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outlook

The 'National' and the 'Cosmos'

The emergence of synthetic biology in China

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Given its potential to aid developments in renewable energy, biosensors, sustainable chemical industries, microbial drug factories and biomedical devices, synthetic biology has enormous implications for economic development. Many countries are therefore implementing strategies to promote progress in this field. Most notably, the USA is considered to be the leader in exploring the industrial potential of synthetic biology (Rodemeyer, 2009). Synthetic biology in Europe has benefited from several cross-border studies, such as the 'New and Emerging Science and Technology' programme (NEST, 2005) and the 'Towards a European Strategy for Synthetic Biology' project (TESSY; Gaisser *et al*, 2008). Yet, little is known in the West about Asia's role in this 'new industrial revolution' (Kitney, 2009). In particular, China is investing heavily in scientific research for future developments, and is therefore likely to have an important role in the development of synthetic biology.

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In 2010, as part of a study of the international governance of synthetic biology, the author visited four leading research teams in three Chinese cities (Beijing, Tianjin and Hefei). The main aims of the visits were to understand perspectives in China on synthetic biology, to identify core themes among its scientific community, and to address questions such as 'how did synthetic biology emerge in China?', 'what are the current funding conditions?', 'how is synthetic biology generally perceived?' and 'how is it regulated?'. Initial findings seem to indicate that the emergence of synthetic biology in China has been a bottom-up construction of a new scientific framework; one that is more dynamic and comprises more options than existing national or international research and development (R&D) strategies. Such findings might contribute to Western knowledge of Chinese R&D, but could also expose European and US policymakers to alternative forms and patterns of research governance that have emerged from a grass-roots level.

A dominant narrative among the scientists interviewed is the prospect of a 'big-question' strategy to promote synthetic-biology research in China. This framework is at a consultation stage and key questions are still being discussed. Yet, fieldwork indicates that the process of developing a framework is at least as important to research governance as the big question it might eventually address. According to several interviewees, this approach aims to organize dispersed national R&D resources into one grand project that is essential to the technical development of the field, preferably focusing on an industry-related theme that is economically appealling to the Chinese public.

Chinese scientists have a pragmatic vision for research; thinking of science in terms of its 'instrumentality' has long been regarded as characteristic of modern China (Schneider, 2003). However, for a country in which the scientific community is sometimes described as an "uncoordinated 'bunch of loose ends'" (Cyranoski, 2001) "with limited synergies between them" (OECD, 2007), the envisaged big-question approach implies profound structural and organizational changes. Structurally, the approach proposes that the foundational (industry-related) research questions branch out into various streams of supporting research and more specific short-term research topics. Within such a framework, a variety of Chinese universities and research institutions can be recruited and coordinated at different levels towards solving the big question.

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It is important to note that although this big-question strategy is at a consultation stage and supervised by the Ministry of Science and Technology (MOST), the idea itself has emerged in a bottom-up manner. One academic who is involved in the ongoing ministerial consultation recounted that, "It [the big-question approach] was initially conversations among we scientists over the past couple of years. We saw this as an alternative way to keep up with international development and possibly lead to some scientific breakthrough. But we are happy to see that the Ministry is excited and wants to support such an idea as well." As many technicalities remain to be addressed, there is no clear time-frame yet for when the project will be launched. Yet, this nationwide cooperation among scientists with an emerging commitment from MOST seems to be largely welcomed by researchers. Some interviewees described the excitement it generated among the Chinese scientific community as comparable with the establishment of "a new 'moon-landing' project".

Of greater significance than the timeframe is the development process that led to this proposition. On the one hand, the emergence of synthetic biology in China has a cosmopolitan feel: cross-border initiatives such as international student competitions, transnational funding opportunities and social debates in Western countries—for instance, about biosafety—all have an important role. On the other hand, the development of synthetic biology in China has some national particularities. Factors including geographical proximity, language, collegial familiarity and shared interests in economic development have all attracted Chinese scientists to the national strategy, to keep up with their international peers. Thus, to some extent, the development of synthetic biology in China is an advance not only in the material synthesis of the 'cosmos'—the physical world—but also in the social synthesis of aligning national R&D resources and actors with the global scientific community.

To comprehend how Chinese scientists have used national particularities and global research trends as mutually constructive influences, and to identify the implications of this for governance, this essay examines the emergence of synthetic biology in China from three perspectives: its initial activities, the evolution of funding opportunities, and the ongoing debates about research governance.

> **...training for iGEM has grown beyond winning the student awards and become a key component of exchanges between Chinese researchers and the international community**

China's involvement in synthetic biology was largely promoted by the participation of students in the International Genetically Engineered Machine (iGEM) competition, an international contest for undergraduates initiated by the Massachusetts Institute of Technology (MIT) in the USA. Before the iGEM training workshop that was hosted by Tianjin University in the Spring of 2007, there were no research records and only two literature reviews on synthetic biology in Chinese scientific databases (Zhao & Wang, 2007). According to Chunting Zhang of Tianjin University—a leading figure in the promotion of synthetic biology in China—it was during these workshops that Chinese research institutions joined their efforts for the first time (Zhang, 2008). From the outset, the organization of the workshop had a national focus, while it engaged with international networks. Synthetic biologists, including Drew Endy from MIT and Christina Smolke from Stanford University, USA, were invited. Later that year, another training camp designed for iGEM tutors was organized in Tianjin and included delegates from Australia and Japan (Zhang, 2008).

Through years of organizing iGEM-related conferences and workshops, Chinese universities have strengthened their presence at this international competition; in 2007, four teams from China participated. During the 2010 competition, 11 teams from nine universities in six provinces/municipalities took part. Meanwhile,

recruiting, training and supervising iGEM teams has become an important institutional programme at an increasing number of universities.

It might be easy to interpret the enthusiasm for the iGEM as a passion for winning gold medals, as is conventionally the case with other international scientific competitions. This could be one motive for participating. Yet, training for iGEM has grown beyond winning the student awards and has become a key component of exchanges between Chinese researchers and the international community (Ding, 2010). Many of the Chinese scientists interviewed recounted the way in which their initial involvement in synthetic biology overlapped with their tutoring of iGEM teams. One associate professor at Tianjin University, who wrote the first undergraduate textbook on synthetic biology in China, half-jokingly said, "I mainly learnt [synthetic biology] through tutoring new iGEM teams every year."

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Participation in such contests has not only helped to popularize synthetic biology in China, but has also influenced local research culture. One example of this is that the iGEM competition uses standard biological parts (BioBricks), and new BioBricks are submitted to an open registry for future sharing. A corresponding celebration of open-source can also be traced to within the Chinese synthetic-biology community. In contrast to the conventional perception that the Chinese scientific sector consists of a "very large number of 'innovative islands'" (OECD, 2007; Zhang, 2010), communication between domestic teams is quite active. In addition to the formally organized national training camps and conferences, students themselves organize a nationwide, student-only workshop at which to informally test their ideas.

More interestingly, when the author asked one team whether there are any plans to set up a 'national bank' for hosting designs from Chinese iGEM teams, in order to benefit domestic teams, both the tutor and team members thought this proposal a bit "strange". The team leader responded, "But why? There is no need. With BioBricks, we can get any parts we want quite easily. Plus, it directly connects us with all the data produced by iGEM teams around the world, let alone in China. A national bank would just be a small-scale duplicate."

From the beginning, interest in the development of synthetic biology in China has been focused on collective efforts within and across national borders. In contrast to conventional critiques on the Chinese scientific community's "inclination toward competition and secrecy, rather than openness" (Solo & Pressberg, 2007; OECD, 2007; Zhang, 2010), there seems to be a new outlook emerging from the participation of Chinese universities in the iGEM contest. Of course, that is not to say that the BioBricks model is without problems (Rai & Boyle, 2007), or to exclude inputs from other institutional channels. Yet, continuous grass-roots exchanges, such as the undergraduate-level competition, might be as instrumental as formal protocols in shaping research culture. The indifference of Chinese scientists to a 'national bank' seems to suggest that the distinction between the 'national' and 'international' scientific communities has become blurred, if not insignificant.

However, frequent cross-institutional exchanges and the domestic organization of iGEM workshops seem to have nurtured the development of a national synthetic-biology community in China, in which grass-roots scientists are comfortable relying on institutions with a cosmopolitan character—such as the BioBricks Foundation—to facilitate local research. To some extent, one could argue that in the eyes of Chinese scientists, national and international resources are one accessible global pool. This grass-roots interest in incorporating local and global advantages is not limited to student training and education, but also exhibited in evolving funding and regulatory debates.

In the development of research funding for synthetic biology, a similar bottom-up consolidation of national and global resources can also be observed. As noted earlier, synthetic-biology research in China is in its infancy. A popular view is that China has the potential to lead this field, as it has strong support from related disciplines. In terms of genome sequencing, DNA synthesis, genetic engineering, systems biology and bioinformatics, China is "almost at the same level as developed countries" (Pan, 2008), but synthetic-biology research has only been carried out "sporadically" (Pan, 2008; Huang, 2009). There are few nationally funded projects and there is no discernible industrial involvement (Yang, 2010). Most existing synthetic-biology research is led by universities or institutions that are affiliated with the Chinese Academy of Science (CAS). As one CAS academic commented, "there are many Chinese scientists who are keen on conducting synthetic-biology research. But no substantial research has been launched nor has long-term investment been committed."

The initial undertaking of academic research on synthetic biology in China has therefore benefited from transnational initiatives. The first synthetic-biology project in China, launched in October 2006, was part of the 'Programmable Bacteria Catalyzing Research' (PROBACTYS) project, funded by the Sixth Framework Programme of the European Union (Yang, 2010). A year later, another cross-border collaborative effort led to the establishment of the first synthetic-biology centre in China: the Edinburgh University–Tianjing University Joint Research Centre for Systems Biology and Synthetic Biology (Zhang, 2008).

Student contests, funding programmes, joint research centres and coordination groups are only a few of the means by which scientists can drive synthetic biology forward in China

There is also a comparable commitment to national research coordination. A year after China's first participation in iGEM, the 2008 Xiangshan conference focused on domestic progress. From 2007 to 2009, only five projects in China received national funding, all of which came from the National Natural Science Foundation of China (NSFC). This funding totalled ¥1,330,000 (approximately £133,000; www.nsfc.org), which is low in comparison to the £891,000 funding that was given in the UK for seven Networks in Synthetic Biology in 2007 alone (www.bbsrc.ac.uk).

One of the primary challenges in obtaining funding identified by the interviewees is that, as an emerging science, synthetic biology is not yet appreciated by Chinese funding agencies. After the Xiangshan conference, the CAS invited scientists to a series

of conferences in late 2009. According to the interviewees, one of the main outcomes was the founding of a 'China Synthetic Biology Coordination Group'; an informal association of around 30 conference delegates from various research institutions. This group formulated a 'regulatory suggestion' that they submitted to MOST, which stated the necessity and implications of supporting synthetic-biology research. In addition, leading scientists such as Chunting Zhang and Huanming Yang—President of the Beijing Genomic Institute (BGI), who co-chaired the Beijing Institutes of Life Science (BILS) conferences—have been active in communicating with government institutions. The initial results of this can be seen in the MOST 2010 Application Guidelines for the National Basic Research Program, in which synthetic biology was included for the first time, among 'key supporting areas' (MOST, 2010). Meanwhile, in 2010, NSFC allocated ¥1,500,000 (approximately £150,000) to synthetic-biology research, which is more than the total funding the area had received in the past three years.

The search for funding further demonstrates the dynamics between national and transnational resources. Chinese R&D initiatives have to deal with the fact that scientific venture-capital and non-governmental research charities are underdeveloped in China. In contrast to the EU or the USA, government institutions in China, such as the NSFC and MOST, are the main and sometimes only domestic sources of funding. Yet, transnational funding opportunities facilitate the development of synthetic biology by alleviating local structural and financial constraints, and further integrate the Chinese scientific community into international research.

In comparison to the increasingly visible grass-roots efforts, the role of the Chinese government seems relatively small at this stage

This is not a linear 'going-global' process; it is important for Chinese scientists to secure and promote national and regional support. In addition, this alignment of national funding schemes with global research progress is similar to the iGEM experience, as it is being initiated through informal bottom-up associations between scientists, rather than by top-down institutional channels.

As more institutions have joined iGEM training camps and participated in related conferences, a shared interest among the Chinese scientific community in developing synthetic biology has become visible. In late 2009, at the conference that founded the informal 'coordination group', the proposition of integrating national expertise through a big-question approach emerged. According to one professor in Beijing—who was a key participant in the discussion at the time—this proposition of a nationwide synergy was not so much about 'national pride' or an aim to develop a 'Chinese' synthetic biology, it was about research practicality. She explained, "synthetic biology is at the convergence of many disciplines, computer modelling, nano-technology, bioengineering, genomic research etc. Individual researchers like me can only operate on part of the production chain. But I myself would like to see where my findings would fit in a bigger picture as well. It just makes sense for a country the size of China to set up some collective and coordinated framework so as to seek scientific breakthrough."

From the first participation in the iGEM contest to the later exploration of funding opportunities and collective research plans, scientists have been keen to invite and incorporate domestic and international resources, to keep up with global research. Yet, there are still regulatory challenges to be met.

The reputation of "the 'wild East' of biology" (Dennis, 2002) is associated with China's previous inattention to ethical concerns about the life sciences, especially in embryonic-stem-cell research. Similarly, synthetic biology creates few social concerns in China. Public debate is minimal and most media coverage has been positive. Synthetic biology is depicted as "a core in the fourth wave of scientific development" (Pan, 2008) or "another scientific revolution" (Huang, 2009). Whilst recognizing its possible risks, mainstream media believe that "more people would be attracted to doing good while making a profit than doing evil" (Fang & He, 2010). In addition, biosecurity and biosafety training in China are at an early stage, with few mandatory courses for students (Barr & Zhang, 2010). The four leading synthetic-biology teams I visited regarded the general biosafety regulations that apply to microbiology laboratories as sufficient for synthetic biology. In short, with little social discontent and no imminent public threat, synthetic biology in China could be carried out in a 'research-as-usual' manner.

Yet, fieldwork suggests that, in contrast to this previous insensitivity to global ethical concerns, the synthetic-biology community in China has taken a more proactive approach to engaging with international debates. It is important to note that there are still no synthetic-biology-specific administrative guidelines or professional codes of conduct in China. However, Chinese stakeholders participate in building a 'mutual inclusiveness' between global and domestic discussions.

The experience of China in synthetic biology demonstrates the power of grass-roots, cross-border engagement to promote contemporary research

One of the most recent examples of this is a national conference about the ethical and biosafety implications of synthetic biology, which was jointly hosted by the China Association for Science and Technology, the Chinese Society of Biotechnology and the Beijing Institutes of Life Science CAS, in Suzhou in June 2010. The discussion was open to the mainstream media. The debate was not simply a recapitulation of Western worries, such as playing god, potential dual-use or ecological containment. It also focused on the particular concerns of developing countries about how to avoid further widening the developmental gap with advanced countries (Liu, 2010).

In addition to general discussions, there are also sustained transnational communications. For example, one of the first three projects funded by the NSFC was a three-year collaboration on biosafety and risk-assessment frameworks between the Institute of Botany at CAS and the Austrian Organization for International Dialogue and Conflict Management (IDC).

Chinese scientists are also keen to increase their involvement in the formulation of international regulations. The CAS and the Chinese Academy of Engineering are engaged with their peer institutions in the UK and the USA to "design more robust frameworks for oversight, intellectual property and international cooperation" (Royal Society, 2009). It is too early to tell

what influence China will achieve in this field. Yet, the changing image of the country from an unconcerned wild East to a partner in lively discussions signals a new dynamic in the global development of synthetic biology.

From self-organized participation in iGEM to bottom-up funding and governance initiatives, two features are repeatedly exhibited in the emergence of synthetic biology in China: global resources and international perspectives complement national interests; and the national and cosmopolitan research strengths are mostly instigated at the grass-roots level. During the process of introducing, developing and reflecting on synthetic biology, many formal or informal, provisional or long-term alliances have been established from the bottom up. Student contests, funding programmes, joint research centres and coordination groups are only a few of the means by which scientists can drive synthetic biology forward in China.

However, the inputs of different social actors has not led to disintegration of the field into an array of individualized pursuits, but has transformed it into collective synergies, or the big-question approach. Underlying the diverse efforts of Chinese scientists is a sense of 'inclusiveness', or the idea of bringing together previously detached research expertise. Thus, the big-question strategy cannot be interpreted as just another nationally organized agenda in response to global scientific advancements. Instead, it represents a more intricate development path corresponding to how contemporary research evolves on the ground.

In comparison to the increasingly visible grass-roots efforts, the role of the Chinese government seems relatively small at this stage. Government input—such as the potential stewardship of the MOST in directing a big-question approach or long-term funding—remain important; the scientists who were interviewed expend a great deal of effort to attract governmental participation. Yet, China's experience highlights that the key to comprehending regional scientific capacity lies not so much in what the government can do, but rather in what is taking place in laboratories. It is important to remember that Chinese iGEM victories, collaborative synthetic-biology projects and ethical discussions all took place before the government became involved. Thus, to appreciate fully the dynamics of an emerging science, it might be necessary to focus on what is formulated from the bottom up.

The experience of China in synthetic biology demonstrates the power of grass-roots, cross-border engagement to promote contemporary research. More specifically, it is a result of the commitment of Chinese scientists to incorporating national and international resources, actors and social concerns. For practical reasons, the national organization of research, such as through the big-question approach, might still have an important role. However, synthetic biology might be not only a mosaic of national agendas, but also shaped by transnational activities and scientific resources. What Chinese scientists will collectively achieve remains to be seen. Yet, the emergence of synthetic biology in China might be indicative of a new paradigm for how research practices can be introduced, normalized and regulated.

CONFLICT OF INTEREST

The author declares that she has no conflict of interest.

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