Wolfgang Sützl, Theo Hug (Eds.)

ACTIVIST MEDIA AND BIOPOLITICS

Critical Media Interventions in the Age of Biopower

CONTENTS

POLITICS

BIOTECH

TWEAKING GENES IN YOUR GARAGE: BIOHACKING BETWEEN ACTIVISM AND ENTREPRENEURSHIP

by Alessandro Delfanti

Garage biology, biohacking, and citizen biology are all expressions that describe a new and emerging movement of amateurs conducting life sciences outside of traditional professional settings such as university and corporate labs. Among several groups of amateur biologists, DIYbio (Do-it-yourself Biology, www.diybio.org) is probably the most well known organisation. It is a network that was established in Boston in 2008 and is composed of several groups in major US and European cities. Their aim is to provide non-expert citizen biologists with a collective environment and inexpensive open source tools and protocols for biological research, which can be conducted in weird places such as garages or kitchens. Although, so far no important scientific innovation has come from citizen biology, the novelties that characterize it have been described in terms of open and peer knowledge production, danger to public health, co-optation, democratic (or apocalyptic) change in the relationship between experts and non-experts, ethical dilemma and public engagement with science (see for example Bloom, 2009; Kelty, 2010; Ledford, 2010; Schmidt, 2008). Yet, a different perspective is possible. Garage biology can be interpreted as an example of a direct transposition of free software and hacking practices into the realm of cells, genes, and labs.

Thus, in one sense, garage biology is part of a well-known story: the emergence of online platforms for the open and collaborative production and sharing of information and knowledge (Benkler, 2006). Within this general framework, in the last few years, we have witnessed the emergence of science movements that rely on distributed and collaborative web tools that allow a proactive approach to information production and to the shaping of the techno-scientific environment in which they exist. For example, in order to share data and information and to organize offline groups that are geographically dispersed (Delfanti, 2010). These movements represent today's expression of an old phenomenon that Clifford Conner (2005) called the *People's History of Science*, a long history of the participation of carpenters, mechanics, miners, and outsiders in knowledge production. It is not difficult to

imagine including citizen biology in this narrative, as it is not limited to the expert community but rather crosses and opens the frontiers of expertise and scientific institutions. On the other hand, though, one might ask if citizen biology represents a challenge to Big Bio, the ensemble of big corporations, global universities, and international and government agencies that compose the economic system of current life sciences. Garage biologists play a role in hacking biology since they embody an active approach in the shaping of the institutional environment in which biological research takes place and in the questioning of the proprietary structure of scientific information: who owns and disposes of biological data and knowledge? In this sense, this movement can be seen as an actor in the shaping of the relationship between research, academia, and the market.

In fact, hackers provide a multifaceted example of a culture attuned to the economic dynamics of the software world made of start-ups, people escaping from academia, corporate networks, garages, and computer science departments. Hacker ethic is composed of a formalised set of moral norms. For example, Steven Levy (2010), defines the ethic through the following positions: access to computers should be unlimited and complete; all information should be free; authority should be mistrusted; hackers should be judged by their hacking, not bogus criteria such as degrees, age, race, or position; you can create art and beauty on a computer; and computers can change your life for the better (other works on hacker ethic, and other versions of it: Himanen, 2001; Jesiek, 2003; Moody, 2001; Raymond, 2001). Hackers also highlight the ambivalent role of garage biology in digital capitalism and neoliberalism. The history of hacking, computers, and software, as well as the battles around information technologies and intellectual property are fully integrated in the history of neoliberalism and the development of informational capitalism (on this ambivalence see Castells, 2005; Coleman, 2004; Coleman and Golub, 2008; Johns, 2009; Mattelart, 2003).

The members of DIYbio have straightforward relationships with the hacker movement. For example, their models are hackerspaces—collectively run spaces that are now widespread in Western countries—where people gather to hack, talk about, and work on computers; spaces where subscribers for a low individual monthly rate can find computers, tools, and other people interested in hacking. Sometimes, when they cannot open their own labs, DIYbio groups collaborate directly with existing hackerspaces in order to set up small labs, or ‘wet corners’ within the computer hardware that fills urban hackerspaces. DIYbio members and groups are also immersed in a dense entrepreneurial environment where start-ups and new open science companies try to navigate their way through the dominance of the Big Bio market.

DIYbio.org

An early explicit reference to the possibility of a biohacker way of conducting life sciences research can be found in 2005. Rob Carlson, a physicist who works in the field of genetics, wrote in a *Wired* article: "the era of garage biology is upon us." Carlson was working at a Berkeley lab and was inspired by the history of the computer revolution that had happened thirty years before in San Francisco Bay Area garages (Golob, 2007; Ledford, 2010). Three years later, exactly in the other epicentre of hacking history, DIYbio was born. In fact, the movement started in Boston in 2008 stemming from an idea by Mackenzie Cowell, a young web developer, soon joined by Jason Bobe, the director of community outreach for the Personal Genome Project at Harvard Medical School. At the first public meeting, held in a pub in Cambridge, Massachusetts, twenty-five people turned-up. By 2010, about 2,000 people had subscribed to the mailing lists and DIYbio counted dozens of local groups, with new chapters popping up in places as far from Massachusetts as Madrid, London, and Bangalore. DIYbio is not a formal organisation but rather an open brand anyone can use for citizen science projects, coupled with a global mailing list where most discussions are conducted and decisions taken. In collaboration with or partially overlapping DIYbio, several other citizen biology projects have emerged, forming a complex network of different experiences.

Today, garage biology consists of elementary scientific practices, such as DNA extraction or bacteria isolation with household tools and products. In most cases, media attention overstates and mythologizes the poor scientific practices: right now garage biology is not a site of research and innovation. However, by the end of 2010 DIYbio groups had begun several scientific projects. The Pearl Gel System is an inexpensive open source gel box that can be used to run electrophoresis (www.pearlbiotech.com). One garage biologist has created a centrifuge that works with an inexpensive and diffused power tool gadget. The design for the centrifuge is free and can be downloaded and fabricated with a 3D printer (Ward, 2010). In the BioWeatherMap project, people are asked to collect bacterial samples from crosswalk buttons in their cities in order to analyse the geographic and temporal distribution patterns of microbial life in a highly distributed way (http://bioweathermap.org). SoCal DIYbio is planning to use Amazon cloud computational power and JCVI Cloud Biolinux software (http://cloudbiolinux.com) in order to conduct grassroots bioinformatics and data analysis. In New York, DIY biologists are extracting and genotyping people's DNA at public events.

DIYbio has also established dialogues and relationships with universities, private companies, media, and the United States Government. DIYbio has raised concerns about security and safety among biologists, ethicists, and government agencies (Schmidt, 2008). This is why the movement has an intense relationship with the Federal Bureau of Investigation (FBI) and with the Presidential Commission on Bioethics. After the problems faced by people who performed garage biology in the United States during the

years after 9/11 along with anthrax hysteria, both the government and DIYbio want to prevent possible problems, misunderstandings, or surprises. In fact, the media employs images regarding biohacking of biosecurity and even bioterrorism: are crazy kids playing with dangerous bugs that some terrorist might use to spread unknown diseases and panic? Indeed, "Hacking is good. But you have to admit the word has a bad reputation" as argued in a *Nature Biotechnology* article (Alper, 2009, p. 1077). Furthermore, DIYbio has appeared in dozens of media reports in newspapers and magazines such as *The Guardian*, *BBC*, *The New York Times*, *The Boston Globe*, *The Economist*, *Wired*, and the like. Also, several mainstream scientific journals have covered the DIYbio rise, for example, *Nature* and *EMBO Reports* (Alper, 2009; Ledford, 2010; Nair, 2009; Wolinsky, 2009).

Through their website and several local online spaces, the members of DIYbio organize collaborative research projects and share scientific data and information. The people who compose DIYbio are diverse, and they generally belong to three different groups: young biologists, such as graduate or even undergraduate students; computer scientists and 'geeks' who want to tinker with biology; and bioartists interested in applying the critical approach of DIY to biology. Some members are concerned with the fact that no real garage labs exist and that access to biological tools and lab equipment is hard to get, expensive, and strictly regulated; therefore, a real garage biology movement is far from appearing. Yet, in 2010, DIYbio and other citizen biology projects opened several community spaces such as Sprout in Massachusetts and GenSpace in New York.

Biorebels

DIYbio is often referred to as a biohacker community, and its members freely use that type of definition. In addressing the question "Who is a biohacker?" found in the DIYbio website FAQs (http://openwetware.org/wiki/DIYbio/FAQ), the following is cited: hacking subculture, the hacker ethic of "biologists, programmers, DIY enthusiasts", the Homebrew Computer Club and the Free Software movement, the importance of enjoying "hacks" and finally the "biopunk" attitude. One of the major public events that presented DIYbio to the world was the hacker conference CodeCon, which, in 2009, replaced one third of its normal program with a special focus on biohacking (http://www.codecon.org/2009/program.html). Media narratives about DIYbio use the word *biohackers* ubiquitously, together with similar phrases such as, for example, *life hackers* (Ledford, 2010). They often draw comparisons between garage biology and the Homebrew Computer Club, the headquarters of Bay Area hackers of the 70s such as Steve Wozniak, Bill Gates, Steve Jobs, and so on (Bloom, 2009; *Economist*, 2009; Golob, 2007; Johnson, 2008). Yet, some individuals linked to DIYbio prefer to define themselves as makers, craftsmen, enthusiasts, hobbyist, or amateurs. They often agree, though, that the garage is an important symbol with respect to the love the media express for DIYbio. Garage labs are

places where one can develop his or her curiosity, creativity, and desire to tinker with genes and cells. After all, the hackers that accomplished the computer revolution were nothing but "a bunch of unshaved guys in a garage" (Golob, 2007). Press accounts of DIYbio and the members I interviewed emphasize how garage biology is to be considered part of the tradition of American innovation—think about Apple or Google and the mythology related to the Silicon Valley garages where they began (Levy, 2010; Vise and Malseed, 2006). After all—who knows?—"the future Bill Gates of biotech could be developing a cure for cancer in the garage" (Wohlsen, 2008).

Other similarities between DIY biology and hacking reside in the obstacles biohackers identify in Big Bio. In DIYbio narratives, universities and corporations are flawed because they rely on specialization and hierarchical systems, but also because they build monopolies and steal individual creativity by means of intellectual property rights. Big Bio is neither open nor inclusive. Big Bio labs are indeed perceived as similar to the Hulking Giants, the huge mainframe computers of the 60s that hackers regarded as difficult to access and that were controlled by a "priesthood" of technicians (Levy, 2010). Perhaps, as Jason Bobe said, "there will always be the giant players—the biotech and pharmaceutical companies—in life sciences" (Nair, 2009, p. 230) but the widespread diffusion of information and sequencing technologies will allow amateur biologists to contribute to the scientific enterprise.

Of course, fun and hedonism are also important ingredients of DIYbio culture. As DIYbio founder Mac Cowell explains, DIYbio gives people the justification for doing silly or weird things because, as in many narratives about rebel science and hacking, innovation arises from having fun and playing with biology. Cowell quit his job because "he wasn't having fun anymore" and he sold his car to start DIYbio (Boustead, 2008). Exactly as Wozniak sold his Volkswagen van to start Apple in his garage (Levy, 2010). Of course, hackers do not always like the sunlight. On the ninth floor of building twenty-six at MIT, hackers would work all night in order to avoid the 'priesthood' that wasted precious time using university computers for dumb tasks, but also because of their weird circadian rhythms and lifestyle. And, so it is with biohackers: "you'll be tweaking genome sequences on your computer late at night" (Carlson, 2005). You will not be able to stop the passion of hacking.

References to hacking are dominant, but the use of the term 'do-it-yourself' positions DIYbio within an old American movement of makers and inventors who work in their garages, giving it a rebel flavour. The expression DIY was broadly adopted in the 80s by the punk-hardcore movement both in the USA and Europe. Now, this movement is witnessing a renewal and is part of a broader social phenomenon centred around the convergence between online peer production; the diffusion of inexpensive open source tools and machinery (such as 3D printers); and a widespread 'maker' culture (Niessen, 2011). DIYbio is part of this movement, the main communication tools of which are

magazines such as *Make* (http://makezine.com) or websites such as Instructables (www.instructables.com). There is also a link between biohacking and craftsmanship. Christopher Kelty, one of the few scholars who has started addressing garage biology from the point of view of its sociological and anthropological dimensions, argues that three figures can be used to understand citizen biology: namely, outlaws, hackers, and Victorian scientists (Kelty, 2010). DIYbio, in some media accounts, is "a throwback to the times when key discoveries were made by solitary scientists toiling away in their basement labs" (Nair, 2009, p. 230). In addition, one of the founders of DIYbio, Jason Bobe, draws this comparison: "in some sense, we're returning to some of the roots of biology, where scientists had laboratories in their parlors. You know, it was parlor science. It was something that didn't actually happen often in institutional settings; it was something that happened at home" (National Public Radio, 2009). For Drew Endy, a Stanford bioengineering professor who is one of the strongest backers of the garage biology movement, "Darwin may have been the original do-it-yourself biologist, as he didn't originally work for any institution" (cited in Guthrie, 2009).

Activism and Citizenship

For its members, DIYbio is not only about biohacking but many other things as well. It is public engagement with science, open source software, decentralisation, participation, and innovation. When asked to interact with the FBI or with the United States Presidential Commission for the Study of Bioethical Issues, DIYbio proved capable of finding ways to position itself in order to avoid backlash and problems. For example, they decided to highlight that citizen biology has an educational side, and that it could provide inexpensive hardware or kits to be used in schools or community labs, besides giving people a vibrant online community wherein to discuss science. DIYbio might become a cultural interface for biology, a place for people to explore biotech. In their letter to the Presidential Commission, members argued that "DIYbio.org was created to help build a positive public culture around new biotechnologies and practices as the number of contributors to the life sciences extends beyond traditional academic and corporate institutions" (DIYbio 2010).

There is the classic problem of the relationship between science and society at stake: participation. It is easy to state that P2P practices are changing and increasing the ways of participating in the production of scientific knowledge. But does this increase consist of a real shift towards democratizing science? Does it actually affect the asymmetrical relationships between citizens and experts? Scholars who have tackled this relationship have generally been very prudent in picturing participation in science. Often, ambivalence is highlighted. Callon and Rabeharisoa (2003) point out that "research in the wild", or the intervention of patients in biomedical research, involves their active participation in

establishing new collectives that include new subjects. Also, the renegotiation of the relationship between research in the wild and research conducted in professional settings involves issues of power, epistemology, and the presence of incentives of a new and different nature. The changing panorama of expertise urges lay people to get actively involved in techno-scientific decisions in order to change the world and not just observe it (Collins and Evans, 2007). While referring to 'geeks' and the diffusion of free software practices outside the computer world, Kelty (2008, 2010) argues that the public can avoid passivity and instead be "aggressively active." Do-it-yourself science certainly challenges mainstream science, asking for more access and involvement. But amateurs are also redefining what 'the public' means in the current configuration of science-society interaction: an active role substitutes the simple encounter between science and its public and creates new spaces of interaction and participation (see Nowotny, 1993). DIYbio is a site where different approaches coexist. For example, DIYbio amateurs who work outside of traditional professional settings can have "access to a community of experts" (http://openwetware.org/wiki/DIYbio/FAQ).

This is not too different from the perspective of the Critical Art Ensemble (CAE), an artist-activist group whose works and writings are considered by many garage biologists as a foundational myth (www.critical-art.net). In 2004, one of the CAE members, Steve Kurtz, was arrested under the suspicion of bioterrorism when, after his wife died of a heart attack, the FBI found cell cultures and lab equipment in his apartment (Simmons, 2007). CAE used amateur biology as a tactical practice in an artistic context in order to create what they called "a counter symbolic order" against the power of Big Bio. The public space their practices aimed to create was intended to be "one where the authority of the scientific personality is not so powerful. The hierarchy of expert over amateur has to be suspended in this context. If experts have no respect for the position of amateurs, why would they come to a place where dialogue is possible?" (CAE, 2002, p. 66).

Yet, the vision of citizen biology as a site for participation has a completely different side. While for CAE, the goal was to enable people to challenge the capitalist face of Big Bio by providing conceptual and political tools, in some biohackers' view, participation could help overcome some of the problems faced by Big Bio itself. There is an ambivalence, though, with respect to the political and economic role of this sharing: is it going to be part of an expropriated gift economy (Barbrook, 1998; Levina, 2010) or rather a resistance against the intellectual property rights enclosures that sustain Big Bio monopoly power? The biocitizenship imagined by DIYbio includes very different features, and the answer to the question is not clear among garage biologists.

Free as in Free Genes

When it comes to openness and sharing, DIYbio members would certainly agree with the free software foundational definition: "free as in free speech, not as in free beer." Access to knowledge is another important framework under which DIYbio operates, as it enables citizen participation in science. Indeed, openness is one of the core legal implications and needs of user-led science. In "Open Science: Policy Implications for the Evolving Phenomenon of User-led Scientific Innovation," Victoria Stodden (2010) analyses citizen science in relation to the access and sharing of knowledge. Public involvement as well as collaborative models between scientists and non-scientists require policy solutions that support not only data and knowledge sharing, but also the sharing of benefits deriving from it. Drawing from computational science examples, Stodden points out that the incentive model of citizen science is closer to that of open source software than to that of Big Bio. But for DIYbio, openness refers both to the open access to data and knowledge according to an explicit open source model, and to open participation directed to *all*, regardless of professional recognition from Big Bio. The DIYbio online FAQ page states that the organisation offers the "groundwork for making this field open to anyone with the drive to become great at it" (http://openwetware.org/wiki/DIYbio/FAQ). In which case, then, the free software model would apply to genes and cells?

In typical hacker fashion, garage biologists have different modes for finding the tools and machinery needed for their labs. These tools are usually expensive or difficult to buy since companies do not often sell equipment, reagents, and so forth to individuals for safety and regulatory reasons (Alper, 2009), but also because they do not perceive the possibility of a non-institutional market. This constitutes a threshold that is hard to overcome. The story of two PCR machines can explain how DIYbio answers this problem. In San Francisco, two young electrical engineers, Tito Jankowski and Josh Perfetto, are developing OpenPCR, a project to build an inexpensive Polymerase Chain Reaction machine under open source principles: anybody would be able to download the instructions to build it and the software to run it, and thus have an easy-to-use $400 machine at their disposal. As with other DIYbio projects, the money needed to develop OpenPCR was raised with a crowd-funding scheme through the website Kickstarter (http://openpcr.org). In Los Angeles, SoCal DIYbio found two used—and broken—PCR machines that the group fixed using members' electro-technical skills and adapting free software to control them. Other DIYbio techniques for putting together inexpensive equipment include stealing, buying used stuff such as benches or glassware from university labs, or using the university address of their graduate student members in order to get material shipped from companies. They also use skills acquired working in 'ghetto labs' in universities that were not well funded. Again, garage biologists have an ambivalent relationship with big institutions. On the one hand, they rely heavily on universities for material, education, used machinery, and other needs. Yet, they also lack

recognition with respect to their scientific projects. In 2009, for example, DIYbio was excluded from the annual iGem competition, where dozens of teams of undergraduate students from all over the world compete to design and build the best biological systems and operate them in living cells (http://ung.igem.org/Main_Page; see also Alper, 2009).

Intellectual property rights are not perceived as evil necessarily. Garage biology surely adopts an open attitude, using open access tools, Creative Commons licenses, and so forth when it comes to sharing data and protocols of knowledge. For some members there is a political commitment to open science: to prevent people from practising science is against freedom of thought. But for others, openness is a means towards a different end: entrepreneurship. Openness is a way of defying incumbents and restoring the freedom of the market against the obstacles represented by the broad patents owned by Big Bio: a typical anticommons effect (Heller and Eisenberg, 1998). Thus, often when DIY biologists talk about innovation happening outside traditional settings such as the academy and corporations, they also want to highlight that openness is not only good per se but also part of the strategy against Big Bio monopoly power. Indeed, biohacking is laden with anti-institution and anti-bureaucracy claims. Giving people inexpensive and widespread tools for biology, DIYbioers want to avoid academic paternalism and demystify 'official' science. For example, even though many members are getting their doctorates, the importance of the normative, institutional course of scientific education is not taken for granted. One important barrier of entry for people who want to practice biology is formal education, but garage biologists are often convinced that participation in DIY projects is more important than a formal, 'normal' university career—something they want to demystify (Wolinsky, 2009). According to Jason Bobe (2008), a DIYbio founder, we are going to see a scientific renaissance that will be funded and enacted outside the incumbents of Big Bio and their slow and bureaucratic processes. The peculiar feature of this renaissance is that "it's going to take place outside of 'science proper', away from universities which dominate now, and funded out-of-pocket by enthusiasts without PhDs." Moreover, formal education is an aspect of Big Bio that garage biologists cannot stand because it is the expression of the power of an old boy network: "Nowadays, biology is like a medieval guild. Firstly, you have to get a PhD, but if you want to practice then you need venture capital, otherwise you don't have the tools" (Bloom 2009).

In fact, garages are spaces where people can work outside of institutions in order to avoid patenting their findings and inventions through the university. For some DIY biologists, this is a problem related to individual rights rather than a more general problem of knowledge privatisation and academic capitalism. They want to keep their intellectual property rights and not remise them to the big institutions they work for in their daily jobs.

You do not Need a PhD to do Biology

Thus, DIYbio embodies different faces of hacking such as openness regarding data and knowledge sharing as well as openness regarding the doors to scientific institutions, but also rebellion, hedonism, passion, communitarian spirit, individualism, entrepreneurial drive, and distrust of bureaucracies. DIYbio is an interesting case because it includes all the cultural and political ambivalence of hacker ethic and FLOSS practices (Barbrook and Cameron, 1996; Coleman, 2004; Coleman and Golub, 2008). Up to now, the results of garage biology have been modest. So, from the scientific viewpoint it is hard to state that they are actually hacking DNA and cells, and we do not know if they will be able to hack them in the near future. Yet, DIYbio is making biology hackable in several ways. First, the kind of acknowledgment and incentives they recognize are not always related to the ones of institutional science: a good hack does not need to be peer-reviewed, though it surely has to be shared with other biohackers. You do not need a PhD to do biology. Second, garage biologists use informational metaphors and aim at standardizing genetics in order to make it inexpensive and more easily accessible. Third, they are opening community spaces for people to conduct biology outside the boundaries and limits of Big Bio. Finally, they are trying to open up the boundaries of life sciences entrepreneurship by experimenting with new business models based on open source approaches.

Through making biology hackable in these different ways, garage biology is producing a picture of a different way of conducting research in the life sciences: more open and horizontal, within a mixed constellation of different actors such as start-ups, universities, individuals, community spaces, and with a prominence of small and open companies instead of Big Bio slow giants. With its radical requests for openness and inclusion and with its rejection for institutional prerogatives and constraints, garage biology surely challenges many assumptions about public participation in scientific knowledge production. Citizen scientists and users contributing to science claim to be part of the scientific process on almost any level. They point to a problem in the current distribution of power over knowledge (Kelty, 2008). Distributed social production has already proven to be enormously productive in many fields of knowledge and DIYbio claims a positive change accompanied by a redistribution of power. Big Bio will have to take into account amateurs' needs and interests, as companies and scientific institutions are asking citizens to contribute by crowd-sourcing knowledge, sharing and analysing data, or performing scientific research (Delfanti, 2010; Hope, 2008; Levina, 2010).

The Ambivalence of Biohacking

Garage scientists depend on big science but try to live beyond its frontiers, in a no man's land: they are somehow *outlaws* (Kelty, 2010). This has important implications for the relationship between different types of expertise, as I argued above. But here I also want

to draw a comparison between garage biology and other forms of production situated outside the boundaries of institutions. In *Convergence Culture*, Henry Jenkins (2008) depicts the clashes that involve fans and mainstream media industries. Fan creation 'in the wild', as I would say to connect Jenkins with studies on the participation of lay people in biomedical research, can be a rich resource that companies can harness to capitalize new content and get in touch with their public (Arvidsson, 2008; Terranova, 2000). On the other hand, companies are always challenged by content creation that happens outside their boundaries because they need to control it in order to avoid injury, and this can be an expensive and puzzling task. The pessimistic side of this balance is represented by the exploitation of creativity and appropriation of free labour by greedy corporations (Barbrook, 1998). This description somehow echoes Marxist ideas of the relationship between capital and labour. Italian autonomist Marxists have, since the late 50s, argued that workers' struggles are one of the main engines of technological innovation and of capitalistic transformation and evolution. Yet capital is never able to fully control workers' social practices, nor to reconcile its inside with its outside. This very edge is where capital struggles to survive, and feeds on new ideas and solutions, and therefore evolves. Struggles against exploitation are both the driving force and the opposition of capital (Panzieri, 1976; Tronti, 2006).

Of course, garage biologists are neither workers struggling against capital, nor fans shooting a short movie of the Star Wars saga without the authorisation of George Lucas, but they have an ambivalent role with respect to Big Bio. One interesting question is whether in the future their hacks will favour, change, or disrupt today's life sciences incumbents. They challenge, in new and deeper ways, the separation between the roles of experts and non-experts. They refuse the absolute authority of universities on scientific recognition and of both academia and industry on intellectual property rights. But they also represent an attempt to participate in new ways in an innovation regime that includes universities, corporations, start-ups, patients' associations, and so forth. DIYbio often refers to the possibility of developing a new market for biology tinkering tools or to the possibility for small companies to rely on open science practices not patents.

Less than ten years ago, CAE was highly sceptical about the possibility of a corporate side of amateur biology when it argued that "even entrepreneurs do not seem to have any interest in finding a way to capitalize on this divide" between experts and amateurs (Critical Art Ensemble, 2002, p. 123). Yet, an important act of DIYbio is this precise investment in the role of entrepreneurship and corporations as a way of sustaining a possible biohackers movement. In this sense, again, DIYbio's relationship with Big Bio is ambivalent. The anti-bureaucracy side of garage biology is trying to challenge Big Bio incumbents. Garage biologists would like to dismantle monopolies based on intellectual property rights, capital-intensive laboratories, and scientific expertise. However, most of them are not interested in a critique of academic capitalism or biocapitalism, but rather in

the possibility of opening up new markets where smart, small-scale, open source models could compete with Big Bio and its Hulking Giants. Others hope Big Bio will finance their activities, recognizing biohackerspaces and biohacker communities as innovation incubators where new ideas, start-ups, and entrepreneurs might be born in the near future. Both models are similar to free open source software economic models. Garage biology represents a shift towards a more open approach to life sciences. It challenges the incumbents of the current life sciences system, what I have called Big Bio, to highlight the role of big corporations, global universities, and international regulatory agencies. Yet, it also shows how this open science is strictly related to entrepreneurship, academic capitalism, and neoliberalism.

References

Alper, Joe. (2009) "Biotech in the Basement." *Nature Biotechnology,* 27 (12), pp. 1077–1078.

Arvidsson, Adam. (2008) "The Ethical Economy of Customer Coproduction." *Journal of Macromarketing* 28 (4), pp. 326–338

Barbrook, Richard. (1998) "The Hi-tech Gift Economy." *First Monday,* 3 (12). http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/631/552 [Accessed 10-03-2011].

Benkler, Yochai. (2006) *The Wealth of Networks.* New Haven: Yale University Press.

Bloom, James. (2009) "The Geneticist in the Garage." *The Guardian*, March 19.

Bobe, Jason. (2008) "Science without Scientists." DIYbio.org. http://diybio.org/blog/science-without-scientists [Accessed 10-03-2011].

Boustead, Greg. (2008) "The Biohacking Hobbyist." *Seed Magazine.* http://seedmagazine.com/content/article/the_biohacking_hobbyist/ [Accessed 10-03-2011].

Callon, Michel and Rabeharisoa, Vololona. (2003) "Research 'in the wild' and the Shaping of New Social Identities." *Technology in Society* 25, pp. 193–204.

Carlson, Robert. (2005) "Splice it Yourself." *Wired* 13.05.

Castells, Manuel. (2005) "Open source as social organization of production and as a form of technological innovation based on a new conception of property rights." Presentation at the World Social Forum 2005. http://www.choike.org/nuevo_eng/informes/2623.html [Accessed 10-03-2011].

Coleman, Gabriella. (2004) "The Political Agnosticism of Free and Open Source Software and the Inadvertent Politics of Contrast." *Anthropological Quarterly* 77 (3), pp. 507–519.

Coleman, Gabriella and Golub, Alex. (2008) "Hacker Practice: Moral Genres and the Cultural Articulation of Liberalism." *Anthropological Theory* 8 (3), pp. 255–277.

Collins, Harry and Evans, Robert. (2007) *Rethinking Expertise*. Chicago: Chicago University Press.

Conner, Clifford. (2005) *A People's History of Science: Miners, Midwives, and Low Mechanics*. New York: Nation Books.

Critical Art Ensemble. (2002) *The Molecular Invasion*. New York: Autonomedia

Delfanti, Alessandro. (2010) "Users and Peers. From Citizen Science to P2P Science." *JCOM* 09 (01). http://jcom.sissa.it/archive/09/01 [Accessed 10-03-2011].

DIYbio. (2010) Draft letter to the PCSBI commission. Personal email from Jason Bobe.

Economist. (2009) "Hacking Goes Squishy." *The Economist,* September 5, pp. 30–31.

Golob, Jonathan. (2007) "Homebrew Molecular Biology Club." *The Stranger.* http://slog.thestranger.com/2007/11/homebrew_molecular_biology_club [Accessed 10-03-2011].

Guthrie, Julian. (2009) "Do-it-yourself Biology on Rise." *San Francisco Chronicle*, December 20.

Heller, Michael and Eisenberg, Rebecca. (1998) "Can Patents Deter Innovation? The Anticommons in Biomedical Research." *Science* 280 (5364), pp. 698–701.

Himanen, Pekka and Torvalds, Linus. (2001) *The Hacker Ethic, and the Spirit of the Information Age*. New York: Random House.

Hope, Janet. (2008) *Biobazaar. The Open Source Revolution and Biotechnology.* Cambridge: Cambridge University Press.

Jenkins, Henry. (2008) *Convergence Culture: Where Old and New Media Collide*. New York: New York University Press.

Jesiek, Brent. (2003) "Democratizing Software: Open Source, the Hacker Ethic, and Beyond." *First Monday* 8 (10). http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/rt/printerFriendly/1082/1002 [Accessed 10-03-2011].

Johns, Adrian. (2009) "Piracy as a Business Force." *Culture Machine* 10, pp. 44–63.

Johnson Carolyn. (2008) "Accessible Science. Hackers Aim to Make Biology Household Practice." *The Boston Globe*, September 15.

Kelty, Cristopher. (2008) *Two Bits. The Cultural Significance of Free Software.* Durham: Duke University Press.

Kelty, Cristopher. (2010) "Outlaw, Hackers, Victorian Amateurs: Diagnosing Public Participation in the Life Sciences Today." *Jcom* 09 (01). http://jcom.sissa.it/archive/09/01/Jcom0901(2010)C01/Jcom0901(2010)C03/ [Accessed 10-03-2011].

Ledford, Heidi. (2010) "Life Hackers." *Nature* 467, pp. 650–652.

Levina, Marina. (2010) "Googling your Genes: Personal Genomics and the Discourse of Citizen Bioscience in the Network Age." *Jcom* 09 (01). http://jcom.sissa.it/archive/09/01/Jcom0901(2010)A06/ [Accessed 10-03-2011].

Levy, Steven. (2010) *Hackers: Heroes of the Computer Revolution.* Cambridge: O'Reilly.

Mattelart, Armand. (2003) *The Information Society: An Introduction*. London: SAGE Publications.

Moody, Glyn. (2001) *Rebel Code. The Inside Story of Linux and the Open Source Revolution*. Cambridge: Perseus.

Nair, Prashant. (2009) "Straight talk with...Mac Cowell and Jason Bobe." *Nature Medicine* 15 (3), pp. 230–231.

Niessen, Bertram. (2011) *Independent Design and Manufacture*. Preprint.

Nowotny, Helga. (1993) "Socially Distributed Knowledge: Five Spaces for Science to Meet the Public." *Public Understanding of Science* 2, pp. 307–319.

NPR. (2009) "Taking Biological Research out of the Laboratory." December 27. http://www.npr.org/templates/story/story.php?storyId=121954328 [Accessed 10-03-2011].

Panzieri, Raniero. (1976) *Lotte operaie nello sviluppo capitalistico*. Torino: Einaudi.

Raymond, Eric. (2001) *The Cathedral and the Bazaar*. Cambridge: O'Reilly.

Schmidt, Markus. (2008) "Diffusion of Synthetic Biology: a Challenge to Biosafety." *Systems and Synthetic Biology* 2, pp. 1–6.

Simmons, Michael. (2007) "Terrorizing the Artists in the USA." *The Huffington Post*, June 14. http://www.huffingtonpost.com/michael-simmons/terrorizing-the-artists-i_b_52261.html [Accessed 10-03-2011].

Stodden Victoria. (2010) "Open Science: Policy Implications for the Evolving Phenomenon of User-led Scientific Innovation." *JCOM* 09 (01). http://jcom.sissa.it/archive/09/01/Jcom0901(2010)A05 [Accessed 10-03-2011].

Terranova, Tiziana. (2004) *Network Culture: Politics for the Information Age.* London: Pluto Press.

Tronti, Mario. (2006) *Operai e capitale*. Roma: Deriveapprodi.

Vise, David and Malseed, Mark. (2006) *Google Story*. New York: Delta.

Ward, Mark. (2010) "Tech Now: Life Hacking with 3D Printing and DIY DNA Kits." *BBC News*. http://news.bbc.co.uk/2/hi/technology/8595734.stm [Accessed 10-03-2011].

Wohlsen, Markus. (2008) "Do It Yourself DNA: Amateurs Trying Genetic Engineering at Home." *The Huffington Post.* http://www.huffingtonpost.com/2008/12/25/do-it-yourself-dna-amateu_n_153489.html [Accessed 10-03-2011].

Wolinsky, Howard (2009) "Kitchen Biology." *EMBO Reports* 10 (07), pp. 683–685.