brief, standardized and clear.

The assessment should say what the on-board reactor is, what operational restrictions are in place, and what assumptions are made for the approved route. It must include plans for how shutdown and decay-heat removal are to be managed, which accident pathways have been evaluated, who has command of the emergency operations, and what information will be monitored and shared. The port layer should then address issues beyond the reactor itself, including fuel and waste liabilities, the extent of insurance coverage and the basis for suspending entry to the port.

It should capture war risks as well. Although sensitive design information that could reveal a ship's vulnerabilities should remain confidential, the components of the threat envelope must still be defined: collision, fire, drone strike, direct missile hit, underwater explosion, cyber intrusion, hijacking, crew evacuation, sinking and denial of refuge. These risks should be assessed when a route is designated. For instance, a ship certified only for low-risk Atlantic corridors should not enter a missile-threat area unless safety has been assessed for that threat level.

Amass evidence before deployment

Regulatory authority should remain with public institutions. It should be the nuclear regulator that is responsible for reactor and radiological safety, and the maritime administration that is in charge of the safety of the ship and crew. Port states must maintain their right to set entry conditions, contingency plans and emergency-response requirements. Shipping 'classification societies' and the industry can standardize hull rules, inspection methods and different ways of presenting evidence.

The IMO and IAEA need a joint framework, not two separate systems that cause confusion. At present, the IMO amends rules on ship design, certification, crewing, port-state control and the Code of Safety for Nuclear Merchant Ships, whereas the IAEA guides nuclear safety, security, safeguards, emergency preparedness and fuel-cycle management. A nuclear merchant vessel, however, would sit across these mandates. It would travel between jurisdictions, carry a reactor and nuclear fuel through dangerous waters, and ask ports that did not license the reactor to shoulder emergency and liability burdens.

To close this gap, ATLAS and the IMO amendments should rely on a standardized 'evidence pack'. This pack should distinguish between a trading ship with a propulsion reactor, a floating nuclear power plant and a port-linked nuclear power plant. It should include the reactor design reviewed, the route or site assumptions, fuel and waste responsibilities, liability cover, emergency command, radiological monitoring, and the criteria for granting, refusing or suspending port entry. It should also record the approved operating route or site, fallback ports or anchorages, and the evidence needed before those limits can be widened.

The pack should specify which hostile scenarios have been assessed. A low-risk route might be one with a focus on the threat of collisions, fires, flooding, blackouts, running aground and cyber intrusion. In dangerous waters, the envelope must widen to include drone impacts, missile attacks, armed boarding, the challenge of crew evacuation, denial of refuge and delays to salvaging the vessel. Sensitive designs can remain under wraps, but the approved threat envelope should be visible to regulators, ports and emergency planners.

Fleet deployment should be preceded by demonstrable evidence. Designers must show that a reactor can shut down unattended and that the decay heat can be removed after a fire, flooding or a loss of power, communications or crew access. Emergency power, cooling pathways, radiation-monitoring instruments and remote status-reporting capabilities must be protected, able to operate independently, and validated to work on a moving ship subject to waves, vibrations and partial flooding.

If a voyage no longer fits the approved threat assumptions, or if shutdown, cooling or monitoring is compromised, operations should pause. Regulators should ask whether the reactor remains controlled when the ship is burning, abandoned or under attack, not just whether it works during an apparently safe promotional voyage.

Nuclear power is not simply a cleaner propulsion option. In a world in which commercial shipping is already being attacked, the risks and burdens must be taken seriously.

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How to turbocharge bioengineering in Europe

Vasilis Ntziachristos, Thomas Schwarz-Romond & Fiona M. Watt

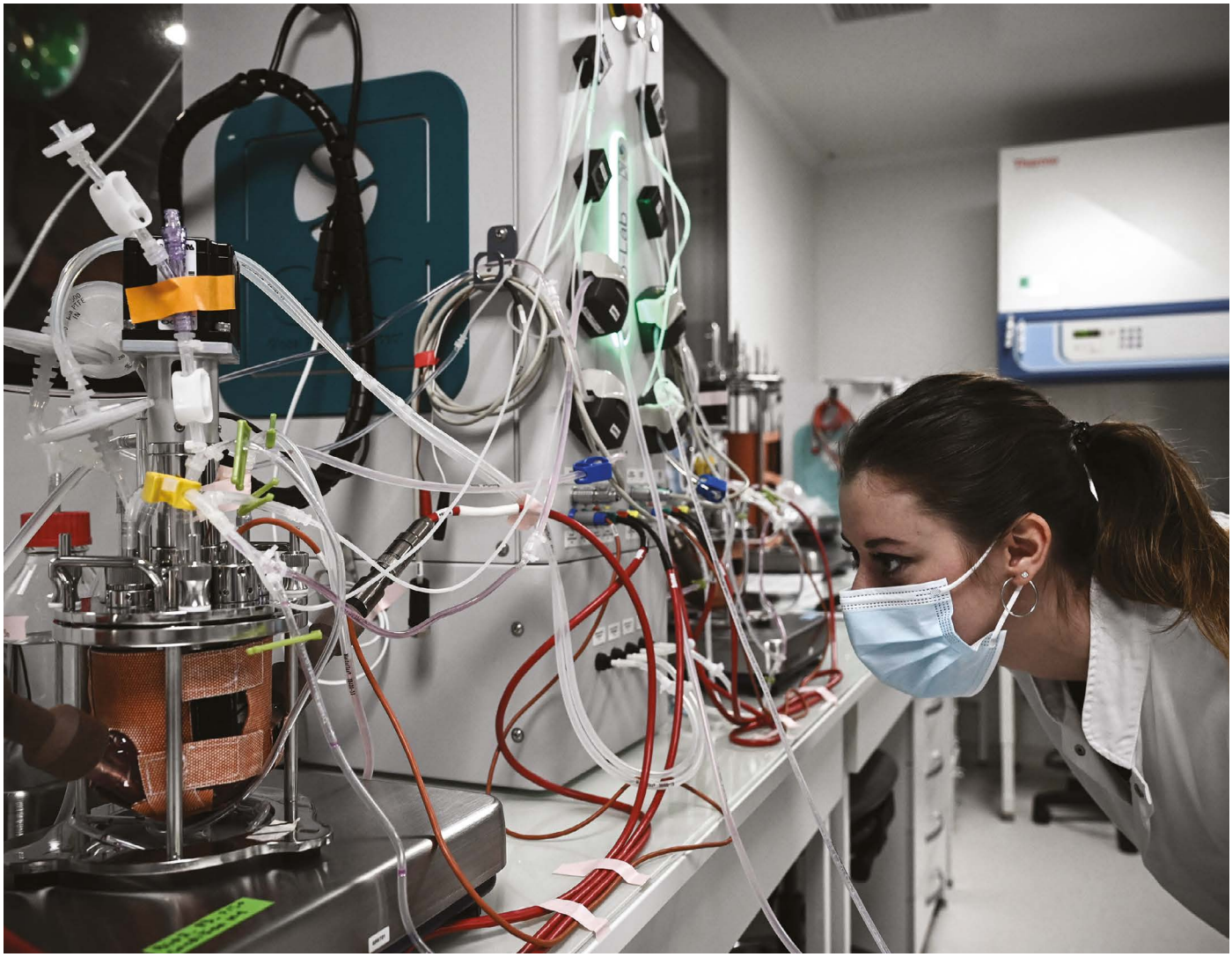
Sustaining the region's strong position in the life-sciences sector will require investment and education in the field.

Europe is losing ground in one of the most innovation-intensive sectors in biomedicine and health care: bioengineering[1]. Many advances in biomedicine are technologically driven, for example, the use of artificial intelligence to predict protein structures and rapid genome sequencing for precision medicine.

Bioengineering produces technologies that aim to solve medical problems, by merging methods from mathematics, computation, engineering and biomedicine. Many countries, including the United States[1], China, Switzerland and the United Kingdom, understand the power of such research. Yet, the European Union has still not caught on.

The EU's 27 member states (EU27) host fewer than ten fully autonomous bioengineering departments, compared with more than 100 each in the United States and China. Not one EU27 university made it into the 2025 ShanghaiRanking's top-30 list of biomedical engineering departments, compared with 18 from Asia.

Investment in medical technologies in the EU27 is low (see 'Untapped potential'). In 2023, biotechnology companies in Europe



PHILIPPE LOPEZ/AFP VIA GETTY

Bioengineering can produce tools for use in cutting-edge cell therapies, among other applications.

attracted US$11.5 billion in funding, compared with about $57 billion in the United States and $21 billion China (see go.nature.com/3twrfgr and ref. 2).

Concerned about this widening gap, in March, 25 specialists from around the world — including us and our co-signatories (see Supplementary information) — came together at Europe's life-sciences organization EMBO in Heidelberg, Germany, to find ways to address it. Here, we call on the European Council and relevant EU directorates to adopt a European bioengineering agenda that focuses on three themes.

Build academic excellence

The EU can build on its vibrant life-sciences sector, which contributes €1.5 trillion to its economy and supports 29 million jobs (see go.nature.com/4fr475p). The region has a strong culture of collaborative research, academic–industry partnerships and funding programmes that encourage the development of technologies. For decades it has excelled in other engineering disciplines, from civil to computational. And the EU's open society, social-security systems, healthcare and education infrastructures attract global talent.

What's needed now is coordinated European investment in bioengineering education, research and innovation ecosystems, to create the conditions for globally competitive healthcare technology and biotech companies to flourish.

The EU should incentivize national governments to establish dedicated bioengineering departments at their leading universities. Funding programmes should be used to promote bioengineering excellence.

Universities should recruit dedicated bioengineering staff members with a range of expertise to establish world-class curricula. This should be done in a similar way to how electrical and computer-engineering faculties were established originally, by bringing together top researchers from physics, mathematics and other engineering and technology fields.

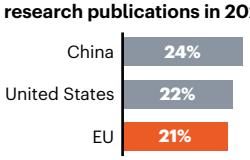
New bioengineering institutions should teach students how to develop a problem-solving mindset[3]. This skill can be applied across life-sciences research, including to methodologies that advance biomedical discovery and technologies that improve clinical care.

Curricula should also emphasize medical

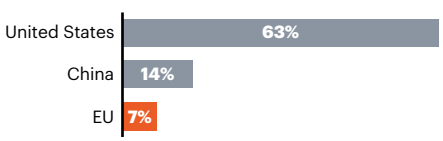
UNTAPPED POTENTIAL

Despite a strong record in biomedical research output, the European Union is failing to attract investment in biotechnology.

Global share of the 10% most highly-cited biological, biomedical and clinical research publications in 2022



Global share of private investment in health biotechnology between 2015 and 2025



SOURCE: EUROPEAN COMMISSION

ethics and regulation, to help students embrace the processes involved in developing successful biomedical technologies. This will help future bioengineers to navigate the rules and market forces that are specific to technology acceptance in medicine, which are different from other engineering products and pipelines.

Having several such top-level departments will build homegrown expertise and attract medical technology and biotechnology companies. Evidence for this can be found in Boston, Massachusetts, and San Francisco, California. These areas are home to biotechnology and medical-technology hubs, the foundations of which were built on a reputation for education and research excellence, including top-ranking bioengineering departments.

Recognition and celebration of high-achieving bioengineers can enhance the visibility and reputation of the field, initiating a virtuous cycle that makes entering the bioengineering industry more desirable. As the number of bioengineers in Europe grows, these researchers could establish dedicated societies that can present scientific awards, elect fellows, recognize early-career achievements and establish distinguished lectureships, as well as inspire established funders, societies and philanthropists to support bioengineering.

Invest in bioengineers

The EU invests billions of euros annually in biomedical and life-sciences research, including through research funding from the European Research Council and the European Innovation Council. Yet, dedicated review panels for assessing bioengineering grant proposals are absent, and funding proposals are typically assessed by researchers in neighbouring disciplines, such as biology, medicine, physics and engineering. Although reviewers might have relevant expertise, they are likely to evaluate proposals through the lens of their own disciplines.

The EU should establish dedicated funding schemes and review panels for bioengineering research. Experts in the field should also be involved in shaping future initiatives. These include Framework Programme 10 — the EU's next research and innovation funding programme, which is currently being developed and is scheduled to run from 2028 to 2034.

To rapidly translate research into marketable products, Europe needs policies that actively engage industry, venture-capital and investment firms. The region cannot establish global leadership in bioengineering while much of its talent is moving abroad and its innovations are being commercialized elsewhere. Dedicated funding programmes, public–private co-investment schemes, tax incentives for investments in technology and reduced administrative barriers to technology transfer are essential at both the EU and national levels. These efforts should be complemented by regulatory pathways that support safe but efficient early approval of technology for use in clinical settings.

The 2017 EU Medical Device Regulation, which was introduced to increase the quality and safety of medical technologies, serves as a cautionary example of how well-intended safety regulations can unintentionally weaken biomedical innovation. It resulted in increased certification costs, a limited number of organizations that are allowed to check devices and lengthy approval processes, which have led many companies to discontinue products or deprioritize the European market[4]. The lesson is not to lower safety standards, but to distinguish more clearly between early-stage clinical approval and market authorization, ensuring that prototypes can generate clinical evidence under proportionate regulatory requirements while maintaining rigorous patient protection.

Establish a flagship research hub

EU member states should invest in a central research institution that can serve as a European hub for training and education.

"The EU should establish dedicated funding schemes and review panels for bioengineering."

The European Molecular Biology Laboratory (EMBL) shows the power of this type of strategic investment. It was established in 1974 to provide Europe with a shared centre of excellence in molecular biology. It helped Europe to become a global leader in the life sciences, by training generations of researchers, pioneering breakthroughs in molecular and cellular biology and establishing crucial research facilities and infrastructure across Europe.

Similar to EMBL, a European bioengineering research centre could serve as a focal point for the bioengineering community, attracting talent, shaping research priorities and strengthening Europe's competitiveness in biomedical innovation. The European Commission, together with interested member states, should initiate a road map for establishing a European bioengineering research centre as a pan-European research institution or intergovernmental organization, with long-term funding shared between the EU Framework Programme and participating countries.

Implementation could follow a phased approach, evolving from a coordinating hub into a distributed network of leading bioengineering centres across Europe. The required investment would be comparable to that of other European research infrastructures and represent only a small fraction of the EU Framework Programme budget.

Bioengineering innovation hubs should be established in areas where leading universities, hospitals, companies, investors, regulatory expertise and entrepreneurial talent are already concentrated. Building on existing regional strengths will maximize the societal and economic impact of European bioengineering.

When establishing this network, the EU should examine the operation of institutes that successfully translate research into innovative technologies. Examples include the Wyss Institute in Boston, Google's X, The Moonshot Factory in Mountain View, California, the Institute for Human Biology in Basel, Switzerland, and the Mechanobiology Institute at the National University of Singapore. Common features of these organizations include performance-driven funding, rapid project evaluation, early intellectual-property protection, entrepreneurial mentorship and close interaction with industry, investors, regulators and clinicians. These mechanisms support inventions and innovations, and consistently translate scientific discoveries into patents, licences, start-ups and venture-backed companies.

For too long, Europe has failed to harness its engineering excellence to establish global leadership in bioengineering. In the United States, philanthropic organizations have invested billions of dollars in bioengineering since the 1970s (see go.nature.com/4vhcdxa) — resulting in an ecosystem capable of identifying, evaluating, funding and developing engineering-driven biomedical innovation. It's time for Europe to follow suit.

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