# A conversation with Dr. Allison Snow, March 17, 2015

## Participants


- Allison Snow, PhD – Professor, Department of Evolution, Ecology, and Organismal Biology, Ohio State University, Columbus, OH
- Nick Beckstead – Research Analyst, Open Philanthropy Project


**Note**: These notes were compiled by the Open Philanthropy Project and give an overview of the major points made by Professor Allison Snow.

## Summary


The Open Philanthropy Project spoke with Professor Snow of Ohio State University as part of its investigation into the potential ecological risks of synthetic biology. Conversation topics included worst-case scenarios, potential risk-management strategies, and the role for ecologists in promoting safe applications of synthetic biology.


## Synthetic biology

Synthetic biology is a highly advanced form of genetic engineering. Many proposals in synthetic biology involve altering organisms' DNA for economic gain or other goals. The rate of adoption for these new proposals remains low, but rapid advances in the field are ongoing.

Many people are concerned about how these new technologies will be applied. Synthetic biology is an incredibly powerful tool and could be dangerous if it is not applied safely. It's not clear whether people who are currently designing new organisms or altering existing ones understand the potential environmental and ecological risks involved. Not all of synthetic biology is dangerous and a single application is unlikely to cause an ecological catastrophe.

### A role for ecologists

Ecologists can help describe the worst-case scenarios associated with synthetic biology, such as what would happen if a dangerous engineered organism were unintentionally released and began reproducing. Dr. Snow co-wrote a paper on "Genetically Engineered Organisms and The Environment: Current Status and Recommendations" in 2005. The Ecological Society of America adopted it as its position paper. Most of the issues and concerns haven't changed in the last ten years: when considering releasing a new or genetically altered organism into the environment, it is important to ensure that it isn't going to be invasive, replace other organisms, or disrupt natural functions.

Ecologists can also help develop the general principles that should be used when designing organisms. Ecologists can think about the consequences of synthetic biology ten to twenty years into the future, combining principles and relevant case studies from ecology and evolutionary biology.

There is currently a training gap. Graduate programs aren't training ecologists to think about the ecological implications of synthetic biology. Also, there aren't a lot of grants available to study these issues and thereby engage junior-level professional ecologists. These gaps need to be addressed before there will be many ecologists available to comment on specific applications of synthetic biology.

## Potential risk management strategies

*Increasing communication*

Increasing communication between ecologists, synthetic biologists, and the general public could help address potential risks. Currently, there is very little communication about what kinds of organisms are being proposed. Ecologists and other scientists also need to do a better job communicating about the risks of synthetic biology. So far, there has been more discussion of the ethics of synthetic biology than there has of the potential ecological and environmental consequences. Increasing communication about potential synthetic biology applications will help to spread the idea that there are both smart and dangerous applications.

Ideally, once more people become familiar with the risks and benefits of synthetic biology, scientists will help to regulate each other. Communicating with scientists across relevant disciplines about the potential risks of synthetic biology is important. Formal government regulation won't be enough in the USA or around the globe.

*Setting outer limits*

It is also wise to think about what should be the outer ethical limits for synthetic biology. Discussing the ethical limits of genetic engineering will help to direct attention to possible solutions that don't involve synthetic biology. Many scientists and ethicists have argued against the use of genetic engineering for humans, for example using a new technique known as CRISPR.  Parallel discussions are needed for plants, animals, and microbes.

A ban on all environmental releases of organisms that have been altered by synthetic biology is probably extreme, although some people are advocating for that. If there is a chance that novel organisms will thrive without human attention, ethical as well as ecological implications and possible risks should be investigated.

*Biological confinement*

Biological confinement techniques prevent organisms from living on their own. For example, scientists can reprogram an organism to require an amino acid that is only available in a controlled environment.

Biological confinement is a new and evolving science. It is a good area in which to direct more resources. It is possible it might become very advanced. Biological confinement strategies should also be paired with the best management practices to avoid unintentional and unwanted escapes of synthetic GMOs.

## Specific applications of synthetic biology

### Gene drives

Dr. George Church, Professor of Genetics at Harvard Medical School, is proposing some of the most controversial synthetic biology applications, such as designing gene drives to eradicate certain unwanted species and other new techniques for "re-creating" extinct species like the wooly mammoth. Gene drives alter inheritance patterns and can thereby change the genetic makeup and survival of entire populations. This research is in very early stages. The Bill and Melinda Gates Foundation and others also have explored the possibility of using genetically modified mosquitos to control malaria.

There is a risk that gene drives will unintentionally harm or kill other species or populations. It will be very important to control where and how gene drives are used. In any species that uses sexual reproduction and has rapid life cycles, gene drives could spread desired genes through a population very quickly. In an exaggerated worst-case scenario, a campaign to eradicate rats also might eradicate all animals related to rats, or a campaign to eradicate rabbits in Australia might eradicate rabbits on other continents. Dr. Church's group has said they are developing "anti-gene drives" that could correct mistakes, but it may turn out to be difficult to correct gene drive errors.

Gene drives might also alter local ecological systems in a way that would harm rare species and/or favor invasive species, which are very hard to get rid of. For centuries, humans have underestimated the effects of moving plants and animals around the world. A species may be native in one setting and invasive in another. Eradicating a population might leave space for other species to become invasive.

There is also the possibility that individuals will make bad decisions about gene drives. For example, some people don't like squirrels or starlings, but that is a bad reason to eliminate certain populations. Thus far, there have been no international agreements about how these techniques should be implemented.

### Food and fiber production

Some researchers are examining how to use synthetic biology to enhance plants grown for food, wood, fiber, or other products. It's possible that this would lead to a "superweed" problem where a single engineered species becomes incredibly invasive. Uncontrolled growth would harm local ecosystems and farmers. Compared to gene drives, however, these synthetic biology applications may be easier to detect and manage. If someone designs a form of switchgrass that grows to be 10 feet tall, for example, others will likely notice.

*Genetically modified crops*

Synthetic organisms and genetically modified (GM) crops exist on a continuum. In principle, they are very similar. All GM crops could probably be made in a more sophisticated manner with synthetic biology methods such as "genome editing".

In general, synthetic biology involves modifying a wider range of organisms, many of which we don't understand as well as domesticated crops. GM crops usually involve small, incremental changes to already domesticated species (e.g., adding one gene to make crops resistant to herbicide or caterpillar larvae). These changes are easier to control and don't have the same potential catastrophic effects of full-scale synthetic biology.

There is also a large community of people and companies designing GM crops, so there is some self-policing along with regulatory oversight. Because so few companies are involved in synthetic biology for environmental releases, there has been less discussion about how to grow novel engineered organisms in controlled ways.

However, even though methods for designing GM crops are becoming more precise, they remain very polarizing. A lot of non-governmental organizations remain very skeptical of anything involving genetic modification. Some of their concerns are valid, but the dangers are often exaggerated.

## Microbes and algae

Microbes are among the easiest organisms to genetically engineer. There is a lot of potential to manipulate their functions for economic benefit. However, there could be serious problems if hardy engineered microbes escape into environment.

For example, some kinds of altered soil bacteria might pose risks if they interfered with nutrient cycling and became widespread. Experts in nutrient cycling and the role of carbon in the soil would know more about this.

There are currently many proposals to modify plants and algae grown outdoors to produce biofuels, though it is still not clear if such biofuel production will be profitable. Blue-green algae, which are a type of bacteria, could be modified to be more productive and more tolerant of variation in the environment (e.g., amount of water, nutrients, or sunlight). These modified algae would also be engineered to produce more oil, because the end goal would probably be to use them for biofuel. In some cases, engineered algae could grow faster and be hardier than native algae.

*Worst-case scenarios*

Proposals for genetically engineered algae have included programmed "suicide genes" because if modified algae got out into the broader environment and started to reproduce, they could be destructive. Dr. Snow published a paper in *Bioscience* with an algal ecologist titled "Genetically Engineered Algae for Biofuels: A Key Role for Ecologists." This publication outlined a potential risk: genetically engineered algae might get into estuaries and fresh and salt water and disrupt ecosystems. If engineered algae begin to grow and reproduce outside of defined, cultured environments they could evolve into entirely new (and potentially invasive) populations.

In a hypothetical worst-case scenario, super-strong engineered algae might spread along coastlines worldwide, clog waterways, contaminate beaches, produce neurotoxins, or create dead zones in the water. While these are extreme examples, they may be the most plausible worst-case scenarios regarding synthetic biology so far.

Dead zones already occur seasonally when excess nutrients, often from agriculture, run off in the water. This causes algal blooms, which deplete oxygen levels in the water, killing fish and other species. Dead zones typically don't cause species to go extinct, but they kill most forms of life within a certain area. Dead zones in the Gulf of Mexico and Chesapeake Bay are becoming more common. The Environmental Protection Agency and others are exploring how to change farming practices and sewage treatment to prevent excess nutrients from entering the water.

## Groups working on assessing risks of synthetic biology

- **The Wilson Center –** The Wilson Center is a non-partisan policy forum based in Washington, D.C. It runs the Synthetic Biology Project. Its website lists some of the worst-case scenarios. The Wilson Center has received funding from the National Science Foundation to look at the gaps in ecological research that needs to be addressed as synthetic biology becomes more common. The Wilson Center mainly employs policy researchers, not ecologists.
- **The ETC Group** – The ETC Group is a non-governmental organization based in Ottawa that address the socioeconomic and ecological effects of new technology. They are working on synthetic biology issues (http://www.synbiowatch.org/).

## Other people to talk to

- Todd Kuiken, PhD – Senior Program Associate, Science and Technology Innovation Program, The Wilson Center
- Jim Thomas, Research Programme Manager, ETC Group, Ottawa
- George Church, PhD – Professor of Genetics, Harvard Medical School; and Kevin Esvelt, PhD – Research Fellow in the Church group
- Craig Venter, PhD – Founder, Chairman, and Chief Executive Officer, J. Craig Venter Institute

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