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Outlaw Biology

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A couple of guys in a garage changed computer technology. Will someone in a basement one day transform biology just as radically? We explore the tantalizing — and maybe terrifying — frontier of synthetic biology and do-it-yourself life science.

There's something strange in the neighborhood. Something being cooked up — more or less literally — in garages and basements across America. Something that requires materials you can find around your home or buy for a couple thousand bucks. Something you can find out about readily and in great detail with a simple surf of the Internet.

Something that is incredibly, geekily cool — but which may one day transform society as explosively as the first Apple computer did when it was built on a wooden workbench in a suburban garage in Northern California in 1975.

"Messing up molecules in your garage is exponentially more dangerous than screwing up a motherboard. That's why the FBI has developed close relationships with the DIYbio community."

It's called synthetic biology, the futuristic combination of biology and engineering that probably

has as many definitions, descriptions and nicknames as it has practitioners. Synthetic biology is being done by some of the most talented scientific minds in the world — but it also has given birth to a nascent but exuberant related "movement" called DIYbio, or do-it-yourself biology, in which an intrepid handful of scientific explorers, generally young and in college, work not in gleaming, glistening, bleeding-edge university or corporate laboratories, but in attics, basements, garages and, in one case, even a tricked-out bicycle called a "velolab."

These are "outlaws," as UCLA anthropologist Chris Kelty described them in a blog column, but not in a criminal sense. They are instead "like Robin Hood, unaccountable but connected, poaching resources and distributing them to people who could never imagine having them. Outlaw biologists love demystifying science," and they "can exist inside as well as outside of science."

Also out there doing it themselves, Kelty wrote, are DIY explorers such as "bio-hackers" who "reconfigure the system from within," and "Victorian gentlemen scientists," who "have a circle of friends with access to the best tools and techniques, and a coterie of willing participants in their schemes. Artists are more likely to be Victorian Gentlemen."

And scientists at established institutions as well, such as Stanford Assistant Professor Drew Endy, one of the field's foremost pioneers and an ardent evangelist for open-source biology. Among other accomplishments, he helped launch the nonprofit BioBricks Foundation and repeats, "How do we make biology easy to engineer?" in interviews so often it sounds like a mantra.

So it is true that one needs at least some kind of minimal training to do DIYbio. Definitely more than was required to use one of those old chemistry sets in the '50s. But maybe not much more.

Synthetic Biology

Synthetic biology expert Drew Endy gives a 10-minute presentation about making nature easier to engineer. Imagine having "gigantic programmable gourds that differentiate into four-bedroom, two-bath houses," he says.

Indeed, even kids can do DIY science in general, and they have for decades. David Rejeski, director of the Science and Technology Innovation Program at the Woodrow Wilson Center in Washington, D.C., remembers youthful adventures as an amateur rocketeer and owner of these chemistry sets. "By the time I was 12 or 13, everything I knew about chemistry and the heavens I learned from some form of DIY," he recalls. "I wouldn't have become a scientist without it."

Undoubtedly, DIYbio could wreak havoc, and not just because of its obvious potential for bioterror. Messing up molecules in your garage is exponentially more dangerous than screwing up a motherboard. That's why the FBI has developed close relationships with the DIYbio community, working to create effective safety processes and minimize the possibility of something going catastrophically sideways.

But those who study or practice synthetic biology and DIYbio insist its potential for good far outweighs its risks. They contend that it's a form of public participation that has positively impacted other areas of society. Think open-source software, peer-to-peer networks or crowdsourcing, only with bacteria and "wetware."

They claim that DIYbio offers a new canvas upon which artists can create "bio-art." And that science done outside the mainstream spurs innovation and interest in science overall. And perhaps most important, that it could lead to treatments or even cures for exotic diseases Big Science does not or cannot address.

Who would argue, for example, that projects like creating a mechanism for detecting the presence of toxins in baby food isn't a good thing? Or a biological sensor that finds land mines. A biological agent for identifying arsenic in well water. Or reprogramming bacteria to create a vaccine against ulcers.

"A lot of people want to build lab equipment in their garage. Or cure a disease in their family where, for whatever reason, there isn't government or corporation support for that."

And few would deny that scientific innovation could indeed one day arise from such whimsical DIYbio efforts as extracting DNA from strawberries using only household products or concocting a bacteria relay race in which molecular material is passed back and forth. The science of genetics, after all, began with the observation of pea plants.

These are all examples given by the people whose voices you will hear in this story of experiments done in seminars and conferences, by individuals in their homes or teams in synthetic biology competitions like the International Genetically Engineered Machine and organizations like the BioBricks Foundation.

And, increasingly, in Westwood.

Get In Touch With Your Inner Outlaw

In January, Kelty organized a symposium on synthetic biology presented by the UCLA Center for Society and Genetics at the California NanoSystems Institute (CNSI) called "Outlaw Biology: Public Participation in the Age of Big Bio."

"I'm interested in how these new kinds of sciences are changing how scientific research gets done," he explains, estimating that the gathering drew an eclectic crowd of several hundred high school students, Bruin undergrads, artists, lawyers and ethicists as well as scientists. What Kelty and company found was that there was no consensus about the implications or impact of DIYbio. But there were any number of "conversations happening."

"First, the issue of safety and risk always comes up with people doing biology outside of the mainstream," he says, "and second, a very important discussion about the nature and extent of participation, whether or not we should think of it as an either/or proposition: biology happening in the mainstream and these wacky hackers outside, or boundaries between both dissolving."

One example of the latter, he continues, "was patient advocacy groups, which came up over and

over. People coming together around subjects not addressed by mainstream science ... You don't have to be a biologist. There are publications and databases [available to the public]. If you have the money, you can call a supply house and get what you need. It's one of the most open areas of science."

But, he underscores, "You can do it from the outside, but from the inside, too." And, as the efforts of leading thinkers like Endy vividly illustrate, it is true that Big Bio is quite capable of exploring the boundaries of knowledge in this area.

"Some of these [synthetic biology] activities are going on in academic institutions, as well," agrees Anne Andrews, UCLA visiting professor of psychiatry and a member of the Semel Institute for Neuroscience and Human Behavior, the Hatos Center for Neuropharmacology and CNSI. "I don't see such a huge dividing line, that these activities are only occurring outside of what you might call mainstream academic and institutional science. Maybe there are certain things that can only be accomplished within a more structured environment with a lot of resources behind it and more structured methods for collaboration and sharing ideas."

This is good, she argues. "One of the things brought up in the workshop was self-policing dangerous things that could be discovered outside of institutions that have controls in place," Andrews explains. "I recently read about efforts by growers to keep wild-grown food separate from genetically grown food. Monsanto can't accomplish that. Can we really expect someone working in their basement to be able to do that?"

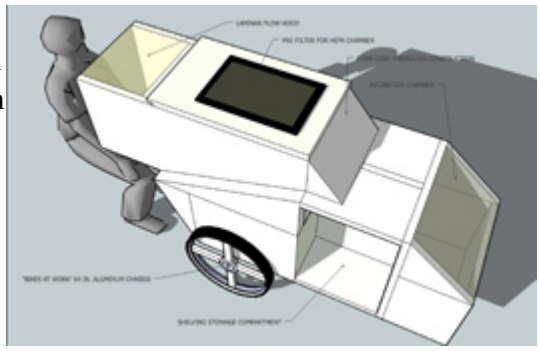
In fact, the scientist spoke at the symposium because she, like Kelty, sees the growing interaction of science and the public as a net gain for both. "I understand workshops like 'Outlaw Biology' are trying to get [institutional scientific discovery] to people working outside mainstream science."

Just Doing It

The Wilson Center's David Rejeski isn't a big fan of cool names like "outlaw biology" and "DIYbio" because he thinks they obscure what's most intriguing about the movement. He argues that the true significance of the symposium at CNSI was captured "on the right side of the colon [of the event's title], where it said, 'Public Participation in the Age of Big Bio.' Nobody noticed that because they were too caught up in imagining what outlaw biologists looked like. Up to now, public participation in science and technology has mostly meant letting the public weigh in on our research programs and priorities through conferences, online surveys or public meetings — and then largely ignoring their input. It was never about people with DNA synthesizers in their kitchens. That's downright subversive."

And that's music to the ears of the boundary pushers. Like Jason Bobe and Mackenzie Cowell, the two independent bio geeks with ties to academic institutions, who launched the DIYbio movement in April 2008. And the explorers who've followed them, like Romie Littrell M.S. '10, who works with UCLA Design | Arts Professor Victoria Vesna [see *End Point: In Living Color*]. Littrell attended the symposium and is one of the organizers of the newly minted Los Angeles chapter of DIYbio.

"I love to tinker, to create, to find out how things work," he says. "For me, and I think for many, creation is an end of its own. A lot of people want to build lab equipment in their garage. Or cure a disease in their family where, for whatever reason, there isn't government or corporation support for that. It's both a grassroots revolution for giving people things that don't exist right now and a new field of play."



Starr's design for his velolab (courtesy of Samuel Starr).

The play's also the thing for Jillian Theil '10, a research assistant who worked on "Outlaw" and wrote about her symposium experience as a "cowgirl."

"In five minutes, one can acquire strawberry DNA by simply smushing strawberries, adding soap, and then slowly adding a little bit of rubbing alcohol," she blogged on outlawbiology.net. "To get down the exact method, you can just Google 'strawberry DNA extraction.' I had a lovely preschooler assist me with the undertaking [at the symposium] and reveled in his glory as he squished DNA in his fingers like a booger. Strawberry DNA really does look like snot."

Another attendee, an inventive Pomona College art major named Samuel Starr, took a year off to take basic science courses at the University of Minnesota and then built the aforementioned lab-on-a-bicycle, which he pedaled over to CNSI in January. Starr constructed the velolab because, "by designing a portable laboratory, I hoped to uproot expectations for who would be engaging in scientific study and where they would be doing so." Starr plans to conduct his first experiment on the velolab this fall.

"I'd like to do mushroom-growing workshops using the laminar flow hood for inoculations," he says helpfully. That, and "pair up with someone who has more in-depth experience than I do running PCRs [a machine for sequencing DNA] so we can use the velolab as a portable DNA fingerprinting station."

There are now DIYbio groups in Boston, New York, San Francisco, Seattle, Houston and Austin as well. "People are doing it for fun, for art and for profit," says Cowell. "And research, of course. We just completed a survey of the community and when we asked why people were interested in DIYbio, tinkering and research were neck and neck."

The research potential is why Kelty identified patient advocacy group involvement as a key theme of his symposium. And there are any number of obvious, albeit as yet untapped, implications for DIYbio research, particularly into rare diseases that mainstream science cannot cost-effectively investigate and for which funding is almost impossible to come by.

One well-known example is symposium participant Hugh Rienhoff, a Northern California physician and biotechnology consultant who has been working tirelessly to uncover the mystery hidden within the genes of his 6-year-old daughter, Beatrice. She is afflicted with an exotic disorder no doctor has been able to identify, let alone treat. The disease has left Beatrice frail and fragile, and, as *Wired* magazine noted, could even threaten her heart.

Rienhoff first began to chart Beatrice's genetic code, utilizing a used PCR he bought for $750 (and yes, he keeps it in his basement), wrangling other materials by various means, and convincing a lab to help analyze the results.

Beatrice, says her dad, who founded MydaughterDNA.org, a group dedicated to greater understanding of genetic conditions, is "slowly getting better." And he adds that she's "a can-do spirit who reminds you she doesn't need help putting on her shoes."

But Dad does welcome help with his ongoing quest. "Every time I see someone with a new set of skills, I go out and try to find that person," he says. "Now I'm working with somebody who has Beatrice's DNA, so I'm not doing any of the lab work myself."

Safety First

"In my freshman year, I learned it's really easy to make anthrax," says strawberry smusher Theil. "It's scary thinking about the implications of that."

Danger is a common companion for any outlaw. And a huge question mark hovering over synthetic biology — like other envelope-pushing areas such as nanotechnology — is safety and the potential for deadly applications. That's why the FBI has partnered with the DIYbio movement all over the country.

In 2009, the Bureau hosted a conference on the subject in San Francisco, in partnership with the Department of Health and Human Services, the U.S. State Department and the American Association for the Advancement of Science. At the conference, members of industry, academia and the DIYbio community came together and were introduced to their local FBI Weapons of Mass Destruction (WMD) coordinators, who now have regular interaction with the DIYbio community across the country.

"We engaged with DIYbio because we understood post-9/11 that we had to be more proactive," says Edward You, supervisory special agent for the FBI in the Weapons of Mass Destruction Directorate and also a speaker at "Outlaw Biology." "As part of that, we are charged with determining the emerging technologies popping up and figuring out ways to mitigate the risks that they pose. This all started with a synthetic biology initiative, part of a multiagency effort to prevent individuals from illicitly acquiring DNA sequences for dangerous pathogens."

The FBI has become a full-fledged member of the movement, even joining the iGEM competition in 2009 and setting up an outreach booth. And in August, the Bureau will again hold a synthetic bio conference, this time in Boston.

"Last year we addressed biosafety and looked at the ethical impacts of [a DIYbio] project," You says. "Now we're asking them to look at security ... Our role is to provide education not just on terrorism, but also on personal health and safety issues. And to understand that the FBI is not just a law enforcement agency, but also a resource."

In fact, there's plenty of need for education. A 2009 study found that 90 percent of Americans think there should be more information available on breakout technologies like synthetic bio. That's another reason why Rejeski is leery of provocative names.

"What it's called becomes what it is," he says, noting that his own organization's polling finds the vast majority of people "go very quickly to the negative connotations — artificial life, stem cells, cloning, genetically modified foods and all the third rails. Once we give them information, they feel better about it, although they're still very cautious. So how they hear about this really makes a difference."

By any other name, though, synthetic biology tantalizes — and terrifies. Its DIYbio manifestation is a tiny swell in the scientific sea right now, but just like those computer tinkerers in that Northern California garage, it could grow into a wave that sweeps in a transformative cultural force.

"You might argue that the applications of DIYbio are trivial, but that's not the point," concludes Hugh Rienhoff. "The payoff never comes from the first app, so we shouldn't be too harsh on people extracting DNA from strawberries. The fact is, they're getting their hands dirty, and that's good."