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> ONE MONTH, ONE PROTEIN <

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# of plastic and men

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Nature has extraordinary resources. Here we are trashing her land, sea and atmosphere – and have been for over a century now – with all sorts of chemistry she didn't ask for and which, sooner or later, will prove to be harmful to those who are putting it there. Despite this, sometimes she manages to find ways of twisting something bad into something good. Polyethylene terephthalate, also known as PET, is one. It is a plastic we have all heard about, man-made and widely used in industry for clothing but also for liquid and food containers, and is frequently shaped into the form of plastic bottles. PET – like other plastics – is piling up on Earth, slowly making its way into ocean sediments and more alarmingly into the food chain. Recently, a team of Japanese researchers discovered a new species of bacterium that has found a way to live off PET thanks to a hydrolase which seems to have evolved especially for this, and has been coined: PETase.

Squall on the horizon, by Gustave Courbet

Courtesy of the artist

Scientists became increasingly interested in plastic as a multipurpose material during the industrial revolution mainly because of its capacity to bend and be shaped. The first plastics to be used were natural, but it was not long before they were chemically modified to gain properties such as greater strength, suppleness and watertightness for instance. Synthetic plastics soon followed. The very first man-made plastic was developed following the condensation of phenol and formaldehyde and is the renowned plastic Bakelite – synthesized in 1907 by the Belgian-American chemist Leo Baekeland. Because of its electro-physical properties, Bakelite slipped effortlessly into many household items: from radios, jewellery and kitchenware to toys, telephones and fountain pens.

Over the years, plastics of all kinds gradually spread into every nook and cranny of human daily life, replacing the more common – and usually more costly – materials such as wood, stone, bone, leather, paper, metal, glass and ceramic. The plastic invasion has been so huge that scientists now talk about the Plasticene Age. And since the end of the 20th century, the role plastics have in modifying the environment has been of growing concern. Plastics decompose slowly. The human population keeps increasing, and so are the piles of plastic on our planet. What is more, one of the most widely-synthesized plastics, i.e. PET, is made from petroleum; a fossil fuel…

300 million tonnes of plastic are produced every year worldwide, and it has been written that all the plastic ever produced could wrap the earth in a film of plastic. The image is powerful. A lot of it is buried, but an awful lot also ends up in the earth's oceans. In 1997, the American oceanographer Charles Moore was the first to observe what has been called the Great Pacific Garbage Patch – a sort of floating heap of trash. Other Garbage Patches are also probably drifting on the Indian, Pacific and Atlantic oceans. Their surface is estimated at something between 700,000 km^2 and 15,000,000 km^2 – and they must be dragging trash beneath water level too. Besides these islands of debris, tonnes of tiny plastic fragments are also floating in our oceans, deposited in sea sediment or trapped in

ice. Needless to say, something needs to be done.

Plastics are not the only culprit – but they do form 70% of the trash, and PET is one of the major pollutants. This is why it is necessary to find ways of degrading and recycling PET without having to use processes that are too expensive. Not so long ago, scientists believed that PET could not be degraded because it is chemically inert and resists to microbial degradation. Yet, recently, after having collected debris from a PET bottle recycling site and taking samples of the surrounding sediment, wastewater and sludge, a Japanese research team found an organism that actually lives off PET: a new species of bacteria they named *Ideonella sakaiensis*. After isolating it, the researchers set it free on a film of PET to see what would happen. Appendages protruded from each cell – some long, others short. The long ones are used to adhere to PET and to neighbouring cells, while the shorter ones are used to deliver PET-degrading enzymes. Little by little, minute pits began to form on the film, and within six weeks it had been consumed.

The PET-degrading enzymes are hydrolases which have been coined PETase, and MHETase. The expression of PETase seems to be induced when *Ideonella sakaiensis* adheres to PET. PETase degrades PET to MHET – or mono(2-hydroxyethyl) terephthalic acid. MHET is then immediately degraded by MHETase to produce terphthalic acid and ethylene glycol, the original – and harmless – molecules that are used to synthesize PET. So we've gone full circle.

On closer inspection, PETase lacks the usual substrate-binding motifs that are generally observed in glycoside hydrolases – which would indicate that it works differently. However, its 3D structure would have to be determined to understand its exact binding mechanism. To date, there seem to be no other known organisms that present a set of genes like those found in *Ideonella sakaiensis* for PET metabolism. This could imply that *Ideonella sakaiensis* was subject to a mutation which gave it the capacity to use PET as a substrate; in which case, it would quite logically have been selected in a PET-enriched environment.

So here is a creature that has adapted to man-made pollution from which we can gratefully benefit. The fact that *Ideonella sakaiensis* degrades PET into its initial benign monomers suggests that the bacteria could be used not only for PET degradation but also for its recycling. What more could you ask for? Well, speed… Though the process occurs at 30° Celsius, the rate at which PET is degraded is slow: an estimated rate of 0.13mg per cm^2 and per day, which is barely the size of a thumb nail. This would need to be accelerated to be of any interest on a more global scale. Humans are pumping unnatural materials into the environment; we need to help Nature deal with it. This said, there may be an intriguing consequence of plastic pollution. Scientists have observed microgrooves in fossilized worms. If the grooves of vinyl fragments fossilize, then perhaps sound can be fossilized too?

Cross-references to UniProt

PET hydrolase, *Ideonella sakaiensis* : A0A0K8P6T7
MHET hydrolase, *Ideonella sakaiensis* : A0A0K8P8E7

References

1. Yoshida S., Hiraga K., Takehana T., Taniguchi I., Yamaji H., Maeda Y., Toyohara K., Miyamoto K., Kimura Y., Oda K.
   A bacterium that degrades and assimilates poly(ethylene terephthalate)
   Science 351:1196-1199(2016)
   PMID: 26965627

2. Reed C.
   Plastic Age: How it's reshaping rocks, oceans and life
   The New Scientist, issue 3006, published 31 January 2015

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