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The field of futures studies can focus on specific technologies or consider existential risks.

WHAT'S NEXT FOR 'DEEP FUTURE' RESEARCH? TOP INSTITUTE SHUTS

Researchers from several disciplines hope to predict — and prevent — scenarios that pose risks to humanity.

By David Adam

The science-fiction author Ray Bradbury once wrote: "I don't try to describe the future. I try to prevent it." From asteroid strikes and nuclear winters to runaway artificial intelligence (AI), there are plenty of scenarios that humanity would rather avoid. So much so, that a burgeoning research discipline is dedicated to that task.

Consider the Centre for the Study of Existential Risk at the University of Cambridge, UK, which focuses on the study and mitigation of threats that could lead to human extinction or civilization collapse.

"There are cascade effects between different kinds of hazards," says historian Matthew Connelly, the centre's director. "And, really, if you want to understand the future of life on this planet, you have to look at it in terms of systems."

Some future shocks are hard to avoid — as researchers at the 19-year-old Future of Humanity Institute (FHI) at the University of Oxford, UK, discovered last month, when the institute was shut down in the wake of "increasing administrative headwinds", according to a statement on its website.

"We had a good run," says philosopher Nick Bostrom, who led the FHI since its creation in 2005. "I think the death by bureaucracy was regrettable, but there are now so many more places where this [research] can be done."

Forward-thinking approach

A loose confederation of academic interests, the field of futures studies embraces everything from philosophical musings to more constrained and rigorous exercises that map out how specific technologies are likely to progress.

Kerstin Cuhls, a scientific project manager at the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe, Germany, last year completed one such foresight exercise for the German government, investigating chronobiology and circadian rhythms.

"We invited a lot of people who know about chronobiology, but also people from associations and companies, and brought them together to discuss what could be the future of the field and applications," she says. Projecting over 20 years, the exercise covered probable scientific advances, such as a better understanding of the molecular and genetic mechanisms linked to sleep; the impact of increased screen use; and the potential knock-on effects of widespread disruption to circadian rhythms, including mental-health problems and obesity.

"We try to promote action," Cuhls says — most notably by using the study outcomes to support a (so far unsuccessful) attempt to abolish Germany's annual shift to 'summer time', when clocks are set forward by one hour, and to argue that teenagers would benefit from starting school later in the day.

Exercises such as this one are different from conventional forecasts, says George Wright, a psychologist and futures researcher at the University of Strathclyde in Glasgow, UK. Rather than using statistics to extrapolate a single data series on the basis of current trends, futures studies try to account for variation and uncertainties across many influences and variables.

"In the future, there will be political change, economic change, social change, technological change, legal change, maybe regulatory change," he says. To account for this, futures researchers often produce and describe several alternative scenarios.

Risks to humanity

Patrick van der Duin, a foresight consultant based in the Hague, the Netherlands, and co-editor-in-chief of the journal *Futures*, says that focused foresight exercises, such as the chronobiology one, are different from newer, more speculative research on existential risk. The speculative approach often focuses on low-probability events that have a very large potential impact, he adds, rather than projecting from the present on the basis of plausible and predictable steps.

Bostrom points to raising the profile of the existential risks posed by AI as the FHI's biggest achievement over the past decade. "We were the first in academia to develop the fields of AI safety and AI governance," he says. "At the time, many viewed this stuff as outlandish, but these concerns are now embraced by many AI leaders and echoed by many political leaders across the globe."

Some futures researchers go further than exploring possible scenarios, and actively seek ways to promote what they see as the most desirable vision of the future.

"We've done a lot of work on lethal autonomous weapons," says Emilia Javorsky, a physician-scientist who directs the Futures Program at the Future of Life Institute in Campbell, California. "These are very much challenges of today that are just going to be amplified tomorrow if we don't do something about them."

In 2017, the institute produced a viral video called *Slaughterbots* as part of a campaign against AI-enabled weapons. The video is widely credited with helping to build opposition to the technology. "We are seeing tangible outputs of this work," Javorsky says.

Several national governments are establishing groups to examine existential risk, including from AI. Although there is growing public and political interest in futures studies, much of the research that feeds into these discussions is still funded by philanthropic organizations, rather than government grants. That hurts the field's reputation, Connelly says, and is something he is trying to change.

Winning competitive grants is "what we need to do to establish this field for the long run and to earn the respect of others in academia", he says. This is a common issue, he adds, for emerging areas of research that are multidisciplinary or don't fit into existing fields.

"If you want to stick around, then you have to begin to demonstrate the work does meet the standard people would expect of any kind of academic work," he says.

MEET 'GOLDENE' — THE GILDED COUSIN OF GRAPHENE

This atom-thick sheet of gold might find use as a catalyst, or in light-sensing devices.

By Mark Peplow

It is the world's thinnest gold leaf: a gossamer sheet of gold just one atom thick. Researchers have synthesized[1] the long-sought material, known as goldene, which is expected to capture light in ways that could be useful in applications such as sensing and catalysis.

Goldene is a gilded cousin of graphene, the iconic atom-thin material made of carbon that was discovered in 2004. Since then, scientists have identified hundreds more of these 2D materials. But it has been particularly difficult to produce 2D sheets of metals, because their atoms have always tended to cluster together to make nanoparticles instead.

Researchers have previously reported single-atom-thick layers of tin and lead stuck to various substances, and they have produced gold sheets sandwiched between other materials. But "we submit that goldene is the first free-standing 2D metal, to the best of our knowledge", says materials scientist Lars Hultman at Linköping University in Sweden, who is part of the team behind the new research. Crucially, the simple chemical method used to make goldene should be amenable to larger-scale production, the researchers reported in *Nature Synthesis* on 16 April[1].

"I'm very excited about it," says Stephanie Reich, a solid-state physicist and materials scientist at the Free University of Berlin, who was not involved in the work. "People have been thinking for quite some time how to take traditional metals and make them into really well-ordered 2D monolayers."

In 2022, researchers at New York University Abu Dhabi (NYUAD) said that they had produced goldene, but the Linköping team contends that the previous material probably contained several atomic layers, on the basis of the electron microscopy images and other data that were published in *ACS Applied Materials and Interfaces*[2]. Reich agrees that the 2022 study failed to prove that the material was single-layer goldene.

However, Ramesh Jagannathan, who led the NYUAD study, stands by the work and disputes the Linköping team's assertions about it. "We did extensive characterization using atomic force microscopy," he says, referring to a technique that images surfaces by scanning them with a cantilever. The NYUAD researchers also demonstrated that their material is a semiconductor, as expected for monolayer gold.

Golden age

To prepare goldene, the Linköping researchers started with a material containing atomic monolayers of silicon sandwiched between titanium carbide. When they added gold to this sandwich, it diffused into the structure and changed places with the silicon to create a trapped atom-thick layer of gold (see 'Gold mining'). They then etched away the titanium carbide to release goldene sheets that were roughly 400 times as thin as the thinnest commercial gold leaf, Hultman estimates.

That etching process used a solution of alkaline potassium ferricyanide known as Murukami's reagent. "What's so fascinating is that it's a 100-year-old recipe used by Japanese smiths to decorate ironwork," Hultman says. The researchers also added surfactant molecules – which form a protective barrier between goldene and the surrounding liquid – to stop the sheets from sticking together.

The Linköping team suggests that goldene might be useful in applications in which gold nanoparticles already show promise. Light can generate waves in the sea of electrons at a gold nanoparticle's surface, which can channel and concentrate that energy. This strong response to light has been harnessed in gold photocatalysts to split water to produce hydrogen, for instance. Goldene could shine in areas such as this, Hultman says, but its properties need to be investigated in more detail first.

"I think the research is really interesting," says Graham Hutchings, a chemist at the University of Cardiff, UK, who develops gold catalysts. But he worries that any residual traces of iron from Murukami's reagent might hamper the development of goldene as a catalyst. "I would think that potential contamination with iron is going to cause a few problems in applications," he says.

For now, the Linköping researchers are seeking better ways to sieve goldene from the solution used to make it, and to grow larger flakes of the material.

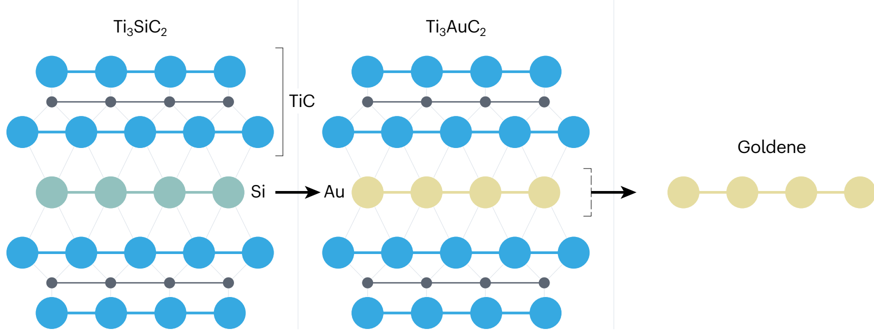
GOLD MINING

Researchers have made goldene — a single layer of interconnected gold atoms — with a relatively simple method.

First, the team made a material containing a silicon monolayer sandwiched between sheets of titanium carbide.

They then added gold atoms, which diffused into the structure and replaced the silicon.

Finally, they etched away the titanium carbide with an oxidizing reagent to release the goldene sheet.



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1. Kashiwaya, S. *et al. Nature Synth*. https://doi.org/10.1038/s44160-024-00518-4 (2024).
2. Sharma, S. K., Pasricha, R., Weston, J., Blanton, T. & Jagannathan, R. *ACS Appl. Mater. Interfaces* **14**, 54992–55003 (2022).