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

Something we've learned from doing a podcast about science on the ISS is that, in order to capture a representative mix of all the experiments going on over our heads, about one in four episodes have to be about robotics – and yes, it's that time again. Humanoid robots from science fiction are generally metallic – think Robbie the Robot or Hymie. Not only are they metal, but their muscles joints and tendons, are mostly pulleys, levers and cables. Similar principles also apply to fictional prosthetic appendages, think Jaime Sommers or Luke Skywalker.

But there is another class of fictional robots that are more biosynthetic than metal – think the androids from the Blade Runner and Alien movies, or even the Battlestar Galactica reboot. They all seem to have something much more biosynthetic going on. At this point in history, the metallic levers-and-pulleys option seems to be winning, as exemplified by Robonaut 2 and its newly-installed legs aboard the ISS – although the completed robot still spends most days in a storage compartment.

In robotics and prosthetics, people talk about actuators – that is, mechanisms that turn energy into motion. These traditionally depend on the rotary motion of an electric motor, which might turn a joint, or wind up a cable to move a piston – or drive more distant actions via hydraulics or pneumatics.

But, what if instead of pulleys, levers and cables, we could build robots with synthetic muscles? Synthetic muscles are still actuators, but their contraction, expansion and rotation are all managed by a single component. For example, your bicep is a single component that can contract and straighten, as well as twist and turn. Various arrangements of pulleys, cables and levers can mimic those actions, but they work as *composite parts*, not as one component. Synthetic muscle is commonly made from a flexible polymer that contracts in response to electrical stimulation and then expands back to its original shape when the charge is either reversed or just removed.

Such electroactive polymers could become the muscles of anthropomorphic robots, not to mention non- anthropomorphic robots. They are probably also the best bet for bionic prostheses that really could closely mimic the shape and the actions of a human limb. And synthetic muscles would be ideal for the thing that everyone else is waiting for… a powered exoskeleton. Of course powered exoskeletons will allow firepeople, police and soldiers to do their jobs better – saving more people's lives, as well as their own – which is great. But, meanwhile, the rest of us will be running one minute miles and leaping tall buildings in a single bound, just for the heck of it.

A simple synthetic muscle can be created from twisted strands of fishing line – which is a polymer fibre. When coiled in a particular way, the polymer fibre coil expands when heated and returns to its original state when the heat is removed. And if coiled in a *different* way the same polymer fibre will *contract* when heated. In either configuration, the contraction and expansion can be repeated again and again, allegedly a million times over, without the fibre coil degrading significantly. It's been suggested that such a synthetic muscle could be a boon for passive air conditioning – opening vents when it's hot and then closing them again when it cools down. That may be a crude example, but the principle is much the same for any synthetic muscle. So, if you have an electroactive polymer, that responds to electricity rather than heat, you can start making artificial limbs with muscles that respond to electricity conducted to different points within that limb. A bionic arm with synthetic muscles that are differentially-responsive to different electrical signals could not only lift weights, but might also play the piano – given enough programming code.

Synthetic muscle won't have the jerkiness that is commonly associated with mechanoid robots that rely on hydraulics or pneumatics , where momentary stops and starts are required, while feeder hoses are repressurized – actions that are also accompanied by a lot of huffing and puffing. Synthetic muscle action will be smooth, sinuous and quiet.

The main application of synthetic muscle in space is likely to be in humaniform robots, which we might start seeing applied in Robonauts 4, 5 or 6. Humaniform robots can use the same tools as humans, fit through the same hatchways and provide the same point of view for remote observation – if they have cameras positioned where human eyes are normally positioned, which is what Robonaut 2 has. These qualities make humaniform robots useful trail-blazers for real humans to follow.

Synthetic muscle may become widely-used in non-humaniform robots too. The lack of jerkiness could deliver new unthought-of solutions to a whole range of mechanical engineering issues. The holy grail of robotics is to find a material that, like real biological muscle, is actually strengthened by repeated stretching and relaxing, rather than being worn out by it. Advocates of the latest forms of electroactive polymers think that they have achieved this already.

So with all that background established, you shouldn't be too surprised to hear that some samples of an electroactive polymer were launched to ISS in April 2015. The experiment was simple. Samples of the polymer were attached to small frames of titanium, mimicking how synthetic muscle might attach to synthetic bone. Then those samples were packed into containers with a window that would allow the mounted muscle to be observed and photographed over time. The plan was just to test the effect of the ISS environment on the muscle samples – that is the effect of microgravity and the increased radiation levels that are found in low Earth orbit. All the astronauts had to do was to check on the samples once a month and photograph them.

In fact, the effect of radiation on the same polymer – developed by the *Ras Labs* team led by Lenore Rasmussen – had *already* been tested, by exposing the polymer to strong radiation doses under laboratory conditions on Earth – where they received doses equivalent to what you might expect from a trip to Mars and back – and those samples were largely-unaffected by it. So, the planned three month sojourn on the ISS was not *really* expected to find anything different. But, a field test is a field test – you have to go through the motions to confirm all expectations, before you can take the experiment to the next level. And of course there is nothing routine about going into space – as soon became apparent.

In June 2015, the Space X Commercial Resupply Services mission, CRS 7 – which was *meant* to be the cargo return mission for the synthetic muscle experiment, not to mention a bunch of other experiments, suffered a launch failure. Well, in fact it did *launch* and it flew for over two minutes to an altitude of nearly 80 kilometres – but then… kablooey.

Apart from the Soyuz, which is mainly devoted to returning crew back from the ISS, the Space X Dragon capsule is the only currently-flying vehicle that can also return cargo to the ground, safely and intact. All other uncrewed CRS vehicles return from the ISS as trash cans – they and their contents burning up during atmospheric re-entry. Such vehicles include the Russian Progress spacecraft, the European Automated Transfer Vehicles, or ATVs, the Japanese Kounotori , or H2 transfer vehicles, and the US Cygnus spacecraft.

So the synthetic muscle experiment got stuck on the ISS for much longer than originally planned. The next Space X mission, CRS-8, launched in April 2016 – and included the Aspergillus fungus experiment, which was the subject of our last ISS episode – but we couldn't see the Rasmussen synthetic muscle samples anywhere in its return cargo manifest. So, as far as we can tell, they're still up there.

It's more than likely that nothing unusual will happen to the samples, despite all their extra time in orbit – and it's also more than likely that we will never hear anything about it. An announcement that *we spent a few million bucks sending something up to the ISS and nothing happened* doesn't make for a great news story and it isn't the best way to get more research grants. However, it would be a cause for quiet celebration if your experiment, which involved testing whether something would be affected by the harsh environment of the ISS, found absolutely nothing. Indeed you'd be positively-thrilled if your three month trial was extended to a 15-months-and-counting trial – and it *still* found absolutely nothing.

And if you never hear anything about this experiment ever again, that's probably how it turned out.

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