

genome to put it to better use. And “hedgenetics” could become a good case providing a legal context for realizing the active participation of citizens in complex matters of new and emerging technologies.

To conclude, Fuller’s co-authored book deals with one of the most exciting topics of recent times, i.e. the challenges of transhumanism. Moving through this intellectually stimulating book will force readers to re-think fundamental questions like where as a biological species we come from and where we are going with the help of the great achievements of modern scientific-technological progress.

Toni PUSTOVRH
Faculty of Social Sciences,
University of Ljubljana

George Church and Ed Regis
**Regenesis: How Synthetic Biology
Will Reinvent Nature *and* Ourselves**
Basic Books, New York 2012,
pp. 284, (ISBN 978-0-465-02175-8)

“Engineering recapitulates evolution” (p. 12). George Church, genetics pioneer, Professor at Harvard and cofounder of several biotechnology companies, with the help of science writer Ed Regis, uses this leading idea to take the reader on a tour of the evolutionary history of life on Earth, presenting biological mechanisms and organisms of rising complexity that have emerged during six evolutionary epochs, and are increasingly

subject to redesign by synthetic biology with the aim of serving human needs and purposes. In *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*, Church’s first book, the authors interweave three levels of narrative. The first recounts the evolutionary emergence of life and its mechanisms, starting with the Late Hadean and the primordial DNA that gave rise to all terrestrial life, all the way to the emergence of mammals and finally of human civilization in the Homo Sapiens dominated Anthropocene era. The second traces the history of synthetic biology and its origins from early biotechnology to modern synthetic genomics, Do-It-Yourself Biotechnology, and iGEM, the international student competition in engineered microorganism systems, often recounting Church’s own involvement in landmark research, development and entrepreneurial activities. The third takes a more predictive and sometimes speculative approach to what applications the progress of synthetic biology might yield in the short and mid-term, but also in a possibly more distant future. Along the way, the authors tackle some fundamental questions, such as what is life, what distinguishes animate and non-animate matter, whether this leaves any room for theories of vitalism, what is the origin of the primordial DNA, as well as address some of the technical challenges and the societal ramifications of such developments, including questions of (bio)safety and (bio)security.

The book serves as a good introduction for the non-expert reader to the history and the possibilities implicit in the development of synthetic biology, although some segments tend to get a bit more technical by delving deeper into some aspects of genetic and genomic mechanisms. In addition to giving an authoritative and of course opinionated view of an emerging field, in which Church continues to be a pioneer and shaper, *Regenesis* provides the reader with a myriad of interesting scientific facts and historical sketches, which are characteristic of Regis's writing style. In this way, the popular science parts, often dramatized to place the reader *in medias res*, balance the more technical and challenging segments. But what will make the book appealing (or appalling) to most readers are the speculations on ways in which synthetic biology may enable us to "re-design nature *and* ourselves".

Following the structure of the book through the six evolutionary eras of terrestrial life, the authors propose and envision several grand possibilities for biological redesign at the level of microbes, animals and humans. The fact that most biomolecules are "handed", that is, also having a mirror counterpart with different chemical effects, could be used to create "mirror life" by using the mirror counterpart molecules of the originals as the building blocks, thus ensuring incompatibility with viruses that rely on the cellular machinery to propagate themselves, as well as an inability to exchange genetic

information with "natural" organisms. In this way, "mirror" synthetic organisms could be made safer by severely limiting their interactions with existing life, and also made to produce valuable and exotic chemicals and materials. And although there are still large technical obstacles to creating the simplest mirror microbe, Church nevertheless envisions the possibility of creating "mirror humans", which would be immune to all natural viruses. But their mirror physiology would also make them unable to digest non-mirror food and be unable to procreate with regular humans. Harnessing the power of synthetic genomics, the engineering, evolution and selection of synthetic genomes, opens many possibilities to employ redesigned microorganisms as microbial factories, especially for producing pharmaceuticals, chemicals and biofuels. Church thus criticizes the use of crop plants, especially food crops, as harmful, inefficient and much less sustainable than using engineered microbes that use waste water, minimal space and few feedstocks to produce sustainable petroleum, which he sees as one of the major upcoming synthetic biology markets. Sequencing the genomes of other species will further enable us to uncover valuable traits and functionalities, and incorporating them into the human genome (or using engineered microbes to perform specific functions in the human body) could enable humans to acquire greater physical robustness, immunity, health and longevity, and

possibly increased physical and mental capacities. While the authors do acknowledge that experiments with enhancing interventions in the human genome are currently impossible due to legal and ethical barriers, they do think that such prohibitions will be seen as outdated as the technology and its efficacy and safety improve, given the enormous potential benefits of such interventions. The possibility of reconstructing the genomes of extinct species (or using the preserved genomes of recently extinct species) could enable the return of species once thought to have been lost forever, by using cloning and surrogate pregnancy in related animals. This might enable the return of lost biodiversity, presupposing that the species habitats were reconstructed as well, and even of prehistoric creatures, such as the woolly mammoth, although the required technology is far from mature and the mammoth's genome would actually need to be gathered from damaged fragments in several preserved specimens, and accordingly redacted from an elephant's genome. And what has perhaps recently garnered most attention (and outrage) and gone somewhat viral in the media, was the further suggested possibility of reconstructing a Neanderthal genome that could be cloned and brought to term by a "surrogate mother chimp - or by an extremely adventurous female human" (p. 11). These are only some of the more radical applications that will give the reader further thought on what might

be achievable (or desirable) in the age of a maturing synthetic biology, and what the societal consequences of such developments might be. In a more immediate future, Church sees great value in large (open) databanks of sequenced human genomes, which is not surprising, as he is also founder and subject of the Personal Genome Project that aims to provide the fully sequenced genomes of volunteers, along with their physiological and medical information, openly accessible on the internet. Such databases would enable the identification of the genomic bases coding for various traits, diseases and dysfunctions, as well as speed up predictive medical and lifestyle interventions, resulting in greater personalization of approaches and treatments.

The authors are certainly not blind to the possible unintended and undesirable consequences, especially those pertaining to safety and security. Church has been involved in several expert groups that produced recommendations on how to govern developments in biotechnology and synthetic biology, and has made several proposals that are now widely accepted, such as licensing DNA synthesis companies and screening orders for pathogenic sequences. Ultimately, he sees built-in safety features of synthetic organisms as the most likely safeguards, such as "death genes", dependence on specific feedstocks or watermarks that would enable tracing. Despite the possibilities of laboratory accidents and engineered pathogens, the authors

remain optimistic of the promise of synthetic biology, indeed firmly convinced that prohibitions do little more than delay beneficial developments and obscure the hostile uses of new technologies. They argue that it is also in the interest of increasing biodiversity that we should not just resurrect extinct species, but create completely new organisms, with entirely new functionalities. The capabilities offered by synthetic biology, which are in the end just a logical continuation of humanity's previous attempts to harness nature, will ultimately be necessary to surpass or at least maintain the current level of civilization, and possibly of life itself. Along these lines, Church points to the prudence of spreading life to other planets, especially in case the Earth were to suffer a global catastrophic event, either natural or manmade, and synthetic biology would help facilitate this spread.

Regenesis attempts to provide (a necessarily condensed and simplified) history of life, civilization, (biological) science and technology, and synthetic biology, along with the prospects of what might be possible in the near and distant future. Although the reader may be skeptical of the possibility and desirability of some of the developmental trajectories proposed, Church is nevertheless a visionary who has already turned some of his past predictions into reality, and some of his extrapolations in *Regenesis* just might become regular features of everyday life in the coming years and decades.

Simone ARNALDI

Centre for environmental, ethical, legal and social decisions on emerging technologies (CIGA) & Department of Political science, law and international studies, University of Padua, and Department of Humanities, University of Trieste

Antoni Kukliński

In search of new paradigms.

Selected papers 2001-2011

The Policy Economic Society,
Warsaw 2013, pp. xvi+327,
(ISBN 978-83-88700)

What do copper regions and *pax kantiana* have in common? Why is the future of Europe linked to the sword of Alexander the Great? The variety of topics in Antoni Kukliński's book *In search of new paradigms* is impressive, but their reading is a compelling and fascinating exercise in intellectual inquiry. *Fragstellung*, questioning, is admittedly the "greatest fascination" of the Author's academic activity (p. xiii) and the volume collects ten years (2001-2011) of notes and papers that are meant to be provocative contributions to the public debate on the future of Poland, Europe and the Western "megaspaces" (p. 3ff). The book is anything but a neutral, detached analysis of these issues and it rather constitutes a testimony to the author's intellectual commitment and civic passion, both blended with insightful thinking. It is such a combination that makes Kukliński to challenge the "conventional wisdom" of both