NATURE'S GREEN-COLLAR WORKER?

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PICTURE THIS:

You're seven years old, sitting in science class. The teacher flashes images on the screen: glossy plastic water bottles, disposable cutlery and food containers, all adorned with huge red crosses. The first time you learn that plastic is bad.

Now, you're not seven anymore. You're not sitting in science class. But the crosses never left. They showed up in conversations, posters, campaigns and TV adverts.





PET plastic bottle

If plastic is so bad, can't we just... destroy it?

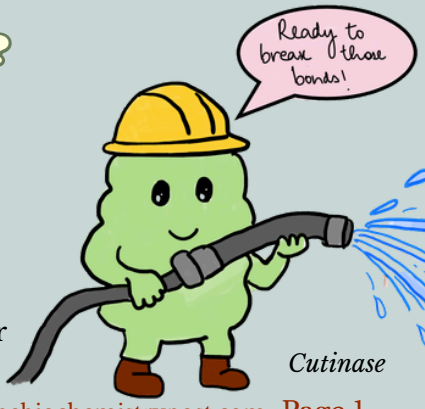
Sort of. The trick is to do it without creating more problems along the way. Plastic waste has been a persistent environmental issue, with PET (polyethylene terephthalate) amongst the most widely used plastics. This is the durable plastic used in plastic bottles and containers, which fill up oceans and BBC Science's evening broadcasts. Traditional waste-management approaches have struggled to deal with the scale of the problem. Recycling can recover some PET, but much plastic is still sent for disposal.

In this case, enzyme-powered approaches offer a promising pathway by breaking down plastics into their molecular building blocks. They can then be recycled into new PET.

WHAT ARE ENZYMES AND HOW CAN THEY BE USED?

Enzymes are biological helpers, most commonly proteins, produced by all living organisms. They have meticulously evolved unique shapes that enable them to speed up chemical reactions without being consumed themselves.

Some enzymes called cutinases act like demolition workers. They use water to break the chemical links holding molecules together. One type of link they can break is an ester bond, which is also found in PET. Now, what if we could engineer the powers of this worker to withstand the conditions needed to attack PET?



Cutinase

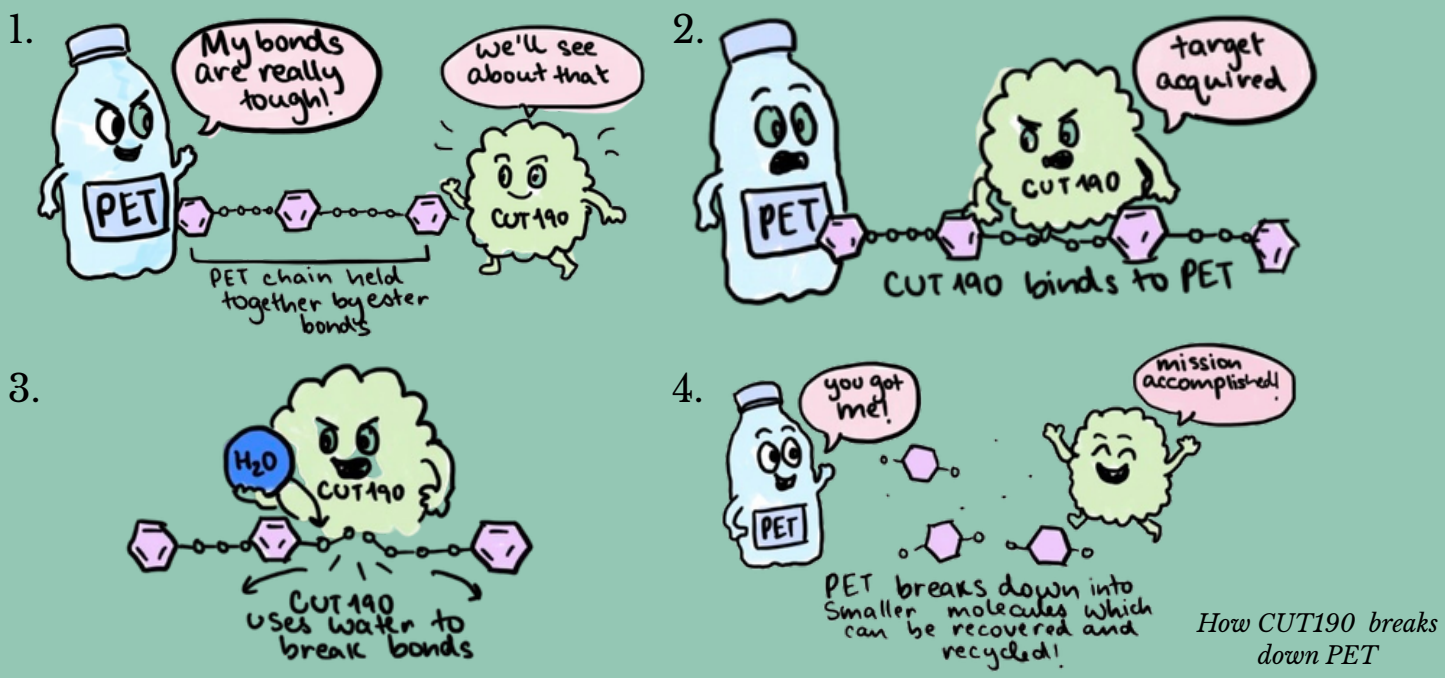
ENTER: CUT190

In 2014, Japanese scientists identified a cutinase-like gene from a heat-loving bacterium called Saccharomonospora viridis AHK190 (S. viridis AHK190). They expressed this gene in the bacterium Escherichia coli (E. coli), producing an enzyme they named Cut190. This resulting enzyme showed potential to break down PET. However, this isn't to say that scientists had discovered a plastic-eating machine overnight. At least not yet.

PET's structure is a long chain of molecular building blocks, each linked to the next by strong chemical bonds — like a game of chain-tag. Around 70 °C under typical conditions, it reaches its glass-transition temperature, where these molecular chains become more mobile. Increased mobility loosens up the material, making it easier for enzymes to break their chemical bonds.

Although Cut190 was originally a stable, heat-resistant candidate, it wasn't enough. So, scientists changed specific amino acids in its structure. This made it more heat-tolerant, helped the enzyme release the plastic fragments it had produced and hastened its activity. Adding a disulphide bond further strengthened it from falling apart at high temperatures.

These mutations produced increasingly engineered versions of Cut190, culminating in its best-performing variant to date. Its actual name is a mouthful of alphanumeric codes, so we'll stick to Cut190.



How CUT190 breaks down PET

PET's chains can be either tightly packed and crystalline or disordered and amorphous. Cut190 employs a tactical approach for this challenge.

It first attacks the PET surface through endo-type breakdown, cutting bonds within the polymer chain and creating shorter fragments. It then switches to exo-type breakdown, trimming these fragments from their ends and releasing smaller molecules such as MHET, BHET and terephthalic acid (TPA).

But there's a catch! Cut190 isn't your normal enzyme. It changes its shape. First, the enzyme adopts a conformation that allows it to grab the PET surface. Once in place, calcium ions help the enzyme change shape so that it can carry out the cut. This creates a tricky balancing act: the enzyme must be sturdy enough to remain functional at PET-degrading temperatures, yet flexible enough to change shape when needed.

SO, DID WE JUST SOLVE PLASTIC?

Hold up. Not quite. Although Cut190 has come a long way since it was first discovered, it still poses a few problems.

Firstly, real-world PET waste contains additives, contaminants, dyes, etc., making it difficult for enzymes to break down. Moreover, Cut190 is highly effective when acting on larger surface areas and powdered PET rather than film PET. Scientists are currently researching sustainable pretreatment methods that would convert PET waste into material that Cut190 can work with.

A 2022 life-cycle assessment found that, across most categories, enzymatic PET recycling had 1.2–17× higher environmental impacts than producing virgin PET/TPA. Much of this impact came not from the enzyme itself, but from collecting waste PET and using sodium hydroxide and electricity during processing. These environmental impacts could potentially fall if researchers make energy-intensive steps, such as amorphisation pretreatment, more sustainable.

Then, there's calcium. The very calcium ions that help the enzyme change shape in accordance with the necessary step in PET breakdown can hinder its efficiency when present in abundance. Scientists are trying to understand how to control this molecular problem.

In summation, nature hasn't simply solved a problem we created for ourselves. Instead, it has given us a molecular worker, one that wears a green collar. But the journey is far from complete. Science rarely moves in a straight line: every breakthrough can reveal a new bottleneck, and every solution can create a new question. Variant by variant, scientists are learning how to tackle them to create a better, greener future.



Further Reading:

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