5 Ways Biology Is Transforming Buildings

When you think about what contributes to climate change, construction materials may not come to mind first, but making things like cement, steel, and plastic releases a lot of greenhouse gases. In this video, we investigate the ways architects and engineers are drawing on inspiration from nature to create building materials that are safer, more resilient, and better for our planet. By using materials that are inherently stronger to build more earthquake-resistant structures, developers are also finding ways to create safer, less wasteful buildings.

0:00

Image of "How to Avoid a Climate Disaster".

This video was created in partnership with Bill Gates, inspired by his new book "How to Avoid a Climate Disaster." You can find out more about how we can all work together to avoid a climate disaster in the link below.

Images of shelter.

One of the basic human needs is shelter. And over the short time humans have been on Earth, we've come up with a lot of different ways to shelter ourselves— from mud huts, to wooden buildings, to the towering skyscrapers of many cities.

But many of those materials aren't as strong as they could be. And the ones that are can have an outsized impact on our planet.

0:41

Video clip of a forest.

So now, architects and engineers are turning to nature for inspiration for more resilient materials—stuff that improves on what we use now, and that often minimizes the impact we have on this planet.

From cement that acts like sweat glands to glass that mimics fish scales, here are some biology-inspired materials that could transform the future of construction.

Video clip and images of building dangers and solutions.

One major threat to buildings is fire. When a fire sweeps through a structure, it often means a lot of new construction is on the way. That often means more cement and steel— and making both of those involves a lot of greenhouse gases.

Thankfully, there are all kinds of ways to make a building safer in a fire. In addition to fire alarms, extinguishers, and sprinklers, you can add fireproof materials to the building's support structure to keep it from failing, as well as to the walls, floors, and ceilings, to keep fire from spreading. But these are all passive methods. And because they're extra materials, they add extra cost and take extra energy to make.

1:41

Images and diagrams about sweat gland cement.

So it would be helpful if there were materials that could actively prevent fire damage, plus be supportive. Well, researchers in China may have invented just that, using human sweat glands for inspiration.

In a paper published in 2019, they shared their development of a fire-retardant cement blend, which stops fire from damaging a building's structure sort of like how sweat keeps human bodies cool. The cement is a blend of three materials: a set of compounds named APP-PER-EN, some reinforcing fibers, and a concrete binder. Under normal conditions, it does what you'd expect— it holds up the weight of a building. But if there's a fire, it goes through four stages to stop that fire in its tracks.

First, as temperatures rise between 100 and 160 degrees Celsius, the reinforcing fibers and the APP-PER-EN start to melt — kind of like how sweat glands make sweat when you start to get warm. When the temperature reaches above 170 degrees Celsius, micro-channels and cracks form.

2:39

Then, temperatures above 300 degrees cause the APP-PER-EN to foam, filling the micro-channels and cracks and forming a fire insulation layer like sweat on skin.

And finally, as the insulating layer forms, gases get released, including water vapor. This mimics the cooling mechanism of sweat— how when sweat evaporates, it takes some of the body heat with it.

This insulating layer protects the cement from falling under high heat by taking on a honeycomb shape. This adds strength while also insulating against heat transfer using the air trapped in the honeycombs.

I know! It sounds like science fiction!

Then, after a fire, you can remove the honeycomb layer and repair the material instead of having to replace the entire cement structure, saving costs and resources.

3:22

Diagram and images of heating systems and polar bears.

Next, speaking of heat, humans have been passively heating their homes with sunlight for thousands of years. But we couldn't control the release of this heat until the 20th century. Only then did we invent collectors like thermal walls, which could absorb heat from sunlight and slowly release it over time, keeping us warm throughout the day. The trouble is, most of these collectors are made from rigid, heavy materials, which means their uses are limited.

So engineers are looking to polar bears as inspiration for textile-like solar collectors, which would be more efficient, lightweight, and flexible than their predecessors.

Polar bears have white fur and black skin that work together as a natural solar collector and insulator, which helps them stay warm in the extreme cold of the Arctic. Their outer fur is actually transparent—it only looks white because of the way it's structured. That transparency allows the sunlight to reach their dark skin, which converts the sun's energy into warmth. Another layer of dense underfur close to their skin is spaced just right, creating little pockets of air that trap heat close to the bear's body.

4:23

Diagram of polar bear heating systems.

In fact, they radiate so little heat that they're almost invisible to infrared detectors. The surface of their coats looks the same temperature as their environment!

Inspired by this heat-trapping ability, researchers based in Germany and Austria shared a new type of solar collector in a 2015 paper. They imagine it being used as part of solar power, but this general idea could also help with buildings, too.

The collector has two layers of transparent plastic and silicone that let light pass through to the bottom layer. These layers are positioned around a centimeter apart, trapping a layer of air between them and minimizing heat loss like a polar bear's underfur. The bottom layer is black silicone, which absorbs the sun's light and converts it to heat. And the warm air can be pumped out by a fan and stored for later use.

Early tests show that this collector is able to generate temperatures of up to 150 degrees Celsius—although right now that only works when it's in direct sunlight.

Still, while those extreme temperatures might be helpful for solar power, that's also not the kind of heat you'd need in a building.

5:23

Images and diagrams of sustainable buildings.

So, this idea could really come in handy, especially as textile-based buildings become more mainstream. These futuristic buildings are constructed from lightweight materials stretched over a frame or woven together, and are making everything about a building more sustainable, including its design, materials, usage, and even how it's recycled at the end of its life. Adding a polar bear-inspired heating system would make them even more versatile.

Buildings also need to stay comfortable in hot weather, though—and traditional cooling systems aren't always the most efficient way of managing a building's temperature. Also, heating and cooling systems account for a lot of the greenhouse gases we emit as a planet.

Architects in the U.S. may have come up with a more efficient way of regulating a building's temperature, though, and once again they have drawn on inspiration from the human body.

6:11

Images and diagrams about homeostasis facades.

In 2011, they released a prototype of a building exterior modeled after a biological process that's similar to a thermostat—if a thermostat could control more than just temperature. That process is called homeostasis, and many organisms use it to keep their bodies functioning within pre-set limits, like an ideal temperature range or fluid balance. Basically, it allows things to remain stable on the inside even as conditions change on the outside.

The team designed a glass building facade inspired by the way human muscles maintain homeostasis, by expanding and contracting to regulate heat as they work inside our bodies.

Similarly, the facade helps regulate the internal temperature of the building by opening and closing itself. The exterior of the building is made up of two layers of glass, and sandwiched between them are swirling silver lines. Those lines are made up of ribbons of a special type of polymer that can have an electric current applied to it. It also has a silver coating that distributes an electrical charge across the entire surface.

7:13

When sunlight warms the silver coating, the polymer expands and shades the building. Then, when the building cools off, the polymer contracts and allows more light inside. That way, the building responds to changing environmental conditions throughout the day, helping manage energy use in a more efficient and sustainable way.

Now, this tech might not be best for places where you want extra sunlight—like, in the middle of a cold winter. But for a lot of climates, it could be a great step forward.

Images and videos of concrete use and production.

Next up: concrete. Like we mentioned earlier, making concrete is a major contributor to climate change, but sometimes, it seems like there's only so much you can do about that. Like, if a building is damaged during an earthquake… well, you're gonna have to build another one.

Some teams are looking into concrete recipes or processes that are overall better for the planet, but some are taking another route. Like, researchers at Purdue University are trying to strengthen concrete instead… by using cracks.

8:08

Images and diagrams about mantis shrimp cement.

More specifically, in 2018, they developed 3-D printed cement structures inspired by the mantis shrimp. Mantis shrimp hit their prey with a club-like front claw at an extremely high speed, which generates a lot of force. But even then, that claw does not crumble under pressure, thanks to the way the shell's microscopic layers are arranged.

The layers are stacked in a spiral, each layer slightly offset from the next. When stressed, cracks form in the microscopic layers, but the twisted structure keeps the cracks from spreading through the entire club.

Specifically, the spiral forces the cracks to form parallel, or side to side within a layer, instead of perpendicular—or top to bottom. And every time a crack has to change direction, it requires a lot of force to do so, which causes it to lose some of its energy.

If a crack does spread top to bottom, the next layer vibrates as the crack reaches it, absorbing the energy from the crack, keeping it from traveling into the next layer. Ultimately, these tiny twisting cracks stop the club from falling apart, by preventing larger cracks from forming that would compromise the structure.

9:12

Using this club for inspiration, the researchers 3D printed a cement paste that's laid out in a similar spiral design. Poured cement is brittle and when stressed, large cracks can form and lead to catastrophic failure.

Not so with this 3D-printed material. Here, tiny cracks are stopped so they don't spread throughout the layers, just like with the mantis shrimp. So the concrete is inherently stronger.

The goal is to eventually use this type of material to build more earthquake-resistant structures. And that means less wasted concrete!

9:42

Images and diagrams about fish scale glass.

Finally, windows. Windows can be an incredibly important part of a building on an aesthetic level. But since they're so fragile, they're also the weakest.

Except, by mimicking an overlapping pattern found in fish scales, researchers may have found a way to improve the strength of laminated glass, while still preserving the ability to see through it.

Laminated glass is created by sandwiching a soft, polymer-based layer between two layers of regular glass. This keeps the glass together if it breaks, making it safer. But it is not stronger—or at least it wasn't until researchers in Canada discovered a way to improve the lamination process.

In a paper published in 2018, they outlined their process for strengthening glass with a new lamination technique. They started by coating two sheets of glass with a flexible, heat-resistant polymer film, and then etched straight lines into the glass with a laser. The polymer film holds the glass together through the etching process.

10:38

Then, they laid the sheets of glass on top of each other, with another layer of flexible polymer sandwiched between.

They also rotated the top sheet of glass so the etched lines go in the opposite direction—known as cross-ply architecture—and that gives the glass added strength and flexibility.

When this type of glass is stressed, the cross-ply architecture and stretchy polymer middle work together to help the glass be stretchy and tough instead of brittle.

Testing revealed this glass to be 50 times tougher than regular glass, while still maintaining its see-through qualities.

If this kind of glass spread, that would mean stronger, safer windows that might need to be replaced less often—all thanks to a pattern inspired by fish.

11:19

Video clips of nature.

Nature has been around for a long time, and we're only beginning to tap into the engineering insights you can get from billions of years of evolution.

But with materials like these, we're looking at a future of buildings that are safer, more resilient, and better for our planet.

When you think about things contributing to climate change, construction materials might not be what comes to mind first. But making things like cement, steel, and plastic releases a lot of greenhouse gases.

Image of "How to Avoid a Climate Disaster".

And if you want to keep learning more about how we can make those things better, you can read Bill Gates's new book "How to Avoid a Climate Disaster." It talks about manufacturing, but also food, heating and cooling, transportation, and more. If you're interested, you can find out more about how we can all work together to avoid a climate disaster in the link below.