GET RID OF MALARIA?

The easiest way to prevent people from getting malaria is to prevent them from getting bitten by infected mosquitoes. Malaria has been around for thousands of years and also used to be a big problem in Europe and the USA. In the 19th and 20th centuries, European countries and the USA spent a lot of money getting rid of standing water and killing mosquitoes by spraying chemicals. All people with malaria were given anti-malaria medicines for free. Since the 1950s and 1970s, these places have been considered malaria free.

The number of people dying from malaria has decreased by 30% in the last 20 years [5], meaning that fewer people get malaria now

than a long time ago. However, about 500,000 young children still die of malaria each year, and a lot still needs to be done before no one gets malaria anymore. Eliminating malaria may be possible if *all* countries of the world contribute and people all over the world work together. Different methods must be combined, such as building more hospitals, training more nurses and doctors, building houses with window screens, providing bed nets, making anti-malaria medicines available and *affordable* for everyone, and spraying chemicals against mosquitoes. At the same time, scientists must keep working on discovering new and better anti-malaria medicines, and a more effective vaccine. (For more information about vaccines and how they work, see this, this, or this Frontiers for Young Minds article).

ACKNOWLEDGMENTS

We thank John Heim (artbyheim@gmail.com) for the illustrations (Figures 1–4). RG, AG, BG, AN, EB, and SB work in the Bunnik laboratory. The Bunnik lab is supported by the National Institutes of Health (R01 AI153425 to EB).

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SUBMITTED: 02 October 2023; **ACCEPTED:** 17 January 2024;
PUBLISHED ONLINE: 01 February 2024.

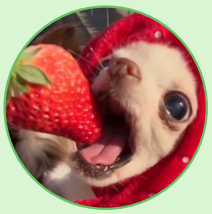
EDITOR: Viduranga Y. Waisundara, Australian College of Business and Technology, Sri Lanka

SCIENCE MENTORS: Cora J. Burt and Vincenzo Torraca

CITATION: Garza R, Huson M, Garcia A, Gonzalez B, Musinguzi K, Nagaragere A, Nansubuga E, Zedi M, Bunnik EM and Bol S (2024) Malaria—Why Do Mostly Children Get Sick? Front. Young Minds 12:1305938. doi: 10.3389/frym.2024.1305938

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS



FANGYI, AGE: 15

Hello! I am a student in Grade 10. I love learning about science and I believe that learning should be fun. I am on a curious mission to decode the world's most puzzling scientific mysteries, one at a time.

ROSA, AGE: 15

Hey! My name is Rosa. My favorite subject is science, particularly biology and pathology. I think it is interesting to learn about different diseases and how it affects the human body. In my free time, I love cooking, drawing, hiking, and gardening.

SCUOLA IC PICENTIA, AGES: 12–13

Alfonso: I am 13 years old and would like to become a writer or a singer. I have recently learned about human anatomy, and I look forward to seeing how AI will evolve in the future.

Olga: I am 12 years old, I love science and my career ambition is to become a teacher. I have recently studied the periodic table at school and I am very concerned about the war in Israel.

Lorenzo: I am 13 years old and I love psychology and rap songwriting. At school, we recently learned about mechanical energy. Besides psychology and rap music, I also enjoy martial arts, drawing and walking.

AUTHORS

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Rolando is an M.D./Ph.D. student at the University of Texas Health Science Center in San Antonio in the USA. When he is done with this 8-year program, he will be both a medical doctor and a scientist. He was born and raised in rural Texas and went to

college at the University of Texas San Antonio. In addition to being very smart, he is super friendly and fun to be around. Rolando loves SpongeBob, dinosaurs, rock climbing, and playing one of his many guitars.

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Mischa is a clinician specialized in infectious diseases. She has studied and worked in several African countries (Uganda, Gabon, and Malawi) for a total of 2 years. She currently lives and works in the Netherlands where it is mostly travelers from the tropics who come to the hospital with malaria. She is passionate about training young doctors and improving healthcare for everyone. In her free time, she loves running, yoga, making buntings from fabrics she collected on her travels, and spending time with her children.

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Anakaren is originally from El Paso Texas but is now studying biology at St. Mary's University in San Antonio, Texas in the USA. When she finishes her studies at St. Mary's, Anakaren hopes to get an M.D./Ph.D. and become both a doctor and a scientist, so she can focus on diseases in children. Outside of school, she enjoys movie nights with friends, taking long walks, and exploring new coffee shops in San Antonio.

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Bella is in the Voelcker Biomedical Research Academy at the University of Texas Health Science Center in San Antonio, TX, USA. This academy helps Bella get hands-on experience in biomedical research. Born and raised in San Antonio, Bella grew up riding horses and has always loved animals. She hopes to become a veterinary doctor one day. She also wants to earn a Ph.D. in veterinary medicine. While she enjoys studying and learning new things, Bella also loves to create art and collect old vinyl records.

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Kenneth is an immunology laboratory scientist with over 9 years' experience in malaria basic science and clinical trial research. He has excellent scientific skills such as white blood cell separation from blood, cell culture and flow cytometry. He has a master's degree in biomedical laboratory sciences and management. Born and raised in Uganda (located in East Africa), he hopes to contribute efforts toward eliminating malaria infection from children. He loves mountain climbing, listening to music and watching TV channels such as National Geographic and Discovery.

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Avani is in the Voelcker Biomedical Research Academy at the University of Texas Health Science Center at San Antonio in the USA. For her career, she wants to go to underserved communities around the world and establish solid healthcare systems. She loves playing volleyball, the piano, volunteering to help her community, and going to the library. Her favorite movie is Disney's Beauty and the Beast. Avani loves to talk with people and make new friends.

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Evelyn is a laboratory technologist working at Infectious Diseases Research Collaboration in Uganda. This means that she works in the laboratory on blood samples from malaria patients. She was born and raised in Uganda and goes to college at Makerere University in Uganda to pursue her master's degree. In addition to being very passionate about science, she also enjoys rock climbing, listening to music and dancing. She is friendly and loves children.

MAATO ZEDI

Maato is a clinician currently working with the Infectious Diseases Research Collaboration in Uganda. He has a diploma in clinical medicine and community health and 9 years' experience in malaria research and expertise in management of studies offering treatment not only for malaria, but also other medical conditions in the community. Born and raised in Uganda, he is knowledgeable about most of the community norms, behaviors, attitudes, and practices toward health care. He likes hiking, playing basketball, watching National Geographic Wild, and reading.

EVELIEN M. BUNNIK

Evelien started her own research laboratory (bunniklab.org) at the University of Texas Health Science Center in San Antonio in the USA in 2016, where she studies the malaria parasite and how the human body defends itself against it. She was born in the Netherlands and studied at the Universities of Leiden and Amsterdam. Before she moved to Texas, she and Sebastiaan lived in beautiful California for 5 years. She enjoys cuddling their cats, running, cycling, and solving puzzles.

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Sebastiaan works as a scientific researcher at the University of Texas Health Science Center in San Antonio, Texas, USA. He works in the lab of his wife, Evelien. He studied molecular biology at Wageningen University and the University of Amsterdam in the Netherlands, where he was born and raised. In his free time, he does cat research, enjoys remodeling the house to make it a cat paradise, and working on their land to make it a good place for the local wildlife to live. He also loves listening to heavy metal music and smelling lots of different perfumes. *bols@uthscsa.edu