Lecture 9: Species interactions 3

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Today we're going to speak about species interactions with a focus on parasitism and mutualism.

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The learning outcomes for this lecture, we hope to understand the types of symbiosis, be able to describe what a parasite is and to give an example.

Be able to describe an example of a mutualistic relationship.

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So of the six species interaction types that we have been talking about, today we will focus on parasitism which is a relationship between two organisms that negatively affects one partner and positively affects the other, and mutualism, which is a symbiotic relationship that benefits both partners.

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A parasite is an organism that lives inside or on the surface of a partner, and from now on we will be calling it the host species that derives benefits from the association at the expense of the host

Almost all animals will have some kind of parasite that lives on them and most plants as well will have some kind of parasite. Globally there is an enormous health and economic cost to parasitism

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More than half of the species on Earth are parasites. The human body is host to many other species. The parasite is looking for a food source. It is good to keep the host alive to continue feeding. Many parasites also use the post as a location to lay eggs. When the eggs hatch, the host is a food source for the offspring. The difference between a predator and a parasite is that the parasite does not immediately kill the host. Parasites take many shapes and forms and their effects can be termed “sub lethal” where they do not kill the host or “lethal” where the association ultimately results in the death of the host.

We also recognize two distinctions of the requirements. Some parasites cannot live without a host. This is termed obligate. Other parasites are called facultative. They can live without a host.

Parasites may reduce the performance of the host through affecting its growth, development or reproductive success.

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There are many different types of parasites. Parasites exist in every kingdom of life microparasites are microorganisms, including bacteria, viruses, fungus and prions. We would call these pathogens or diseases. Macro parasites include tapeworms, liver flukes, nematodes, wasps and plants.

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There are various advantages and disadvantages to living in or outside of the host. Ectoparasites live on the outside of the host. These can include malaria mosquitoes, fleas, mites, ticks and leeches. They can disperse between hosts easily and they will not be attacked by the immune system of the host. The disadvantages of living outside the host are that they may be attacked by natural enemies, so the malaria mosquito may be eaten by a bird or lizard. They are also exposed to the external environment with all the difficulties and risks that involves. Finally, it may be difficult to find a host, especially if like the mosquito. It needs to travel between lots of hosts.

Endoparasites include tapeworms, liver flukes, bacterial and fungal pathogens. Many endoparasites live in the gut of an animal host and feed on its digested food, thus reducing the nutrient intake of the host. In plants bacteria and fungus can cause the plant to decay from the inside out. However, they will have a problem with dispersing which may be overcome in a number of ways. Parasites from the gut, for example, may be dispersed in faeces.

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We'll start with macroparasites. Invertebrate parasites of plants can cause big problems when they are of economic importance. Here we can see a root knot nematode affecting tomato roots. The nematode will lay eggs near the root particularly near the meristems in the root tips, then the juvenile will hatch and enter the root. The root will grow galls which are these big swellings in the bottom photograph. You can see the swellings on the left and on the right is a healthy root. The above ground plant parts will show symptoms of water and nutrient stress. Yellowing of leaves, poor fruit crop and stunting. The nematode in this picture *Meloidogyne* is an important parasite all over the world. So it is definitely in Myanmar, and there are many attempts to control it, including rotation of the crop with resistant species or cultivars, and biocontrol. In this case, the biocontrol is to use fungus to kill the eggs of the nematode.

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There are also plant parasites that have various impacts on their host and play ecological roles. In temperate areas, there is a genus called *Rhinanthus* or yellow rattle, which is known as a hemiparasite with grasses. While the *Rhinanthus* is quite capable of living alone, it will choose to attach to the root system of fast growing grasses. Fast growing grasses are highly competitive and from a conservation or restoration perspective, they are not desirable species. Plant species that are required for a high diversity grassland are poor competitors and need significant help. Therefore *Rhinanthus* is a good thing in grasslands, because it helps reduce the competitive ability of fast growing grasses, by taking the nutrients. They will then grow more slowly, and the more desirable species will have a chance to establish.

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Another example of a parasitic plant is dodder or *Cuscuta*. This is an obligate parasite, so it cannot survive without a host. Dodder is found all over the world, including in Asia. Dodder will take all of the nutrients and water it requires by inserting a haustorium into the vascular system of the host. A haustorium is a specialized organ used by both parasitic plants and fungi to penetrate a plant cell wall. Dodder is one of the worlds most important plant parasites because it is so successful and widespread. It attacks agricultural and horticultural crops and can attack many at the same time.

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Parasites and hosts occur in all environments. Every animal can be parasitised by a wide range of organisms. The huge diversity means that the host is constantly using energy and resources to survive the parasite infection or deter it from attack. It is thought about 10% of insects are parasitoids.

Parasitoids are a specialized group. They are insects that lay their eggs on inside the host, which is usually another insect. They grow in close association with the host.

The parasitoid life cycle generally follows the pattern that I have shown here. When the adult is ready to lay eggs it will find a host. In this image, it is a caterpillar, and the adult parasitoid will penetrate the body of the host using an ovipositor, which is basically a tube that's like a needle in the back end of the insect and it will insert his eggs into the body of the host. The eggs will then hatch, and the larva will feed on the inside of the host. Eventually it will kill it, and then the larva will leave the dead body of the host and then it will complete its life cycle to become an adult. The host will almost always die, but before that in some examples, the parasitoid can change the activity of the host in order to protect the eggs and the larvae. I have added a YouTube video in the summary to illustrate this.

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I'm just going to briefly touch on microparasites, or pathogens, before moving on to mutualism. It is a huge subject, and one that we cannot cover in too much detail here. Fungus is a type of ectoparasite, which affects the outside of the organism. In humans, we get athlete's foot, a fungal disease of the feet, and various other fungal infections. More than 5000 species of fungi affect important crop and horticultural plants. Depending on the symptoms, we call them mildews, rusts or smuts, and they can have a large economic impact. Like the dodder plant the fungus has a root-like haustorium, which is inserted into the plant vascular system or cells to extract nutrients.

There are a range of fungi that infect insects, and cause a syndrome called summit disease. This is where the fungus will take over the brain of the insect and make it climb to the top of the plant it is standing on. The reason for this is because the spores of the fungus can then disperse longer distances. A common place to find these infected insects, which will die fixed in position, is in very dry areas near water bodies such as rivers. It is thought that the high humidity next to the river makes favourable conditions for the fungus to release spores.

Bacteria do not have much persistence in the soil, but they can cause a wide range of diseases which alter plant competitive interactions and reduce crop yields. Where fungi have haustoria which push into plant cells, bacteria grow in the spaces between cells. They often cause overgrowth of plant cells to create structures such as galls and cankers. In animals and humans bacteria are responsible for a wide range of infectious diseases that can lead to outbreaks, particularly in social animals that live in large groups or in captivity.

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Responses to infection really depend on the type of infection. Plants do not have a systemic immune system that can adapt to infection in the way that animals do. A plant is basically modular - all of it cells have the capacity to fulfil any role. A pathogen can enter a plant through the stomata as it is taking in carbon dioxide or through a wound. For example, where a caterpillar has fed fungi and nematodes can also directly penetrate cells. The damaged cells can send signals to other plant cells which can then isolate the infected areas. If possible, there is a hypersensitive response, which will cause rapid growth of cells surrounding the infection. This will restrict the growth of other pathogens.

Insects do have an immune system. It is actually quite similar to that of mammals. When social insects like ants and bees are exposed to a disease, they may be able to reduce the risk of passing it to others in the nest. Three ways they can do this are by grooming spores from each other before they take them back to the nest. Generating a fever response which means that the rising temperature of the insect could trigger further immune responses to kill the pathogen. Or as a last resort to leave the nest and die away from the group so as not to spread infection.

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We are now going to move on to mutualisms. A mutualism is a relationship between two different species where both get a benefit. There are many examples. In rainforests of Sri Lanka, India and across Asia, there is a relationship between spiders and frogs. The spider makes a burrow for its eggs. The frog comes to the burrow and the spider leaves it unharmed, because the frog has poison on its skin. The frog eats the insects that come to eat remains of the spiders prey. This benefits the spider because often these invertebrates also eat the spider eggs. So the frog will protect the eggs. It benefits the frog because it gets lots of food and the spider will protect it from other predators.

Another example is ant-plant mutualisms, so this over here. In South East Asia, there is a genus of plant called *Myrmecodia* which has structural adaptations to let the ants live inside it. The plant is an epiphyte, it does not have roots and it clings to the outside of the tree. Instead, it has a number of chambers and the walls of some of the chambers can take in nutrients just like roots. So ants contribute excrement and dead bodies to feed the plant and the plant offers food in the form of fruits. Therefore, the benefit to the plant is the nutrients the ants provide and also defence against herbivory because the ants will attack herbivorous insects that try to eat the tree. The benefit to the plant is the habitat the plant provides.

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Lichens are symbiotic associations between a fungus and an alga or a cyanobacteria. The fungus provides the thallus, which is the physical structure of the lichen. It also creates many different chemicals which have roles such as protection against UV light, drying out and herbivores. It may also offer improved access to mineral nutrients which the alga cannot get itself. The alga is able to photosynthesize so the sugars it creates are useful to the fungus. There's some debate about whether this association is a mutualism at all as it seems that the fungus can choose which alga to associate with in order to meet its ecological needs. However, the numbers of the population of the alga in a lichen association are far higher than free living algae suggesting that the alga does in fact receive a benefit.

Lichens are interesting because they are useful indicators of nitrogen pollution. There are some species that are very sensitive and will not be found in towns and also some species that prefer a high nitrogen environment.

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We talked briefly in a previous lecture about *Rhizobium* bacteria and how an association with a plant enables the plant to take up nitrogen. Legumes are plants that have a facultative relationship with *Rhizobium*. The relationship occurs when the legume is starved of nitrogen. As for the lichen, the symbiosis results in carbon for the *Rhizobium* and nitrogen for the plant. Legumes will have nodules on the roots that the *Rhizobium* live in. When nitrogen is very low in the soil the legume will send out signals through the root using flavonoid molecules. These will attract the *Rhizobium* and also trigger nodule development. The legumes have a competitive advantage when nitrogen in the soil is low. If it is high, there is no advantage to the mutualism, and so it may not occur. This association is useful to other species in nitrogen deficient soil because the *Rhizobium* fixes more nitrogen than the legume needs, so the extra will be released into the soil for use by other plants.

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In this experiment, Kim and colleagues were looking at how different types of *Rhizobium* increased the growth rate of the population of green algae. As you can see, when *Rhizobium* was added to the culture of algae there was a large increase in cell numbers of algae because the *Rhizobium* can supply the algae with nitrogen. These figures are different species. By increasing the cell number, it may be useful as a biofuel application. So it may be possible to create numbers of algal cells that are usable at an industrial scale.

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The final mutualism we will talk about is mycorrhiza. It is a fungus that will associate with a plant, for the same reason as with lichens and *Rhizobia*, the plant gives photosynthetic carbon and the fungus gives nitrogen. And in this case, phosphorus, as well.

There are four main types of mycorrhizae and together they infect almost all land plants. As you can see in this photograph the pine seedling is quite small. If you look closely, you can see that the plant root is actually quite small. So it's just this, the orange colour. The rest of what you can see in white is the mycorrhiza. This is a tree seedling so the fungus will be ectomycorrhiza. The mycorrhiza will hugely increase the surface area of the root to fill the soil and collect nutrients.

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So ectomycorrhiza are found in tree roots. They are vital for helping trees to forage for nutrients. The fungal hyphae which are branching structures of fungi fill the spaces between the cells in the root. They form a Hartig net, and may also form a sheath over the root tip.

The ectomycorrhizae may form a common mycelial network where they link together many trees. This has been extensively studied and researchers have shown that carbon and phosphorus are transferred between trees in natural ecosystems.

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This is a classic example from Finley and Read in 1986. They showed that if you add isotopic labelled carbon to one plant, it will appear in the tissues of the other. The conclusion is that the carbon was passed through the mycelial network. It does not seem to matter if the plants are the same species or not. So isotopes, which were used in this study, are molecules that are heavy because they have an extra neutron in the atom. They are not ionically charged, but they are identifiable in special scientific instruments as being different to the natural or stable isotopes. For carbon, the stable isotope is carbon 13 because it has 13 neutrons. The heavy isotope used for labelling has 14 neutrons. So, it is called C14. Isotopes are very useful when you want to show how molecules move through an organism and where they go. In this case, the 14C was added to one plant as carbon dioxide in a sealed chamber. This was then followed through the common mycelial network and found in the tissues of the other plant. In the graph, we see that each bar represents the amount of labelled carbon that passes from the donor plant to the receiver plant. The white bars have no mycorrhizal fungus in the soil. So no common mycelial network. And as you can see very little labelled carbon appears in the tissues of the receiver. When the mycorrhiza *Suillus bovinus* is in the soil we see very high labelled carbon in the receiver plant. The amount is shown in these dotted bars. So this is no mycorrhiza. And where mycorrhiza is present, you can see that the radioactive isotope is much higher in the receiver plant where there is mycorrhiza. This means that the carbon must have been passed through the mycelial network. We can also see on this on the left with passing from *Pinus contorta* so one type of pine tree, to *Pinus sylvestris*, which is a different type of pine tree. So the network does not matter about being the same species. The network includes everybody in the area. In this test they've done one as the donor and one as the receiver and then the previous receiver is now the donor and the previous donor is now the receiver and you can see that both directions, you will get carbon transfer.

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Now we will talk about vesicular arbuscular mycorrhiza. These are mainly found in grasses and herbaceous plants. So it's sort of small flowers and wild flowers, although some trees form associations too. AM fungi are hugely common, thought to associate with over 90% of land plants.

These also form common mycelial networks. Unlike ectomycorrhizae, AMF penetrate the cells of the plant roots and they form arbuscules inside which are these tree-like structures. Arbuscules are highly branched and form the site of nutrient exchange between the fungus and the plant.

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In summary, we have seen the parasite negatively affects its host for food, shelter, or reproduction.

A mutualist works together with another organism and both benefit.

There are many examples of both in nature and these have varying degrees of cost benefit. So if you'd like to watch the video of parasitism, I think you'll find it quite interesting.

Reading

Chapters 12 & 13 Begon

Plant immune system paper