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Emerging Biotechnology Case Study: DIY Biology and the Case of the Glowing Plants [1]

In 2013, the Glowing Plant Project raised money to fund amateur biologists attempting to insert a firefly gene into a small flowering plant called *Arabidopsis thaliana*. The amateur scientists aimed to create a plant that would emit green light once its modified genome prompted it to produce bioluminescent enzymes, such as *Luciferase*. The project advertised on the popular crowd-sourcing website, Kickstarter, and raised close to $500 000 (https://www.kickstarter.com/projects/antonyevans/glowing-plants-natural-lighting-with-no-electricit). The initiators of the campaign promised that, if successful, supporters would receive the seeds of the genetically modified plants to grow wherever they wanted. The distribution of these seeds would not be subject to any institutional regulation, required for other bio-engineering companies, like Monsanto, that determines whether new GMOs are safe for humans and whether they pose any environmental risks (Grushkin 2013).

The initiators of the project believed that the Glowing Plant project would popularize new technologies in synthetic biology, such as gene-writing software and the creation of synthetic DNA, and perhaps also inspire and educate the broader public about these new biotechnologies. However, many scientists objected to the project's goals and Kickstarter eventually revised its guidelines to prohibit the distribution of GMOs as a reward for investment. Several critics of the project deemed it controversial.

On the one hand, some scientists argued that the project's aims were frivolous and did not contribute to the development of any beneficial applications. For that reason, they believed the risk of releasing GM plants to the general public, and thus into the wild, with potentially detrimental consequences, was too great. Others simply criticized the project for being biochemically unfeasible, claiming that the small plants would not be able to produce enough energy to glow for any extended period of time. The objections to the Glowing Plant Project led to other fund-raising campaigns, like Kickstopper, intending to stop all projects involved with GMOs.

On the other hand, supporters of the project emphasized the potential of DIY biology projects, such as the Glowing Plant Project, to democratize science and encourage creativity and innovation to help solve real-world problems. They also downplayed the risks involved in both the procedure of genetically modifying these plants and their potential release into the environment. The researchers behind the Glowing Plant Project explained that they would insert the genes using a ballistics-powered device, called a gene gun, rather than using a bacterial transfection vehicle, such as *Agrobacterium* (Callaway 2013). Because of the gene-gun method, the project lay beyond the jurisdiction of the US Department of Agriculture (USDA). Second, they claimed that both the plant species and the gene circuitry that the scientists proposed to use in the project are well-studied and well-understood systems and do not pose safety risks to humans or the environment.

Discussion Questions:

- What are the ethical, social and legal issues in the case of the glowing plants in DIY biology, and in DIY biology more generally?

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- Should DIY biology be subject to government oversight? Or should it be self-regulated by members of the DIY biology community? What are the potential trade-offs in governmental oversight compared to a system of self-regulation?
- What kinds of institutions, if any, should regulate DIY biology projects?
- Should Kickstarter have banned the distributions of GMOs as rewards for DIY biology project supporters?

Content Commentary

Projects within DIY biology are often thought to be part of a political movement that represents "a material re-distribution, a democratization, and an alternative to established, technoscience" (Meyer 2012). The very politics of transparency and accessibility of the DIY biology movement is what generates many ethical, social, and environmental concerns about biosafety and biosecurity (e.g. bioterrorism). The movement also invokes larger questions about governance and the regulation of scientific research.

Bioengineering research and development outside of academic and research institutions raise concerns about the potential release of harmful biological materials into the environment, and its potential effects on human health. The challenges of assessing and managing risks in this area are even greater given our current limited knowledge about complex adaptive systems, from microorganisms to ecosystems. That level of uncertainty and unpredictability poses serious concerns: "Experimentation with living organisms […] is problematic because they are self-replicating and transmissible, so they pose many hazards that one would not encounter in many other types of do-it-yourself science" (Wolinsky 2009).

However, many projects in bioengineering, including projects in DIY biology, promise beneficial applications of the new biotechnologies and the new modified organisms. For example, members in the DIY biology community have made efforts to develop biosensors and biomarkers, such as DNA bar coding, intended to improve food safety (Landrain *et al*. 2013). Critics of the Glowing Plant Project argue that it has no purported benefits of improving human health, safety, or the environment, whereas its promise of distributing genetically modified seeds to its supporters presents a potential risk to the environment. Supporters of the project have responded by claiming that basic scientific research motivated by pure curiosity often leads to beneficial applications down the road. The CEO of the project, Antony Evans, suggested that a future goal of the project could be the development of a biotechnology that could replace street lamps with glowing trees, which might help to reduce carbon dioxide emissions and the modified glowing trees would last longer than most current street lamps.

The issue of balancing potential risks and benefits in the development of this new biotechnology invokes a larger ethical issue. The main concern isn't solely about the potential release of harmful biological materials into the environment, but rather about the lack of regulatory oversight that might set dangerous precedents for future projects. Given these concerns, questions arise about what kinds of oversight agents or bodies should regulate citizen-science movements, such as DIY biology, and the extent to which these projects ought to be regulated.

Currently, the DIY biology community is self-regulated (Wolinsky 2009; Landrain *et al*. 2013). In the case of the Glowing Plant Project, the modified plants are beyond the jurisdiction of the Animal and Plant Health Inspection Service (APHIS), an agency of the US Department of Agriculture (USDA), because the agency only regulates genetically modified plants if plant pathogens are part of the process. A common method to produce genetically modified plants makes use of a plant pathogen, *Agrobacterium*, to transfect foreign genes into new host cells. But, the scientists at the Glowing Plant Project sidestepped this method by using a gene gun instead, and dodged the legal and regulatory oversight of the APHIS. Because of that, detractors have also criticized the project for capitalizing on a regulatory loophole.

Despite that criticism, the DIY biology community has considered some of the worries about the release of harmful biological material. They have taken a "bottom-up" approach to self-governance by drafting a code of ethics and by encouraging transparency and collaborations with public authorities (Landrain *et al.* 2013). However, the extent to which members of the community follow this code remains questionable (Evans & Selgelid 2014).

An additional challenge for DIY biology is how potentially beneficial innovations, if and when they are developed, will fit into current social institutions and economic and political arrangements. Take the case of drug development as an example. There is much more to that process than developing a new drug to which a current disease has no resistance (Evans & Selgelid 2014). There needs to be knowledge about how and when to use the drug correctly, about drug resistance, and about the manufacturing and distribution processes, which invoke many economic and sometimes political challenges (Evans & Selgelid 2014). Thus, as Evans and Selgelid have argued, any benefits that come out of DIY biology efforts will be "contingent on the performance of other institutions, including but not limited to health and security establishments" (Evans & Selgelid 2014, 1076).

Lastly, a difficult question regarding governance and the regulation of DIY biology concerns finding the right scope and balance of regulation. On the one hand, ensuring global and national biosecurity and biosafety, and protecting the environment, are paramount. On the other hand, too much regulation may lead to underground operations that are more difficult to track and might pose a greater risk (Wolinsky 2009). Landrain *et al.* sum up the challenge accordingly:

> "The regulation and governance of DIY biology calls for a balancing act: to collectively set ethical standards without alienating individuals, to establish a global set of principles that makes sense in local contexts, to be close enough to authorities, yet far enough to avoid losing the counter-cultural and innovative edge that DIYbio stands for" (Landrain *et al.* 2013).

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