FUNGI FORAGERS

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OUR PURPOSE: TO RAISE AWARENESS AND INTEREST IN FUNGI OF THE CAIRNS REGION

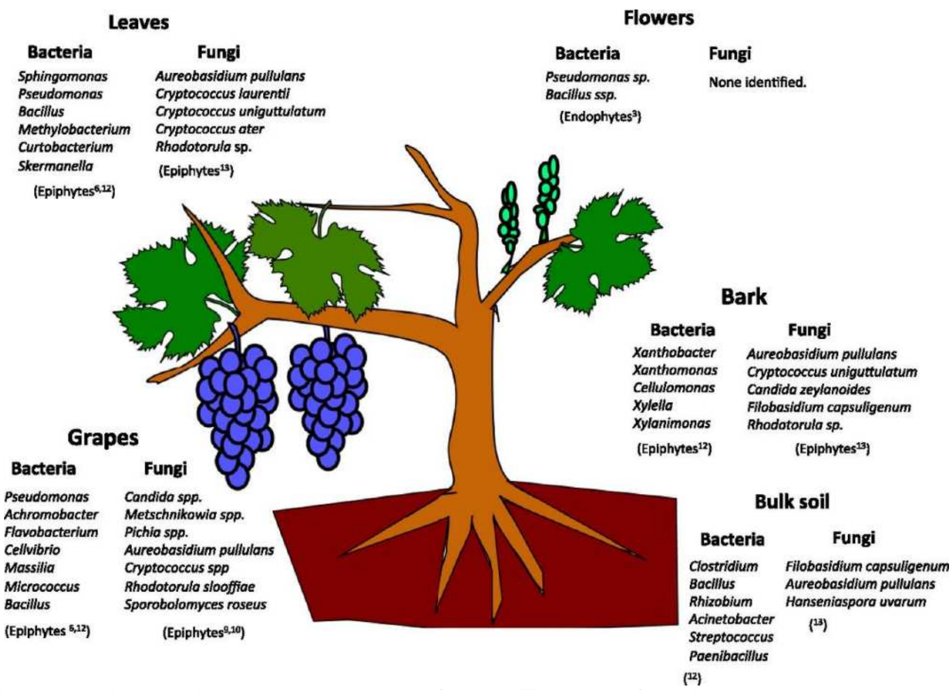
This newsletter is not associated with any club or organisation but is emailed free of charge to anyone who may be interested. Anyone who wishes to contribute to the newsletter with observations, anecdotes, corrections, comments or photographs is welcome to do so. Although this "newsletter" is science-based we try not to make it too "scientific". We recognise that there are school children, bush-walkers and others just interested in fungi, and we hope this leaflet will become a medium for furthering that interest. **The emphasis is on fungal biology and ecology** rather than identification.

Barry Muir, Editor Jenn Muir

Field meetings to find interesting species of fungi (not necessarily edible species) are known as 'forays', after the first such meeting organized by the Woolhope Naturalists' Field Club, Herefordshire, England, in 1868 and entitled "A foray among the funguses" [*sic*]. The Woolhope Club was an early member of the British Mycological Society founded in 1896. (Wikipedia)

NOW FOR A NICE GLASS OF FUNGI

The composition of soil has long been thought to provide wine with characteristic regional flavors. Wine experts can often tell not only what region a wine has come from by it's taste, but can even sometimes say what side of a vineyard hill the grapes were grown on.



It is well recognised that soil microbes can break down organic matter and also trigger plant defence mechanisms and that this activity influences the flavor and quality of both the grapes and the final wines. Additionally, the soil is a potential source of microbes such as yeasts that can influence fermentation and contribute to final wine characteristics. Thus, soil type and climate are obviously vital to wine production, but the precise contribution to flavours and aromas made by bacteria and by fungi was unclear. Evidence is mounting that bacterial activity actually produces fewer active biochemical substances than do fungi. The soil fungi may play a much larger role in flavour development than originally thought. Fungi are certainly key factors in the fermentation process, but their role in the soil was less obvious.

A study of vineyards in southern Australia has found that the soil fungal communities are of primary importance for developing the aromas found in wines. The researchers propose a mechanism by which yeast fungi can behave as endophytes, moving from the soil through the vine via the sap and eventually end up in the grapes and hence flavour the wine.

For more information on endophytes of grapes see:
Liu D, Chen Q, Zhang P, Chen D, Howell KS. (2020). The fungal microbiome is an important component of vineyard ecosystems and correlates with regional distinctiveness of wine. mSphere 5:e00534-20. https://doi.org/10 .1128/mSphere.00534-20

Image from pnas.1320471110fig01

FUNGAL FACTORIES

Fungi are amazing critters. Apart from their role in keeping the planet cool and keeping us humans fed, clothed, housed and supplied with clean water, they have evolved, during the six to eight hundred million years since they first appeared, into organisms that occupy almost every ecological niche on Earth. To achieve that, they have developed a vast array of digestive enzymes, antibiotics and toxins. Some of these substances have long been well known, such as the antibiotic penicillin, while others are recently discovered, e.g., glomalin protein, which holds soils together to prevent erosion.

What makes fungi so good at manufacturing this multitude of substances? Firstly, their adaptability to such a diverse range of environments has caused the necessity to develop unique, specialised substances to permit survival and exploit their habitat. Secondly, they have a vast surface area, as the fungal mycelia are of small diameter and there may be many tens of kilometres of those mycelia in a square metre of soil or a single rotting log. This results in the ability of some of the fungi to physically and chemically alter their environment to suit themselves.

Fungi also have a very complex ‘mating’ system; whereas most plants and animals have only two sexes, fungi can have hundreds of ‘sexes’. That permits a vast array of possible new genetic combinations from even a single pairing. They can also turn selected genes on or off, as they require, and can produce durable spores that can survive for long periods of time until the right conditions occur to allow germination.

The usual way we think about growing moulds – on petri dishes in the laboratory

Fungal hyphae are marvels of engineering! A mycelium comprises a string of joined hyphal compartments - cells. Inside these compartments, extending over considerable physical distances, are longitudinal “tracks” along which materials and organelles, the minute internal cell components, are moved. The compartments contain nuclei and cell structures called Golgi which bud out thousands of tiny sacs every second for fusing with the cell wall to allow extension of the hypha. Growth rates at the hyphal tip can be as high as 4 – 6 cm per hour. The hypha has two ‘parts’: an apical region where growth occurs and, behind the apex, a rigid wall which is elastic enough for it to extend rapidly, but rigid enough to prevent it blowing up like a balloon from the internal pressure. The rigid part is selectively porous to allow digestive enzymes to exit through the wall and nutrients to enter, but at the same time retain some larger molecules within the hypha.

The cells or compartments along the hypha are separated from adjacent cells by cross-walls called septa. These provide additional strength to the hypha in the same way as struts between two poles. Although vital for strength, they serve other purposes. If a hypha is cut through, say by putting a shovel through a mycelial mat, the septa prevent the contents squirting out under pressure, so the hyphae are 'self-sealing' if damage occurs. None the less, because communication is needed between cells, each septum has a minute central perforation. Through this perforation materials and organelles are moved to replace dysfunctional portions of the cell contents, or to allow no longer required organelles or materials to be recycled forwards into the newly growing parts of the hyphae. If the hypha is damaged or broken these septal perforations are sealed almost instantly by plug-like structures called Woronin bodies that are held back from the perforation when everything is working well, but snap instantly into place if damage occurs. They can also be used to isolate a portion of the hyphae if a new process is to commence, such as the development of a fruiting body.

Growing fungi in sophisticated manufacturing facilities makes it possible to produce valuable drugs and chemicals for use in science, medicine and industry. Picture from: 20200929-Evologic_INDUSTRIEcMichael-Gizicki2020_002-e1621546022782

With respect to fungal cells as 'chemical factories', the abilities and structures discussed above have been harnessed by humans to manufacture substances useful to us. The rapid growth rate of fungi makes it possible to grow them in quantity quite quickly, sometimes hours, whereas animal cells may take weeks or plant cells months to produce useable quantities of specialised enzymes or chemicals.

Thousands of fungal colonies can be produced quickly, in a small space, allowing rapid and easy selection of the best strains to be used for future culturing. Yeasts, in particular, can be grown rapidly, in various forms with differing characteristics, proving more opportunity for variation development and selection. Many of the substances fungi produce can be easily modified into other forms or compounds with other uses. Additionally, many fungi are easily grown in culture media with just simple, inexpensive, sugars and nitrogen compounds like urea as the energy and nutrient sources.

As an example, a mould called *Trichoderma viridi*, isolated from mouldy cotton fabric in the Solomon Islands, has an incredible ability to produce an enzyme that can degrade cellulose into glucose that can then be further converted to bioethanol (fuel alcohol) by a yeast fungus. P*estalotiopsis microspore*, a fungus found on plants in the Amazon has been used to break down polystyrene and other plastics and convert them into non-toxic masses of mycelia than can then be used for other purposes. Experiments are underway to see if these fungal products can be used to manufacture new containers, or even as human or animal food. *Pestalotiopsis microspore* doesn't need oxygen to grow, so it can be used to decompose plastic buried in landfills. In CFF No. 28, January 2022 was an article about artificial leather made by fungi, but some fungi can also be grown in moulds that, when growth is complete, the mycelial mat has taken on the shape of the mould, such a bricks or table tops.

Japanese researchers have developed a strain of *Mucor* fungus that can be used to make chymosin, an enzyme that precipitates protein out of milk to make a cheese. The cheese manufacture does not require rennet (an animal product) in its manufacture, thus producing vegan cheese. *Aspergillus awamori* fungus has been used to produce thaumatin, a protein 3000 time sweeter than cane sugar and now used as an artificial sweetener.

We must not forget that chemicals in fungi have served other purposes as well as the ones discussed here. There is strong evidence that the hallucinogens in Fly Agaric *Amanita muscaria* has links to the origins and evolution of religion.

Enzymes in detergents that were originally made from crude pancreatic extracts of animals have been replaced by lipid (fat) dissolving enzymes cultured from *Thermomyces lanuginosus* fungus in combination with *Aspergillus oryzae* fungus. The enzyme is used in hot-water machine-wash detergents for clothes and dishes. A fungus called *Chrysosporium lucknowense*, isolated from soil in Far-east Russia have been used to create a enzyme that is used in softening the denim used in the manufacture of jeans.

Human breast milk contains a compound called lactoferrin that is highly protective against viral and bacterial gut infections in human babies. The fungus *Aspergillus awamori* is now used to produce large quantities of lactoferrin that has identical properties and antimicrobial characteristics as human milk. The fungus *Pichia pastoris* has been used to convert methanol (a highly toxic alcohol) into gelatin, an animal protein, and into protein-based carriers for production of human vaccines. *Pichia* is also used to make insulin structurally identical to that made by the human pancreas and which can be used to treat diabetes.

These examples are but a handful of fungal species out of the 70,000 or more that could be suitable sources for manufacture of a wide range of chemicals and materials that can be used to improve our world. Even that number is a tiny fraction of the estimated two million species of fungi believed to exist and about which we know very little.

REFERENCE
Many documents reviewed, but a key one is Maheswari, R. (2006). Fungi as cell factories: hype, reality and hope. Indian J. Microbiol. 46(4): 307-324.

FUNGI TO CONSUME PLASTIC

Here we have two interesting issues linked together. Firstly, microplastics have been found in the human blood stream for the first time: These microplastics get into us mainly through eating food containing microplastics, and in turn, the food plants and animals get them from the polluted environment in which they live. The discovery shows that particles can travel around the body and may lodge in organs. The impact on health is as yet unknown, but it is known that microplastics cause damage to human cells grown in the laboratory in the same way as air pollution particles can damage cells.

Huge amounts of plastic waste are dumped in the environment and microplastics now contaminate the entire planet, from the summit of Mount Everest to the deepest oceans. People are already known to consume the tiny particles via food and drinking water as well as by breathing them in, and microplastics have been found inj the faeces of both babies and adults.

Analyses showed that half the plastic found in blood was HDPE, which is commonly used in drinks bottles, while a third contained polystyrene, used for packaging food and other products. Some samples contained polyethylene, from which plastic carrier bags are made.

The second issue is, of course, now that we have this plastic pollution, what can be done about it? While reusing and recycling plastic into new products can solve part of the problem, there any many plastics that can't be recycled and such a huge volume of plastic waste to work with, it is far from a viable solution. Some kinds of plastic take up to 1000 years or more to degrade naturally. Using processes like chemical, thermal, photooxidation, and biodegradation use energy and sometimes produce their own pollutants. Additionally, it is estimated that about 79% of plastic produced ends up in landfill or the oceans, so we can't even get hold of them to process. Maybe one answer is fungi to prevent the problem from getting worse.

Scientists have discovered that microorganisms can play an important role in ridding the planet of waste-plastic, with over 90 known genera of bacteria and fungi able to degrade plastic. For example, students from Yale University in the USA have discovered a mushroom species that can eat plastic. The fungus, called *Pestalotiopsis microspore,* comes from the Amazon rainforest but can survive on plastic alone. The fungi consume polyurethane and convert it into organic matter. Importantly, this plastic-eating fungus can also live without oxygen – making it the perfect candidate for cleaning up landfills.

Research scientist Katharina Unger of Utrecht University in Sweden found that the Amazonian fungus is not the only one that can eat plastic. Some other common mushroom species like the Oyster mushroom, which is edible, can also consume plastic. Unger claims that once the mushroom has consumed the plastic, there is no actual plastic left in the mushroom and it can be eaten safely by humans.

REFERENCES
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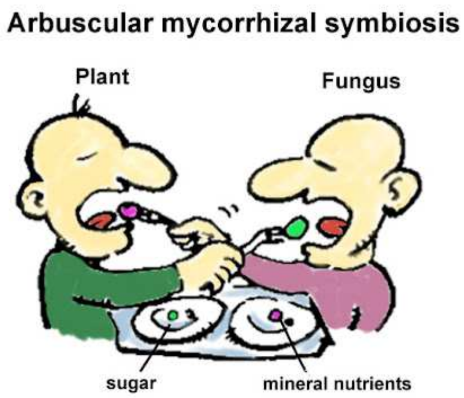

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