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Opinion

# Paving the way for synthetic biology-based bioremediation in Europe

**Manuel Porcar**[1,2] **and Andrés Moya**[1,3,4]*
[1]*Institut Cavanilles de Biodiversitat i Biologia Evolutiva, Universitat de València, València, Spain.*
[2]*Fundació General de la Universitat de València, València, Spain.*
[3]*Centro Superior de Investigación en Salud Pública (CSISP), València, Spain.*
[4]*CIBER en Epidemiología y Salud Pública (CIBEResp), Barcelona, Spain.*

Synthetic biology (SB) has a dual definition. It is both the design and construction of new biological parts, devices and systems, and also the re-design of existing, natural systems for useful purposes. The latter field is maybe one of the major challenges within this discipline, since the promising prospect that biological systems may be used as biomachines will certainly be exploited in the near future.

Synthetic biology has challenging conceptual possibilities (Moya *et al*., 2009a) and impressive progress has already been made in biotechnology following SB approaches (de Lorenzo and Danchin, 2008). Much more is expected in the near future from current efforts aiming to make synthetic genomes for minimal cells to be applied in biomedical, bioremediation or bioenergy applications (Moya *et al*., 2009b). In addition to standard academic research, the growing success of the International Genetically Engineered Machine (iGEM) competition organized by the Massachusetts Institute of Technology demonstrates how diverse the practical applications of even relatively simple SB projects can be.

Synthetic biology is more a framework than a discipline, as it deals with the rational combination of biological properties with central elements of engineering design. Although a living organism cannot be simplified as the mere sum of its parts (Peretó and Català, 2007), the fact is that these parts can indeed be used as heterologous functional elements for a wide range of biotechnological applications. Thus, by merging the biotechnological toolbox already available with disciplines such as electrical, mechanical, or chemical engineering and computer sciences, there is an extraordinary opportunity to take a fresh approach to many biotechnological problems, including long-standing environmental pollution, through a vigorous application of modelling techniques and organizing the development of novel biological (e.g. catalytic) systems within a hierarchical architecture with defined and standardized interfaces. The success of this objective would not only apply to bioremediation but also to many technologies that could benefit from a *à la carte* performance of engineered living systems. However, this endeavour faeces three major obstacles that have, up to date, hampered the development of an SB-based framework for bioremediation: (i) the new field is still missing a comprehensive language and a shared conceptual framework for the description of minimally functional biological parts (specifically dealing with catalytic properties and regulatory circuits); (ii) scientists and technicians responsible for the application of SB to environmental issues (i.e. environmental biotechnologists, bioinformaticians and experts on the origin-of-life topic), particularly in Europe, have so far failed to recognize their latent capacity to shape a brand-new discipline within their very scope, probably because of a lack of common technical language and tools; and (iii) promotion of SB might touch upon social sensitivities related to recreating 'life-in-the-test-tube', which threatens a re-enactment of the controversy stirred up by GMOs. Indeed, the difficulties encountered regarding public opinion of GMOs should serve as the strongest incentive to set up clear and transparent SB technical and ethical frameworks and establish the basis of a constructive dialogue between scientists and society on the risks and benefits of this new discipline. Unfortunately, we forecast that future development of bioremediation and any other technology based on SB will certainly be affected by the public's negative perception, due to both its nature (a combination of living beings and human manipulation which is homologous to that of biotechnology), and its name: as Kenneth A. Oye stressed, the term *synthetic* (artificial) biology could almost have been calculated to cause a strongly negative response (http://www.synbiosafe.eu/).

Research on SB is almost solely performed in developed countries. There are currently 184 identified sites in

Received 27 October, 2009; revised 6 November, 2009; accepted 9 November, 2009. *For correspondence. E-mail andres.moya@uv.es; Tel. (+34) 96 3543480; Fax (+34) 963 543670.

the USA and 51 in Europe along with several research centres in Japan and China exploring this emerging discipline (http://www.synbioproject.org/). Synthetic biology-focused universities, companies, research institutions and policy centres are, however, prone to work independently and coordinated efforts have only recently started. One example of these is the programme entitled Targeting Environmental Pollution with Engineered Microbial Systems *à la carte* (hereafter, TARPOL) led by the Universitat de València and composed of a total of 18 partners (http://www.sb-tarpol.eu/), which is currently developing a dynamic two-year programme of activities, run by a large collection of European stakeholders in the field and aimed at coordinating the so-far fragmented efforts to channel this emerging discipline into the most industrially beneficial and socially viable directions.

A major obstacle for full development of SB in *Europe* is the lack of a critical mass of synthetic biologists. Thus, the energization and mobilization of a large portion of European scientific, technical and social professionals to empower a new capacity to exploit properties present in Biological Systems for the prevention, monitoring and remediation of environmental pollution is imperative. In this context, TARPOL has already been successful in recruiting the necessary environmental competences from neighbouring disciplines and developing numerous material and computational resources for advanced re-factoring of biological systems (Jimenez *et al*., 2002). Furthermore, TARPOL has progressed in laying the foundations of SB, particularly on genome reduction strategies including a novel view of living organisms as information traps (Danchin, 2009; Moya *et al.*, 2009b).

The current pool of senior scientists, however, will certainly not be enough to achieve the goal of a critical mass of synthetic biologists. This is why the TARPOL consortium intends to pay particular attention to education. A TARPOL-supported team of students led by University of Valencia and Universidad Politécnica de Valencia participated in the international iGEM competition that took place in Cambridge (Massachusetts) in November 2008 with an SB project on thermogenesis in genetically modified yeast (Delás *et al*., 2009). Interestingly, 10 out of the 18 gold medals of the 2008 competition were awarded to *European* teams (three teams from UK; two from Germany and the Netherlands; and one from Belgium, Spain and Slovenia), and 11 out of the 19 prizes also went to teams from our continent, including the Grand Prize awarded to Slovenia for an outstanding SB-based development of a vaccine against *Helicobacter pylori* infection. The potential of SB in Europe was further demonstrated in the recent 2009 iGEM edition when all the six finalists were European teams (Groningen, Heidelberg, London, Valencia, Freiburg and Cambridge; the latter winner of the Grand Prize).

International Genetically Engineered Machine is only a fraction of the teaching efforts that TARPOL is making in order to spread SB. In fact, during the last year, several courses were organized by TARPOL partners: Université de Lausanne organized a student's block on Synthetic Biology for Biology students in their second year, within the 'Biology and Society' programme; Imperial College London organized a Master in Systems and Synthetic Biology; University of Evry (*France*) a European Master in Systems and Synthetic Biology; and ETH Zurich (Switzerland) an MSc in Biotechnology focused on SB (more information on these courses can be found at http://www3.imperial.ac.uk/systemsbiology, http://www.mssb.fr and http://www.bsse.ethz.ch/education/msc). Finally, TARPOL will organize two major training events, in the form of intensive SB Summer Schools to be held in Valencia (Spain) and Basel (Switzerland) in Spring and Summer 2010 respectively.

Mobilization, interdisciplinary collaboration and training: the objectives of TARPOL concerning SB converge into a single goal: to set up this brand-new discipline that may have revolutionary effects on our lives, in Europe. Achieving such objectives will be a key step to implementing a powerful, sustainable knowledge-based bio-economy in our old continent.

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