recovered from steppe herders called the Yamnaya, who lived in what are now Russia and Ukraine around 5,000 years ago, closely matched that of 4,500-year-old individuals from present-day Germany, who were part of a group known as the Corded Ware culture that encompassed most of northern Europe. The similarities suggest "a massive migration into the heartland of Europe from its eastern periphery", the team writes.

Yamnaya ancestry survives in the genomes of modern Europeans, with northerners such as Norwegians, Scots and Lithuanians maintaining the strongest link. The geographical extent of the Yamnaya migration is not clear, but the researchers note that the eastern migrants could have completely replaced existing populations, at least in what is now Germany. It is impossible to know the language these migrants spoke, but it is likely to have originated in the steppe homelands of the Yamnaya.

"This seems like very striking support for at least part of the traditional steppe model of Indo-European diversification," says Andrew Garrett, a historical linguist at the University of California, Berkeley, whose own work adds further support. When he and his team re-analysed the data from Atkinson's 2012 family tree, this time taking into account the approximate ages of ancient Indo-European languages, they dated the origin to around 6,000 years ago, in line with the steppe hypothesis (W. Chang, *et al. Language*; in the press).

Atkinson says, however, that the analysis assumes that ancient languages such as Latin and Old Irish are direct ancestors of modern languages, instead of side-branches of a common ancestor. This makes it appear that these languages evolved faster than they did, he says, and would argue incorrectly for a more-recent common tongue.

Heggarty points out that Reich's ancient DNA study is not the final word on the steppe hypothesis either. He suspects that the Yamnaya spoke a language that later developed into Slavic, Germanic and other northern European tongues, but he doubts that the group imported the predecessor of all Indo-European languages: "For me, these data look like the steppe population was speaking a branch of Indo-European."

Reich and his team acknowledge that attributing the origin of all Indo-European languages to the Yamnaya migration would require the discovery of their genetic signatures in samples from further east, such as from India and Iran. But Carles Lalueza-Fox, a palaeogeneticist at the Institute of Evolutionary Biology in Barcelona, Spain, notes that the climates of the Middle East and southern Asia do not augur well for preservation of ancient DNA: "It could be difficult to find good samples from the right time frame." ■

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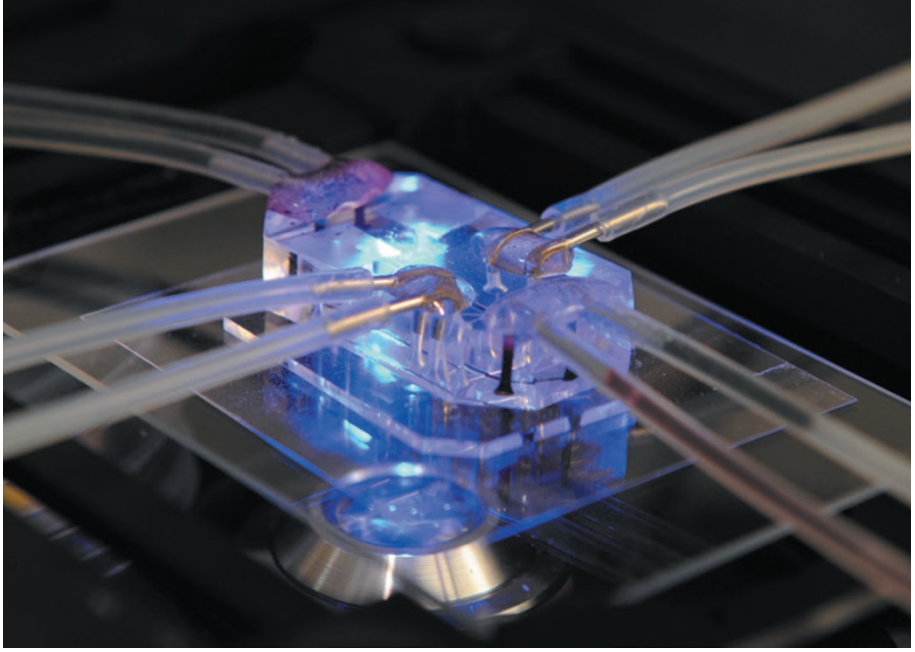

'Organs on chips', such as this simulated lung, could be used to test bodily responses to toxic chemicals.

BIOENGINEERING

Scientists seek '*Homo chippiens*'

Biodefence projects aim to mimic the human body using networks of simulated organs.

BY SARA REARDON

Each year, the US government spends hundreds of millions of dollars stockpiling countermeasures for potential biological, chemical and radiological warfare agents. For ethical reasons, many of these treatments have never been tested in humans. Now, the US military and civilian science agencies are supporting the development of the next best thing for tests: miniature human organs on plastic chips.

"It's unethical to expose humans to the kind of radiation that you'd see in a disaster like Fukushima, but you need to be prepared," says Donald Ingber, a bioengineer at Harvard University's Wyss Institute in Boston, Massachusetts. With support from the US Food and Drug Administration, he is adapting his 'bone marrow on a chip' to study the effects of harmful radiation and experimental remedies.

Other researchers working along similar lines discussed their work on model organs for biodefence applications at a meeting of the American Society for Microbiology (ASM) last week in Washington DC. The hope is that these complex three-dimensional systems will mimic human physiology better than do cells grown in a dish, or even animals.

A common way to form a model organ is to seed cells into channels in a small plastic chip and then feed them with nutrient-rich fluid that flows through the system to mimic blood. The devices can be used individually or connected to other types of organs-on-chips to approximate a biological system, or — eventually — perhaps an entire human body.

The US Environmental Protection Agency plans to announce next month an US$18-million programme to link 'livers on chips' with chips that simulate fetal membranes, mammary glands and developing limbs. The ultimate aim is to study how environmental contaminants such as dioxin and bisphenol A alter metabolism in those organs once they have been processed by the liver.

The flexibility afforded by model-organ systems is especially attractive to researchers who are investigating dangerous pathogens, given the expense of animal studies and the security restrictions required. At the ASM meeting, microbiologist Joshua Powell of the Pacific Northwest National Laboratory in Richland, Washington, presented experiments testing the ability of anthrax spores to infect a three-dimensional 'lung' grown from rabbit lung cells. The cells sit at an interface between liquid and air, much as in real lungs.

Powell says that the US Department of Homeland Security is interested in using the system to answer questions such as how many anthrax spores are necessary to cause disease in the body.

For some viruses in particular, Ingber ▶

says, researchers "have no idea about the mechanism, and they need the mechanism to get new drug targets". Infecting model organs could allow researchers to watch how gene expression and metabolism change in real time.

This sort of information could also be used to identify an unknown agent during a chemical, biological or radiological attack, by providing baseline data on known agents for comparison. John Wikswo, a physiologist at Vanderbilt University in Nashville, Tennessee, and his colleagues have shown that they can rapidly distinguish poisons such as ricin and botulinum toxin by analysing the metabolic activity of cells (S. E. Eklund *et al. Sensors* **9,** 2117–2133; 2009), and will now apply the model-organs approach.

Researchers have already developed dozens of individual model organs; the next challenge is to hook them together with the eventual goal of forming an entire human body on a chip, says Kristin Fabre, a programme manager at the National Center for Advancing Translational Sciences (NCATS) in Bethesda, Maryland. This would provide a more accurate picture of the effects of a drug, toxin or other agent on human physiology.

Wikswo humorously dubs such a system *Homo chippiens* — but warns that simulating a human body will not be easy. Among other challenges, the blood substitute that flows between model organs must reach them in the right order and in the right quantity, and carry the right nutrients for each organ.

But plenty of people are trying. An NCATS-funded project aims to hook together at least 4 chips; 11 research teams are participating. The US Department of Defense's Defense Advanced Research Projects Agency is supporting the development of techniques to link ten organs, and its Defense Threat Reduction Agency aims to build two four-organ systems.

Fabre predicts that some of the systems could be available to academics and industry within five years. She is hopeful that they will prove especially useful in cases in which animals are poor models for human physiology. As researchers inch closer to that goal, she says, "it's like sci-fi comes to life every day". ■

An ARPA-E-funded technology to control power flow is being used by US utility companies.

SMART WIRES

TECHNOLOGY

Radical energy ideas secure private funds

US federal start-up funds inspire investment in ARPA-E technologies.

BY JEFF TOLLEFSON

As it enters its seventh year, an ambitious US Department of Energy effort to trigger innovation in clean-energy technology is celebrating some success. At the start of the annual summit of the Advanced Research Projects Agency—Energy (ARPA-E) on 9 February, the programme's management announced that ARPA-E-supported technologies have attracted US$850 million in private investment.

At the same time, however, the market for new ideas in energy is not booming, and the mood at the summit was more sedate than in earlier years, when sessions swarmed with investors looking for the next big thing. Most observers of energy innovation counsel patience: even useful ideas often take decades to reach broad application. The US defence department's Defense Advanced Research Projects Agency (DARPA) was the model for ARPA-E, and its biggest success story — the Internet — took decades to be recognized.

"If we look in 20 or 30 years and can't see an impact, then we can say we have failed," says Ilan Gur, a former ARPA-E programme director who now heads a programme to advance technological innovation at Lawrence Berkeley National Laboratory in Berkeley, California. "The real contribution that ARPA-E has had is in laying out the challenges and bringing together the communities that can solve them."

General enthusiasm for nudging new technologies to market has shrunk since ARPA-E was founded. Venture-capital investments in the United States have dropped off sharply in the past two years; funding for early-stage

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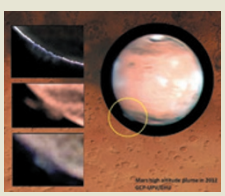

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