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Faith and Science:

Synthetic Biology and Bioethical Questions

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Society has become quite familiar with the reality and possibilities of genetic sequencing and genetic screening. We know that each of these can be a two-edged sword, working for good and evil. They can help diagnose problems which are possibly treatable. Genetic screening can sometimes be a bearer of information about future possibilities, leaving people with the burden of knowing that some illness may possibly occur at some future point, but not necessarily.

Genetic screening of babies in the womb can be done, and, if a mother opts for testing, the results may either reassure her or present her with a dilemma. If she is told that the baby has Down Syndrome, for example, she may decide not to continue with the pregnancy. Studies show that the number of children with Down syndrome has dropped drastically, not because the syndrome can be prevented, but because these babies are frequently aborted. Troubling questions of false negatives and false positives in diagnosis arise, presenting other moral considerations for parents in making decisions.

Similar questions apply to pre-implantation genetic diagnosis, when embryos created through *in vitro* fertilization are tested for genetic health before being selected for implantation in the mother's womb. Who is likely to "choose" an embryo diagnosed with a serious health issue, physical or mental? Mostly, such human embryos are discarded.

Genetic engineering is a field where treatment and cures of genetic problems may be sought. The capacity to detect and deal with genetic mutations has come about because of the development of techniques such as CRISPR-Cas9, a unique technology that enables geneticists and medical researchers to edit parts of the genome by removing, adding or altering sections of the DNA sequence.[1] Genes are defined by their specific sequences, which provide instructions on how to build and maintain an organism's cells and the capacity for altering those sequences can be useful for treating genetic disorders.

The CRISPR system seems to be the fastest and most reliable system for "editing" genes, although it is unlikely to be used routinely in humans for some time. Research is still mainly on animal models or isolated human cells, where work is on modifying genes in living cells and organisms. So far, changes have been made in the genes of organisms such as fruit flies, fish, mice, plants and even human cells. In the future, it may be possible to correct mutations at specific locations in the human genome to treat genetic causes of disease. Research suggests that CRISPR can be used to target and modify errors in the three-billion-letter sequence of the human genome, with the ability to target multiple genes simultaneously. CRISPR techniques allow scientists to modify specific genes while avoiding interference with others, so important because a change in the sequence of even one gene can significantly affect the biology of the cell and in turn may affect the integrity of an organism

Society is already familiar with GMOs and we have seen the effects in GM plants and animals. So far, many countries have enacted laws to restrict the type of genomic modification that may be made on humans, resisting the enhancement model and encouraging curative models. These scientific developments, coupled with the ability to alter or engineer DNA and the ability to manufacture DNA, have led to the relatively recent scientific possibilities provided by what is known as "synthetic biology."

This science has been defined as "the intentional design of artificial or reworked biological systems."[2] It involves the design of minimal cells and organisms, the identification and use of biological parts and the construction of totally or partially artificial biological systems. The UN describes synthetic biology as "…the design, redesign, manufacture and/or modification of genetic materials, living organisms and biological systems."[3] Synthetic biology aims to engineer living organisms in a structured manner, using methods stemming from engineering sciences and practices, particularly mathematical modelling and computer simulation. There are large numbers of videos on the internet showing the results of these developments using live organisms coupled and adapted with these applications, resulting in new organisms, some of which appear "fantastic" and many of which are already showing success in the fields of health, energy, the environment and agriculture.

A well-known figure in synthetic biology is Professor Drew Endy of Stanford University, whose work aims to make biological substances into engineerable substances. He emphasizes the importance of knowing how things work and how all the components interact, which is the basis of the scientific endeavour. He thinks we can learn by taking everything apart and putting it back together, which is presumably true, but he goes further: he thinks we can collect, refine and eventually *repackage* nature, i.e., make (engineer) living organisms that are now different, directed by scientists towards specific goals.[4] Science will direct these new organisms' genome, not nature itself. While we know this has already been achieved in the genetic modification of plants and animals through changes which affect the germline, Endy's and others' aim is to be able to discover and then formulate "bio-bricks" for use as basic life constructs. While it sounds like science fiction and the stuff of the scientific "Holy Grail," this research seems to be close to that goal.

The availability to researchers of DNA sequences from nature is the condition of possibility for the giant strides made in this endeavor by synthetic biology. DNA can be printed by 3-D printers; it can be ordered online as any other product; and anyone can work with it, even at home. In fact, "garage hackers" is the term used for non-scientists using it in all sorts of experiments. Scientists are rebuilding living organisms and adding parts to change their formulation, in effect "creating" new organisms, i.e., synthetic organisms. Craig Venter, an American scientist whose Institute is dedicated to synthetic biology, was the first to replace the DNA in one bacterium with that of another, thus creating a "new" living organism, one that did not exist in nature before.[5]

There are many other examples of engineering DNA to make products with their own genetic code, many of which are aimed at the health care field. *Artemisinin*, an anti-malarial medicine, has been synthesized from the plant *Artemisia annua*, which has been used in China for over 2000 years to combat malaria. Unfortunately, the amount needed no longer keeps pace with demand. Researchers extracted the plant's genes, optimized their expression and introduced them into brewers' yeast, managing to build a pathway for synthesizing a precursor of artemisinin. After studying the effects of adding several DNA sequences over a period of years of experimentation, artificial artemisinin was developed, with better quality and availability and at half the cost of deriving the product directly from nature.

Household products and fabrics that use biological models are already features of everyday life: sometimes we are unaware of how they are made. For example, some chairs are made of mycelium, the vegetative part of fungi which has strong and elastic properties. The mycelium is processed by 3-D printers and is used in constructing the equivalent of plastic chairs, but without the environmental cost that is an important consideration. DNA does not have to be altered in these cases, and 3-D printing in manufacturing and replicating biological forms is simply part of the necessary conditions for the speedy and efficient manufacture of such products. Mycelium is also used in making *Mushroom* packaging (a compostable alternative to plastic foam) and *Myco Board* (replacing wood products such as particle board).[6] Some synthetic biologists have engineered structures to help multiply the production of silk by silk worms, creating clothing at a much faster pace than in nature. Bowls, bricks and insulation are other items to look for, if one is interested in their "synbio" genesis.

Yeast is a useful growing medium, and perfumes are now being made by adding the genetic pathways of flowers, rather than by the time-honoured method of using the petals and stems of the flower itself. Researchers can splice and dice genetic codes to make different fragrances that do not exist in nature. For example, vanillin is an engineered product of vanilla, much cheaper and made in large quantities. Flavours can be added to foodstuffs by the same methods, and this could be of benefit in extending possibilities of variety in countries existing on staples, just as proteins are added in some cases through genetic modification to enrich grains such as rice.

Additions to agricultural products which could prove useful are slugs that are programmed to seek acidic soils and neutralize them by dispersing an alkaline fluid through seed dispensers made from both living organisms and designed parts, to increase biodiversity. Other research is being done with plant-based fuels, where speedy reproduction would assist in the global effort to replace fossil fuels used for motor oils and plastics.

In the field of health, there is current experimentation and research in using genetically altered male mosquitoes to render future partners sterile, and thus diminish the mosquito population. This is being seen as a possible solution to dengue fever and malaria, and in trials in Cayman, Panama and Brazil, the population of dengue-carrying mosquitoes was reduced by 90%.[7] The long-term consequences of such alterations are unknown, and this raises questions about the ethical implications of the use of synthetic biology.

ETHICAL ISSUES

Some urge society not to think of synthetic biology as a panacea to replace our own personal and global conservation efforts. Instead, we must continue our efforts to conserve and think wisely about our current usage, e.g., of automobiles and about emissions. Most of us, however, will be resistant to cutting back on our driving, and will welcome biofuels only if they become plentiful and available, and only once our regular sources become limited. In that case we will be more likely to welcome the discoveries of synthetic biology!

There do not appear to be major ethical questions about altering plant sources *per se,* but they may become more obvious in the long run, as often happens. Are there any dangers in over utilizing *those* sources, causing further problem? And what are the consequences of designing and developing other life forms? Are we humans, in "interfering" with nature, actually interfering with Creation, by altering existing forms with designs of our own? Will the speed of change, compared with the eons over which evolutionary change takes place, affect us? Clearly, Creation does change, of itself, through evolution. Is the fact that humans can now design and instigate more changes wrong? We need a forum for a deep, ethical discussion of these matters, and the UN could be a possible forum for that. Ethical questions arise after the proverbial horse has already bolted, and that leaves society not only with questions, but also with situations lacking responsibility and oversight. Designers, discoverers, engineers and entrepreneurs in the field of synthetic biology could remain unchallenged until ethicists and others formulate the questions for which society needs answers.

One of the major ethical questions is about gene drives, where the possibility of altering the genetic code of an organism means that its own DNA not only can be altered but those changed characteristics will now be passed on to future generations. The United Nations has been monitoring living organisms to see the effects of these changes in health, agriculture, the work place and in other outcomes, specifically through the Conventions on Biological Diversity. The CBD is the first and only international body addressing issues of governance in this field, and is now monitoring synthetic biology for the same purpose. It uses as its criteria the principles of precaution, fairness (sharing of benefits) and prior informed consent in any proposed alteration to living organisms.[8] There is great concern for indigenous populations and a growing awareness of their right to be consulted on, and to consent to, any experiments on their crops, seeds, soil, livestock, etc., which will use genetic or synthetic biological means.

This echoes Catholic Social Teaching and its insistence on the need to maintain both the individual *and* the common good. These principles challenge any uses of biotechnology that are aimed at maximizing profits without careful studies of its effects on people and the environment, as well as the possibility of any long term risks to personal, societal, global and ecological health. Pope Francis believes that society is enthralled with a technocratic paradigm which promises unlimited growth, but this "is based on the lie that there is an infinite supply of the earth's goods, and this leads to the planet being squeezed dry beyond every limit."[9] The Pope is scathing about those who show no interest in more balanced levels of production, a better distribution of wealth, concern for the environment and the rights of future generations."[10] *Laudato Si*!, for example, calls us to a different way of life, where "… we have to realize that a true ecological approach *always* becomes a social approach; it must integrate questions of justice in debates on the environment, so as to hear *both the cry of the earth and the cry of the poor."*[11]

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