Hi, this is Janet for Cheap Astronomy, www.cheapastro.com. This is SISS, Science on the ISS – and today's episode is *Space fungus*.

The human adventure in space was preceded by fruit flies, dogs and monkeys and even today it continues to be accompanied by many of Earth's other inhabitants. When we do eventually start doing some serious mileage out there, we will also be taking along some photosynthesising algae and plants, for oxygen and food – and the latest thinking is that we might need to take along some fungi as well.

Imagine you are Dr McCoy readying for a five year mission to explore strange new worlds. You can leave your stethoscope and thermometer at home, since you'll have your trusty tricorder. The only other thing you'll need is a well-stocked medicine cabinet… and there's the rub. It's unlikely that anyone would think of embarking on a five year mission to explore strange new worlds without a formidable array of pharmaceuticals – but what do you do when your stock passes its use-by date?

This is the rationale for the latest in the long line of "*hey, let's fly this up to the ISS and see what happens*" experiments. *Aspergillus nidulans* – or *A nidulans – is* a type of bread mould and is to fungal research what rats and mice are to mammalian research. A nidulans is a *model organism* for fungi partly because it survives well under laboratory conditions – and also because it's a fairly bog-standard fungus that does what most fungi do. And something most fungi do is manufacture a range of surprisingly-useful *secondary metabolites*.

A secondary metabolite is something produced by an organism that is not vital to its metabolism, growth or reproduction – but may still be useful for its survival. Good examples of secondary metabolites are caffeine and aspirin – which are unpleasant-tasting compounds produced by plants to discourage herbivores from eating them. In fact, there are many other secondary metabolites produced by plants for much the same reason. But, most of them don't have names because they are of no great interest to humans or they live somewhere inaccessible and have not been discovered by science yet. Caffeine and aspirin have names because they are of *huge* interest to humans, due to the coincidental effects that they have on us.

Where fungi differ from most plants, is that they can switch the production of secondary metabolites on and off. *A. nidulans* – along with many other fungi – has gene clusters within its genome that are normally dormant, but become active in response to different stimuli – making the fungus commence production of different secondary metabolites.

The most famous fungally-derived secondary metabolite is of course penicillin. It so happens that *A nidulans* can produce penicillin under the right conditions, although penicillin is produced much more abundantly by fungi *Penicillium*, a fungal family that includes the mould that Alexander Fleming found on some petri dishes that he'd hadn't got around to cleaning up yet.

The gene clusters that produce secondary metabolites are generally activated by some kind of stress. Much like plants, the best defence for relatively-immobile fungi is to pump out chemicals that can either make them inedible or otherwise kill off anything that might be competing for the same nutrients. Thus, penicillin kills off any bacteria that might have otherwise digested what the fungus likes to digest. In fact, the most common human medicines produced by fungi are anti-fungal agents, since – when you're a fungus – your biggest competitor is generally another fungus.

The logic behind sending *A. nidulans* up to the ISS is that the stress of microgravity and a slight uptick in radiation might switch on a new gene cluster that no-one has seen switch on before. Because *A. nidulans* is such a widely studied *model organism*, its genome has been fully-mapped, so the moment it does produce anything new, we can compare the fungi on the ISS with some control specimens back on Earth and so identify which gene cluster caused the ISS fungi to do whatever they did.

If that gene cluster turns out to be common to other fungi, then the next mission might involve flying up lots of different fungi with that same gene cluster to see which one produces most of the secondary metabolite we are interested in. Then we might start investigating what it is about microgravity that switches on the gene cluster that creates that secondary metabolite – and then we might start investigating how we could go about switching on that gene cluster – back on Earth.

Despite the Dr McCoy introduction, the short-term goal of this work is to see if exposure to microgravity will make fungi produce something new and medicinally-useful for the people back on Earth. The next trick is then to produce it in large quantities, which is why Alexander Fleming, who kind-of stumbled upon penicillin, ended up sharing a Nobel Prize with Howard Florey and Ernst Boris Chain – who figured out how to mass-produce it. For the record, Fleming was a Scot, Florey was an Australian and Chain was a German Jew who'd had to flee his home country because of the Nazis – once again demonstrating that evicting your best scientists is no way to win a war.

Anyhow, specimens of *A. nidulans* were launched to the ISS aboard a Space-X Dragon capsule on 8 April 2016. The specimens only stayed aboard for a few weeks and then returned to Earth on the same capsule on 11 May 2016. Who knows if a few weeks in orbit will stress a fungus into producing a secondary metabolite that is new to science? But a fresh culture of *A. nidulans* can begin creating reproductive structures with a day, which we might consider fungal adolescence – so we can expect such a culture will produce all the secondary metabolites it's ever likely to produce within a few weeks.

However, it's unlikely we'll be hearing anything about the results of this ISS fungus experiment within a few weeks. Apart from all the analysis and gene sequencing required, figuring out if whatever the fungus produced is *medicinally-useful* is going to require some exhaustive trials and tests – unless of course we stumble upon something amazing after someone forgets to put one of the samples back in the fridge.

But getting back to the issue of why we started this podcast with the Dr McCoy reference, there are some long-term objectives for this research project. Fungal genomes are interestingly-flexible – stress them a bit and they switch on dormant genes clusters. So, with the right collection of fungi and the right kinds of stress, we might be able to restock our starship pharmacies and we might then start to think that fungi really are the ideal travelling companions for any long space journey.

And it's even possible that just one fungus would be enough. *A nidulans* already produces a bit of penicillin, and with some genetic enhancement might be encouraged to produce a lot more. As it happens, *A nidulans* also produces substantial amounts of Vitamin C – just in case we don't find room to grow orange and lemon trees on our first starships.

With its genome already fully-mapped, *A nidulans* is a prime candidate for genetic modification. If it does produce useful secondary metabolites under the stress of microgravity and space radiation, we may want to modify the relevant gene clusters so they can express themselves more productively.

But even if *A nidulans* doesn't end up producing exciting new metabolites on its own, we might still be able to introduce exciting new gene clusters into its genome. A modified *A. nidulans* might then produce a whole range of secondary metabolites – perhaps even aspirin and caffeine, if we insert some plant gene clusters.

And maybe if we took this approach to extremes, that modified fungus might cease to be *A. nidulans* in any real sense, and instead become a *synthetic organism*. This synthetic organism would still metabolise, grow and reproduce – and, growing in a nutrient-rich medium under ideal environmental conditions, it would have ample excess energy to manufacture a wealth of useful by-products. That is, by-products that are useful to us, rather than to the fungus. In exchange, the synthetic fungus and its generational progeny would be doted upon, while they are flown around the cosmos. Like any symbiotic relationship, there are benefits for both parties.

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