**Cutin close upBack in 2016, scientists at a recycling plant in Kyoto in Japan discovered a mysterious sludge that seemed to be engulfing a huge pile of plastic bottles that had been left in the yard outside the facility**

**It looked like the growth was actually feeding on the plastic itself, which was pretty weird, because as far as science was concerned, the stuff that these bottles were made from,**

**a polymer called Polyethylene Terephthalate or PET,**

**was pretty much indestructible in nature.**

**I imagine the thoughts racing through the scientists’ minds were not unlike those that Alexander Fleming experienced when he came back to his lab after a summer holiday and noticed he’d rather clumsily left a petri dish open containing a bacterium he’d been working on called staphylococcus.**

**The exposed bacterium looked like it was being consumed by some sort of fungus and Fleming realised that nature might just have gifted him something of great significance.**

**In Fleming’s case of course, it turned out he’d accidentally discovered Penicillin, which did prove to be really quite significant indeed.**

**In the case of the Japanese scientists at the recycling plant, what they’d stumbled across was yet another example of nature’s astonishing ability to overcome just about anything in the evolutionary struggle for life.**

**The mystery sludge was in fact a microorganism containing a bacterium that had adapted to digest the plastic down into its constituent parts, using the carbon content as an energy source.**

**The potential impact of this adaptation was not lost on the Japanese scientists. And because they were scientists, they decided to give this new bacterium the fantastically snappy title**

**of Ideonella Sakaiensis.**

**Idiots…what was wrong with ‘monster romper plastic chomper’**

**It’s not a scientific term is it, you muppet!!**

**Hello and welcome to Just Have a Think,**

**Polyethylene Terephthalate was regarded as a triumph of human ingenuity when DuPont started marketing it as Mylar back in 1951.**

**Up until then, plastic manufacturers had been struggling to find a material that could replace the heavy and expensive glass bottles that were used for drinks like colas and other sodas.**

**They WERE already making plastic bottles, but if those bottles were filled with carbonated drinks and left on the shelf for more than a few days, the carbon dioxide gas molecules escaped through the polymer walls and the drinks went flat.**

**So, customers were complaining, and sales were suffering.**

**The structure of PET effectively reduces the gaps in the polymer chain to a size that’s smaller than a Carbon Dioxide molecule. The result was a light weight, transparent tough plastic bottle that kept fizzy drinks fizzy.**

**The consequence of that was that sales doubled during the first few years after PET was introduced.**

**And those sales numbers kept on going up and up.**

**So much so that in 2016, 480 billion plastic bottles were produced globally.**

**Only about 7% of plastic bottles today are actually recycled to perform the same function twice.**

**About half of them get downcycled into something less valuable like fibres for clothing or flooring and the rest end up in land fill or waterways.**

**This chart, from the Ellen McArthur foundation, shows the growth in plastic production reaching more than 300 million metric tons by 2014.**

**About 8 million tons of that plastic is now floating around in our oceans.**

**Out there in the wild, as this graphic from the National Oceanic and Atmospheric Administration shows us, plastic bottles hang around for about 450 years.**

**And the plastic never goes way completely of course. It just degrades into smaller and smaller microplastics that get ingested by sea life and then passed up the food chain to us humans with all the potential health impacts that we hear so much about in the news these days.**

**So, you can probably see why our Japanese friends were feeling pretty motivated.**

**On closer inspection of the new bacterium the scientists found that it actually used specific enzymes to break down the two components of PET.**

**Those two components are** **Dimethyl terephthalate or DMT, and ethylene glycol, both of which are originally derived from oil and combined by humans to make the very useful but also very problematic and, virtually indestructible, polymer chains.**

**Once they’re separated out though, both these compounds are harmless and potentially quite useful.**

**But the Kyoto scientists knew from experience that there are all sorts of practical problems when you use microorganisms directly for industrial purposes.**

**You have to let the bacteria grow to a useable size for a start, and you have very little control over whether the microorganisms thrive or die, so it’s all a bit hit and miss. And big industrial manufacturing doesn’t really do ‘hit and miss’**

**So, the team drilled down and identified the gene in the bacteria’s DNA that’s responsible for the PET-digesting enzyme.**

**Then they reproduced that enzyme and did experiments that showed that just the enzyme on its own, without the rest of the bacterium, was enough to successfully break down the PET.**

**That was definitely one of those Eureka moments.**

**But as Thomas Edison once famously said “Genius is 1% inspiration and 99% perspiration”**

**And so it proved with Ideonella Sakaensis. Although the rate of PET digestion was hundreds of times faster than the natural degradation of plastic in landfill or the ocean, it was still far too slow to cope with the incredible rate that new plastics are being churned out at all over the world.**

**So, the race was on to improve and strengthen the enzyme genetically so that it could digest far greater quantities of PET far more quickly.**

**That research has been ongoing in several laboratories around the world ever since, with the goal of at least a one-hundred-fold increase in the digestion rate.**

**In 2019, The University of Portsmouth here in the UK established the Centre for Enzyme Innovation or CEI.**

**The centre’s Professor of Structural Biology, John McGeehan recently presented a progress report on his team’s research to a rapt audience at EmTech in Hong Kong.**

**McGeehan explained that over millions of years nature has actually evolved its own natural polyester called Cutin, which provides a waxy protective surface to plants.**

**Over those evolutionary timelines, bacteria have also evolved that can eat through that Cutin layer to get inside the plant and do all their destructive work.**

**Using the now familiar lettering sequences of modern genetic engineering, the researchers were able to show that the PET eating enzyme PETase contained almost the exact same amino acid building blocks as the existing Cutinase enzymes that nature had evolved over the eons.**

**So now they knew the ancestry of the new enzyme and they could see that it hadn’t required a great leap of evolution for a bacterium that knows how to eat natural polyester to mutate into something that knows how to eat a synthetic one.**

**What was remarkable though, says McGeehan, is the fact that this mutation only took 50 years or so to occur. And what they didn’t yet know is HOW the new enzyme worked its magic.**

**Using state of the art technologies, the team purified and crystallised the enzyme. Then they fired X-rays at the crystals and record the refracted light in ultra-sensitive machines, like synchrotrons and vacuum sealed proton detectors, to build up an extremely accurate three-dimensional model of the atomic structure of the PETase crystals, which look like this.**

**And when clever folks like professor McGeehan are able to see three-dimensional atomic structures, they can start to understand how they work, and hopefully how to make them work even better.**

**When they compared the 3D structure of PETase to the 3D structure of Cutinase, the team were able to identify the subtle changes in the PETase enzyme that allowed it to break down PET.**

**Cutinase enzymes break the natural polyester bonds with chemical jaws at this active point where the gap is just less than three ten-billionths of a metre or 0.3 nanometres.**

**What the research team found was that with only a single amino acid change in its structure, the PETase enzyme had changed the shape of the jaws at its active point to make the gap almost 3 times wider.**

**And that change was all it took to enable the new PETase enzyme to accommodate a man-made aromatic polymer like PET.**

**The challenge then, was to apply some sort of reverse engineering to see where the process could be turbocharged to meet the needs of our global plastic waste problem.**

**First of all, they looked at the surface of a plastic bottle under an electron microscope over 96 hours, while it was being digested by the PETase enzyme.**

**As the polymer structure broke down the scientists could identify the basic building blocks of DMT and Ethylene glycol accumulating around the edges of the digestion area.**

**Then with some advanced computer modelling courtesy of the Woodcock Group at the University of South Florida, they produced an accurate image of how the enzyme cuts the bond in the PET polymer chain to release the individual monomers.**

**Then came the reverse engineering bit.**

**The team tried to manipulate the enzyme to turn it back into Cutinase.**

**The idea was that by precisely controlling the steps in that laboratory process they could perhaps determine what they could do going in the other direction to mutate the PETase into something more effective.**

**But the experiment failed to produce a cutinase enzyme.**

**Instead, by sheer chance, what it actually produced was a vastly improved PETase enzyme.**

**These green bars represent the relative sizes of the crystalline structures of the PETase enzyme and the accidentally discovered new enzyme. You can see that there’s a huge increase, which in turn leads to a much faster rate of digestion.**

**The CEI team don’t profess to have solved the world’s plastic problem just yet, but what they have shown is that it is possible to engineer a more effective enzyme just by making very small changes to its DNA. And they suggest that it’s entirely possible that nature may have already produced other enzymes that have found ways to digest the other plastics that we’ve created since the middle of the 20th century.**

**We just need to do the slightly unpleasant work of rooting around in plastic recycling dumps to try to find them.**

**The future of this research looks very promising indeed though. Professor McGeehan is confident that they can engineer faster and faster enzymes and he outlines what he hopes the R&D road map will look like.**

**In an ideal world this sort of research would be regarded as essential to species survival and would be co-funded by every government on earth as a priority.**

**In the real world of market driven capitalism, it will most likely be commercial investment that ultimately provides the key to producing effective enzymes at a large enough scale to make a really positive impact on plastic recycling.**

**But the company with the long-term vision to recognise the value of this work will also get themselves the added bonus of two very useful and very marketable by-products.**

**Professor Anne Meyer, who heads up a separate PETase research group based at the Technical University of Denmark points** out that **ethylene glycol can be used directly in antifreeze, which is in very high demand around the world and is currently manufactured from non-renewable materials. It’s also possible to produce a hybrid material from paper and recycled plastic components that has the right strength properties to be used as a carrier bag but can also be fully recycled or biologically degraded.**

**And the really great thing for our dear investors is that there’s very little chance they gonna run out of raw material anytime soon.**

**That’s it for this week.**

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**As always, thanks very much for watching,**

**Have a great week and remember to just have a think**

**See you next week.**