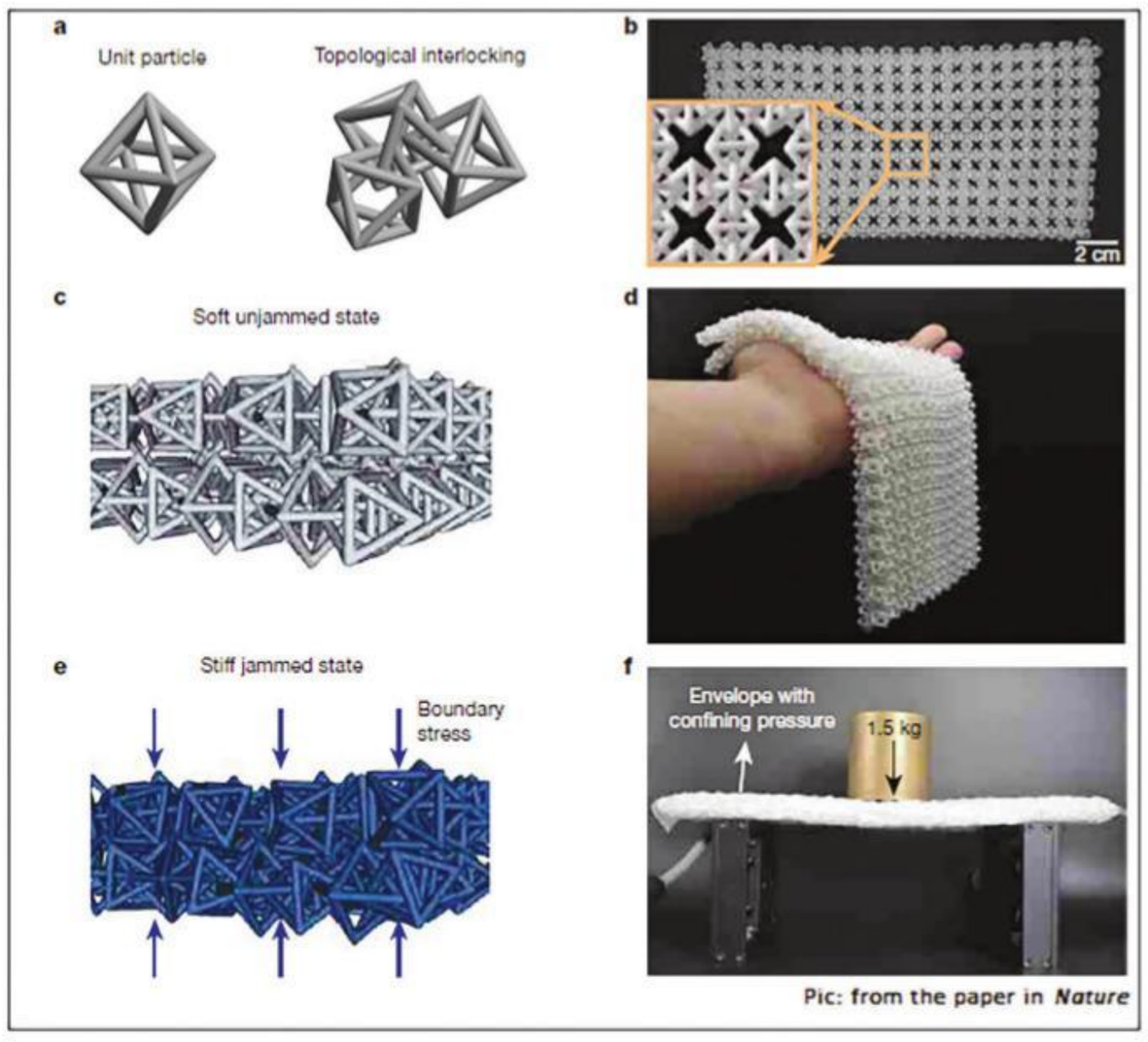
Chain mail in new avatar

An ancient armour has inspired researchers to develop a 'smart fabric'



Pic: from the paper in *Nature*

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Personal protection was of pivotal importance in the hand-to-hand fighting that marked warfare in earlier times. Chain mail was a mesh of metal rings linked together, covering the torso and limbs for protection against sword slashes and many kinds of arrowheads.

In a paper in the journal, *Nature*, Yifan Wang, Liuchi Li, Douglas Hofmann, José E Andrade and Chiara Daraio, from the California Institute of Technology, Jet Propulsion Laboratory at Caltech, and the Nanyang Technological University, Singapore, describe a return of the structure of chain mail in the creation of a fabric that is light and flexible but can resist impact.

Warfare has been a driver of technology for centuries, and it was skill in the smithy, of fabricating light and flexible armour, that spelt military success. The growth of weapons made of iron and steel was matched by hardier personal covering. And chain mail, which combined protection with flexibility, was common between the third century BCE and 16th century AD in Europe, and longer in Asia and North Africa. Early forms of flexible armour, which consisted of iron rings sewn onto cloth or leather, were used from Roman times and for several centuries. It was improved in medieval times by eliminating the cloth or leather underlay, and interlacing the rings, which were closed by welding or riveting.

A representation of the eighth century shows a short shirt, or coat, of chain mail covering the upper body, with a separate sleeve for the sword arm. Later models, from records in the 11th century, depict a longer coat, with full sleeves and divided for use on horseback. After the 14th century, the breastplate was added, and soon there was plated armour. It was done with separate plates connected to enable movement, and with chain mail supporting the region below the joints.

The paper in *Nature* describes how the structure of chain mail can be used for an architected fabric that displays a range of useful properties. Current trends in "smart fabrics", the paper says, are wearable fabrics that sense and respond to stimuli from the environment. And such fabrics are usually made by integrating sensing and computing components — like flexible electronics, materials that switch from liquid to solid, and back when the temperature changes, or materials that respond to light — into conventional fabrics.

Another kind of fabric would be one that alters its mechanical properties and provides to the wearer support like assistance to joints or perception of touch. Conventional smart fabrics, the paper says, are woven or knitted with continuous material, like fibres or wires. The fabric now proposed, however, is made up of discrete, that is separate, particles. A collection, or a sheet, of connected particles, like the rings of chain mail, is known to change the mutual orientation of the particles from being flexible to one being rigid, when subjected to pressure — a change known as "jamming", the paper says. It is similar to water changing from liquid to solid, as ice, when the temperature changes — only in this case, it is a change of mechanical properties, which depend not on the temperature, but on how the particles in the assembly are connected.

The paper cites another study, which has examined how the fluid flow of assemblies of particles, like a pile of sand, parcels on a conveyor belt, or beans being poured out of a bottle, could get "jammed" — and the "jam" could be released, sometimes by a gentle disturbance, like a tap. The cited study, which is in the journal, *Physical Review Letters*, considers the particles in the jam, like particles of sand stuck in a pipe, as one of rigid particles, which cannot be deformed. The pile can then support a very large force in the jamming direction.

But a light force, like a hammer tap in the pipe, would destroy the jamming formation of the sand particles and the flow would resume. For an extended material, like one consisting of sand particles, the material is fragile in the sense that a slight change in direction of the applied stress will change the entire structure of the force chains that give the pile its rigidity.

Based on such principles, some smart materials, which adapt their rigidity, have been developed. These materials, however, are dense and need to be in large volumes for appreciable effects, the paper says. And furthermore, they can be used only with crushing, or compressive forces, not when the forces are tensile, that is to say, forces which tend to stretch the material.

The paper then cites instances of the structure of interlocked units found in ancient chain mail being used to create chains which are long enough to form loops and which exhibit stiffening when stretched. And then, inspired by ancient chain mail armour, the authors of the paper developed a fabric consisting of two layers of interlocked particles — where each particle is a hollow 3-D structure, built of connected members, as shown at (a) in the picture. The design aims at the lowest weight and the greatest number of points of contact between particles placed together. The shape of the particles is hence the octahedron, or eight-sided cube, which allows forming sheets with increased contact between layers when they are stacked.

The resulting stack, the paper says, can freely bend, fold and drape over curved objects (c and d in the picture). And then, to trigger jamming, the sheet in (d) is confined in an envelope and the air is pumped out. The lateral force of atmospheric pressure on the envelope jams the structure — and it gets the rigidity to carry a load, as shown in (e) and (f) in the picture.

The team has then carried out trials and measured the strength that the material develops when jamming is triggered, to understand its mechanics. As the jamming transition — from free to jammed and vice versa — is seen not to depend on the size of the components, the fabric dimensions could vary, in principle, from microns to metres, and to use different materials, the paper says.

The pressure applied to start the jamming need not be the envelope that was used, but could be electrical or magnetic, for instance. That would widen the areas in which the material could be used. For instance, there could be a wearable body support that stiffens when the user bends, loses balance or strength, according to how the material is designed. Or for different kinds of medical support.

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PLUS POINTS

Constant presence

Sharks may have been spared a global extinction event millions of years ago that wiped out several species, including all large marine reptiles like mosasaurs and non-avian dinosaurs, according to a new study.

Scientists, including those from Sweden's Uppsala University, have shed light on how the dinosaur-killing extinction event transformed ecosystems and the kinds of marine organisms the change favoured. They found sharks to have maintained a constant diversity across the Earth's oceans during that time.

The researchers analysed the morphology of 1,239 fossil shark teeth pertaining to the K-Pg boundary, which is the period between the late Cretaceous 83.6 million years ago and the early Paleogene 56 million years ago. It was when the age of the dinosaurs came to an end.

The analysis, published recently in the journal *PLOS Biology*, included shark species in eight existing orders and one now-extinct order. Based on the study, scientists point out shark dental diversity was already declining prior to the K-Pg boundary, but remained relatively constant during the mass-extinction event itself.

While some shark species, particularly those with triangular blade-like teeth, suffered selective extinctions during this period — linked to the extinction of their prey species — researchers say other shark lineages increased in dental diversity after the K-Pg boundary.

"Cretaceous anacoracids (an extinct shark family that lived during the Cretaceous period) suffered a selective extinction, captured by the loss of triangular, blade-like tooth morphologies traditionally associated with apex predator lifestyles," the scientists wrote in the study. They observed that sharks in the Odontaspididae family, which have narrow, cusped teeth adapted for feeding on fish, increased in diversity, coinciding with the rapid diversification of finned fish in the early Paleogene.

The study suggests this pattern of selective extinctions may reflect an ecological shift from specialist predators to more general bony fish diets. "Coincidentally, the Paleocene diversification of teleosts (a group that includes sharks and fishes with bony skeletons and symmetrical tails) offers a potential driver, coupled with the dietary adaptability of selachimorphs (groups of fishes, including sharks, that have distinct features including cartilaginous skeleton and five to seven gill slits on the sides of the head) as opportunistic 'generalist' predators capable of exploiting emergent food resources," the researchers added.

The scientists have called for further studies assessing the shark diversity of the time period sampling more fossil teeth across time and geographies.

— The independent

Joint research

Indian Institute of Technology-Madras and Vellore Institute of Technology, Chennai, are collaborating with Queen Mary University of London, to develop India-centric air sanitisation technologies and guidelines to prevent the spread of coronavirus and tuberculosis. This system is aimed at deployment in confined indoor places such as offices and hospitals.

This joint research aims to develop a robust low-cost bio-aerosol protection system to suppress air-transmitted diseases in indoor locations. In collaboration with Magneto Cleantech, an industry start-up based in Delhi, the testing and implementation will be done with real-time applications in various Indian environments.

The target geographies for this project are India and its adjacent countries. The major factor working with this area is the high population and heavy urban pollution. It is expected that this project, when successfully implemented, will benefit nearly 100 million people in the Indian sub-continent.

The project will be aimed at developing an experimental proof-of-concept of a revolutionary air filtration system using "Ultraviolet-C" radiation. It has a strong potential to increase the effectiveness of eliminating viruses and other airborne pathogens and reduce maintenance costs as compared to the available filters, which is important for developing countries such as India.

NEXT EVOLUTIONARY STEP?

Advances in science will allow us to live unshackled from our dying bodies


Neil Harbisson

Kevin Warwick

BIJU DHARMAPALAN

One often wonders if humans evolved from apes, then why are we not evolving into another organism?

During our lifetimes, however, there have been changes in the human species due to the incorporation of technological innovations. Most human births now are assisted by technology and delivered according to our whims and fancies. Doctors regularly use scanning, genetic and blood tests to assess the foetus, and if any abnormality is noticed, they are corrected with supportive technology and medicines.

As we incorporate newer innovations, we are moving towards creating "designer babies". Children can even be born to a single parent through cloning but ethical considerations in research prevent scientists from doing so.

In November 2018, however, Chinese scientist He Jiankui from the Southern University of Science and Technology in Shenzhen stunned the world when he declared that he had created the first gene-edited babies, Lulu and Nana. He used the CRISPR, or clustered regularly interspaced short palindromic repeats, system to edit the Deoxyribonucleic acid, or DNA, in human embryos to make them less susceptible to human immunodeficiency viruses. The edits were designed to disrupt a gene which codes for a protein that allows HIV to enter immune cells. Jiankui and his colleagues were sentenced to three years in prison for flouting regulations of research and medical ethics.

What the authorities failed to see was that societal ethics change, especially over longer time frames and Jiankui represents a substantial step forward in human embryo editing. Now, there is a clear path that anyone can follow, when before it was only a dream.

Many scientists were punished during their time before being accepted by the mainstream scientific community. In the next 100 years, thousands of edited embryos will be implanted and become children. Embryo editing and implantation will someday be viewed with as much legitimacy as in vitro fertilisation, since no parent would want their child to be born with a genetic abnormality.

Humans have incorporated other technological innovations in their life. At the age of 21, iconic physicist Stephen Hawking was diagnosed with amyotrophic lateral sclerosis, or ALS, commonly referred to as Lou Gehrig's disease. As ALS progresses, the degeneration of motor neurons in the brain interferes with messages to muscles in the body. Eventually, muscles atrophy and voluntary control is lost.

As is well known, Hawking used assistive technology to compensate for his mobility and speech difficulties. By squeezing his cheek muscles and "blinking", an infrared switch was activated, and he was able to scan and select characters on a screen in order to compose speeches, surf the Internet, send emails and "speak" through a voice synthesiser. Only because of technological incorporation could the great scientist do research till the age of 76.

With the emergence of custom-made prosthetics, neural implants that change how our brains work, and new senses that one never dreamt of having, it is time to start imagining what a better version of us might look like. Many people have augmented their body with implants to overcome a diseased state or enhance ability. We are indeed moving towards becoming cyborgs — part human and part machine.

Neil Harbisson, the first legally recognised cyborg in the world, has an antenna implanted into his skull that gives him access to something he was born without — the ability to perceive colour. Professor Kevin Warwick, a leading global expert in cybernetics, implanted a neural system that allowed him to control a robotic hand via brain signals. Some biohackers are now getting radio-frequency identification devices and magnets implanted. People even get implants in their ears to function like internal headphones for playing music.

The idea of technologically enhancing our bodies is not new. In the past, we made devices such as wooden legs, hearing aids, spectacles and dentures. In the future, we might use implants to augment our senses so we can detect infrared or ultraviolet radiation directly or boost our cognitive processes by connecting to memory chips.

Modern technology offers humans the chance to live for aeons, unshackled from the frailties of the human body. Failing organs would be replaced by their longer-lasting high-tech versions just as carbon-fibre blades could replace the flesh, blood and bone of natural limbs.

James Lovelock, the famed British environmentalist and futurist, wrote in the book *Novacene* that he imagined cyborgs would fill every evolutionary niche on the planet. "I think of cyborgs as another kingdom of life," he said, "They will stand to us in much the same way as we ourselves, as a kingdom of animals, stand to plants."

The technology needed to achieve such goals, however, relies on yet unrealised developments in genetic engineering, nanotechnology and many other sciences and may take many decades to reach fruition. Evolution is a slow affair, taking millions of years to turn a chimpanzee-like creature into humans. But what happens when we push on the accelerator, and take command of our bodies and brains instead of leaving it to nature? What happens when biotechnology and Artificial Intelligence merge, allowing us to redesign the human species?

Historian Yuval Noah Harari explores these questions in his runaway bestseller, *Homo Deus: A Brief History of Tomorrow*. He writes, "It is very likely, within a century or two, *Homo sapiens*, as we have known it for thousands of years, will disappear. Not because, like in some Hollywood science fiction movie, the robots will come and kill us, but because we will use technology to upgrade ourselves — or at least some of us — into something different; something which is far more different from us than we are different from Neanderthals".

Advances in AI, including machine learning, may soon let us build brain-computer interfaces that will blur the line between man and machine. Even today we can see how AI affects our mind — it selects friends for us on social networking websites and helps in browsing the Internet. Virtual assistant gadgets, smartphones and smartwatches are becoming an indispensable part of life.

At the current rate of technological augmentation, there is no doubt that *Homo sapiens* (wise humans) shall evolve into *Homo deus* (god humans) with god-like mastery over their environment.

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