BIOLOGY 2.0
What nature would never have made
SCRIPT

NARRATOR
01:00:05
From cells to fully-fledged organisms... from molecules to eco-systems... life exists in a myriad of forms.
01:00:15
Until now, biology has sought to observe and understand it, perhaps even to control and exploit it...
But today scientists are looking to invent and manufacture new living beings; basically, to synthesize life.
01:00:29
This is the challenge of a new techno-science, synthetic biology.
Biology 2.0, which promises to solve all our problems.
Is this a new, and ultimate, industrial revolution?
01:00:43
Or is it just the opposite? By affecting life in such proportions, are we not taking unprecedented risks?
01:00:54
To find out, I travelled the world to meet the field's leading figures... to learn and discover more... and sometimes getting completely lost!

JAY KEASLING
01:01:04
I envision a day when if you want to produce a particular product you might custom build a cell for it.

ED YOU
01:01:13
There are so many capabilities - We want to ensure that we leverage only the benefits, and we try to identify any security vulnerabilities or risks, to mitigate them.

JIM THOMAS
01:01:24
Since this is gonna be so powerful, since it's gonna have such wide impacts, let's slow down, let's think carefully, let's put a bit of a pause on commercializing these technologies.

NARRATOR
01:01:38
My first surprise is to discover that certain applications are already being studied, and are even at an advanced stage. There aren't many of them, but they're very promising. They promise to invent... what nature would never have made.
Quite something, uh? In any case, the notion immediately arouses my curiosity.
I come across one American scientist near San Francisco, who is using a yeast, an astonishing unicellular fungus, to produce a molecule to combat malaria.

I head for the West coast of the USA.
A yeast... to make bread, or brew beer...
And as it happens, my appointment isn't at a laboratory, but in a micro-brewery.

IN 01:02:25
Charles : Hello!
JK : Hi! Welcome!

JAY KEASLING
01:02:29
My name is Jay Keasling. I'm a professor at the University of California Berkeley, I'm also CEO of the joint Bioenergy Institute in Emeryville, California.
My definition of synthetic biology is the engineering of biology, manipulation of biological systems to accomplish some goal.

NARRATOR
01:02:53
Jay Keasling is one of the stars of this new discipline.
As he describes the beer manufacturing process step-by-step, Jay tells me that his reputation came from his work on artemisinin, a molecule discovered in the 1970s, to combat malaria.
01:03:12
Until now, this molecule was extracted from a small, rare shrub; which only grows in a few parts of the world.
Jay Keasling has found another way to produce it, by modifying the genome of a yeast.

JAY KEASLING
01:03:26
We've taken the genes out of the plant that naturally produces artemisinin, and put them into yeast. And so, it's just like brewing beer.
You put the yeast in a vat with water, and sugar, and some other nutrients, and the yeast grows up, and rather than spitting out ethanol, as it would in making beer and wine, it spits out artemisinic acid, a precursor to artemisinin.
And then we use a process and it transforms from artemisinic acid into artemisinin.

NARRATOR
01:04:09
Fortunately, what Jay gives me to drink is only beer...
It all seems so simple... making a new yeast and investing it with a role that nature had never thought of. It makes my head spin. Or maybe it's the beer...
I don't think it was drinking beer that gave Jay the idea in the first place.
A short drive away is the University of California campus at Berkeley, where he started working, at a time when synthetic biology didn't yet exist.

JAY KEASLING
01:04:37
I was fascinated with genetics, this is why got into biology and why I took an engineering route. So when I started it as an assistant professor I realized that we

didn't have tools available to readily engineer metabolism inside cells. And so I started projects with my students on developing tools for metabolic engineering.
But you can't just develop tools and not use them for something, not prove that they are going to be useful. And I decided, you know, I should better think about some applications for these tools.
01:05:16
So we started looking for applications and we found artemisinin. I knew about malaria from my microbiology course in college. Knew nothing about artemisinin and we looked into it and we said, boy, I think we can produce this or at least a precursor to this.
01:05:47
At the end of 2004 we had a 42 million dollar grant from Bill and Melinda Gates foundation to finish off the process, to engineer a microbe to produce the product, and then licence it out to a company.
Everything moved, in retrospect, pretty quickly, when you're in the process you think can't we move this faster, can't we move this faster, there's people dying!
Now, there's a large scale process for producing it. They produced on the order of 60 tons of the material which is enough for a hundred and twenty million people.

NARRATOR
01:06:26
The wager paid off.
Engineering life, as one would engineer a machine...
To understand how this is possible, we have to look at the basic tools of synthetic biology: using and combining the functions coded within DNA.
Jay Keasling first of all reminds me that each organism, each living cell, has one or more functions. Certain cells aid in digestion, others convert light into energy for plants, or transform sugar into alcohol, like yeast, a surprising little unicellular fungus.
But how do these cells know the nature of the work they have to accomplish? They quite simply have a manual, or a program, inscribed in their nucleus, their genome.
01:07:18
The genome is an organism's instruction book for life. It describes all of a life-form's functions. The book is made up of several chapters - which we call chromosomes. Chromosomes themselves are composed of genes. They form the sentences in the book. Each gene, or each sentence, is read like an instruction. All the genes together tell the cell what it has to do.
01:07:47
All of this is written using an alphabet, DNA, made up of the well-known molecules A, G, T and C... for Adenine, Guanine, Thymine and Cytosine, which are always organized in pairs: the A with the T, and the C with the G, known as base pairs.
01:08:10
Genes are transmitted from one generation to the next, identically, or are modified to respond to essential new functions or new requirements for the cell to survive. This is what we called evolution!
If we know how to modify them, and put them together, we can then change very simple functions into more complex ones. We can then imagine useful combinations that nature never attempted through evolution. With Artemisinin, Jay has demonstrated that it was feasible, and workable on an industrial scale. He transformed a cell into a chemical factory that produces active molecules.

This concept enabled synthetic biology to avoid the problems that previously limited production capacities.

JAY KEASLING
01:09:00
There are many advantages of producing a drug through microbial fermentations rather than having to extract it from a plant.
One of the challenges with a plant is that it takes a significant amount of time between the time that farmers get seeds and companies decide how much they really want in contract with those farmers.
The farmers get the seeds, plant them, harvest it, get the molecule, the extraction to the pharmaceutical company and then they derivatize it and put it into the drugs.
That process takes somewhere around 14 months to 2 years. And because of those long time scales, there's been large swings in the price and availability of artemisinin.
It swung anywhere from about 200 dollars a kilogram to over 1100 dollars a kilogram.
And what that means is that when the price is high, people in the developing world can't afford it. When the price is low farmers don't want to plant it because they can't make a profit so they switch to other crops.

NARRATOR
01:10:09
Be Jay Keasling or myself or a developing-world farmer... we're all the same. Whatever the invention, however avant-garde it may be, we also want it to be profitable.
Jay is not only a scientist, he's also a businessman. He set up a company and runs another, JBEI, a laboratory co-funded by various companies and the American government. Along the way, has he forgotten his noble ideas about saving the world?

JAY KEASLING
01:10:35
I believe strongly in the well regulated capitalistic system but we have this system that gets products out to people.
The company won't make any profit of this anti-malaria drug. In fact the University of California which holds the patents to my work gave the process away for free. We'll make a profit on something else that doesn't have to do with the developing world. I don't think that the non-profit model works for everything, right?
What the company gets out of it is a well honed organism that produces artemisinin acid. But you can make a few changes in its genetic make-up now and it will make many other things. This is really a core demonstration of the power of synthetic biology. You build a platform and it can do many things.
Just like a computer, you can use a computer to write a document, a book, to give a presentation to an audience. You can use it to control the heating system in a building so it's optimized. You can also use it to control some of the circuits in a car. Computers have many uses just like some of these platform organisms will have many uses.

NARRATOR
01:11:59
Jay Keasling intends to make money from other applications derived from the same platform that's used to make artemisinin.

JAY KEASLING
01:12:10
It turns out that I can apply that to many things: to producing drugs, to producing flavors and fragrances for ice-cream and for perfumes. I can apply it to produce say fuels that would be carbon-neutral, to producing the precursors to carpet, that is produced in an environmentally friendly way that maybe has different characteristics. So, my science is extremely narrow. But I can apply it to many different things.

NARRATOR
01:12:50
Listening to Jay Keasling, I wonder what the future of synthetic biology holds. Will it be the eagerly-anticipated new industrial revolution? Some say there's no doubt...

JAY KEASLING
01:13:04
We've got a long way to go. I'd say that we're still in the very early stages of what we'll eventually be able to do with synthetic biology.
Right now, we use microbes, that have been demonstrated by industry to be scalable. We can build chromosomes, and people can claim that it's a new life form, but for the most part they're copying what nature gave us and making some changes in the DNA. Wholesale re-engineering of an organism, that's still many years off.
I envision a day when, if you want to produce a particular product, you might custom-build a cell for it.
01:13:54
I'm hoping that we'll have plants in the environment that can help clean up the environment. Maybe they will sequester carbon from the atmosphere better or that will degrade contaminants that have been accidentally spilled in the environment.

NARRATOR
01:14:22
Meanwhile, one of the key applications of Keasling's yeast concerns one of the planet's major preoccupations... ensuring energy supplies, and in a cleaner manner.
As Jay confirms, few molecules offer an energy/volume/simplicity ratio as effective as oil. We therefore have to find alternatives, but which pollute less. He believes synthetic biology has the potential for putting an end to an economy based on non-renewable resources, to one based on inexhaustible resources.
01:15:05
Can we not imagine a living organism producing something that nature would never have imagined? Fuel, for example... produced directly by providing it with sugar or some other food... There would be no need to dig, pump and refine... just to draw it from a tap, like a draft beer.
Well, this already exists... and one of the numerous laboratories working on the question is just downstairs from Jay's, in the same building in Emeryville.
I have a meeting there, with Joel Cherry, the research director.

JOEL CHERRY
01:15:11

I am Joel Cherry, I'm the president of research at 'Amyris', Emeryville, California. We're a bioscience company that engineers microbes to produce hydrocarbons, primarily.
01:16:28
The two that are currently on the market is a diesel fuel, called 'farnesene' and the emollient called 'squalene', which is a dimer of farnesene.
If you smelled farnesene you would recognize the smell, but you probably wouldn't be able to guess where it came from. It's produced in nature from a wide variety of plants, and it's particularly concentrated in the skins of green apple. If you walk through our labs when we have lots of fermenters running, producing farnesene, you get a slight smell of green apple.

IN *01:17:03*
JC : It looks like this. It's the fermentation…
Charles : And that's farnesene.
JC : And it smells like …green apple
Charles : OK

NARRATOR
01:17:15
Farnesene is promising... but trying to produce it from apple skin would be ludicrous. Obtaining just one litre would require about 100,000 apples. This is where synthetic biology is a game changer.
Jay Keasling was a little evasive about how he transforms his yeast, so I ask Joel Cherry to tell me more about the techniques that are used to modify a cell's metabolism and get it to produce something other than what its genome originally planned.

JOEL CHERRY
01:17:44
Converting a yeast strain into a farnesene producing strain really only requires the insertion of one new gene that encodes one enzyme that makes farnesene.
We do that by reprogramming the yeast. We change the typical route that they take sugar, which is through ethanol, And we re-route that production so that the carbon that the yeast eat, the sugar that they eat, gets converted into the products that we want.
We rewrite the programming inside the yeast cell using DNA. And we introduce DNA from either synthetic DNA or DNA from other organisms.

NARRATOR
01:18:27
Enzymes, coding, genes, synthetic DNA... I'm not sure it's very clear. I didn't even know there was carbon in sugar.
In order to illustrate the delicate construction work carried out on a nanometric scale, Joel decides to explain things in more familiar terms. He leads me along the building's corridors...

JOEL CHERRY
01:18:50

If you think of a cell as a very complicated building with a plumbing system, the incoming pipe is sugar. The pipes inside a building go all kinds of places. What we really are doing is trying to pinch-off specific pipes in that building and direct the flow of that carbon, the sugar, into a specific place.
01:19:15
What we're doing when we're pinching off these pipes and trying to maximize flow of the carbon from the sugar into farnesene, is we're decreasing the amount of carbon that goes into the yeast cell for things we don't think it really needs, and increasing the flow of the carbon into farnesene.
We're the plumbers. And we have a very complicated building, where we have 50% - 70% idea of where all the pipes go. We don't see all the connections and there's still rooms that we don't understand.

NARRATOR
01:19:51
It's incredible. All the equipment, all the investments, all the people working on the production of the product in question, farnesene, and Joel Cherry the plumber admits that he doesn't know the half of what really goes on inside a cell.
And yet this doesn't stop him or his team from making constant progress and gradually increasing their production.

JOEL CHERRY
01:20:18
What we're talking about is really designing the product we want to make, outside the cell, using computer assisted design tools. And then, using a collection of parts that is all the DNA that's been sequenced or the instruction manual that's been read so far, to construct outside the cell, what it would look like. And then combine those pieces using the tools of genetic engineering. So it's really transitioning from a very artisanal or craftsman approach to an industrial approach.
And the net result is we end up with a system that uses the engineering cycle which is: design, build, test and learn. And we run that cycle recursively, over and over again, iteratively, to make minor improvements on the original design.
01:21:18
In synthetic biology, we're applying standardized parts, processes and tools, so that we can automate many of the steps we take when we're engineering organisms, much like we use when we engineer and build a car.
The aim of the research is to maximize production. And we want to maximize the efficiency by which yeast convert sugar into our final product. How much farnesene is made per gram of sugar fed. They can make more than twice their cell weight in a few hours.

NARRATOR
01:21:59
These little vials contain the most effective yeasts his team has managed to perfect, after continually enhancing the capacities of the modified organisms.
01:22:13
Thanks to these yeasts, Joel Cherry is now ready to move from the lab to large-scale production.
01:22:21

Brazil? I love it... Joel gives me an appointment thousands of miles from the San Francisco bay, in a small town in the heart of the Sao Paulo province.
01:22:40
We meet again in the middle of a vast sugar cane field, where there's a vague smell of apples in the air. This isn't so surprising, as this is the site of his fuel production plant. It's eminently practical, as the ravenous yeast he's brought from California will have all the food it needs to reproduce and get down to work.

JOEL CHERRY
01:23:02
Because it's a growing organism, you just need a little bit and you can grow it into a giant 200.000 litre tank in Brazil and it makes product. We have a plant with a capacity of about 40 million litres per year. It is built right next door to a giant sugar mill. And in between our plant and a sugar mill runs a big pipe, and that pipe carries sugar cane which gets fed directly into a giant steel tank that is called the fermenter.
All we do is add our yeast cells to that fermenter, with a few vitamins, and allow it to grow.
01:23:47
And it grows for a couple of weeks. It's constantly being fed sugar, and we are constantly removing product from the tank.
While that fermenter is growing, we have 3 layers form inside the fermenter. The bottom would be the solid yeast cells, the middle would be the sugar juice, that doesn't have any sugar anymore, so it's mostly water, and then the top layer is the oil.
We can separate first the cells and then the water from the oil, and we end up with a product that’s about 95% one-molecule farnesene, that can be distilled into a product that’s about 98 - 99% pure. So it’s a really simple process.

NARRATOR
01:24:43
But will the fuel produced here be able to compete with, and later replace oil?
Not really. Not right away.
Oil is still much cheaper than Farnesene, seven times cheaper, and so those who benefit from fossil fuels still have much to look forward to.
01:25:07
Today, only a few buses fueled by farnesene run in the streets of Sao Paulo.
But this won't always be so. The day oil prices go up, energy companies will turn to biofuels in a hurry. They're well aware of this, and so they're all already investing in synthetic biology.
01:25:31
For the moment, however, Joel Cherry's company is benefitting from opportunities in the cosmetics sector.
Synthetic biology has a role to play here too: making what's rare and precious available to the masses.
Cost-effectiveness is not easy to attain today. And indeed, in economic terms, clear figures are also difficult to establish. No financial expert would risk making hazardous estimates concerning the global value of the synthetic biology market, for example.
01:26:11
A company like Evolva, in Europe, has developed cells capable of producing the molecule of saffron, a highly-prized product for thousands of years. Until now,

obtaining one kilo of saffron required 200,000 crocuses. One simple fermentation tank can today produce the same quantity.
01:26:34
The same company, Evolva, is also counting on Resveratrol, the molecule in red wine that certain studies claim has beneficial effects on the longevity of mammals. However, in order to for it to be effective, one would have to drink 6 bottles a day. Which might have certain side effects on the longevity of the mammal in question.
With synthetic biology, there's no need to consume so much to age more slowly...
Such benefits, promises and products see the light of day in a fermentation tank, that could perhaps soon become a household appliance...
For scientists, as well as students, the grail is the discovery of the right combination of genes, the right formula to design a cell that produces something rare and precious. That would mean hitting the jackpot.
01:27:34
Synthetic biology envisages new ways of producing, alternative avenues for research, off the beaten track. Even at home, or in a garage.
As it happens, this is what Thomas Landrain is working on: in a lab unlike any other called La Paillasse, Paris, France.

IN 01:28:02
TL: Hello.
Charles: Hello Thomas.
TL: Thomas Landrain. Welcome to La Paillasse.
Charles: How long have you been here?
TL: Just under two months.
Charles: Just under two months.
TL: It's all quite new. Just before, we were in a squat at Vitry-sur-Seine. So for us it was a huge step forward.

THOMAS LANDRAIN
01:28:22
My name is Thomas Landrain. Until now, I've been a doctoral student in Synthetic Biology, and at the same time, I set up La Paillasse, which now takes up all my time. I've always been a rebel. I've always loved doing things myself, and at certain times, when I don't get enough freedom in my own professional environment, I tend to move away and do things myself.
La Paillasse has ultimately been an opportunity to create my own laboratory to work on the projects I've wanted to develop.

IN 01:28:52
TL: We have two rooms here. There's another one in the back. These two rooms will be used for major programs.

THOMAS LANDRAIN
01:28:58
La Paillasse is an open, civically-minded community laboratory for bio-technologies, and more generally, for all new technologies. The idea is to provide people with a space where they can experiment, and meet people who spark new ideas concerning these new technologies. We've tried to create a place where people have freedom: somewhere where we can give people who have an idea the possibility to work on

whatever they want, as they want and with whomever they want. We're creating here the same sort of thing that happened in the 70s with the geeks and the hackers.

NARRATOR
01:29:38
The myth of Silicon Valley garages where DIY engineers created hugely-successful start-ups never ceases to fascinate. Having worked in institutional labs, Thomas Landrain is convinced that the same model can be applied to synthetic biology. He wants to introduce a breath of fresh air to the field.
But I wonder... A lab handling chemical products requires rather different facilities than a computer engineer might need. There are specific tools, and safety measures to respect...
And yet for Thomas, the best proof of such garage labs' potential is the project he has developed himself. For a biological ink.

THOMAS LANDRAIN
01:30:18
One of the flagship projects at La Paillasse today is a project that will enable everyone to grow their own ink, biologically. It has to be said that inks are some of the most polluting products on the planet. Among other things, they're made of heavy metals and some pretty nasty solvents.
The idea is – 1 : to provide a bio-degradable alternative to these inks, and 2 : to come up with an alternative that could provide a degree of self-sufficiency. And so it was through a discussion that I had with a designer, Marie Sarah Denys, that we imagined a pen that could produce its own ink. Instead of having a cartridge, there'd be a bio-reactor, with bacteria: the bacteria would produce pigments and we could use the pigments to write with. In exchange, we'd feed the bacteria, and so we end up having to feed our own pens.
01:31:17
Even if the idea was completely insane, we began with the idea of using a bacteria that's naturally present in our ecosystem, and which could perform that role. After about a month studying the relevant scientific literature, I managed to find a candidate that's non-pathogenic, which grows easily, and which produces a blue pigment in vast quantities. We simply fed it with fairly classic nutrients: sugar, a little nitrogen, phosphate etc. The pigment isn't toxic, and above all it's biodegradable. This means we could use it to feed another micro-organism which could then produce other things.
01:32:00
In this way, synthetic biology will enable us to obtain very practical results, and relatively rapidly, I believe.
01:32:09
We have here some matter that's very interesting, that people can grow at home; they just have to grow a small bacteria culture.
01:32:22
It will be open-source technology. That means people can share it. We want to prevent it from being taken over by the big multinationals that have the ability to flood the market. So we'll probably have to apply for a patent and then issue free licenses.

NARRATOR
01:32:39

The overall philosophy seems fine. Garage labs like this one are springing up all over the world. Although one can wonder about the scale of the projects that are developed there. They're generally very small, but as synthetic biology uses pre-existing bricks, it's not so much the technology that's important, but the ideas. It's not impossible that an interesting idea could emerge from the hackers' shareware universe.
But I'm still not necessarily reassured about the use of potentially dangerous products or organisms, outside official control...

THOMAS LANDRAIN
01:33:15
It's clear today that there's no real surveillance of what we could call the « garages ». Meaning those places which are beyond regulatory measures and which are invisible to national regulatory bodies.

NARRATOR
01:33:26
So should we be afraid?

THOMAS LANDRAIN
01:33:30
Making a synthetic virus today is extremely difficult. It's not even about whether you have the equipment or the required knowledge. It's about expertise and experience. And there's a certain form of transparency, which generally means that when someone sets off in the wrong direction, they're very rapidly steered back on track. The framework has to be respected. You don't work with pathogenic organisms. You need licenses for that. You need the right equipment for that. And it's within that context that we've established the first ethical code for biotechnologies.
01:34:04
La Paillasse is probably one the biggest bio-hackerspaces in the world today. I think we'll soon be joined by other spaces like this in other places. I wouldn't be surprised to see around a hundred of them within the next five years. We're already in the process of setting up a network. For example, there are « Paillasses » in Bordeaux and Lyon, and also in Lausanne, and one is being created in Manilla in the Philippines.

NARRATOR
01:34:28
Thomas Landrain clearly has a broader vision. And it's true that when we see the popular success of the meetings and events organized around synthetic biology, there is good reason to be ambitious.
01:34:50
The reference is no doubt IGEM, an event organized each year in Boston by some of the disciplines key figures, all from the prestigious MIT. Thomas Landrain himself has attended, and on his advice, I decide to take a look.
Since 2004, this competition has seen students from around the world inventing cells with innovative properties. They work with a library of bio-bricks, genes from sequenced genomes that each have a specific biological function.
01:35:27

The components they invent subsequently integrate the same open-source data-base. There is something for everyone: from the most serious to the most bizarre project, in an atmosphere of intense emulation.
01:35:57
I happen to meet a rather unexpected character among the young scientists; an FBI agent. So maybe my concerns about security are shared by others after all.

ED YOU
01:36:04
My name is Ed You. I'm a Supervisory Special Agent from the FBI's Weapons of Mass Destruction Directory. I work in the biological counter-measures unit.
01:36:17
The mission of our unit is to provide a prevention mission on looking at how do we protect the life sciences, how do we prevent, detect and deter the development and acquisition of biological weapons.
The FBI has been a sponsor of IGEM since 2009. We conduct outreach to the students here. And we actually host a biosecurity workshop every year for the students and the theme is safeguarding science in the future.

IN 01:36:49
Charles: So that's your…what are those cards?
EY: These are biosecurity outreach and education trading cards. It does a nice job of explaining the differences and microbes…

NARRATOR
01:36:59
Ed You's background illustrates the evolution of governmental preoccupations concerning science and security issues.

ED YOU
01:37:07
Before joining the FBI, my background is in biochemistry molecular biology. So I was involved in human gene therapy research and I also worked for a bio-tech company during cancer research.
Post 9/11, the FBI diversified their workforce. So they hired individuals like myself, computer science individuals, people with foreign language skills.

IN 01:37:31
Voice: We have the FBI represented by Ed You…
01:37:36
EY: We're living in a different world now. It forces the FBI to change. We can no longer be just reactive so if a crime occurs we go in. Now we have to be pro-active. We prevent another event like 9/11 from ever happening again, not only in the US but anywhere else in the world: that has now become our priority mission and…

ED YOU
01:38:02
So we're starting with this generation that's up and coming. These are the future scientists, the future CEOs and future policy makers. And as we've always seen

historically, with any innovation or scientific advances, policy is always playing catch up.
01:38:35
We are instilling this awareness and I guess the best way to characterize it is: "Not on my watch". Meaning that - during my time, whether I'm a student or a full time scientist or a business person, that, now that I understand what the security concerns might be, what can I about it now, how can I actively prevent this potential misuse or abuse or exploitation and notify the right authorities.
01:39:07
The experts who can identify what the new security challenges are going to be - it's going to be the students. Because they're the ones that are actually doing the work, they're in the best position to then teach the FBI that based on what I'm doing with my now security awareness and I do my assessment, here's a potential vulnerability that you should be aware.
01:39:33
We are gonna be dependent on that partnership to determine if there was some incident, we're gonna need their expertise to help us determine, in our investigations, was this purely an accident?

NARRATOR
01:39:49
Ed You has no intention of minimizing the risks. Furthermore, in view of the extent of potential applications for synthetic biology, it's becoming increasingly complicated to evaluate them.
In any case, rather than being called in merely to put out a fire, the FBI is being proactive. And yet I doubt that the dependence on the collective conscience, the "not on my watch" premise, involving mutual surveillance among scientists, regulated by a code of conduct, will suffice in allaying the widespread doubts linked to synthetic biology.
01:40:31
Such actions also reveal the inability of government agencies to keep an eye on everything at once.
Fears concerning the abuse or misuse of science are not limited to questions of security.
01:40:47
A good many NGOs are attempting to raise public and political awareness about other issues too.
01:40:56
To learn more, I've come to Montreal in Canada, to meet one of their representatives, Jim Thomas.

JIM THOMAS
01:41:08
My name is Jim Thomas. I work for an organization called the ETCetera Group. I'm a Program Director and we track the impacts of new technologies on society, on the environment, on economies.

NARRATOR
01:41:23

Jim Thomas observes, criticizes and sometimes denounces the failings of techno-science and scientists. He has recently pointed his finger at nanotechnology and geo-engineering, but his favorite target today is synthetic biology.

JIM THOMAS
01:41:42
The natural world isn't a machine. The idea that you're gonna be able to improve nature is remarkably naive. There's a complexity there that has to be understood and that complexity is not just ecological complexity, it's also social complexity and economic complexity.
What worries me is that the field of synthetic biology works on some very simplistic premises that may not even be right. Synthetic biologists in their laboratories are working on a very specific applications, are looking narrowly, they're not looking at the complexity of a social situation of the ecosystems into which their organisms are gonna be released. And, in fact, often when you talk with synthetic biologists, they'll sort of admit that they can't even begin to think about that complexity.

NARRATOR
01:42:53
Jim is particularly concerned about the pretentions of bio-engineers, and their blinkeredness.
He travels round the world trying to mobilize the public at large.
01:43:11
He takes me to Tunisia, where he's taking part in the World Social Forum, where science is one of the issues to be discussed.
The country is undergoing upheaval, but attracts militants from around the world.

IN 01:43:31
JT: (conference)

NARRATOR
01:43:51
After his first intervention at the University of Tunis, Jim Thomas takes me the city's medina. He wants to show me some examples of traditional production that synthetic biology intends to replace.
In his view, it would mean the end for small-scale producers.
01:44:20
Even the most useful product can be criticized, in his opinion. For example, he lambasts the idea of manufacturing the yeast that produces artemisinin, which would appear to be of great benefit to humanity.

JIM THOMAS
01:44:36
The claim that this organism, by producing this important antimalarial drug would be a major boom for the fight against malaria, but we very soon discovered was artemisinin which was already grown by hundreds of thousands of farmers worldwide and it instantly raised the question, well, what happens to those farmers. If there had been a lack of artemisinin and it hadn't been possible to get it from the farmers then this might have been a good, but that wasn't the reality. The reality is there was enough artemisinin…

NARRATOR
01:45:11
Far from hi-tech labs and industrial installations, Jim Thomas is above all interested in human beings, in the producers who are the most at risk.

JIM THOMAS
01:45:21
That really pointed towards some of the sort of large economic changes that could happen once you can begin making commercially important compounds through synthetic biology.

NARRATOR
01:45:46
Another issue has also drawn his attention: the question of sugar.
01:45:53
Sugar is THE raw material for synthetic biology. It's used in many projects, and supply and demand constraints could lead to problems.

JIM THOMAS
01:46:16
Basically, you have a system where you're feeding large amounts of sugar to these engineered organisms. And on a small scale, this might be no problem but if you begin to talk about producing large amounts of a product such as bio fuels for example, or plastics, you'll need a large amount of sugar. And the production of sugar, particularly sugar cane in Brazil is associated with all sorts of environmental problems, it's associated with social problems, with land-grabbing. It's destroying one of the most fragile regions of Brazil. So, this is potentially a very damaging ecological trend.
01:46:58
Increasingly, the synthetic biology industry is saying, ok, then we'll not take any material from the land, we'll go to the sea. We'll see if we can use seaweed and we'll grow large sea weed farms of the coast of China, and of the coast of Chile but once again, this is gonna have ecological implications. It's not possible to produce large quantities of something using biology as a basis without disrupting biology on quite a wide scale.

NARRATOR
01:47:33
I sometimes get the impression that Jim Thomas is against everything. Against technology, against big business... But this is no doubt his role, as a form of counter-weight and opposition to the buzz and the general enthusiasm generated by synthetic biology is essential.

JIM THOMAS
01:47:54
The techniques that are used in synthetic biology of creating new living systems, are tremendously exciting and interesting and I think they are very useful for better understanding the way in which life processes work. They have a lot of value within laboratory for science and for improving our knowledge of the world. Where I get

concerned is when those techniques are taken to the market-place for producing industrial applications and, and without really understanding the implications.
And so until society has a way to address those disruptions, we need to be exceedingly cautious.

NARRATOR
01:48:36
Caution is good... and words can be powerful, but can they really change anything? I ask Jim Thomas about the possible solutions that he and his group have envisaged.

JIM THOMAS
01:48:48
I think what would be the best outcome, where if the governments of the world said: wait a second, since this is gonna be so powerful, since this is gonna have such wide impacts, let's slow down, let's think carefully, let's put a bit of a pause on commercializing these technologies and putting them out to the environment. That would require strong international governance, it would require a willingness to listen beyond the companies and the narrow group of scientists who are controlling this debate but I think it would be a very sane decision for the next 150 years.

NARRATOR
01:49:26
Whatever the field of research, communication between scientists and ordinary citizens has to be developed.
These synthetic biologists, in managing to evolve evolution to make what nature never intended or imagined, have initiated a technological revolution that no doubt goes far beyond anything the world has seen before.
A revolution, I believe, it would be a shame to scupper. Does it not have a great deal to offer us, a great deal to teach us about life itself?
It can help our society to progress, to consume less and more efficiently, to preserve the environment, to find new therapies to cope with diseases...
But unfortunately, there will be errors. There will be accidents; there always have been... it would be pretentious to claim the opposite.
Will we be able to anticipate them? Will we be ready to face them?
Such questions merit further investigation. There is still so much more to discover...

END CREDITS 01:50:21