Canadian Friends Service Committee
(QUAKERS)

Information Kit
for
Consultation and Discernment Process
on
Synthetic Biology
for
Monthly Meetings of Canadian Yearly Meeting

April 2013

This kit was prepared by Canadian Friends Service Committee's Quaker Peace and Sustainable Communities Program Committee (QPASCC).
Primary Authors: Fred Bass, Gianne Broughton and Anne Mitchell.

This kit is available for download from the CFSC website at: www.bit.ly/SynthBioKit
(Note, this link will re-route you to the CFSC website, it is simply a short cut).

Information Kit for
Consultation and Discernment Process on *Synthetic Biology* for
Monthly Meetings of Canadian Yearly Meeting

Why is this process needed?

Synthetic biology is a complex subject. It touches on major issues that confront our world. The well-motivated and spiritually-guided people of Canadian Monthly Meetings, by exploring the issues, potential benefits and potential conflicts raised by synthetic biology, will make an important contribution.

A new technology, synthetic biology, is growing very rapidly. It combines biology, engineering and other fields to literally manufacture new and unique forms of life. It has developed only a half-century after the structure of DNA, the key molecule that controls all cell growth, was identified. Synthetic (artificial) biology (life) is likely to have a very significant impact for humans, yet few of us are aware of its existence and the risks and benefits it offers. Prudent consideration is essential. Prudence should be found in science and ethics, and through the guidance that spiritual discernment offers. The testimonies of the Religious Society of Friends (Quakers),are highly appropriate for this topic and Friends' input is warranted and needed.

The concern about synthetic biology was first brought to CFSC (via QPASCC) by the Canadian Council of Churches' (CCC) Biotechnology Reference Group early in 2012 when they invited comment on their endorsement of *The Principles for the Oversight of Synthetic Biology.* These principles embody the "precautionary principle"[1] well, but QPASCC felt that spiritual aspects of the concern were absent. CFSC board member Fred Bass facilitated a discernment meeting at Vancouver Monthly Meeting, and then a Special Interest Group at Canadian Yearly Meeting (CYM).

At the 2012 annual sessions of Canadian Yearly Meeting, a minute was approved requested Canadian Friends Service Committee (CFSC) to consult Monthly Meetings across Canada towards developing a Canadian Quaker perspective on synthetic biology. **This kit has been created to support the requested consultation, which will culminate at Canadian Yearly Meeting in session in August 2014.**

Since last summer, QPASCC has been in touch with the relevant branch of the federal government. They welcomed our interest, and have begun to engage with the CCC's Biotechnology Reference Group. The results of this consultation with Meetings will be shared through that channel, among others. Details of this communication are given in Section 3.3.1.

Because this concern may seem quite new to many Friends, and because of the newness of the science behind the technology, we have provided quite a lot of resource information. But in some ways, the issues are not new. This is yet another place where the market economy

[1] The "Precautionary Principle" indicates that if a new action or policy may cause severe or irreversible harm to an individual, a community or the general public, in the absence of full scientific certainty that harm would not ensue, the burden of proof falls on those who would advocate taking the action.

and the sharing of the ecological commons clash. We hope the material raises readers' ethical and spiritual antennae. This consultation process will be a sharing of what those antennae have perceived. Please read what your time and energy allow and then participate in your monthly meeting's discussion to voice a concern, to ask question, to help in the discernment.

Contents of the Information Kit

The kit is organized into three sections:

Section 1: An Outline of a Study and Discernment Process
Section 2: Three Suggested Queries
Section 3: Basic Information and References on Synthetic Biology

Four booklets published by the Quaker Institute for the Future (QIF) are being distributed with this kit to each Monthly Meeting. These are also available for download (see below for links). The booklets address the issues raised by the clash between the market economy and the commons in the context of biotechnology, of which synthetic biology is a recent development. Below is a brief summary of the points each booklet raises:

How on Earth Do We Live Now? Natural Capital, Deep Ecology, and the Commons (QIF #2)
http://www.quakerinstitute.org/wp-content/uploads/2011/05/HowonEarth-final.pdf

> … The critical factors of ecological integrity and social equity are compromised and unhinged by an economy that is both dysfunctional and out of control. This pamphlet asks, "how on Earth do we live now?" as both a cry of alarm and a call to action. It views our dilemma through the lens of "natural capital" and the lens of "deep ecology." It explores two essential parts of Earth's commons: property and water. It looks at systems of governance for the commons, and human nature's capacity for collaborative action on behalf of the common good. It concludes by considering what Quakers, and all others who place a high value on the ethics of right relationship, can bring to the task of rebuilding environmental integrity and advancing social equity at home and worldwide.

Genetically Modified Crops: Promises, Perils, and the Need for Public Policy (QIF #2)
http://www.quakerinstitute.org/wp-content/uploads/2011/08/BiotechPamphlet-final-2.pdf

> … For several decades, large agri-business corporations, utilizing a growing range of biotechnologies, have claimed the use of their products is the only way to feed the world. A key factor on which they pinned their forecast was the increased use of genetically modified (GM) crops. This pamphlet assesses this claim in the light of current evidence. It surveys the controversy over agricultural biotechnology and the role of public policy in the regulation of transgenic crops. It places biotechnology within an ethical context of concern for equity, the environment, and the common good. It presents a framework for understanding the varieties of biotechnologies and for gauging strategic action on public policy.

It's the Economy, Friends: Understanding the Growth Dilemma (QIF #5)
http://www.quakerinstitute.org/wp-content/uploads/2012/06/IEF-web.pdf

> …With the world's dominant economic system now struggling to recover from near collapse, it is important to ask: "What is the economy for?" It is no longer appropriate to seek increased material

wealth through unconstrained economic growth. In 2009 Quaker Institute for the Future (QIF) published the book *Right Relationship: Building a Whole Earth Economy* which concluded that "the purpose of the economy is to preserve and enhance the integrity, resilience, and beauty of the whole commonwealth of life." It's the Economy, Friends is aimed at understanding the dilemma that the unremitting drive for growth creates within the limited ecosystems of Earth.

Beyond the Growth Dilemma: Toward an Ecologically Integrated Economy (QIF #6)
http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf

...builds a framework for the changes that are needed to lead us to an ecologically integrated economy. This kind of economy leads to prosperous and thriving lives for humans and other creatures within the limits of planet Earth. Our society's basic goal must change from "more" to "enough." Changes in the way we earn our livelihoods, goods are produced, money is created, and the commons are governed are all considered.

Please Note: QIF suggests donations of $3-$5 for each booklet downloaded; see:
http://www.quakerinstitute.org/?page_id=89

Note: All websites referenced in this information kit are gathered, in order, in a list in Appendix Three of the kit.

Section 1: An Outline of a Study and Discernment Process

The table below is a suggested process for organizing study and discernment in the response to this request for consultation. Each Monthly Meeting (MM) will undoubtedly develop its own approach but may find the following to be a useful guideline.

Please inform QPASCC by June 30, 2013 of the decision about whether or not your Meeting wishes to engage in this discernment or not, and please send in a report of discussions by December 31, 2013. Contact: qpasc@quakerservice.ca

Timing	Activity
By June 30, 2013	a) The Meeting decides whether or not to participate in the consultation process, and informs qpasc@quakerservice.ca b) If the Meeting decides to participate, it forms a Synthetic Biology study group including at least three roles—a clerk, a recorder (a different person than the clerk) and someone comfortable using the internet. Please inform QPASCC about the study group members.
Preparation for the first MM consultation meeting	The study group: a) Reads enclosed information, the four Quaker Institute for the Future booklets, and consults the internet links in Appendix Three. b) If there are interested Meeting members who do not have easy access to the internet, the group makes hard copies of internet info for the Meeting library, or otherwise makes the information available. c) Schedules two 2-hour study and discernment meetings at times convenient for interested Friends to attend, the first before October 1, 2013, the second before Dec. 1, 2013.
Before Oct. 1, 2013	The study group convenes Meeting One, concerned with reviewing persons' understanding of synthetic biology—what it is, its development so far, and issues that have arisen. Section 3 of this Information Kit can be handed out or e-mailed out prior to Meeting One. Questions and insights should be noted. The queries to be addressed in Meeting Two should be reviewed at the end of the meeting.
Before Dec. 1, 2013	The study group convenes Meeting Two, concerned with the three queries given in Section 2 below. The report should provide responses to the three queries. Further questions, insights, leadings and recommendations should also be noted.
Dec. 2013 (or earlier) Meeting for Worship for Business	The study group presents its report to the Meeting. The Meeting approves sending it on to QPASCC.
Before Dec 31, 2013	Final date for MM to send the report to QPASCC.
Before January 25,	QPASCC staff sends summary of MM responses to QPASCC in

2014	preparation for Spring CFSC Meeting (end of February 2014).
Before April 1, 2014	QPASCC/CFSC a) Provides a summary report for Documents in Advance for Yearly Meeting and sends a copy of the summary report to all MMs. The summary report will include a draft of a possible Yearly Meeting minute expressing whatever unity is evident from the consultation. b) Requests a Special Interest Group at Yearly Meeting to season the findings and the draft minute.
At Yearly Meeting, August 2014	QPASC convenes the Special Interest Group and reports its results to Yearly Meeting, which may approve a minute of record.

Please note: The information presented in Section 3 may stimulate stressful feelings. Friends may find the need for breaks for silent worship or for worship sharing or other means of caring as they go through the discernment process.

Section 2: The Three Suggested Queries

The Principles for the Oversight of Synthetic Biology (see section 3.3.2) provide a good framework for the precautionary regulation of the technology. Through the three suggested queries listed below, we invite Friends to share what the Spirit is prompting within them, and to consider them in the light of the Quaker testimonies, particularly the testimonies of equality, ecology, and simplicity.

By listening within, to the Spirit amongst us, we hope to address a perceived ethical deficit.

Queries:

1) How can Quakers use their spiritual insight to appraise the consequences, actual and potential, of synthetic biology and then, as thoughtful citizens, contribute to its development?

2) Do Quaker and other ethical values warrant the recommendation that some zones of organic processes and ecological relationships should be *off limits* for synthetic biology? If so, which ones?

3) What should Quakers testify to the world in regard to synthetic biology?

Section 3: Basic Information and Issues regarding Synthetic Biology

3.1 Synthetic Biology: What is it and what is the range of views about its role?

Synthetic biology is the use of computer-assisted, biological engineering to create new biological systems and forms of life that do not exist in nature.

In 2011, a U.S. Presidential Commission defined synthetic biology as "an emerging field of research that combines elements of biology, engineering, genetics, chemistry, and computer science… [It relies] on chemically synthesized DNA [a building block of all living cells], along with standardized and automatable processes, to create new biochemical systems or organisms with novel or enhanced characteristics."[2]

Proponents of synthetic biology see its potential for developing new materials (eg, a synthetic version of spider silk), foods (providing food in quantity in developing nations), medicines (eg, production of an anti-malarial drug), energy sources (eg. biofuels from algae), ways to remedy pollution (eg. detecting arsenic in water sources), and new means of computing. The military-industrial sector also sees potential weapons applications.

To exemplify the proponents' views, we have excerpted a page each from two sources. Though the excerpts are long, they give a good overview of the substance of the field. A comparison of the two demonstrates the way bias can permeate discourse (which of course can be true for various perspectives). There are also two six-minute videos on the SynBERC website (the synthetic biology center at the University of California) which are worth viewing[3]. The first uses animated graphics to depict what synthetic biology does at the genetic level: http://www.youtube.com/watch?v=rD5uNAMbDaQ. In the second one, SynBERC's Drew Endy, describes the foundational techniques of synthetic biology as an extension of genetic engineering: http://www.youtube.com/watch?v=XIuh7KDRzLk

Our first excerpt is from a review of *Regenesis: How synthetic biology will reinvent nature and ourselves* by Harvard genetics professor George Church and Ed Regis (2012):

> DNA was only discovered about a century ago, and its structure remained a mystery until about half a century ago, but since this time our knowledge and understanding of DNA has grown immensely (indeed exponentially). What's more, this understanding has evolved to include not just an understanding of how DNA works, but also how it can be manipulated to help advance our ends. The most glaring example here is the phenomenon of genetically modified food. Though not without controversy initially (and some fringe opposition that lives on to this day), it is fair to say that genetically modified food was one of the major scientific advances of the 20th century. Over and above this, our understanding of DNA appeared to reach its most impressive manifestation with the successful sequencing of the human genome in the year 2000.

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[2] Presidential for the Study of Bioethical Issues, "*New Directions: The Ethics of Synthetic Biology and Emerging Technologies"*, December 2010: http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-FAQ.pdf, p. 1. The full 177-page report is available at (copy and paste link for it to work): http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10_0.pdf

[3] http://www.synberc.org/content/resources

> … genetically modified food and the Human Genome Project are but the tip of the iceberg when it comes to the potential of genomics. Indeed, since the year 2005, the exponential growth rate in our ability to read and write DNA has increased from 1.5-fold per year (a rate that matches Moore's law), to the incredible rate of 10-fold per year... This explosion in scientific and technological progress has resulted in dramatic advancements in the areas of biochemicals, biomaterials, biofuels and biomedicine. What's more, advancements in these technologies are but in their incipient stage, and the future of genomics promises to dwarf these initial achievements...
>
> When it comes to the current state of the field, manipulating DNA has already allowed us to produce organisms with new features, such as foodstuffs with novel properties, greater productivity and nutritional value, and resistance to pathogens. Over and above this, micro-species have been programmed to do such things as detect impurities in drinking water, produce electricity from wastewater (and purify the wastewater in the process), produce blood, produce vaccines, take pictures, and even store information. Indeed, the potential to use DNA as a store of information is already recognized to be the likely next leap in computer science, and is poised to initiate a revolution in informatics (just imagine storing all of the information in Wikipedia [in every language] on a chip the size of a blood cell, for a cost of $1 for 100,000 copies).
>
> And, of course, the potential to manipulate genomes does not end with other species: it can also be extended to our own. Actualizing this potential is not far off, and includes such things as increasing intelligence, gaining full immunity to any pathogen (real or hypothetical), and dramatically extending the lifespan (if not eradicating mortality altogether).
>
> In addition to manipulating genomes for the purpose of creating organisms with new biological features, the productive capacity of the genome can also be exploited to produce new substances and materials, such as chemicals, plastics, fuels, drugs, and vaccines. Successes in each of these areas have already been achieved, and the field is on the cusp of scaling-up these processes to an industrial scale. What's more, manipulating genes shows the promise of expanding the current repertoire of the building blocks of substances and materials to produce a whole new array thereof. [4]

The second excerpt is from the website of the University of Washington (Seattle). The page is entitled, "Life: a 21st Century Technology":

> The term "synthetic biology" was first coined in 1974 by Polish geneticist Wacław Szybalski, but the field itself was born around the turn of the millennium as an offshoot of genetic engineering and molecular biology. Broadly speaking, synthetic biology refers to the creation of novel organisms or artificial life. While the term synthetic biology is provocative and, to some individuals, alarming in its implications, it is important to understand that this term is still quite visionary while the field itself remains limited in scope. What is meant by a "novel organism" is typically, but not always, a unicellular microorganism which can be manipulated through recombinant DNA technology and molecular biology. While some efforts in synthetic biology are concerned with creating living, molecular systems *de novo*, most current efforts in synthetic biology are concerned with altering or adding new features to already existing model organisms. Synthetic biology promises to enhance our fundamental understanding of life, while producing important technological solutions for the 21st century.
>
> The question, What is life? is one of the most fundamental questions in all of science. Synthetic biology provides insight into this question by explaining living systems in terms of engineering principles. In many ways, a living cell has similarities to familiar, artificial systems. Just as a thermostat regulates the temperature in a room, a cell possesses control mechanisms

[4] To go beyond the excerpt from the book, visit this site, where the book is summarized and illustrated by videos: http://newbooksinbrief.com/2012/10/30/23-a-summary-of-regenesis-how-synthetic-biology-will-reinvent-nature-and-ourselves-by-george-m-church-and-ed-regis/

that maintain its internal environment. From an engineering perspective, one might also describe a cell as a biological computer in which calculations are performed by molecular reactions. The computational properties of biochemical systems are a subject of study in Professor Georg Seelig's lab at UW.

Synthetic biology also considers the inverse problem, which is, How may life inspire new ideas about engineering? A living cell differs remarkably from classically engineered systems. For example, even the simplest of bacteria are controlled by bafflingly complex networks of genes, proteins, and other molecules. This complexity is a universal feature of life at all levels. One area of research in synthetic biology is concerned with how complex systems are assembled from simpler parts. For this reason, unraveling the complexity of biological systems requires the collaboration of researchers from diverse backgrounds, and the community of synthetic biology researchers at UW includes biologists, engineers, computer scientists, and physicists.

One goal of synthetic biology is to harness the creative power of nature to solve important technological challenges in energy, medicine, and environment. Over billions of years, evolution has generated innumerable lifeforms, each adapted to its own ecological niche. Many of these lifeforms have evolved solutions to problems of great importance to human beings, such as the capture of energy from sunlight, the production of medicinal compounds, and the neutralization of toxic waste. Many efforts in synthetic biology are focused on refactoring microorganisms to be used specifically for these purposes. Such biologically-based solutions are potentially sustainable, renewable, and compatible with naturally occurring eco-processes. Currently, several investigators at the University of Washington are collaborating in order to develop methods for sequestering carbon dioxide from the atmosphere and producing biofuels using re-engineered microorganisms.

Creating new life forms is a tricky business. Many of the current success stories in synthetic biology were the result of much trial-and-error experimentation. In order to make it easier to engineer living organisms, many researchers in the community are working to define design standards for biological parts. Standards have been essential in the success of classical engineering. For example, the nuts and bolts at your local hardware store come in standard sizes that greatly facilitate the assembly of the many kinds of machines that are ubiquitous in modern society. Similarly, standardized biological parts may make it easier to assemble cells from macromolecular components such as DNA, RNA, and proteins. However, this traditional engineering approach may be limited when applied to complex life forms. That's why in many cases, synthetic biologists use techniques collectively described as "directed evolution" to create novel biological functions. Faculty researchers at UW are developing standards for biological engineering, and at the same time employing "evolution in action".

Synthetic biology has emerged recently as a field of interest to many investigators, both public and private. Its recent rise is in coevolution with other, enabling technologies. Advances in microprocessing speed and information technology enable scientists to tackle complex biological questions. Whole-genome sequencing, DNA synthesis-to-order and whole-genome construction are successful commercial biotechnology ventures that will be essential for the synthesis of artificial life forms.

What are the perils of synthetic biology? Like many modern technologies, synthetic biology is a "dual-use" technology. Nuclear physics may be used to either power cities or alternatively destroy them. Chemistry may create either miracle cures or addictive drugs. Likewise, synthetic biology has the potential to serve in the interest of human society or to be used for nefarious purposes. Open dialog between the synthetic biology community and the public at large is necessary to ensure that the technology continues to be developed and applied in a safe and just manner. One of the goals of this website is to generate enthusiasm and interest among the public, especially among the younger generation for whom this emerging technology will have the most significant consequences.

> There is currently an ongoing debate about the best course to proceed with the development of synthetic biology. Some groups favor a "pre-cautionary" approach while others favor a "pro-actionary" approach. Ultimately, what lies at the heart of the these matters is often a question of personal ethics and values, especially in regard to how one perceives humankind and its relationship to nature[6]. On December 16th, 2010 the Presidential Commission on Bioethical Issues delivered a report to President Obama that weighed the potential benefits and harms of synthetic biology[7]. The report charts a course of "prudent vigilance" that steers midway between the pre-cautionary and pro-actionary philosophies. [5]

Those who are cautious about synthetic biology direct attention to what is absent in its development. They are concerned about what artificial organisms might do unexpectedly, since they have not yet existed in nature. They are concerned about the social justice aspects of synthetic biology: will the benefits of synthetic biology be distributed equitably among poor nations as well as wealthy ones? Will patenting of life forms lead to monopolistic control of benefits? Will large amounts of public funds be spent on unproven technology?

The Principles for the Oversight of Synthetic Biology, developed by a broad coalition of organizations from around the world (including the Biotechnology Reference Group of the Canadian Council of Churches, see section 3.3.2) begins with:

> Synthetic biology, an extreme form of genetic engineering, is developing rapidly with little oversight or regulation despite carrying vast uncertainty. To protect public health, worker safety and ecosystem resilience, it calls for risk research and development of alternatives, a robust pre-market regulatory regime, strong enforcement mechanisms, immediate action to prevent potential exposures until safety is demonstrated, ongoing monitoring for unintended consequences, immediate action to prevent potential exposures until safety is demonstrated … a ban on using synthetic biology to manipulate the human genome in any form, no commercialized or released (building blocks) without full disclosure to the public of the nature of the organism and results of safety testing, .. and …a moratorium on the release and commercial use of synthetic organisms and their products to prevent direct or indirect harm to people and the environment (until government bodies, international organizations and relevant parties implement strong precautionary and comprehensive oversight mechanisms). [6]

In 2012, the Global Forest Coalition published *Bio-economy versus Biodiversity*; it noted:

> While the idea of using renewable resources instead of fossil fuels is a good idea in theory, the way in which the bio-economy approach proposes to achieve this goal is at best deeply flawed and inequitable, and at worst downright dangerous. The planet's capacity to produce biomass is limited, and increasing demand for land is already leading to the destruction of forests and biodiversity, escalating hunger, and conflict over land. Without reducing consumption and demand for energy and products, the sheer scale on which biomass would have to be produced to meet the demands of a global bio-economy would severely exacerbate these problems.
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> Proponents of the bio-economy argue that new technologies, such as the production of algal oil in aquatic environments, would minimize these pressures. Yet these innovations are uncertain at best, and the commercial production of algal oil certainly looks unlikely at present. While promises of a

[5] http://synbio.washington.edu/about/

[6] www.foe.org/news/blog/2012-03-global-coalition-calls-oversight-synthetic-biology and http://libcloud.s3.amazonaws.com/93/ae/9/2287/1/Principles_for_the_oversight_of_synthetic_biology.pdf, pg 1.

> 'clean, green future' may allow risky new technologies to attract investment, the reality on the ground is that in the near and medium term future there will be increased pressure on land and forests. Even though there is much hype about new, high technology approaches as part of the bio-economy, the current impacts are primarily linked to simple, relatively cheap combustion and refining technologies, including 'first generation' biofuels and a very rapidly growing, subsidized push to burn wood for electricity and heat.
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> The bio-economy proposal is not about protecting the environment: it is about promoting the economy – in spite of clear indications of the harmful impacts that are already resulting from massive new demand for biomass, including loss of biodiversity and escalating hunger and conflict. The bio-economy agenda is especially attractive to fossil fuel companies who want to be seen pursuing an exit-from-oil strategy; and to biotechnology companies desperately in need of a Trojan horse to provide safe passage for risky and unpopular new technologies. [7]

In a review of the implications of major corporate investment in synthetic biology, the ETC Group (which addresses the socioeconomic and ecological issues surrounding new technologies) and the Heinrich Böll Foundation, noted:

> The quest to secure biomass for feedstocks is creating new configurations of corporate power. Major players in all sectors are already involved: Big Energy (Exxon, BP, Chevron, Shell, Total), along with the US military; Big Pharma (Roche, Merck); Big Food & Ag (Unilever, Cargill, DuPont, Monsanto, Bunge, Procter & Gamble); and Big Chemical (Dow, BASF).
>
> The push for a bio-based economy comes with a call for market-based mechanisms for the financialization of the Earth's natural processes, re-branded as 'ecosystem services' (the cycling of carbon, soil nutrients and water, for example), which also encourage land and water grabs. Companies are no longer focused narrowly on the control of genetic material found in seeds, plants, animals, microbes and humans; they've widened their scope to include the reproductive capacity of the entire planet.[8]
>
> … Synthetic biology companies are engineering synthetic DNA to custom-build microorganisms to behave as tiny 'biological factories' that can manufacture high-value products. While it's not the first time that researchers have tried to apply new biotechnologies to displace natural commodities (ETC Group – then RAFI – reported on similar efforts a few years before the first Earth Summit), the level of current research and investment activity suggests that commercial viability could be near. In the past five years, synthetic biology has moved from being a 'fringe' science to an area of intense industrial interest and investment. The world's largest energy and chemical companies – the New BioMassters – are now buying, making strategic investments in or partnering with synthetic biology (synbio) companies, which are, generally, start-ups operating in stealth mode.[9]

3.2 Issues in the Development of Synthetic Biology

This section looks at progress in the development of synthetic biology, safety issues, ecological aspects and social justice aspects. This is by no means comprehensive but touches on selected aspects to help the reader gain awareness of these dimensions of synthetic biology.

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[7] Hall, Ronnie, *et al*. *Bio-economy versus Biodiversity*, (Global Forest Coalition: 2012), p. 2: http://globalforestcoalition.org/wp-content/uploads/2012/04/Bioecono-vs-biodiv-report-with-frontage-FINAL.pdf

[8] *Biomassters Battle to Control the Green Economy* (ETC Group and Heinrich Böll Foundation: 2012), p. 3, 6: http://www.etcgroup.org/sites/www.etcgroup.org/files/greco_A4_eng_v16.pdf

[9] Ibid., p. 6

3.2.1 Progress and Technical Challenges

Friends of the Earth, a sponsor of the *Principles for the Supervision of Synthetic Biology* statement, includes a list of applications of synthetic biology in "Synthetic Biology 101":

> Proponents hope synthetic biology will produce the next-generation of fuels, industrial chemicals, natural product substitutes, and biomedical applications. Eventually, synthetic biologists believe they could replace our oil-based economy with a new "bioeconomy" in which synthetic organisms can break down biomass to produce any type of fuel, industrial chemical, natural products, or medicines and vaccines.
>
> ***Biofuels****:* Biofuels production through synthetic biology is being conducted in two main ways. First, organisms synthetically engineered to break down biomass into sugars for fuel. Enzymes, which are proteins that catalyze reactions, are being engineered by synthetic microbes that are tailored to break down certain types of biomass, such as sugarcane, woodchips or corn stalks for example. These microbes would become "living chemical factories" that could be engineered to pump out almost any type of fuel or industrial chemical. Second, organisms are being designed to produce fuel directly. Algae naturally produces oils, but through synthetic biology tools algae can be reengineered algae to produce oils that are chemically similar or identical to the oils that are currently used in today's transportation and energy infrastructure.
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> ***Industrial Chemicals:*** A wide range of industrial chemicals are being produced through synthetic biology. Amyris Biotechnologies, for example, is producing farnesene – an essential building block for a wide range of chemical products (detergents, cosmetics, perfumes and industrial lubricants and transportation fuels) – through its synthetically engineered yeast. DuPont is working with Tate and Lyle to use their synthetically engineered yeast to ferment corn sugars into a bio-plastic, marketed as Sorona.
>
> ***Natural Product Substitutes****:* Synthetic biologists are working to replace natural products with synthetically produced equivalents. Much attention is being given to the synthetic production of rubber through isoprene – a crucial building block for making artificial rubber. The gene encoding isoprene (previously found in rubber trees) has been synthetically engineered by DuPont subsidiary, Genencor, into E. coli to produce isoprene. Other products currently being produced through synthetic biology include vanilla, stevia, and palm oil among others.
>
> ***Biomedical Applications:*** The other major application of synthetic biology that will likely see commercialization soon is the production of medicine. Already in production is arteminisic acid – a precursor to the important anti-malarial medicine arteminisin – which is being produced by E. coli with synthetic DNA. Other researchers and companies are working on ways to produce vaccines through synthetic microbes. [10]

On July 20, 2012, scientists at Stanford University and the J. Craig Venter Institute reported they had completed the first software simulation of the lifespan of an entire organism, a "humble single-cell" virus that lives in the human genital and respiratory tracts[11]. The complexity of

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[10] Friends of the Earth, Synthetic Biology 101, p. 2: http://www.foe.org/projects/food-and-technology/synthetic-biology and http://libcloud.s3.amazonaws.com/93/41/1/971/Issue_brief_-_Synthetic_biology_101.pdf

[11] Markoff, John, "In Software emulates the entire life cycle of an organism for the first time", in *The New York Times*, July 22, 2012: http://www.nytimes.com/2012/07/21/science/in-a-first-an-entire-organism-is-simulated-by-software.html?_r=0

computer modeling 525 genes running the organism's lifespan required 128 computers. The bacterium E. coli, a one-cell creature, has 4288 genes and would be even more challenging. So, synthetic biology does not appear ready to manufacture higher life forms.

However, as an editorial in *Nature* about the remarkable scientific progress in synthetic biology notes, "Bringing these applications to reality has proved much harder than was originally hoped." [12] The hoped-for, positive impacts of synthetic biology for the human community have been slow to arrive. The technical challenges for this discipline are also documented by Roberta Kwok in the same issue of *Nature*.[13]

In his article in *The Guardian*, "Synthetic biology: 'playing God' is vital if we are to create a better future for all", Adam Rutherford weighs heavily the pros of synthetic biology without assessing the cons:

> Detractors use the phrase "playing God" to provoke emotive opposition without defining what it is about synthetic biology that is qualitatively different to the previous advances that they enjoy and benefit from every day. Should we go back to the time before humans started playing God through their development of sanitation, vaccines and measures to counter widespread child mortality?
>
> There will be very few aspects of our lives that will remain untouched by synthetic biology. Advancing technology is not risk-free, and needs to be regulated, understood and, if necessary, curtailed. But those decisions need to be made as part of informed public conversations about the relative risks and benefits. The opportunities are too great for synthetic biology to be written off with fear-mongering maxims. [14]

In another assessment of the challenges facing synthetic biology, Porcar and co-workers recognize that Darwinian natural selection (God's handicraft) is likely superior and its strategies could even be integrated into the development of synthetic microorganisms:

> The potential of SB-based approaches lies on the engineering principles of abstraction, decoupling and standardization as well as on modeling, but the experience reveals that rationally designed genetically engineered organisms might in fact be less adaptive than natural selection-shaped ones (Chan et al. 2005). The astounding complexity and diversity of natural living beings are the best demonstration of the superiority of natural selection over rational design. Thus, the combination of rational design (modeling-based and using standard biological parts) with selection strategies such as directed evolution, adaptive evolution and other Darwinian approaches might result in an exponential acceleration of the achievement of artificial live forms. [15]

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http://www.nytimes.com/2012/07/21/science/in-a-first-an-entire-organism-is-simulated-by-software.html?_r=0

[12] "Ten years of synergy" (Editorial), in *Nature* (No. 463, January 2010, p. 269): http://www.nature.com/nature/journal/v463/n7279/full/463269b.html

[13] Kwok, Roberta. "Five hard truths for synthetic biology", in *Nature* (No. 463, January 2010, pp. 228-290): http://www.nature.com/news/2010/100120/full/463288a.html

[14] Rutherford, Adam. "Synthetic Biology: '' is vital if we are to create a better future for all", in *The Guardian* (July 27, 2012): http://www.guardian.co.uk/commentisfree/2012/jul/27/synthetic-biology-playing-god-vital-future

[15] Porcar M, Danchin A, de Lorenzo V, et al. "The ten grand challenges of synthetic life", in *Systems & Synthetic Biology* 2011-5 (June), pp. 1-9. "The ten grand challenges of synthetic life", at US National Library of Medicine, National Institutes of Health): http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3159694/

Dr Gregor Wolbring, an expert on ableism ethics and governance, speaks on the potential benefits of new technologies, and also warns about inadequate consideration of social impacts. He notes:

> The lack of diversity of stakeholders in the NBICS (his acronym for nano- and bio-technology related science) discourse led to an excessively narrow definition of the issues to be covered. Many nanoengagements are too narrowly focused on medical health, safety and environmental safety, ignoring good governance and practice and risk evaluation related to social non-medical health impacts and social safety. So far some efforts are underway to look and deal with personal and worker, environmental and ecosystem safety. However as in the bio debate social safety is mostly missing in the today's discourse of NBICS as are disabled people. [16]

3.2.2 Safety Issues

It takes little imagination to think that synthetic biology could lead to products which deliberately (in the hands of a terrorist) or accidentally, might create illnesses, epidemics, unhealthy conditions, or other biological stresses among people, animals, plants or even microorganisms.

Thus, it is disconcerting to read that in 2011, Paul M. Rabinow, who was hired to evaluate security and ethical ramifications of SynBERC's research (a U.S. federally-funded research centre for synthetic biology) resigned because his recommendations "were largely ignored."[17]

The Woodrow Wilson International Center for Scholar's Science and Technology Innovation Program established The Synthetic Biology Project to foster informed public and policy dialogue. Its work includes evaluation of implementation of the recommendations of the President's Commission for the Study of Bioethical Issues (including synthetic biology).[18] 17 recommendations were to be completed by June 2012 and the results made public; four of the recommendations showed "no federal activity":

#1	Public Funding Review and Disclosure
#7	Risk Assessment Prior to Field Release
#10	Ongoing Evaluation of (moral) Objections to Synthetic Biology
#18	Risks and Benefits of Commercial Production and Distribution

Also on The Synthetic Biology Project's website is a survey of the U.S. population, done in January 2013. These findings have implications for the pressure government feels to act on matters of safety regarding synthetic biology:

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[16] Wolbring**,** Gregor. **"**NBICS With, For, and By the People: What it is, what it means and why it matters" (no date)**:** http://www.bioethicsanddisability.org/healthwright.html

[17] Gollan, Jennifer. "Berkeley Scholar Raises Alarm on Synthetic Biology", in *The Bay Citizen*, October, 22, 2011: https://www.baycitizen.org/news/science/berkeley-scholar-raises-alarm-synthetic/

[18] http://synbioproject.org/scorecard/recommendations/

Despite advancements in the field of synthetic biology, three out of four adults surveyed in a national poll released today have heard "just a little" or "nothing at all" about the emerging technology, a level of awareness that has changed little since 2010…

…The national poll of more than 800 U.S. adults conducted by Hart Research Associates and the Synthetic Biology Project at the Woodrow Wilson International Center for Scholars finds that there has only been a minor shift in public awareness of synthetic biology, an area of research focused on the design and construction of new biological parts and devices, or re-design of existing biological systems.

As the public learns more about synthetic biology, there is greater movement toward concern about risk than optimism about benefits, the poll finds. After hearing some basic information about synthetic biology, 33 percent of adults express greater concern about risks from the technology, while 24 percent express more optimism about its benefits.

This survey reveals the American public's nuanced and varied impressions of synthetic biology depending on the information provided and the application in question," said Abigail Davenport, a partner with Hart Research. "While the majority would like to see the science proceed, there are several findings that highlight the public's call for caution in moving ahead."

The public has divided opinions on the future of synthetic biology and the role of government regulation. While 61 percent think the science should move forward, one-third of respondents favor a ban "on synthetic biology research until we better understand its implications and risks.

Despite a low level of confidence in the federal government to maximize the benefits and minimize the risks of synthetic biology and less support for federal government regulation of synthetic biology than seen previously, the public is still divided in its support for voluntary guidelines developed by both industry and government (43 percent) compared with support for federal regulation (45 percent). [19]

3.2.3 Ecological Issues

Synthetic biology, ecosystems and reductionism:
An aspect of synthetic biology that receives little attention from its proponents is how its applications may interact with current or future ecosystems. This is not surprising since many of synthetic biology proponents appear reductionistic in their arguments. That is, they tend to hold the perspective that, given a thorough and scientific understanding of the pieces, one can build and understand the whole. It is true that molecular biology and genetics help to explain a great deal and, in theory, there is enormous potential for many applications of synthetic biology. However, many scientists believe that critical interactions take place at all levels, from the molecular to the ecosystem level, and that some interactions are best understood at multiple levels (molecule, cells, tissues, organs, individuals, families, communities, ecosystems). Views that seek to look at whole systems hold that the critical interactions, whichever their level, must be well understood to avoid potentially serious errors in applying new technologies.

Technology versus Nature:
If one compares the experience of nature, which has been doing experiments in natural selection over the past 4.5 billion years, with the experience of the technology of synthetic biology, which

[19] http://www.synbioproject.org/process/assets/files/6653/_draft/synbiosurvey2013.pdf

is at most a few centuries old, the better bet would seem to be nature. As noted in Porcar and co-worker's review of the challenges that synthetic biology faces (see section 3.2.1 above) "experience reveals that rationally designed genetically engineered organisms might in fact be less adaptive than natural selection-shaped ones."[20]

Interestingly, Nature, in its non-synthetic form, is gaining **legal standing** in various parts of the world. This may conflict directly with synthetic biology. *Beyond the Growth Dilemma; Toward and Ecologically Integrated Economy* (QIF #6, p. 58) notes:

> In late 2010, the Pittsburgh City Council voted unanimously to pass a local ordinance that not only banned natural gas drilling in the city, but recognized rights that have never before been recognized in law, including the right of natural communities and ecosystems. In the spring of 2011, Bolivia went a big step farther, passing the world's first laws granting all nature equal rights to humans. These rights include:
>
> • the right to life
> • the right to exist,
> • the right to continue vital cycles and processes free from human alteration,
> • the right to pure water and clean air,
> • the right to balance,
> • the right not to be polluted,
> • the right not to have cellular structures modified or genetically altered, and
> • the right not to be affected by mega-infrastructure and development projects that affect the balance of ecosystems and the local inhabitant communities.
>
> This Law of Mother Earth redefines the country's rich mineral deposits as "blessings" and is expected to lead to radical new conservation and social measures to reduce pollution and control industry. [21]

Ecological aspects of synthetic biology are inextricably linked to issues of social justice; they are all one piece. Anne Mitchell notes in *Genetically Modified Crops; Promises, Perils, and the Need for Public Policy*:

> Innovative technology applications may be deemed "safe" by scientists, but there are many reasons for citizens to be concerned: lack of long-term studies; lack of consideration of societal or ethical dimensions; lack of understanding of impact on communities. Communities in the global south are particularly vulnerable. There is a view that new innovative GM (genetically modified) agriculture will contribute to sustainability and food security. However, evidence is emerging that GM agriculture is destroying biodiversity, soil fertility, as well as communities and local, traditional agricultural practices.[22]

Do synthetic biology proponents recognize that, to preserve ecological health, there must be limits and the wealth of nature must be shared? The implications of these ecological limits are recognized in *Beyond the Growth Dilemma; Toward and Ecologically Integrated Economy*:

What Must We Give up to Keep What We Value Most?

[20] Porcar, et al. *op. cit.*, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3159694/
[21] http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf, p.18.
[22] Ibid., p. 18.

> In an ecologically integrated economy, providing a basic livelihood for everyone inevitably would mean limiting how much of many things any individual can use. It would mean revising what can and cannot be owned by whom, and what an "owner" is required to do and prohibited from doing. The idea of a comprehensive and permanent system of rationing seems repugnant and unworkable by current standards. Yet this is exactly what markets do, based on the amount of money people have at their disposal. Boulding and Daly are both strong believers in the uses of well-designed markets.
>
> Devising ways for using markets to allocate and distribute the fruits of a limited flow of resources with wisdom and fairness would perhaps be the only way for an inclusive ecologically integrated economy to function without exceeding Earth's bio-capacity. Fair distribution will be made all the more challenging because people's legitimate needs are most certainly unequal, and the same limited flow of resources that provides goods and services for its people, *i.e*., its human and social capital, must also be allocated to maintain and enhance its natural and manufactured capital.
>
> There must be a systematic means to limit the size of the population if it does not occur by individuals' choices. Either the death rate must be managed according to the birth rate, or the birth rate must be managed according to the death rate. Otherwise the population will become self-limiting in an unpleasant and dangerous Malthusian fashion. [23]

3.2.4 Social Justice Issues

The Quaker testimony of Equality calls for sharing—sharing fairly the earth's wealth and what derives from that abundance. In recent decades, the richer segments of most societies have gotten richer and the poor, poorer. Quakers have warned that technology has not served societies equality:

> Renowned Quaker scientist, Ursula Franklin, argues that the spread of technology has become self-reinforcing in a way that can hinder viable and appropriate political or economic change, and cause humans to become servants to technological requirements, rather than actively engaging in creation and decision-making. She questions any technological fix that does not also promote justice; restore reciprocity; confer divisible or indivisible benefits; maximize gain or minimize disaster; and favor people over machines, conservation over waste, and the reversible over the irreversible.[24]

In preparation for the 11th meeting of the Parties to the (U.N.) Convention on Biological Diversity, held in Hyderabad, India in October 2012, delegates were offered these ten points to consider about synthetic biology by Canada's ETC Group:

> 1. The industry is global, well financed and rapidly expanding with products already in the marketplace.
> 2. It can be clearly defined.
> 3. It differs from recombinant DNA technologies.
> 4. It is controversial.
> 5. It has not yet come under any national or global oversight.
> 6. Its governance is best dealt with under the Convention on Biodiversity and its protocols.
> 7. It threatens the conservation of biological diversity.
> 8. It threatens the sustainable use of biological diversity.
> 9. It threatens the equitable sharing of benefits arising from genetic resources.

[23] http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf, p. 80.
[24] Ibid p. 55.

> 10. Its activities can be brought under an enforceable moratorium on environmental release and commercial use.[25]

In reading these points, one can see that the issues of ecology and social justice are linked.

In addition to Friends' testimonies of Equality, Ecology and Simplicity, the Peace testimony may also be relevant. Mansfield and Dreby write in *It's the Economy, Friends: Understanding the Growth Dilemma:*

> Structural violence occurs when physical and psychic harm results from the conduct of social institutions stemming from laws, regulations, and policies, rather than being directly caused by overt force (concept developed by Galtung)…
>
> Structural violence as a concept is of recent origin. Yet, many of the social causes for which notable Friends provided leadership were responses to instances of structural violence of an earlier time. In the past, the abolition of slavery, prison reform, women's rights, and other crusades for justice have been viewed as separate from the Friends Peace Testimony. As the idea of structural violence becomes more widespread among Friends, it may become yet another way the Peace Testimony has evolved from its 17th century origins to today's broader, yet perhaps more controversial, applications.
>
> The issue of ownership of life forms, the very products of synthetic biology, may be an major, but not always obvious, form of structural violence. [26]

Gregor Wolbring, a University of Calgary academic specializing in ableism ethics and governance, notes the lack of application of these technologies to marginalized peoples. He finds that the development of these technologies shares the same biases of society at large and concludes:

> The nanodiscourse exhibits a hierarchy towards social group involvement with the most marginalized social groups the least visible.
>
> The inclusion of disabled people and indigenous people in the governance of science and technology in general and nano and NBIC in particular is essential for disable and non-disabled people. The goal of involving disabled people and indigenous people fits well with the language from six major health promotion conferences the recent statement by the Global Forum for Health Research at the conclusion of Forum 8 Mexico City (*42*), the UN Convention on the rights of persons with disabilities (*43*) and the suggestions in other international documents, such as the final documents of the UNESCO World Conference on Science.(*44;45*) [27]

Synthetic biology is now developing outside of an economy that is equitable. Derby and Mansfield invite us to "envision an economy that functions in right relationship with the commonwealth of life" by asking four questions:

> How much labor, manufactured capital, and resources from natural capital should be used to produce how much and what kinds of goods and services?

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[25] http://www.etcgroup.org/content/synthetic-biology-10-key-points-delegates
[26] http://www.quakerinstitute.org/wp-content/uploads/2012/06/IEF-web.pdf, p. 63
[27] http://www.bioethicsanddisability.org/healthwright.html

> Who owns and profits from Earth's natural capital and society's manufactured and financial capital?
>
> How is money created and managed?
>
> How are decisions made about the economy's legal framework and management? [28]

Given the drastic difference the answers to these questions would imply, what should the Religious Society of Friends say and do about the development of synthetic biology within today's economy?

In addition to Wolbring's suggestions, if synthetic biology develops in this economy without public awareness and input how can we assure that synthetic biology will contribute in a socially just way?

3.3 Spiritual Groups and Synthetic biology

Quakers are not the only faith group that has begun to address the questions raised by synthetic biology. The authors of this kit have found informed commentary from other faith-based sources within the Christian tradition. We would be delighted to know of resources from other faiths. In this section, we give two examples, and some Canadian Quaker history on this topic.

3.3.1 Christian Leaders Speak

In 2009, the Canadian Council of Churches' Biotechnology Reference Group held a forum called *Faith, Life and Technology* in Toronto, Ontario to discern their focus for the coming decade. A full report is available on their website[29]. We excerpt the first page of the keynote address by Janet Sommerville (former General Secretary of the CCC), *People of Faith Need Bioethics Awareness*. She references inspiring quotations from leaders from the Christian Orthodox tradition:

> What does it mean, in the 21st century, to think of humanity as created in the image and likeness of God? What does it mean to think of humans as "stewards" within creation?
>
> Listen to a molecular biologist as she speaks to a hushed roomful of ethicists, scientists and theologians: We humans have basically the same genetic code as other living organisms. In the case of humans and chimpanzees, what we can describe genetically is approximately 98.6% identical one with the other.
>
> Yet the human impact on the world, as everyone knows, is dramatically different from that of chimps. It is, in fact, in a class by itself, for better and for worse.

---

[28] *It's the Economy, Friends: Understanding the Growth Dilemma* (QIF 5), pp. 44-45 http://www.quakerinstitute.org/wp-content/uploads/2012/06/IEF-web.pdf

[29] Find the full report, entitled *Faith, Life and Technology: The Canadian Council of Churches celebrates 10 years of biotechnology, theology and ethics, Forum Report, December 3-4, 2009* (Canadian Council of Churches' Biotechnology Reference Group, 2009) on this web page: http://www.councilofchurches.ca/en/Biotechnology/biotechnology-consultations.cfm

There are other ways to look at ourselves, the biologist added. Genetic structures are not the whole story. Human culture is rich in traditions and innovations that cannot be described as points on a genome. Human consciousness has unique possibilities. In the words of a present-day Orthodox Bishop, Calistos Ware, *humanity is the part of creation that contemplates*.

The human specialty is meaning—transcendent meaning included. But because of the ways in which a ravenous market economy has jet-fuelled scientific research, there is very rapid movement now from discovery to application. In the resulting rush, no space is left for contemplation of the meanings and consequences of what is being made, patented and promoted.

The scientist describing this "contemplation deficit" was Dr. Gayle Woloschak of the Feinberg School of Medicine in Northwestern University. Besides being a professor of radiation oncology and Associate Director of a centre for nanotechnology in cancer therapy, she is also a Ukrainian Orthodox Christian and Director of the Zygon Centre for Religion and Science in Chicago. [30]

3.3.1 Canadian Quakers' Engagement with Genetics and Technology

Friends' core value of spiritually-based simplicity offers a firm ethical and moral basis for caution about genetics and technology. Such simplicity forms an appropriate antidote to the general ignorance science and governments often show to the complex relationships found among species and their ecosystems. Spiritually-based simplicity grounds us in the Precautionary Principle and makes it a firm and conserving basis for advancing the interests of people and all life. Appendix Two gives a few pages of excerpts from Quaker writings that expound further on testimonies relevant to this topic.

Quaker discernment regarding, "What is it in nature and human knowledge that we have the right to own?" led Anne Mitchell to bring the issue of whether Canada should allow patenting of high forms of life to the attention of the Canadian Council of Churches (CCC). The CCC and the Evangelical Fellowship of Canada then intervened in a landmark case before the Supreme Court of Canada. The specific case was the patenting of the onco-mouse, a research animal developed at Harvard University.[31] The Court decided in 2002 not to allow the patent. Anne Mitchell also served as one of the Canadian Council of Churches' representatives to the World Council of Churches' Consultation on Genetics and the New Biotechnologies, held in South Africa in 2007.

In 2001, the Quaker Institute for the Future published the booklet *Genetically Modified Crops: Promises, Perils, and the Need for Public Policy*[32], written by Anne Mitchell with Pinayur Rajagopal, Keith Helmuth, and Susan Holtz (with an introduction by Ursula Franklin) – all members of Canadian Yearly Meeting. The Canadians also fundraised for the editing and publishing of the booklet.

In 2012, Toronto Monthly Meeting participated in a pilot review of the curriculum on faith and genetics that the Biotechnology Reference Group (BRG) of the CCC was developing. The

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30 Somerville, Janet. "People of Faith Need Bioethics Awareness", in *Faith, Life and Technology The Canadian Council of Churches celebrates 10 years of biotechnology, theology and ethics, Forum Report, December 3-4, 2009* (Canadian Council of Churches' Biotechnology Reference Group, 2009), p. 3

[31] *Genetically Modified Crops; Promises, Perils, and the Need for Public Policy*, 2011 (QIF#3), p. 8

[32] Ibid.

Meeting drafted some queries to be attached to the curriculum as an appendix and brought them forward to Canadian Yearly Meeting (which is the member of the CCC) for consideration. The queries were amended and approved by CYM in 2012.

From 2007 to 2011, the Quaker International Affairs Program, a CFSC program, focused on "giving voice to the commons" by "supporting people who are reclaiming, securing, strengthening and protecting the commons". Canadian Friends may recall participating in workshops with Tasmin Rajotte, QIAP Representative, who used a portable loom to invite interaction with complex concepts about the commons.

In 2012, following a report from those who participated in the Special Interest Group on synthetic biology at CYM's annual sessions, CYM directed CFSC to write a letter to several federal ministers urging protection of the common good from unintended social and environmental consequences of research and development in this field. CFSC did so, and have had a welcoming response. As a direct result, Sandra Fry, Director General of the Pathogen Regulation Directorate of the Public Health Agency of Canada has been invited by the CCC's BRG to meet with the churches represented on the BRG and other interested people in Toronto in fall 2013.

3.3.2 The Canadian Council of Churches and Synthetic Biology

As mentioned in Section 1, the BRG of the CCC consulted CFSC before signing on with over 100 other endorsing organizations from around the world to *The Principles for the Oversight of Synthetic Biology*.[33] This joint statement urges the following principles for the assessment and oversight of the emerging field of synthetic biology:

I. Employ the Precautionary Principle
II. Require mandatory synthetic-biology-specific regulations
III. Protect public health and worker safety
IV. Protect the environment
V. Guarantee the right-to-know and democratic participation
VI. Require corporate accountability and manufacturer liability
VII. Protect economic and environmental justice

3.3.3 The Church of Scotland's Report on Synthetic Biology

The Church and Society Council of the Church of Scotland issued an 18-page report, *Synthetic Biology,* in May 2010[34]. The first 14 pages provide a full review of the history, benefits, risks and spiritual issues pertaining to synthetic biology. The report explored ethical questions relating to:

- The reductive approach to life.
- The right relationship between Creator and created.

[33] www.foe.org/news/blog/2012-03-global-coalition-calls-oversight-synthetic-biology *and* http://libcloud.s3.amazonaws.com/93/ae/9/2287/1/Principles_for_the_oversight_of_synthetic_biology.pdf
[34] Church and Society Council, Church of Scotland. "Synthetic Biology" (2010): http://www.churchofscotland.org.uk/__data/assets/pdf_file/0003/3792/synthetic_biology_ga10.pdf

- The responsibility of humans towards God and the rest of his creation.
- The concept of telos, sometimes also termed the 'intrinsic value' or 'integrity' of a being.

It also identified the following concerns, among others:

- **Biosafety "**is a more difficult area in synthetic biology than in traditional genetic engineering, as components may be introduced which do not exist in nature."
- **International justice**. "the question of fair distribution of resources, availability of new drugs and therapeutics to all people still remains."
- **Patenting and creation of monopolies**. "has raised concerns for some about the creation of de facto monopolies, for example potentially 'locking out' some developing countries from the technology."
- **Unregulated developments:** "The manipulation of DNA and other biological materials by hobbyists (as opposed to trained and supervised professionals) already appears to exist as a significant phenomenon[35]."

In its concluding two and a half pages, the summary minimizes doubt about synthetic biology. A closing paragraph in the summary notes:

> 7.7.12.3 Humanity is charged not only with the stewardship of the world around us but also the care and concern for other people. To deny the technological breakthroughs and consequent benefits promised by synthetic biology would be irresponsible. The Bible makes clear the need for humans to act in a humble and responsible manner toward God, their fellow creatures and the environment.[36]

In contrast, the longer, more technically detailed version of this report, available on the same website, presents the following version of this same paragraph:

> 12.3 Humanity is charged not only with the stewardship of the world around us but also the care and concern for other people. For many, to deny the technological breakthroughs and consequent benefits promised by synthetic biology would be irresponsible. The Biblical story of the Tower of Babel could be seen as a salutary illustration of the wrong use of advances in technology – humans seeking to utilise the (then-novel?) tools of man–made bricks and bitumen to "make a name for themselves"rather than acting in a humble and responsible manner toward God, their fellow creatures and the environment.[37]

In the first version, 7.7.12.3, the second and third sentences appear to represent a narrowing of the more detailed version, 12.3. Neither version describes how the conclusions were drawn. Contention notwithstanding, this report is a useful and broad introduction to synthetic biology.

3.4 Conclusion

In a previous century, Quakers discerned that it was unethical to own people and acted on that discernment to stand firmly against slavery. Today, what do Quakers discern about the manufacture and ownership of life, and how are we willing to act on that discernment? Are there co-relations between these two issues?

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[35] Schmidt, M. *et al*. "SYNBIOSAFE e-conference: online community discussion on the societal aspects of synthetic biology", in *Systems and Synthetic Biology*, vol. 2 (1-2) (2008), pp. 7-17.
[36] http://www.churchofscotland.org.uk/__data/assets/pdf_file/0003/3792/synthetic_biology_ga10.pdf
[37] http://www.churchofscotland.org.uk/__data/assets/pdf_file/0004/3793/synthetic_biology_report.pdf, p. 26

This kit presents basic information on the complex and challenging subject of synthetic biology. It includes perspectives of proponents and of those who are cautious or contrary about this emergent technology. It supplies relevant resources from the Quaker Institute for the Future and 22 web link references. It presents information about the progress, safety, ecological and social justice aspects of this subject.

The discernment process described in Section 1 invites Friends to respond to three queries listed in Section 2, and to send a report by Dec 31, 2013. The reports will be collated and considered in time for the 2014 annual sessions of Canadian Yearly Meeting, which asked CFSC in 2012 to facilitate this consultation. We believe that the information in this kit has demonstrated an ethical deficit in the development of synthetic biology. Our hope is that Friends can contribute to the reduction of this deficit.

In absorbing the information presented in this kit, readers may feel powerless and be searching for inspiration. The authors have found useful guidance expressed well in *How on Earth Do We Live Now? Natural Capital, Deep Ecology, and the Commons*:

> First of all, we must live our lives in a manner that sets an example. While this can be done household by household, collective action in creating ecologically sound communities that are also viable for the larger society remains a great challenge.
>
> Secondly, the practice of collaborative discernment and decision making that Quakers cultivate should be brought into the public policy arena at every opportunity. Quakers hold to the experience of the Inner Light not only as a spiritual reality, but as a way of informing decision-making process. Decision making that arrives at unity, rather than majority rule, has been long practiced by the Society of Friends, and is precisely what is needed for successful governance of the commons.
>
> And finally, in line with the Quaker insight that the Inner Light creates the potential for everyone to manifest the Spirit of God in the world, Friends firmly hold to expectation that people have the potential to choose the common good. But do we proceed with this in mind when we deal with economics and the ecology of the planet? Winning arguments about correctness should be less important than finding the common vision for action that will advance Earth restored. It is this faith in the future, this willingness to continue laboring at the task, and this belief in the inherent goodness of Creation, which leads Quakers to engage the world for radical change, knowing that the outcomes we seek will not come easily, as soon as we might like, or in exactly the way we might envision. [38]

Dear Reader,

This is a challenging topic. We appreciate your commitment to understanding this issue and we look forward to learning your thoughts and suggestions on this subject.

In Friendship,

The Quaker Peace and Sustainable Communities Program Committee of Canadian Friends Service Committee

[38] http://www.quakerinstitute.org/wp-content/uploads/2011/05/HowonEarth-final.pdf, pp. 75 – 76.

APPENDIX ONE:

Excerpts from *Genetically Modified Crops: Promises, Perils, and the Need for Public Policy (QIF#3, 2011),* by Anne Mitchell with Pinayur Rajagopal, Keith Helmuth, Susan Holtz (all members of Canadian Yearly Meeting).

(For the convenience of Friends who are not able to read the entire pamphlet)

From Preface:

Transnational corporations are offering agricultural biotechnology and genetically modified foods as a solution to food scarcity and the alleviation of hunger in the world. This pamphlet considers some of the controversies surrounding agricultural biotechnology and critiques these claims

…

A group of Quakers came together to consider the patenting of life forms for commercialization. Our discernment brought us to the question: "*What is it in nature and human knowledge that we have the right to own?*" I [Anne Mitchell] then brought this concern to the Canadian Council of Churches (CCC) where the query was considered. The CCC agreed to intervene before the Supreme Court of Canada, arguing that the patenting of the oncomouse [a mouse genetically modified to be susceptible to cancer] was a commodification of life. The Supreme Court decided in our favour by overturning the decision of a lower court to legally permit patenting the oncomouse. Canada is now the only G8 country that does not allow the patenting of higher life forms.

From Chapter Three: Why is Public Policy so Private? (Rajagopal)

…Over the years, Quakers have been given pioneering moral insights regarding the keeping of slaves, participation in war, incarceration in prisons, gender and sexual orientation equality, and, now "right relationship" with Earth's ecosystems.

…

The genomic revolution resonates with previous contestations of technical change, but has raised genuinely new problems. The scope of this global dispute is reflected in titles of recent books: *Gene Wars*; *Pandora's Picnic Basket*; *Lords of the Harvest*; *Politics of Precaution*; *Seeds of Suicide*. Science is the fulcrum on which this contentious politics rests. Science is an agnostic method for adjudicating truth claims. Applied in genomics, scientific truth is overwhelmed by a politicized science constructed to legitimize the strategies of corporations, government agencies, and politicians who receive the generous support of industry.

…However, the benefits of bioeconomy to the UK and EU were extremely limited.[39]

- The net value of the bioeconomy worldwide was estimated to be zero or negative: with only two US medical biotech companies, Amgen and Genetech, and one US agricultural biotech company, Monsanto, making significant profits.
- Only two types of GM crops had been commercialized on any scale: insect-resistance and herbicide-tolerance. These crops are grown largely in North and South America for use in animal feed and subsidized industrial-scale biofuels.

…

From Chapter Four: Genetic Engineering: Challenging the Worldview of Right Relationship (Helmuth)

[39] Wallace, Helen. "Health, agriculture and the development of the 'knowledge-based economy'", in *Policy-Making in the European Union, 4th Edition* (New York: Oxford UP, 2000).

...
Biotechnology has changed the game with respect to the processes and relationships of life. The question of right relationship in this new complex of science and technology is highly problematic, and, in some respects, seems completely off the agenda.
…
3) Not only are these technologies transforming fruits, vegetables, and livestock, they are now poised to alter the human species in a variety of ways.
…
A brief review here of Quaker testimonies, along with some contrasting characteristics of genetic engineering and its commercial development, will help create a platform from which further scrutiny can be launched.
...
Simplicity: Simplicity is, in large part, about focusing on relationships and processes that are fundamental to a well-balanced life.
…
Biotechnology has a very different orientation. It is not interested in achieving balanced functioning within natural and social systems. Natural and social systems are often the problem it seeks to overcome. Biotechnology is aimed at unbalancing natural and social systems in favour of controlled, selective benefit for commercialization and capital accumulation.

Peace: The Quaker peace testimony manifests in both personal life and in larger social forms.
…
It is well known that war and preparation for war stimulates scientific research and technology development. Biotechnology is no exception. It is firmly ensconced in the military saddle.[40]
...
Equity: …the ethic of equity. Equity means a fair share, a valued status, the prospect of a fulfilling and productive life.
…
Biotechnology's relationship to equity is complex and increasingly problematic. … Through inequitable trade agreements and quasi-legal regulations, agri-industry and pharmaceutical giants are systematically enclosing the genetic commons, turning germ plasma into a commodity over which they then have exclusive control.
…
Integrity: …At the first level it encompasses truthfulness and ethical consistency. In a widening perspective it includes devotion to right relationship and the high valuing of direct experience in the formation of knowledge and judgment.

Biotechnology, on the other hand, … works for the enclosure, monopolistic control, and commercialization of integral biotic components, and for their excavation and transplantation into now redesigned organisms that will yield market value.
…
Community: Largely because Friends have had an enduring concern for right relationship, and because Friends have a well-tended tradition of collaborative discernment in decision-making, the soul of community has been kept alive in Quakerism.
…
In contrast, biotechnology has no particular interest in community. The industry is focused on the individual components of organisms and on individual organisms.
…
From the standpoint of Quaker testimonies, three questions about biotechnology and other powerful new technologies come into view:

1) How can their benefits be developed and applied in an equitable way, a way that serves the common good?

[40] Wheelis, M and Dando, M. "On the Brink: Biodefence, Biotechnology, and the Future of Weapons Control", in *Chemical and Biological Weapons Control Bulletin* (December 2002).

2) How can damaging and potentially disastrous consequences to ecosystems and social systems be foreseen and forestalled?
3) Are there zones of organic process and ecological relationships that should be ethically off limits for genetic engineering?

From Chapter Six: Quaker Contributions and Future Trends (Mitchell)

Scrupling has been used in the past by Quakers to consider issues such as war and slavery. …Scrupling is not a debate, an argument or a panel discussion. Rather it is a process where one searches one's conscience about what is the right way forward and shares this with those gathered, not to reach consensus or unity, but to hear what others are saying. …Quakers can work with those in the broader faith and secular communities to expand and develop public policy guided by the common good.

Quakers also have a long and well-practiced tradition of collective decision-making in which an open process of discernment and collaboration works toward unity on whatever matter is under consideration.
…

In entering the dialogue on biotechnology, public policy and the common good, we should ask the question: Do we proceed according to an ecologically informed worldview of *right relationship*, of do we follow a *reductionist* worldview into an *instrumentalist* manipulation of life and relationships? Central to this process of discernment is the question of the commodification and control of life.
…
How will these technologies evolve? Will there be opportunity to develop public policy that defines and considers the common good? How will the great number of people deeply concerned about these technologies respond to issues of food and human security, control and access to seeds, and military applications?
…
Quakers and all others devoted to the well-being of their communities and their society, need to be involved in a quest for responsible public policy on these new technologies.

APPENDIX TWO:

Relevant Quotations from Faith and Practice and other Quaker Spiritual Writing:

Kabarak Call

In April 2012, the World Conference of Friends, gathered at Kabarak University in Kenya, issued "The Kabarak Call for Peace and Ecojustice".[41] Some of its phrases are relevant to synthetic biology:

> "…we must become careful stewards of all life."
>
> "We are called to work for the peaceable Kingdom of God on the whole earth, in right sharing with all peoples."
>
> "We are called to teach our children right relationship, to live in harmony with each other and all living beings in the earth, waters and sky of our Creator, who asks, "Where were you when I laid the foundations of the world?" (Job 38.4)

2011 SPG Lecture

In her 2011 Sunderland P. Gardner Lecture, "In Search of a Moral Economy"[42], Marilyn Manzer (a Canadian Friend) noted:

> Individualism, ingenuity, and inventiveness—the culture of enterprise—have dominated western civilization. We exalted an economic system based on private gain…But it's worse than that. Karl Polanyi showed us the inherent fatal flaw of capitalism. It destroys the basic factors of production—nature (ecological systems), people (individual and social well-being) and capital (both manufactured and financial) by treating them as commodities always available for sale at a price determined by markets.
>
> The idea of mastery was born with agriculture—master, as opposed to connection—and from that idea flowed an altogether new set of values, the values of Enterprise…For the farmer, land, animals, and even human beings were resources that he must bring under control, and the man most adept at exploiting those resources was rewarded.
>
> With development of the "culture of enterprise," we had to elevate ourselves above the Spirit-filled local ecosystem. We needed a new concept of divinity. This was provided in the first two chapters of Genesis which posited that God intended to have dominion over every other living thing—an idea completely opposite to the values of "belonging."[43] With the culture of enterprise God also underwent a transformation, becoming masculine and supreme…God was relocated to the heavens, to oversee things…The values of enterprise promote disconnection from nature, from other people, and from Spirit.[44]

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[41] http://www.saltandlight2012.org/call.pdf

[42] The printed lecture was inserted into the December 2011 edition of *The Canadian Friend.* It can be purchased from Quaker Book Service in Ottawa. Email: quakerbookservice@quaker.ca

[43] Flinders, Carol Lee, *Rebalancing the World: Why Women Belong and Men Compete and How to restore the Ancient Equilibrium* (San Francisco: Harper Collins, 2009), p. 63.

[44] Ibid., p xix-xx

Individualism, ingenuity, and inventiveness - the culture of enterprise- have dominated western civilization. We exalted an economic system based on private gain. Our blind belief in this system has inspired war against alternative economic systems all over the world. This belief is akin to religious fanaticism, based on unexamined ideology…. It destroys the basic factors of production- nature (ecological systems), people (individual and social well-being) and capital (both manufactured and financial) by treating them as commodities always available for sale at a price determined by markets.

Faith and Practice

Quaker Faith and Practice of Canadian Yearly Meeting has many relevant entries. Here are a few from *Quaker Faith & Practice of Britain Yearly Meeting*[45].

20.32

The Creator of the earth is the owner of it. He gave us being thereon, and our nature requires nourishment, which is the produce of it. As he is kind and merciful, we as his creatures, while we live answerable to the design of our creation, are so far entitled to a convenient subsistence that no man may justly deprive us of it. By the agreements and contracts of our fathers and predecessors, and by doings and proceedings of our own, some claim a much greater share of this world than others: and whilst those possessions are faithfully improved to the good of the whole, it consists with equity. But he who, with a view to self-exaltation, causeth some with their domestic animals to labour immoderately, and with the monies arising to him therefrom, employs others in the luxuries of life, acts contrary to the gracious design of him [the Creator] who is the true owner of the earth; nor can any possessions, either acquired or derived from ancestors, justify such conduct.

John Woolman, 1763

Relevance: Humans do not own the earth…We live answerable to the design of creation (as opposed to our own design)…equity in the sharing of this world is necessary even when it may contradict legal agreements …immoderate use of domestic animals or employment of people for the excessive luxury of others is contrary the Creator's design…

20.35

Is our concern for simplicity relevant to our concern for the national economic situation? If we think of simplicity in terms of doing without certain things, of voluntarily reducing our standard of living, I believe this is almost irrelevant at the economic level in view of the scale of the world's need.

If we think of simplicity as a spiritual quality which incidentally simplifies our lifestyles then I believe it has relevance. This kind of simplicity goes straight to the heart of things and puts first things first, is needed to rectify our distorted values, to help us accept changes in our pattern of living. As this simplicity grows in our hearts and bears fruit in our lives, we may learn and help others to learn that the really abundant life is not to be found in the clutter of material complexity, but in simplicity.

L. Hugh Doncaster, 1976

Relevance: Quaker simplicity is not merely doing without; it empowers us to find abundance outside of material clutter.

[45] http://qfp.quakerweb.org.uk/

25.04

All species and the Earth itself have interdependent roles within Creation. Humankind is not the species, to whom all others are subservient, but one among many. All parts, all issues, are inextricably intertwined. Indeed the web of creation could be described as of three-ply thread: wherever we touch it we affect justice and peace and the health of all everywhere. So all our testimonies, all our Quaker work, all our Quaker lives are part of one process, of striving towards a flourishing, just and peaceful Creation - the Kingdom of God.

Audrey Urry, 1994

Relevance: All species are intertwined, in fact, peace, justice and the health of all are also intertwined and part of one piece—a flourishing, just and peaceful Creation.

25.07

As to our own planet, which God has given us for a dwelling place, we must be mindful that it is given in stewardship. The power over nature that scientific knowledge has put into our hands, if used in lust or greed, fear or hatred, can bring us to utter destruction. If we choose life we may now feed the hungry, clothe the naked, and heal the sick on a world scale, thus creating new conditions for spiritual advancement so often till now prevented by want. Many of our resources - of oil, of coal and of uranium - are limited. If by condoning waste and luxury we overspend the allowance God has given us, our children's children will be cheated of their inheritance. Limited too is the annual bounty of nature. The material foundation of our life is the tilling of the earth and the growing of food... We must conserve the goodness of the soil and not exploit it.

We must guard, too, the abundance and variety of untamed nature, and not forget the spiritual resources available to us in the continued existence of unoccupied lands. Modern civilisation perpetually threatens our awareness of the true nature of our being which in the presence of the wild we can more easily retain or at length recapture. Year by year silence and solitude are growing more needful, yet harder to obtain, and contacts, by this means, with the mind of the Creator more tenuous. To conserve nature is thus again a contribution to the fuller life of mankind.

Norfolk, Cambs & Hunts Quarterly Meeting, 1957

Relevance: We are in stewardship of creation and are obligated to use our scientific nature, not for personal gain, but to feed the hungry, clothe the naked and heal the sick. The annual bounty of nature is limited and we must conserve it, not exploit it. We are obligated to preserve tracts of nature as we have received them, rather than turn them over for commercial exploitation.

25.14

We are building towards the climax of crisis. The spiritual crisis is folding into the ecological crisis and the ecological crisis is folding into the economic crisis. As Christians, it seems to me, we are now required to critically assess the capital driven market economy and identify it as a false religion, a fabulously productive but ultimately destructive system bringing closure on God's goodness in creation and bringing a creeping atheism to the soul. To look this system straight in the eye and call it to account is a critical test of Biblical faith.

Challenging market economics with a Biblical sense of the goodness of God in creation is to join a spiritual struggle. Faith in God, solidarity with the suffering poor and all other forms of life demands that we take a stand and say, 'This destruction must stop.' We must be perfectly clear about the implications of undertaking this responsibility. It is more than just setting up household recycling bins, growing organic vegetables or riding a bike to work. It is more than a talking job. It is a renovation which will change everything: the way we do business, the way we eat, the way

we travel, the houses we build, the products and services we can expect and the prices we pay for them, the way we feel about trees and the way we worship God.

Keith Helmuth, 1990

<u>Relevance</u>: We are building towards a crisis—spiritual, ecological and economic. We have a spiritual duty to recognize the capital-driven market economy to be a false religion and to challenge it, to say that this destruction must stop. This will lead to a profound change in the way we do business, food, travel, housing, economics, forestry and, in fact, all products and services.

25.15

Our testimonies against war and inequality have been aimed at persuading people, and reminding ourselves, as to where their wealth lies: in the discovery of a common identity and a common cause with other human beings. Those testimonies apply in the same way to our treatment of our natural environment, which, as Augustine said, is itself like a 'commonwealth', in which every creature in its own way serves the interests of the others. The difference now is that the commonwealth of people and the commonwealth of the earth have become inseparably interrelated and interdependent - have become in fact one new commonwealth of life. Our thinking about God and the world and the way we live in relation to them must now give recognition to that fact.

Rex Ambler, 1990

<u>Relevance</u>: Just as Quakers have held fast against war and inequality, so must we do with the threats to our natural environment which is the commonwealth of all creatures. All are inseparably related and Quakers must live in relationship to this fact.

APPENDIX THREE:

List of links to synthetic biology websites for Monthly Meeting consultation 2013

The links are in the order that they are referred to in the information kit.

This kit is available for download from the CFSC website at: www.bit.ly/SynthBioKit
(Note, this link will re-route you to the CFSC website, it is simply a short cut).

1. (QIF #2) *How on Earth Do We Live Now? Natural Capital, Deep Ecology, and the Commons* http://www.quakerinstitute.org/wp-content/uploads/2011/05/HowonEarth-final.pdf

2. (QIF #3) *Genetically Modified Crops: Promises, Perils, and the Need for Public Policy* http://www.quakerinstitute.org/wp-content/uploads/2011/08/BiotechPamphlet-final-2.pdf

3. (QIF #5) *It's the Economy, Friends: Understanding the Growth Dilemma* http://www.quakerinstitute.org/wp-content/uploads/2012/06/IEF-web.pdf

4. (QIF #6) *Beyond the Growth Dilemma: Toward an Ecologically Integrated Economy* http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf

   Please Note: *QIF suggests donations of $3-5 for each booklet downloaded; visit: http://www.quakerinstitute.org/?page_id=89*

5. Report of the Presidential Commission on the Study of Bioethical Issues, "*New Directions: The Ethics of Synthetic Biology and Emerging Technologies"* (December 2010). FAQ: http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-FAQ.pdf (see page 1). The full report is at: http://bioethics.gov/sites/default/files/PCSBI-Synthetic-Biology-Report-12.16.10.pdf

6. http://www.synberc.org/content/resources

7. Church, George and Regis, Ed. *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves* (New York: Basic Books, 2012). For those who want to go beyond the excerpt in the kit, please visit these websites, where the book is summarized and illustrated by videos:
   a. http://newbooksinbrief.com/2012/10/30/23-a-summary-of-regenesis-how-synthetic-biology-will-reinvent-nature-and-ourselves-by-george-m-church-and-ed-regis/
   b. http://newbooksinbrief.com/2012/10/30/23-a-summary-of-regenesis-how-synthetic-biology-will-reinvent-nature-and-ourselves-by-george-m-church-and-ed-regis/

8. http://synbio.washington.edu/about/

9. *Principles for the Oversight of Synthetic Biology* (endorsed by100+ international groups, including Canadian Council of Churches, Biotechnology Reference Group. 17 pp.) : www.foe.org/news/blog/2012-03-global-coalition-calls-oversight-synthetic-biology and http://libcloud.s3.amazonaws.com/93/ae/9/2287/1/Principles_for_the_oversight_of_synthetic_biology.pdf, p. 1.

10. Hall, Ronnie, et al. *Bio-economy versus Biodiversity*, (Global Forest Coalition: 2012), p. 2: http://globalforestcoalition.org/wp-content/uploads/2012/04/Bioecono-vs-biodiv-report-with-frontage-FINAL.pdf

11. *Biomassters Battle to Control the Green Economy* (ETC Group and Heinrich Böll Foundation: 2012), see p. 3, 6: http://www.etcgroup.org/sites/www.etcgroup.org/files/greco_A4_eng_v16.pdf

12. *Synthetic Biology 101* (Friends of the Earth: no date), see p. 2: http://www.foe.org/projects/food-and-technology/synthetic-biology and http://libcloud.s3.amazonaws.com/93/41/1/971/Issue_brief_-_Synthetic_biology_101.pdf

13. Markoff, John. "In First, Software Emulates Lifespan of Entire Organism", in *The New York Times*, July 22, 2012: http://www.nytimes.com/2012/07/21/science/in-a-first-an-entire-organism-is-simulated-by-software.html?_r=0

14. "Ten years of synergy" (Editorial), in *Nature* (No. 463, January 2010, p. 269): http://www.nature.com/nature/journal/v463/n7279/full/463269b.html

15. Kwok, Roberta. "Five hard truths for synthetic biology", in *Nature* (No. 463, January 2010, pp. 228-290): http://www.nature.com/news/2010/100120/full/463288a.html

16. Rutherford, Adam. "Synthetic Biology: 'Playing God' is vital if we are to create a better future for all", in *The Guardian* (July 27, 2012): http://www.guardian.co.uk/commentisfree/2012/jul/27/synthetic-biology-playing-god-vital-future

17. Porcar M, Danchin A, de Lorenzo V, et al. "The ten grand challenges of synthetic life", in *Systems & Synthetic Biology* 2011-5 (June), pp. 1-9. "The ten grand challenges of synthetic life", at US National Library of Medicine, National Institutes of Health): http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3159694/

18. Wolbring**,** Gregor. **"**NBICS With, For, and By the People: What it is, what it means and why it matters" (no date)**:** http://www.bioethicsanddisability.org/healthwright.html

19. Gollan, Jennifer. "Berkeley Scholar Raises Alarm on Synthetic Biology", in *The Bay Citizen*, October, 22, 2011: https://www.baycitizen.org/news/science/berkeley-scholar-raises-alarm-synthetic/

20. The Synthetic Biology Project, established by the Woodrow Wilson International Center for Scholar's Science and Technology Innovation Program: http://synbioproject.ord/scorecard/

21. Results of a poll about American public awareness of synthetic biology. http://www.synbioproject.org/process/assets/files/6653/_draft/synbiosurvey2013.pdf

22. (QIF #3) *Genetically Modified Crops; Promises, Perils, and the Need for Public Policy* (p. 18): http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf

23. (QIF #6) *Beyond the Growth Dilemma; Toward and Ecologically Integrated Economy* (p. 55, p. 80) http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf

24. (QIF #5) *It's the Economy, Friends : Understanding the Growth Dilemma*, p. 63 *:* http://www.quakerinstitute.org/wp-content/uploads/2012/06/IEF-web.pdf

25. *Faith, Life and Technology: The Canadian Council of Churches celebrates 10 years of biotechnology, theology and ethics, Forum Report, December 3-4, 2009* (Canadian Council of Churches' Biotechnology Reference Group, 2009). Click on the link to it on this page: http://www.councilofchurches.ca/en/Biotechnology/biotechnology-consultations.cfm

26. (QIF #3), *Genetically Modified Crops; Promises, Perils, and the Need for Public Policy*, p. 8: http://www.quakerinstitute.org/wp-content/uploads/2012/10/BGD-web.pdf

27. Church and Society Council, Church of Scotland. "Synthetic Biology" (2010): http://www.churchofscotland.org.uk/__data/assets/pdf_file/0003/3792/synthetic_biology_ga10.pdf

28. (QIF #2) *How on Earth Do We Live Now? Natural Capital, Deep Ecology, and the Commons,* pp. 75-76: http://www.quakerinstitute.org/wp-content/uploads/2011/05/HowonEarth-final.pdf