will split US$3 million between 14 projects — 6 working to develop lab-grown meat and 8 focusing on plant-based proteins. Each team will receive up to $250,000 over two years.

"It does seem like the largest contribution that I can think of toward cellular agriculture research," says Kate Krueger, the research director of New Harvest, a non-profit organization in New York City that has contributed almost $1 million in the past decade to academics working on clean-meat research.

### WHERE'S THE BEEF?

One area where the money could make a difference is in developing publicly available cell lines derived from the muscles of cows, pigs, fish and other food animals. Without such cells, researchers must either obtain tissues from slaughterhouses or run their experiments with mouse cells. The Norwegian Center for Stem Cell Research in Oslo plans to use a GFI grant to help build its Frozen Farmyard, a repository of agriculturally relevant cell lines.

Other researchers want to apply lessons learnt from decades of research in regenerative medicine. Amy Rowat, a biophysicist at the University of California, Los Angeles, who normally studies the biomechanics of cancer cells, is attempting to design scaffolds that can grow combinations of different types of cow cell to promote the marbling of fat in lab-grown steaks.

"It's still the same basic tissue-engineering principles," says Andrew Stout, a New Harvest fellow at Tufts University in Medford, Massachusetts. "But we need to start thinking about the design constraints from a food and sustainability perspective."

Clean-meat entrepreneurs, for their part, say they hope to see a larger contingent of scientists step into the field. The industry needs "innovative approaches to high-yield cell-based meat biomanufacturing", says Nicholas Genovese, chief scientific officer of Memphis Meats in Berkeley, California. "Academic research can play a significant and lasting role in accelerating the path to market."

The quest to culture meat in a dish dates back decades. In the 1990s, Dutch researcher and entrepreneur Willem van Eelen cobbled together research funding from private investors and produced the first clean-meat patent. He later convinced the Dutch government to award €2 million (US$2.3 million) to a consortium of scientists interested in taking the work further. This ultimately led Mark Post, a vascular biologist at Maastricht University in the Netherlands, to unveil the world's first lab-grown hamburger in 2013 — at a cost of €250,000.

***"Academic research can play a significant and lasting role in accelerating the path to market."***

But public financing for the project dried up as Dutch lawmakers prioritized research into cheaper plant-based protein sources, such as bean flours and pea protein, says Post, who has since founded the food-technology company Mosa Meat in Maastricht. And aside from a few pilot grants, such as one from NASA in the late 1990s to develop *in vitro* fish flesh, few government agencies have spent significant money on such research — in large part, experts say, because it is risky, complex and crosses disciplines.

In the United States, the National Institutes of Health funds most tissue-engineering research, but focuses on biomedical applications; the Department of Agriculture funds most food-science studies, but spends little on lab-grown meat. "This falls between the chairs," says Amit Gefen, a bioengineer at Tel Aviv University in Israel who is trying to grow chicken meat on scaffolds created by stripping apple flesh of its cells.

Funding opportunities are slowly beginning to sprout in some countries. The Israel Innovation Authority (IIA) funds the lab-grown-steak start-up Aleph Farms, whose work is based on the research of biomedical engineer Shulamit Levenberg at the Technion–Israel Institute of Technology in Haifa. Now, the IIA is putting up more than 100 million shekels ($27.7 million) over 8 years to create a food-tech incubator to help support many more such academic spin-offs.

Private investment in the clean-meat industry has already cut the cost of production. Post says that he can make a 140-gram burger for €500. Levenberg says that her company can culture a thin slice of steak for about $50.

And with prices expected to drop further, some scientists challenge the idea that foundational research in meat cultivation is lacking.

"We're now taking something that works with humans and works with mice and moving it into bovine cells," says Yaakov Nahmias, a biomedical engineer at the Hebrew University of Jerusalem in Israel and the chief executive of Future Meat Technologies, an Israeli start-up. "I'm not sure we're talking about basic science any more."

But, as with any first-generation product, there's room for improvement, says Ido Savir, chief executive of SuperMeat in Rehovot, Israel. The initial lab-grown meats will be more akin to that found in fast food than haute cuisine, he notes. That first batch will help to "set the ground for a new industry", but what's needed, Savir says, is to "actually create a new field of science here". ■

POLITICS

# Ukraine's science revolution stumbles

*On the fifth anniversary of a pro-European uprising, scientists say things are changing too slowly.*

BY QUIRIN SCHIERMEIER

Ukraine's science system is in a precarious state, despite promised improvements in the wake of a revolution five years ago that aligned the country with the European Union. National science spending remains low, government funding is used inefficiently and low salaries discourage talented students from embarking on research careers in the country. "We've been promised change for years," says Nataliya Shulga, chief executive of the science-advocacy group Ukrainian Science Club in Kiev. "But what's happened so far is an imitation of change, rather than genuine reform."

The 'Euromaidan' revolution, also known as the Revolution of Dignity, was sparked by a wave of protests and civil unrest that, in February 2014, culminated in a change in leadership. It severed Ukraine's ties with Russia and prompted the election of a pro-European government, raising hopes among scientists that Western partnerships would form and steer them out of international isolation.

The initial aftermath was promising: the new government promised to revamp the obsolete, Soviet-style science system, and to boost research expenditure. In 2015, Ukraine started participating in EU research programmes as an associated country, earning the same rights as member states when applying for grants. And in early 2016, the parliament passed a law to strengthen science, technology and innovation.

But those early efforts haven't substantially improved things, say scientists. Government spending on science declined to a historic low of 0.16% of gross domestic product in 2016, and has not increased much since.

The little public money that there is goes largely to research institutes operated by the National Academy of Sciences of Ukraine (NASU) — the country's main basic-research organization — many of which are outdated. The academy will receive nearly 5 billion

hryvnias (US$183 million) from the government in 2019 — almost twice its 2016 allotment.

But Shulga says that this money will not be enough for the academy's institutes to buy modern research instruments, such as electron microscopes and spectrometry machines, without foreign aid. This, in turn, limits Ukrainian scientists' ability to compete with researchers in richer countries. Patience is wearing thin, in particular among young scientists, who can barely get by on their scant salaries. PhD students get between 3,000 hryvnias (US$110) and 4,800 hryvnias a month, and even experienced scientists rarely earn more than 13,500 hryvnias. Ukraine "deserves a science system worthy of a developed country", says Yulia Bezvershenko, a physicist at the Bogolyubov Institute for Theoretical Physics in Kiev and a co-chair of the NASU's Council of Young Scientists.

Some things are changing, albeit slowly. A new grant-giving agency is expected to become operational this year. The National Research Foundation of Ukraine will fund individual scientists and groups on the basis of independent peer review. And over the next few years, the share of national research funding distributed on a competitive basis is to double from around 20% to 40%, says physicist Anatoly Zagorodny, a vice-president of NASU, which employs more than 15,000 researchers across 160 institutes.

## NEED FOR SPEED

But many scientists in Ukraine want more changes, more quickly. Ahead of the presidential election in March, and parliamentary elections later this year, leading scientists are calling for more government support for science, which they see as the key to improving not just research, but also the ailing economy. "There's no way to modernize Ukraine's economy without strengthening research and development capacity in our country," says Zagorodny.

Efforts are under way to streamline and modernize the NASU, a mammoth organization that has been led for decades by metallurgist Boris Paton, who turned 100 last year. In Ukraine, as in many former Soviet countries, researchers at the academy, rather than at universities, do almost all of the basic science. An evaluation of 94 NASU institutes, carried out between 2016 and 2018 by more than 440 Ukrainian reviewers, deemed 21 of the institutes to be old-fashioned or underperforming. This has led to the closure of more than 200 research departments, collectively employing 4,700 people, says Zagorodny, who acknowledges that the academy is underfunded and overstaffed, and that parts of it produce little competitive science.

And, he adds, deficient units, such as the NASU's coal-energy-technology institute in Kiev and a geotechnical-mechanics institute in Dnipro, are also set to be reorganized or closed.

But critics point out that the review involved few foreign specialists, so might have failed to reveal the full scope of the academy's weaknesses — and just how out of touch it is with the needs of modern science. Alexej Verkhratsky, a neuroscientist at the University of Manchester, UK, describes the academy as "outdated": in his opinion, it should be rebuilt from scratch. Some academy researchers do produce good science — for example, in astronomy, theoretical physics and mathematics, says Verkhratsky, who led a research group at the Bogomoletz Institute of Physiology in Kiev in the 1990s. But even for those pockets of excellence, money for travelling to meetings abroad or for buying lab equipment is lacking. The academy's competitive labs should be merged with universities to link research and teaching, suggests Verkhratsky.

Zagorodny acknowledges that many institutes are insufficiently equipped and cannot afford to replace obsolete equipment. The reason only a few foreign experts were involved in the evaluation was also a lack of money, he says. But he doesn't agree that the academy should be dismantled or merged with universities. Following the reorganization, research will focus on technological and socio-economic priorities, including communication technologies, energy, environmental management, life sciences and materials research. "Many institutes and departments must indeed change, and some changes are already in progress," he says.

The country's science struggle also limits its participation in EU-funded competitive research. As of January, Ukrainian researchers had received a modest €19 million (US$24 million) from the EU's €80-billion Horizon 2020 research-funding programme, in which they compete on equal terms with researchers from other EU member states and associated countries (see 'EU funding'). Its smaller neighbours in eastern Europe, Poland and Romania, by comparison, received €340 million and €131 million, respectively. As yet, Ukraine has failed to win any grants from the European Research Council (ERC), the EU's flagship mechanism for funding basic research.

At a ministerial meeting in Kiev last month, research-policy specialists with the commission urged Ukraine to speed up the pace of reforms to become more internationally competitive in science. "Ukraine's government has outlined ambitious reform plans," says Luca Polizzi, a research-policy officer in the commission's research and innovation directorate in Brussels. "Now it must put the same effort into implementing these plans."

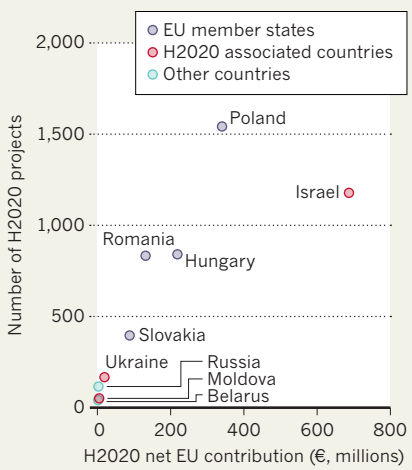
But many doubt that the required changes will come from the top. "We do have power to change the system," says Bezvershenko. "But if we want things to change, the revolution of dignity must proceed in our everyday life." ■


STR/NURPHOTO VIA GETTY

**Ukraine's scientists are calling for more improvements to the country's research system.**

## EU FUNDING

Ukraine wins relatively little funding from the European Union's biggest research and innovation programme, Horizon 2020 (H2020).

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