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## What's your favourite fungus?

# The One That Makes Plant Roots Work

Plants gain their nutrients by absorbing minerals and water from the soil using their roots. But they do get quite a lot of help from certain species of fungi. The relationship appears to have started because the plant roots alone are not able to supply the plant with all the nutrients it needs. The fungi associated with plant roots are called **MYCORRHIZAS**, which increase nutrient availability to the plant. The numerous hyphae of the fungi greatly increase the surface area available for absorbing minerals. The hyphae can also go looking for food; because they can grow to areas of fresh nutrients when local supplies become depleted. The relationship between the plant and fungus is mutualistic. That means that both sides gain something from having the other present. The plant pays for the privilege of using this fungus to bring it nutrients by sharing up to twenty-five percent of the products of its own photosynthesis with the fungus. The fungus benefits by taking readily available sugars from the plant. Despite this 'tax' on its activities, the plant grows much better than it could without the mycorrhiza.

Some mycorrhizal fungi form a mat of fungal tissue around the root; the fungal cells grow between the cells of the plant root, but never actually cross the plant cell walls. These are called '**ECTOMYCORRHIZAS**'. In another mycorrhizal partnership (called **ENDOMYCORRHIZAS**) the fungal cells enter the plants cells. Inside the plant cells they make structures that absorb materials from the plant cytoplasm.

By greatly increasing the absorbing surface of a host plant's root system, mycorrhizas improve the plant's ability to tolerate drought and other extremes, like high and low temperatures and acidity.

It is thought that has many as 95% of all plants have mycorrhizal associations, showing just how important these types of fungi are for the growth of so many plants, including all the crop plants we need to feed the human population, and all the trees in all the forests.

What's your favourite fungus?

# The One That Keeps Grandad Alive

Cholesterol is a type of fat that comes from animal products such as red meat and eggs. But humans can also make cholesterol – in addition to that obtained from the diet, the liver is also able to produce cholesterol. There are two forms of cholesterol. Cholesterol is needed for cell membranes and for the production of steroid hormones, but if we have too much it is stored in our blood vessels. Low density lipoprotein or LDL is the dangerous type; and high density lipoprotein (HDL) is the good type.

If we have too much cholesterol the body is not able to use up the excess. In such circumstances the excess cholesterol sticks to the inside walls of blood vessels. This build up makes the diameter of the blood vessels narrower and this restricts blood flow. If blood vessels that supply blood to the heart become clogged up like this it can cause a heart attack, because the heart muscle does not receive enough oxygen to function properly. This can lead to the death of a small section of the heart muscle, but in severe cases the heart attack can cause the person to die. So to control heart disease it is important that humans regulate their cholesterol level.

The most effective cholesterol lowering-agents are called Statins, and these are produced by fungi. The two fungi used to produce statins are called *Aspergillus terreus* and *Penicillium citrinum.*

Statins work by inhibiting the enzyme called 'HMG-CoA reductase' which is needed for the production of cholesterol. Statins block HMG-CoA reductase activity as they compete for the active site of the enzyme. If the activity of this enzyme is blocked the production of cholesterol is slowed down, and this in turn will significantly decrease the patient's cholesterol level. Statins also increase LDL-receptor production in the liver, which help clear the bad cholesterol from the blood stream.

Statins from fungi are of great importance as many people rely on them daily to help keep their cholesterol level normal, therefore reducing the risk of blocked blood vessels. There are three statin 'drugs' in the top five most widely prescribed pharmaceuticals – with annual sales in excess of £3 thousand million!

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## What's your favourite fungus?

# The One That Makes Cyclosporin to Combat Rejection in Transplant Patients

Transplant of livers, kidneys, hearts and lungs has been made possible by the discovery of Cyclosporin in 1976, a compound produced by the fungus *Tolypocladium inflatum*. The fungus was isolated from a soil sample and screened to test if any compounds produced by the fungus could be of medical use. The results were very positive as the compound Cyclosporin was found to have strong activity at suppressing the immune system (called immunosuppressive).

When a patient receives an organ transplant, the body recognizes the organ as a foreign object, just like it would a pathogen. Our bodies are programmed to eliminate such foreign things, because the object may be harmful to the body. This means that the body will naturally reject a transplant; and part of that rejection is that the organ is damaged so that it stops functioning. The detection and elimination of foreign bodies is carried out by the immune system, which is made up of several cell types that act to protect our bodies from potentially harmful organisms. Cells of the immunes system are equivalent to white blood cells and a particular sort, called lymphocytes, are the cells that are able to detect foreign objects. They attach themselves to pathogens identifying them as things to be destroyed by other white blood cells.

In transplant operations the donor's organ must be accepted by the recipient's body so that it can function properly and save the life of the patient. So in transplant patients the transplanted organ needs to be protected from the patient's own immune system.

This is where Cyclosporin is used. This compound helps stop the body rejecting a transplant by stopping the production of lymphocytes. If lymphocytes are not able to increase in number there is a greater chance that the transplant will not be detected by the body, and will continue to function normally. Cyclosporin has been used in transplant operations since 1983, and is currently the most effective and widely used immunosuppressive drug.

## What's your favourite fungus?

# The One That Veggies Like To Eat

In the 1960s there was concern over the future supply of protein from the traditional sources of cattle, pigs, poultry and fish. It was thought that the supply of these foods would not be able to match the world demand, and protein would have to be obtained from a new source. Projects were started to produce protein from microorganisms.

In 1964 it was decided to try to produce protein from filamentous fungi. Ideally, the fungus used should have good nutritional value, be easy to cultivate and inexpensive to produce. Three thousand species of fungi were collected and tested to see if they were suitable, the one finally chosen was called *Fusarium venenatum*.

This fungus is grown continuaously in a large fermenter at the optimum temperature of 30°C. Constant production and collection of the fungal biomass occurs. The product is then heated to 64°C so that the RNA is destroyed to make it safe for people to eat.

It's then filtered to remove the liquid medium, leaving behind what looks much like a sheet of raw pastry, which is then flavoured and shaped ready to be transported to the shops. This product is called 'Quorn' and has been on sale since 1980. It is available in a wide range of forms, such as burgers, sausages, mince and chunks. Quorn has been very successful, with annual sales of more than £15 million per year, and is popular with vegetarians who can obtain many nutrients from it that others get from eating meat.

Apart from the high protein content it is low in calories and saturated fats, contains no cholesterol and is rich in zinc, B-vitamins, and fibre. It is ideal for people who are watching their diet but who still want to enjoy the taste and texture of meat. This is because *Fusarium venenatum* is a filamentous fungus with a stringy consistency which is comparable to the texture of meat. The fungus also absorbs flavours well so can be altered easily during cooking to suit individual tastes.

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## What's your favourite fungus?

# The One That's the Largest Organism on Earth

If you ask people what the world's biggest organism is, most will guess the Blue whale. They can grow up to 33 metres long and are the largest animals alive today. Whales are pretty big, but there's an even bigger organism that claims the title 'largest organism on earth'.

This living thing is estimated to be between 1900 and 8500 years old, it spans an area of 2,200 acres (that's about the same as 1,220 football pitches) and weighs at least 150 metric tons. This makes it among the heaviest, but certainly the largest and oldest living thing on this planet. You must have guessed it by now; it's a fungus!

The common name of the fungus is the 'honey mushroom' as during Autumn it produces golden-coloured mushrooms. Its scientific name is *Armillaria ostoyae*. This gigantic fungus was found in the Blue Mountains of eastern Oregon in America, and is a pathogen of the roots of trees. Being a pathogen means that the fungus is harmful to the tree on whose roots it lives. The fungus takes water and carbohydrates from the tree and so interferes with its growth.

The tree eventually dies owing to lack of nutrients. The fungus is hidden, because it grows underground extending its hyphae from tree to tree in special structures called rhizomorphs. It cannot be tracked easily on the surface, but because the fungus slowly kills trees it has infected, it makes the leaves turn yellow as they become starved of nutrients.

By looking for trees with yellow leaves the mycologists were able to map the presence of the fungus. Because it grew over such a large area, a helicopter was used to obtain an aerial view of the forest showing all the trees that had been infected.

What's your favourite fungus?

# The One That Digests All the Old Timber

Ever wondered what happens to all the leaves that fall from the trees, or the branches that fall to the ground in storms, or when a tree dies? Somehow there's never a build up of all this organic matter, but what happens to it? Where does it go?

Many organisms like bacteria, insects, worms and many fungi are involved in the break down the plant material. Humus is the term used to describe material once it has been broken down; it is nutrient rich and can be used by plants for their growth.

Plant tissues are very strong. The components that provide the strength are cellulose and lignin. Fungi are very important for the decay of wood because they are the only organisms capable of breaking down **BOTH** cellulose and lignin.

Cellulose is a polymer of glucose that forms fibres which are incredibly strong. Brown rot fungi are responsible for the breakdown of cellulose. Brown rot fungi are so called because the lignin remains intact so the wood keeps its brown colour. The enzymes released by brown rot fungi break the cellulose chains into single molecules of glucose that can be re-used by the fungus.

Lignin is the other strong polymer. It is the second most abundant natural polymer on earth after cellulose. The fungi that break down lignin are called white rot fungi; this is because as the content of lignin is decreased, the wood becomes lighter in colour. White rot fungi degrade lignin by producing oxidising enzymes that are released from their hyphae – they 'burn' the wood in an enzyme-controlled way. Lignin contains phenols and the white rot fungi are the only organisms that can deal with them.

These two types of fungi have important roles in the recycling of nutrients. Without them, old plant material would not decay and the soil nutrients would be locked into an accumulating mass of undegradable biomass.

## What's your favourite fungus?

# The One That Digests Grass for Cows

Many animals including cows, sheep, goats, deer, and even giraffes, are known as ruminants. This is because they have a specialised four-chambered stomach needed for the digestion of their exclusively vegetarian diet. The first chamber the food enters is called the rumen, hence the name ruminant. The ruminant discussed here is the cow. Cows spend most of their time eating mainly grass and hay.

Plant cells walls contain cellulose, which is an excellent source of fibre in the diet of most animals. Fibre is important as it provides roughage which keeps the egestion of waste products regular. However cows themselves do not produce enzymes capable of digesting cellulose. The cow overcomes this problem by having special fungi in the rumen called chytrids; or more generally called rumen fungi. These fungi are anaerobic, meaning they are able to survive without oxygen. Even without oxygen, chytrids are able to digest plant cell walls by making specific enzymes called **cellulases**. The rumen acts like a large fermenter because the grass is stored there whilst the fungal enzymes from the chytrids break down the cellulose.

After the plant material is processed in the rumen, it is brought back up into the mouth of the cow. This material is now called 'cud' and the cow chews it up again to break it down further. When it is swallowed for the second time it passes through the next three chambers of the stomach. The chytrids are thought to pass from one animal to the next by being transferred in saliva, but they also occur in large number in cow dung. From the dung the fungi get attached onto surrounding grass. When another cow comes along and eats the grass, the fungi carry on their work in the new host.

The relationship between chytrids and ruminants is said to be symbiotic. This means that both the fungi and the cow benefit from having the other present. In this case the cow benefits because plant material the animal can't degrade is digested and turned into nutrients the cow can absorb. In return, the fungi live off some of the nutrients obtained from the cow's food, and live out their lives in the cow's rumen.

What's your favourite fungus?

# The One That's Used in Fizzy Drinks

Fizzy soft drinks contain many chemicals. One of these is citric acid - a weak acid that is naturally found in citrus fruits such as oranges, lemons and limes. It is added to soft drinks to give a slightly sour taste, to stabilise the 'fizz' and also to serve as a preservative. The process of carbonation puts the 'fizz' in drinks. This is achieved by dissolving carbon dioxide in water to produce carbonic acid. The addition of citric acid creates a buffer that stabilizes the carbonic acid, so that the fizz remains in the drink after the bottle is opened.

Initially, citric acid was obtained from lemons, but since 1923 all commercial citric acid (600,000 tons every year) has been obtained from fermentation by *Aspergillus niger*, a filamentous fungus. Citric acid is the first product to be made from a cycle of conversions known as the citric acid, or Krebs cycle. This cycle occurs in the mitochondria of all living cells that use oxygen for respiration. The cycle is important, as it is part of the metabolic pathway that breaks down carbohydrates, fats and proteins into carbon dioxide and water to generate energy for the cell.

*Aspergillus niger* accumulates large amounts of citric acid. This is achieved by reducing the level of iron in the growth medium because the enzymes that convert citric acid into the next product of the cycle need iron. Keeping the iron content low stops the Krebs cycle before the citric acid can be converted, so the acid can be harvested and used commercially.

Large quantities of *Aspergillus niger* are grown on a medium containing sugar as its carbon source. The fungus grows at the surface of the medium and the citric acid product is released into the liquid below. The mould is then filtered out and the remaining citric acid collected. When citric acid is added to a solution it forms citrate ions. Citrates are excellent buffers for keeping the pH of acids steady. In the case of soft drinks, the citrate ions ensure that the carbonic acid remains stable, keeping the 'fizz' in your drink.