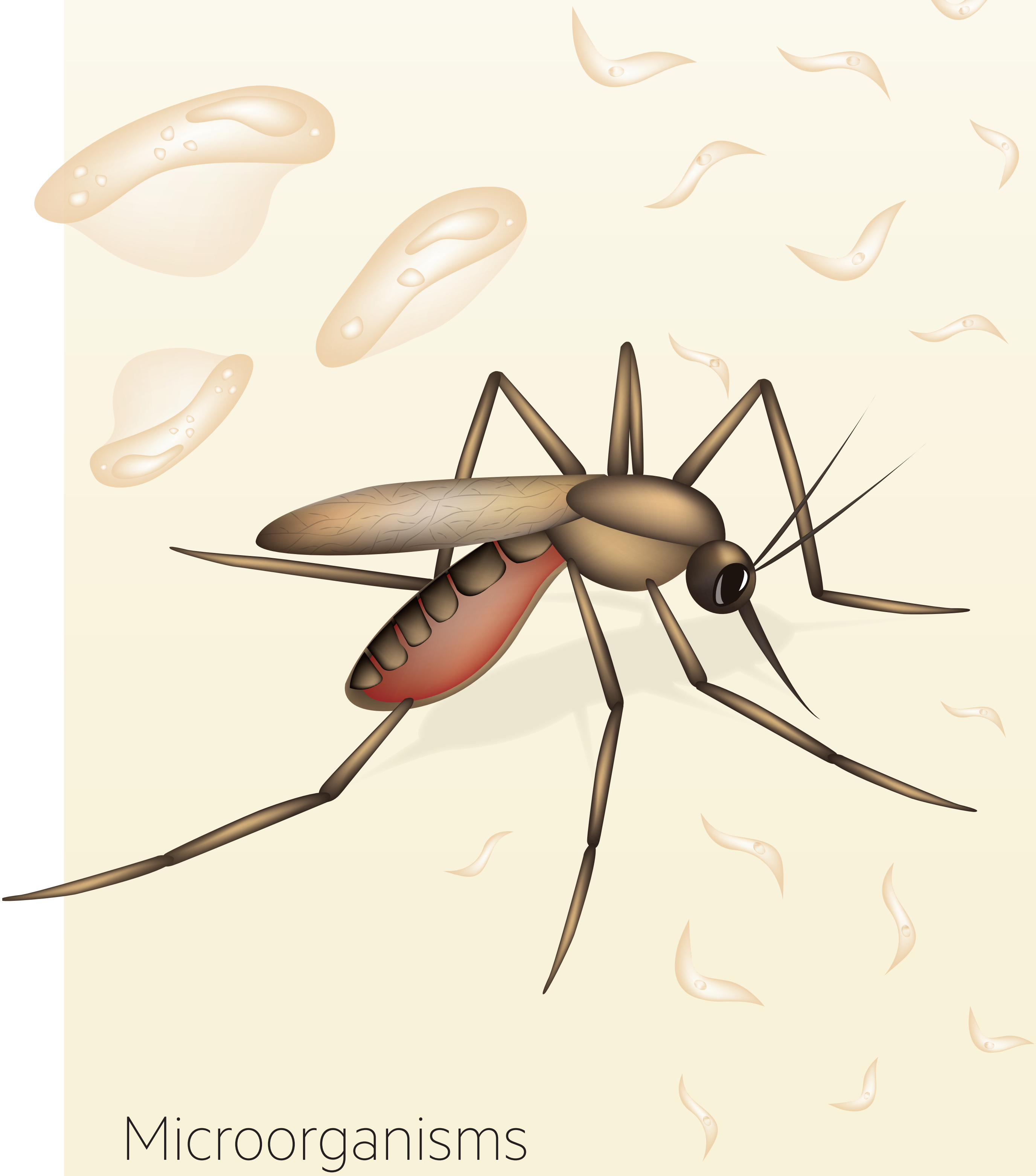


Microorganisms and Malaria

YEAR NINE STUDENTS

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM | Queensland Government

Introduction

The Queensland Museum contains a large collection of microscope slides of bird blood smears. This collection is called the International Reference Centre for Avian Haematozoa, or IRCAH, and it comprises over 60,000 specimens of bird blood parasites. The IRCAH is a significant world resource containing samples from over 4,000 bird species (representing about 150 bird families), collected from 63 countries from all over the globe. Collections like these allow researchers to study parasites and other microorganisms, furthering our knowledge of existing species, and helping scientists discover new ones. This is important because microorganisms have an enormous impact not just on people, but also on our pets, livestock, crops, wildlife, and ecosystems.

As this resource has been designed to complement classroom-based teaching and learning experiences, students are assumed to have developed knowledge about the following concepts:

— Cells are the basic units of living things and have specialised structures and functions
— The human body has three lines of defence against infection

Note to teachers: pages 15 to 17 provide answers to the questions on page 9.

Australian Curriculum Links

YEAR 9

Science Understanding

Biological Sciences

Multi-cellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment *(ACSSU175)*

— investigating the response of the body to changes as a result of the presence of microorganisms

Science as a Human Endeavour

Nature and Development of Science

Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries *(ACSHE158)*

Use and Influence of Science

Values and needs of contemporary society can influence the focus of scientific research *(ACSHE228)*

Science Inquiry Skills

Processing and analysing data and information

Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies *(ACSIS169)*

Use knowledge of scientific concepts to draw conclusions that are consistent with evidence *(ACSIS170)*

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC project aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers — creating a highly capable workforce for the future.

Microorganisms: what are they?

Microorganisms are microscopic organisms, living things that are too small to be seen by the naked eye. Microorganisms are found everywhere, from the desert to the deep sea, and on every living thing. Because microscopic organisms are so small, their existence was not confirmed until the 17th century, when people started using compound microscopes.

Humans can be infected with many different kinds of microorganisms; examples of these are shown in Figure 1. Some more information about microorganisms is also given in Table 1.

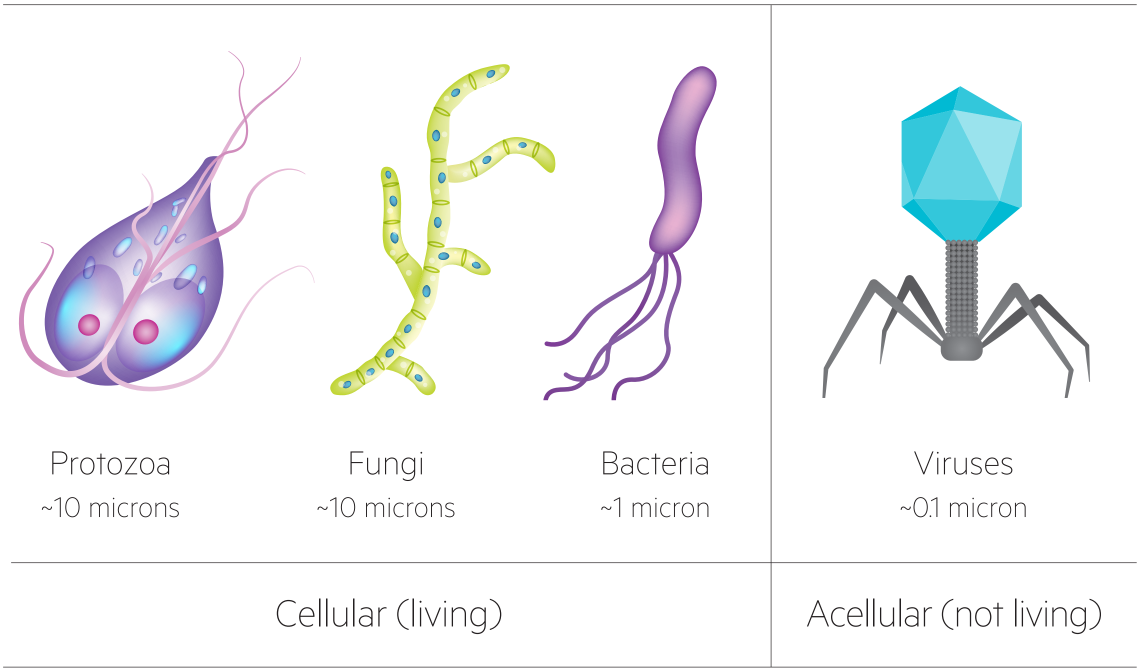


Figure 1. The different kinds of microorganisms that can infect people. For example, the common cold is caused by a virus, strep throat is caused by bacteria, athlete's foot is caused by a fungus, and giardiasis (a form of gastroenteritis) is caused by a protozoan. Viruses are not strictly microorganisms because they are not living organisms, but we can consider them as part of this category because they are tiny pathogens that can cause disease.

Table 1. Some distinguishing characteristics of different microorganisms.

	Contains DNA/RNA?	Made of living cells?	Type of cell?	Unicellular or Multicellular?
Viruses	Yes	No	—	—
Bacteria	Yes	Yes	Prokaryotic	Unicellular
Protozoa	Yes	Yes	Eukaryotic	Unicellular
Fungi	Yes	Yes	Eukaryotic	Unicellular/Multicellular

Microorganisms and parasites

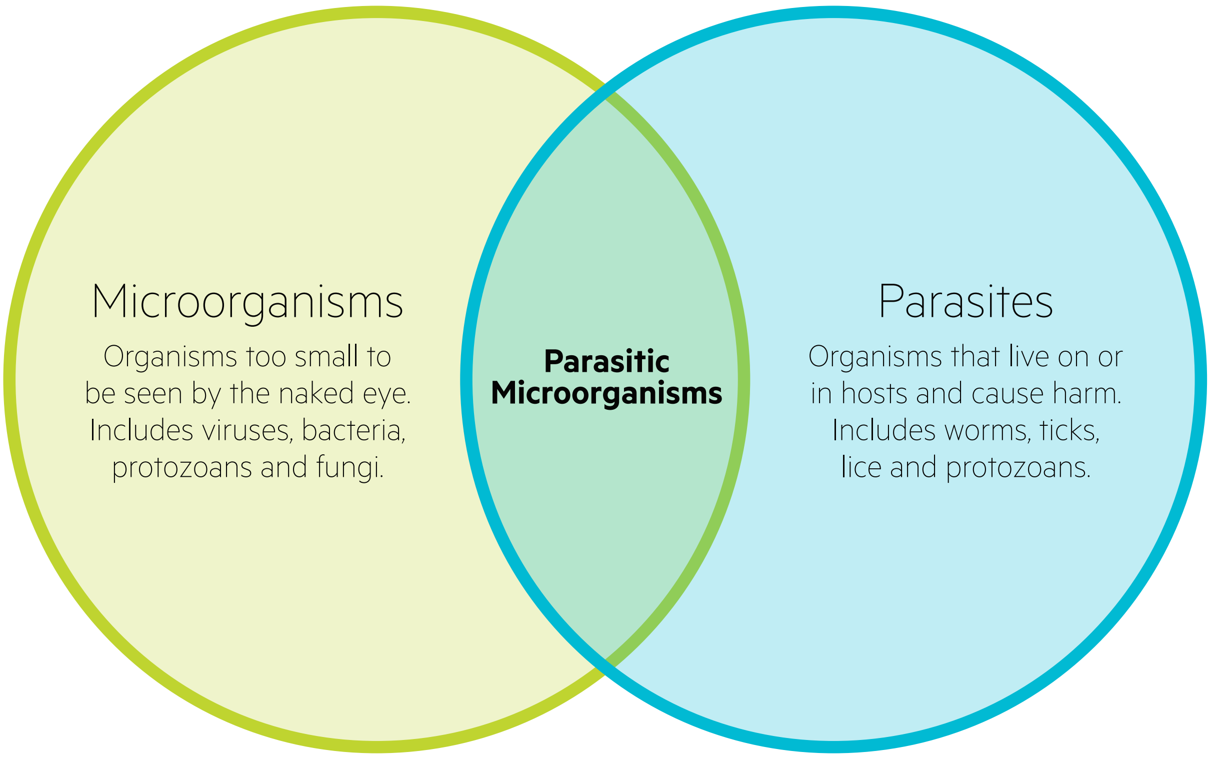
Microorganisms that cause disease can also be called parasites because of their effect on the human body.

— A parasite is an organism that benefits by harming, or living at the expense of, another organism (its host). Parasites live in or on their hosts for at least part of their life; common human parasites include head lice, tapeworms, roundworms, and *Plasmodium* and *Giardia* species.

Not all microorganisms are parasites. For example, the bacteria that live in our gut and help us digest food are beneficial, not harmful, so they are not parasites.

Similarly, not all parasites are microorganisms. For example, head lice are visible to the naked eye, and are too big to be microorganisms.

Instead, there is an overlap between the categories of microorganism and parasite, as shown below.



There are many different kinds of parasitic microorganisms that can live in, and on, many different parts of the body. This resource will focus on parasites that live in the blood of people and animals.

Blood: what is it?

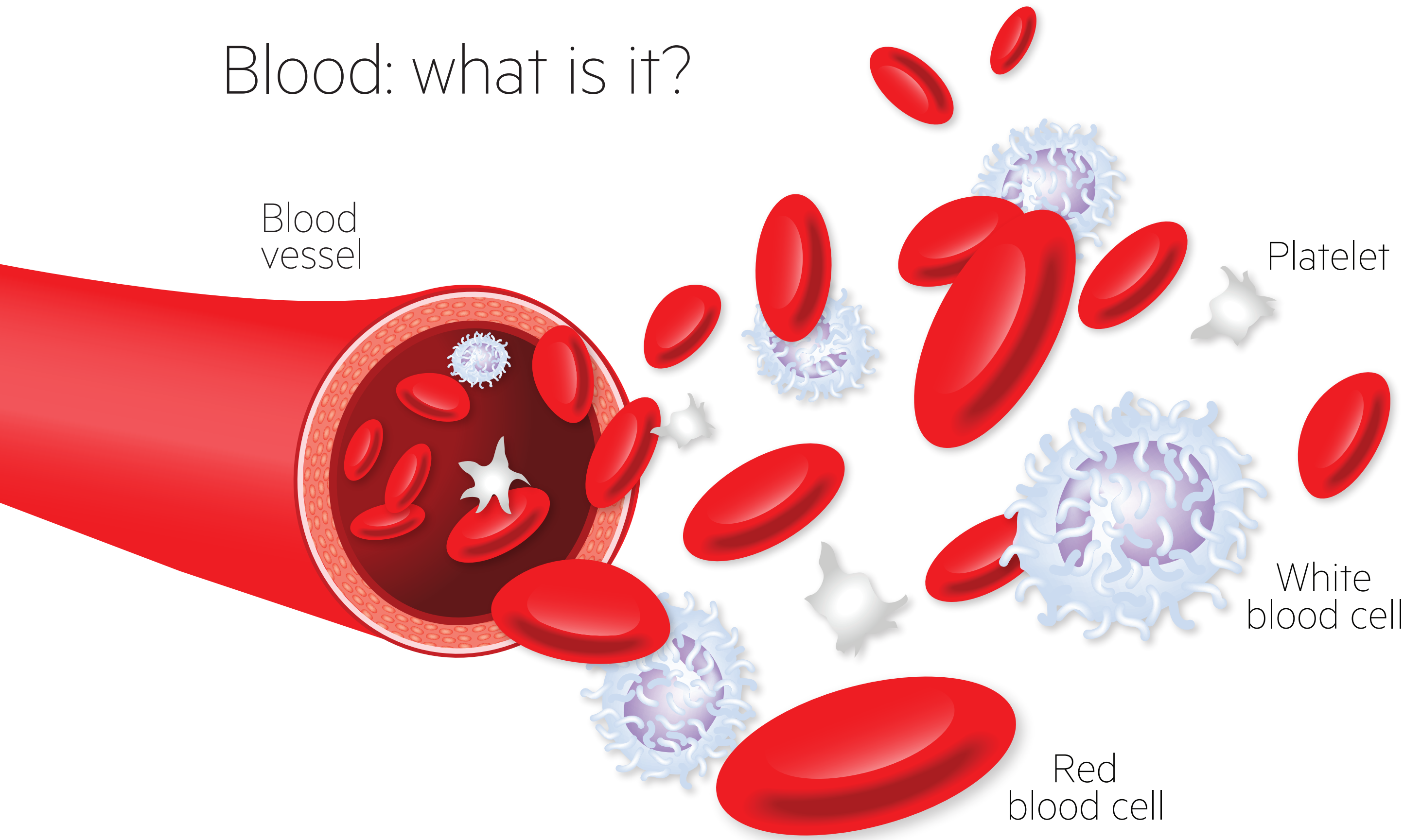


Figure 2: A cross-section of a blood vessel showing the three different types of blood cells, which range in size from about 2 to 20 microns.

Human blood consists of three different types of cells: red blood cells, white blood cells, and platelets (Figure 2). White blood cells are part of the immune system, and platelets help blood clot, but these two types of cell are not very abundant; the majority of blood cells are red blood cells, which transport oxygen throughout the body. Red blood cells also remove carbon dioxide waste and transport it to the lungs for us to exhale.

Did you know that an adult person has about 30 trillion red blood cells in their body?

Many different kinds of parasites can live in blood. For example, one type of blood parasite is called a trypanosome (Figure 3). While trypanosomes consist of only one cell, they have a very distinctive eel-like shape. Trypanosomes can cause diseases like African sleeping sickness, which kills thousands of people every year.

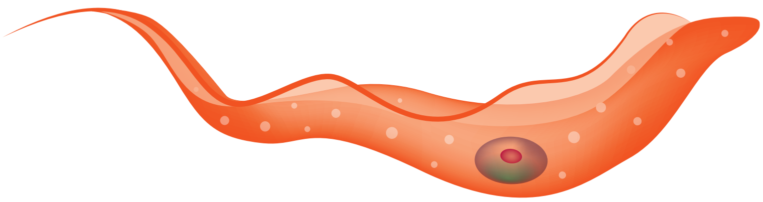


Figure 3: Illustration of a trypanosome parasite. Trypanosomes can be about 50 microns in length.

In terms of number of deaths per year, however, the deadliest blood parasite of all is the one that causes malaria.

Malaria

Malaria is a disease that kills hundreds of thousands of people every year, and is found in over 100 countries. Over 3 billion people are at risk of infection. Because malaria affects so many people, it has been the subject of much research and funding; over $2 billion USD was spent on malaria control programs in 2010 alone[1].

Because of all this research, we know a great deal about malaria. Malaria in humans is caused by protozoans in the genus *Plasmodium*. These parasites are transmitted to people by *Anopheles* mosquitoes. When someone is infected with malaria, the parasites go through several stages inside the human body, as shown in Figure 4.

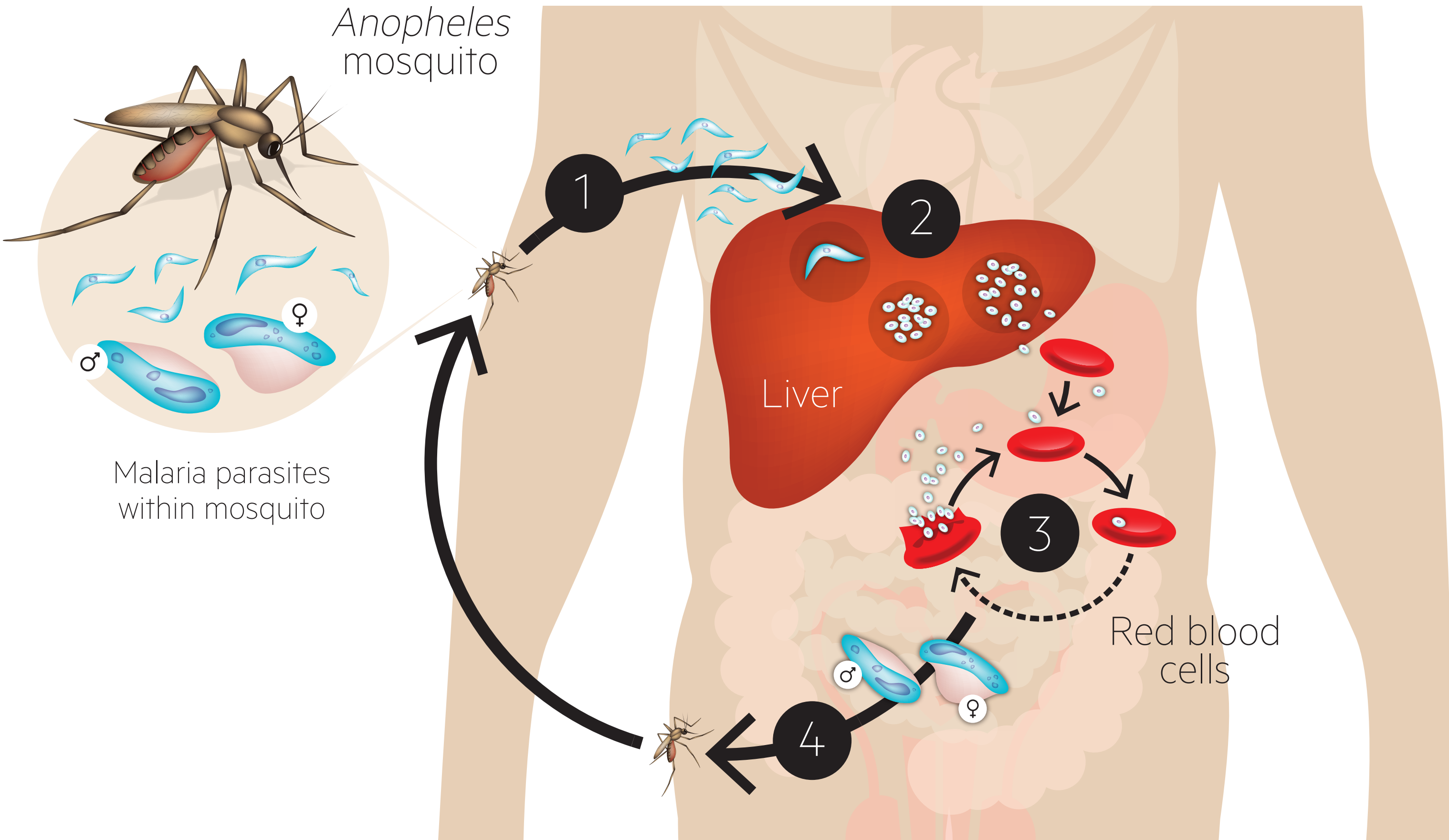


Figure 4. The life cycle of the malaria parasite and its development in the human body.

When a person is infected with malaria via mosquito bite (1), the parasites travel with the bloodstream to the liver (2). The parasites multiply in liver cells and release more parasites, which infect and destroy red blood cells. The dotted line indicates that multiple steps occur between infection and destruction of blood cells (3). Some parasites are also taken up by the next mosquito that bites an infected person (4), allowing the life cycle of the parasite to continue.

[1]Pigott, D.M., *et al.* (2012). Funding for malaria control 2006–2010: A comprehensive global assessment. Malaria Journal 11: 246.

1. The body has several lines of defence to prevent infection by harmful microorganisms. How do the malaria parasites get around the body's **first** line of defence? (See Figure 4.)

2. One way malaria parasites evade the **second** and **third** lines of defence is by replicating within our own liver and blood cells. How might this "trick" our immune cells?

Scientists can study blood parasites like malaria by taking a blood sample from an infected person or animal and making a blood smear on a microscope slide. The slide can then be examined under the microscope for the presence of parasites. A picture of a human blood smear containing a malaria parasite is shown in Figure 5. You can see in Figure 5 that malaria parasites multiply within red blood cells.

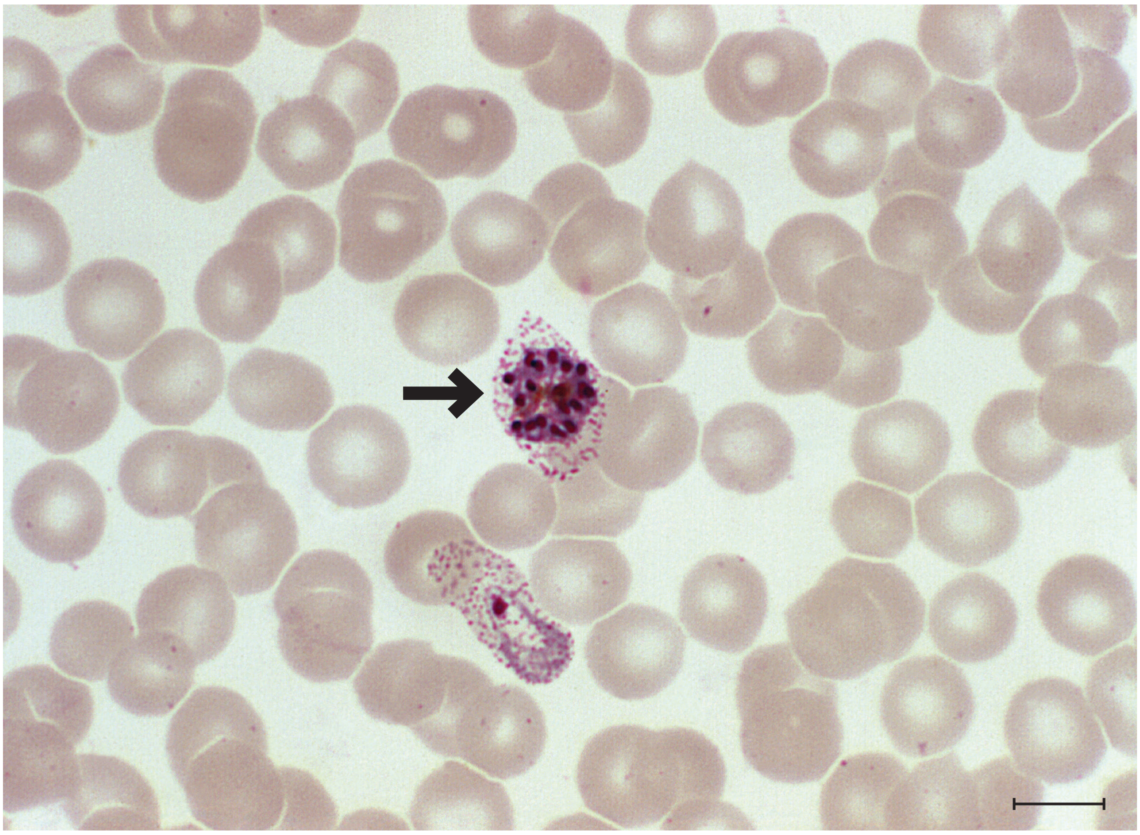


Figure 5. A human blood smear showing the malaria parasite *Plasmodium vivax* within a red blood cell (arrow). Many uninfected blood cells are also visible. Image: CDC/ Dr. Mae Melvin. Scale bar: 7 microns.

In the life cycle of malaria, the parasites in red blood cells cause most of the symptoms of malaria infection. Once malaria parasites enter red blood cells, they consume haemoglobin, the protein that binds to oxygen. The parasites then multiply within red blood cells until the cells burst and die.

3. How do you think the destruction of red blood cells might affect a person infected with malaria?

4. One of the most common symptoms of malaria infection is a fever. Why do you think the presence of the parasite triggers a fever?

Malaria and other blood parasites in birds

Malaria is the deadliest parasitic disease of humans, but other animals can also be infected with malaria, including birds. Malaria in birds is called avian malaria, and is caused by different species of *Plasmodium*. Other blood parasites (haematozoans) can also cause malaria-like disease in birds as well.

Malaria in birds is significant for several reasons. First, birds can die from avian malaria, and research at the Queensland Museum has found that up to 10% of birds in southeast Queensland are infected with blood parasites[2]. Considering that Australia is home to more than 700 species of birds, with many iconic groups that are rare elsewhere (e.g. parrots, cockatoos, honeyeaters, bowerbirds and kingfishers), monitoring avian malaria is part of the preservation of our native fauna.

Second, studying malaria in birds helps scientists understand malaria in humans. In fact, the scientist who discovered that malaria is transmitted by mosquitoes, Ronald Ross, worked with avian malaria to make this important finding. Ross received a Nobel Prize in 1902 for this work. (Before the role of mosquitoes was discovered, the transmission of malaria remained a mystery. Because malaria outbreaks often occurred near swamps, some people believed infection came from breathing the air in swamps, giving rise to the name malaria, which comes from Italian words *mala* and *aria*, meaning "bad air.")

The Queensland Museum contains a significant collection of microscope slides of bird blood smears. This collection is called the International Reference Centre for Avian Haematozoa, or IRCAH, and it contains specimens from about 45,000 infected birds from many different countries. This is the largest collection of avian blood parasites in the world! In the following activity you will examine some images of microscope slides from the IRCAH.

Activity

Look at Image 1 (next page), which shows a blood smear in which no parasites are visible. The blood cells look like ovals with dark centres (also shown in Figure 6).

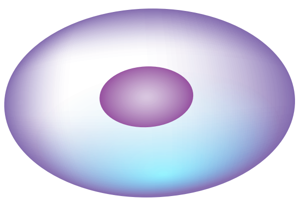


Figure 6. An illustration of a bird blood cell, showing the nucleus in the center. Note: human blood cells do not have nuclei, which is why the blood cells in Figure 5 don't look like this.

1. Examine Images 2, 3 and 4. Can you see the parasites in each image? Circle the parasites you can see. (They may look bizarre, but these represent only a tiny sliver of the incredible diversity of parasitic microorganisms that exist...there are about 11,000 species of parasitic protozoans!)

   Once you have circled the parasites in each image, check your answers on pages 15 and 16.

2. Using the information you have learnt about malaria in humans, which image do you think shows malaria in birds? Why? (Parasite identities given on page 17.)

[2]Adlard, R.D., et al. (2004). Blood parasites of birds from south-east Queensland. Emu 104: 191-196.

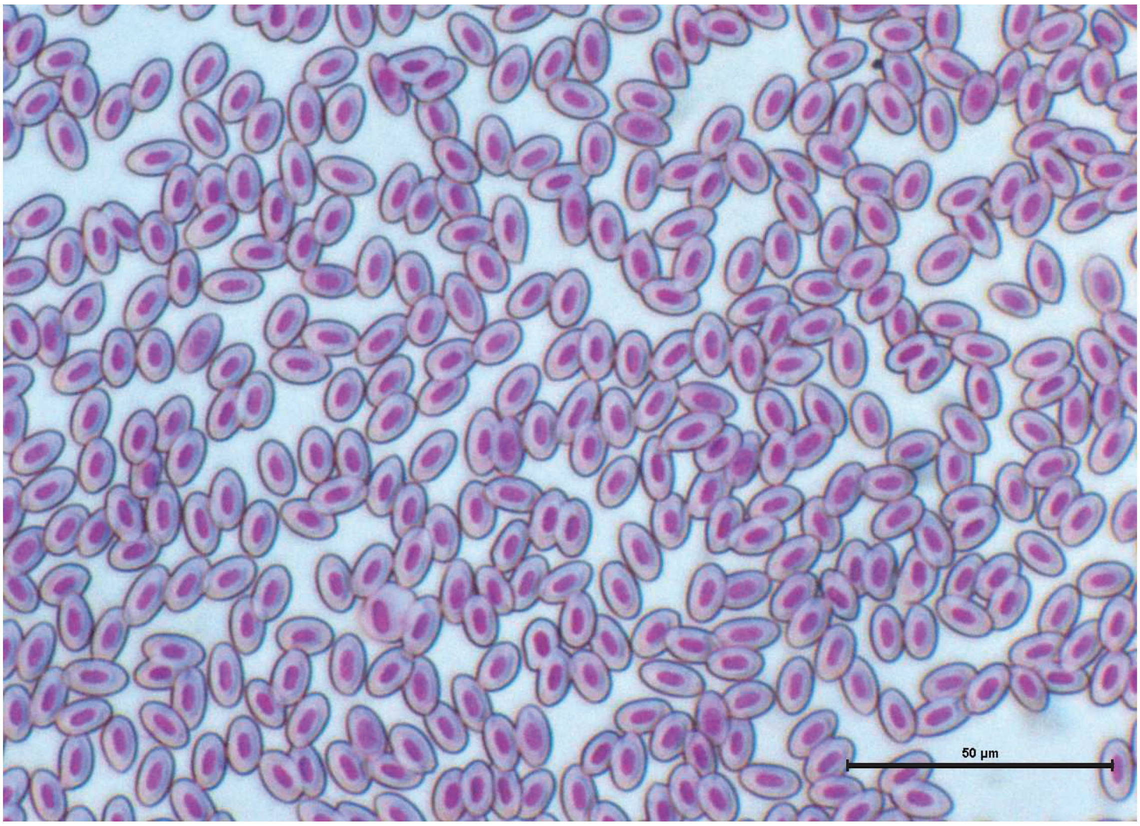


Image 1: A bird blood smear in which no parasites are visible. 40x objective. Scale bar: 50 microns. Image: Marissa McNamara, QM.

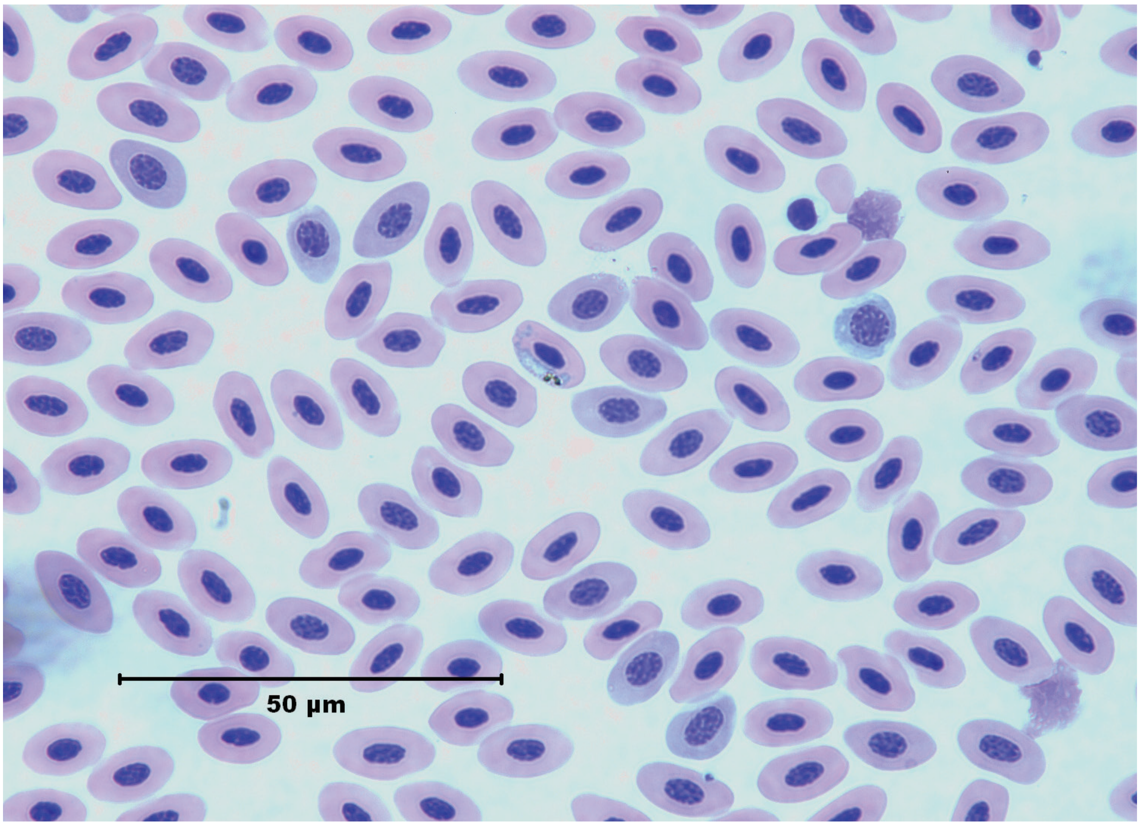


Image 2: A bird blood smear in which a parasite is visible. 100x objective. Scale bar: 50 microns. Image: Robert Adlard, QM.

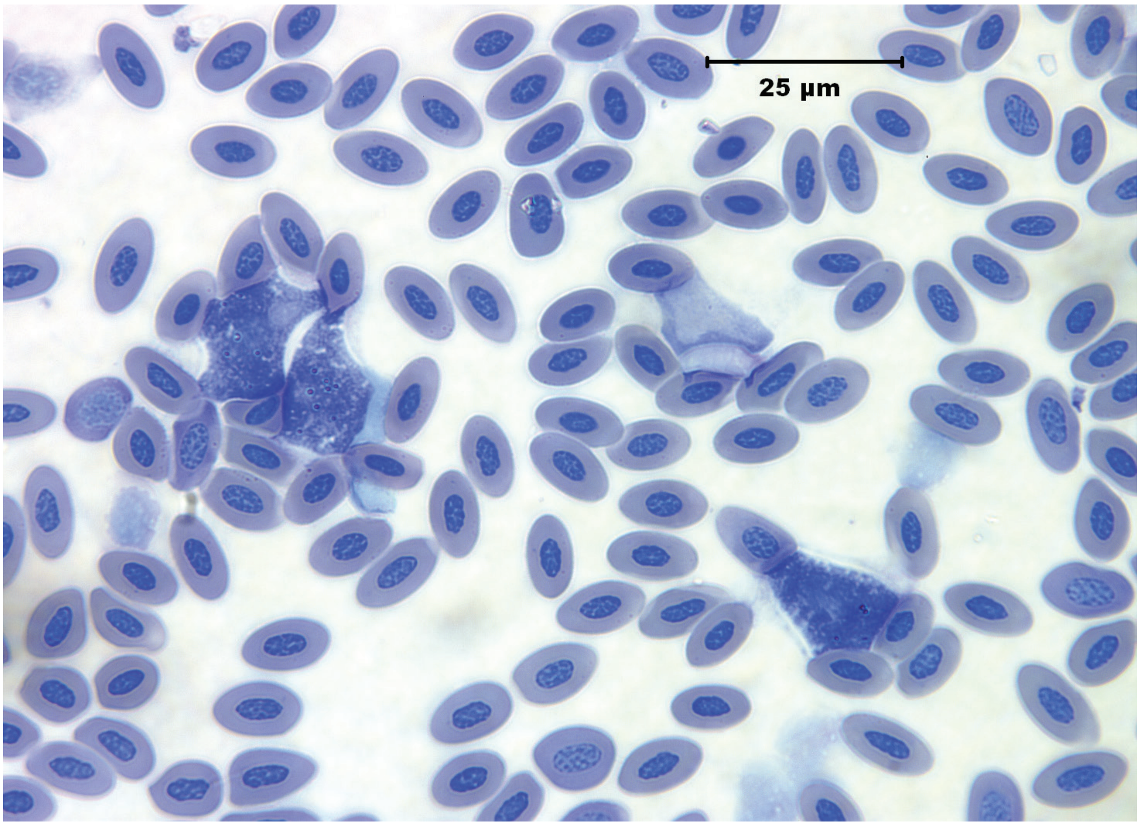


Image 3: A bird blood smear in which parasites are visible. 100x objective. Scale bar: 25 microns. Image: Robert Adlard, QM.

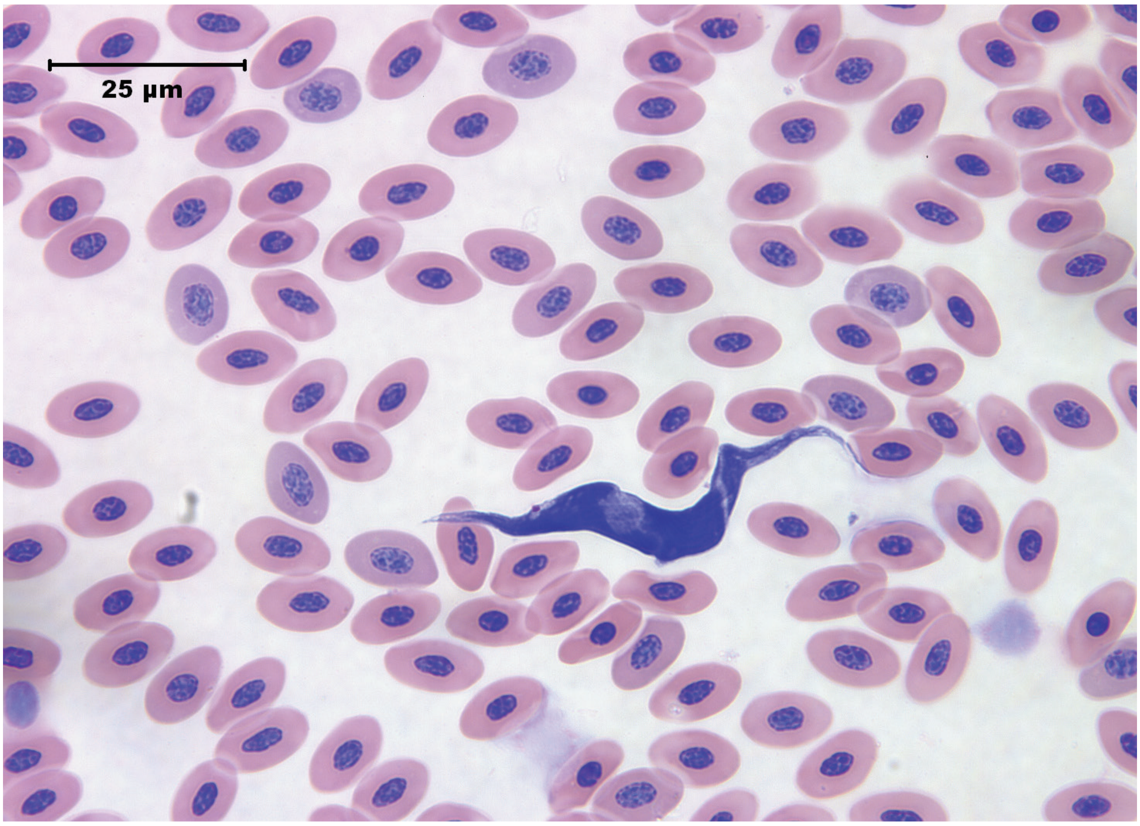
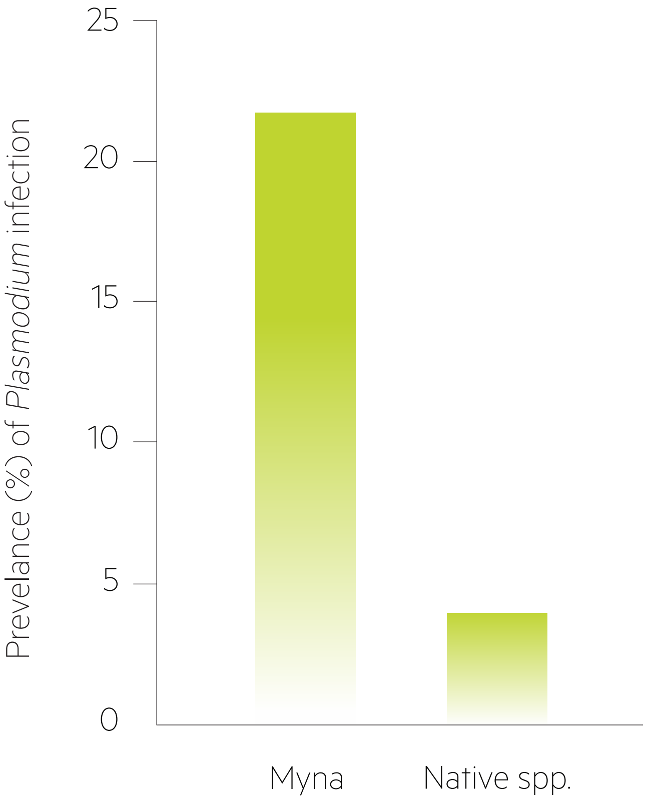


Image 4: A bird blood smear in which a parasite is visible. 100x objective. Scale bar: 25 microns. Image: Robert Adlard, QM.

Malaria in an invasive bird species

Recent research[3] carried out in association with the Queensland Museum investigated avian malaria in birds in Queensland and New South Wales. This research examined native Australian birds and invasive common mynas.

Common myna *(Acridotheres tristis)*. Image: Bruce Cowell, QM.



In this study, the prevalence of avian malaria in common mynas differed significantly from the prevalence of avian malaria in native species (Figure 7). Prevalence is the number of individuals in a population that are infected with a parasite. For example, a prevalence of 10% means that 10% of the population is infected.

Figure 7. The prevalence of *Plasmodium* infection in invasive mynas and native Australian birds[3].

[3]Clark, N.J., *et al.* (2015). Specialist enemies, generalist weapons and the potential spread of exotic pathogens: malaria parasites in a highly invasive bird. International Journal for Parasitology 45: 891-899.

1. According to Figure 7, what percentage of common mynas are infected with avian malaria *(Plasmodium)* in Australia?

2. According to Figure 7, what percentage of native species are infected with avian malaria *(Plasmodium)* in Australia?

3. In light of these data, do you think we need to be concerned about the presence of invasive bird species? Why or why not?

4. How do you think humans and human-related activities could influence the prevalence of malaria in birds?

Extension Activity

Australia is currently considered to be free of malaria, but malaria was present in Australia in the past.

Australian soldiers digging anti-malaria drains on a Cairns army camp, Queensland, ca. 1944. Image from the State Library of Queensland.

Investigate malaria in the world today by considering the following questions:

— List three countries in which malaria is found. Can you find out the prevalence of malaria in one of those countries?

— List three countries that have eradicated malaria.

— When was malaria eradicated from Australia? Do malaria cases still occur in Australia?

— Explore some different methods of malaria prevention (e.g. mosquito netting, malaria vaccine), and describe the one that you think would be the most effective in eradicating malaria in one of the three countries you listed. Justify your answer.

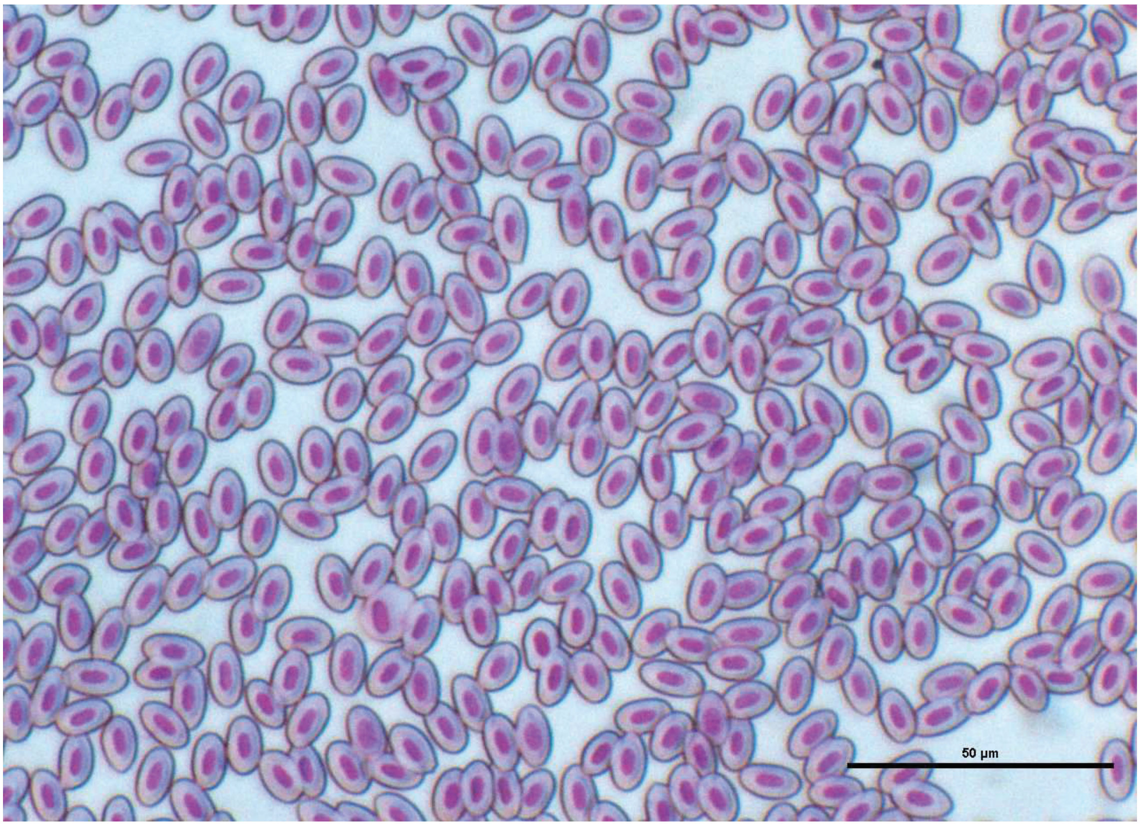


Image 1: A bird blood smear in which no parasites are visible. 40x objective. Scale bar: 50 microns. Image: Marissa McNamara, QM.

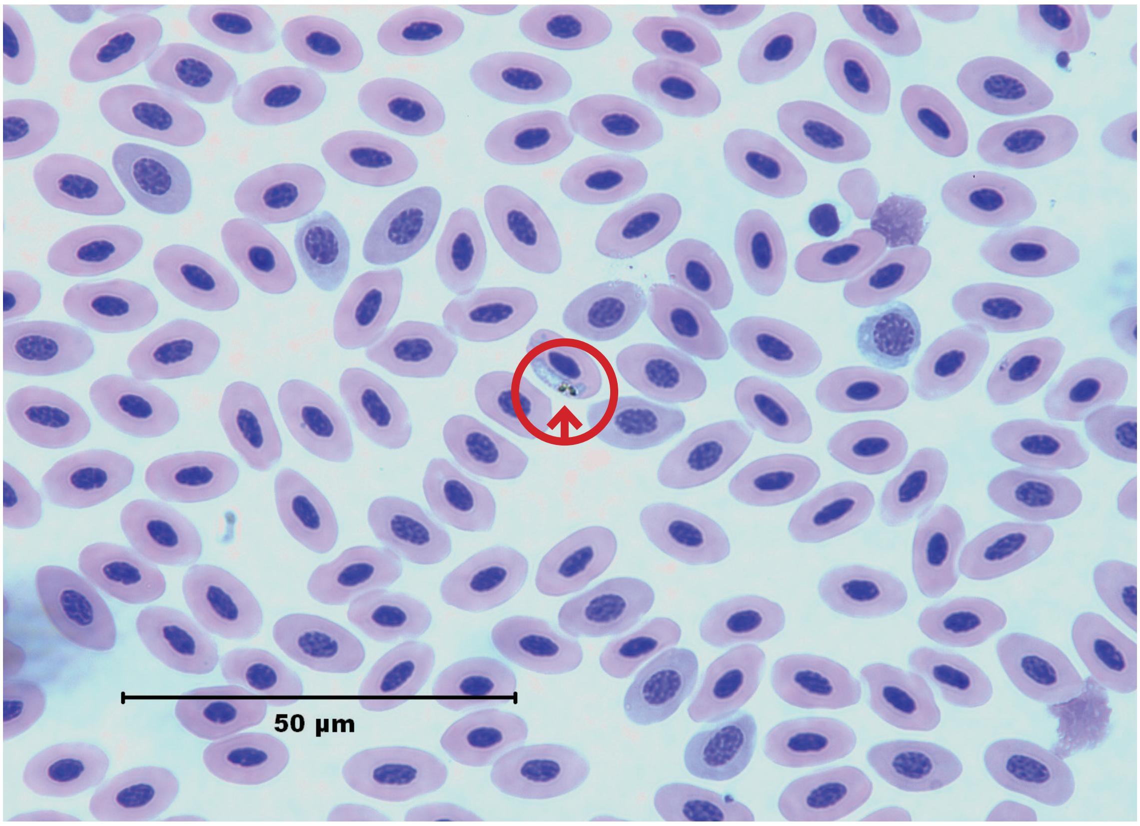


Image 2: A bird blood smear in which a parasite is visible inside a blood cell (arrow). 100x objective. Scale bar: 50 microns. Image: Robert Adlard, Queensland Museum.

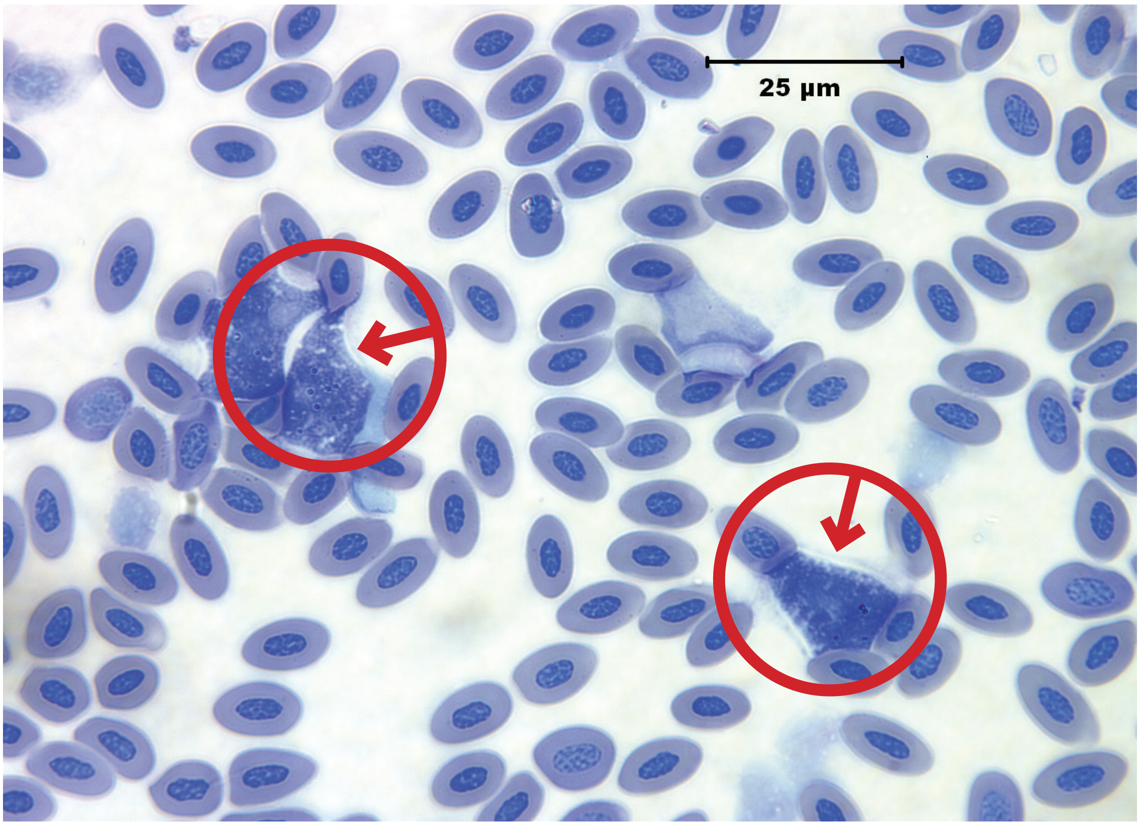


Image 3: A bird blood smear in which parasites are visible adjacent to blood cells (arrows). 100x objective. Scale bar: 25 microns. Image: Robert Adlard, Queensland Museum.

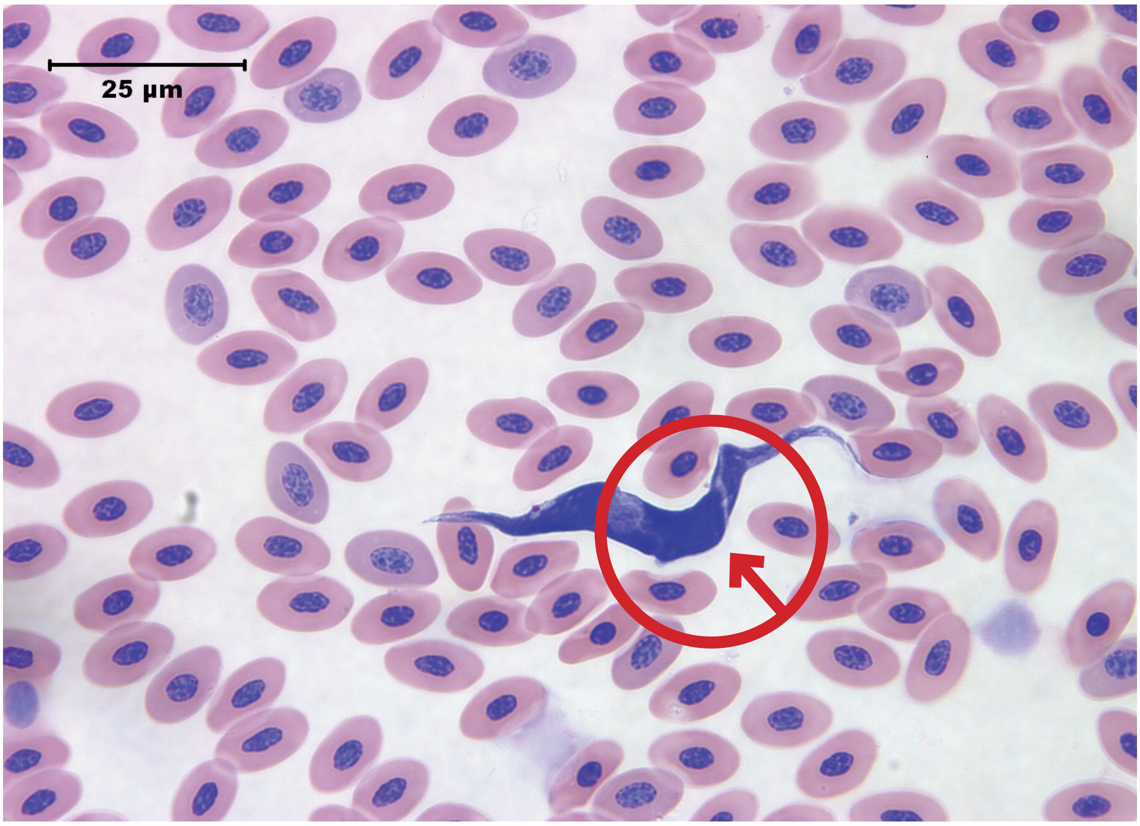


Image 4: A bird blood smear in which a parasite is visible. 100x objective. Scale bar: 25 microns. Image: Robert Adlard, QM.

Identity of parasites:

Image 2: a bird blood smear in which an **avian malaria** parasite (*Plasmodium* sp.) is visible inside a blood cell (arrow). 100x objective. Scale bar: 50 microns. Image: Robert Adlard, Queensland Museum.

(The section on human malaria explains that malaria parasites multiply *within* blood cells. This is the clue that students can use to conclude that Image 2 shows avian malaria; of the three images, only Image 2 shows a parasite inside a blood cell.)

Image 3: a bird blood smear in which another kind of blood parasite (*Leucocytozoon* sp.) is visible adjacent to blood cells (arrows). 100x objective. Scale bar: 25 microns. Image: Robert Adlard, Queensland Museum.

Image 4: a bird blood smear in which a trypanosome parasite is visible adjacent to blood cells (arrow). 100x objective. Scale bar: 25 microns. Image: Robert Adlard, Queensland Museum.