# iGEM: A case study for open source biological engineering

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## Introduction

The international Genetically Engineered Machines (iGEM) competition challenges students during the summer break to engineer genetic devices using standard genetic parts. iGEM is structured very similarly to open source software development projects, where large groups of developers contribute to a common end product, only in this case, the end products are the parts and part experience maintained by the Registry of Standard Biological Parts. iGEM provides a unique opportunity to examine the practical use of open source biology.

Here, using data and experiences collected from five years of iGEM competition, we review some of the successes and challenges of open biology, and discuss how these findings are helping further the development of a robust and sustainable bioeconomy in Alberta.

## Alberta Biotechnology

Biotechnology use is expanding globally. With abundant natural resources, a highly trained population, exceptional research facilities, and economic growth unrivalled in Canada, Alberta is well-positioned for bioindustry. The challenge is to create critical mass. The biotechnology industry is a stable monopoly, with no new major players in 20 years (Table 1).

The $1B Alberta Ingenuity Fund (AIF) works to foster a rich and diverse bioeconomy in Alberta. As part of this effort, it is creating five $100M *Accelerators* in advanced technologies, including nanotechnology and information and computer technology. Synthetic biology – a potentially disruptive technology that aspires to programming life forms rapidly, cheaply, and reliably – is under consideration as an emerging cornerstone platform for Accelerator development.

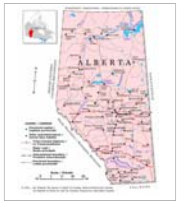

**Figure 1.** The province of Alberta and its location within Canada.

Distant from the biotech hubs in Boston and California, disruptive business models may also be necessary to spur development. Open source biology, the biotechnological equivalent of open software, could prove an efficient stimulus, if the practical dynamics of the model could be understood. To better examine open biology, AIF is supporting three iGEM teams in Alberta in 2007.

**Table 1.** North American biotech companies with market capitalizations > $5B

| Company | Mkt Cap ($B) | Revenues $B | Employees | Year Founded |
|---|---|---|---|---|
| Genentech | 81.1 | 10.14 | 10,533 | 1976 |
| Amgen | 66.5 | 14.74 | 20,000 | 1980 |
| Gilead Science | 32.3 | 3.36 | 2515 | 1987 |
| Celgene | 22.2 | 1.01 | 1287 | 1980 |
| Biogen Idec | 17.6 | 1.95 | 3750 | 1985 |
| Genzyme | 17.2 | 3.34 | 9000 | 1981 |
| Medimmune | 13.8 | 1.35 | 2359 | 1987 |
| Amylin Pharma | 5.4 | 0.6 | 1550 | 1987 |

Yahoo Finance, June 9, 2007

## iGEM Overview

Briefly, iGEM works to organize undergraduate student teams worldwide to experiment with standardized biological parts called *BioBricks*™ (Endy, 2005). Created by MIT, the program is the first large-scale effort that applies open source principles to biotechnology. Now in its fifth year of operation, iGEM provides a unique case study for evaluating open biology.

At the start of each competition, which runs from May to November, teams are provided with a distribution of available parts from the Registry of Standard Biology Parts (the Registry), as well as access to online resources describing their specifications, use, and end-user experiences. Teams use these parts to create biological machines of their own design. If necessary, new parts can be created using BioBrick design rules. Competition rules dictate that data and new parts be deposited in the Registry, creating a positive feedback loop. Teams seek independent funding, distributing operational costs.

**Figure 2.** Some of the 350 student participants at the 2006 iGEM competition. (Photo: R. Rettberg)

**Figure 3.** Examples of iGEM-related media coverage. iGEM work enjoys a positive media bias although involving genetically-modified organisms.

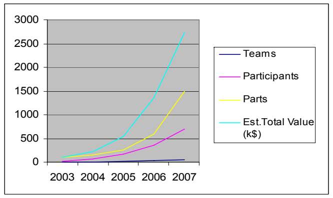


**Figure 4.** Growth dynamics of the iGEM program. The total value of the BioBrick™ collection was estimated by the formula ∑ (number teams * $25K (avg. funds raised per team, R. Rettberg, personal communication)). This dollar figure may be conservative, as many teams do not pay student stipends.

**Figure 5.** Towards commercialization: The 2006 Edinburgh iGEM team (left) and the bacteria-based biosensor they developed to test for arsenic water contamination. If approved, the test could significantly improve arsenic detection yet cost only pennies per use.

## Successes and Challenges

•Rapid growth
•Distributed cost
•Powerful student experience
•Merit-based results
•Even playing field
•Growing parts registry
•Growing user experience
•Successful projects
•Quality publications
•Positive media bias
•Public outreach and awareness
•Active, empowered community
•Seeding educational programs and reforms
•Teams attracting funding
•Potential for low cost biological end-products

•Managing rapid growth
•Lacks clear licensing, IP, and commercialization policies
•Registry software development and standards
•Core funding and support
•Creation of regional offices
•Part quality and documentation
•Low adoption of parts outside the iGEM community

## Conclusions

iGEM is successful, as measured by rate of growth, the number of teams and students, and aggregate dollar value of the Registry's library of standard genetic parts. Many teams also realize their project design goals in only a few months. By pooling the efforts of a diverse community of developers and distributing dollar costs, the open development model used by iGEM appears capable of growing the value of a shared resource (the Registry) and of accelerating applied biological engineering.

iGEM also generates numerous ancillary returns, including positive media, community outreach, and educational development. The program is continues to attract high quality institutions and students and produces a valuable educational experience for students. Many institutions choose to establish formal synthetic biology courses or programs following participation in iGEM.

As a business model, the litmus test for open biology will be whether it can lead to commercial products and make money (Henkel and Maurer, 2007). If it can, companies will eventually adopt it for development. Today, with no open source biology companies, the relative economic merit of exchanging proprietary rights for access to pooled community resources cannot be determined. However, iGEM suggests that, for some applications, the model could be viable.

For Alberta, open biology could help stimulate growth and interest in biotechnologies by making the technology more accessible and reducing overheads. Participation in iGEM is permitting low-risk, low-cost evaluation of the potentials of synthetic biology and open source, with the added benefit of improving undergraduate biology education.

## Literature cited

Endy, D. 2005. Foundations for engineered biology. *Nature* 438:449-453

Henkel, J. Maurer, S.M. 2007. The economics of synthetic biology. *Molecular System Biology* 3:117

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The Alberta Ingenuity Fund supports advanced science and engineering research in areas with long lasting social and economic impact.

## For further information

Please contact *ahessel@gmail.com*. A copy of this poster can be found online at http://openwetware.org/wiki/Andrew_Hessel. Further information about the iGEM competition, the Registry, and the use of standardized biological parts can be found at *www.igem2007.com*. To learn more about BioBricks™, see *www.biobricks.org*. For detailed information about Alberta Ingenuity, go to *www.albertaingenuity.ca*