This SynBio future was developed by the 2012 UCLiGEM Team:

Expectations have been set high for the synthetic biology future. From biosensors that detect and destroy disease to advanced biofuels and oil-free plastics, synthetic biology has certainly made some lofty promises. We need only remember stories of flying cars and robot butlers to know that any attempt to predict the future of a developing technology is likely to prove over-optimistic at best, and completely wrong at worst. Realistic or otherwise, such hopes for the future may also raise some very real fears. With this in mind, we present a 'disaster scenario' that takes place in some possible future where synthetic biology technologies are commonplace. In this way we hope to address concerns around synthetic biology by considering how we might respond if fears become reality. The scenario offers exploration of issues such as: commercialization of SynBio, deliberate release, transboundary movement, risk management and liability.

More background information on the scenario as well as a position paper of the UCLiGEM team be can be found at:

http://2012.igem.org/Team:University_College_London/HumanPractice/MOYM

A synthetic biology crisis

Part 1: Synthetic beginnings

The year is 2030. For the past 15 years, farmers across the world have been using the FertiBac bacterial fertiliser system, a new kind of fertiliser which uses modified *E.coli* to detect where the soil is low in nitrate and then produce nitrate to bring the soil to its optimum level. To ensure environmental safety, FertiBac uses GeneShield, a standard gene transfer prevention mechanism based on freely available BioBrick parts from the parts registry.

FertiBac was one of the first synthetic biology technologies to be commercially released, and as such it set a precedent for the regulation of synthetic biology products. Extensive safety testing was carried out in a step-by-step fashion, first with small and then large-scale controlled field trials, and then a pilot release on a remote island off the Scottish coast, each wider release being permitted only if evidence from earlier releases indicated complete safety. Europe-wide public consultation was carried out in parallel with the testing, involving a programme of education and debate devised by scientists and policy-makers in collaboration with farmers and concerned non-governmental organisations. To ensure the debate remained unbiased, anyone with a financial interest in FertiBac could not take part, although those who stood to gain in other ways from wider acceptance of synthetic biology technology could be included. As FertiBac passed through ever-larger scale testing without incident, and as news arrived of exciting new synthetic biology products that were being developed in the lab, public opinion began to sway more firmly in support of release of FertiBac.

So it was that in 2015 FertiBac was granted permission for release to market, first becoming available in the UK and then in other countries, often backed by government subsidy to ensure that all farmers would be able to benefit from the new system. Since its release, farmers have seen their yields improve dramatically and their fertiliser expenses decrease. They can now grow crops in areas that would have previously been considered unusable and they no longer have to worry about damaging their crops from over-fertilisation. The original patents on the FertiBac technology have expired and several companies are now producing variations on the fertiliser. This first successful implementation of synthetic biology

to solve a real-world problem opened the door for further technological developments in this field, and products of synthetic biology - agricultural, environmental, and medical - are in widespread use throughout most developed countries, and increasingly so in less economically developed parts of the world.

Part 2: Crisis

In the island city of Singapore, people are falling victim to a strange new disease. It starts with fever and nausea. Sufferers then experience deteriorating vision, and within a few weeks they are blind. After extensive investigation, the source of the outbreak has been traced to rice imported from Thailand, where a chemical spill has contaminated crops in the area. The affected crops are destroyed and many countries place temporary bans on the import of Thai rice.

So when dozens of new cases appear in Europe a few months later, the problem appears significantly more grave than previously thought. Imports from Cambodia, Laos, and Vietnam are also found to be contaminated, far beyond the reach of the chemical spill. Authorities are stumped - until a connection is discovered between certain affected crops and FertiBac-based fertilizer. The chemical spill, combined with a record heat wave and unusually high amounts of rainfall, has caused the FertiBac bacteria to mutate, producing a toxin which poisoned the Thai crops. To make matters worse, the GeneShield system has been degraded, allowing the mutant genes to spread to wild-type soil bacteria, which are then transported from field to field on farmer's clothing and shared farm equipment. This has allowed toxin-producing bacteria to reach neighboring countries - but we do not yet know how far the contamination might have spread. Cases with the same symptoms are beginning to appear the world over.

This is now an international issue. What is the best course of action?

Scan the QR code to view a video clip
based on this scenario or click here.

According to its supporters, the use of synthetic biology could, in the near future, substantially reduce the global shortage of food. Genetic modification – the introduction of a new gene into an organism – is highly inefficient when compared with the tools of synthetic genomics, enabling a complete redesign of plants on the basis of synthesized DNA. Synthetic biology thus entails the promise to make agriculture much more productive. We may foresee crops with higher yields, which need less water and will be more pest resistant, which contain more healthy components and may be better adapted to weed control and mechanical harvesting. But will it work in practice? We are dealing with living organisms that are hard to control and there may be risks involved like sturdier pests, increased pesticide resistance, growth of invasive species, uncontrolled environmental escape or release and attendant disruption to ecosystems.

Source: Presidential Commission for the Study of Bioethical Issues (2010). *New Directions. The Ethics of Synthetic Biology and Emerging Technologies*. Washington, D.C. [www.bioethics.gov]

Activists accuse each other of irresponsibility

News article

For months, human rights activists from Poverty Watch and Bread For the World have been campaigning to lift the current restrictions on the sales of Waterless© – a wheat produced by means of synthetic biology. Currently, sales are restricted to EU countries that are able to maintain the infrastructure necessary to safeguard the environment. Although this product could seriously reduce starvation, the European safety requirements are so strict that no African country has ever qualified to buy Waterless©.

In an attempt to reduce starvation in Sub-Saharan Africa, the Aid Development and Cooperation Directorate of the European Commission has proposed to alleviate current restrictions, a proposal which is strongly endorsed by human rights organisations. Poverty Watch activist Jane Edinburgh stated earlier today "It is time to act. Now synthetic biology helps us to get rid of hunger, it would be a grave irresponsibility not to do so." Waterless©, a highly nutritious wheat, has minimal water use, allowing for cultivation under harsh conditions. The European Commissioner Jan Pietrov added "By allowing African countries to buy Waterless©, we could reduce starvation on the African continent by an estimated 45%. Given that about 950 million people in the world are malnourished – most of them living in Sub-Saharan Africa and South Asia – this would be a phenomenal achievement".

It is unclear whether the proposal will make its way through the European Parliament and the Council of Ministers, because environmentalist organisations are vehemently fighting the proposal. "Lifting the conditions for the cultivation of engineered wheat is irresponsible to the extreme," says Greenpeace press officer Michael Fuhrmann. "We have these restrictions in place for a reason, and if we

lift them we will do more harm to the African continent than we will do good. Without continuous and meticulous monitoring, Waterless© is bound to escape into nature. Developing countries lack the infrastructure and resources to react in cases of such an inevitable emergency. What if Waterless© mutates, endangering other plants, or insects vital to the agriculture and lives of so many people? Lifting export restrictions will result in mutating and destroying African biodiversity."

Human rights advertisement

Every five seconds, a child dies from hunger. What if we could save them?

Monsanto and Wheat For All make billions of money with their patents on genetically modified wheat to safeguard proper usage. By open-sourcing their technology, millions of people could be saved from starvation.

Join the fight against patenting life. Let's make hunger history.

United Environmentalists advertisement

Fighting starvation by easy-to-produce food sounds like a brilliant idea. But is it really?

Check out our website to find out how genetically synthesized food may be a short-term solution to hunger, but will threaten the world's global natural balance, animals, and in the long-run, us all.

Human rights activists are outraged. "People starve," comments Poverty Watch activist Jane Edingburgh, "and while the EU could do something about it, it prefers saving its own farmers."

Developing vaccination against viruses is an important aim in synthetic biology research. First, the specific coding of the virus has to be read. Computational technologies help to identify relevant parts of the virus's genome. By subsequently copying and slightly changing parts of the genetic code, one can produce an attenuated virus. This virus produces less virus protein than a normal one, and can therefore be used to vaccinate people against the real virus. The technology is applicable to all sorts of viruses, and it is claimed to be fast and effective. Researchers of Stony Brook University designed an attenuated polio virus. Recently, they also synthesized attenuated influenza viruses. These virus vaccines are claimed to be safer – only a low dose is needed and the virus regains virulence less often – and to have effectively protected mice against an influenza virus that was lethal in non-vaccinated mice.

http://www.cs.sunysb.edu/~skiena/press/scibx.2010.817.pdf
http://2008.igem.org/Team:Slovenia

At the doctor

"Hi, this is Doctor Schmidt. I'm calling with regard to the meeting we had this morning and the symptoms you showed. I dived into some old literature, which strengthens my hypothesis that it might be an old virus called influenza, or the flu. I don't know whether you've heard of it before? It only pops up once in a while in people who traveled to some exotic regions or who were in touch with such travelers. Maybe you know somebody that recently came back from a journey?"

"Eeuh … I have indeed heard of the disease. I'd better not update my online status with that. But how can that be? I don't know anybody that went to a distant country recently."

"Well, once in a while viruses outsmart us by mutating in a way we had not anticipated. Maybe something like that happened here. We will check that as soon you're in and then try to identify the source by mapping all the contacts you had during the last week. Which reminds me that I was one of them. But our top priority is to get you in quarantine to prevent further infections. So I have to ask you stay inside from now on. We will send a special taxi to fetch you and bring you to the former military basis in Soesterberg, the location for quarantined people in our region. Your wife and children…"

"But in quarantine – that's impossible! I have to finish a very important project at my work, I can't simply chicken out! Can't you just give me a pill and make it go away before the day after tomorrow? How can I explain this to my boss? I bet he will not understand! And what about my daughter's birthday tomorrow?"

"I'm sorry to be the messenger of such bad news. But we have to take into account the societal risk of having huge numbers of people affected with flu and not able to work. We simply have to think of the economic impact a flu epidemic

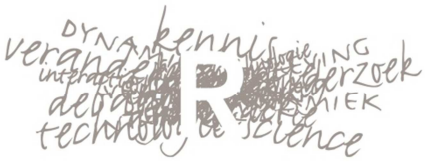
would have. I know quarantine can be very inconvenient, but it won't take long. You are infectious for a brief time only. I'm afraid that the symptoms will get a little worse and teleworking from the centre may be quite difficult at first. You should take a good rest. Of course the quarantine centre will do all that's possible to make your stay with them as comfortable as possible, and when you feel like it you can start working again from the centre until you're released. All in all, it will take you one to two weeks."

"But I cannot tell my friends that I have the flu! What would they think of me having such an awful disease?"

"It is too bad people think of the flu as if it were something like the plague. It is nothing to be ashamed of. Contrary to what you sometimes hear it is *not* transferred by rats or insects of any kind, neither does it have to do with an unhygienic lifestyle. And it's not that long ago that flu viruses were around everywhere. The general flu vaccination program ran from 2020 till 2037. It was so effective in eradicating the disease that it was stopped, but only after the flu hadn't shown up anymore for years. Back in those days it was a very common disease and not that harmful, but rather uncomfortable. You should definitely not be ashamed of it. Although I agree that nowadays the flu has a rather bad name, the stories are most often wrong and easy to refute."

"Hmm, still.. I think I'd rather tell the world that I'm having one of those 'save yourself a burnout' long weekends. Thank you very much for your call, although I'd rather have heard a different diagnosis."

"Thank you for your cooperation for the common good! The car will be there in less than two hours. In the meanwhile you can pack some personal stuff. I hope you will have a quick recovery!"



Given the energy crisis facing our planet, synthetic biology could contribute by developing alternative ways of lighting, which currently accounts for 8% of our use of electricity. In order to provide any solution to the problem, a biological solution must tap into a currently unused energy resource. For this reason we decided to consider the use of bioluminescent trees to replace conventional street lamps. A tree in this position would be able to photosynthesise during the day, building up reserves of energy. We then imagined it emitting light by night, using the bacterial luciferase system. We placed genes from fireflies and bioluminescent bacteria into E.coli. Codon optimisation and single amino acid mutagenesis allowed us to generate bright light output in a range of different colours. We built a set of Bricks to allow bioluminescence in a wide range of colours which have applications as natural light sources.

http://2010.igem.org/Team:Cambridge

Bioluminescent street lamps

Her husband thought these shining trees were spooky. Awful Christmas days now seemed to last the whole summer and it was only a matter of time until they would teach the damned trees to sing Jingle Bells too. And where was the off-button on these things, he would complain. What did a man have to do nowadays to get some descent darkness in this world of light?

But she herself thought them beautiful as she gazed up to the intricately fingered web of soft bluish light that waved silently above her head in the gentle breeze. Oh, if only it could always be summer, so that the trees were shining. She had come to hate the harsh, unforgiving mechanical light of the old-fashioned street lamps, which of course still had to be used during winter when the trees didn't work. Especially ugly was spring-time, when the still hesitant glow of the trees had to compete with the street lights that were still on.

Well, her husband was just being grumpy and old-fashioned. Bioluminescent plants had become all the rage, and now each day some creative do-it-yourself synthetic biologist would proudly present a new home-grown bioluminescent garden-variety. There were contests, where juries would visit the beautifully luminating gardens. Of course, during grey seasons you had to 'feed' light into your plants using enormous electric lamps, but then the result was so much better.

To be honest, if you wanted to see 'lumis', you were no longer restricted to streets or gardens. More and more wild varieties were popping up in woods and meadows. Well, what could you expect? It is simply impossible to have all those enthusiastic amateur breeders stick to industrial safety regulations. Never mind!

No one has been poisoned yet, and that some species of nocturnal animals had moved on to darker areas of the world….well, who cares. It is hard to shed a tear for animals that you never see anyway.

Rathenau Instituut

The notions of biosafety and biosecurity refer to a variety of regulations that should prevent health threats, biological risks, laboratory accidents and misuse of scientific research in synthetic biology. Broadly, two kinds of risks are identified: people making mistakes – 'bio-errorism' – and, on the other hand, intentional misuse of available knowledge and technology – 'bioterrorism'. With the advent of synthetic biology, biosecurity has become a special concern in the context of rising threats of terrorism. But biosecurity measures always come at a cost, how safe is safe enough? And who are the experts exactly? Is a biologist an expert on terrorism? Is a security officer an expert on public health policy? And what about the expertise of a policeman who has to distinguish between synthesised and natural viruses? Biosecurity is an interdisciplinary field in which experts of all kinds have to communicate and learn from each other.

T.H. Murray (2010). Synthetic Biology: What is it? What challenges does it pose for ethics and public policy? http://www.youtube.com/watch?v=1y4jt7oDrZI

Biosecurity: hopes and fears

Setting: a parliamentary committee interviewing some leading synthetic biologists

Q: You have asked for a substantial increase in funding for synthetic biology. What in your eyes warrants this extra investment?

A: Synthetic biology has an almost unlimited potential. It will make it really easy and cheap to design and build super-organisms that will do all kinds of useful work for us. Soon there will be DNA synthesizers the size of a microwave, costing less than twelve grand. The number of manufacturers of synthetic DNA is rapidly growing, and prices of key materials are dropping fast. Synthetic biology will provide us with a toolbox of standardized procedures and methods that is easy to handle for everyone. Already today, the direct synthesis and assembling of DNA encoding for genes is routine in the laboratory. Moreover, because practitioners share their information via an open source model, knowledge is growing exponentially. The field is booming! There is so much creativity there and so much is happening, that it is even hard to keep up with all developments or to have a good overview. Really, the sky is the limit!

Q: That sounds very promising indeed. However, we would also like to hear your opinion on some concerns with regard to biosecurity. First of all, if things will really become so easy as you hope, is it not conceivable that ordinary people will start building organisms at home, in a completely uncontrolled way, maybe concocting some deadly virus?

A: You are talking about bio-hacking, or garage biology. But we can assure you that the risk is highly exaggerated. First of all, synthetic biology will remain very, very expensive – too expensive for amateurs. And it is not an easy thing: synthesising DNA! And mind you, crucial information will often be patented and restricted, because of its commercial value.

Furthermore, most of the people in this field are driven by scientific curiosity, not by malicious intent. And they do keep an eye on each other. If there is a rotten apple, someone is bound to alarm the authorities. And last but not least, there are good safety regulations in place. For instance, in the USA and Germany, gene synthesising companies already screen incoming orders. When hazardous gene sequences are detected, orders are cancelled and the authorities notified.

Q: mmmmm…..

Okay, then let's talk about our second concern: bioterrorism. The problem is, as we understand it, that the same synthetic biology tools that can be used to develop vaccines can also be deployed to generate novel hyperpathogens. This problem is referred to as 'dual use'. A disgruntled biologist may turn rogue, but also rogue states or terrorist groups may develop biological weapons through synthetic biology.

A: Well, yeah, but with this argument of 'dual use', we might as well stop all technology! Anything can be used for right or wrong causes. But anyway, don't worry about biological weapons. First they are not very effective, a particle isn't a lethal dose. And it is still very unclear whether dangerous hyperpathogens can be synthesized. Anyway, why would someone take the trouble of designing a Frankenstein virus if so much dangerous stuff can be found readily waiting in nature? Especially when normal (wild type) organisms always win from synthesized ones, when they compete. Artificial organisms are always weaker. And last but not least, we scientists are a very responsible lot, and we take really good care in our laboratories that security regulations are in place and followed.

Q: mmmm….. Are you sure self-regulation is enough? We were thinking about developing some European security regulations and….

A: Well, we really don't think this is necessary. That will only increase bureaucracy, restrict academic freedom, and frustrate scientific creativity. And in the end, scientific and social progress themselves will be endangered.

Synthetic biology may help to develop new and more effective strategies in combating infections. One such strategy is to engineer bacteriophage in such a way that it will disperse pathogenic bacterial biofilms, as for example in dental plaque (as well as in other applications, like medical devices and implants, industrial processing and food packaging). The engineered phage expresses an enzyme which degrades the biofilm. It is claimed to be much more effective in dispersing biofilm than 'normal' phages, reaching a removal level of 99.997%.

http://www.pnas.org/content/104/27/11197.full

Dental care crisis

Reminiscent Daily, July 8, 2061

DENTISTS WARN! A new form of pathogen leads to intense pain and attacks our teeth.

A recent increase in cases of intense toothache led to several studies concerning oral hygiene. Most important conclusion: the supposedly harmless bacteria Streptococcus mutans has mutated into a form that resists all treatments currently in use.

Over half a century ago, tooth decay, caused by Streptococcus mutans, was very common. It not only degraded teeth but also caused horrific pain. In 2013, German synthetic biologists succeeded in designing a bacteriophage that immediately breaks down the layers of dirt on teeth (then known as dental plaque) produced by Streptococcus mutans. The German scientists patented the phage and set up a company selling phage containing mouth spray (brand name Lentilax). When it was shown that monthly use of Lentilax resulted in a dramatic reduction of tooth decay, dentists all over the world started advising their patients to switch to this product. Since using Lentilax meant that there was no need to uphold the cumbersome habit of brushing two (or even three) times a day, most people were happy to follow their dentist's advice. Now Argentinean scientists have discovered a new pathogen, named Streptococcus mutans alpha D10. This bacterium is different from the one treated by Lentilax, meaning Lentilax is no longer effective.

Dentists advise all citizens in affected areas to return to old routines of brushing teeth at least twice a day.

The attempts to explain the recent rise of toothache cast a more gloomy light on Lentilax in other ways as well. According to recent reports by Global Dentists, the status of tooth gum has significantly degraded since Lentilax was introduced. Canadian studies of the history of dental care have shown that former habits of tooth-brushing not only rubbed away the above mentioned plaque (a layer of bacteria, food leftovers and dental enamel) but also strengthened tooth gum and

refreshed breath. Asked for a response, the communication officer of Lentilax said that the firm is still studying the research results. MPs have summoned the Minister of Health to Parliament. They want her to explain the government's role and responsibility in the market approval of Lentilax at the time.

Market researchers have reacted in mixed way to the Global Dentists' urgent advice not only to revive, but also to intensify the ancient habits. Some predict a serious decline of the sales of successful mouth spray brands like Icebreathzand oro-free, as breath refreshers will be barely needed anymore when people follow the most recent advice. Others see business opportunities for selling vintage looking toothbrush sets and toothpastes with all kinds of flavors.

Rathenau Instituut

Biomass has been seen for some time now as an alternative source of energy and chemicals that might reduce our dependency on fossil resources. The efficiency of the processes in which biomass is converted into useful products is often limited, however. It takes a lot of energy to break down biological feedstock. Synthetic biologists are pursuing a variety of methods to more efficiently extract sugars from cellulosic biomass. For example, they are trying to design microbes which can break down cellulosic biomass, and they are also transforming microbial cells into living chemical factories. With the help of synthetic biology, biorefineries are expected to finally become the basis of a new bio-based economy.

http://www.stwr.org/multinational-corporations/the-perils-of-the-coming-sugar-economy.html
http://advancedbiofuelsusa.info/12-synthetic-biology-biofuel-biochemical-companies-to-watch

Frustrated housewife

Grace is sitting in front of the television. Her husband Karl is reading the newspaper while she waits for the commercials to end so she can continue to watch her favorite series. Damn, there is that awful advertisement again! A green animated figure, made out of leaves and grass, jumps up and down the television screen. As if that isn't horrible enough, they put jumpy, happy, bubbly music behind it while the green figure sings about biodegradable packaging. How we should separate it from other waste materials to save our environment and help our economy.

'Aarghh I've had it with these stupid advertisements! First the orange plastic hero and now this greenish jumpy clown. Do this, do that, be good and create a better planet. Yeah sure, but they don't have to spend their time walking from the one recycle bin to the other. And in the end they all throw it in one big bio refinery tank. Why should I even care about this separation. It's an illusion we will save the environment by such small scale changes.'

'Well come on honey, it's not that bad, is it? You only have to separate the paper, biodegradable plastics, artificial plastics, food, glass, tin and chemical waste – unless the chemicals are biodegradable, of course, then you put it with the biodegradable plastics.'

'Do you hear what you are actually saying? Chemicals and plastics that are biodegradable. I always learnt that chemicals and plastics are the opposite of biodegradable. Maybe we were not respecting the environment in the past, but at least things were less confusing. When I'm done cooking I have to face my six bins while studying every package to decide where to throw it. Does it contain this label or that symbol, should I separate the cap from the

bottle or can I throw it all together? Really, it would save me hours a week if I just threw it in one bin. And if we have trouble doing it, what about less educated people? Carina, you know her, from three blocks down, she says that it's not even processed separately in our town since it is cheaper to throw it all together again and then separate it, instead of looking for the possible mistaken parts in every single recycle line.'

'But you have to admit that these synthetic bacteria degrading our waste in bio refineries are a great invention! If they had not come up with those, we still would be depending on fossil energy.'

'Synthetic bacteria! That's another example of how we have gotten things mixed up lately. Biology is supposed to deal with living beings, with what is there, not with what humans make or synthesize! And no, I'm not too impressed by human invention. It often destroys as much as it is supposed to offer. I hate all these extra trucks on the road, transporting the biomass towards local bio refineries. And these local refineries really spoil the landscape view. Ok, maybe we help the economy of developing countries like Nigeria by importing their cassava, and also the few local farmers left may benefit, but at the same time we demolish the economy in the Middle East since their oil export lowers every year. It only brings political harassment in these countries. And as regards the environment, I'm pretty sure that our kids and grandchildren will grow up just as happy as we did, with or without a bio based economy.'

'Yeah, you're right honey' Karl says absent-mindedly, having started reading his newspaper again. 'Your series, "as the green world turns" is starting again.'

The potential for designing DNA and other parts of living beings has opened a discussion on the need for and value of intellectual property rights in the context of synthetic biology. As in Information and Communication Technology (ICT), some defend an open source approach in which all designs are made publicly accessible, whereas others defend patenting and licensing as ways to ensure profit for those who invested time and money to develop the biological parts. The iGEM competition is based on an open source approach initiated by the BioBricks Foundation. iGEM participants can use BioBricks from the repository, and are in turn expected to contribute one or more BioBricks to the repository as well.

M. Schmidt et al (2008), SYNBIOSAFE e-conference: On line community discussion of the societal aspects of synthetic biology. In Systems and Synthetic Biology 2: 7-18.
H. van den Belt (2009), Playing God in Frankenstein's footsteps: Synthetic biology and the meaning of life. In Nanoethics 3 (3) 257-268.
http://biobricks.org/

Let's make it a contest!

When the last speaker was finished, she joined the other speakers behind the table and the chairman took the microphone. "Ladies and gentlemen, the floor is now open for discussion with the audience. Please use the microphones available in the auditorium, and introduce yourself before you make your contribution." Several people were already impatiently lining up in front of the microphones.

"My name is Susan Christchurch and I am a professor in biological engineering at Toronto University. I want to thank all speakers for their interesting contributions to the debate on intellectual property rights in the field of synbio. I wholeheartedly agree with Mr. Endy that open source biology is crucial to the field. If every tiny part of DNA is covered by one or more patents, it will be too expensive to make anything useful or complex. I particularly liked his metaphor of the 'Balkanisation of basic biological functions', because it aptly expresses that fragmentation of intellectual property rights will lead to unproductive strife. Therefore, I want to plea for cooperation. In view of the commercial pressure to patent any part of DNA, even if it exists in nature, I think public institutions should join forces. We should push all publicly funded researchers to place as many DNA parts as possible in the public domain. This also increases the chance that the standards everybody wants to share will be public ones. Ultimately, this might discourage even commercial actors to choose the road of patenting."

"Paul Deakin, SynergeticsInc, Palo Alto. When Professor Christchurch refers to standardization, she seems to forget that patenting and licensing are very important elements in standardization. When our company develops a specific DNA sequence for making bacteria produce ethanol, we file for a patent to make sure that we will see some returns on our investments. But patenting law requires

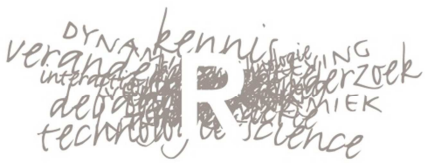
us to make all our procedures publicly accessible. So patenting actually ensures that our inventions are transparent to others, who may then use them as a starting point for related applications. Moreover, if the patent is granted and licenses start being sold to other companies or institutions, these institutions have to exactly reproduce our procedures. Only in this way, standardization can be achieved. In the case of open source code, developments are in a constant flux and people are not really held accountable for what they do. BioBricks can be continuously changed, for example, so this whole idea that a public repository alone is able to guarantee standardisation is misguided. The BioBricks initiative may therefore lead to a slightly different type of Balkanisation, but Balkanisation it is!"

"I am Gyorgy Postas, lawyer and legal scientist at the Technical University of Berlin. I have done quite a bit of work on biotechnology and law before synthetic biology entered the field, and that experience makes me rather pessimistic with regard to the possibilities for synthetic biology to pursue a radical open source strategy. After all, patents have been granted on unmodified DNA that is present in nature, like the breast cancer gene BRCA1. Patents like these have been granted because companies invented technical procedures to isolate the DNA. But if this is sufficient to grant a patent, it will be rather difficult to reject claims of those who invented the technology to produce modified DNA. In other words, those who do file for a patent are very likely to get it, and the open source movement in synbio therefore depends on the goodwill of all parties NOT to file for patents."

"Mr. Chairman, my name is Claire Postman, and I am head of the R&D department at Syntech. First, let me thank the former speakers for their insightful contributions. However, it struck me that they all seemed to presuppose that commercial companies in the field are by definition in favor of patenting all their inventions. This need not always be the case. Therefore, I want to share some personal experiences with you. Our company has been trying for years now to modify viruses in such a way that they will be harmless and able to pass the blood brain barrier. As you can imagine, such a technology would have a tremendous social value, in particular as a tool for drug delivery. However, the task we set ourselves has proven to be more than daunting, and recently we have been considering whether we should continue the work or not. We already contacted the three biggest universities in the USA working on this topic. We also asked all our license holders. All the experts consulted were puzzled by the problems facing us. Then a junior member of our R&D department, who took part in the iGEM competition a few years ago, more or less jokingly suggested that we should make it a worldwide public contest. With such a contest, we might be able to reach the widest range of people working on this topic in synthetic biology. Or even those working on other topics, since what we really need are people who can think out of the box. Of course, those who really contribute to the ultimate solution would be financially rewarded, provided they are willing to hand over their inventions to our company. The proposal for a competition was received

with genuine enthusiasm in our department. Ultimately, however, it was not realized, mainly for two reasons.

One was that we had trouble explaining our problem without reference to classified knowledge. The executive board of our company did not like the idea that participants in the contest might be able to adapt our technologies for private or commercial purposes. So it seems that the past choice to patent our work now limits our possibilities to go in another directions. Moreover, the same seems to be true the other way round. In a survey carried out by our marketing department, it appeared that potential participants would not be willing to partake in the contest if they would be expected to hand over their ideas to our company, not even in exchange for a substantial amount of money. So it seems to me we have reached a deadlock here. Is there anyone who sees a way out? Because this lack of fruitful cooperation and exchange between commercial companies and open source proponents is slowing down innovation and may be depriving society of important benefits.”



Rathenau Instituut

Researchers have succeeded in creating animals with specific characteristics by inserting genes coding for a specific trait in animal embryos. One of the first applications, now commercially available, was a 'GloFish®': a fish with skin that glows in the dark. There are also glow-in-the-dark-pigs and Turkish Angora cats with a protein that makes their skin glow when exposed to ultraviolet light. Synthetic biology might add to a future in which we can playfully re-create our own forms of life.

http://www.glofish.com/
http://www.dailytech.com/South+Korean+Scientists+Clone+Glowing+Cat/article10042.htm

The Light-Emitting Fish kit

"Look, my dad brought me a luminous fish kit!" Ann was holding a colorful box with an inscription on it. The inscription said: *Light-Emitting Fish (LEF) Create your own special toy!* Her classmates were crowding around her and looking curiously.

"What is it?"

"Can you make a fish?"

"Will it be alive?"

"Does it glow?"

"Is it a toy, really?"

They kept asking questions and everybody wanted her to answer. Fortunately, she knew something about synthetic biology. Her father was a bioengineer and for the last five years he had worked on the development of kits enabling people to modify their pets. The LEF was the first product to be put on the market. He had given her one of the first prototypes as a present for her twelfth birthday. And he had been right, it made quite an impression on her class mates!

"You need fish laying eggs and then you should inject the stuff in this kit into the eggs. They call the stuff biobricks. These bricks are responsible for color, smell, or any other characteristic. This kit has bricks that make your fish glow. So when fish grow from the eggs, they will glow in the dark! They are also going to offer kits to produce fish with any colour you like."

"Wow, that's cool!"

"I would like that!"

"My dad says I can do it this Saturday when he's at home to help me. If it works, I'll bring one for the school aquarium!"

A few months later

“Ann”, Ms. Verger asked, “whatever happened to your luminous fish? Didn’t you promise to bring us one for the school aquarium?”

“Ehh, maybe I did… But, I don’t have one anymore.”

“Oh, why’s that? Didn’t your kit work out?”

“Yes it did! They actually glowed so much my father had to put a towel over the aquarium when he wanted to take a nap on the couch! At first I really thought they were cute. But after a few weeks I got bored with them and we threw them away.”

“Oh, that’s too bad… Did you release them in the neighborhood pond?”

“No, according to my father we were not allowed to release them outside. So we had to put them in the trash bin for chemicals.”

“But … that’s really awful! You can’t simply throw away a living being as if it’s a can of paint!”

“They’re just toys, Ms. Verger. My father says the kits for creating colourful cats are almost finished. Shall I ask him whether I can have one for school?”

“Well, it’s nice of you to offer that, Ann. But I don’t think school needs a cat, whatever its colour.”

Ms Verger finished the conversation and put the children back to work. While they were doing their history project, she reflected on the previous discussion. Usually Ann was a sensitive girl, perfectly willing to acknowledge the needs of others. The other children had not seemed too shocked either. She sighed, it was a sign of the times. Society was so crazy about synthetic biology these days! She decided that the topic was too important to leave it at this and made a note to put the issue on the agenda of the teacher association’s meeting next month. If selling kits like these could not be forbidden, at least schools could teach children the difference between toys and living beings.

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Synthetic biology may contribute to healthier and longer lives by facilitating early diagnosis and prevention of cancer, improving our intestinal flora, but also by countering the ageing process more directly. Telomeres (structures at the end of our chromosomes involved in cell division) have been known for some time to be related to ageing. With each cell division, the telomeres become shorter, ultimately leading to inhibition of the capacity for replicating, and thus to cell death. The enzyme telomerase is known to counteract this shortening of telomeres. Several companies are now constructing synthetic molecules able to increase telomerase production in cells. How effective this will be in countering the ageing process is still being contested.

http://www.sierrasci.com/proof/index.html

Mother's Day

`Do you have your drawings, Lisa?' `Yes mom.'

`Richard, the flowers are in the trunk, right?' Yes dear.'

`Seatbelt on, Jonathan? She hears a click, followed by `Yes mom.'

Richard starts the engine. `We are going to your mother first, right?'

Mom Sarah: `Yes, we will have coffee and lunch in her nursing home. I brought cake and sandwiches, so it will really be a festive meal for her! After lunch we go to your parents.'

Lisa: `Are we going to see granny Smith too? I have drawings for her too.'

`Yes, we will see her after lunch, dear.'

Lisa: `Mom? I don't understand. Teacher said we should all make five drawings. But I have only two grandmothers, right?'

`Yes: Granny Smith is the mother of daddy. Grandmother is my mother. And I am your mother of course, but you know that,' Sarah smiled.

`Then I have two drawings left,' Lisa said.

`Perhaps that's because many children nowadays have great-grandmothers too. But you can give a drawing to the ladies living in the quarter's next to grandma's. They would like that, since they have no children to visit them,' Sarah answered.

`You mean the ones who don't look old at all?' Lisa asked

'Yea, the ones that smell funny', Jonathan mumbled.

Richard did not rebut. After all, he was right. He thought about the ladies living next to his mother-in-law. In contrast to her, they had to share a room. They had been among the first people to buy the juvenating cosmeceuticals that were claimed to stop your telomeres from shortening. The therapy had not been as perfect then as it was today, but it had bought the trendsetters some time. If he remembered it correctly, they were 110 and 112 right now. Back then, the government had been afraid that the therapy would be so effective that widespread use would lead to overpopulation. That's why the sales of the product were strictly regulated and limited to people who had no children and who had been sterilized. Now that these women were in need of assistance, they had come off second end again. Because of the overflowing of homes for the elderly, only very basic care was reimbursed. Nobody had anticipated that people 'ageing successfully' (as they called it) at a certain point would need care nonetheless. If you wanted extra care, you had to pay for it yourself. He was glad his parents had not spent their money on these juvenating therapies. They might grow less old, but at least they could afford sufficient care. Sarah's mother was less well off, but at least she had a room of her own.

He was startled when the very young voice from the navigator announced 'You have reached your destination.' The nursing home looked even worse than on previous visits. Apparently they did not have money to do even basic maintenance. After she greeted her grandmother Lisa went to the two neighbors. She was back very soon, looking disappointed

'And, what did they say? Did they enjoy your drawings?' Sarah asked.

'Actually, I don't know. One lady started crying and saying, "you are a very sweet girl, why didn't I realize how much I like children?" It was a bit awkward to get away from her. And the other didn't say anything! She just put my drawing on this huge pile of drawings in her cupboard.'

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Synthetic biology has been used by researchers to change the smells and/or colours of bacteria. For example, students from an MIT iGEM team managed to change the awful smell of Escherichia coli into a minty one. Another iGEM team engineered bacteria in such a way that they indicate the presence of a specific substance by emitting a specific colour (visible to the naked eye). This technology can be useful for all kinds of sensing and warning systems (it could for example warn that drinking water contains toxins by turning it red), but it might be used for more frivolous purposes as well.

http://openwetware.org/wiki/IGEM:MIT/2006/Blurb
http://www.echromi.com/

The Make-Your-Stool-Smell-Nice pill

It will be her birthday tomorrow, her tenth already! She has been waiting for it such a long time. Birthdays always means having a party, cake and, of course, lots of presents. She loves presents so much! Only last night she was dreaming about that little doll she saw in the shop and how happy she would be to get it. But her best and probably most unrealistic dream is to get that little pill, the one that makes your poop smell like flowers, sweets, or whatever you like. Actually everybody in her class uses it and when you enter the bathroom it smells so nice there! She likes to sit in the bathroom, likes the cleanliness and pleasant smell of this big white room. Sometimes she even goes there in the middle of a class, just to have a break from the crowded classroom. Not that she would ever dare to use the bathroom for its real purpose – oh no! She will never, never let her classmates laugh about her like they did about Lilly last year. Some children discovered that Lilly did not use the Make-Your-Stool-Smell-Nice or MYSSN pill. In less than a day, all children knew and in the end Lilly had to change schools. It was a shame, one of those shames that is not likely to be forgotten. And of course she was called Lilly the stinky.

Unfortunately her parents do not earn enough to buy MYSSN pills. Moreover, they do not really understand how important it is for her to have it. All the girls from her class started using the MYSSN pill a couple of years ago, often at the age of 8. There is a rule that MYSSN pills can be sold only to children of a certain age. First it was 16, but the minimum norm has been gradually lowered to 8 in past years. All her class mates smell so nice! Mary today used the most fashionable and expensive variety, the one with the Coca-Cola smell. It couldn't be missed when she had to come to the blackboard to make a report. She probably farted on purpose, just to show how trendy she was.

She turns on the TV. A little blue poop sings how nice is it to smell like the ocean breeze. It's a blue, healthy poop. She knows that. She recently saw a BBC documentary in which scientists explained how they can change bacteria in your body so that they will change colour if something in your body is going wrong. For

example, if your poop is pink you need to eat more fruits and vegetables. But actually, every school girl has known for years that bacteria can change colour. At least since they invented these MYSSN pills that not only change smell, but also give your poop a colour. They cost even more than the basic variety.

Her parents seem to think this is all utter luxury. Her father repeatedly told her that there is nothing to be ashamed of in the smell of poop. But of course that is not true. Your poop is something that should smell like flowers, or at least like ocean breeze, and not have that disgusting, unnatural smell that makes you want to vomit! Her parents just do not understand her basic needs.

Yes, it will be her birthday tomorrow, but will it be a happy one? She knows that she will never, never be really happy without those little yellow MYSSN pills!

One of the promising applications of synthetic biology is the creation of artificial antibodies for medical purposes. Antibodies play an important role in the human body, identifying as well as neutralizing pathogens causing disease. This makes them suitable candidates for diagnostic and perhaps also for therapeutic purposes. Each antibody targets one protein molecule type. Until recently, creating synthetic antibodies required a lot work and was very expensive. Synthetic biologists now have found a way to build antibodies from scratch which makes their production much faster and cheaper. Moreover, synthetic antibodies, unlike biological ones, remain stable over time. They may also be engineered to emit a sign that can then be transmitted to an external computer system. These developments are expected to lead to simple diagnostic test kits for a variety of diseases.

http://www.sciencedaily.com/releases/2010/05/100519173100.htm

Perry's responsibility

A package arrives. "Hey! What's that?" Franz yells at his housemate Perry. "This is awesome", Perry replies. He rapidly rips the brownish delivery paper off the package. In his hands he now holds a white box with big red letters saying "HEALTH-O-MEASURER". In big blue letters, though smaller than the red ones, it says "~because we care~". "I don't know how it actually works, but is has something to do with antibodies. The crucial thing is, these antibodies can indicate whether my body is diseased. With this, who needs a doctor for diagnosis? Their tests are similar to this one, but you need a time-consuming visit. My test just needs a sample of my blood, but how?"

"Don't act silly Perry. Just get a hold on the manual", Franz says. Perry carefully follows the instructions in the manual and with special attention he punctures a tiny needle in the skin of his right upper arm to draw some blood, trying not to spill any of it. Despite his nervous tremor, he manages to collect some blood and puts it in the HEALTH-O-MEASURER. He disposes the used needle in the bin. "And now what?" asks Franz. Perry, still looking at the instructions looks up, "It says that it will automatically send the diagnosis to my bio-account, which is synchronised with my tablet computer."

Perry walks slowly towards his bench and plumps down on it. "How long do you have to wait before you'll get the results?" Franz asks. "The box does not say anything about the duration of the test, so I will have to wait till my computer reacts. It probably won't take that long. I hope that it will bring some answers. I've not felt that healthy for the last couple of months. God, I hope it is nothing serious."

Franz picks up the instructions and starts reading aloud. "This kit contains a spectrum of synthetic antibodies capable of binding to a set of 60 proteins, believed to play a role in aging processes and diseases like obesity and several forms of cancer. Mmm, believed to play a role, that's not a very strong claim, is

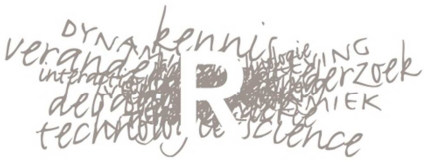
it? And aging and obesity, why would you need a kit for proving you're old or fat? You really think they can do something about that! Oh, and this is too good to be true! Perry, how much did you actually pay for this fake test kit? Look here, the disclaimer says that the producer will not take any responsibility for the diagnosis. 'If you have any doubts concerning the result, please consult a physician.' That way, I can make money too!"

"Beep-beep-beep-beep". "Oh God, it's my computer!" Perry jumps at his feet and picks up his tablet. He hesitates a little before touching it. He taps his finger on the screen and waits till the result pops up. "Hmmm, nothing, nothing, nothing. Wait - what? A 66% chance of having CA15-3-related cancer? What does this mean? Do I or don't I have cancer? This is total madness!" "Just relax Perry! Look at that disclaimer."

Perry quickly looks at the accompanying disclaimer. "HEALTH-O-MEASURER inc. is neither legally nor medically responsible for the test-results". "Is this it? Oh God" he mumbles. He is breathing faster and with every breath his tremor is getting worse. "You need to see a doctor, it is their responsibility to take care of the ill. They know how to interpret those test results and if necessary, they will even know how to treat you." Franz says.

"No, this is about my test results, my body and my health. This is MY responsibility! And moreover, going to the doctor is so terrible expensive these days. I just need to do some background research about this test and the cancer." Perry is taking longer and deeper breaths and calms down. He grabs his tablet computer and plumps down on the sofa again.

"I'm not sure about your idea of responsibility" Franz carefully replies. "But I think I should just look for a more reliable home test. Maybe there's some sort of official body marking the quality of tests like these?"



Rathenau Instituut

The resurrection of extinct species, especially the large creatures of the past, has appeared as a popular theme in works of fiction. With fast and cheap technologies to 'read' (sequence) and 'write' (synthesise) DNA currently available, it also becomes the objective of some researchers in synthetic biology. Thus we have seen the resurrection in the laboratory of the extinct virus which caused the deadly 1918 flu pandemic. Most researchers may not be primarily interested in the resurrection of a living animal, but hope to find new ways to understand disease or evolution. But a few, perhaps, would like to bring back one of our lost species in a zoo, or in the wild.

http://www.telegraph.co.uk/science/science-news/4161743/Extinct-animals-could-be-brought-back-to-life-thanks-to-advances-in-DNA-technology.html
http://www.nature.com/embor/journal/v9/n1s/full/embor200862.html

Reinventing the dodo

It was a sorry sight, the immense stable filled to the brim with thousands of ungainly, lethargic, clumsy forms, bumping into one another like blind people, producing that incredibly loud annoying honking noise. She loathed them as much as she felt pity for them

Sara sighed. It was hard to bring back that incredible excitement when the first egg had hatched, only a few years before. Scientists all over the world had trumpeted the event as a moral redemption. Science had finally found a way to make up for our past crimes against nature, to restore creation to its original splendour and richness. A synthesised Eden. After centuries of science and technology spelling bad news for biodiversity, they finally seemed to be taking nature's side. Synthetic biologists had managed to recreate the dodo!

Some environmentalists remained unconvinced, stubbornly denying that this creature was the real thing, as it wasn't 100% genetically pure. However, enthusiasts waved their arguments away by pointing out that genetically purity is a fiction anyway. All existing organisms are patchworks and hybrids – that is just the way nature works. Everything and everyone is work-in-progress. And anyway, if restoring biodiversity is the goal, who cares about hybrids? The reinvention of the dodo is just a matter of 'bios' getting even a little more diverse!

Every zoo had wanted one, or two, and so had many rich individuals. But the fad had faded quickly, as it soon became apparent that an animal may be restored in body, but not in spirit. Birds depend on imprinting to learn their specific behaviour, but no one knew how dodos behaved. So the re-created dodos were utterly stupid! You even had to force-feed them, as they had no clue themselves about what to do when you laid the food in front of them. In some cases they did learn to be a turkey, but – be honest – what was the fuss all about then? As if we

don’t have enough turkeys already. And their natural habitat had also vanished since their extinction. Experiments with turkeys as parents, were inconclusive and dodos that were let loose in De Veluwe, a Dutch national reserve, soon died in their new habitat. In the end, one had to conclude that the bird was, and remained, completely dependent on humans.

So within two years, the bird that had been designed to be the symbol of the reconciliation of science and technology on the one hand, and nature on the other, had turned into the symbol of artificiality. People started to hate the bird for its stupidity, for its accusatory dependence, for its inability to absolve humankind of its earlier sins.

Naturalists pleaded to have them killed. However, their pleas provoked protests from unexpected corners. Farmers now argued that as we had brought this creature back into the world, we now had a special obligation towards it. Did we really want to commit the same crime twice?

And so the bird stayed. Thousands and thousands cramped together in huge stables like this one. And yes, thought Sara, it was true, these dodos do make excellent, tasty burgers.

Algae may be used for fuel production by extracting the so-called bio-oil content from algal cells. Synthetic biology aims at engineering algal cells to secrete oil continuously through their cell walls and thereby increase yield. Currently, there are a few companies that use algae for fuel production. Although developments are still at an experimental stage, firms expect to enter industrial-scale production soon. A firm that already produces fuel from algae is Solazyme – albeit on a very modest scale – which sells its product under the patent Soladiesel®. There is also considerable interest from traditional energy suppliers. Graig Venter's company Synthetic Genomics entered into a $600 million multi-year agreement with ExxonMobil to develop algae fuels. The use of algae as an energy source has the potential of reducing greenhouse gas emissions because algae consume carbon dioxide. Algae also may be grown in open water ponds or closed fermentation tanks in areas not suitable for food production and, unlike fossil fuels, algae are biodegradable and therefore relatively harmless to the environment if spilled. Thus, according to its proponents, the promise of this technology is a future of low emission transport fuel, infinite energy supply, affordable prices and energy independence.

Presidential Commission for the Study of Bioethical Issues (2010). *New Directions. The Ethics of Synthetic Biology and Emerging Technologies.* Washington, D.C. [www.bioethics.gov]

Still proud

The woman lowered her window and waved to the man in the Oldsmobile waiting next to her own car.

-You really take good care of that car, don't you?

-Oh yeah, I have been driving this baby for more than twenty years now, and she is still going strong.

-What a traffic jam, again, eh?

-Yeah, well, tell me something else that's new?

-I am sorry, but don't we know each other? I am Ann, and I think we studied together. You are John, right?

- Ah, now I recognise you too. How have you been doing since graduation.

-Well, up and down. A little down, at the moment, to be honest.

-Oh?

-You remember what an enthusiast I was for solar, water and wind energy? So, I have been working in that sector for almost fifteen years. But the company I worked for closed doors last month, the last of its kind.

-You spent fifteen years of your life working on those obsolete technologies? Boy, you don't know when to stop, do you? As soon as they came with this cheap biofuel – remember how mad those Arabs were? – it was clear to everyone with eyes to see that other technologies wouldn't stand a chance. And you know why? Because thanks to biofuel, I can still drive this old baby. Bio-oil may be new, but she likes it just as much as good ol' petrol.

-But John, don't you see that is exactly the problem?! We are living way above our standards. And people started to realize that, then. That there are limits. I thought humans would learn to live more in harmony with the environment. Not necessarily because they wanted to, but because they were forced to by the scarcity of energy. Together with the shift towards sustainable energy, I hoped we would change our lifestyles. That we would stop being so…. so….. greedy. But you must think I am very old-fashioned, don't you? Nowadays, no one seems to care anymore.

-Well Ann, maybe you would have been more successful if you had concentrated on selling technology rather than morals. Because let me tell you one thing about humans. They don't like limits. They are born greedy and they die greedy. They always want more. And when they have that, then they still want more. Look around you. Now fuel is so cheap, everyone is using his or her car to drive everywhere. Remember those bicycles? Trust me, you can change technology but you cannot change humans.

The man honked in frustration to the endless queue of cars around him.

-Boy, he sighed, when will those worthless politicians finally see that what we need in this country is more roads.

Rathenau Instituut

Many people believe in the notion of a balance of nature. However, supporters of synthetic biology are coming up with quite different conceptions of nature. “Behind much of the resistance to the notion of synthetic life is the intuition that nature (or God) created the best possible world. Synbio proponents are taking a new tack, and they’re not afraid of the implications” (Lee Silver 2007). In this approach, radical interventions in nature are legitimate. As one of the founders of synthetic biology points out: “If you consider nature to be a machine, you see it is not perfect and that it can be revised and improved” (Drew Endy 2005). Indeed, if there is no master plan anyway, there is no prohibition to meddle with nature, on the condition, of course, that we deal adequately with the risks to health, safety, and biodiversity. No doubt, in our political system, everyone is entitled to his or her own religious beliefs. Politics and religion are treated as separate domains. But, in a future shaped by synthetic biology, the consequences of religious or non-religious beliefs may touch everyone. Is there a task for politics here?

http://fbae.org/2009/FBAE/website/images/PDF%20files/synthetic%20biology/2007%20!!!%20TOP%20NewsweekMSNBCtext.pdf
Drew Endy, Foundations for engineering biology, Nature 438, 449-453 (24 November 2005) doi:10.1038/nature04342

Synthetic Theology

- Professor, may I ask you something?

-Mmmm…..

-Are you never afraid of all this power that synthetic biology gives us?

-Why should I be? Power is good, because now we are going to solve some problems. Like hunger. Like disease.

-Yes, I know, but, well, I mean, you know….

-No, I don’t know. Young man, if you want to become a scientist, you will have to learn to express yourself with more clarity and precision.

-Sorry ma’am. Well, I meant it differently… I think. Are you never worried about – well – playing God?

-God may have been playing, but I am dead serious.

-Huh?

-Well, be honest; look at this Creation of His!

-I do, and I think it is awesome. That is exactly the reason why I want to study biology. Nature is such a beautifully ordered system. Everything fits, everything is in balance, and everywhere I look I see miracles big and small. When I study the endless intricacies of life, everything I learn seems to testify to God's infinite power, wisdom, and goodness.

-To His infinite amateurism, you mean! Everywhere I look I see waste and lack of efficiency. And the only miracle I see is that anything actually works, so badly designed are most natural organisms. It's like God just threw together what was at hand, and then in rare cases found Himself lucky enough to see the thing actually starting to move and reproduce. If you look closely at any organism, you will see that it is a little machine that is kept together with tape and strings. You have to understand that any organism is no more than a collection of solutions to the problems the organism faces. And believe me, most of these solutions would make an engineer cry, so inefficient are they. For example, these two little points I see under that tight T-shirt of yours, wouldn't you agree that they are in your case rather pointless? Care to explain how any rational designer could come up with the idea of giving nipples to males?!

-Professor, I cannot believe my ears! I'm shocked! How can you be so ungrateful!?

-Ungrateful? Mmmm…. Well, yes, I suppose you are right. We should be grateful and I am, of course. I agree I was a little too harsh on God. He did a fine job, I suppose. After all, He was only a beginner at the time. But isn't the best way to express our gratitude to Him by helping Him to put His Creation straight?

Synthetic biology might contribute to the development of biofuels through two different kinds of processes. Firstly, synthetic biologists can use synthetic DNA to tailor-make enzymes that can break down biomass much more efficiently than traditional methods. These synthetic enzymes, which can now be tailored towards specific types of biomass (like woodchips, corn stalks or sugar cane) increase the rate at which biomass is broken down into sugars that can then be fermented into ethanol or other types of fuels. A second approach is to create synthetic organisms (like synthetic algae) that can produce fuels directly from sunlight, water and fertilizers. Scientists are trying to customize these organisms (or 'living chemical factories' as they are often referred to) in such a way that the oil they produce is chemically similar (or even identical) to the oils we use in our current transportation and energy infrastructure. Large surfaces of land (and shallow waters) will be required for the production of biomass and the direct production of biofuels through algae. Where will this land be found, and under what conditions will it be purchased?

ETC Group. (2010). 'The New Biomassters. Synthetic Biology and the Next Assault on Biodiversity and Livelihoods'. http://www.etcgroup.org/en/node/5232

This land is your land, this land is my land

Wearily he looked down at the protesters outside the window. It's ironic, he thought, as I could be standing there myself, waving banners and yelling slogans, because I fully agree with them. But they are protesting against me.

For years, everyone had been worrying about the depletion of fossil fuel. Not anymore, thanks to synthetic biologists like himself. He and his colleagues had helped create new generations of bio-oils that were no longer produced from the edible parts of plants – like sugarcane or corn – but from useless biomass (wood, weeds) or produced by algae. And what a success their bio-oil had been! It was plenty, clean to produce, cheap, and most importantly, it had put an end to the dependence of the industrialized countries on countries with large reserves of fossil oil but with questionable political regimes.

Of course, producing bio-oil in large quantities did require immense surfaces of land and shallow water. So, big companies had busied themselves for years buying large stretches of land and water in developing countries in Africa and South America. Mind you, they didn't purchase productive areas that could be used for industrial agriculture, but only marginal, idle, degraded, abandoned wastelands. So, no one took much notice.

But in recent years, highly critical reports had started to appear, pointing out that these supposedly useless stretches of lands – natural forests, grasslands, deserts and wetlands – had been home to millions of indigenous peoples, most of whom had by now been relocated by their own, often corrupt, governments.

Habitats, societies and livelihoods that had sustained local peoples for centuries were destroyed in the course of a few years. Instead of being able to set up and manage their own small companies and self-sustaining local economies, farmers were lured or forced into selling their land and working as temporary employees instead, thus increasing their dependence on the global north.

Furthermore, the large monoculture plantations had destroyed some of the most diverse ecosystems on the planet. Marine ecosystems and the more fragile ecosystems in deserts and wetlands had been devastated by the commercial growth of algae and the sowing of new varieties of grasses and crops that had been engineered to be drought-tolerant. Some reports even claimed that by destroying these eco-systems, bio-oil had actually exacerbated climate change rather than diminishing the problem, as these eco-systems had played a crucial role in regulating climate.

‘But why lay all this misery on my doorstep?’, he wondered. Did these protesters think that he had wanted all these bad things to happen, that he liked it? Of course not! As a citizen he shared all their concerns, and yes, somebody ought to do something to help these victims. But that was something for politicians. As a scientist, he didn’t feel a twinge of regret or remorse. Science and technology bring good things, it is society that then goes on and messes things up.

He opened the window and shouted “Go take your protest to the politicians! I am a scientist I am not responsible for what people do with my inventions! Don’t blame me!”

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One of the ambitions of synthetic biology is to make the engineering of life easier, faster and cheaper by developing standardised building blocks, so-called 'biobricks'. These are small DNA sequences with well-defined functions that can be combined by fitting them into each other (a bit like Lego). In this way, doing synthetic biology not only becomes cheaper and easier, it also means that less expertise is needed to build a biological machine. In the future, even amateurs may be able to engineer life! Some enthusiastically endorse do-it-yourself (DIY) or garage synthetic biology as a democratisation of science and technology. They compare it to the hackers culture in ICT. And indeed, DIY hacking communities in the field of synthetic biology have already emerged.

http://biobricks.org/
http://biohack.sourceforge.net/

Unconvincing rhetoric

Dear Prime Minister, I think that I speak on behalf of many in this parliament when I say that we should reconsider regulation concerning synthetic biology, in particular regulation concerning DIY synthetic biology. This week, a substantial number of people in our country turned orange for a few days. Investigation by the National Institute for Public Health and the Environment has shown that this outrageous epidemic is very likely caused by a synthetic virus sold on the internet as a cheap Viagra-like drug. The virus was definitely not created in an academic or industrial lab. It is the work of biohackers, who created it at home.

Prime Minister, these hackers may have a weird sense of humor. But they do uncover the weaknesses in our system. We can only thank God that this time they did not cause any physical harm – at least not as far as we know now. Need I remind you of the two deaths and many more lives threatened about a year ago by some amateurs posing as pharmaceutical experts? It is clear, moreover, that it is only a matter of time before people with really malicious intentions will start tinkering with biobricks in their garage. They may even be doing this right now! Prime Minister, for the safety and health of our citizens, I urge you to reconsider the regulation of synthetic biology. Clear the garages of this country and let's move science and engineering back to where they belong: in the labs of those who know what they are doing."

After finishing these words the parliamentarian walked back to his seat. The Prime Minister cleared his throat and started to speak.

"First of all, I want to say that I really pity those who fell victim to this nasty – or should I say sick – joke. Of course, it's awful to turn orange and these people deserve our concern. However, liberalism has brought our country great benefits and we should not restrict freedom lightly. The situation is not as clear-cut as the former speaker suggests. For the moment, there is no hard evidence that the virus was created in a home environment. We even do not have conclusive proof

that it was created synthetically. For all I know, it may have been a mutation from a natural virus. And I think you will grant me that politicians like you and I cannot forbid nature to evolve as it does.

But let's suppose synthetic biology is indeed to blame. Then I still would like to emphasise that the open exchange of biobricks has enabled our country to become one of the world leaders in the field of synthetic biology. Big corporations are building and planning to build factories and laboratories in our country because of our permissive regulation. Biobricks created by DIY biologists not only help those corporations to develop new products, they also help these people to create their own product. This contributes enormously to creativity and innovation. Amateur biologists can easily adapt a product to specific needs or provide products for niche markets.

Despite a few incidents, many citizens already benefited financially from home-brewn drugs, small scale bio-based alternative energy sources, and numerous other applications. Again, I would like to emphasize that the recent incident was very unpleasant, but not harmful. Incidents like these may be the price we have to pay for all the advantages of DIY synthetic biology gave and will give our society. It's a freedom and a future that we should not just throw away."

Imagine a technology of skyfarming. A skyfarm is a large skyscraper in which fruits, vegetables and grains are produced. It would be self-sustaining and might even provide a net output of energy and clean water. Synthetic biology may contribute to the realisation of skyfarms by engineering plants in such a way that they can grow inside. Moreover, modified bacteria could considerably improve the efficiency of food and energy production. Proponents claim that skyfarming is a good substitute for agriculture, reducing the need for space and transport. This would help the fight against global warming, in particular when the land formerly needed for agriculture would be reforested. Ultimately, skyfarming is proposed as an important contribution to a sustainable economy.

http://nymag.com/news/features/30020/
http://www.popsci.com/environment/article/2007-07/skyscraper-farms

Under the starry sky

With a deep breath, the sheikh makes little bubbles rise in the water of his water pipe, filling it with smoke. Sitting on his roof terrace with his grandson, his 75th birthday nearing, he is in a reflective mood. “Well, at least we are self-sufficient now. Who could have thought of this a century ago, when our oil sources made us the center of the world? It is such a shame that all that is gone by now. But as I said, it is great that we invested in our skyfarms, what would have become of us if we hadn’t done that?”

“Yeah, I don’t know”, his grandson responds, “maybe you could have invested in tourism, like they did in Dubai? Of course they had to shut down the indoor ski facility, something that is out of the question with the current energy fright in most countries. Indoor skiing in the desert, imagine the decadency – but it was a great idea nonetheless! Why did you actually opt for sky farming, out of all the options?”

“Well, it was clear enough we had to do something. As you know, the global oil reserves started to run out about when I was born. Fortunately, our wells were among the ones that lasted longest, and that gave us some more time than other countries to consider which way to go. The USA and Europe decided to develop more bio based forms of energy production. But since in particular Europe is very densely populated, it was clear right away that they would not be able to produce sufficient biomass for themselves. So they convinced other countries to go green – or should I say forced them? Russia, for example, only started producing biomass because it was a condition to finally become a member of the European Union. I considered starting a biomass plantation myself, but when I visited Russia to learn from their experience, it was clear enough what the sudden transition had done to the country. Whole regions were turned into large greenhouses, emitting light night and day. You could hardly see the stars

anymore, imagine that! And the Baikal Lake was transformed into an algae bed, irrespective of the myriad of species that lived there before. Also, the labor conditions were horrible. The Russians had everybody, men, women, children, working on the plantations for very long days and ridiculously low wages to make their biomass as cheap as possible. There was a fierce competition to offer biomass for low prices, since many formerly third world countries decided to start producing biomass for the Western world."

"But some people say Russia still trades the oil they have left with China."

"Oh, that may well be true, Putin the younger is smart enough not to put all his stakes on one horse. But if the other European countries ever get substantial proof of that, he may be kicked out of the Union. Anyway, I saw what cultivating biomass for export purposes did to Russia and how it made them not less, but even more dependent on trade with Europe. Even though they were on the providing side, they still had to conform to the rules of the market. When I saw that, I knew I wanted to do it differently. So I decided that our country should become self-sufficient if it wanted to remain autonomous."

"But how did you actually achieve it? We were one of the first to go back to nature, weren't we?"

"Haha, back to nature – forward with high tech you mean! But of course, your idea of nature is hardly comparable to my old fashioned one. Whatever, we certainly were one of the first. We hired some Dutch folks who were already thinking about agricultural skyscrapers and with the money my ancestors made during the oil bubble we started developing some very high tech solutions to provide all resources we need ourselves. It is really great that we can produce food and energy for the whole country with these things. And since everything is based on natural resources we can also reuse all our waste, which makes it quite a fruitful enterprise."

"I guess so. But still… I would have liked to live in a country that was the center of the world, like we were in the old times. The global community just seems to forget about us. Do you really think it was a good choice to invest in this direction? The stories I heard at school about the past prosperity really suggest that in the past we could do everything we wanted. Back then we had to trade with the United States of America instead of China, and they treated us like kings! I want that back!" "I'm sorry Mohammed, but there is no real center of the world in that sense anymore. Since many countries produce biomass and many others followed in our footsteps, energy production has been decentralized. Energy is not the backbone of power relations any more. We still trade in the excess biomass that we produce, but that's marginal compared to the oil recovery back then."

The sheikh blows a small cloud of smoke and stares into the sky. After a while he starts smiling and looks up towards Mohammed “Aren’t these stars beautiful? I really think that’s what struck me as the worst thing in Russia, back then, that you could not see the stars anymore. It felt as being severed from the cosmos. In that sense you’re right, these high tech farms help us to be one with nature again.”