I used to hate parasites but then they grew on me.

You're sat at home, relaxing, when you hear a drone-like buzzing. Do you stay still or run? Too late. You feel a sharp sting penetrate your abdomen, then nothing. You can't move your legs; you can't even feel them. What you can feel is an excruciatingly sharp second stinger, piercing its way through your neck and into your brain. The pain remains but more than anything you feel dirty, so you clean your body scrupulously.

An hour passes and the wasp returns. Has it come to finish you off? You've begun to feel sluggish so when the wasp grabs you and pulls you like a dog on a leash you follow without a fight. You're brought to its burrow. Here, the wasp lays its egg on your leg, covering the nest and burying you alive before it leaves.

Before you know it, the egg hatches. The hatchling is ravenous, and the juices held within your leg are on the menu. Still not satisfied, the hatchling begins to make its way to your internal organs and devours everything in its path.

With nothing left to give, your body gives up. But death is not the end of this horror story.

Now that your organs are gone it feels quite homely in your abdomen. The perfect home in fact, for the new occupier to grow and change. Forty days later, like a beautiful butterfly emerging from its cocoon, the emerald wasp bursts through your carcass, ready to find a victim of its own.

Did you find this tale barbaric, spine-chilling or flat out horrifying? Whichever it is, be thankful you are human and not cockroach, for if you were, the Emerald Cockroach Wasp could be after you.

The What, How and Why of Parasites:

Parasites are not classified as a family of organisms such as cats (Felidae), for example. Instead, parasitism, also known as incomplete predation, is a mode of survival in which an organism takes and relies upon resources stolen from another, usually to the detriment of the host.

Parasites can be passed between organisms through many different mediums such as the food we consume, the water we drink and bathe in, the people we encounter, the pets we keep and the insects that bite us. It's fair to say that parasite knowledge is an easy gateway to hypochondria.

As old as the dinosaurs, parasites have followed animals like a shadow throughout history and it's estimated that they make up 40% of all animal life. From Frankenstein-looking appearances to mind control and endings as horrific as being eaten alive from the inside-out, parasites leave death and destruction in their wake. Yet, the end of one animal is a source of sustenance and life for another and without them whole ecosystems would crumble. Understanding the gruesome ways of life for these creatures is crucial to our understanding of how animals function as circular systems and how they evolved.

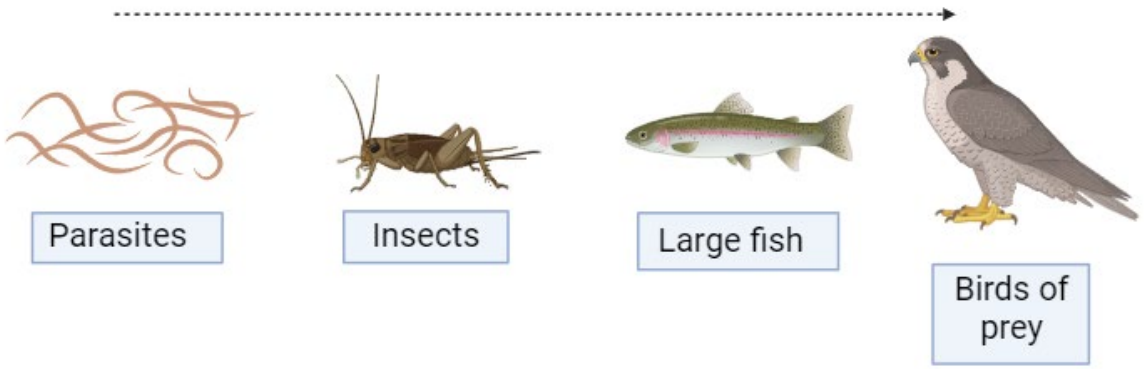

Figure 1: The importance of parasites in fresh-water ecosystems. Image created using BioRender. Parasites infect insects, causing them to drown in water systems, here the worms and insects become a food source for fish which in turn get eaten by large birds of prey such as hawks.

Not So Innocent:

Mistletoe (*Viscum album*) is celebrated in the Christmas period and hung from ceilings and door frames for lovers to steal a kiss under to bring about good luck. The ancient Greeks thought of it as a plant of healing and the Druids, a plant of fertility. But what you might not know is that mistletoe is a parasite!

Most plants acquire nutrients from the soil, obtained through their roots and sent to where they are needed throughout the plant. Mistletoe defies the norm by making its home on pre-existing trees such as apple or hawthorn and growing into the tree, stealing the nutrients for its own use. The host tree is not killed but weakened, forced to share its hard collected resources like a dutiful older sibling.

Mistletoe once again exploits nature to its own advantage to ensure the spread of its species. The white berries that grow from winter to spring are covered in a sticky substance which adheres to birds when they come foraging. These birds then unwittingly spread the mistletoe seed to other trees, leaving a less than favourable Christmas gift.

Mind Control:

The mind is often thought of as impenetrable, yet real life examples of mind control exist throughout nature. Some parasites can bend the will of their host to advance their own malicious intents.

The Gordian or Horsehair worm is one of these mind controllers and can be found on all continents except Antarctica! Once eggs have been laid in the sediment or water they wait to be consumed by a host. Like many parasites, they can be a bit picky, meaning if the eggs or larvae are consumed by the wrong host then the parasite will remain dormant, instead using its host for transport. Crickets, for example, are a more than favourable host so when they ingest the parasite eggs it's go time. Within

2-8 months a fully grown worm up to 2m long is living inside its cricket host, but there's one problem; gordian worms live in the water while their host lives on land. The solution? Mind control. The host is compelled towards water where it takes a final leap, ending its own life where the worm can slither out through the abdomen, a display enough to make anyone feel queasy.

But these worms aren't the only mind controllers. Another example is *Leucochloridium* which urge ground-dwelling molluscs to climb high up. Once in position, the eye stalks which have been taken over and transformed into a colourful pulsing beacon, ensuring the snail is spotted by its bird prey and devoured on sight.

Figure 2: Illustrated snail infected with *Leucochloridium* visible in the eye stalks.

Science Fiction or Reality?

The Cordyceps fungus rose to public notoriety through the popular game and 2023 TV adaptation of "The Last of Us" which is set in a world where climate change has forced the mutation of the Cordyceps fungus to infect humans, causing a zombie apocalypse. Although fictional, some aspects mirror the real-world horrors of parasites.

The zombie-ant fungi (*Ophiocordyceps unilateralis*) begin as spores carried in the air until they make contact with their ant victims. Over the next three weeks a network of mycelium roots infiltrates the muscle cells and spreads throughout the body. Although the brain remains clear of fungal cells, it becomes flooded by chemicals, driving the ant to move towards the perfect conditions for the fungus to grow. The ant's final act is to bite down, securing its place and simultaneously its death. Finally, a long antenna-like spike emerges from the ant carcass, soon to release its spores and kill its next victim.

There are over 600 species of Cordyceps, commonly found in humid jungles, which have each spent millions of years co-evolving with their hosts, be it ants, spiders or moths. Fortunately for us, humans have complex immune systems which are vastly different genetically to those of insects, protecting us from zombie-like infections anytime soon.

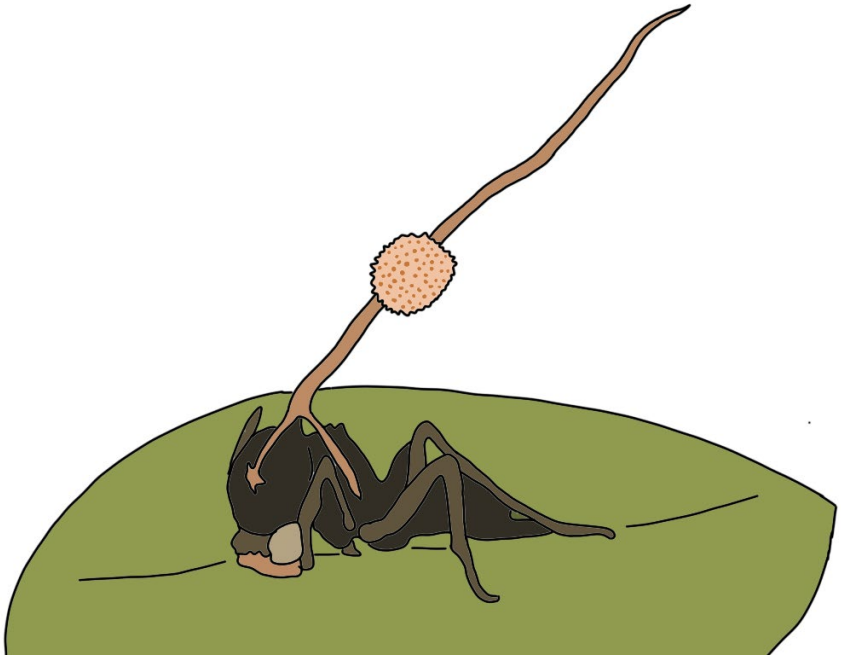

Figure 3: Illustrated ant with cordyceps infection causing a fungal growth with spore capsule.

Neglected Tropical Diseases:

Although zombie-like fungi and wasps which eat their victims alive are not worries of humanity, many parasites can infect humans and carry harmful and sometimes life-long problems for entire communities.

Neglected tropical diseases (NTDs) are a group of 20 conditions, prevalent in tropical areas, especially of low-income (Figure 4). NTDs not only devastate human health but also have complex ramifications in social and economic matters for the more than 1 billion people effected.

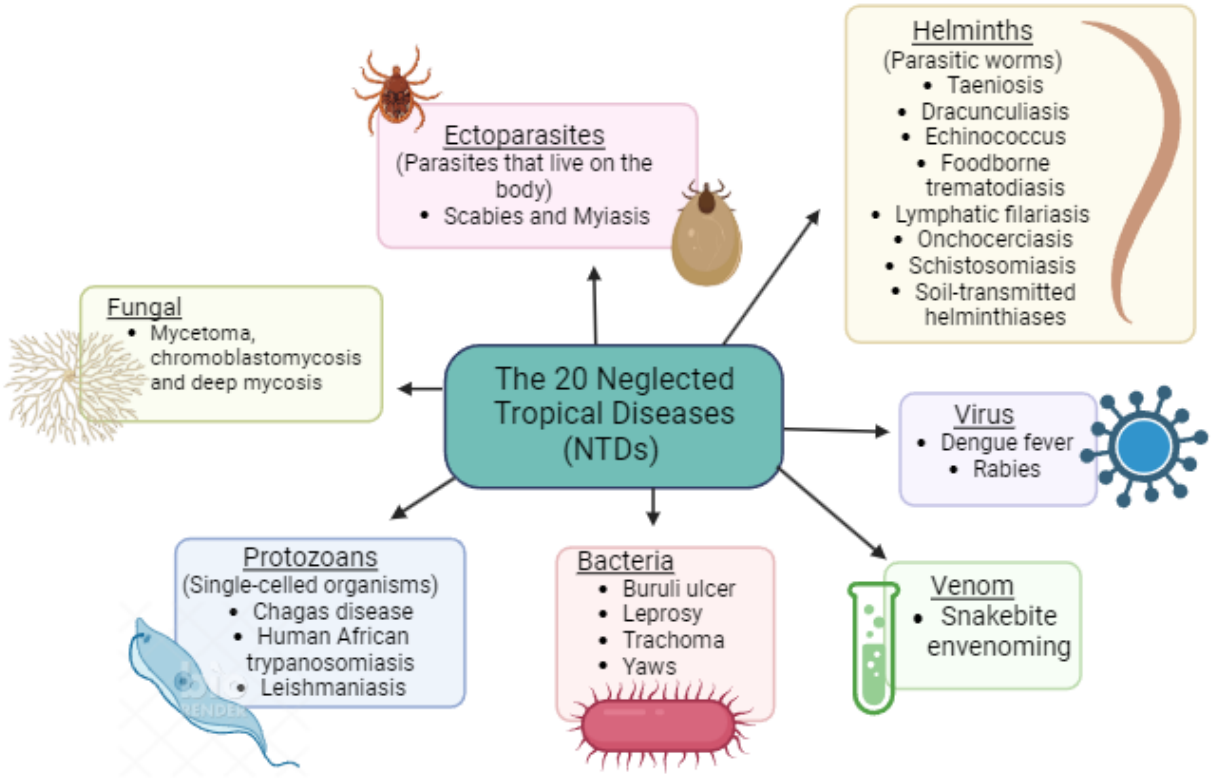

Figure 4: Explanation of NTD classification. Figure made using BioRender. There are 20 NTD infections which are divided into 7 groups: helminths, viruses, venom, bacteria, protozoans, fungal and ectoparasites.

The *Trypanosoma brucei* complex transmitted by the Tsetse fly across a majority of Africa can infect both humans and cattle. In humans the condition causes profound neurological symptoms, leading to the development of repeated comas and, if left untreated, death. In contrast, the disease in cattle leads to less fatal but more chronic symptoms such as reduction in milk yield and muscle wastage. For people whose livelihood depends on cattle, this disease can have catastrophic economic consequences.

Leishmaniasis is a widespread NTD transmitted by sandflies. The visceral form of the disease has a 95% fatality rate in cases left untreated while the cutaneous form causes lesions on the skin and life-long disfigurement. Due to stigma surrounding scarring, those infected often experience social exclusion including in finding employment.

As the name suggests, NTDs are neglected meaning that although they are preventable, they are ignored by global health agendas and funding agencies leading to a fundamental issue in human rights. Tackling this health crisis requires a holistic approach both for treatment and prevention. Increasing knowledge and public awareness of these diseases ensures the protection of individuals globally and supports the efforts of organisations such as the World Health Organisation (WHO) and UNICEF which work tirelessly to direct funding and support to those who need it most.

The last decade has seen a 25% decrease in populations requiring intervention. However, the road ahead of us is long if we wish to truly win this war against parasites and the diseases they can cause.

Further reading:

Ed Yong. “Animals Have Evolved into Parasites At Least 200 Times.” National Geographic (July 20, 2016)

Sara B. Weinstein & Armand M. Kuris. “Independent origins of parasitism in Animalia.” Biological letters (July 1, 2016)

Maridel A. Fredericksen *et al.* “Three-dimensional visualisation and a deep-learning model reveal complex fungal parasite networks in behaviourally manipulated ants.” PNAS Nexus (November 7, 2017)

Centres for Neglected Tropical Diseases Control and Prevention. Neglected tropical diseases (Last reviewed June 19, 2023) https://www.cdc.gov/globalhealth/ntd/index.html

https://www.youtube.com/watch?v=B9_RUwR3RFU

https://www.ted.com/talks/ed_yong_zombie_roaches_and_other_parasite_tales

https://www.youtube.com/watch?v=ovo_T0KqdYg