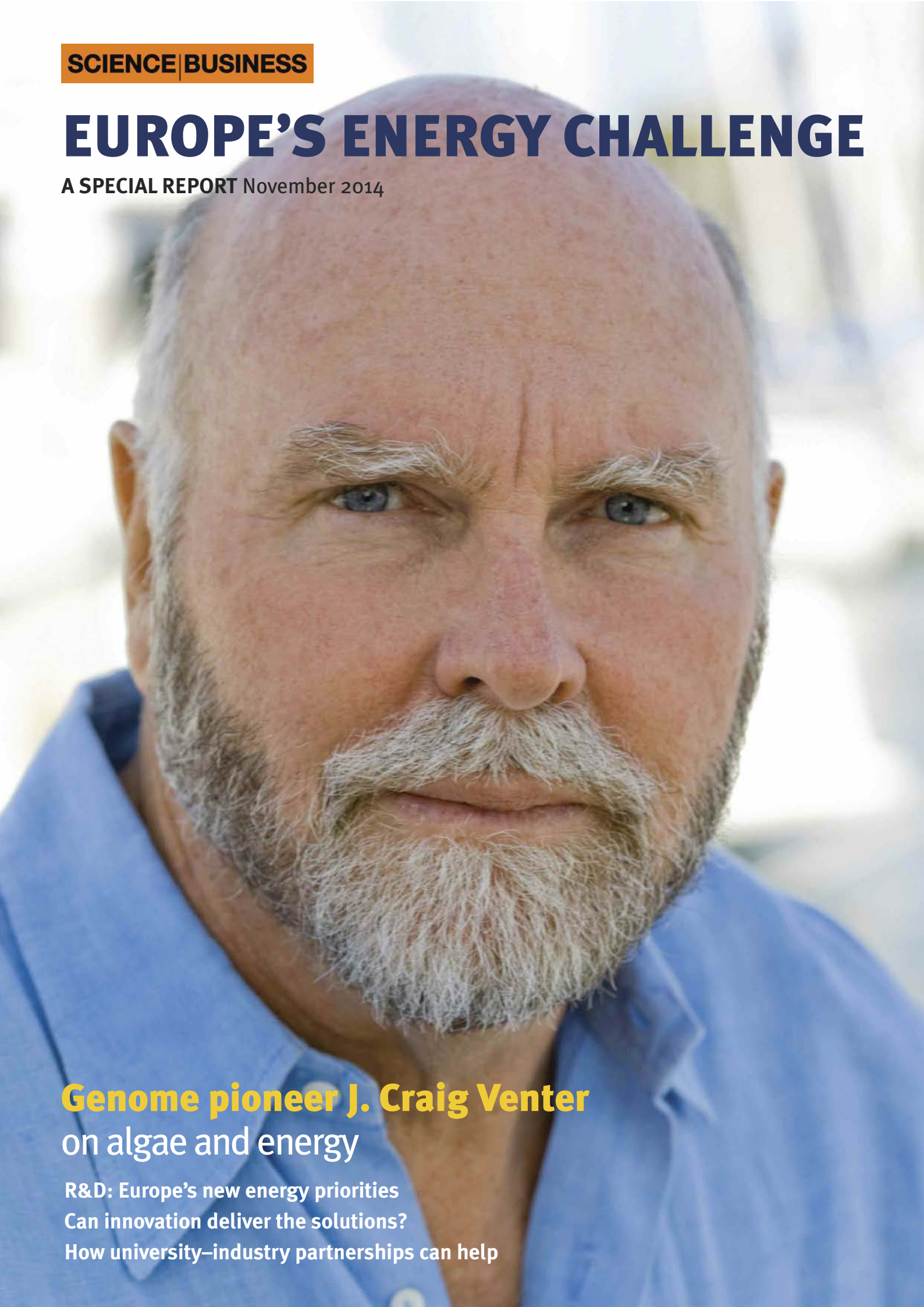
SCIENCE|BUSINESS

# EUROPE'S ENERGY CHALLENGE

**A SPECIAL REPORT** November 2014



## Genome pioneer J. Craig Venter on algae and energy

**R&D: Europe's new energy priorities**
**Can innovation deliver the solutions?**
**How university–industry partnerships can help**

# **A technology optimist** but a policy pessimist

## Carbon pricing holds the key to success in the fight against climate change, says gene sequencing pioneer **J. Craig Venter**

BY JOHN CAREY

To gene sequencing pioneer J. Craig Venter, it's obvious that the world must reduce its use of oil and other fossil fuels. "Our oil-based society is not sustainable," he says. That's why he powers his two Tesla electric cars with electrons from the solar panels on his house. It's why he has built the world's first carbon-neutral research lab at his J. Craig Venter Institute (JCVI) in San Diego. And it's why he and his San Diego company, Synthetic Genomics, have been working since the company's founding in 2005 to coax algae and other microbes to make renewable substitutes for oil.

Venter is a technology optimist. "We can engineer cells to replace the components that come from oil, so that it's all renewable-based," he says. "We can replace a lot of oil." He is also a big proponent of solar energy. Over the next few decades, he believes, it is technologically possible to replace the majority of fossil fuels with renewable energy, dramatically cutting carbon emissions and slowing climate change.

But Venter also fears that the world is fumbling these opportunities. It is failing both to leap forward in technology and to put the right policies in place. For instance, the current approaches being taken by companies trying to make renewable fuel from algae and other microbes are woefully inadequate, he says. "The yields are at least ten to fifteen times lower than what one needs to make it even remotely economically competitive," he explains.

And even if gene-spliced microbes did produce a flood of biofuels, that very success would drive down demand—and thus prices—for oil, making it harder for renewable options to complete. As a result, Venter argues, little real progress in the fight against climate change is possible without one crucial policy—a realistic price on carbon. Yes, Europe has a carbon-trading scheme that currently prices carbon emissions at about €5 per ton, and some US states have a similar policy that pegs the price at about $5 per ton. But Venter argues that the US and the world need a simple tax on all carbon emissions.

"Until we get serious about the $CO_2$ in the atmosphere and put a tax on carbon that recognises the real cost of taking carbon out of the ground and burning it, we will never be able to come up with an alternative solution," Venter says. The right price? Venter leaves that up to the economists. The US Environmental Protection Agency, for example, calculates the so-called social cost of carbon (the price of the damage that carbon does) at between $12 and $235 per ton, depending on discount rates and time horizons.

### Bucking the trend

Venter has a long history of bucking conventional wisdom, and being proven right. A one-time self-described surf bum who worked as a night clerk at Sears, Roebuck & Co, his ambition kicked in after patching up wounds as a Navy medic in Vietnam. "I got a lifetime of education packed into one year," he recalls. After racing through college and his PhD, and snaring a research post, Venter pioneered a controversial method for finding genes by copying the genetic messages, messenger RNA, floating around in cells. Then he co-led the effort to read the human genome.

Now, at his research institute and company, he's pursuing the once unimaginable goal of creating whole living cells from scratch, while also developing new methods and tools for synthesising large amounts of DNA cheaply and other tasks, while working with companies like Archer Daniels Midland on algal factories to make commercial products like omega-3 fatty acids. For example, "with combinatorial DNA synthesis, we've made an enzyme that does not exist in nature," he says. "We're also working on sending biology through the Internet by building a digital biological converter that would take a digital message and convert it to DNA. We could email you proteins or even cells, and the converter would spit out the DNA instructions for making them."

While only a small fraction of Synthetic Genomics' efforts have been aimed specifically at producing biofuels using algae, an ExxonMobil-funded project has given Venter a close view of the challenges. In 2009, the oil giant proposed tapping into the unique algal strains Venter had discovered on a sailing voyage around the world. Exxon figured that, with the right algal strain, the company could apply its expertise to successfully scale up production of a renewable oil.

"In retrospect, it was pretty naïve," says Venter. "People had been doing the same experiment over and over again for more than 50 years—with the same result," he says. They would grow a natural strain of algae in open ponds on a large scale, hoping to get large amounts of renewable oil. But it never happened. "The yield is always nowhere near enough to be economically viable," Venter says. "And things that grow

J. Craig Venter surrounded by the algae he created with the aim of producing biofuels.

more robustly come in and kill what you are doing."

Venter tried to convince Exxon that the only real hope lay in genetically modifying the algae. "From the beginning, I argued that the only thing that would a difference would be a genetic engineering approach," he recalls.

But Exxon forged ahead with the traditional method—and the project flopped. So in 2013, Exxon pared back the original collaboration with Synthetic Genomics and refocused the effort on creating gene-altered algae with yields an order of magnitude higher. "The latest programme is where I wanted to start years ago—adding a synthetic chromosome to change the genetics of algae," says Venter. "It's the only approach that has significant hope."

**Breakthrough**

It will take several years to test the approach, but Venter believes such souped-up algae are possible. More important, a scientific breakthrough may not translate into a successful renewable fuel business. The issue is that fuel is about the last thing a company wants to make with super-yielding algae. "Producing fuel is the absolute bottom of the barrel," explains Venter. "You can produce a litre of proteins like monoclonal antibodies that is worth $10 million. Or you can produce a litre of oil, worth maybe a buck."

So while making products like renewable jet fuel may garner headlines, those efforts aren't a viable solution to climate change, says Venter. "The press is full of these boutique proof of concept productions," he says. "But while you can burn the fuel in airplanes, it has no practical consequences at changing the $CO_2$ balance."

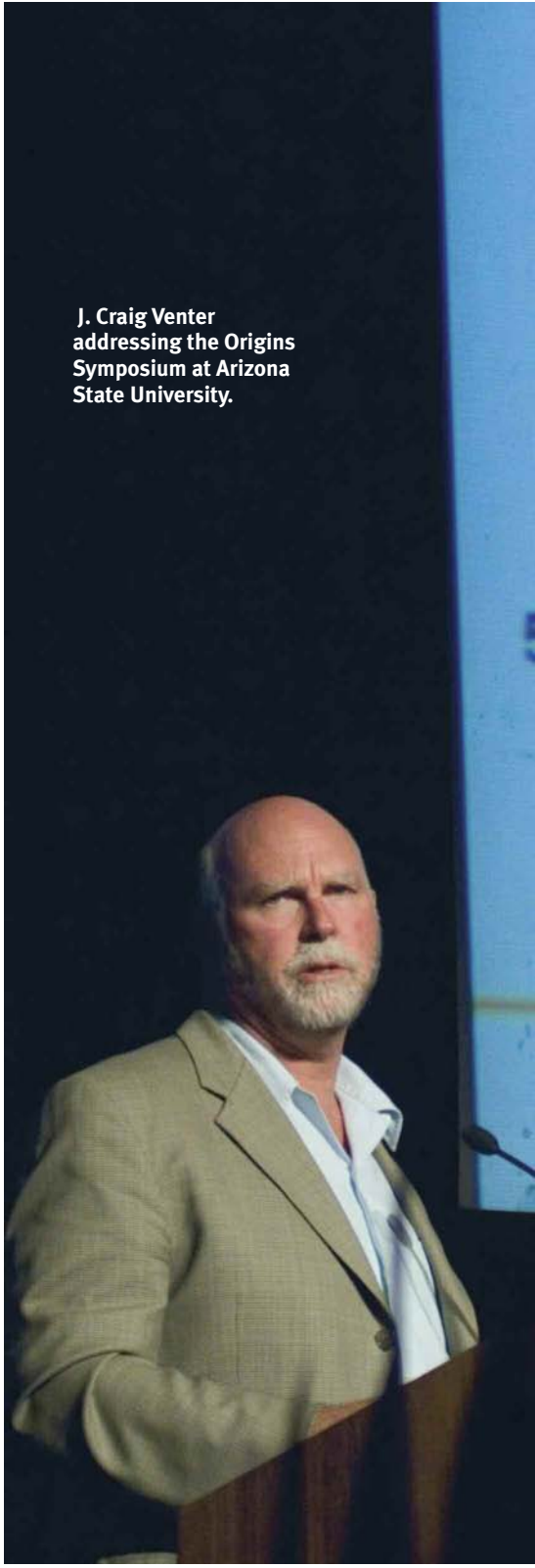
In fact, virtually all of the original biofuel companies, once portrayed in the media as bringing renewable alternatives to oil, have shifted their focus to products more likely to bring profits. South San Francisco-based Solozyme, for instance, is producing lubricants, skin care products and food. Amyris in Emeryville, California, makes drugs, cosmetics and fragrances. "People would be pretty dumb not to shift away from fuel to higher-valued products," Venter says. Venter's own company is working not just on omega-3 fatty acids, but also on algae-produced astaxanthin (a dietary supplement), vaccines, and pigs with humanised genes whose organs could be transplanted into humans.

Still, putting advanced biofuels on the back burner doesn't necessarily mean abandoning the fight to reduce $CO_2$ emissions and to mitigate climate change. About five per cent of the world's oil and gas production goes to make plastics, for instance. And one of Synthetic Genomics' successes has been inventing an enzyme that converts sugar into plastic for bottles and other uses. The sugar, in turn, could come from plants or microbes. "We can create products that will have billion-dollar impacts—and more important, replace all that oil," says Venter. That strategy may be better for both business and the climate than converting the sugar to fuel. "To take the same products and burn them doesn't seem like the wisest approach," Venter says.

Spurring renewable plastics and other creative ideas that can reduce carbon emissions, however, will take better policies and financial incentives than those in place now. Venter is pessimistic about the chances of such policies. Because of the current flood of relatively inexpensive oil and natural gas, "the only approach that makes sense is a price on carbon," he says. Yet a carbon tax is now a political impossibility in the US and many other countries.

That's why Venter suggests that, in addition to technological advances, "social engineering has to happen." At a time when people seem to be working less for the overall good of society and more for themselves, "can we change the culture so people are judged by how much they give back to society and life versus how much they take from it?" he asks. And more specifically, he says, "how do we select for and build in evidence-based decision making" so that governments make policies based on evidence instead of ideology?

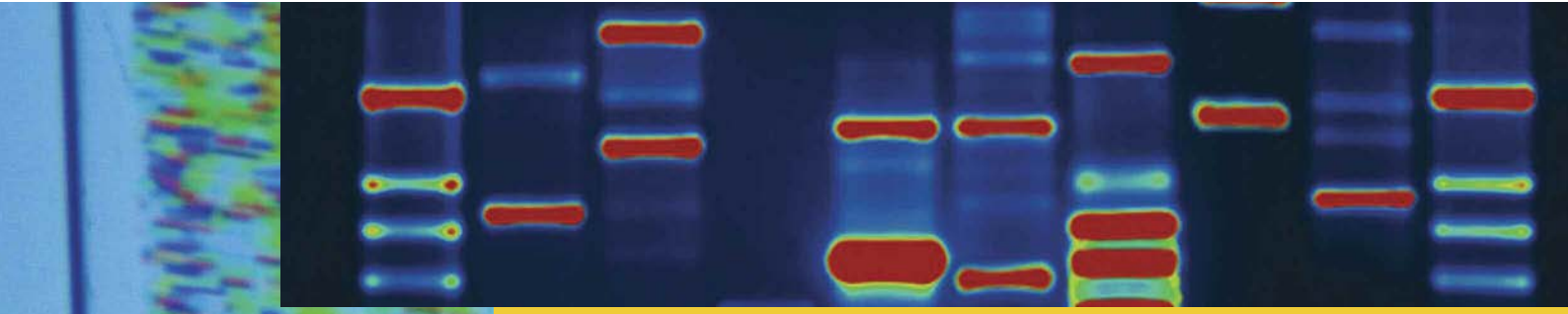
Those are questions that even Venter's genetic engineering wizardry may not be able to answer.

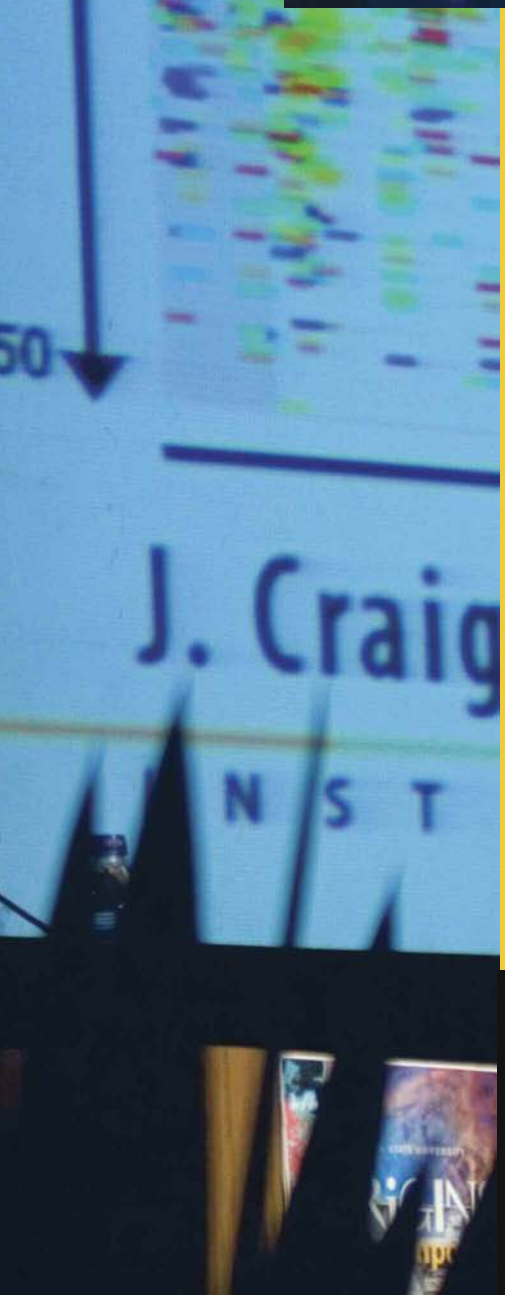


**J. Craig Venter addressing the Origins Symposium at Arizona State University.**

***Haemophilus influenzae*** **(right) was the first living organism to have its genome decoded.**

**Human male karyotype (far right)**





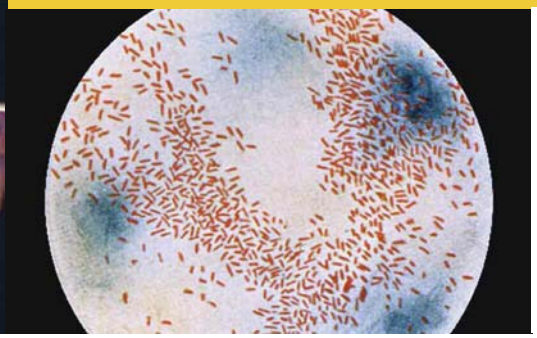

## Timeline of a trailblazer

J. Craig Venter has blazed numerous new trails across the fields of biology and genetics. After a tour of duty as a Navy Corpsman in Vietnam, a PhD from the University of California at San Diego and a stint at the University of New York at Buffalo and the Roswell Park Cancer Institute, he moved to the National Institutes of Health in 1984. That's where he pioneered a powerful new strategy for finding new genes—copying the messenger RNA floating in cells. At a time when discovering a single new gene typically took years of work, Venter suddenly was able to quickly find thousands.

The method's promise enabled Venter to snare funding in 1992 for his own non-profit research institute, The Institute for Genomic Research. At TIGR, he developed a new technique, called whole genome shotgun sequencing, for reading the entire genetic code of a species. He and his team proved the method's worth in 1995 by being the first to decode the genome of a free-living organism, the bacterium *Haemophilus influenzae*.

Venter's next bold step, at a company he founded called Celera Genomics, was successfully sequencing the entire human genome, a feat that won headlines in 2001.

Since then, Venter has founded another non-profit research organisation, the J. Craig Venter Institute (JCVI), as well as Synthetic Genomics, a privately held company aimed at engineering new life forms. He and his scientists have created synthetic chromosomes, developed new tools for synthesising DNA, and genetically modified a host of organisms, among many other accomplishments. He's also sailed the world's oceans, discovering millions of new genes along the way. And now, he's hoping to solve the mysteries of ageing by sequencing the genomes of thousand of people a year in order to pin down the genes linked to chronic illnesses like cancer, Alzheimer's and heart disease.



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