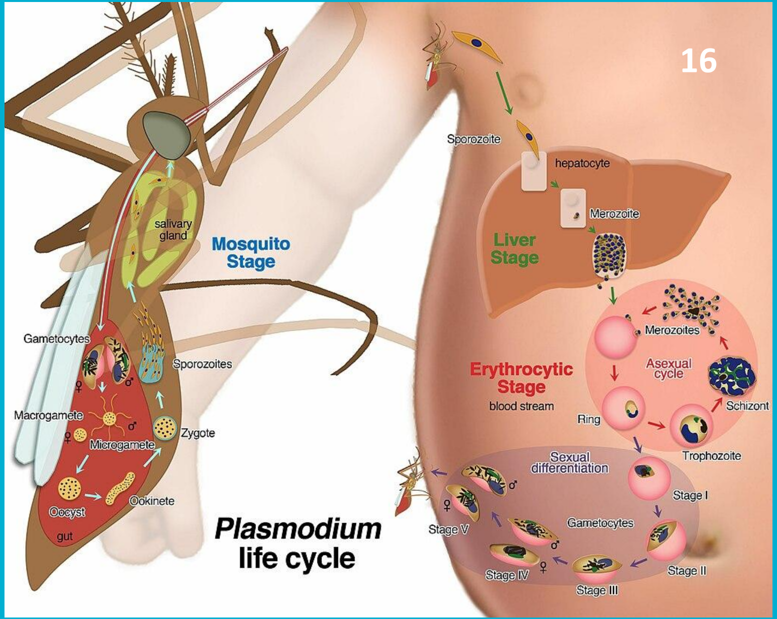
PARASITISM

DEFINITION, CLASSIFICATION CRITERIA, EXAMPLES, STRATEGIES, EVOLUTIONARY SIGNIFICANCE



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PARASITISM

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ETYMOLOGY

PARASITISM: etymology

The term parasite derives:
from the Latin parasītu(m)
from the Greek parásitos "commensal," composed of para- 'para-' and sîtos 'food, nourishment.'

Literally, it means "one who eats at the table of another."

DEFINITION

PARASITISM: definition

We are already somewhat familiar with the term parasitism. Our minds immediately go to lice that nestle in hair and fur, feeding on blood and causing annoying itching with their excrement. To intestinal worms that can reach considerable lengths. And to the countless bacteria, viruses... all there, on or inside our bodies, taking advantage of an environment rich in nutrients and ideal for their survival and reproduction.

PARASITISM: definition

In reality, the concept of parasitism is more complex and doesn't only concern humans. Consider the image on the side. Six eggs are laid in the nest, but one is clearly foreign. The brown-headed cowbird has struck again!

PARASITISM: definition

It has laid its egg among those of another brood. Thus, the parents of the host brood will take care of the chick. Obviously, at the expense of their own brood. The brown-headed cowbird, a passerine bird, is a typical example of a brood parasite.

1

PARASITISM: definition

Here are the most well-known brood parasites. On the left, the brown-headed cowbird, and on the right, the cuckoo.

2

3

PARASITISM: definition

And this is a "foster mother" of the cuckoo chick. A reed warbler of significantly different size.

This first example leads us to conclude that even this case of biological interaction is not always simple and evident.

PARASITISM: definition

To clarify, here's a list of typical characteristics of a parasite compared to its host:

- ❑ generally smaller;
- ❑ faster life cycle;
- ❑ generally, it has a high degree of specialization and is structurally adapted to this lifestyle;
- ❑ primarily, it has relationships with a single host but, in some cases, it may have a definitive host and one or more intermediate hosts.

PARASITISM: definition

At this point, we can provide a more complete definition of a parasite: a living being that lives on or in an organism of another species (its host) to obtain the nutrients necessary for its survival.
In this interaction, the only beneficiary is the parasite because its host usually suffers more or less severe damage.
Let's now see how we can classify them.

CLASSIFICATION CRITERIA

CLASSIFICATION CRITERIA

From what we've seen, parasitism is practically a form of disharmonious symbiosis because, in this close and sometimes long-term interaction, only the parasite benefits. The host, on the other hand, is harmed.

The damage stems from the fact that the parasite finds a way to feed on its host or "share" part of its food, as in the case of intestinal parasites.

CLASSIFICATION CRITERIA

It's worth noting that the parasite's strategy generally aims to keep its host alive to avoid losing not only the source of nourishment but also the environment necessary for its multiplication.
However, there are cases where the damage causes diseases, leading to the parasite being classified as a pathogen.
And we reach the extreme of some fungi that continue to feed on their hosts even after their death.

CLASSIFICATION CRITERIA

From this initial series of reflections, it's clear that classifying parasites isn't simple because it depends on many structural and functional factors.

In short, quite a dilemma for taxonomists, those who classify living beings!

CLASSIFICATION CRITERIA

Let's start with the simplest, most basic functional characteristic. Parasitism affects practically all living beings: viruses, bacteria, protozoa, fungi, plants, and animals. Parasitic organisms have been divided into two groups:

- Microparasites: essentially viruses and microorganisms that complete their life cycle and reproduce within the host.
- Macroparasites: multicellular organisms that pursue the same goals inside or outside the host.

CLASSIFICATION CRITERIA

Considering their life cycle, parasites are classified in:

- obligate, if they completely depend on the host to finish it;
- facultative, if they do not absolutely rely on any host for the completion of their life cycle.

CLASSIFICATION CRITERIA

Regarding the life cycle, it can be:

- direct, if it relies on a single host;
- indirect, if the parasite has multiple hosts, including one or more intermediate hosts and the definitive host is where it reproduces sexually.

CLASSIFICATION CRITERIA

Another important criterion is the "preference" shown by the parasite for settling in its host. From this perspective, the classification is among:

- ectoparasite that lives on the surface;
- mesoparasite that enters a cavity where it remains partially embedded;
- endoparasite that settles inside.

CLASSIFICATION CRITERIA

Another classification method is between generalists and specialists. What does this mean?
Some parasites have no preferences regarding their food source and settle in very different hosts.
Others, like some intestinal worms in animals, exhibit high specificity.
The following slides are dedicated to some concrete examples with specific reflections to facilitate a full understanding of the topic.

SOME PRACTICAL EXAMPLES

SOME PRACTICAL EXAMPLES – VIRUSES

Let's start with viruses.

Viruses are obligate intracellular parasites. To survive and reproduce, they must enter a cell where they multiply at its expense. At this point, the newly produced viruses leave the cell to invade others.

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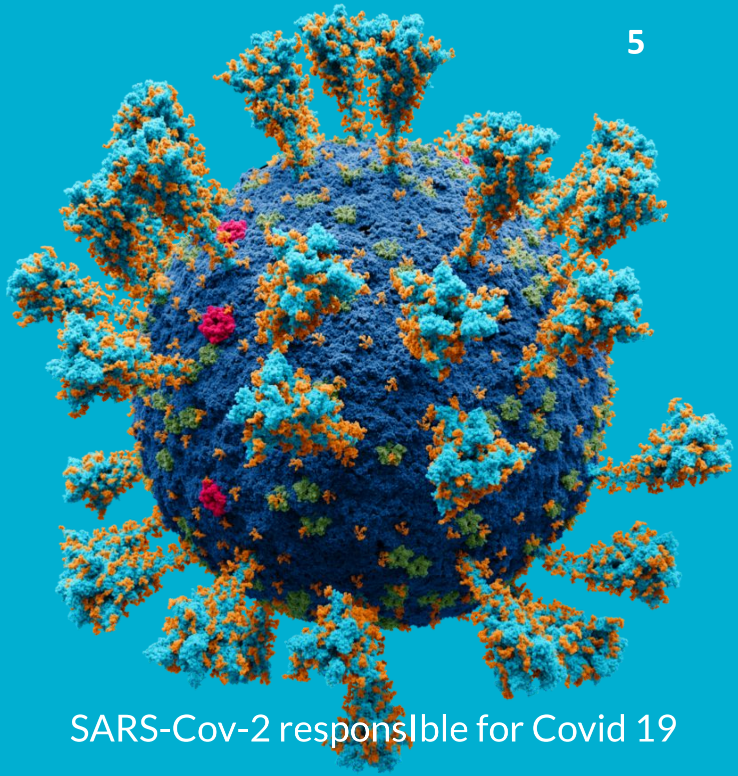
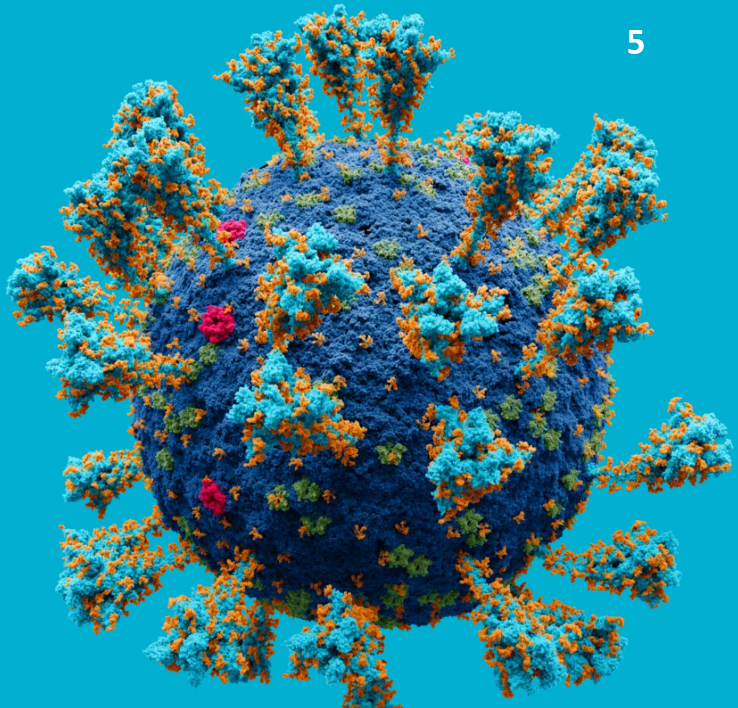


SARS-Cov-2 responsIble for Covid 19

SOME PRACTICAL EXAMPLES – VIRUSES

Viruses. Viruses are very small. They generally range from 20 to 200 nm. They can only infect certain species, and within those species, they only penetrate specific cell types. The choice of the SARS-CoV-2 virus? Mainly the olfactory and respiratory epithelial cells of humans.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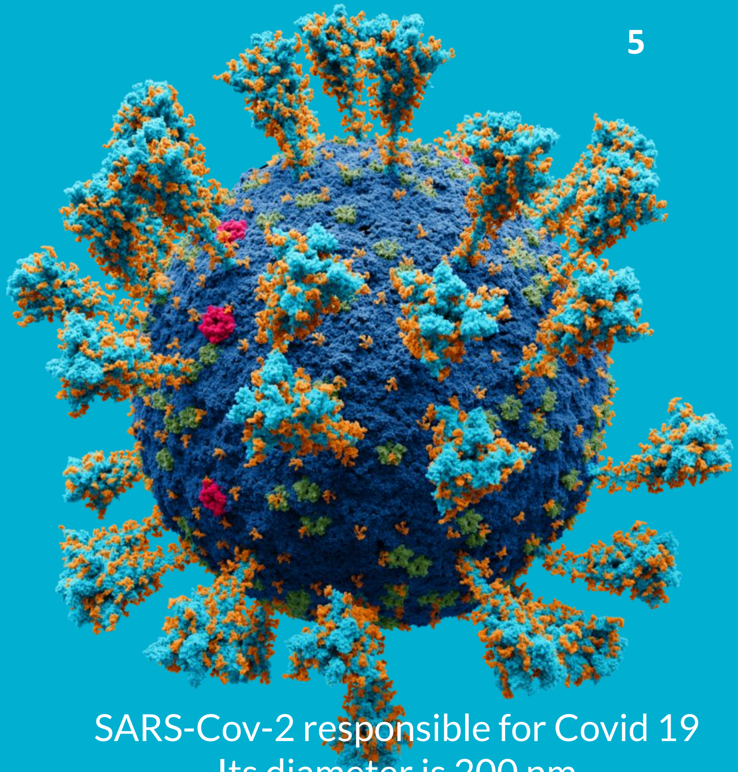
SARS-Cov-2 responsible for Covid 19
Its diameter is 200 nm

SOME PRACTICAL EXAMPLES – VIRUSES

Viruses.

Based on the description and the classification criteria, how would you define viruses?

The answer at the end of the slides.



SARS-Cov-2 responsible for Covid 19
Its diameter is 200 nm

SOME PRACTICAL EXAMPLES - PLANTS

Let's continue with an example of a parasitic plant. Mistletoe, a symbol of Christmas festivities, is a parasitic plant of many broadleaf trees and even conifers.
Its presence is evident in the cold months when plants are devoid of leaves, as in this photo taken in France.

Viscum album

SOME PRACTICAL EXAMPLES - PLANTS

Mistletoe. The sticky seed of the plant is transferred by the wind or a bird and, deposited among the branches of a plant, germinates by emitting roots that penetrate the host's trunk to suck water and nutrients.

Viscum album

SOME PRACTICAL EXAMPLES - PLANTS

Mistletoe. On the other hand, mistletoe has green leaves. The presence of chlorophyll suggests that it performs photosynthesis and produces energy. Now the question is: can it survive without interacting with the host plant? The answer at the end of the slides.

Viscum album

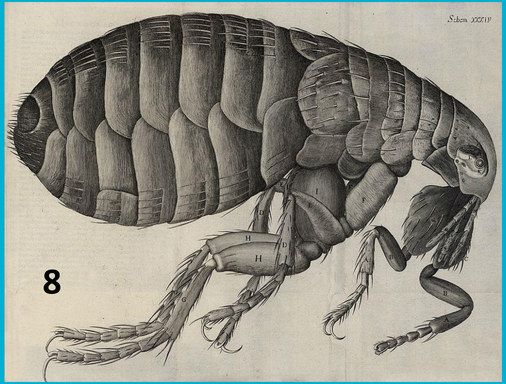
SOME PRACTICAL EXAMPLES – INSECTS

Fleas. These are wingless insects with hind legs adapted for long jumps. They feed on the blood of mammals and birds thanks to their piercing-sucking mouthparts, which serve to pierce the skin. Due to this behavior, fleas can be vectors of pathogens like Yersinia pestis, the bacterium that causes bubonic plague. The disease was transmitted to humans from rodents bitten by infected fleas.

Pulex irritans - scanning electron microscope image. Colors are false.

SOME PRACTICAL EXAMPLES – INSECTS

Fleas. They have a rather complex life cycle that goes from eggs to the adult stage, passing through larval and pupal stages. They generally exhibit species-specificity, but there are several exceptions. It's interesting how they can feed on blood from different species. Their first blood meal is essential for their maturation, but the ability to reproduce always occurs within the same species.



Robert Hooke (1635 - 1703) had already drawn them!

SOME PRACTICAL EXAMPLES - INSECTS

Fleas

Fleas are:

- ectoparasites;
- endoparasites;
- mesoparasites.

The answer at the end of the slides.

Bites of flea on a human

SOME PRACTICAL EXAMPLES - ARACHNIDS

Mites form a subclass of arachnids (Phylum Arthropoda). Mites are divided into several orders, including the Parasitiformes. Let's take the scabies mite (Sarcoptes scabiei) as an example, which parasitizes humans and all domestic mammals, causing scabies, a contagious skin disease transmitted through direct contact.

Sarcoptes scabiei

SOME PRACTICAL EXAMPLES - ARACHNIDS

The scabies mite is not visible to the naked eye (the photo on the side was taken under a microscope). It's a nocturnal animal and prefers warm areas. It cannot survive for more than a few days outside the organisms it typically parasitizes. The female reaches the host's surface and, using its keratolytic fluid, passes through the superficial corneal layers where it awaits the male.

Sarcoptes scabiei

SOME PRACTICAL EXAMPLES - ARACHNIDS

Once fertilized, the female begins to dig its burrow (tunnel) at the border between the granular and corneal layers, where it proceeds to lay eggs (2-3 per day for about 30 days). Only 10% of the eggs mature and hatch.

The disease manifests with a series of reactions to antigens produced by the parasite: very intense itching that intensifies at night.

Close-up photo of a scabies burrow. The large scaly patch on the left is due to scratching. The mite is visible at the top right where it has moved by digging its burrow.

SOME PRACTICAL EXAMPLES - ARACHNIDS

At this point, the question is interesting.

Is the scabies mite an ectoparasite or an endoparasite?
The answer at the end of the slides.

Sarcoptes scabiei

SOME PRACTICAL EXAMPLES – WORMS

Cutaneous larva migrans. In this case, we're not talking directly about the parasite but about a disease caused by nematode worm larvae. The nematode worms responsible usually live in the intestines of domestic and wild animals.

Cutaneous larva migrans

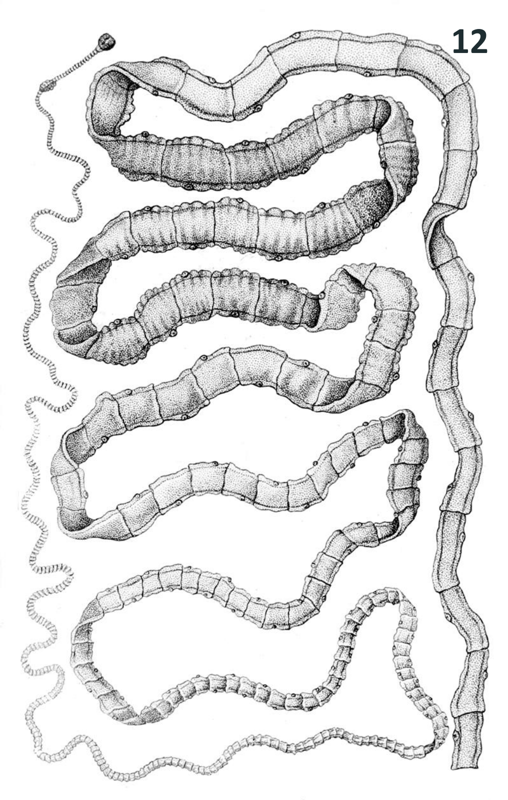
SOME PRACTICAL EXAMPLES – WORMS

Cutaneous larva migrans. Humans can be accidentally infected by coming into contact with the larvae, but they cannot penetrate the human skin and remain trapped, moving just below the epidermis. Can humans be considered definitive hosts? The answer at the end of the slides.

Cutaneous larva migrans

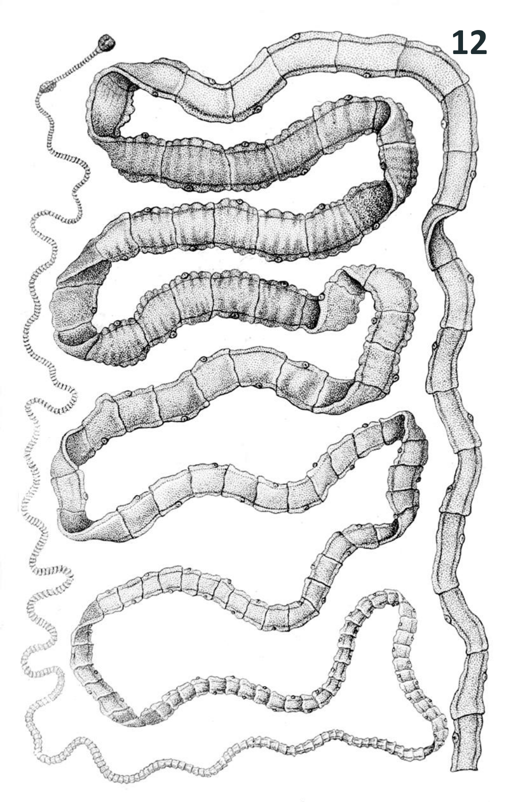
SOME PRACTICAL EXAMPLES – WORMS

Quite different from the nematodes examined earlier are the dimensions of the tapeworm (Taenia solium). The adult tapeworm, which lives in the human intestine, can reach a length of 2-3 meters (drawing on the side). It's a parasite that lives in both pigs and humans and is therefore very common in countries where pork is consumed. In addition to the tapeworm, there are also other species that are grouped under the common name of tapeworms.



SOME PRACTICAL EXAMPLES – WORMS

Tapeworms are parasites of humans and domestic animals and are known for two characteristics.
Their body is segmented. Each segment is called proglottid. The proglottids increase in size moving from the head to the tail. They are egg collectors.



SOME PRACTICAL EXAMPLES – WORMS

The head of tapeworms is called a scolex and has four suckers with which it attaches to the intestinal wall (photo on the side). These worms do not have a mouth because they absorb nutrients directly from the intestine. The parasite has a rather complex life cycle, but, simplifying, we can say that the embryonated eggs can be ingested by all hosts.

Scolex

SOME PRACTICAL EXAMPLES – WORMS

The ingested embryonated eggs transform into oncospheres that cross the intestinal wall of the host and, thanks to the bloodstream, reach the muscles where they lodge as cysticerci. Therefore, humans eating raw or undercooked pork can contract taeniasis. It's a form of infestation that is not particularly serious but can cause weakness due to the continuous intestinal subtraction of nutrients.However, humans, being the only ones to expel the eggs, can in turn ingest them through contaminated food or water.

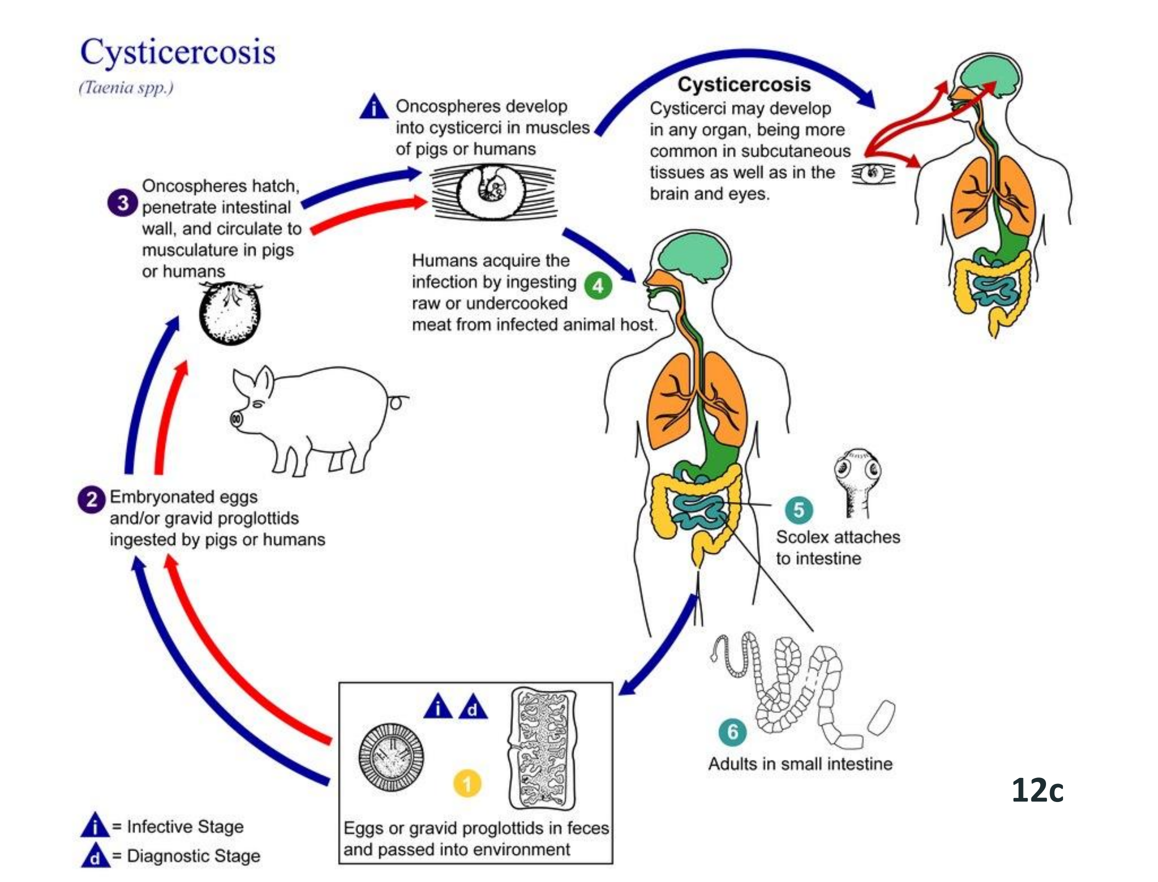
SOME PRACTICAL EXAMPLES – WORMS

And, therefore, humans, like pigs, can host oncospheres and cysticerci. This develops a completely different infestation, cysticercosis. In humans, the cysts settle not only in the muscles but also in the skin, eyes, and brain. The effects can be devastating on health.

Now, pay attention. Based on the description and the image of the life cycle of Taenia solium that you find in the next slide, answer the question: between humans and pigs, which is the definitive host?

SOME PRACTICAL EXAMPLES – WORMS

The answer at the end of the slides



SOME PRACTICAL EXAMPLES – ???

This is a very particular case, and to avoid giving you clues, I haven't completed the slide title.
Observe the image carefully. What's on the tongue of this fish (Lithognathus mormyrus)?

There's a parasite called the tongue-eating louse (photographed on the spoon). It's a tiny crustacean whose female enters the fish through its gills.

SOME PRACTICAL EXAMPLES – ???

It attaches to the tongue and severs the blood vessels at the base, causing the tongue to fall off; then the crustacean replaces it. The male positions itself below and behind the female, attaching to the gill arches.

It doesn't seem that infested fish show significant problems unless they are attacked by multiple parasites.

SOME PRACTICAL EXAMPLES – ???

Now the question is:
what form of parasitism is this?

The answer is at the end of the slides.

SOME PRACTICAL EXAMPLES – FUNGI

Now, we tell about fungi.
A good example is honey fungus (Armillaria mellea). Those who gather it in the woods know that it's often found at the base of dead plants.

Armillaria mellea

Guess why? The fungus has a dual behavior. As a parasite, it causes a disease called Armillaria root rot.

SOME PRACTICAL EXAMPLES – FUNGI

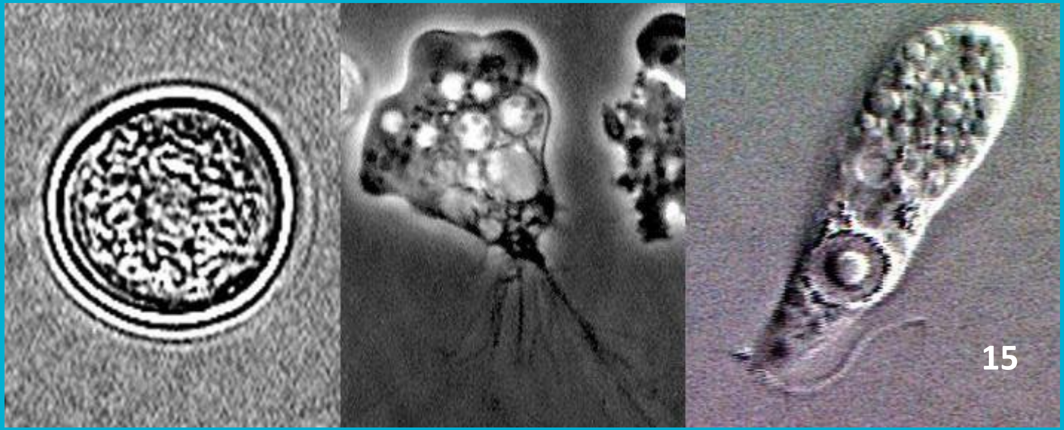
Initially, the fungus mycelium infiltrates beneath the woody tissue and, over time, causes the detachment of increasingly larger areas of bark. When the plant dies, it behaves as a saprophyte, feeding on the dead wood. Meanwhile, it spreads through hyphae called "rhizomorphs" to attack surrounding healthy plants.

Armillaria mellea on an apple tree

Based on the description, are honey fungi obligate parasites? The answer at the end of the slides.

SOME PRACTICAL EXAMPLES – PROTOZOA

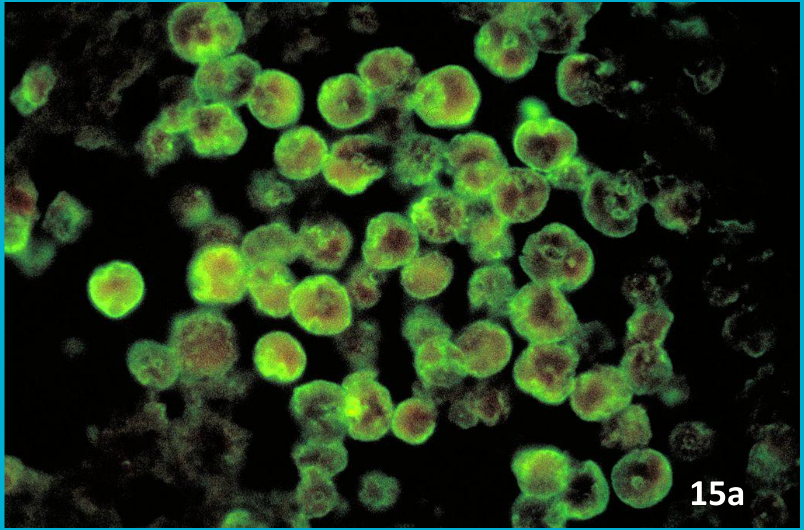
Now let's consider protozoa. Particularly interesting is Naegleria fowleri, a protozoan familiarly called the "brain-eating amoeba." The image shows the three stages of its life cycle.



From left to right, the three biotic stages: cyst, trophozoite, and flagellate

SOME PRACTICAL EXAMPLES – PROTOZOA

Without too much detail, N. fowleri in one of its stages resembles an amoeba. In humans, it can cause a very serious disease: primary amoebic meningoencephalitis (PAM), which is often fatal (90%).



Naegleria fowleri observed under a microscope using a direct immunofluorescence technique. The microorganisms are stained with specific labeled antibodies.

SOME PRACTICAL EXAMPLES – PROTOZOA

The protozoan has a simple biological cycle. It usually transforms into a cyst when the temperature is not favorable (below 10°C). Otherwise, it's found in a biflagellate stage in the waters of rivers, lakes, or swimming pools where filter cleaning is not regular or chlorination is not properly done. In this stage, it actively feeds and reproduces.

Humans become infected by swimming. The protozoan enters the nasal cavities and penetrates through the olfactory mucosa, ascending through the olfactory nerve into the cranial cavity.

SOME PRACTICAL EXAMPLES – PROTOZOA

Here, Naegleria fowleri multiplies actively, as long as it finds optimal conditions, and begins to feed on the central nervous tissue through enzymatic digestion. It normally feeds on bacteria, but when the opportunity arises, it evidently changes its diet.

The numerous necrotic-hemorrhagic lesions are the cause of death.

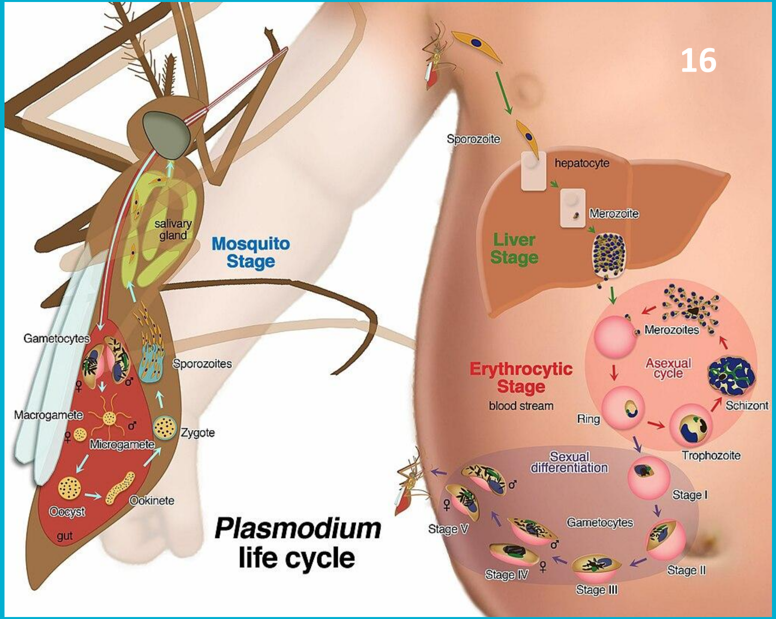
Based on the description, is this protozoan an obligate or facultative parasite? The answer at the end of the slides.

SOME PRACTICAL EXAMPLES – PROTOZOA

We cannot conclude this quick overview of examples without mentioning one of the most well-known diseases since antiquity: malaria, caused by a blood parasite of the genus Plasmodium. This is not the place to go into details. Here, we only want to understand the role of the parasite and its hosts.
Let's start with the description of the life cycle of the parasite, more commonly known as Plasmodium.

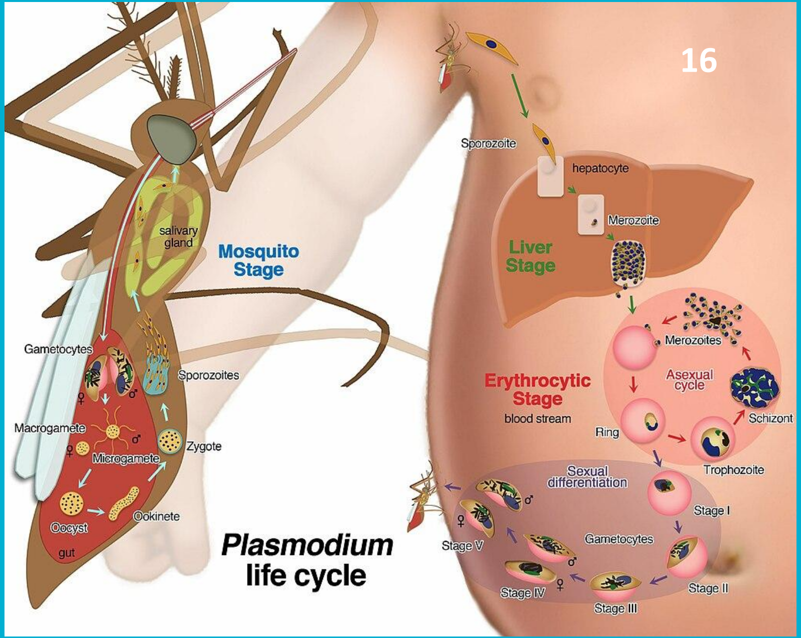
SOME PRACTICAL EXAMPLES – PROTOZOA

We'll use the drawing on the side to help us with this explanation. Plasmodium is a unicellular eukaryotic organism, an obligate parasite of vertebrates and insects. It develops in a blood-feeding insect; therefore, during its blood meal, the insect can inoculate the parasites into the bloodstream of a vertebrate.



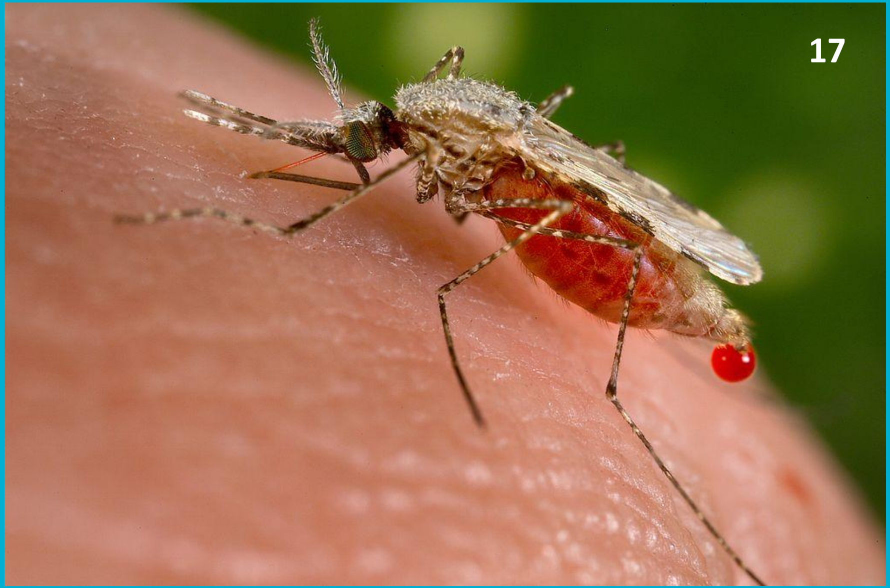
SOME PRACTICAL EXAMPLES - PROTOZOA

In the vertebrate, Plasmodium often reaches the liver, where it undergoes transformations. At this point, it's ready to enter the bloodstream, where it destroys red blood cells, leading to malaria. At this point, any blood-feeding insect that bites the vertebrate allows for the reiteration of the cycle.



SOME PRACTICAL EXAMPLES - PROTOZOA

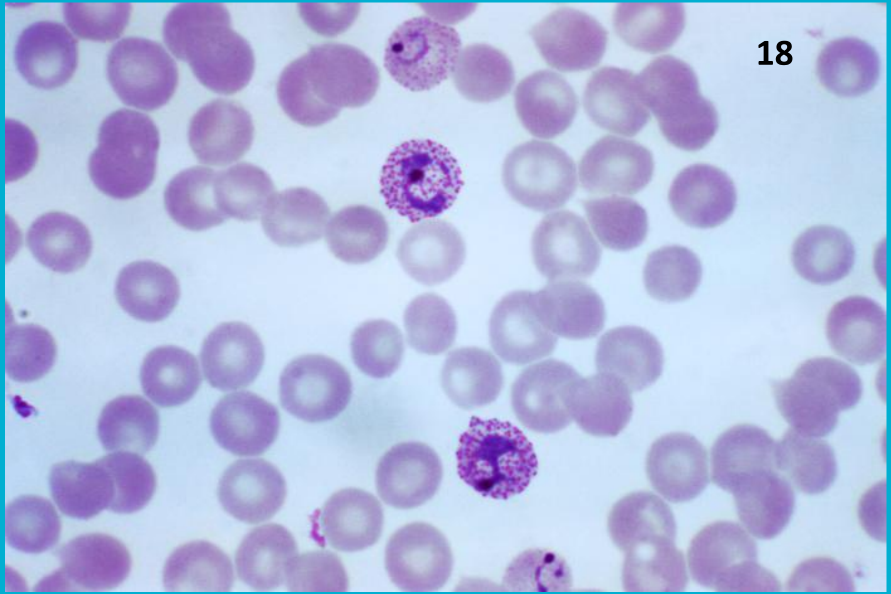
The insect, involved in the vast majority of cases, is a mosquito of the genera Culex or Anopheles.
The vertebrate hosts include reptiles, birds, and mammals. Of the 200 described Plasmodium species, only 5 directly affect humans.



Anopheles stephensi taking a blood meal. A drop of blood is expelled from the abdomen because it's too swollen with inoculated blood.

SOME PRACTICAL EXAMPLES – PROTOZOA

Human blood smear where specific forms of Plasmodium vivax can be identified among the red blood cells, at different maturation levels.
P. vivax is one of the five genera of Plasmodium that parasitize humans.



SOME PRACTICAL EXAMPLES – PROTOZOA

Undoubtedly, this last example is an excellent case study. It allows for reflection on the organisms involved and the different aspects of parasitism.
After all, two types of parasites are involved. Could you identify the ectoparasite and the endoparasite?

The answer at the end of the slides.

PARASITISM STRATEGIES

PARASITISM STRATEGIES

What are parasitism strategies? They are all the methods that parasites use to adequately exploit their hosts and thus obtain nourishment and reproductive opportunities.
In the following slides, we'll see the main ones, and in most cases, you'll be able to recognize some examples we've already examined.

PARASITISM STRATEGIES

Direct transmission. The parasite moves directly from one host to another, often through close contact or contamination of the environment. An example is lice. We've examined fleas with the same transmission mode.

PARASITISM STRATEGIES

Trophic transmission. The parasite is ingested by a host when it consumes infected prey. The tapeworm is an excellent example that we've examined. Humans can ingest the parasite in two different forms: by eating raw or undercooked pork infested with cysticerci or by consuming food contaminated with eggs, or even by drinking water contaminated with eggs.

PARASITISM STRATEGIES

Vector transmission. The parasite relies on another organism, called a vector, to transport it between hosts. This is exactly what we saw in malaria transmitted by mosquitoes.

PARASITISM STRATEGIES

Parasitic castration. The parasite manipulates the host's reproductive system, preventing it from reproducing and diverting resources towards the parasite's growth.

Nature presents us with several cases, especially among barnacles, small marine crustaceans that attach to ships and piers. But parasitic forms also exist.

PARASITISM STRATEGIES

Parasitic castration. Parasitic barnacles have crabs or turtles as hosts. The photo on the side shows a male swimming crab where the effects of the barnacle Sacculina carcini are easily visible, destroying the genitals and rendering it permanently sterile.

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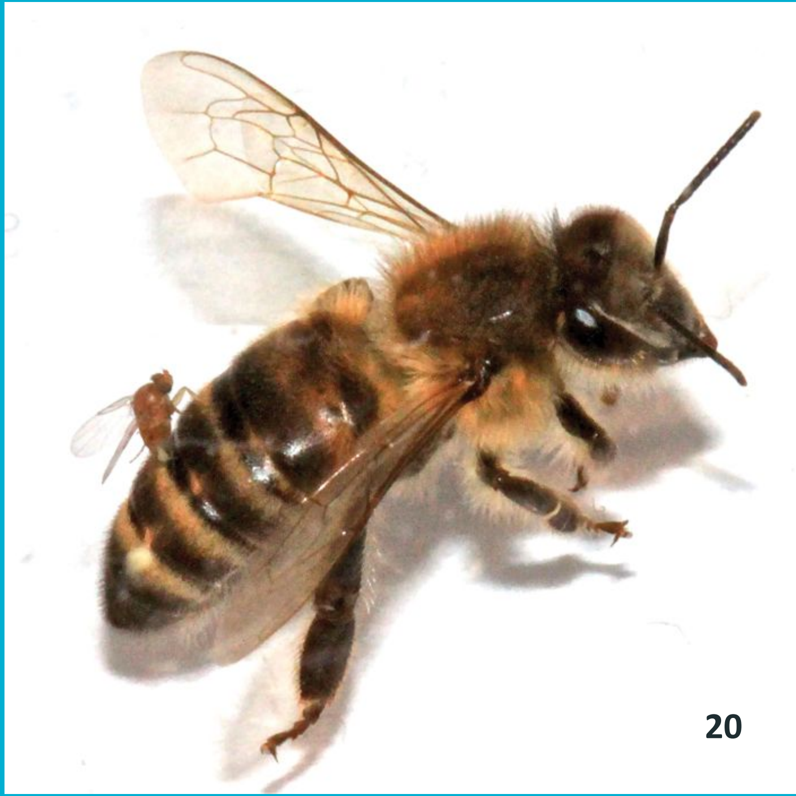
PARASITISM STRATEGIES

Parasitoidism. The parasite ultimately kills its host, often after completing its development within the host's body.
This is the typical case of some wasp and bee species (Hymenoptera) and flies (Diptera). And the list doesn't end here because, as studies continue, beetle species are also being added.
The following slides are dedicated to two specific cases.

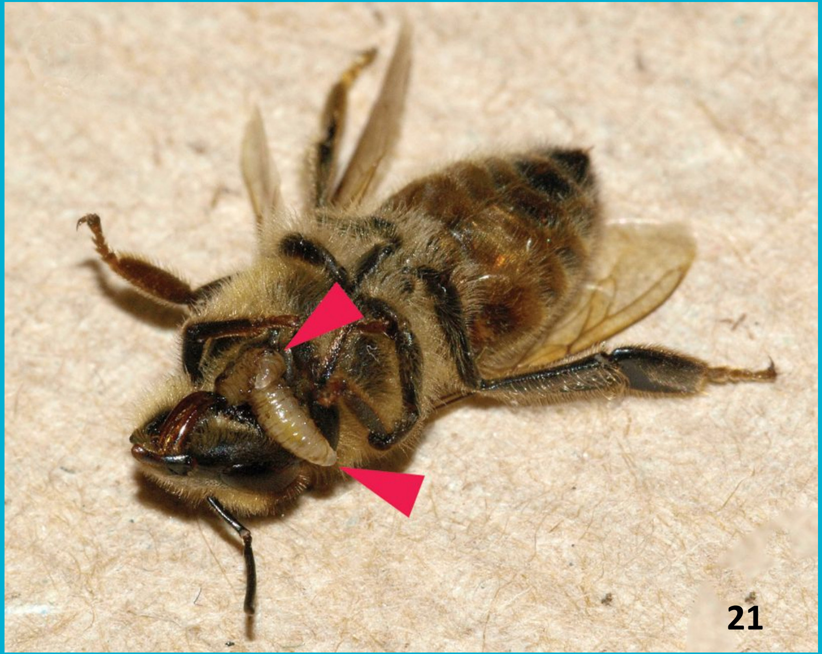
PARASITISM STRATEGIES

The photo on the side is very significant. It shows a female Apocephalus borealis laying eggs in the abdomen of a worker bee. Look at the next slide!



PARASITISM STRATEGIES

This is the final evolution. Two A. borealis larvae emerge from the junctions of the head and thorax of the worker bee.



PARASITISM STRATEGIES

Spathius galinae is a genus of wasp whose larvae feed on beetle larvae. They practically act as biological control agents for some pests like the emerald ash borer.

Adult specimen of Spathius galinae probing the bark for the host larva

PARASITISM STRATEGIES

Micropredation. Here's the last parasitism strategy. The parasite consumes small amounts of tissue or fluids from multiple hosts. It's called micropredation because it borders on a form of predation, in a reduced format, one could say. For example, fleas and mosquitoes feed on the blood of live animals, and we've already examined these examples. We could add aphids that suck sap from plants and leeches.

PARASITISM STRATEGIES

Micropredation.

Leeches are interesting. In medicine, they have always been used since ancient times and up to the 19th century to draw blood from patients (the famous bloodletting).

They are still used today.

The most well-known specimen is Hirudo medicinalis, the medicinal leech, which feeds on blood after adhering to the skin through a sucker and secreting hirudin, an anticoagulant peptide.

PARASITISM STRATEGIES

Micropredation.
Extracted hirudin is used in the treatment of blood clotting disorders.
The leech, as a live specimen, can be useful in microsurgery and for some diseases like osteoarthritis of the spine.

The most well-known specimen is Hirudo medicinalis, the medicinal leech, which feeds on blood after adhering to the skin through a sucker and secreting hirudin, an anticoagulant peptide.

CURIOUS FACTS TO KNOW ABOUT PARASITISM

HYPERPARASITISM

It refers to an epiparasite that feeds at the expense of another parasite.
An example? A protozoan parasite in the digestive tract of a flea that lives on a dog ;))
Hyperparasitism can result from interspecific competition between parasites of different species associated with the same host (co-parasitism)

HOST SIGNALS

More or less, everyone knows that exhaled carbon dioxide attracts mosquitoes which are ectoparasites as we have learned. This is one of the many signals emitted by parasitized hosts.
Any other signals? vibrations, skin odors, visual or thermal traces, humidity. The list does not end here. Excellent in-depth topic.

THE EVOLUTIONARY SIGNIFICANCE OF PARASITISM

PARASITISM: EVOLUTIONARY SIGNIFICANCE

Parasites are ubiquitous and represent more than 50% of living beings. It's intuitive to imagine that there has always been a race between parasites and hosts to refine their available weapons, a sort of arms race. As hosts develop defenses against parasites, in turn, parasites evolve ways to overcome those defenses. In other words, there is and always has been continuous adaptation and counter-adaptation.

PARASITISM: EVOLUTIONARY SIGNIFICANCE

And it's equally plausible that there has also been a sort of coevolution.
This has led and can lead to complex relationships where parasites become highly specialized to exploit specific hosts, and hosts develop specific defenses against those parasites.

PARASITISM: EVOLUTIONARY SIGNIFICANCE

Certainly, parasitism is a widespread phenomenon in nature and is believed to have contributed and continues to contribute to biodiversity by driving speciation and diversification in both parasites and hosts.
And it's equally certain that parasites play crucial roles in ecosystems by regulating host populations, influencing community structure, and contributing to nutrient cycling.

THE ANSWERS

THE ANSWERS to return to the question click on ⇚

Viruses: microparasites, obligate, with a direct life cycle, endoparasites, specific. ⇚

Mistletoe: no, it only has the ability to partially produce its own nourishment. It's a particular form of parasitism: obligate hemiparasitism. ⇚

Fleas: ectoparasites. The explanation clearly indicates this as it mentions mouthparts adapted to pierce the skin to suck blood. ⇚

THE ANSWERS to return to the question click on ⇚

Scabies mite: ectoparasite. The term includes temporary blood-sucking arthropods like mosquitoes and all those that stick to the surface or penetrate the surface layers even for relatively long periods of time ⇚

Cutaneous larva migrans: no, because the parasite cannot reach its natural habitat and complete its development. Some researchers define this situation as aberrant by associating it with the definitive or intermediate host. ⇚

THE ANSWERS to return to the question click on ⇚

Tapeworm: the definitive host between pig and man is man because he is the only one who hosts the embryonated eggs in his body. The pig is only an intermediate host because the reproductive process does not take place in its organism. ⇚

Tongue-eating louse: this is the case of a mesoparasite entering a cavity where it remains partially incorporated. ⇚

THE ANSWERS to return to the question click on ⇚

Honey fungus :no, because they can survive even without parasitizing living organisms. In fact, they transform into saprophytes under certain conditions. ⇚

Naegleria fowleri: it is a facultative parasite because it feeds and reproduces without the need to parasitize a host. ⇚

Plasmodium: the plasmodium is the endocellular parasite while the mosquito is the ectocellular parasite

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PHOTO CREDITS

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WEBLIOGRAPHY

https://necsi.edu/parasitic-relationships

https://extension.umd.edu/resource/parasitoids/

https://australian.museum/learn/animals/insects/predators-parasites-and-parasitoids/

https://www.medicalnewstoday.com/articles/220302#prevention

https://www.cdc.gov/parasites/about/?CDC_AAref_Val=https://www.cdc.gov/parasites/about.html

https://en.wikipedia.org/wiki/Parasitism

https://www.nature.com/scitable/knowledge/library/ecological-consequences-of-parasitism-13255694/

https://www.paho.org/en/topics/ectoparasitosis

WEBLIOGRAPHY

https://www.who.int/health-topics/taeniasis-and-cysticercosis

https://www.cdc.gov/dpdx/malaria/index.html

https://www.pnas.org/doi/full/10.1073/pnas.1619147114