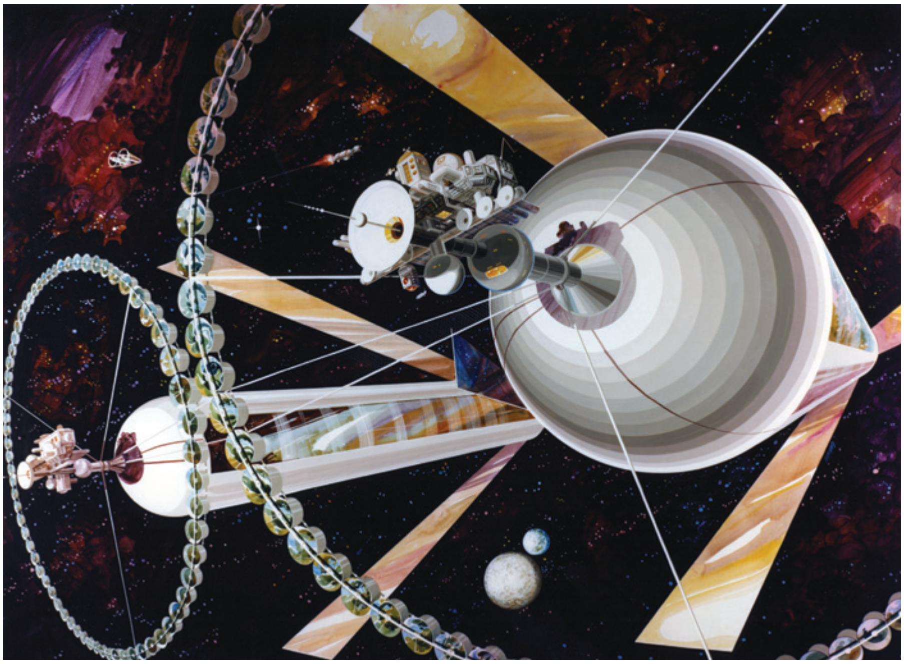


RICK GUIDICE/NASA

The Cylindrical Colony: one of several designs for a space settlement mooted by Gerard O'Neill.

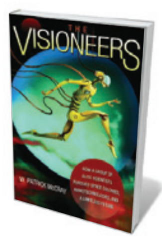
INNOVATION

Limits be damned

Cyrus Mody applauds an examination of the twentieth-century scientists who dreamed of breaking the bounds.

To the best of our knowledge, human life is constrained by natural limits: we do not live forever, we cannot transport ourselves or transmit information faster than the speed of light, and there is a finite supply of fossil fuels. Debates about such limits have shaped, and been shaped by, scientific and technological knowledge for centuries. Even faulty predictions about limits have made important contributions. Thomas Malthus' pessimism, for instance, prepared the ground for Darwin's theory of natural selection, and the overly optimistic vision of Lewis Strauss, former chairman of the US Atomic Energy Commission, of "energy too cheap to meter" facilitated decades of nuclear-power research and development.

In *The Visioneers*, science historian Patrick McCray of the University of California, Santa Barbara, argues that the resource-scarcity debates of the 1970s inspired a generation of visionary scientists and engineers. This influential crew had big dreams about overcoming all kinds of limits; occasionally built working models to demonstrate progress towards their dreams; and passionately assembled coalitions to make those dreams a reality.



The Visioneers: How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future
W. PATRICK MCCRAY
Princeton University Press: 2012. 328 pp. £19.95, $29.95

McCray focuses on Gerard K. O'Neill, the Princeton physicist and designer of space colonies, and on his protégé, K. Eric Drexler, the 'speculative engineer' trained at the Massachusetts Institute of Technology (MIT) in Cambridge who helped to put nanotechnology on political agendas in the early 1990s. Along the way, McCray introduces a large and colourful cast of others who, over four decades, promoted technological progress as the way to overcome every limit.

O'Neill's ideas reached a mass audience in part through the L5 Society founded in 1975 by Keith and Carolyn Henson. These livestock farmers and Tolkien enthusiasts from Arizona later drifted into advocacy for the Strategic Defense Initiative and cryonic life extension, a proposed technology by which all or part of a human body would be frozen at death in the hope that it could be re-animated later. Drexler also imagined that cryonic immortality could be facilitated by programmable 'molecular assemblers' — nanometre-scale robots, or nanobots — repairing the tissues of corpses frozen at death.

Pillars of the California counterculture — such as the psychologist and LSD advocate Timothy Leary, and Stewart Brand, founder of the *Whole Earth Catalog* — also took up the visions of O'Neill and Drexler, working them into manifestos on transhumanism and the 'electronic frontier'. Brand served on the board of the Foresight Institute, set up in 1986 by Drexler, and made Drexler's molecular assemblers a centrepiece of the future scenarios that his Global Business Network sold to enthralled chief executives.

McCray documents how cryonics and radical life extension, space colonies, molecular nanotechnology and exotic sources of energy (such as solar-power satellites and zero-point energy) were widely popularized, alongside unsceptical articles about paranormal phenomena, by the pornographers Bob Guccione and Kathryn Keeton in their glossy monthly magazine *Omni*. Indeed, McCray argues that the audience that *Omni* catered to — young and male, with a taste for luxury goods, high-tech gadgets, libertarian politics and libertine excesses — strongly resembled the visioneers and many of their followers.

One thread ran through all of this: the 1972 blockbuster *The Limits to Growth* (Universe), by global think-tank the Club of Rome. This book goaded O'Neill and Drexler, says McCray, into sketching their plans for a limitless future. *The Limits to Growth* — along with public intellectuals such as the biologist Paul Ehrlich and the ecologist Garrett Hardin, plus fictional films such as *Soylent Green*, *Logan's Run* and *Silent Running* — popularized the idea that resource scarcity and a growing population would combine to create shortages of economically crucial materials. That message took root around the world in the 1970s, particularly (if temporarily) in a United States beset by 'stagflation', oil shortages and environmental crises such as the Santa Barbara oil spill of 1969.

However, the original computer models on which *The Limits to Growth* was based, developed by veterans of Jay Forrester's systems-dynamics group at MIT, failed to account adequately for the role of technological innovation in ameliorating resource scarcity, at least over the near term. Although the models were later refined, the 1972 version provoked a storm of criticism, much of it justified. Many lay people, particularly those of the generation whose childhoods

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Hugh Gusterson on how the hippies saved physics:
go.nature.com/rzxvhe

were infused with the optimism of the US space programme, responded to talk of scarcity with a visceral aversion. These teens and twenty-somethings latched on to O'Neill's visions of suburbs in space piping abundant solar power and lunar regolith back to Earth. O'Neill himself was ambivalent about their support, and when his star faded they moved on to form or follow other high-tech enthusiast movements, each of which took *The Limits to Growth* as its foil.

McCray's book is especially convincing in following the various movements that arose in reaction to the Club of Rome's 1972 book. At present, we face genuinely alarming limits to growth. Our ability to comprehend and act on such constraints — particularly with respect to climate change and alternative energy — is still distorted by the infelicities in the first edition of *The Limits to Growth* and the ferocious reaction to its conclusions. Some visioneering ideas for overcoming limits to economic growth have contributed to inaction on climate change by promising an appealing but impossibly easy, sacrifice-free, small-government path to a limitless future. These have distracted attention from politically difficult, less technology-intensive solutions.

McCray's argument that visioneers play an important part in the "technological ecosystem" is also compelling, but asymmetrically deployed. For one thing, as the book's subtitle implies, only those who propose a limitless future get to be visioneers; technical experts who popularize visions of a future that is constrained by scarcity (Forrester or the biologist Barry Commoner, for example) apparently do not count. McCray also sometimes treats his visioneers less critically than their foils. He describes *The Limits to Growth* as "refuted" by experts, but treats equally damning arguments against the visions of O'Neill and Drexler in a 'he-said–she-said' fashion. For instance, Nobel Laureate Richard Smalley's contention that Drexler's molecular gears and conveyor belts obey an impossible chemistry is dismissed as "Drexler and Smalley largely talk[ing] past one another".

Yet McCray is correct that visioneers influence, and are influenced by, an ecosystem of philanthropists, politicians, funding agencies, entrepreneurs, undergraduates, scientists and others. That group spurs technological innovation, crafts science policy, and shapes and shares widely held visions of the future. ■

Cyrus C. M. Mody *is an assistant professor in the History Department, Rice University, Houston, Texas.*
e-mail: cyrus.mody@rice.edu

ASTROBIOLOGY

The cosmological you

Birger Schmitz weighs up an exploration of how the Universe permeates us.

Neil Shubin's masterpiece *Your Inner Fish* changed the way I see myself. Using evidence of the first fish-amphibians that left the oceans for land 375 million years ago, Shubin described with stunning clarity how every aspect of our anatomy goes back to our distant ancestors.

Now, in his follow-up *The Universe Within*, he takes the discussion a step further: how the Universe formed, our place in the Solar System and the intertwined evolution of our planet and life. He shows that all this is built into us as physical beings.

Inside us, for instance, are atoms that formed in exploding stars. The movements of heavenly bodies are inherent in our perception of time and in biological clocks. Physical parameters such as gravity determined our shapes and sizes. Had Jupiter formed closer to the Sun, we would have turned out short and squat; farther out and we would have been slender and elongated. This is because Jupiter formed before the inner rocky planets, and its position relative to the Sun determined Earth's size and gravity.

Shubin starts with the formation of the Universe 13.7 billion years ago, segueing into that of the Solar System 4.6 billion years ago. Much later, about 200 million years ago, when the supercontinent Pangaea broke up, the continents and ocean basins we know today began to form. This was accompanied by the rapid evolution of more complex life forms — dinosaurs, mammals and birds.

> *"The mystery of why we are here is perhaps greater than ever."*

Shubin suggests a rather original connection between continental break-up and the evolution of such creatures: mud settling on the vast stretches of coastline created by the break-up of Pangaea buried biological material that would otherwise have decayed in water, using up oxygen. The result, Shubin says, was an increase in atmospheric oxygen, one of the key factors that allowed animals to conquer land. Mammals require a lot of oxygen to maintain their high-energy, warm-blooded lifestyle. Life on the low-oxygen Earth of 200 million years ago would have been like that today at 4,500 metres above sea level.

Much of the second half of *The Universe Within* summarizes the history of how our geological view of Earth developed. It incorporates stories such as how the discovery of similar fossil organisms on distant continents led Alfred Wegener and others towards the idea of continental drift. We also meet William Smith, who invented stratigraphy, Louis Agassiz, who discovered ice ages, and geologist Bruce Heezen and oceanographic cartographer Marie Tharp, who were central to developing the theory of plate tectonics.

The Universe Within: Discovering the Common History of Rocks, Planets, and People
NEIL SHUBIN
Pantheon: 2013. 240 pp. $25.95, £20

Shubin is at his best when he deals with anatomy and biology, as in his discussion of the inventive geologist Michel Siffre. In 1962, Siffre spent two months living in a subterranean cave to gauge whether he could track time without any tools with which to measure it. After two months, he was convinced that only 37 days had passed. This was in line with what we know about the role in 'internal clocks' of the pineal gland, which regulates the production of sleep-inducing melatonin depending on the available light. Shubin's storytelling in such passages is gripping.

The Universe Within is a charming and enjoyable read, but it does not reach the heights of *Your Inner Fish*. There is a familiar feel to some of the sections, and the book's title raises expectations that are not really met. Where are the mysteries of the brain, the laws of thought and our consciousness? These, to me, are the most amazing aspects of the 'universe within'. In my view, the popular astronomy writer Timothy Ferris has touched on these aspects of the relationship between the soul and the Universe in a more thought-provoking way in books such as *The Mind's Sky* and *The Whole Shebang*.

And what if our view of the Universe continues to change as much as it did in the past century? From Shubin, one gets the impression that much is now solved. But the mystery of why we are here is perhaps greater than ever. Maybe, as the physicist Max Planck put it: "Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are part of nature and therefore part of the mystery that we are trying to solve." ■

Birger Schmitz *is a professor of geology at Lund University in Sweden and the leader of the ASTROGEOBIOSPHERE project.*
e-mail: birger.schmitz@nuclear.lu.se