This is SISS, Science on the ISS, the International Space Station – and today's episode is *Materials.*

Welcome to another episode of SISS where we will spend most of the episode explaining some underlying theoretical principles before we can even start talking about what is going on up over our heads.

A colloid is something that been mixed in with something else. A good example is butter fat mixed into a lactose solution – where the butterfat doesn't really dissolve, but it doesn't sink straight to the bottom either. Instead the butter fat particles organise into a stable matrix that allows them to just sit there evenly distributed throughout the fluid volume, forming a colloid that we call milk.

This is quite different from salt water, in which sodium and chloride ions really are fully dissolved in the water solvent. It is also quite different from what happens if you mix sand into water, where the sand doesn't dissolve at all and, unless you keep stirring it, the sand quickly sinks to the bottom. So salty water is a solution, sandy water is a suspension and milk is a colloid.

But not all colloids have to be fluids. Fog is a colloid, since it's composed of water droplets evenly distributed within air. Gels are solid colloids, made up of a fluid evenly distributed throughout a solid - although there's also aerogel, which is composed of air evenly distributed throughout a solid.

What makes a colloid a colloid is the stable and even distribution of one substance within another. This may be the result of the geometric or electrostatic properties of either or of both the substances that have been mixed together – and it sometimes turns out that mixing two things together can create something quite different, which has quite different physical properties.

This where the ISS comes into the story. In the absence of gravity, two mixed materials have more time to form a stable relationship as a colloid, before one or the other is forced to separate out and settle to the bottom due to gravity. In the absence of gravity there is more opportunity for the mixed components to naturally organise into a state of lower free energy - that is, a state of higher entropy - in accordance with the second law of thermodynamics. And if that state of lower energy happens to be an evenly-distributed sub-structure, perhaps even a crystalline sub-structure, then you have achieved what is known as colloid self-assembly.

And taking all this one step further, on the ISS there is also an opportunity to test for what is known as *directed* colloid self-assembly. Imagine you have a colloid which doesn't do anything particularly interesting until you expose it to a magnetic field. In a magnetic field, loosely-organised particles could suddenly shift about to align with the magnetic field and thereby form a radically-different sub-structure that completely changes the physical properties of that colloid.

Still with me? Well, to understand why changing the physical properties of a colloid with the flick of switch might be useful, we should now consider Newton's third law of motion – the one about equal and opposite reactions. In material science you mostly have Newtonian materials, but you also have a few Non-Newtonian materials. For example, Silly Putty is a non-Newtonian material. The gentle pressure of a child's hand will easily compress it flat, but whack Silly Putty with a hammer and the hammer just bounces off. And Silly Putty is just one kind of non-Newtonian possibility. Consider ketchup, which is a colloidal fluid. Gently tip a ketchup bottle upside down and the darn stuff refuses to flow, but if you whack the bottom of the bottle you can alter the viscosity of the ketchup, so that it gushes forth.

These are two extremes of non-Newtonian behaviours. You can have materials that give gently under soft pressure, but stiffen under strong pressure – and you can have materials that firmly resist soft pressure, but quickly collapse under strong pressure. The former could underlie a better braking system, while the latter could underlie a better suspension system.

And then consider further that you might be able to change the physical nature of a material from Newtonian to non-Newtonian with the flick of a switch, through *directed* self-assembly. For example: *(sound byte)*

But, this is where it gets hard to tell you much more of this story. For all we know, Batman really could be doing science on the ISS. Whatever breakthroughs are taking place more than 300 kilometres over our heads, most of it is kept under wraps. Even if it's not Bruce Wayne's money, there is still a lot of someone's money involved and an awful lot of effort put in by an awful lot of people, both in the development phase of an experiment and in all the lobbying required to get an experiment launched to the station.

So, this is the challenge of trying to report on science that is being done on the ISS right now, like today now. You might read in an astronaut blog that "*we did some really cool stuff with colloid self-assembly yesterday"*. So you go and find out what the heck colloid self-assembly is and then you go find a relevant reference on NASA space flight systems or on the NASA station mission pages.

From there you will discover that the experiments inSpace 2 and inSpace 3 are "*investigating the three dimensional structures of a magnetorheological colloidal fluids under the influence of pulsed magnetic fields".* And if you dig deeper for more detail, you may also discover that the latest InSPACE-3 experiment *is "investigating the effect of non-spherical super-paramagnetic particles on the visco-elastic properties of these fluids"*.

Amazing, right? And you heard it here first, on a cheap astronomy podcast.

Seriously though, despite the almost impenetrable commentary, it is to NASA's credit that you can even find out this much. A lot of what is happening on the ISS today is what is known as *proprietary* research, which means that someone pretty-much owns a research project and it's up to them to decide if they want you to know about it. Each proprietary research project may have substantial government and private financial backing and those funding bodies all have high hopes of gaining a substantial return on the investment that they have made.

So, given all of that, long before you should expect to hear any news of a major breakthrough in colloid science on a cheap podcast, the principal investigators with three PhDs apiece will have already done the global conference circuit, submitted their journal articles to Nature and gotten a whole bunch of patents pending. And good luck to them.

As much as we can gather from reading between the lines, the objectives of directed colloid self-assembly are fairly pragmatic. The most likely use for a radical new colloid with radical new physical properties will be in transportation. A colloidal gel-based suspension system perhaps, or some new kind of vibration-dampener – or it might just be a new kind of brake fluid. There might be a few military applications involved, but more likely it will just be something that gives you a smoother ride to work each day. And since several million people on the planet would appreciate a smoother ride to work each day, that could be quite enough to give the financial backers of an ISS experiment a substantial return on their investment.

And folks, that would be a very good thing. Once the ISS produces something that *everyone* wants and it's something that can only be produced in microgravity – then, that's the game changer. That's when you'll get people marching up and down in front of the Whitehouse if NASA's budget is under threat. And maybe you'll get people marching up and down in the Red Square and even Tiananmen Square too, all rallying for their own respective space budgets.

A large proportion of humanity still needs convincing that we need to be in space. Maybe it will be ISS science that finally convinces them.