Adaptations and Survival Mechanisms of Plasmodium falciparum

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Abstract

The deadly severe disease malaria, caused by a tiny parasite known as Plasmodium falciparum, remains a major concern for global health. Even after efforts to combat and cure the disease, it still remains a significant global concern. This paper will discuss this particular parasite, its life cycle, and how its survival strategies combined with its stages of life ensure maximum survivability on the parasite's end. Understanding these adaptations and mechanisms is crucial to develop treatments and combat the impact of malaria. Continued research and approaches are essential to mitigate the effects of this disease.

Introduction

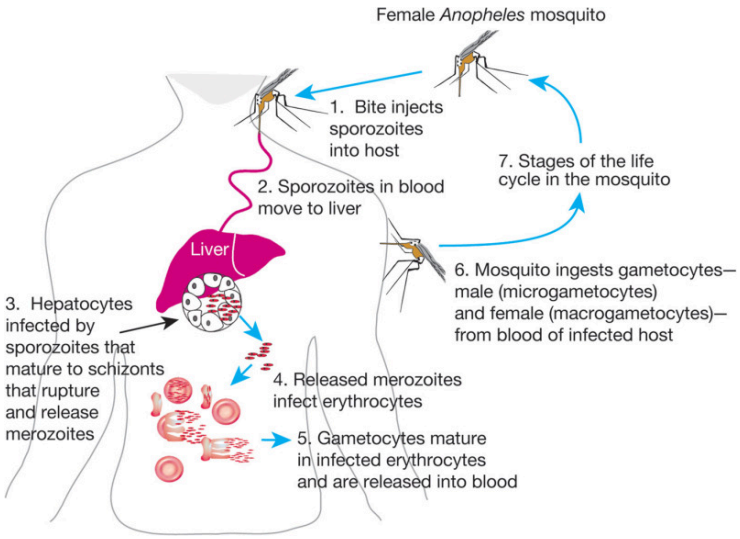
Malaria is a deadly disease caused by a Plasmodium parasite that infects a type of mosquito called an Anopheles mosquito, which can then transmit this disease to humans through biting. According to the World Health Organization (2023), there were about 249 million malaria cases and 608,000 deaths because of malaria in as many as 85 countries in 2022. [1] Although the numbers of malaria deaths decrease every year due to technological innovations, there is still a long way before the causes of death due to malaria entirely disappear or become negligible. In this paper, we will look at the different adaptations and survival mechanisms of Plasmodium falciparum, a parasite that is a big contributor to the transmission of malaria, to better understand how it resists and effectively transmits malaria along with ways to try to mitigate the spreading of malaria and its effects.

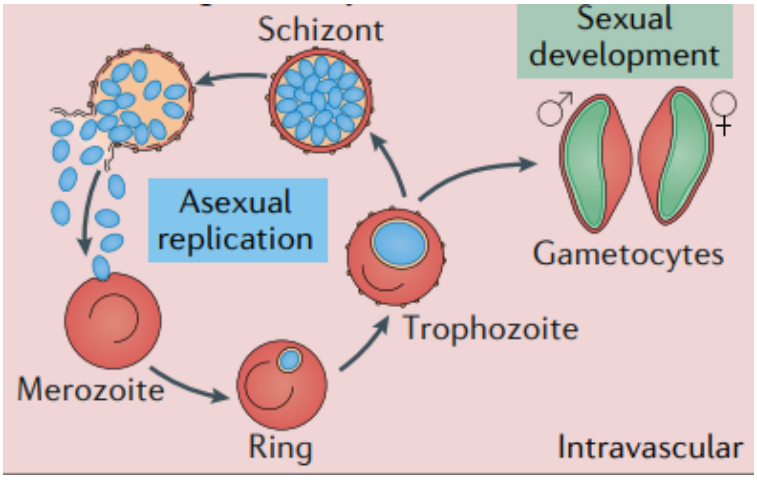
Plasmodium falciparum Explained

Before delving into the adaptations and survival mechanisms of this particular parasite, let us first discuss the generalities of Plasmodium falciparum. According to information from ScienceDirect (2002), Plasmodium falciparum is a unicellular, protozoan parasite responsible for the most pathogenic form of malaria. [2] This particular parasite can develop within the red blood cells of their hosts (humans) and make it so that the red blood cells cannot function properly. [2] According to the National Library of Medicine, P. falciparum modifies these infected blood cells by inserting proteins into and onto the membranes, which may hinder these infected RBCs in a way which can benefit the parasite's evasion of the host's immune system or survival. [3] According to the World Health Organization (2023), mild symptoms of malaria include the following : fever, chills and headache; however, severe symptoms may consist of trouble breathing, confusion, and seizures. [1] While malaria is a treatable disease, there may be more difficulties depending on the severity as well as the resources available in certain countries. To expand on, developing countries may have a harder time curing malaria due to the disparity in resources compared with developed countries.

Life Cycle of P. falciparum

To the right we have an image from the National Library of Medicine that shows the life cycle of this particular parasite. According to the National Library of Medicine (2022), an infected female Anopheles mosquito begins the whole life cycle by biting into a human, or host. The bite then transmits sporozoites, or mobile spore-like stage of the parasite into the host, which then moves to the liver, infecting liver cells. The sporozoites then mature into schizonts, which basically are sporozoans with multiple nuclei that divide asexually to make more and more cells.





After this, merozoites (parasites in the phase specialized to invade red blood cells) are released which then infect red blood cells. [5] Gametocytes, which are basically the parasite version of gametes, then develop in the infected red blood cells and are released into the bloodstream. Lastly, a mosquito will ingest these gametocytes, becoming infected and starting the cycle all over again. To the left is another image to clarify the different stages of the parasite.
[5][6]

How P. falciparum Ensures Maximum Survivability with its Life Cycle

There are many different nuances and aspects within the life cycle of P. falciparum that ensures maximum reproductive success and survivability. For starters, according to the University Corporation for Atmospheric Research, the vectors that P. falciparum utilize (Anopheles mosquitoes) thrive in warm humid areas.[7] As a result, this parasite has adapted to not only be able to live in warm temperatures but also to thrive in these temperatures so both the mosquitoes and the parasites can develop properly. Because this parasite thrives in warm and humid areas, it is no surprise that it will strive to find the area with the most favorable climate within the host. As a result, P. falciparum will migrate to the liver and infect liver cells, exploiting the liver's environment for optimal replication. The optimal environment allows the parasite to rapidly reproduce and multiply. However, this parasite does not only adapt to match the mosquitoes preferred environment and the host, but also coordinates its life cycle with that of the mosquito. The parasite has evolved to synchronize its gametocyte release with the feeding habits of female Anopheles mosquitoes. Gametocytes are released into the bloodstream when mosquitoes are likely to feed, increasing the chances of transmission to the vector and continuing the life cycle.

Survival Mechanisms of P. falciparum

Plasmodium falciparum is able to change the proteins on the surface of the red blood cells it infects through a process called antigenic variation. This ability helps the parasite evade detection and being attacked by the host's immune system. According to Medtigo (2023), the parasite does this by switching between different var genes. These genes code for a group of proteins known as PfEMP1, which are displayed on the surface of the infected red blood cells. By changing which var gene is active, the parasite can alter the surface proteins on the infected cells. This constant change makes it hard for the host's immune system to recognize and fight the parasite, as the immune system has to keep adapting to the new surface proteins each time they change. [8]

One other mechanism that this parasite uses is the process of sequestration. Sequestration refers to the process by which infected RBCs adhere to the walls of blood vessels in various organs. This mechanism is critical for the survival of the parasite but has significant implications for disease severity and transmission. According to a study published in the Proceedings of the National Academy of Sciences (PNAS), sequestration helps P. falciparum avoid clearance by the spleen, which filters abnormal cells from the blood. By adhering to the blood vessel walls, the infected RBCs can avoid being destroyed by the spleen, thus prolonging the parasite's survival within the host.

However, sequestration also contributes to the severity of malaria. The accumulation of infected RBCs in vital organs can obstruct blood flow, leading to complications such as cerebral malaria, where the brain's blood vessels are blocked, causing neurological damage. This can result in severe symptoms, including seizures and coma, and can be fatal if not treated promptly. [9]

Moreover, sequestration facilitates the transmission of the parasite. By maintaining a reservoir of infected RBCs in the host's bloodstream, *P. falciparum* increases the likelihood that gametocytes (the sexual form of the parasite) will be taken up by a mosquito during a blood meal. This enhances the chances of the parasite being transmitted to a new host, ensuring the continuation of its life cycle. [9]

How P. falciparum Ensures Maximum Survivability with its Survival Mechanisms

Through a process called antigenic variation, constantly changing surface proteins like PfEMP1, the parasite is able to hide from the host's immune system, which cannot keep up with the rapid changes and struggles to recognize and attack the infected cells.

In addition, the infected red blood cells stick to the walls of blood vessels in different parts of the body, such as the brain, which can lead to a severe form of malaria known as cerebral malaria, and the placenta in pregnant women. This sticking process, known as sequestration, helps the parasite avoid being cleared out by the spleen, an organ that typically removes abnormal cells from the bloodstream. By avoiding the spleen, the parasite can continue to survive and multiply within the host, making it harder for the immune system to eliminate the infection.

Drug Resistance and Adaptation

Plasmodium falciparum has developed ways to resist the drugs used to treat malaria, making the disease harder to cure. According to a study published in the National Center for Biotechnology Information (NCBI), this parasite changes its genes to survive even when drugs are present. These genetic changes affect how the parasite takes in and processes the drugs, allowing it to continue growing and multiplying despite treatment. The parasite also adapts by changing the proteins that the drugs target. For instance, if a drug is designed to attack a specific protein in the parasite, *P. falciparum* can alter that protein so the drug no longer works effectively. This makes it difficult to treat malaria with the same drugs over time because the parasite keeps finding new ways to survive. In response to these challenges, scientists are working on developing new treatments that can overcome these resistance mechanisms. One

approach is to use combinations of drugs, which can attack the parasite in multiple ways, making it harder for the parasite to adapt to all of them at once. Researchers are also looking for new drug targets within the parasite to find treatments that can work even if the parasite becomes resistant to existing drugs. [10]

Conclusion

To sum it all up, the P. falciparum parasite is highly adaptable and uses many different ways and methods to thrive within its human host. This parasite, through antigenic variation, can change its surface proteins to avoid the immune system of the host; additionally, it can also make infected red blood cells stick to the walls of the blood vessel using a process called sequestration in order to avoid being cleared out by the spleen. Furthermore, this parasite has become resistant to many drugs that are used to treat malaria, the deadly disease it causes, which makes it harder to cure. In the future as technological and research advances combined with a deeper understanding of the adaptations and survival strategies of this parasite, we can better combat malaria and reduce its impact all over the world.

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