Frazier (nulltone) presents…

Biohacking: Sometimes Spooky Stuff and Sometimes Wonderful Stuff

"Biohacking is the practice of engaging biology with the hacker ethic." - Wikipedia

About

- I'm Frazier, aka nulltone. Hi everybody!
- I've been going to IVU since the days of Maki-Maki.
- I've had the privilege of knowing Freaky for about 15 years.
- We met at DEF CON 7 in 1999, when I was 12, and you can find a video of his talk about Mac Security at DEF CON 7 on YouTube, posted by the official DEF CON account! w00t w00t :D

Why are you talking about biohacking?

- I studied many things over the years, including many aspects of biohacking. Topics include microbiology, immunology, some clinical medicine, environmental economics and policy, systems engineering, biostatistics, synthetic biology, bioethics, biopolicy & biosecurity, public health, international trade and technology transfer, venture capital & other funding markets, the FDA and USDA, and applied genetic engineering (which is basically synthetic biology)

What is the Hacker Ethic?

- Many definitions, some agreement
- Ideals: Freedom of Information, Improving Society and Life, Open and Free Access
- White hat vs Black hat (and of course, Grey)
- Examples: EFF, Open Source, Wikipedia
- Sharing and other “counter-culture” ideals
- Meritocracy and mistrust authority

What is Biohacking?

- Some of it is transhumanist, such as DIY body-enhancements (magnetic implant for 6th sense) or wearable tech (Google glass)
- Some of it is behavioral & diet like the Quantified Self health-focused community.
- Some of it is done like biotech at a university or company or government lab, which can get expensive and is usually great or dangerous.

Can biohacking mean anything else?

Sure, in my opinion, biohacking can be considered as the reverse engineering of biology, and this has been happening for a very long time. Humans have some elements of the hacker ethic and hacker archetype within them naturally, and just because one lacks computer skills does not exempt them from all other elements of a hacker mindset.

More examples of biohacking

- People who take nootropics (brain boosters)
- QuantifiedSelf: Biometric Data + Interventions
- Transhumanist, Techno-Progressivism, Cyborg
- At home gene sequencing, DIY genetics kits for schools and young kids, essentially mail-order “kitchen biotech” kits that are designed to be harmless but fun and educational.

Who are biohackers?

- Life Extension People
  - Lots of Venture Capitalists are into this!
- DIY bio people
  - Biopunk, hobbyists, artists, curious folk, futurists.
- Academics & Industry
  - These people are often very serious and experts.
- Normal people!
  - Making Beer, Making Yogurt, Growing Veggies!

Why do people hack biology?

- For fun and profit!
- To save the world!
- To take over the world!
- To cure a disease
- Other altruistic stuff
- Other evil stuff
- The “God-complex” and natural curiosity.

Ethics

… *awkward silence* …

Seriously, Ethics!

- In the medical context: “First, do no harm.”
- Specific to SynBio – Synthetic Biology
  - Containment & Safety, Possible Clinical Research Requirements, Intellectual Property & Funding, Dual-Use Tech (just like computers), Export Restrictions, DNA printing restrictions, Homeland Security & FBI outreach programs and vigilance, some potential for Cold War style paranoia too…

Dangers & Potentials

- It doesn't help that the DNA sequences for smallpox and 1918 influenza, both highly deadly and easily spread, are online and available for anyone to download.
- DNA printing is becoming cheaper, just as DNA sequencing is becoming cheaper & faster. Soon it will cost $1000 to decode your entire genome. Printing DNA is ~$1/base-pair (ATCG)

More Clear & Present Dangers

- Bioweapons or mass production of toxins
- Increased chance of accident or natural pandemics
- Low barrier to entry, bioweapons are much more likely to be used by rouge states or terrorist groups than any other weapon of mass destruction.
- Genetic Printing is getting cheaper and better faster than Moore's law! It is incredible…

Bad History of Evil Biotech

- Japanese Unit 731 known to public as the “Epidemic Prevention and Water Purificaiton Department”
- 40 years of Imperial Japan Biowarfare
- Some of the most notorious warcrimes, around 10,000 civilians died from human experimentation at the camp of Unit 731. Because the Japanese burned records, research, and the weapons themselves, we do not know much about the extent of their bioweapon program, but much of mainland Asia reports bioweapon testing, as well as South East Asia and even Singapore. Anywhere Imperial Japan was, they did awful human testing.

Unit 731

- Experimented with Plague, Cholera, Hemorrhagic fever, and that is just what we know about. Very evil stuff, they also did live-human vivisection =(
- One experiment resulted in more than 10,000 Japanese military casualties and the death of 1,700 Japanese soldiers, revealing the difficulty of waging effective biowarfare.
- No estimate is provided of Chinese and Russian deaths, just as the DoD only [publically] kept track of American body counts in Iraq.

Local Bioterrorism

- A Indian Guru who led a Laguna Beach cult, that moved to Oregon at their peak, was eventually implicated in several bioterrorism plots in the late 1980s. They made thousands of people sick by spreading lab-cultured salmonella in Salad Bars and grocery stores. They did this to try to win a county election as they were in a dispute about land-use and population density. *facepalm*

Rajneesh's wild ride

- They were also experimenting with more scary bioterrorism agents, like botulism. I do not think anyone died from their experiments, but many people were hospitalized with severe dysentery.
- When causing symptoms like the flu or dysentery, some bioweapons can be more like incapacity agents and mostly non-lethal.

The [Potential] Benefits of SynBio

- Cheaper, better, safer medicines, materials, energy… this alone covers *a lot* of ground!
- Clean water, better food, drought-resistant crops, more ecologically sustainable systems.
- Small & Cheap bioreactors in the home or community lab that can make beer, medicines, chemical materials, and hopefully not evil stuff like pathogens.

What is SynBio?

- SynBio = Synthetic Biology and it is “The Design and construction of biological devices and systems for useful purposes.” Nice!
- Bioengineering, designing bacteria computers
- Bacteria computers + chemical factories
- They use sugar & other cheap feed-stock
- So much potential… for good and for evil.

SynBio in Media

- Some coverage here and there, from business to social commentary. Some of it is science news for the public, but the most active source of information is among academic journals that specialize in this topic. They can be found thru http://pubmed.gov and if not open access (free to read), you can use library access at a college or university to read it.

Brief history of biohacking & medicine

- Before 1900, biohacking and medicine were essentially the same thing.
- Unfortunately, methods were crude and brutal until the mid 1800s, when the first wave of modern medical technology was discovered, such as antiseptics.
- This is largely irrelevant to SynBio, but I suppose it shows how far medicine technology has evolved in just 100-200 years.

More History

- If pre-1900 was mostly misinformation, superstition, and plant-based therapies or even harmful therapies (blood-letting)
- The 1900s was a century that had fully realized the scientific method, and there was a massive wave of biomedical research and development. In the context of SynBio, most of it started in 1978 with the discovery of reliable genetic engineering technology.

Major Biotech of the 1900s

- Antibiotics, other medicines, and vaccines
- Green Revolution from 1950s to 1970s
- Genetic Revolution in 1980s (for medicines)
- Transgenic Plants (Monsanto)
- Much advancement in medicine technology
- National Institute of Health, Food and Drug Administration, USDA, USAMRIID, non-profits

About Pills and Stuff

- Many medicines come from plants or were discovered by accident (or trial and error) thru synthetic chemistry technology, the byproduct of alchemy! Some early medicines were actually fabric dyes or extracts of plant or animal body parts.
- The FDA and the USDA are very interesting organizations from an Economics, Public Safety, and Social Justice perspective. If you'd like to hear my opinion on it, ask me.

What “Green Revolution”…?

- This was basically lots of R&D, liberal tech transfer to the “third world”, plus some foreign direct investment from the 1940s to 1970s and it increased agriculture production worldwide. Due to a surge in the global human population since World War 2, it is a conservative estimate that the Green Revolution, a term coined by USAID in 1968, saved over one billion humans from starvation.

But what AgTech was used…?

- All sorts of modern farming stuff
- Irrigation, Management, Hybridized (not yet GMO) seeds, synthetic fertilizers, pesticides, herbicides, and eventually the “Monsanto-era” technology.
- Hybridized Seeds, for wheat and corn had strong genes, but with standardized seeds came genetic monoculture and some biodiversity risks, which are complicated and can take a generation or two before causing problems.

AgTech in the 60s was Impressive

- There was some very advanced work in molecular genetics by the USDA, UN, and many universities in the 1960s, and this work led to some of the crowning achievements of the Green Revolution.
- The genomes of grains (wheat, corn, rice, etc) were sequenced and strong traits (mutant genes) were inserted before the biotech revolution.

The Biotech Revolution

- Also known as the “genetic revolution”
- Human Genome Project
- Recombinant DNA and PCR
- Easier, faster, and finally cheaper sequencing of whole genomes, leading to a foundational technology for SynBio
- Services looking for SNPs like 23andMe

More Genetic/Biotech stuff

- Lots of modern medicines
- Can fight cancer without cytotoxic chemotherapy effects
- Also useful for many other diseases
- Also useful for insulin, people who have anemia, and there are nearly 100 medicines developed since 1980 that are “biologics” instead of “small molecule”

So that means…?

- That essentially means that medicines started a transition from small-molecule, products of our advanced synthetic chemistry industry and mostly from the 20th century, to large-molecule "biologics" that are basically clones of proteins and other naturally occurring complex chemicals in our body. Sometimes the immune system catches them, other times the biologics work great & save lives.

The Dark Side of Biotech (pre-2000)

- Sorry everyone, but for me to skip this would be unethical, albeit easy and less awkward.
- Even before the 20th century, chemical & biological weapons have been used on soldiers & civilians.
- I don't even have time to list them all, but I made a list, pulled from Wikipedia, of the bio-weapons that are declassified.

Biosecurity Threats

- Bacteria, Virus, Amoeba, Parasite, and Fungus
- Inflammation, Allergy, Toxins, Infections
- Contagion (not just a movie…)
- HHS Select Agents and Toxins include…
- Botulism bacteria and/or the toxin, black plague, Rickettsia, Francisella, Coxiella, and those are just the bacteria! For whatever reason, they do not include Anthrax, Cholera, Tularemia (Lyme Disease), Listeria, super-pathogenic E. coli, Salmonella, C. diff… any sources of dysentery.

Biowar

- Clearly, you can incapacitate an Army or entire country with those [weaponized] bugs, and that was just Bacteria!
- I'm not trained in virology outside of a little bit of public health, so I'm not going to list them all. The most famous scary ones are smallpox, any type of encephalitis or meningitis, and of course the most scary viral hemorrhagic fever!

Fungus and What Else?!?

- Only one fungus weaponized and declassified, known as OC, latin name *Coccidioides immitis*, and it is actually from the southwestern USA.
- It causes a disease called Valley fever, I don't know much about it, but it sounds pretty bad… it is considered Biosafety level 3, so that includes West Nile virus, SARS, rabies, and other fairly contagious agents. BSL-4 is the highest and for stuff like Ebola & Smallpox.

Some really cool tech that is kinda related

- DNA computing: few successful experiments
- DNA in bionanotechnology: using DNA as a material, like a molecular scaffold for nanotech, and not for storing information. New Nanotech Medicines for Cancer
- Natural computing: Bio-inspired Design
  - Evolutionary Algorithm, Neural Networks, Swarm Intelligence, Artificial Immune Systems, Fractal Geometry, Artificial Life, DNA/Molecular Computing, Quantum Computing, Membrane Computing
- Materials Science & Engineering

MOAR SLYDEZ?!?!11

- Okay everyone, I am not going to talk much about the incredible advances in medicine research, techniques, and technologies like robots and even super cool stuff like nanotech, just because I want to try to limit the scope of this talk to biotech, genetic engineering, and most of all trying to define the concept of “biohacking” =]

Nap time? =P

[This is a chance to take a quick break and maybe I can answer any pressing questions about the information presented thus far…]

Questions are encouraged, but optional.

Biohacking since 2000

- So much has happened since 2000, it is going to be impossible for me to cover this all in an hour, let alone a half hour or whatever time I have left…
- I'm going to talk about (and maybe show) a few examples, list about a few theoretical applications that are important for society, and then finish the slides and open up for any and all questions. Remember, no stupid questions, just stupid people.

Standardization in DNA programming

- If you want to learn more about Synthetic Biology from a hacker/programmer perspective, watch the Chaos Computer Club Congress talk titled “Programming DNA” by Drew Endy. He is a genius and spends lots of time on a point I am about to make…
- Synthetic Biology requires standardization, as has every field of engineering & production.

Some cool examples

- Creating a strain of bacteria that lives in the gut, like a probiotic from yogurt or pills, but this strain of bacteria is a synthetic organism, a genetic chimera. Thus, it can do something important like produce a harmless & natural anti-inflammatory peptide that results in some disease (MS, Crohn's, Lupus, Cancers) to go into remission.

More cool examples

- Unlike the previous example, here is one actually in production. It works on an amino acid involved in the formation of scar tissue in the arteries. Therefore, this symbiotic (helpful) gut bacteria, similar to a probiotic, would reduce the risk of developing hardened arteries & other aspects of heart disease. This was developed by a University in the iGEM competition.

DNA for Data Storage

- The idea and the general considerations about the possibility of recording, storage and retrieval of information on DNA molecules were originally made by Mikhail Neiman and published in 1964–65 in the Radiotekhnika journal, USSR.
- On August 16, 2012, the journal Science published research by George Church and colleagues at Harvard University, in which DNA was encoded with digital information that included an HTML draft of a 53,400 word book written by the lead researcher, eleven JPG images and one JavaScript program. Multiple copies for redundancy were added and 5.5 petabits can be stored in each cubic millimeter of DNA. The researchers used a simple code where bits were mapped one-to-one with bases, which had the shortcoming that it led to long runs of the same base, the sequencing of which is error-prone. This research result showed that besides its other functions, DNA can also be another type of storage medium such as hard drives and magnetic tapes.

A contest to program bacteria? wtfbbq? …no, it is called iGEM!

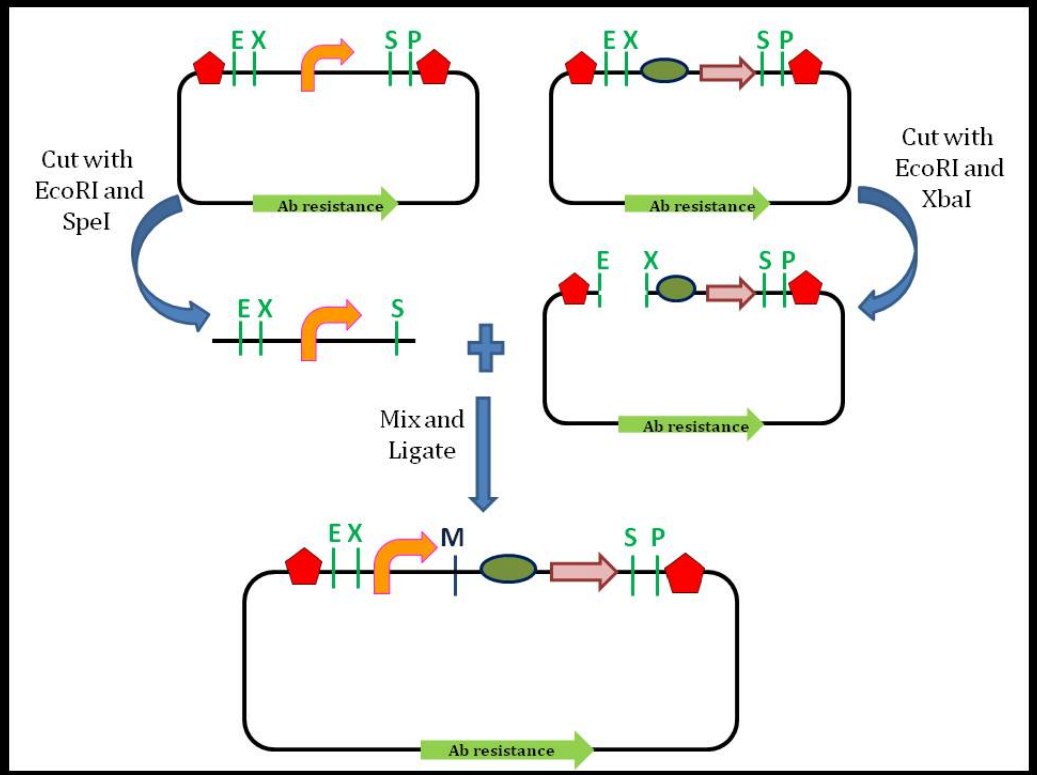
- International Genetically Engineering Machines
- It is a competition, usually with around 50 teams from all around the world, with mostly undergraduate students, but some high school students compete. It has cutting edge science.
- Some of these projects make a traditional school science fair look incredibly inadequate

And how about BioBricks?

- iGEM works with BioBricks, a wiki-style collective of open source “biological parts”… so, part means the DNA sequence that codes for certain parts of a bacteria cell. BioBricks and pretty much all of Synthetic Biology only works with Bacteria, although sometimes Fungus/Yeast is used. Synthetic Biology never involves trans-genetic engineering in animals.

Examples of BioBricks

- Promoters, Coding Sequence, RBS, DNS, Inverter, Plasmid Backbone, Terminator



Let's hear more about Biohacking!

Three Domains

- Controlled: To make medicines or other valuable & useful chemicals in a sealed lab
- In a human: complex medical use, such as gut flora (with added benefits to treat disease or extend life)
- In the wild: sometimes for geoengineering, sometimes to clean pollution, sometimes for evil (biowar, bioterrorism, etc)

Biopunk sounds a lot like Cyberpunk…

A Biopunk Manifesto by Meredith Patterson

The following was delivered yesterday at the UCLA Center for Society and Genetics' symposium, "Outlaw Biology? Public Participation in the Age of Big Bio". It is inspired by, and deliberately follows the form of, "A Cypherpunk Manifesto" by Eric Hughes.

Scientific literacy is necessary for a functioning society in the modern age. Scientific literacy is not science education. A person educated in science can understand science; a scientifically literate person can *do* science. Scientific literacy empowers everyone who possesses it to be active contributors to their own health care, the quality of their food, water, and air, their very interactions with their own bodies and the complex world around them.

Society has made dramatic progress in the last hundred years toward the promotion of education, but at the same time, the prevalence of citizen science has fallen. Who are the twentieth-century equivalents of Benjamin Franklin, Edward Jenner, Marie Curie or Thomas Edison? Perhaps Steve Wozniak, Bill Hewlett, Dave Packard or Linus Torvalds -- but the scope of their work is far narrower than that of the natural philosophers who preceded them.

Citizen science has suffered from a troubling decline in diversity, and it is this diversity that biohackers seek to reclaim. We reject the popular perception that science is only done in million-dollar university, government, or corporate labs; we assert that the right of freedom of inquiry, to do research and pursue understanding under one's own direction, is as fundamental a right as that of free speech or freedom of religion.

We have no quarrel with Big Science; we merely recall that Small Science has always been just as critical to the development of the body of human knowledge, and we refuse to see it extinguished.

Research requires tools, and free inquiry requires that access to tools be unfettered. As engineers, we are developing low-cost laboratory equipment and off-the-shelf protocols that are accessible to the average citizen. As political actors, we support open journals, open collaboration, and free access to publicly-funded research, and we oppose laws that would criminalize the possession of research equipment or the private pursuit of inquiry.

Perhaps it seems strange that scientists and engineers would seek to involve themselves in the political world -- but biohackers have, by necessity, committed themselves to doing so. The lawmakers who wish to curtail individual freedom of inquiry do so out of ignorance and its evil twin, fear -- the natural prey and the natural predator of scientific investigation, respectively. If we can prevail against the former, we will dispel the latter. As biohackers it is our responsibility to act as emissaries of science, creating new scientists out of everyone we meet. We must communicate not only the value of our research, but the value of our methodology and motivation, if we are to drive ignorance and fear back into the darkness once and for all.

We the biopunks are dedicated to putting the tools of scientific investigation into the hands of anyone who wants them. We are building an infrastructure of methodology, of communication, of automation, and of publicly available knowledge.

Biopunks experiment. We have questions, and we don't see the point in waiting around for someone else to answer them. Armed with curiosity and the scientific method, we formulate and test hypotheses in order to find answers to the questions that keep us awake at night. We publish our protocols and equipment designs, and share our bench experience, so that our fellow biopunks may learn from and expand on our methods, as well as reproducing one another's experiments to confirm validity. To paraphrase Eric Hughes, "Our work is free for all to use, worldwide. We don't much care if you don't approve of our research topics." We are building on the work of the Cypherpunks who came before us to ensure that a widely dispersed research community cannot be shut down.

Biopunks deplore restrictions on independent research, for the right to arrive independently at an understanding of the world around oneself is a fundamental human right. Curiosity knows no ethnic, gender, age, or socioeconomic boundaries, but the opportunity to satisfy that curiosity all too often turns on economic opportunity, and we aim to break down that barrier. A thirteen-year-old kid in South Central Los Angeles has just as much of a right to investigate the world as does a university professor. If thermocyclers are too expensive to give one to every interested person, then we'll design cheaper ones and teach people how to build them.

Biopunks take responsibility for their research. We keep in mind that our subjects of interest are living organisms worthy of respect and good treatment, and we are acutely aware that our research has the potential to affect those around us. But we reject outright the admonishments of the precautionary principle, which is nothing more than a paternalistic attempt to silence researchers by inspiring fear of the unknown. When we work, it is with the betterment of the community in mind -- and that includes our community, your community, and the communities of people that we may never meet. We welcome your questions, and we desire nothing more than to empower you to discover the answers to them yourselves.

The biopunks are actively engaged in making the world a place that everyone can understand. Come, let us research together.

Credit: Meredith L. Patterson

SciFi Super-Dangers: Grey Goo

- Grey Goo is from science fiction of nanotechnology, but as much molecular biotechnology can also be considered nanotech, as it is a technical (yet natural) mechanism at the nanoscale, Grey Goo can apply to bacteria.
- Imagine if we make a super bacteria that eats garbage. Well, it could mutate and start eating everything and turning all biomass on earth into itself. This is an example of the Grey Goo Theory.

Why Grey Goo is unlikely…

- Bioengineers code many fail-safes into synthetic organisms, so Grey Goo is unlikely. Also, it will be a long time before genetically engineered bacteria are being used outside of controlled environments, as there has not yet been a consensus on the regulation of releasing genetically modified bacteria. GMO plants do have regulation in place, clearly.

Wrapping it up

- Much of synthetic biology is just like the rest of science, but it can be defined as applied genetic engineering of microbes with the mindset of a systems and/or software engineer. AKA microbial engineering.
- After all, DNA is the code of life, SynBio is all about programming DNA effectively.
- No instruction manual; all reverse-engineering

The End

There is so much more I could talk about, in depth and in breadth, but due to time limits and wanting to keep this slide-show manageable, I decided against graphics. I also left out many examples of SynBio projects. In reality, there have been thousands of SynBio experiments in the past decade! Most of all, this talk is trying to explain the core premise & give a few examples.

So, any questions…?