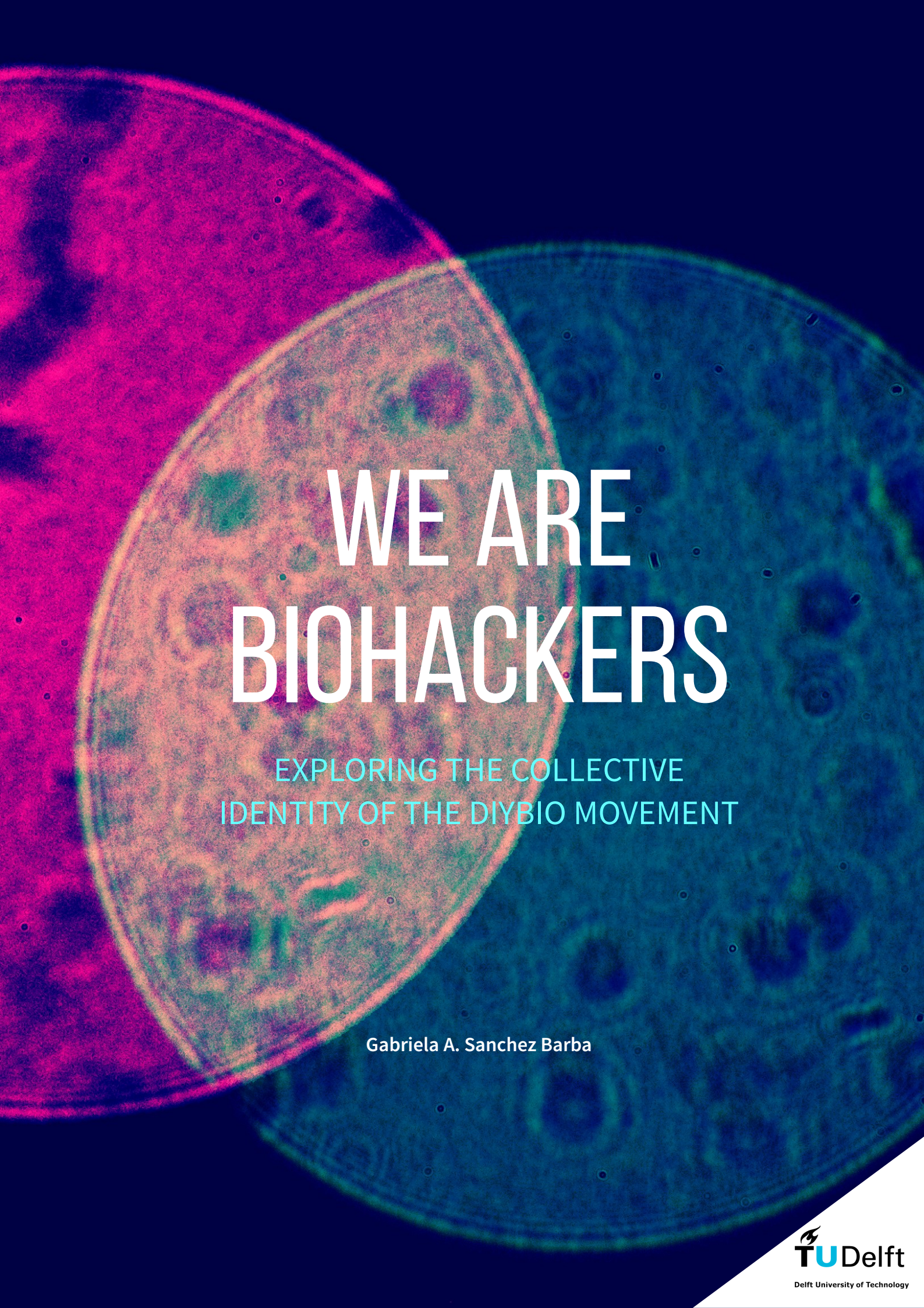

WE ARE BIOHACKERS

EXPLORING THE COLLECTIVE IDENTITY OF THE DIYBIO MOVEMENT

Gabriela A. Sanchez Barba

TU Delft
Delft University of Technology

COVER PHOTO: Count the ways. Original size courtesy by Mathias Pastwa.

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“Information wants to be free”

– Stewart Brand

“Information wants nothing. People want to be free”

– Cory Doctorow

Delft University of Technology
Faculty of Applied Sciences
Department of Biotechnology

WE ARE BIOHACKERS: EXPLORING THE COLLECTIVE IDENTITY OF THE DIYBIO MOVEMENT

by

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THESIS

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LIST OF ABBREVIATIONS

AI	After-Internet
BI	Before-Internet
CBPP	Commons-Based Peer-Production
CC	Creative Commons
CCC	Chaos Computer Club
CERN	European Council for Nuclear Research
DARPA	Department of Advanced Research Projects Agency
DE	Germany
DIO	Do-it-Ourselves
DIT	Do-it-Together
DIWO	Do-it-with-Others
DIY	Do-it-Yourself
DIYbio	Do-it-Yourself Biology
EULA	End-User License Agreement
FabLab	Fabrication Laboratory
FBI	Federal Bureau of Investigations
FLOSS	Free/Libre Open-Source Software
FOSS	Free Open-Source Software
FR	France
FSF	Free Software Foundation
GMO	Genetically Modified Organisms
GNU	GNU is Not Unix
GPL	General Public License
HGP	Human Genome Project
HP	Hewlett Packard
IAP	Independent Activities Period
IBM	International Business Machines
ICT	Information and Communication Technologies
iGEM	International Genetically Engineered Machine
IMP	Imposed Monopoly Privileges
IPR	Intellectual Property Rights
IT	Italy
KE	Kenya
MIT	Massachusetts Institute of Technology
MOOC	Massive Open Online Course
NIH	National Institute of Health
NGS	Next Generation Sequencing
NYC	New York City
OHL	Open Hardware License
OSH	Open-Source Hardware
OSI	Open-Source Initiative
OSS	Open-Source Software
P2P	Peer-to-Peer
PCR	Polymerase Chain Reaction
PGP	Personal Genome Project
Pro-Ams	Professional Amateurization
QS	Quantified Self
S&P	Systems and Power
STI	Science Technology and Innovation
Synbio	Synthetic Biology
TAPR	Tucson Amateur Packet Radio
TRMC	Train Railroad Model Club
UK	United Kingdom
US	United States

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ABSTRACT

Social movements are important sociological phenomena because they are the key agents that provide societies with new ideas and ideals to change people's behavior or their understanding of the world. This thesis aims to investigate into how the *collective identity* of the *biohacker* in the *Do-it-Yourself Biology* (DIYbio) movement mobilizes collective action to achieve social change. The collective identity of a movement is the "we" that influences how biohackers give meaning to the collectivity and make sense of their actions and the goals they pursue based on shared beliefs, values, critiques and visions of the world. The biohacker can be understood as the bio subgenre of the *hacker*, whose ethic and practices of free and open-source software and hackerspaces—or in other words practices of *Commons-Based Peer-Production*—are adapted to the life sciences and technologies. To research how the collective identity is constructed I analyzed the practices and discourses of the DIYbio movement. I performed participant observation in movement areas where they carry out collective action; an online discussion forum and in a biohackerspace. I also performed documentary analysis of popular media articles and discourse analysis of in-depth interviews with biohackers from around the world. To understand the dynamics of how biohackers mobilize collective action I proposed a framework in which biohackers define problems and solutions based on their communal values of openness, freedom, and collaboration. The DIYbio movement coordinates collective action for social change on a political level as it aims to democratize biology and create a commons of the means of production, and on a cultural level by promoting a work ethic of freedom of inquiry and sharing under a collaborative commons.

KEYWORDS: Social Movement • Collective Identity • Do-it-Yourself Biology (DIYbio) • Biohackers • Hackers • Commons-Based Peer-Production

PREFACE

This work was developed as my thesis project as part of the requirements to obtain the degree of Master of Science (M.Sc.) in Life Science and Technology at the Delft University of Technology (TU Delft). Although I am technically educated as a natural scientist and engineer, I have always been interested in the philosophy, history, and sociology of science. Fortunately for me the Department of Biotechnology holds the Biotechnology and Society (BTS) research group where they research topics related to the Ethical, Legal, and Societal Issues (ELSI) in Biotechnology with special interest in their impact in innovation, social responsibility, and science communication. The group welcomed me to do my thesis project with them and guided me through the work of this research.

The topic evolved (a lot) through a series of thoughts and research into the concept of 'fair-trade' in relation to knowledge and technology transfer in the field of biotechnology. This led me to investigate the different models of the production and dissemination of scientific knowledge and information. The models can be understood in simpler terms as falling into a spectrum of closed/proprietary and competitive science *vs* open/free and collaborative science. In the field of biotechnology, biohackers and DIYbio are an instance of the diverse initiatives that support, advocate, and most importantly practice the latter model which is rapidly unfolding and gaining strength with the technical resources and culture of the Internet.

In a time of worldwide crises of impending environmental catastrophes including global climate change, and an inefficient and unresponsive system to develop urgent solutions, has made me turn my attention for alternatives that promise and could potentially resolve these issues at a faster, cheaper, and more distributed way. This thesis is my small contribution to understanding some of the efforts by many individuals and groups that are working together to produce a more open and collaborative model of science that may lead to a more equitable and sustainable planet.

I hope you enjoy and learn from it as much as I did.

Gabriela A. Sanchez Barba

August, 2014

Delft, Netherlands

CHAPTER 1
INTRODUCTION

“Revolution doesn’t happen when society adopts new technologies—
it happens when society adopts new behaviors”
— Clay Shirky

This thesis investigates into the emerging Do-it-Yourself biology (DIYbio) movement which is formed by a growing international community of professionals, amateurs, and enthusiasts with a shared interest in studying, designing, and engineering biological systems under different settings from traditional scientific institutions. The life sciences and technologies will play a major role in developing solutions in the fields of health care, agriculture, industrial processes, and environmental managing, and the premise of the DIYbio movement is that opening access and participation in biotechnology can have the potential to "spur global innovation and promote scientific literacy" (Frushkin, Kuiken, & Millet, 2013). Although DIYbio is very often defined as a movement[1], so far it seems this concept has not been properly analyzed from social movement theory. Social movements are important sociological phenomena "because they are key agents for bringing about change within societies" (Crossley, 2002). Movements are a 'source of creativity' for societies that provide new ideas, identities, and even ideals to try to change individual and group behaviors, policies or the cultural understanding of a society (*ibid*). Paradoxically, social movements are in themselves manifestations of social change and the DIYbio movement can be seen as contemporary to similar counter-movements that are already transforming society towards participatory and collaborative practices like the open science and citizen science movements (Bauwens, 2010). Studying DIYbio as a social movement can generate insight into the dynamics of the movement in terms of how it brings about social change.

The first thing to consider in analyzing DIYbio as a social movement is to understand what is classified as a social movement. Scholar definitions on what counts as a social movement vary. Mario Diani (1992) proposed a definition based on a comparative discussion of definitions and defined that social movements are a distinct social process consisting of mechanisms through which actors engage in collective action. He identifies three mechanisms: *(i)* informal networks where resources are exchanged in pursuit of common goals; *(ii)* political or cultural conflicts in which actors engage to initiate or halt social change; and *(iii)* a shared collective identity upon which collective action is coordinated. The first point sustains that collective action is carried out in informal networks that represent movement areas that act as cultural laboratories where individuals are free to invest in "the experimentation and practice of new cultural models, forms of relationships and alternative perceptions and meanings of the world" (Melucci, 1989, p. 60). The second point asserts a conflictual factor in social movements. The conflict arises from a tangible discontent of 'old' models—political, cultural, economic—to what actors consider a public issue and therefore aim to articulate new models through collective action to enact

1 A Google Search on "DIYbio" and "movement" results in a variety of sources that define DIYbio as such. Some examples include articles from: Wikipedia (for starters), Nature, The Scientist, h+ Magazine, The New York Times, Popular Science, Discover Magazine, Slate Magazine, The Guardian, Vice, the BBC, Singularity Hub, Forbes, WIRED, P2P foundation, and so forth.

social change (Touraine, 1985). The third point maintains that individuals recognize themselves and others as a collectivity and construct a collective identity—the formulation of a "we"—that encompass the shared belief structures that is used to dictate collective action (Melucci, 1993). The purpose of this research is to provide the foundation to understanding DIYbio as a social movement by generating insight into these mechanisms; through which the movement mobilizes collective action to achieve social change.

To investigate these mechanisms I decided to take the concept of collective identity as my main analytical tool because it provides the framework for my methodology and my background. The first reason to focus on the collective identity is because it influences and many times defines the other mechanisms characteristic of social movements. The construction of the collective identity can arise from individuals that orient themselves and identify others as part of the movement because they share similar grievances and agree on the course of action (goals) to create social change. The collective identity is also often reproduced and reinforced in movement areas—the informal networks—that create solidarity among members. Therefore my research questions are:

(0) How is the collective identity of the DIYbio movement defined?

(1) How do members perceive conflicts and enact goals in accordance with its collective identity?

(2) How is the collective identity reproduced through its informal networks?

My next reason to focus on the collective identity of the DIYbio movement has to do with the book *Biohackers* (2013) by Alessandro Delfanti—one of the few scholars who has addressed the DIYbio movement. In his book he presents the politics of open science as a remix between traditional academic norms and the hacker[2] ethic and he presents DIYbio as one of its manifestations. For Delfanti, "DIYbio [is] a very interesting example of a direct translation of free software and hacking practices into the realm of cells, genes, and labs" (2013, p. 112) in the context of a deeper transformation of the way science is done based on more open and collaborative web-based tools that enable a 'proactive' approach to the production of information. Therefore my starting point is to conceptualize the biohacker as the collective identity for the DIYbio movement.

To gain insight into the translation that Delfanti refers to I focused on understanding the three connections he mentions give rise to the DIYbio movement: the hacker, the Internet, and open science. To understand the degree to which biohacking is an extension of the hacker ethos it is imperative to unfold the hacker identity as to ascertain the meanings that the biohackers copy from it. Therefore in

2 It is important to note that the word *hacker* carries the popular stigma of cybercriminals and 'security breakers' but these are known as *crackers* by the hacker subculture "hackers build things, crackers break them" (Raymond, 2001). Hackers value freedom and mutual help.

section 2.1 I review the history and the most popular narratives that form part of the hacker culture, which includes the development of the personal computer and free and open-source software. I then examine the hacker ethic that was instilled in the development of both and how it has moved from cyberspace into urban space in the form of hackerspaces. Free software laid the foundations into a new mode of production, governance, and distribution that has extended beyond software into other realms of social production. In section 2.2 I analyze these economic and cultural transformations in the context of the Internet and its participatory architecture as to give insight into the emergence of a more open and collaborative culture and production model described as Commons-Based Peer-Production. Next in section 2.3, I explain the changing landscape in science from a closed and hierarchical model towards an open and distributed model. Finally in section 2.4 I present the roots and catalysts of the DIYbio movement and I present the biohacker community, who they are, what they do, and what they believe in to begin to understand the biohacker collective identity.

For my methodology, researching the collective identity of the DIYbio movement enables to study the formulation of the "we" through the shared cultural materials of the movement which are empirically less challenging to explore than other forms of culture. Public symbols carry a set of meanings that can be clearly identified as people use them and are defined around them. The concept of collective identity therefore can be used to direct attention to the observable practices and the discourses through which members of the movement give meanings to their actions. That is, the "we" is used as a symbol through which members give meaning to the movement and their participation in it. To explore how the movement is defined I used a combination of qualitative methods such as participant observation (online and offline) in movement areas which included a mailing list that works as a discussion forum and a biohackerspace where they work on their DIYbio projects, documentary analysis of popular media articles to obtain 'outsider' discourse, and in-depth interviews with members of the DIYbio movement to obtain an 'insiders' perspective. Since language is the medium for the social construction of reality, analyzing discourse can provide meaningful insight into how biohackers—as the collective identity of the DIYbio movement—make sense of the world and how the movement fits into it, this can provide rich data into why (grievances) and how (goals) they mobilize collective action towards social change (purpose).

CHAPTER 2

BACKGROUND

“Technology is not neutral. We're inside of what we make, and it's inside of us. We're living in a world of connections—and it matters which ones get made and unmade”

— Donna Haraway

To fully understand the *biohacker* as the collective identity of the DIYbio movement it is necessary to comprehend the central character of the *hacker* as to give insights into the meanings that the DIYbio movement adopts and adapts from it (see Delfanti, 2013). A short archeology of the hacker culture (§2.1) provides the foundation to understand the attitudes that have built much of our current techno-culture as hackers are considered the heroes of the computer revolution and the architects of the Internet (Levy, 2010). If we consider that technologies are infused with the values of its creators then we must acknowledge that the hacker ethos is embedded in the Internet and propagates within it and has thereby extended into broader realms of social production beyond software and hardware. It is therefore also necessary to appreciate the significance of the hacker ethos and how it is transforming our models of production towards more open and collaborative models (§2.2) and to understand how it is particularly transforming the realm of science (§2.3). This will provide the basis to understand the context that the DIYbio movement emerges from and how the biohacker fits into it (§2.4).

2.1 A HACKER ORIGIN

The history and culture of the hacker is best told by Steven Levy (1984) in his book *Hackers* and the story starts in the late 1950s in MIT with a group of students in the Train Railroad Model Club (TRMC) of the Signals and Power (S&P) Subcommittee who used the word *hack* to denote a project that not only was constructive but was pleasurable as well. The S&P engineers would program telephone dial switches to control the model trains, and creating a clever connection between relays could be considered a hack but to qualify as a true hack “the feat must be imbued with innovation, style, and technical virtuosity” (Levy, 1984, p. 10). The group became increasingly interested in the emerging field of computing but by then these mainframe machines were reserved for authorized technicians who they called the ‘priesthood’ who ‘zealously guarded the machines’. In 1959, the TX-0 computer arrived and was managed under fewer restrictions and allowed the TRMC hackers to use it; they would stalk the computer room waiting for empty slots and would stay late nights when the computer was ‘off-hours’ just to use it. The hackers were not interested in performing complex arithmetical computations, simulations or statistical analysis as did the ‘Officially Sanctioned Users’, instead they just wanted to explore the limits of the machine. They would spend their time punching out computer code to create programming tools, music programs, and simple games. The programs developed by the hackers were freely shared among each other as a way to admire each other's work, build on it, and even improve it.

In the following decades computers were becoming smaller and considerably more affordable with microcomputers, nevertheless they continued to be reserved for professional settings as they were deemed useless anywhere else. By the 1970s, hackers and entrepreneurs started to use computers for

commercial applications in the area of arcade and video games such as *Pong* in 1972 and *Space Invaders* in 1978 by Atari which launched the computer (and video game) industry into the mainstream market. At this time computer enthusiasts were beginning to create their own personal computing devices. Hackers and hobbyists began meeting in hobby computer clubs to share and trade parts, circuits, and the designs of their inventions. It was the first meeting of the Homebrew Computer Club in 1975 in Silicon Valley that inspired Steve Wozniak to design a personal microcomputer kit (Wozniak, 2007). Wozniak at the time was working at HP but did extra design work for Atari with his friend Steve Jobs who was employed there. Wozniak presented his kit to the club in 1979 and together with Jobs it became the Apple I computer. With seed money from Wozniak selling his car they founded the Apple Computer Company to manufacture and market the Apple I from Job's family garage (Ceruzzi, 2003). Personal computers were becoming no longer a hobby/do-it-yourself activity where hackers manufactured and shared designs with each other, instead they began to compete as computers became a viable consumer product in the market. The subsequent success of Apple II and Macintosh (and similar ventures) were first ignored and disparaged by universities and corporate giants because of their humble garage origins, “but soon the upstarts became the establishment and the union of capital with this fledging science occurred at warp speed” (Conner, 2009, p. 488).

Computers are of course possible because of their hardware components but software is what makes it useful. When computers were mainly mainframe machines with vacuum tubes that filled up an entire room they were very expensive, so they were leased rather than purchased with software and services included (Ceruzzi, 2003). The source-code (as in human-readable computer-commands) was freely supplied and users were able to customize it to their needs and create new programs. It was until 1969 when the US government sued IBM for attempting to monopolize the computer market that as a response IBM ‘unbundled’ the software and services from hardware sales and ceased to share their source-code (Burton, 2002). Software became a new commodity and underwent legal procedures to secure assets through the Intellectual Property Rights (IPR) regime and was deemed patentable by the UK in 1962 and copyrightable by the US in 1974 (for a quick crash-course on IPR see Box 2.1). Software companies soon started to lease software for a fee and restrictions on its use were enforced through contract law prohibiting users to copy, share, reverse engineer or modify the product without permission (check the Box in a Box 2.1). Licensing proprietary software became a multi-billion dollar industry, by no mistake it propelled Bill Gates, the co-founder of Microsoft, as one of the richest people in the world (Perelman, 2003). As closed software (executable binary code without source-code) was starting to become the *status quo*, rebellious but prodigious hacker Richard M. Stallman saw this as a threat to the communal values of the hacker community and in 1983 he started to work on the GNU project to build a free operating system that anyone would be free to use, copy, and modify.

Box 2.1: Crash-Course in Intellectual Property Rights

Intellectual Property Rights (IPR) are legally recognized exclusive rights to creations that involve authorship, such as music, literature, designs, discoveries, and inventions. Some of these include trademarks, trade secrets, patents, and copyrights. Trademarks™ are designs and symbols that allow a product, company or service to be recognized and distinguished from others. Trade secrets are just that, designs, formulas, and information that are not disclosed to the public. Patents therefore are supposed to work as incentives for inventors to publish their inventions to the public. Patents reserve exclusive rights for 20 years for novel and useful technological inventions to prevent others from commercial use of the invention without permission. The idea of this enforced monopoly control is to recoup initial investment through monopolistic prices and by granting commercial rights to others in exchange for a licensing fee. Obtaining a patent is a lengthy and costly procedure and an application has to be submitted to different countries for approval. Those opposing the use of patents claim that the system has created patent misuse, thickets, trolls, and ambushes. Misuse is the purposeful intent to make patents broad, and thickets refer to the dense number of patents that make it prohibitively expensive to develop new technologies. Trolls are companies in the sole business of licensing, and patent ambush happens when holders allow for technology to develop and suddenly present an essential patent for that technology and sue for infringement. Copyright© restricts use and distribution to the copyright holder for a period of time, usually measured as author's life + 70 years (in the US since 1998). Under the Berne Convention of 1886 signed by most countries, copyright is automatic and does not require application. The idea of copyright is to enable authors to receive financial compensations for their creations. With digital media that can be effortlessly copied infinitely with no additional costs, copyright infringement has become rampant as users share and remix content freely. As a consequence new technologies known as Digital Rights Management (DRM) have been created to control the use of digital content. Those opposing copyright argue that it restricts the free flow of knowledge and culture and therefore hinders their (re)production. For a complete overview on IPR see Richard Stim's book (2014) *Patent, Copyright & Trademark*.

Box in a Box: End-User License Agreements

Licensing is not a form of IPR but is a form of maintaining exclusive control through contract law using End-User License Agreements (EULA); those texts you see/read just before you click “I agree to these terms and conditions”. Restrictive EULA's are a form of DRM. Paradoxically, licensing a software—or any digital material for that matter—requires the user to bear a copy which is technically copyright infringement since the licensee holds no ownership over the copy. The US government amended the Copyright Act in 1980 to grant explicit rights for users to use a copy without infringement. For more information on IPR in the digital world see Peter Yu's (2007) *Intellectual Property and Information Wealth*.

2.1.1 FREE/OPEN-SOURCE SOFTWARE

Stallman, dubbed as the last hacker by Levy, became increasingly discontent with the subsidence of the hacker community to proprietary software which he viewed as "antisocial and unethical" (Stallman, Lessig, & Free Software Foundation (Cambridge, 2010). In 1985 Stallman founded the Free Software Foundation (FSF) as a way to support the development of free software, "*Free* as in *free speech,* not as in *free beer*" Stallman said (2010, pg. 3). The GNU project was growing as developers were hired by the FSF to contribute to the project and as volunteer and paid programmers from industry contributed as well. In 1991 Linus Torvalds, a computer science graduate student from Helsinki, created his own operating system as part of his master thesis and developed the Linux kernel; the missing component for the GNU project. This led to the development of the GNU/Linux operating system which is arguably the most successful and powerful software in the world. Linux runs 81% percent of the total market share in smartphones with Android devices (IDC, 2013) and runs 97% of the top 500 supercomputers in the world (Noyes, 2014); from air traffic control systems, the New York stock exchange, the largest particle physics laboratory in the world (CERN), and even runs various web and cloud services that power Internet giants such as Google, Amazon, Twitter, and Facebook (Amaresh, 2013).

Free software is made possible because of its licensing scheme. In 1989, Stallman with the help of a law professional published the GNU General Public License (GPL). Free Software is distributed under a legal copyright framework that instead of strictly allocating producer control it stresses the rights of the user and guarantees them "the freedom to run, copy, distribute, study, change and improve upon the software" however they seem fit (Stallman et al., 2010, p. 3). More essential is that the GPL holds an EULA (see Box in a Box 2.1) that requires that all subsequent copies and derivatives thereof bare the same license, effectively locking the source-code as unrestricted commons. This 'viral' license is called Copyleft ↄ as a play on the word Copyright ©. In 1997 Eric Raymond published his book *The Cathedral and the Bazaar* where he provides a reflective analysis on the different dynamics between organizational models for the production of software—after being intrigued over the success of the Linux system which he attributed to the bazaar model; as self-organized, decentralized, and distributed (over the Internet) based on voluntary cooperation. The bazaar model describes a model of software production where users are treated as co-developers and software programs are continuously developed and released. Raymond postulated that the bazaar resulted in better software essentially because of what he called 'Linus Law' encapsulated in the aphorism "given enough eyeballs, all bugs are shallow", making reference to harnessing the potential of many contributors, a kind of collective intelligence. In 1998 Netscape inspired by the potential superiority of the bazaar model that Raymond suggested released its browser's source-code and it became Mozilla Firefox. This event incited a group

of people to suggest a rebranding of Free Software as a strategy to make the model more 'business-friendly'. The group founded the Open Source Initiative (OSI) in 1998 and suggested the label Open-Source Software (OSS) which appealed to a more pragmatic stand rather than an ideological one like Stallman's Free Software (FS). Indeed Stallman (1998) maintains that FS and OSS have fundamental different values and ways of looking at the world "For the Open Source movement, non-free software is a suboptimal solution. For the Free Software movement, non-free software is a social problem and free software is the solution", and thus he differentiates them as "OSS is a development methodology; FS is a social movement" (Stallman et al., 2010, p. 84). The term Free/(*Libre*) Open-Source Software (F(L)OSS)[3] is often used to encompass both terms. FLOSS can have distinct philosophical origins (moral *vs* pragmatic) and their definitions on what makes a software free or open-source do vary to the extent that all free software is considered open-source but not *vice versa*, they both however do create copyleft software and use a development methodology—more often than not—of a bazaar-like model.

2.1.2 HACKING PRINCIPLES

The hacker mentality was instrumental in developing the hardware and the software industry. Hackers more than just eager tech-enthusiasts shared a communal set of unstated pragmatic and aesthetic principles which was defined in 1984 in Levy's book Hackers as the *hacker ethic*:

Hacker Ethic

- Access to computers—and anything which might teach you something about the way the world works—should be unlimited and total. Always yield to the hands-on imperative!
- All information should be free.
- Mistrust authority—promote decentralization.
- Hackers should be judged by their hacking, not bogus criteria such as degrees, age, race or position.[4]
- You can create art and beauty on a computer.
- Computers can change your life for the better.

Levy tried to illustrate how hackers distasted restrictions and permissions of all kind, especially bureaucratic ones. They firmly believed that access to 'things' is fundamental and that information is a key component to 'do' anything. Hacking was something that was to be appreciated for its visionary quality, quirky styles, and innovative techniques, and so hackers should be admired for their feats

3 *Libre* is sometimes used to supplement the word *Free* to emphasize that it refers to *Freedom* and not to *Free of Charge* as in *Gratis*. Stallman (2007) argues that FLOSS is better suited as a neutral term to encompass both FS and OSS.

4 Note this norm does not explicitly include gender and although the hacker culture promotes openness and inclusion there is a substantial gender gap in hacker communities. Unfortunately this discussion is out of the scope of this thesis but a review on women's exclusion from FOSS-like communities can be found in "*Free as in sexist?" Free culture and the gender gap* by Joseph Reagle (2012)

alone. They also believed that computers could bring joy for personal satisfaction or communal fulfillments. It is easy to see how the hacker ethic influenced the organizational structure of the FLOSS development model for its open and horizontal features (like a bazaar).

The hacker ethic has also been revised by Pekka Himanen in his book *The Hacker Ethic and the Spirit of the Information Age (2001)*. In the prologue written by Torvalds, he reclaims 'Linus's Law' from Raymond and suggests that motivations escalate from *survival*, *social life* to *Entertainment* with a capital E; "the kind that gives your life meaning" (Himanen, 2001, p. xvi). Torvalds posits that hackers do things because they find them interesting and they want to share this interesting thing with others fulfilling both the entertainment part from doing something interesting and the social part from sharing it with others. Himanen goes on to argue that the hacker ethic represents a different work 'attitude' from Max Weber's *The Protestant Ethic and the Spirit of Capitalism (2001)*. He discusses the current domination of the protestant work ethic where work is seen as a dutiful necessity that is motivated by money and strives towards optimality, consequently work hours are separate from play (leisure) hours. This ethic as explained by Weber is central in the capitalist system. On the other hand hackers value above all passion, creativity, and creating value.

For Himanen hackers are not anti-capitalistic, he explains that for hackers money are the means (rather than ends) to gain freedom and more leisure time. However, George Dafermos and Johan Söderberg, argue that the model of FLOSS explicitly organizes labor in an alternative model based on common ownership of the means of production (*libre* access to source-code), volunteer participation (free association), and self-expression (directed by passion and value-creation), they thus argue that the hackers personify the struggle against the informational capitalism of IPR and to the organized waged labor of centralized market-oriented hierarchies (Dafermos & Söderberg, 2009). Gabriela Coleman and Alex Golub (2008) maintain that the hacker ethic applied in the genre of FLOSS can then be understood as a combination of different moral principles of liberalism. The philosophy of FS invokes issues of freedom and access to knowledge and information that invoke "virtues of sharing and pedagogy" (ibid p. 26). OSS advocates for freedom as well as efficiency in the market, as Raymond (1998) suggested that open-source creates 'better' software because the motivations of hackers rely on joy and recognition rather than based on a salary-incentive. Coleman and Golub also maintain FLOSS ensues viewing work as a creative form of expression and carries an awareness of connection with a community; of acknowledging their contributions to a commons that can be freely used, and reused (*ibid*). The hacker ethic and FLOSS can be then be understood as a new ethos towards the economic, social, and cultural arrangements of the production of valuable goods, and this challenge could extend beyond the realm of computers, as Levy (1984, p. 37) proposed in his book:

> And wouldn't everyone benefit even more by approaching the world with the same inquisitive intensity, skepticism toward bureaucracy, openness to creativity, unselfishness in sharing accomplishments, urge to make improvements, and desire to build as those who followed the Hacker Ethic?

Levy's book was fundamental in describing the hacker community and culture, it gave it a history, an identity and an ethic. During the next years hackers were starting to form more formal collectives, some of these would become the seeds for *hacktivism*; a different genre (application) of the hacker liberal values (G. A. Coleman & Golub, 2008). Eventually hackers started to create different kinds of communities; public communities in dedicated urban spaces known as *hackerspaces*.

2.1.3 HACKERSPACES

Nick Farr (2009) has categorized the emergence of hackerspaces in a 'Toffleresque'[5] framework of successive waves. He identifies the first wave in the early 90s with the establishment of hackerspaces in the US. The second wave emerged in Europe with spaces such as C4 established in 1994 and c-base in 1995 in Germany. These spaces began to shape a more sustainable model for an open and more formally organized space gaining "recognition from the government and respect from the public by living and applying the Hacker ethic in their efforts" (Farr, 2009). The third wave of hackerspaces came in 2007, after North American hackers organized a trip called 'Hackers on a Plane' to tour around European hackerspaces and to attend the Chaos Communication Camp, which is an international meeting of hackers organized every four years since 1999 by one of the oldest and most recognized hacker clubs, the Chaos Computer Club (CCC) in Berlin founded in 1981. The hackers inspired, upon returning to America established their own hackerspaces such as NYC resistor in New York City and Noisebridge in San Francisco (Borland, 2007). This third wave of hackerspaces represents the current generation of hackerspaces. Hackerspaces.org founded in 2007 acts as the main online hub and presents a comprehensive user-maintained list of all active hackerspaces throughout the world counting 1040 so far and 347 in planning. Hackerspaces define themselves as "community-operated physical places where people can meet and work on their projects". Jens Ohlig, a pioneer on the early hackerspaces, defined hackerspaces as: "An alternative educational institution, a place where people can learn about technology and science outside the confines of work or school. It's where people build things because they want to, not because they need to make money." (Newitz, 2009).

The growth of hackerspaces is deeply linked with the development of the *Maker* culture which vows to the educational model of 'learning by making' and to the belief that creating something new and learning new skills is personally enriching and satisfying (Dougherty, 2012). The maker movement has

5 'Toffleresque' refers to Alvin Toffler's (1981) book *The Third Wave* where he describes the technological history of societies in three successive waves: agricultural, industrial, and information-based.

its origins in *Make* magazine which focuses on DIY[6] technology projects and publishes instructions and tutorials to make them. Make magazine was founded by Dale Dougherty in 2005 and he initially wanted to name the magazine Hack however his daughter didn't like the name as it sounded too oriented towards programming, instead she suggested calling it Make because "everyone likes making things" (Cavalcanti, 2013). Some DIY individuals and groups have adopted the word *maker* over the term *hacker* as they think it better accommodates non-engineers or to avoid the popular pejorative perception of hackers as mischievous cybercriminals (Seckinger, Park, & Gerhard, 2012). Although the term maker, hacker, and tinkerer have subtle differences in meaning they are widely used interchangeably inside the maker/hacker culture (Osborn, 2013).

Along with makerspaces and hackerspaces another similar model emerged around 2005 known as FabLabs which describe themselves as providing "widespread access to modern means of invention", but can be understood as a global network of small-scale workshops for personal digital fabrication. The concept was developed by the Center for Bits and Atoms at MIT's Media Lab with the intent of empowering under-served communities with technology at a grassroots level (Mikhak *et al*., 2003). The founding principle of FabLabs is to provide a core set of tools such as 3D printers (adds material), CNC mills (subtracts material), laser and waterjet cutters and so on, that allow individuals to 'make (almost) anything'. Access to these tools have dramatically reduced the costs of prototyping and production allowing individuals to develop customized products unavailable is the mass-production market. These new grassroots models of—predominantly digital—fabrication have gathered a lot of attention for their potential to encourage user innovation, entrepreneurship, and sustainable alternatives (Smith et. al., 2013). Jarkko Moilanen has noted that even though these communities might use different denominations to classify themselves (hackerspaces, makerspaces, or FabLabs) "they are all mainly concerned about projects led by users and about having an impact on the social environment" (Moilanen, 2013, p. 6). He found they hold similar values of sharing, collaborative work, openness, and transparency (Moilanen, 2012). Moilanen has equated these spaces as a third place as defined by Oldenburg; a place separate from work and home where people develop communal ties.

Fablabs, makerspaces, and hackerspaces are all interlinked models which are open co-working spaces where people socialize, learn, collaborate, and share knowledge, tools, and space (Moilanen, 2013). They also organize international community events such as fairs, festivals, conferences, camps, and hackatons[7]. These DIY communities have revived the DIY hardware ethic of the original hackers and

6 The most popular term used is DIY for Do-it-Yourself, but many also use the terms DIT (Do-it-Together), DIWO (Do-It-With-Others), or even DIO (Do-it-Ourselves) to imply that DIY is really a collaborative effort.

7 Examples: Maker Faire in Rome, IT, FabLab Festival in Toulouse, FR, Kids Hacker Camp in Nairobi, KE. Hackathons are events in which people from varying disciplines come together, form teams and focus on prototyping a solution or idea with digital technologies in a range of different spaces such as academia,

hobbyists but have surpassed it in scale thanks to the Internet which has greatly facilitated creating and sharing designs, schematics, and 'how-to' instructions manuals through digital format. Moreover, they have taken the FLOSS model to physical objects practicing open design and most notably Open-Source Hardware (OSH) which includes sharing design files, schematics, firmware, software, and instructions for manufacturing—all is made free to use and remix under copyleft licenses such as OSH, FLOSS, and CC (Creative Commons c), or OHL (Open Hardware License)[8]. New successful business models surrounding open-source hardware have emerged such as Arduino, Adafruit, and Sparkfun where the user (consumer) of the product becomes a co-developer and a producer of his own as well.

The hacker ethos in FLOSS and hackerspaces is not an isolated phenomena, instead it should be understood from the transitions of a social/technological paradigm shift caused by Information and Communication Technologies (ICTs) and a cultural/economic paradigm shift of commons-based peer-to-peer production.

2.2 THE INTERNET PRIMER

As our global society transitions into the Information (Digital) Age[9], we are living under new socio-technical conditions created by the increasing and pervasive use of microelectronics and digital communication networks which have become intrinsically embedded in almost every aspect of our modern human lives. Sociologists Manuel Castells (2000) and Jan van Dijk (2006) have defined this new social (infra)structure as the *Network Society* where ICTs constitute the integral backbone that maintains and develops our economies, our societies and our cultures. Joi Ito calls this new world the After-Internet (AI) world in contrast to Before-Internet (BI), and says that the AI radically reduced the cost of connectivity and democratized participation to all users of the Internet which enabled a more diverse and greater production/innovation capacity at an unprecedented scale (Ito, 2013). New web technologies of the web 2.0[10] have furthered reinforced the *architecture of participation* of the Net as they are designed to support and encourage user-generated content (O'Reilly, 2007), or in other words the work of amateurs. Amateurs in this sense refers to individuals that partake in an activity by the

engineering, music, fashion, government, and so forth (Briscoe & Mulligan, 2014).

8 OHL like the TAPR OHL and the CERN OHL follow the philosophy of FLOSS however hardware is considered 'useful' work so it is protected under patents and not copyright as 'creative' works. Thus the hardware in reality is released into the public domain where anyone can manufacture it without permission and only the design and documentation files are protected under copyleft licenses.

9 As of 2012 about a third of the world's population has been online according to the Internet World Stats. The Digital Divide is of great concern as it affects economic and social inclusion, however it is not addressed in this paper but is elsewhere, refer to *The Digital Divide* by Pippa Norris (2001).

10 The term was coined by Dougherty to denote a new generation of the Web that is user-centric—users create content with tools such as wikis, blogs, social networking sites, video hosting sites, etc.

sheer pleasure and satisfaction they get from it rather than for strictly financial or professional gains. As the technologies, skills, and knowledge required for the production and distribution of content become more easily accessible and affordable through new forms of digital media and tools, amateurs have increased the quality of their work enough to compete with larger, hierarchical, professional organizations, such is the case of the blogosphere *vs* professional publishing (Shirky, 2002). This process has been labeled by Clay Shirky as *mass amateurization* (2008) and by Charles Leadbeater and Paul Miller (2004) as *professional amateurization* (Pro-Ams). Shirky analyzes mass amateurization from the media revolution of the Internet as the first medium that has ever combined two-way group communication which has enabled group forming and group action. In the AI world, people can freely share, converse, collaborate and coordinate collective action through the Net. Shirky (2008) maintains that when content can be produced more easily in a networked and participatory environment it undermines the scarcity model of top-down professionally mass-produced content. Consequently, the traditional linear relationship between producer → consumer is disturbed as leisure becomes an active form of production and is no longer passive consumption. As end-users increasingly (co)produce more content, Axel Bruns (2008) suggests the term *produser* (producer/user) to denote user-led content in a fluid, heterarchical, collaborative commons model like the famous example: Wikipedia (check Box 2.2).

Box 2.2: Wikipedia, Wikipedia and Wikipedia

Wikipedia is cited as one of the most iconic examples of the current shift towards a free, open, decentralized, distributed, and collaborative model of production. Wikipedia is the most popular encyclopedia in the world with a reliability compared to that of traditional encyclopedias (Giles, 2005). The success of Wikipedia is often contrasted with the failure of its predecessor Nupedia, created in 2000 by Jimmy Wales and Larry Sanger. It was to be the first free online encyclopedia in English written by highly qualified expert volunteers and the articles would go under formal peer-review. By the first year they had created 21 articles. Sanger learned about the wiki technology and proposed to attach it to Nupedia as a feeder for discussions and ideas for new articles. They named it Wikipedia and launched it in 2001. By the first year Wikipedia had 18,000 articles. It currently holds over 30 million articles in 287 languages with over 21 million user accounts.

But before Wikipedia there was of course Linux. Raymond (1999) tried to understand FLOSS through the bazaar model; as a permissionless and distributed development model. The socio-economic production model of FLOSS is explained by Yochai Benkler (2002) as *Commons-Based Peer-Production* (CBPP) which describes how content is created and maintained collectively in a commons by a distributed and decentralized community of peers (users and developers) that contribute freely to a project mostly by intrinsic motivations without the need of hierarchical organizations (firm production)

and/or financial compensations (market-based production). Michel Bauwens (2005) calls it *Peer-to-Peer* (P2P) production and differentiates this model as a new mode of: Production, which is oriented towards use-value (for-benefit) rather than exchange-value (for-profit); Governance, which are peer to peer horizontal hierarchies; and Distribution, which is a shared ownership of tangible and intangible commodities. Bauwens further identifies five key infrastructures required for P2P production: (1) Technological Infrastructure that enables distributed access to capital; (2) Information and Communications Infrastructure that allows autonomous content creation and communication between cooperating agents; (3) Software Infrastructure that produces collaborative tools; (4) Legal Infrastructure that protects creative works from being appropriated; and a (5) Cultural Infrastructure, a type of "cooperative individualism needed to sustain an ethos that enables P2P projects". Peter Troxler (2010) thus argues hackerspaces can be seen as the result of applying the CBPP model to both immaterial and material goods.

A key issue in CBPP is the turn to viewing information, knowledge, and culture as a commons; as collaborative authorship that is created collectively and cumulatively as opposed to something that is created individually and thus allows for it to be expressed in terms of individual ownership. Lawrence Lessig (2004) in his book *Free Culture* describes the latter as *permission culture* referring to the traditional producer-control model that enforces IPR[11] to restrict the creation of derivative work which he argues discourages innovation and the (re)production of content. Lessig thus advocates for a default *free culture* where content is freely shared to build and improve upon by changing, modifying or remixing it—or 'forking' in software terms. Just like free software, free culture concerns itself with the freedom of 'produsers' rather than on the exclusive rights of the producer. These transformations have been widely observed and analyzed by new media theorists such as Henry Jenkins (2009) in his account of *participatory culture*, which he characterizes by having low barriers for creative expression and civic engagement, support for creating and sharing knowledge, informal mentorships for transferring knowledge and experience, and a sense of people valuing their own contributions and that of others.

It started all with Linux, it spread through the web 2.0, it became renown with Wikipedia, and it was transformed "from bits to atoms" by DIY community spaces. All realms of social production have been affected by the AI world, including the production and distribution of science. Unlike other areas of social production like popular culture where the authority over culture is of the folk, science is an established institution with a set of norms that are part of the description of what makes science science.

11 Or as Stallman humorously calls them Imposed Monopoly Privileges (IMPs) (Stallman, 2004)

2.3 THE STRAND OF SCIENCE

Science can be recognized as both the organized body of knowledge in any area of inquiry (natural or social) and the social processes and activities of obtaining that knowledge (Bhattacherjee, 2012). This body of knowledge has been accumulating for thousands of years, from the Paleolithic Era to the Post-Modern Era—from stone tools to quantum computers. Throughout history, artisans, philosophers, amateur and professional scientists have contributed to this stock of knowledge (Conner, 2009). Science as we recognize it today is the result of the institutionalization and professionalization of science. In the 17th century early scientific societies composed by gentlemen scientists started to emerge and eventually modeled what would become the modern form of science as a body of authority and control over scientific knowledge and practices (*ibid.*). Modern Science was then defined as a cumulative and collective endeavor that would provide public knowledge and would serve as a modern system for innovation in capitalistic economies (Zilsel, 2000). At the end of WWII a new model for scientific knowledge production emerged that separated scientific inquiry into two different but complementary purposes: knowledge for the sake of knowledge (pure knowledge) in academic science, and knowledge for the sake of profit (practical applications) in industrial science (David, 2005).

2.3.1 CATHEDRAL-LIKE SCIENCE

Academic science was established as a social contract as part of a gift-economy[12] between professional scientists and society (Vermeir, 2012). Academics require capital means to carry out their research and to sustain themselves financially, these funds are provided by society through the patronage of the state. In exchange for freedom of inquiry professional scientists are expected to openly disclose their knowledge, inventions, and discoveries, and to contribute to higher-education in the case of universities. In return for their 'gift' of knowledge they receive recognition and esteem as the material compensation. Robert Merton (1973) maintained that recognition was the reward mechanism for academics rather than money. He explained in his essay *The Normative Structure of Science* the social norms of science as CUDOS, a mnemonic for: *Communalism*, which acknowledges scientific knowledge as a public-commons, *Universalism* means that anyone can contribute equally and knowledge is treated critically equally, *Disinterestedness* in personal gains and focus in 'neutral' science, and *Organized Skepticism*[13] signifies how science should be openly reviewed and scrutinized.

12 An economy describes the activities related to the production and exchange of goods and a gift represents these social exchanges. Gifts are not subject to the cost-benefit reasoning and calculated pricing of the market but instead rely on the rule of reciprocity or altruism.

13 Ziman (2002) has replaced the *Organized* in CUDOS for *Originality* to describe how science favors innovative approaches and address new problems; it is the counternorm of *Expert* in the PLACE norms.

Industrial scientists on the other hand work inside the market-economy where in exchange for financial compensations they develop knowledge in secrecy protected under IPR to maximize profits through commercial exploitation. Industrial science therefore follow the counter norms of CUDOS which John Ziman (2002) coined as the PLACE norms: *Proprietary* to denote how knowledge is privatized, *Local* means it addresses technical problems rather than general understanding, *Authoritarian* describes how scientists work under managerial hierarchical control, *Commissioned* means it has a practical goal, and *Expert* refers to how scientists are hired as problem solvers and not for their curiosity.

The demarcation between academic and industrial science has not always been clearly defined, as "new knowledge produces new practices and *vice versa*", hence basic research and technological development (except for cosmology) "in the long run become indistinguishable" (Ziman, 2002, pp. 171–172). But in the last century academic science no longer strictly follows the idealistic CUDOS norms—if it ever did—but according to Ziman, it follows the PLACE norms and is now a *post-academic* science which represents the reorganization of science under market principles as research projects are established on the interests of funding agents such as private firms and government departments. Thus academics no longer engage in science as a free exploration but instead science is commissioned under the demands of the sponsors.

Academic research is measured primarily by contributions to peer-review publishing which represents the ultimate form of currency that determines the success of a scientist (Long, 1978). This is exemplified in the aphorism of "Publish or Perish". Hence publishing has become an ends instead of the means of scientific research. The distribution of scholarly literature belongs to publishers which establish copyright control—in the digital world the copy is licensed not owned. Meanwhile, public funded research has expanded their efforts to appropriate the intellectual capital of knowledge-workers by patenting scientific discoveries for commercial applications (David, 2004). Increased partnerships with private interests have also resulted in developing knowledge in secrecy as academics trade in publishing in academic journals for financial compensations in the form of a job or licensing fees from patenting (Ziman, 2002). The current model of science has thus succumbed to competitive behaviors under a reward system that measures scientific progress through publications and market potentials, where knowledge and information are treated as commodities rather than as public-commons (Vermeir, 2012). Furthermore, the enclosure of these immaterial assets through proprietary regimes create an artificial scarcity that has considerably constrained the free flow of knowledge and is considered to deter the development of Science, Technology and Innovation (STI) (Heller & Eisenberg, 1998). This artificial scarcity however, is hard to justify and maintain in the AI world where information and knowledge can be shared at a near zero marginal cost.

2.3.2 BAZAAR-LIKE SCIENCE

ICTs have significantly changed the way science can be produced and distributed. Knowledge and information is more easily stored and shared in digital format and web 2.0 technologies have improved the dialog of science by increasing and facilitating communication and collaboration. This new web-based approach to the organization of science is described as science 2.0 (Waldrop, 2008), or networked science as defined by Michael Nielsen (2012), will require to change the culture of science from a competitive ordeal towards a collaborative one that openly shares scientific content. This shift is being facilitated by the open science movement which is part inspired by the FLOSS development model (Willinsky, 2005).

The open science movement aims to make science more accessible to all levels of society by making scientific knowledge free to use, re-use, and distribute without legal, technical or social restrictions (Open Knowledge Foundation, 2014). Open science advocates for open access (*libre* and *gratis*) to scientific literature, primarily scholarly journals but also includes dissertations and books. Open access publication initiatives have been steadily growing and proving to be successful, such as the Public Library of Science (PLOS) project founded in 2000, in which the open access journal of PLOS ONE is now the world's largest journal (Van Noorden, 2013). Open access can also require the non-textual elements of accompanying scientific publications and research and it is sometimes separately addressed as open science data. Open science also promotes new ways of doing research such as publishing the ongoing research process online through digital open notebook science which includes raw data. Another issue that open science advocates is for sharing all of the data obtained, that includes negative results which would otherwise be deemed as 'unpublishable'. Open science can also encourage the engagement of citizen scientists and amateur scientists—whether they work with, at the edges or beyond mainstream science. Citizen science can exist as an extension to institutionalized science where computing resources and cognitive labor is capitalized (crowdsourced) from the public to produce information and knowledge (Hand, 2010). Examples of these include Folding@Home, a screen-saver that performs protein folding simulations and other types of molecular dynamics, and EteRNA, a web-based game where players solve RNA folding mechanics puzzles. On the other hand, citizen science can emerge as grassroots initiatives; as self-organized and autonomous peer-to-peer communities that engage in the development of STI. One example of a community-led science network is the Do-it-Yourself Biology (DIYbio) community.

2.4 A TRANSLATION INTO DIYBIO

Amateur biology hit the DIY scene when Make magazine published its special section in *Backyard Biology* volume 07 in 2006. The section included tutorials on how to freeze and revive a garden snail, how to extract and characterize your own DNA and build a thermal cycler and run PCR[14] for replication, and how to hack your plants with grafting techniques. In the same issue, the featured profile (proto) was entitled "Garage Biotech: For a safer world, Drew Endy wants everyone to engineer life from the ground up". The article featured Drew Endy and his latest campaign to promote the growth of garage biotech arguing that the world would be a safer place if engineers could see biology as hackable. The article ends by saying "Endy hopes that, in a few years, biology will be further demystified as just another technology, the price of gene synthesis will become more affordable, and rank amateurs will take on ambitious projects. The bugs and the bees may never be the same again" referring to the introduction the author gives to Endy as pointing to a bumblebee noting it is an editable reproducing machine saying "Why can't I just hack this stuff?" (Parks, 2006).

2.4.1 BIOLOGY CAN BE HACKABLE

Endy is one of the pioneers of synthetic biology (synbio), a burgeoning field that instead of copying genetic parts and pasting them in other organisms (genetic engineering), synbio envisions biological systems as controllable systems that can be engineered with standardized parts and devices that can be modulated and (re)designed from the bottom-up[15]. The field of synbio has been essential in instilling the sense of understanding living organisms by analogy with electronic devices; cells as the hardware of biology and DNA as the software of life. Endy together with computer scientist Tom Knight at MIT designed the BioBricks DNA assembly standard in 2003 which is commonly explained as Lego-like building blocks (Shetty, Endy, & Knight, 2008). BioBricks are standardized and interchangeable sequences of DNA which are assembled like electronic components into synthetic biological circuits and operated inside living cells. The whole premise of standardized parts in engineering is that the specifications are shared among 'manufacturers' to facilitate automation and part re-use. Endy and Knight founded in 2003 the Registry of Standard Biological Parts, an open-access repository for BioBricks that are collectively created and communally shared. Endy and Knight together with Randy Rettberg and Garry Sussman, established a class in 2003 providing 'hands-on introduction to the design

14 The PCR (Polymerase Chain Reaction) is a thermo-chemical reaction (carried out in a thermo-cycler) in which heat is applied to a DNA molecule to split the two strands of the DNA, it is then cooled down to the polymerase enzyme's optimal temperature that replicates the two strands of DNA (1 DNA → 2 DNAs). This process cycles until sufficient amount of DNA is replicated for analysis. This technology is extensively used in molecular biology for DNA sequencing, DNA cloning, genetic diagnostics, gene analysis, etc.

15 See Synthetic Biology Explained for a crash-course on synbio.

and fabrication of synthetic biological machines' to undergraduates during MIT's Independent Activities Period (IAP); a "four-week period where students engage in innovative projects that combine learning and fun" (Brown, 2007). The 2004 IAP grew into an intercollegiate summer competition with five schools from the US with the goals to increase interest in synbio research and to foster interdisciplinary collaboration (Campbell, 2005). Thirteen teams participated in the 2005 jamboree and included two international teams from Toronto and Zurich; transforming the jamboree into the international Genetically Engineered Machine (iGEM) competition. The teams received non-hierarchical awards such as 'Coolest Part', 'IKEA Idea Award', 'Best "Quantitative" Answer', and 'Most Innovative Abuse of Expensive Laboratory Equipment'. The IGEM competition and the BioBricks Registry according to Peter Robbins (2009) have broken traditional paradigms of science by pushing towards with their open-source innovation model, interdisciplinarity and engagement with social concerns such as biosafety and corporate control. IGEM has since expanded to include high-school students (since 2011), entrepreneurs (since 2012), and community labs (for the first time in 2014). The competition has been widely successful, with 246 teams from Europe, Asia, North and Latin America registered to compete in 2014 with projects that focus on the environment, health and medicine, food and nutrition, energy, and new tracks that focus on art and design, policy and practices, software, etc.

2.4.2 RESOURCES GET CHEAPER

Endy's desire for a demystified biology expressed in his proto piece in Make of 2006 was starting to take shape as students were building complex machines, but affordable machines were still lacking at the time. In 2005 the first Next-Generation DNA Sequencing (NGS) technology hit the market with the 454 Life Sciences Genome Sequencer at a price tag of $500K (Perkel, 2006). In 2008 using 454's sequencer the full-genome of James Watson, the co-discoverer of the double helix, was sequenced in about 2-4 months time for a cost between $1-2M (Davies, 2008). NGS was a significant breakthrough compared to other sequencing projects, like Craig Venter's[16] full-genome sequence took years at a cost of almost $100M, or the international consortium for the Human Genome Project (HGP) which took 13 years and $3B (Bartfai & Lees, 2013).

After the HGP was complete in 2003, George M. Church, a genomics and synthetic biology pioneer, founded the Personal Genome Project (PGP) as an offshoot in 2005 which intends to sequence and openly publish the complete genomes and medical records of 100,000 volunteers. Church rued the cost

16 Craig Venter is one of the most influential and controversial characters in genomics and synthetic biology. For one, Venter tried to compete with the HGP through the private sector (Celera) which intended to profit by charging a subscription fee to a value-added database of genomic data. The public consortium published the human genome first. For more refer to *The Genome War* (2007) by James Shreeve. Venter is also one of the inventors of the first self-replicating bacterial cell.

of the HGP and wanted to make personal genomics a possibility by reaching the holy grail of genomics: the $1,000 genome. At the time, Church's group at Harvard Medical School, were working on a new NGS technology that used “polony bead amplification of the template DNA and a common digital microscope to read fluorescent signals” (Church, 2006). The sequencing machine was launched in 2008 as the Polonator G.007 at a price tag of $150K; a 1/3 of the price of the 454 sequencer. The Polonator used of-the-shelf components and embodied an open-source platform with hackable hardware, software, and protocols. The machine was praised as the ultimate effort to make the technology as accessible and customizable as possible (*ibid*). Jason Bobe, the Director of Community of PGP since 2007, inspired by the DIY low-cost open-source sequencer and its potential for dropping costs cheap enough that everyone would want to have one in their garages decided to name this new garage hobby as DIYbio and registered the Internet domain DIYbio.org in 2007 (Tochetti, 2013).

The rise of the amateur biologist can be seen as the Pro-Ams of biotechnology as the technologies, skills, and knowledge required become more accessible, approachable (easy), and affordable. Biohackers are enabled by web 2.0 technologies for communication, coordination and collaboration in a decentralized and distributed fashion. The capabilities for self-learning have increased dramatically as people have free access to scientific knowledge in the form of open access scientific literature, through Massive Open Online Courses (MOOCs), or through more informal sources such as wikis and how-to instructions. The resources required for DIYbio are not solely confined to those of the cyberspace but also include physical resources of the meatspace[17], these include things such as glassware, plasticware, chemicals and media, wetware, and hardware equipment that are obtained from DIY and institutional settings alike (Kuznetsov, Taylor, Regan, Villar, & Paulos, 2012). Low-cost tools can be obtained from off-the-shelf components or from repairing, repurposing, reverse engineering, or designing their own tools and usually share the instructions online. Many second-hand source their equipment, either bought or donated from universities and companies. Cheap equipment results from the ‘leftovers’ of bankrupt biolabs or from the rapid turnover of equipment in established biolabs (Wolinsky, 2009). This turnover results from the rapid advancements in molecular biology techniques which have not only dropped costs, they have plummeted at an even faster rate than Moore's Law (see Illustration 2.1).

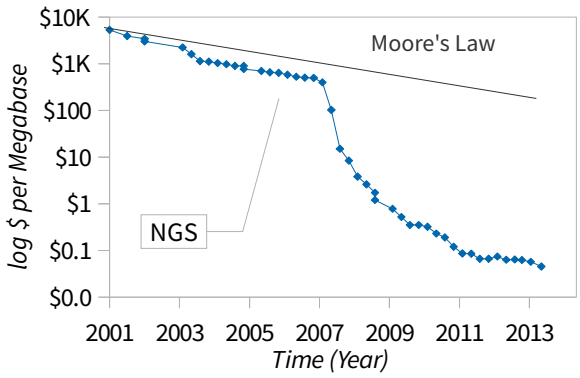

Illustration 2.1: Cost of Raw Megabase pair DNA sequencing. Data obtained from NIH.

17 Meatspace is the world outside of cyberspace; the world of flesh and blood. The term originated from cyberpunk novels.

2.4.3 HOMEBREW BIOTECH

Jason Bobe would meet with Mackenzie Cowell in 2008 at a co-working space in Boston (Tochetti, 2013). Cowell had been working at iGEM before he quit because he "wasn't learning new things" (Bousted, 2008). Cowell sold his car for seed money and together with Bobe founded DIYbio.org which in their own words is an organization that aims to be "An Institution for the Do-it-Yourself Biologist" and established the DIYbio mailing list (Google Groups platform) which currently holds over 3,700 members and over 4,700 topics discussed. Bobe and Cowell called for the first DIYbio meeting to discuss the future of amateur biology. Around 25 biotech enthusiasts gathered at the Irish Pub in Cambridge to discuss biotechnology as a serious hobby "Can DIYbio.org be the Homebrew Computer Club of biology?" they asked (Bobe, 2008). Along these lines DIYbio represents a biological genre of the computer hacker: the biohacker (for the breakdown of biohacking see §2.4.4).

DIYbio started with people tinkering in the garages and kitchens of biotech enthusiasts (Bloom, 2009; Wolinsky, 2009), and eventually moved to dedicated community labs[18] that have integrated into the hackerspace model, either by setting up biolabs in existing hackerspaces or setting up new dedicated biohackerspaces (Kuznetsov et al., 2012). The community lab of Genspace[19], was one of the first to open its lab to the public in 2010 in Brooklyn, New York, founded in part by molecular biologist Ellen Jorgensen. Biohackerspaces finance themselves through different mechanisms, some of these include sponsorship through government and university subsidies, crowdfunding, membership fees, etc. DIYbio.org has become somewhat of the central hub for a global DIYbio network and accounts for 21 DIYbio groups in North America, 18 in Europe, 2 in Asia, 2 in Oceania, and 2 in Latin America in their website. Biohackerspaces comprise diverse sets of individuals such as scientists, designers, software developers, hobbyists, and enthusiasts, that work on a wide range of projects such as citizen science initiatives, amateur science, product development (incubators), artistic work, and educational workshops and courses (Landrain, Meyer, Perez, & Sussan, 2013). Individuals share the infrastructure provided in DIYbio labs to develop and contribute to projects out of their own interests and motivations with no expected outcomes in terms of market potentials, feasibility or social worth, all they have to do is "follow safety guidelines" (Jorgensen, 2012).

The potential widespread access of synthetic biology have caused alarming concerns over biosafety and biosecurity issues (Edwards & Kelle, 2012; Schmidt, 2008), even the FBI has sponsored several conferences since 2009 as outreach workshops to the DIYbio community. The conferences have been

18 In a survey conducted by the Wilson Center, they determined that about 90% of DIYbio'ers work in group spaces rather than alone in their homes (Frushkin, Kuiken, & Millet, 2013).

19 For a look into what a biohackerspace looks and 'feels' like watch Visit to Genspace by Make magazine

successful for building a positive dialogue and bringing awareness for biosecurity and biosafety issues (Jefferson, 2013). Cowell has expressed that building a relationship with the FBI feels counterintuitive but is important “If we're going to walk the walk, we have to be able to talk to the FBI” (Lempinen, 2011). The DIYbio community has also taken a pro-active stand towards good practices. Two regional networks, the European and the North American drafted each a code of ethics in 2011 that expressed commonality calling for *open-access*, *transparency*, *safety*, *education*, *responsibility* towards living beings and the environment, and for only *peaceful purposes* (an insightful comparison is done by Eggleson, 2014).

2.4.4 THE BIOHACKER

The Homebrew ‘Biotechnology’ Club was envisioned before Bobe in 1988 by Michael Schrage in his article “Playing God in Your Basement” in The Washington Post. Schrage makes a comparison between the homebrew hobbyists and the ‘artistic’ hacker subculture that started the personal computer revolution and suggests a similar “technology subculture could grow around DNA just as one did for silicon software”. He named this new hacker genre the *bio-hacker*[20]. The label biohacker has been broadly adopted by DIYbio and by other groups that adhere to other types of biohacking like cyborg hacking (grinders) or sleep and diet hacking (Quantified Self)[21] (see Box 2.3).

Box 2.3: Biohacker Flavors

At least two types of self-proclaimed biohackers can be distinctly discerned from the general brand of DIYBio based on their particular interests. These groups perform self-biohacking to extend and enhance human capacities and many subscribe to the transhumanist philosophy of transforming the human condition through technologies. Self-called grinders perform practical, and sometimes extreme DIY body-enhancements with electronic hardware through body-modification and self-surgery. They are also interested in the use of nootropics and drugs to improve mental and physical functions. The other branch of biohackers can be distinguished by their extensive effort to self-measure and monitor behavioral, physical, biological and genetic metrics for self-knowledge and improvement and fall under the Quantified Self (QS) movement. Some of these groups extend to the DIYbio group and *vice versa* as well. What unifies these groups is the idea of hacking biological systems; of trying to understand how something works by experimentation (hacking) and they are sharing their hacks with others.

20 This is the earliest citation according to Word Spy of the word biohacker. Excerpts from the article can also be found in Afflictor.

21 These variations can hold different values, goals and conflicts and are thus not included in this study.

In the DIYbio/FAQ wiki page they answer Who is a "biohacker"? and reference to the hacker subculture; the homebrew computer club, free software, the hacker ethic, and DIY enthusiasts. It also notes that biohacker "might be somewhat related to biopunk". The term biopunk originates as a science fiction subgenre of cyberpunk, both of which involve narratives of dystopian and dreary futures of high (bio)tech and a subversive culture (punks and hackers) that struggle against the social control of oppressive governments or megacorporations. The term biopunk therefore accompanies meanings of the (cyber)punk ideology and its critiques towards neo-liberalism, late capitalism, and individualistic consumer society, however these philosophies are not necessarily expressed (Schmeink, 2011), as is the case of Marcus Wohlsen's book *Biopunk* (2011), in which he uses biopunk interchangeably with biohackers to refer to amateur biologists and DIYbio to refer to DIYbio.org Another example is Meredith Patterson in *A Biopunk Manifesto* (2010) where she claims:

> As biohackers it is our responsibility to act as emissaries of science, creating new scientists out of everyone we meet (…) We the biopunks are dedicated to putting the tools of scientific investigation into the hands of anyone who wants them.

Overall the labels DIYbio, biopunk, biohacking, and amateur biology can be portrayed as the same thing[22] (Alper, 2009; Bloom, 2009; Frushkin et al., 2013; Whalen, 2009). Biohackers have been characterized for their mode of exploration which relies on understanding biology by making (Delgado, 2013; Roosth, 2010). Moreover, by comparing themselves to computer hackers and open-source software they transfer meanings of the right to access, the right to use, and the right to modify (biological) things (Delgado, 2013, p. 66). Sophia Roosth argues that biohackers beyond trying to "democratize" biology they aim to make it "quotidian, personal, apprehensible" (2010, p. 105)—or as Mac Cowell later responded, they want to 'domesticate' biology (100 ideas, 2009). Roosth continues to say "This is biology as a mode of political action, in which practitioners frame doing biological research as a right rather than a privilege" (2010, p. 105).

According to Ana Delgado et al. (2013) and Alessandro Delfanti (2013) biohackers can be understood as a reaction to the current post-academic model of science which is commissioned, managed, and increasingly privatized which in their own views replaces individual curiosity and creativity. Delgado (2013) claims that herein lies the difference between institutional biology and amateur biology; "a renewed enthusiasm for exploration and discovery". Christopher Kelty (2010) characterizes the (bio)hacker as someone who takes pleasure in understanding and modifying a system and values openness and sharing. Kelty compares the hackers with other figures in participatory biology by

22 A discussion over a Wikipedia cleanup in the DIYbio mailing list was split, some agreed on them being roughly the same, while other strongly maintained that these labels have different meanings and therefore bring distinct imaginaries that depend on the historical and cultural origins of the words.

emphasizing that hackers work together, not alone, unlike the *outlaws* who take delight themselves in solely demystifying and bringing access to biology, or the *Victorian Gentlemen scientists*, who are well-connected eccentric intellectuals that pursue knowledge on an aesthetic and pure intellectual principle.

For Delfanti (2013), biohackers make biology 'hackable'[23] in several ways: First, hacking is the ultimate motive and requirement; you don't need a PhD, you just have to be curious and share your knowledge. Second, biohackers understand biology as programmable information which can be made standardized and modularized to make it cheaper and more accessible. Third, they open up community labs beyond the exclusive domain of Big Bio[24]. Fourth, they entrepreneur in the new business models of the open-source development model. Biohackers are enabled by and foster the grassroots CBPP model of distributed and decentralized open production of common goods that challenge the monopoly of top-down, proprietary 'Big Bio slow giants'. Thus Delfanti maintains the biohacker as the direct translation of hacking into the realm of biology:

> DIYbio embodies different faces of hacking such as openness in data and knowledge sharing as well as openness of the doors of scientific institutions, but also rebellion, hedonism, passion, communitarian spirit, individualism and entrepreneurial drive, distrust for bureaucracies.

Furthermore, Delfanti recognizes that biohackers, much like the hackers (G. Coleman, 2004; Kelty, 2008), value their craft as social and creative expressions and often deny their political intentions. Nevertheless hackers and their FOSS philosophy has extended into the wider publics and has sparked "a commons movement, centered on the idea of creating public goods to reinvigorate democratic principles" (G. Coleman, 2004, p. 514).

23 Or in other words, it is changing, modifying, remixing the system.

24 Big Bio in reference to "the ensemble of big corporations, global universities, and international and governmental agencies that compose the economic system of current life sciences" (Delfanti, 2013, p. 6).

CHAPTER 3
METHODS

“We are all mediators, translators”

— Jaques Derrida

As explained in the Error: Reference source not found I intend to direct attention into the construction of the collective identity, the "we" of the DIYbio movement. To research how participants describe themselves and the practices of the movement, qualitative methods are the most appropriate for tracing processes of meaning-making within the context of a particular community (Krauss, 2005). In the study of social movements semi-structured interviews in combination with participant observation can provide insight into the individual and collective visions, imagining, hopes, expectations, and critiques of their social world and how the movement fits into it [25].

3.1 DATA COLLECTION

Participant observation was carried out in movement areas with the purpose to immerse myself into the practices and discourses elaborated there. The research was done online mainly through direct observation of discussions in the DIYbio mailing list and other social networking sites such as Facebook groups, and offline in a biohackerspace with direct participation in a workshop and in a safety training course.

The interviews were done in a semi-structured manner that involved an interview guide (see Appendix D). The guide was designed with the intent to develop insight into the different meanings and perceptions of the DIYbio movement by those who identify themselves as members. The questions were meant to encourage informants to elaborate their responses and were given the freedom to bring new topics into the conversation they considered relevant. Interviewees self-selected themselves to participate in the interviews based on my inquiry in the biohackerspace I attended to and from a social networking site related to DIYbio which I will keep confidential to keep the anonymity of my informants. A total of seven interviews were performed throughout the course of the study through face-to-face interactions or video chat. Informants were selected based on their active engagement to DIYbio groups from different regions; three from Western Europe, two from Latin America and two from Southeast Asia. A comparative table on demographics and on the stats of the interviews can be found in Appendix E. DIYbio members from North America did not self-select themselves for interviews [26], fortunately their voice is one of the most prominent discourses of DIYbio—as the movement originally started in the US—and is widely available online and accessible to English-speakers. Therefore I focused on obtaining a broader range of meanings from different cultures that have joined the movement.

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25 For a review of the implications and usefulness of semi-structured interviews in social movements, refer to *Semi-Structured Interviewing in Social Movements* (2002) by Kathleen Blee and Verta Taylor.

26 This could be due to a wrong assumption of the diversity of nationalities in the social networking site where I asked for volunteer participation.

Interviews provided an insiders perspective on the DIYbio movement, to compare I also collected documentary sources from popular media outlets as to get an outsiders perspective. My documentary sources were obtained based on a Google Search with the quoted words “DIYbio” and “movement”. Some of the results from this query are listed in the number 1 footnote in page 2 of this thesis. The articles selected chosen were two daily newspapers: The Guardian and The New York Times; one academic journal: Nature; and four magazines that focus on various topics such as business, life sciences, technology, and popular culture: Forbes, The Scientist, Wired, and Vice respectively. A comparative table on publisher and article info can be found in Appendix B.

3.2 DATA ANALYSIS

The analysis of documentary sources and interviews implies regarding language as data and discourse analysis is concerned with the expression of language as a way to transmit knowledge to create meaning. Discourse analysis can provide rich data on the comprehension of the movement from an outsiders (articles) and from an insiders perspective (interviews), and to intentions, feelings and purposes that actors give to the movement. The articles were analyzed and relevant snippets concerning my research questions were taken *verbatim* or summarized and aggregated in Appendix C. The recorded audio from the interviews was transcribed manually with a specialized software (see Credits & Attributions) and the interviews from the Latin American region were translated from Spanish to English by me (a native bilingual Mexican-American). Literal sections were then selected and some are presented as quotes in the text and the rest are aggregated in Appendix E.

3.3 LIMITATIONS AND CONSIDERATIONS

It is important to establish a rapport with the informants so that they feel comfortable and can adjust their discourse to the context. In the interview I first introduced myself and noted that I have a background in engineering and biotechnology as to establish a common jargon. Interviews involve the disclosure of thoughts and feelings of individuals which are considered private. Issues of confidentiality and anonymity were assessed and discussed with informants before and after the interviews were done and permission was granted orally from the informants to record the audio of the interview for transcription. After the analysis was complete and a rough draft of this thesis was edited, a copy was provided to the informants for them to review the interpretation (and translation if applicable) of their personal thoughts to reduce interpretive authority on my behalf. A final consent form for permission was obtained from them to be able to use the material.

Semi-structured interviews can reduce compatibility between interviews but it allows for interviewees

to develop their own coherence which is valuable in itself (Patton, 2002). Also, working in a small-scale research implies that the research is not representative but instead it can provide a rich glimpse into the ethos and diversity of the movement.

CHAPTER 4

FINDINGS

“The composition of a common world would be the definition of politics.”

— Bruno Latour

As I posited in theError: Reference source not found I am interested in gaining insight into the collective identity of the DIYbio movement. My findings were obtained, as I laid out in my Methods, by analyzing the practices and discourses of the DIYbio movement through participant observation in an online and offline DIYbio network (broad descriptions of my experience in them can be found in Appendix A), and discourse analysis from seven popular media articles and seven interviews with informants (info sheets available in Appendix B and Appendix E respectively). For analyzing the articles (Appendix C) I roughly categorized data that conveyed how the authors describe the DIYbio movement and its members, their motivations and values; on how they perceived goals and grievances of the movement; and on the descriptions of how the DIYbio movement operates, particularly how they portray community labs and operate in informal networks. The analysis of the interviews was more divergent as data was highly heterogeneous and not always comparable. I separated applicable quotes into certain themes (Appendix F) roughly following the same categorization as the articles—though the data was far more extensive. The informants were given color code names to keep their anonymity: • Blue, • Green, • Grey, • Black, • Brown, • Red, and • Orange.

The findings are divided in relation to the three mechanisms of social movements. In §4.1 I address how the collective identity of the movement is described or defined—who is the "we" of the movement. In §4.2 I lay out the conflicts and their respective counter-solutions proposed by the DIYbio movement. Finally in §4.3 I briefly show how the informal networks are understood from the discourse analysis and what are the common elements observed from my participant observation.

4.1 COLLECTIVE IDENTITY

The first issue I encountered was on the (dis)agreement on how DIYbio and biohacking are defined. The articles (§C.2) reviewed use both terms synonymously and don't offer a special distinction when using the term *biopunk*[27]. The informants on the other hand expressed some nuances on their meanings (§F.1, F.2). Mostly DIYbio was explained in terms of opening access to biology. DIY was portrayed as inexpensive inventions and workarounds and the term (bio)hacking held a general consensus (§F.2.1) to mean to understand how something works, many times by disassembling it, and then modifying it to change its original function. The activities of DIYbio were acknowledged by the informants as covering a wide range of interests. Grey said that the communality lies in an interest in science, technology, informatics and electronics that gives rise to the "DIYbio idea: a mix between DIY, hacking, biology and

27 The term biopunk is situated in the context of Wohlsen's book (2011) *Biopunk* which as previously mentioned does not stress the biopunk ideology of subversion, rather the biopunk ideology of Meredith Patterson and her biopunk Manifesto of opening access to biology.

science". Only Blue saw this diversity of communities of practice as conflicting in defining DIYbio as he recognized how grinders and QS can be considered to fall under DIYbio while he considers home beer brewers DIYbio "but at the same time those people do not feel associated with DIYbio at all", he pointed out. The boundaries of who is a biohacker were a bit more strict (§F.2.2). Some noted how the term can scare people, Green said this is why he choses the term DIYbio. Red mentioned that he has heard the word used in a pejorative sense by groups that are against Genetically Modified Organisms (GMOs)[28]. Only Brown and Red placed biohacking strictly in high-(bio)tech endeavors such as grinding (in the context of biopunk sci-fi) and synthetic biology and bioengineering. Disagreements were prompted when asked if synthetic biologist Craig Venter and iGEM'ers are biohackers. Some agreed they are as they fulfill the tinkering requirement of the biohacker, as Grey explained "because they look at nature with interest and disassemble pieces to understand how it works". Some disagreed whether these actors can be considered biohackers in terms of whether they are considered part of mainstream science or not. Others expressed that biohackers have to share the knowledge and have to contribute to the ideals of the movement. Green pointed to this boundary from members and non-members of the movement from his iGEM experience:

> It is not that [the people from the iGEM group] are not doing anything to help the DIYbio movement, but they don't see what I see; this way in which we can change how innovation can be done, the way people can use the knowledge of biology.

Furthermore, I tried to explore what it is that interests them and others to join the DIYbio movement as to allude to the meanings they attribute to participating in the DIYbio movement (§F.3). Some mentioned learning as their main motivation, especially to learn and teach across disciplines. They recognized their interest in fulfilling personal curiosities and recognized that DIYbio gives them the freedom to pursue their own interests. The informants also expressed a pronounced sense of making a change; to contribute something of value to society. Blue mentioned the interest in social change as the main reason why people join DIYbio, he calls it:

> Social innovation through biotechnology, and it can be either science, business, philosophy, activism, it can be art, it all has certain impact on how people perceive the world and how they behave. But their attitude is the same.

When asked for the values of DIYbio many responded with the same themes (§F.4): opening access to biology for everyone by sharing and creating open-source tools, a commitment to the freedom to pursue their own interests, approaching things with creativity and curiosity and learning by tinkering. The articles expose similar values and interests (§C.2) and describe biohackers as passionate, playful,

28 In my research of biohackers, this is the first instance that encountered where the term of biohacker is used with this connotation.

and entrepreneurial. The Scientist magazine said biohackers are “dedicated to education, innovation, problem solving using a new model in the human spirit of curiosity and exploration”. There was also another feature characteristic of biohackers that was highlighted, and that was their concern for biosafety (§C.3). Almost all articles pointed to the fear of biohackers having free access to technology that might produce the next global threat, deliberately or accidentally. However biohackers are described as educated scientists that have a proactive approach with a sense of responsibility towards mitigating risks. The Scientist stated “Much of this alarm is overblown, as critics overestimate the current abilities of the DIYbio movement and underestimate the ethics of the participants”[29]. The informants acknowledged the societal concern over the widespread access to biotechnology (§F.5) but distanced themselves from nefarious activities as Black said “We all want to do something good, constructive, we don't want to create bioweapons (…) I think that is something very clear in the movement”. Non of them expressed any distaste over safety and ethical oversight regulations, on the contrary they highlighted it as necessary. They noted the importance of responsibility in DIYbio as Orange said “Handling living creatures is entering a very different techno-sphere”.

Black highlighted how these fears parallel with the concerns that arose when the computer industry was starting saying back then “people thought they were going to build a terminator that would end humankind”, not only did that not happened, he said, but 30 years later we all have smartphones instead. The comparison made with the computer industry is something that was highlighted often (§F.6), even Forbes magazine made the comparison “Biohackers are to biotechnology what Steve Jobs was to the IBM S/360 mainframe”. The comparison is often made of the DIYbio movement bringing biotech to the masses to the transformation of the computing industry—from mainframes in university labs to personal pocket-size Internet-ready microelectronics.

4.2 CONFLICTUAL COLLECTIVE ACTION

The conflicts can be understood as a dichotomy between the movement's grievances and goals. The articles (§C.4) portray the goal of DIYbio as lowering the barrier to entry to biology for citizen scientists, amateurs, and entrepreneurs. The informants (§F.7) expressed in a clear way the goal of the movement as opening access to science and technology to the public; bring science to the people; democratize technology, and so on. When asked whether they considered the DIYbio movement as a political, economic, technological, or cultural movement the response was overwhelmingly cultural or what some called ideological. The goal of opening access is contrasted to the perception of biology as closed, unaccessible outside traditional institutional settings (§C.5,F.8). Some informants noted that for now

29 This phrase by the author, although not stated must have been inspired by Ellen Jorgensen's TED Talk Biohacking — you can do it, too.

only individuals with specialized degrees can work/play with biology which restricts participation from people of different fields of study or without the privilege to formal education. They denounced that even those that do have access (like themselves) don't have the freedom to pursue their own interests since as a researcher one must climb the academic ladder and play into the competitive game of publishing in order to receive grants and have the possibility to manage their own labs or projects (§F.10, F.11). Black succinctly summarized it as “I think scientists have lost a lot of freedom in academia to practice their profession”. Green contrasts this by saying that in DIYbio no one has to justify things in terms of profits or generating new knowledge, “you can explore things just for fun”. In this sense they described DIYbio as a new model of doing science, that is more open and collaborative. They generally note that normal science is to big and slow to change.

Many of the informants expressed that access to education and technology is essential in the GMO debate as they considered that people hold an unfounded fear as they don't understand the science. As Black said:

> [With knowledge people] can understand what is DNA, they can understand that their cells have DNA, understand how a scientist can produce a GMO to produce bioplastics and understand what risks does that involve; what are the ethical and biosafety implications that it entails.

Blue agreed that democratizing science is important as it allows people to “make good decisions about [biotechnology]” and so that people can “express themselves with biotechnology and can then find new applications for it. The things to be able to achieve that; cheap tools, sharing designs, those are all side effects of that”. Expensive lab equipment is stated in the articles as one of the main obstacles biohackers try to overcome and the informants (§F.9) expressed an overall discontent over needlessly expensive equipment as Gray said upset:

> Why does a PCR machine cost €20,000? it is just an easy device. It is more complex to make a microwave and you can buy them at €20 in the supermarket. Why can't I buy a PCR in the supermarket for €20?

All informants agreed that DIYbio and open-source foster low-cost science and technology, and although they noted the DIYbio movement does not hold any formal norms that forbid knowledge produced in biohackerspaces from being patented, ultimately the goal of the DIYbio movement will always try to be open-source as it remains the ultimate truism in opening access. Orange strongly defended that everything should be open-source because it provides access to marginalized communities and because it is more adaptable to people's needs:

> What open-source also allows is that with the knowledge you can actually localize it to your own needs which makes it more inclusive. People can adapt it and hack it to things that are relevant to their communities and their culture.

When it comes to DIYbio and its relationship with academia and industry (§F.12), biohackers acknowledge DIYbio as complementary to academia and industry not as antagonistic. They consider DIYbio as a new way to learn and develop STI, where biohackers are intrinsically motivated by their own ideas and curiosities. They also recognized—an albeit weak—relationship with academia an industry as these institutions value DIYbio as a learning and innovation center. For Black, advancements have been made,up to a point [sic],by universities and industries but says DIYbio wants to be part of the solution and see if they can advance better and faster.

4.3 INFORMAL NETWORKS

From the discourse analysis, only descriptions or mentions to the spaces were obtained. The articles (§C.6) generally portrayed community labs as alternative, eclectic, and frugal spaces with 'makeshift' lab equipment that are open to anyone regardless of scientific background and are unaffiliated with traditional institutions. The informants (§F.13), highlighted the openness of DIYbio labs and online networks; there are no qualifications required to join and everyone is free to choose how to engage, on what and why. Preserving the freedom was highlighted as essential, and the origins of funding was problematized by Green "If money comes in, it doesn't have to restrict my freedom in any sense." Orange maintained that this is why hackerspaces try to remove themselves from the system but maintains that at the same time they are being co-opted with private funding.

From the participant observation the practices and discourse of the free spaces was more evident. First, it was very easy to join in; no requirements and no fees. The biohackerspace (see §A.1) I attended to is sponsored by a variety of government funds that support art, science and technology. The first workshop felt informal, and attendees were from different backgrounds and disciplines, most of them artists and designers. The workshop was intended for discussing projects involving genetic modification, their potentials and risks. The meeting had included free dinner and drinks and after the session was concluded many stayed behind, finished the drinks and got to know more about each other. All the attendees started networking, everyone spoke enthusiastically about their interests in DIYbio, their current and future projects and exchanged contact information for potential collaborations. The second workshop was a safety training for using the wetlab. We reviewed laboratory safety techniques that included YouTube educational videos which were informative as well as humorous. We were given a written exam to test our new safety knowledge and at the end we all went

through the test and discussed the right answers together. The organizers pointed out that these safety rules would become clearer as one starts working in the lab and assured that you can always ask someone for help. We also received a tour of the hackerspace, saw where the equipment was located and how to use them, as the manager of the lab said “we want you to feel at home”.

The online DIYbio mailing list (§A.2) involves actors from many countries and it is encouraged to have all discussions in English. The language used is a mix between informal talk, Internet slang, and biotech jargon. The topics include people updating on their current projects and sharing current events, but most of them have to do with exchanging scientific and technical knowledge—people ask for help, advice, or for expertise. When projects are shared, people inquire about specs and encourage each other to share all the information as to foster collaboration. Topics can then quickly gravitate towards issues of IPR and they discuss strategies and mechanisms to make their projects free/*libre*. There are moderators to the list but they only ‘weed out’ spam and have taken a stance against deleting posts upon requests in an attempt to avoid censorship. The moderators are the original creators of the discussion site and so far their role has not been questioned or challenged on the contrary it has been praised.

Overall both the biohackerspace and the DIYbio mailing list primarily serve as networking places where members apart from serious engagement in the science, they socialize and establish relationships for future and ongoing collaborations.

CHAPTER 5

DISCUSSIONS

“Science is an integral part of culture. It's not this foreign thing, done by an arcane priesthood. It's one of the glories of the human intellectual tradition”

— Stephen Jay Gould

In order to provide the foundation to understanding the DIYbio movement my research questions focus on investigating into the mechanisms characteristic of social movements which includes a shared collective identity that abides by similar values and meanings of the world, a conflictual relationship with the dominant culture and clear goals to enact social change, and informal networks where members communicate, organize, and carry out collective action. I directed my attention to the construction of the collective identity of the movement which influences how individuals and groups make sense of their actions, in how they define opportunities and restraints within a system; and activates the relationship of "being together", it gives sense to the "we" and the goals they pursue together (Melucci, 1993). Therefore my research questions focus on (0) defining the collective identity as the expression of values and beliefs of the movement which (1) dictate collective action to challenge the barriers for social change (the problem-solution), and (2) on the solidarity that develops in the free spaces of the movement. To make the case more concrete I focused on the biohacker as the basis of the collective identity that provides the DIYbio movement the collection of cultural understandings that give meaning to the movement. So the analysis begins by analyzing:

(0) How is the collective identity of the DIYbio movement defined?

Firstly, the term *biohacker* is not necessarily adopted by all members of the DIYbio movement. Its meaning is attached to different concepts that widely affect what people understand what biohacking refers to and thus the concept of biohackers is fractioned which can affect the cohesiveness of the DIYbio philosophy as a derivation of the hacker ethos. The broader issue in defining biohackers is between the perception of hacking as 'good' or 'bad'. Among the general population the word hacker can refer to nefarious cybercriminals[30] that hack passwords and bank accounts which applied to the realm of biology brings understandable concerns over widespread access to user-friendly biotech (Schmidt, 2008). To avoid this misconception some biohackers may use more 'neutral' labels such as DIYbio, citizen science, amateur science, or biotinkering—the same choice has been seen in the creation and use of the word maker and makerspaces. Those who choose to use the term biohacking clearly distinguish it from nefarious activities which they label exclusively separate as bioterrorism. The caricature of the rogue biohacker is demystified in a purposeful effort to define biohacking as constructive and not destructive and conducted or at least supervised by academically trained individuals that follow biosafety guidelines and expert advice on ethical and safety issues. Whether they do so remains unclear and would require an in-depth investigation into the practices of biohackers.

The other tension in the word biohacker has to do with defining boundaries which can preclude and

30 Although the recent uprising of hacktivism with groups like Anonymous might be changing the societal perception of hackers as political cyber activists that hack for social change but this remains unclear.

include different actors from different fields of interest. Taking into account that a hacker is an enthusiast or an expert that enjoys solving problems and the meaning of 'hack' can be characterized as "an appropriate application of ingenuity" anyone can be considered a hacker. Herein lies the process of construction of the collective identity as the movement defines for example whether what Craig Venter, iGEM'ers, grinders, and home beer brewers do is biohacking, DIYbio, or part of the movement. The collectivity of the DIYbio movement in itself can be clearly defined as biohackers can discern those who are part of the movement and those who are not based on a sense of solidarity of sharing the same values, beliefs, and critiques that incite collective action.

The motivations and values expressed by biohackers do reflect what has been previously described in the literature (Delfanti, 2013; Delgado, 2013; Kelty, 2010) which in turn derive from the hacker ethos. Biohackers claim their main drivers are based on learning and curiosity and the desire to solve problems and create social value. They appraise working with passion and creativity and are thus dedicated to innovation and self-expression. They also strongly object to imposed requirements and restrictions of any kind that may exclude people from access and participation or infringe on their freedom of inquiry. These values in a way could be understood as contributing to the *Entertainment* motivation in Linus's Law, the one that provides personal gratification and a sense of personal enrichment, while their values of openness, sharing, and collaboration reflect communal values and fulfill the *social life* part of Linus's Law.

The collective identity of the DIYbio movement does prove to be a kind of sub genre of the hacker ethic. The mobilization of the hacker ethic as I explained elsewhere resulted in the creation of new cultural models and forms of relationship in the shape of FLOSS and hackerspaces for the production of immaterial and material goods. Biohackers mobilize through similar models that can ultimately be described as CBPP which is a new form of organizing production, governance and ownership. Considering DIYbio as a social movement acknowledges their premise for social change. Change is perceived as necessary due to grievances with an 'old' and dominant model that conflicts with how they make sense of the world and therefore formulate goals towards new models that match with their worldviews. The conflictual factor of social movements with the dominant culture can be considered as the main driver that mobilizes collective action to enact social change. Since collective action is directed by the collective identity my next research question addresses:

(1) How do members perceive conflicts and enact goals in accordance with its collective identity?

In short, biohackers challenge the *status quo* of the organization of science, or in hacker terms: they challenge the 'priesthood' and the 'cathedral' of the life sciences and technologies. They oppose the social construction of science as an exclusive activity and therefore try to reduce the barriers to entry to

allow and encourage individuals from different disciplines or without formal education to engage and contribute by providing the resources necessary for biological research. In this respect lies their goal to democratize biology—biology as knowledge, as science, and as a technology. Furthermore biohackers denounce the *Authoritarian*, *Commissioned* and *Expert* PLACE norms of post-academic science; the counter norms to *Universalism* and *Disinterestedness* of CUDOS. Biohackers claim scientists have lost the freedom in their profession and so they counteract with a deep commitment to freedom of inquiry so that scientists, designers, artists, or entrepreneurs can freely engage and pursue their own interests. Finally, biohackers denounce the reward system of scientists which fosters competitive behaviors towards priority (publications) and market potentials, which are furthered protected under IPR which they consider makes science and technology needlessly expensive. Biohackers in this sense advocate for the FLOSS model to revive the *Communalism* of CUDOS by preserving scientific knowledge and technical information in a commons.

To understand the relationship and dynamics between how the DIYbio movement aligns collective action with their collective identity, in Table 5.1 I try to outline what could be considered three communal values that reflect the perceived conflicts as problems and the corresponding solutions as goals that align with their new values; which are given as *openness*, *freedom*, and *collaboration*.

Table 5.1: The problems, solutions and their effects of the goals and values of the biohacker

Value/Purpose	Problem	Solution	Effect
Openness:	Scientific research requires specialized degrees and access to professional labs (the scientific elite).	Provide accessible, affordable, easy-to-use resources with no entry requirements or qualifications needed.	People from different disciplines come together and engage in continuous learning and offer more diverse approaches to problems and solutions.
Freedom:	Scientists comply with developing knowledge for publications or private companies.	Everyone can freely pursue their own interests and curiosities. No justifications needed.	People can express themselves and find meaning and satisfaction from what they do (activism, science, art, entrepreneurship).
Collaboration:	Competition for priority and monopoly prices keeps knowledge a secret and an expensive commodity.	Share everything as free and open-source.	People can freely improve and customize things to their needs. Innovation is faster as more people collaborate and compete with new ideas not keeping secrets.

The effects from the proposed problem-solution framework may represent goals in themselves for some biohackers, for example some may state their goals in terms of education, social innovation,

self-expression, or entrepreneurship. However these should be considered as effects because they are the outcome of the opportunities that the movement creates by democratizing biology.

The practices of DIYbio can be considered as a mode of 'political action' (Roosth, 2010) as they frame science as a right rather than a privilege, and they also question issues of ownership and distribution. Although the term 'democratization' is a politically charged subject, and in effect CBPP is about managing the means of production as a commons which challenges the capitalistic notion of property and waged labor, biohackers much like FLOSS are politically agnostic (G. Coleman, 2004) and frame the DIYbio movement as a cultural paradigm shift—to change the perception that biology can be hackable by anyone and that a CBPP model is a more efficient and productive model for the development and distribution of STI. This aligns with Alan Scott's argument that new social movements[31] are first cultural and second, if at all, political (Scott, 1990). Developing a cultural ethos of "cooperative individualism" is considered by Bauwens (2005) as one of the key infrastructure to enable P2P projects.

In social movement theory, there is also a debate whether social movements are reactionary, proactive or ambivalent towards the dominant culture (Buechler, 1995). As recognized by Delfanti (2013), biohackers portray a general ambivalence towards capitalism, and it is this respect that biohackers reflect the moral ambiguity of OSS in contrast to the moral imperative of FS against IMP. DIYbio is not necessarily antagonistic towards Big Bio institutions, as it depends on their productive activities and sometimes on their funding. The challenge to these institutions lies in their use of a scarcity-based model that is in crisis that offers little to no competitive edge in the AI world of abundant information, and distributed capital and cognitive resources[32]. Big Bio institutions are thus in the midst of a transition themselves with initiatives such as open access and citizen science from academia, and open innovation and open-source business models from industries[33]. This can explain how academia and industry have established relationships with DIYbio as they recognize its potential as low-cost learning and innovation centers. Given that these institutions are big and with well established reward mechanisms, transformation can be slow, therefore DIYbio still operates in symbiosis with big institutions but is able to practice new cultural models in alternative spaces. Which brings me to my last research question:

(2) How is the collective identity reproduced through its informal networks?

31 New Social Movements is a theory of social movements that maintains that social movements in post-industrial societies (since the mid-1960s) are different from previous proletariat mobilizations in that they are related to post-materialistic values. For a review see *New Social Movement Theories* (1995) by Steven M. Buechler.

32 As for example projects like Wikipedia and Linux, or crowdfunding and peer-to-peer business models.

33 Tesla Motors announced in June in a blog post they were releasing their patents "in the spirit of the open source movement, for the advancement of electric vehicle technology".

The informal networks, or otherwise known as *free spaces*, *movement areas*, *cultural laboratories* or *spheres of cultural autonomy* are different names for the same thing to denote "small-scale settings within a community or movement that are removed from the direct control of dominant groups, voluntarily participated in, and generate the cultural challenge that precedes or accompanies political mobilization" (Polleta, 1999, p. 1). Free spaces are essential for social movements as they constitute the places where solidarity, skills, and collective action are developed and identities, values and ideas are reproduced. From my experience in both online and offline networks these spaces effectively do that as dedicated work/play environments where members socialize and establish cooperative relationships; personal and professional, reinforcing the bond of the community. Moreover, these spaces strongly endorse open-source and biosafety practices which are part of the biohacker identity.

Many scholars argue that free spaces *must* be insulated from the dominant culture to avoid ideological intrusions and maintain a safe space where challenging ideas and tactics can be easily formulated (Friedman & McAdam, 1992; Morris & Mueller, 1992). As for many contemporary movements, Internet-based social networks provide the necessary spaces of autonomy for social movements to mobilize collective action (Castells, 2012), and the DIYbio movement thrives in cyberspace as online networks are independently managed and members are free to join and contribute. The solidarity in the DIYbio movement is extended through online social networks beyond a geographic location which enables them to mobilize action at a global scale; as they perceive the lack of access to biology as a structural problem of science as an exclusive and expensive activity and thus establishing biohackerspaces is the local solution to a much broader change. However, the autonomy of community labs in urban space—which are construed as open and alternative community-managed labs—can be compromised by being hosted and financed by formal institutions as some informants suggested their commitment to freedom of inquiry could be co-opted by sponsor interests. Francesca Polleta on the other hand argues that more than the physical separation from the dominant culture, mobilizing action relies on the cultural content, "what is crucial is the set of beliefs, values, and symbols institutionalized in a particular setting" (1999, p. 20). Moreover, to talk about a dominant culture fails to recognize that culture is not static, and that it is at the 'cracks and fissures' of this apparently hegemonic culture where social movements emerge from (Johnston & Klandermans, 1995). Mobilization in conjunction with traditional institutions, rather than co-optation, could signify the symbiosis between the biohacker and a new model of open science and open innovation—or what could be considered as the broader shift towards CBPP. A couple of informants disclosed the nature of their DIYbio labs as 'hybrids' because they are entirely hosted under universities but are combined with biohacking practices of developing open-source tools, sharing knowledge, and opening access to people beyond the 'Officially Sanctioned Users'. For example, although the wetlab I attended is sponsored under a host institution it did not

affect the ‘shoe-string’ budget characteristic of community labs which forces them to be thrifty and resourceful and the fact that I was able to attend educational workshops free of charge demonstrates a commitment to public outreach and engagement, and the lab safety course shows their approach to responsible biosafety.

These informal networks represent the conflictual spaces where their values of openness, freedom, and collaboration have to be defended against any intrusion of private interests to restrict participation, command projects, or seek profits through knowledge-hoarding (refer back to Table 5.1). The relationship and the subsequent power dynamics between biohackers and sponsoring institutions should be furthered studied as to ascertain whether there is a holistic integration of the hacker ethos, or the movement is at risk of exploitation as a cheap source of cognitive capital. Moreover the particular interests from these funding agencies can be called into question, as was the controversial case in the Maker movement of the Pentagon's Defense Advanced Research Projects Agency, or DARPA, donating $10M to expand the hackerspace model to 1,000 high schools in the US by 2014. The program was criticized by many members of the maker community who stood against the program including prominent hacker and co-founder of Noisebridge Mitch Altman “Having these programs in schools is fantastic, but the military calling the shots in American education? (…) I don't see that as a positive move” (O'Leary, 2012). DARPA funded projects are not exclusive to military purposes and are not new to hackers, after all the agency initiated the ARPANET project in 1969; the progenitor of the Internet (Levy, 1984). Back then, Levy explains, hackers defended DARPA sponsorship by claiming the projects were not for the military, which Levy denounced as denying the obvious “who was to say that all that ‘interesting’ work in vision and robotics would not result in more efficient bombing raids?” (Levy, 1984, p. 125). So could DARPA funded biofuel research be considered as a non-peaceful purpose as its intention is to be used in military aviation[34]? Or is it considered positive as it reduces their dependency to petroleum-derived fuels? How the biohacker movement will develop strategies and manage relationships with funding agencies and their interests while preserving their collective identity will be essential in the movement's success in maintaining solidarity and cohesiveness and ultimately achieve social change. The recent announcement of DARPA's new program, the Biological Robustness in Complex System (BRICS) for the development of synbio applications, might provide needed funding for biohackers[35], but it might also put up to debate how the community can maintain alignment with their proposed worldview—which include peaceful purposes—and the encroachment of an agency whose purpose is to develop technology for armed forces that are sanctioned to use lethal-force.

34 Which in all fairness can serve for humanitarian aid or for warfare.

35 Whether the program will officially support biohacking is unclear but is suspected as a biohacker in an online forum claimed DARPA was scheduled for a visit to their community lab. Supporting biohackerspaces could be expected given their recent interest in financing the maker movement.

5.1 RELEVANCE OF THIS THESIS

This thesis contributes to understanding a new sociological phenomena, the DIYbio movement, by generating insight into the mechanisms through which it mobilizes collective action towards social change. The proposed problem-solution framework identifies the key strategies that the movement mobilizes and differentiates these goals—openness, freedom, and collaboration—from more personal goals of biohackers such as learning, or entrepreneurship. Overall the DIYbio movement is part of a shift into P2P science (Bauwens, 2010) which is part of a broader phase transition; Jeremy Rifkin's (2014) Collaborative Commons, Benkler's (2006) CBPP, where the free culture of FLOSS equivalents are mutualizing knowledge, while the sharing economy of hackerspace equivalents are mutualizing the physical infrastructure (Bauwens, 2014). The DIYbio movement can be seen as the key agent to bring about social change in the life sciences and technologies by promoting the transformation into open science, open technology, and open innovation, that is towards CBPP. As academics, industrialists, and policy makers, unite to confront the global challenges of environmental degradation and climate change, the DIYbio movement can be seen as an inclusive and low-cost methodology to crowdsource cognitive and capital resources to face these issues together; the institutions with civil society, and the global north with the global south through the collaborative commons.

5.2 REFLECTIONS ON THIS THESIS

The limitations and implications of this research are worth reflecting on critically; on the methodology and how it can be improved and on the nature of the data obtain. I also provide my personal and expert opinion as a life scientist on the DIYbio movement.

5.2.1 IMPROVING THE METHODOLOGY

Combining several research methods such as participant observation and discourse analysis was helpful in immersing myself in the movement, but it came at a cost of fully analyzing each one of these parts. The participant observation was especially difficult to gather data. In the case of the online forum the information was vast and continuously dynamic and thus complex to code. Also access to the biohackerspace only included workshops in a controlled public outreach setting so I was unable to observe fully how it is that members reinforce their beliefs through their everyday activities in the lab. Therefore I suggest that quantitative discourse analysis of the online discussion forum could provide more substantial data into the topics and themes that are discussed and participation in more biohackerspaces could yield insights into how communities reinforce and reproduce their cultural materials and how they create solidarity between members and how they use it to recruit new actors.

From the interviews, the interview guide was helpful in drawing meanings and values of the informants, however, the questions could have been better designed as to elicit more coherent and concrete answers. The semi-structured format was appropriate for exploring meanings and it provided rich data but it proved to be complex and difficult to manage. The interviews at times would take unexpected turns as the interviewees would interpret questions in different ways, even when I tried to insist for a specific 'answer' they would try to iterate their initial response. I would not push the issue as to avoid taking complete control over the interview as I wanted them to express their own ideas and interpretations. Therefore I would suggest a more structured interview could give more amenable data for comparison. Another issue was the sample size of the interviews conducted (only seven) which can put into question whether different and commons perspectives were missed. Performing more interviews until reaching saturation would be a good method to ensure more representative data. The data obtained from the interviews provided rich data taking into account the global spread of the DIYbio movement with participants from three different regions of the world and six different nationalities. The median age was 24, they were all highly educated, and the majority were male; only one female interviewee. I therefore suggest that it is important to obtain a more heterogeneous mix of social conditions as the opportunities that the movement creates for each may be different and therefore the motivations, values, and grievances might change.

5.2.2 CONSIDERATIONS FOR THE RESULTS

The DIYbio movement portrayed in this thesis concerns itself with opening science which reflects the discontent with post-academic science. But the DIYbio movement is not just for scientists (as all interviewees were see Appendix E) as there are other identities that integrate into the movement, such as artists, activists, and entrepreneurs that may bring different critiques and visions that will influence the overall collective identity and dictate future collective action. Artists and activists may bring more provocative or subversive themes while entrepreneurs may bring leadership and independence which could affect the relationships between the challenging culture of DIYbio with that of the 'dominant' culture. I would suggest expanding data from these perspectives and analyze how they influence and are being influenced by the overall collective identity of the DIYbio movement.

The discourse that was captured was in its majority overwhelmingly techno-progressive and pro-DIYbio as I did not gather opposing or challenging views towards biohacking in my data collection. The insiders point of view was expected to be positive, but the outsiders perspective (articles) did not offer significant counterpoints towards the movement. Opposing views are important as they also shape the collective identity by offering different meanings. These negative perceptions could come from concerns over biosafety or biosecurity, or from bioconservatives that oppose modifying or enhancing

living organisms. Whether the concerns of these individuals are justified or not is beyond the scope of analysis of this thesis in understanding DIYbio as a social movement, however the debate and decision-making on regulations, oversight, and restrictions will most certainly influence the DIYbio movement in terms of creating new strategies of compliance, compromise, or workarounds that should keep in line with the collective identity.

5.2.3 PERSPECTIVE AS A LIFE SCIENTIST

With my former education as a food scientist and engineer I learned how we could use and adapt yeast and bacteria to produce beer and yogurt, and as a life scientist with a major in cell factory[36], I now understand the potentials of using and adapting microorganisms to produce biopharmaceuticals, bioenergy, biomaterials or even for biomining and bioremediation. The difference is that food is mainstream while biotech is not, and this is what the DIYbio movement is trying to change. It is in this contrast where I can draw a meaningful comparison from my experience as a professional in both.

As a food scientist I take my knowledge into the kitchen as I understand and adjust conditions to achieve better fermentations or caramelizations. Most importantly I exercise basic food safety practices to avoid microbial growth, cross contaminations, and I rotate my sanitizers to avoid the proliferation of resistant bacteria. In this respect I can understand why DIYbio has a strong value towards biosafety, as if the production of food were an exclusive practice to food scientists like me, and we were starting the food hacklabs movement, we would implement and teach these basic principles. In its majority all DIYbio labs have highly qualified individuals and they are instilling basic safety practices into DIYbio labs from the get-go.

As a food enthusiast I continue to enjoy and appreciate food for its artisanship and its science. But as a life scientist the practice of biotech is still somewhat unreachable beyond a formal occupation as a student or as an employee in a university or a company. The DIYbio movement empowers scientists like me to explore biotechnology in a way that is meaningful for us. DIYbio may not produce the next synthetic cell anytime soon, but as I come from a developing country I see more value in developing low-cost technology that has great social and environmental impacts while the open-source philosophy ensures free knowledge and technology transfer.

36 Cell Factory is basically the idea of understanding microorganisms as a factory, where raw materials come in, they undergo an engineered production process, and out comes a finished product.

CHAPTER 6

CONCLUSIONS

“The degradation of labor, education, and the environment is rooted not in technology per se but in the antidemocratic values that govern technological development”

– Andrew Feenberg

In this thesis I try to understand DIYbio as a social movement from social movement theory by generating insight into the mechanisms through which the movement mobilizes action for social change. For this, I focused on the collective identity of the movement which I recognized as the *biohacker*; an adaptation of the hacker ethic and FLOSS practices into biology which overall fit into the new socio-technical paradigm of ICTs and the cultural/economic paradigm of CBPP. The collective identity serves as an analytical tool to understand how members of a movement recognize themselves and others as part of the movement and reorient themselves and their actions based on shared meanings of the world. To investigate how members construct the collective identity I researched into the practices and discourses of the movement where they express their motivations, values, and critiques of the social world and how the movement fits into it. I drew my attention into the characteristics, values, and motivations of biohackers, how these collide with the mainstream culture and thus direct collective action for change, and finally how these are reproduced in the online and offline networks where they mobilize action.

What I found is that the word biohacker is a contentious term between the differing connotations of 'good' and 'bad' hacking and thus biohackers take a proactive approach in defining themselves as constructive not destructive, and assert their identity as strongly oriented towards good biosafety practices and distinct from bioterrorist activities. Defining the boundaries of biohacking between actors and fields of interest proved to be problematic as they disagree on for example whether someone like Craig Venter is a biohacker. However, the biohacker as the collective identity of the DIYbio movement is clearly defined as members recognize themselves and others as part of the movement as they share the same values, beliefs, visions, and critiques that incite collective action for social change. To understand the dynamics between these imaginaries I proposed a problem-solution framework based on three main values from the numerous values and motivations of the biohackers—which proved to be a subgenre of the hacker ethos—which reflect concrete actions that the DIYbio movement mobilizes in the informal networks (movement areas) to achieve social change. The first one is *openness* which conflicts with the exclusive practice of science to professional scientists in professional labs, in turn biohackers want to open access, or in other words: democratize biology as knowledge, as a science, and as a technology. The second one is *freedom* which conflicts with doing science for extrinsic motivations, and so the DIYbio movement is committed to freedom of inquiry to enable biohackers to find meaning and satisfaction through DIYbio on their own terms whether that be activism, science, art, entrepreneurship, and so on. The third one is *collaboration* which challenges the current model of science as a competitive ordeal that treats knowledge and information as a commodity—an expensive commodity of protected monopolistic prices—by sharing everything as an open and unrestricted commons where anyone can freely contribute and collaborate to any kind of DIYbio project.

This proposed framework can serve as a basis to understanding the strategies of the DIYbio movement to achieve social change (through openness, freedom and collaboration) as well as to illustrate the opportunities that it creates such as informal education or social innovation. The DIYbio could be considered a political movement as it addresses issues of access and participation to the productive activities of STI, and of the ownership and distribution of the means of production, both material and immaterial wealth such as knowledge and information. Biohackers however are for the most part politically agnostic as they consider the logic of their actions to be cultural rather than political. Nevertheless the goals of the DIYbio movement should be considered as both, as the DIYbio movement develops two key infrastructures (Bauwens, 2005) necessary for sustaining a P2P science: the technological infrastructure by providing access to tools through FLOSS and biohackerspaces and a cultural infrastructure under the (bio)hacker identity with new forms of social relationships and values.

A new model of P2P science is already making its way in institutional science with initiatives such as open science, citizen science, and open innovation, where they establish close cooperation and funding mechanisms with DIYbio. Whether their support comes from legitimately recognizing DIYbio as an low-cost and inclusive solution to education and innovation, or as an exploitation of cheap cognitive capital remains unclear and is yet to be seen. What is certain is that DIYbio will have to develop strategies to take advantage of new opportunities created, as they navigate between the old model and the new model (CBPP), while preserving the ethos of the movement. Such case would be how the movement will manage government and corporate funding whose interests might encroach on their freedom of inquiry by dictating projects or suppress their commitment to openness and sharing by demanding IP protection for commercial exploitation. Whether biohackers defend their ideals, compromise or comply with these intrusions will determine whether the movement is co-opted, or is able to work in a more symbiotic relationship with mainstream science, or both converge into P2P science which could replace the current production model and become the default. Further studies into the different business models and forms of governance of biohackerspaces might give more detailed knowledge on how the biohackers maintain cultural autonomy as the movement grows and struggles between an integral model or a tension model with the mainstream.

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APPENDICES

APPENDIX A PARTICIPANT OBSERVATION

The participant observation was performed through direct participation in offline in workshops of a biohackerspace and direct observation in online social networks and discussion forums.

A.1. DIRECT PARTICIPATION IN BIOHACKERSPACE

I was directed to this biohackerspace by searching online on near DIYbio groups. I was able to join an online meeting platform where events were posted and I R.S.V.P. to two separate workshops with no requirements or fees to attend. The biohackerspace was more of a 'wet corner' in a FabLab that is sponsored by many state initiatives to fund art, science, technology and social innovation. The place offers most of the equipment a FabLab offers and the space had a chic design, with projects showcased around table benches. The wetlab had its own room and was equipped with many of the basic necessities of a lab, like a PCR, a fridge, a centrifuge, a microscope, an incubator and many lab supplies.

The first workshop I attended was in the evening and upon arrival we were invited to dinner and drinks (including beer and wine) free of charge. During dinner, people freely sat close to each other to engage in casual conversation about the workshop and exchanged our interests and our professional and cultural backgrounds. After the 'ice was broken' we went straight into business and started with a presentation by one of the members. In the presentation we reviewed a short history of microbiology and biotechnology, emphasizing the contributions of amateur science. Later we revised two case studies of current projects from DIYbio, we were asked to form teams to explore ideas on possibilities and solutions that can be created with genetic modification. The people in my team was composed by a wide variety of backgrounds, artists, designers, natural scientists, social scientists, and people from the humanities. We all began to exchange ideas, especially the artists and designers and the technically trained people would assess the feasibility of the proposed project. These ideas were presented and we discussed some of the ethical, philosophical, safety and practical implications of everyones project. At the end of the workshop some people left on some stayed to finish the drinks and to continue socializing and conversing with each other about various topics of interest and how they relate to DIYbio. I talked to a designer that is helping in the design for a web application for scientific projects, with emphasis on genetic engineering, I also discussed with artists and their interest in biology where they shared their experience in this new field for them, and I also talked with people from other cities that are involved in other DIYbio groups. At the end of the meeting most of us had exchanged contact info to keep in touch.

The second workshop was a safety training course for working in the lab, no dinner but drinks included(no beer or wine this time). The beginning consisted of going through some of the basics of biosafety, such as what is a pathogen and why is it important to wash your hands, and how you should dress in a lab, and how to handle chemicals safely. The information on lab safety techniques was supplemented with YouTube videos: Zombie College and Crash Course Chemistry. The videos were informative but humorous at the same time which made the meeting more enjoyable rather than just a monotonous talk. We then did a tour of the space and the lab including the equipment and their use, we saw a demonstration on how to wash your hands before and after you go into the lab and the 'most important part' we were taught how to use the coffee machine. The tour of the lab was meant in the host words so "you can feel at home. Given that I am a trained natural scientist and I have had my fair share of time in laboratories, this place would be considered a poor sight to see compared to a university lab but nonetheless it had some of the most basic equipment and materials necessary. The place has been roughly adapted to work as a lab, and being that the lab is managed by individuals with a background in science, it is easy to see that they have applied the practices learned in their academic education There is a requirement to wear lab coats and goggles which are provided in the lab. The lab materials are categorized and labeled, and there was documentation There is a lab notebook for each of the equipment and a manual nearby. After the tour we returned to the open work area and we were given a short individual written test on the lab safety techniques we had learned before. We then discussed the answers and afterwards were were given a certificate for the training and parted ways.

A.2. DIRECT OBSERVATION IN ONLINE DISCUSSION FORUM

Online observation was performed through many online social networks and discussion forums which I easily joined by subscribing or joining the platform. I mainly kept updating on the discussions in the DIYbio mailing list. Here I would revise some of the issues discuss by the participants and review the flow of conversations and raised discussions. The mailing list is a huge network with over 3,000 members subscribed. Although I did not perform any rigorous quantitative measures, my general impression is that there is a much smaller group of active participants and a core group that voice their thoughts more often than others. This core group, judging solely on their names which excludes certainty especially with user names, I would still assert that it is mostly male voices in the forum, although this issue should be properly verified.

APPENDIX B MEDIA ARTICLES INFORMATION

The following table presents a comparative review of the documentary sources and their context

SOURCE INFORMATION*						ARTICLE INFORMATION†			
Publisher	Type & frequency	First issue	Country of origin	Total in circulation	Focus on	Title	Author	Position	Date
theguardian	Daily Newspaper	1821	Britain	192,228	News	Manchester's MadLab spends time with the FBI	Asa Calow	Biohacker	18 Jun 2012
The New York Times	Daily Newspaper	1851	United States	1,250,000	News	When Breakthrough begin at home	Ritchie S. King	Reporter	16 an 2012
nature	Weekly Journal	1869	Britain	--	Scientific Research	The DIY dilemma: Misconceptions about DIYbio mean that opportunities are being missed	Editorial		26 Nov 2013
Forbes	Bi-Weekly Magazine	1917	United States	931,558	Business	Citizen Science Takes Off:Could Community Labs Hatch the Next Generation of Bio Innovators?	Adrianne Burke	Reporter	25 Oct 2011
TheScientist	Monthly Magazine	1986	United States	--	Life Sciences	DIYbio: Low Risk, High Potential.	Todd Kuiken	Researcher	1 Mar 2013
WIRED	Monthly Magazine	1993	United States	851,823	Technology	Genome at Home: Biohackers Build Their Own Labs	Erin Biba	Writer	19 Aug 2011
VICE	Monthly Magazine	1944	Canada	900,000	Culture	For the Most Part, DIY Biologists Are Not Working on Creating Pandemics	Jason Koebler	Writer	19 Nov 2013

* Information obtained from Wikipedia entries for each articles

† Information obtained from the article page‡

APPENDIX C REVIEW OF ARTICLES

The following tables present the discourse conveyed in the seven articles reviewed along with representative quotes. The selection of quotes and the analysis of the whole paper give insight into some of the perceptions given from popular media outlets, which tends to be the first point of contact to the larger audience. Specific information on the publisher and on the article itself can be found in previous Appendix B.

C.1. KEYWORDS MENTIONED

Mention of keywords such as labels, values, etc.

theguardian	DIYBio, DIYbio, Amateur biology, community space, hacking, biotechnology, hackerspace, community lab. (bio)safety, transparency
The New York Times	DIYbio, DIYBio(.org), Citizen science, biohackers, amateurs, biotechnology, open-source, safety, terrorism, sharing
nature	DIYbio, Amateurs, biotechnology, crowdsource, community lab spaces, access
Forbes	DIYbio(.org), DIY bio, Citizen science, public-use laboratory, hackerspace, crowdfunding, biohacker, open-science, open-source, community labs, DIYbio ethics, wetlab, amateurs, entrepreneurs, sharing, access
TheScientist	DIYbio Synthetic biology, biosafety, biosecurity, community laboratory, citizen science, education, innovation, curiosity, transparency, code of conduct
WIRED	DIYbio(.org), Biohacker, open source, creative, amateur, maker, community lab, hackers, free (gratis), sharing, access
VICE	DIY biology (DIYbio.org), Amateur scientist, hackerspace, community labs, biosecurity, terrorist, social good, sharing, transparency, ethics

C.2. DESCRIPTION OF BIOHACKERS

Descriptions on what biohackers do, what they believe in or how they act:

theguardian	Only addresses DIYbio. Notes that they organize, and play. They organize projects for teaching Notes a diversity of scientists, artists, designers, journalists, activists and academics. Also emphasizes values of openness, sharing and transparency.
The New York Times	No distinction between DIYbio and biohackers and calls it citizen science. Mentions their academic degrees. Notes sharing and collaboration. Notes their concern for safety
nature	Only addresses DIYbiologists. They are enthusiasts but are also expert amateurs.
Forbes	No special distinction between DIYbio, biohacking or even biopunk. Although biopunk is mentioned in the context of Marcus Wohlsen's book who compares them with “code hackers who revolutionized personal computing”. Quotes George Church, “Biohackers are to biotechnology what Steve Jobs was to the IBM S/360 mainframe”. Biohackers “want to contribute to society by engineering life itself” Notes biohackers are professionals

TheScientist Only addresses DIYbio, Describes them as concerned for safety. Points out biohackers are professionally qualified scientists."Citizen scientists are dedicated to education, innovation, and problem solving, using a new model in the human spirit of curiosity and exploration"

WIRED No distinction between biohackers or DIYbio. Amateur scientists. Describes biohackers as passionate of what they do. Highlights the desire of biohackers for hackable and open-source machines. Biohackers teach. Biohackers sell their inventions and share them. Biohackers have a reduced interest in money. Highlights collaboration with customers based on modifiable kits and feedback.

VICE Only addresses DIYbiologists and says they adhere to safety standards. Highlights that they are experts and academically trained. Notices how they have created commercial products. Create educational tools.

C.3. BIOSAFETY CONCERNS REGARDING DIYBIO

Some of the articles reflect the concerns of biosafety and bioterrorism with DIYbio:

theguardian The author notes that the words "open" "amateur" and "biotechnology" (his quotes) can cause an initial reaction of concern. Although he does not dismiss the point the text seems as if he does not support this view

The New York Times "The idea of amateurs doing their own biology has raised fears about both deliberate bioterrorism and the unintentional creation of a deadly disease. But making a new and virulent pathogen is far from easy, and the DIYbio community has adopted a set of safety standards to minimize such risks." The author goes on to add how a biohackerspace has a strict policy against working with pathogens and that is established a safety review board members from reputable institutions for approval for new experiments

nature The editorial starts by saying that the DIYbio movement has "an image problem" between low skilled misfits and "twisted experts hellbent on harm" and notes neither is the case and describes them as educated enthusiasts. She acknowledges the potentials from DIYbio that states "a key problem" no governmental oversight.

Implies that DIYbio'ers will do anything as "long as it's legal", saying that this freedom inherently in the movement keeps 'legitimate' funders away and keep community labs under threats of closure. Says government support would "give them more access to and potentially more control over the work that goes in labs that they fund". Goes on to say that DIYbio'ers "do not favour government regulation, now or in the future", but then notes that the people in the survey 43% agreed to regulation in the future "as the movement matures" Like synthesizing DNA at home.

Finishes with "The security and stability of government funds would safeguard the future of the DIYbio movement; the issue is whether the movement would accept the trade-offs that such stability would bring"

Forbes No mention at all of safety concerns

TheScientist The article starts stating the growing concern of DIYbio and concerns and potential dangers especially in synthetic biology and points to articles with this focus. But continues to say "But much of this alarm is overblown, as critics overestimate the current abilities of the DIYbio movement and underestimate the ethics of its participants" He notes that concerned parties have called for government oversight but the community has proven proactive in addressing these concerns with external advisory boards and points to the campaign of "Ask a Biosafety Expert" in the DIYbio mailing list and notes how the community has drafted codes of conduct. "These initiatives demonstrate that citizen scientists understand the risks associated with their work and feel a sense of responsibility to mitigate those risks" Goes on to say that "There is no evidence to suggest that these efforts pose undue risk to society, and the DIYbio community holds the potential to improve science education in the U.S" And finally "Public policy should be written to enable the exploration

and innovation of the DIYbio community—not to limit its reach based on overblown fears of the unknown"

WIRED Makes no mention to biosafety concerns put points to how a biohacker though of moving his lab into the living room near the front door but didn't want to "freak people out". The author says "it's easy to see why he's worried. With its Pyrex containers on metal racks and other clinical-looking equipment, the bedroom looks perfect for cooking crystal meth."

VICE Starts with saying the "mad scientists in the garage" (his quotes) from headlines describing the DIYbio movement "is unlikely to be crazy, perform experiments in the garage, or actually be a (professional) scientist, according to a new study of people who practice the hobby." referring to the Wilson survey. Goes on to quote Grushkin "People think they're the boogeyman, think they're working on creating life or synthesizing something in their home labs, and they're not." Grushkin says that having a community lab "The chance for ignorant people doing ignorant things is lessened when people with lab backgrounds are around."Brings up concerns of some of DIYers creating the next pandemic or homegrown terrorist, even quotes a university professor quoting how he is worried about this.

C.4. GOALS OF THE DIYBIO MOVEMENT

Description of goals and motivations of biohackers:

theguardian Notes a biohackerspace as successful for introducing people to biology. Also notes they make their own equipment and run experiments "just like academic and commercial environments."

The New York Times Notes biohackers for making simple and cheaper lab equipment. Quotes a co-founder of a biohackerspace saying that the concept of a biohackerspace is "to get as many brains as possible working collaboratively on biotechnology"

nature No relation to a goal. Describes the movement as a diverse group of biology enthusiasts that are not affiliated with traditional science centres.

Forbes Cites Wohlsen's book Biopunk casting biohackers as "pioneers of a movement determined to democratize DNA and transform bioscience." Goes on to state that biohackerspaces "aim to lower the barrier to entry for biotech startups by providing shared access to costly tools and connections to like-minded people"

TheScientist There is a sense that it situates DIYbio as citizen science "Citizen scientists are dedicated to education, innovation, and problem solving, using a new model in the human spirit of curiosity and exploration." Also notes the positive impacts of DIYbio of developing cheap technology.

WIRED Defines DIYbio(.org), as a "worldwide network of "biohackers" dedicated to creating pop-up labs and doing biology outside the traditional environments of universities and industry."

VICE Notes a biohackerspace as a community lab that "has given amateur scientists a place to work and to learn from each other"

C.5. CONFLICTS OF THE DIYBIO MOVEMENT

Mention of some of the grievances of biohackers:

theguardian There is no apparent need or grievance as to why people do DIYbio. Notes that biohackers don't buy "the latest and most expensive kit".

The New York Times Notes "To DIY enthusiasts, one of the must frustrating things can be the pace" it refers to how biology is an laborious practice, and that the smallest error can make you start all over again. Also notes "An even bigger hurdle is all the expensive gear".

nature Asserts that DIYbiologists do not favor government regulation.

Forbes References to the 'barrier to entry' and costly tools for doing biotech. Quotes Gentry "There's an elitism around science"

TheScientist Notes a problem with the current state of education "Projects like this are exciting the next generation of scientists, engineers, and innovators in ways that traditional curricula cannot."

WIRED Notes "the barrier to entry wasn't education or even space. It was a lack of affordable tools". Continues "no amateur is going to drop tens of thousands of dollars to get a lab running, and many scientists don't understand the inner workings of their expensive, grant-funded gadgetry well enough to whimsically crack the machines open and see how they can be modified"

VICE No apparent grievances.

C.6. INFORMAL NETWORKS OF THE DIYBIO MOVEMENT

Description of biohackerspaces:

theguardian Describes MadLab as a community space for science, technology and art and describes BioCurious as a community biotechnology lab. Describes BioCurious for repurposing of materials, beer in the fridge and biological equations graffitied in the toilets. "it feels more like a hackerspace"

The New York Times Describes a home laboratory "filled with makeshift equipment." Describes one biohackerspace as a 'rallying point' as a "nonprofit laboratory" "that is open to members of the public, regardless of scientific background"

nature The only description is that they are outside traditional scientific settings "The movement is made up of enthusiasts with a range of backgrounds and interests in biology, who work in wet-lab spaces not affiliated with traditional science centres such as universities."

Forbes Described Genspace as a non-profit laboratory open regardless of scientific background.

TheScientist Describes Genspace as a community laboratory and asserts it is a BSL1 and also describes how the DIYbio.org website also addresses issues of transparency. Notes Genspace for reaching out into the community

WIRED Starts with the description as makeshift in someone's house.

VICE Starts with the myth that biohackers work alone in their garages. They work in community or university labs or in hackerspaces.

APPENDIX D INTERVIEW GUIDE

QUESTIONS:

(1) How would you define DIYbio? How do you explain it to people?

(2) Does DIYbio have goals? If yes, which ones?

(3) Many address DIYbio as a movement. What do you think this means?

The point of a social movement is that it is a collective effort to start or stop change.

(4) Does DIYbio challenge current social structures or have any conflicts?

(5) What do you think attracts people to join DIYBio?

(6) What was it that particularly attracted you about DIYBio? How did you get involved?

(7) How influential is being a part of the DIYbio movement in your life?

(8) Has it changed in anyway how you view or your perspective on things?

(9) What are good and what are bad behaviors in DIYbio?

(10) Where does DIYbio stand in the relationship between science and society?

(11) Where does DIYbio stand with Academic and Industrial science? Are they friends or foes?

(12) In what ways does DIYbio differ from these traditional institutions in the production and dissemination of scientific knowledge (R&D)?

(13) Many use the word biohacking interchangeably with DIYbio. Do they mean the same thing?
Probe are iGEM'ers biohackers? Is Craig Venter a biohacker?

(14) What are the common misconceptions of DIYbio?

(15) Where do you think DIYbio will be in in the future, say 2030? Where would you like it to be?

(16) How do you think of your future-self as part of DIYbio?

(17) What do you think could be 3 positive/advantageous consequences of DIYbio and society?

(18) What are 3 negative/disadvantageous consequences it can have? How could these be overcome?

DEMOGRAPHICS:

- Gender
- Age
- Education
- Occupation
- Biohacker since

APPENDIX E INFORMATION ON INTERVIEWEES

The following table presents demographics of the informants and interview stats.

Informant Demographics							Interview Information		
Code Name	Region	Age	Gender	Education	Occupation	Biohacker since	Time and Date	Duration	Language
Blue	Western Europe	27	Male	M.Sc. In Life Science & Technology	Professional Biohacker	6 months	14:00 hrs 15/05/2014	2 hrs	English
Green	Western Europe	24	Male	M.Sc. In Molecular Biology	M.Sc. student	1 year	16:20 hrs 06/19/2014	1 hr 45 min	English
Grey	Western Europe	29	Male	Ph.D. in Biotechnology	Ph.D. student	1 year	14:00 hrs 23/06/2014	1 hr 40 min	English
Black	Latin America	29	Male	Ph.D. in Biotechnology	Post-doc student & biohacker	5-6 years	12:00 hrs 25/06/2014	1 hr 45 min	Spanish
Brown	Latin America	21	Male	B.Sc. in Biotech Engineering	B.Sc. student	6 months	01:30 hrs 28/06/2014	1 hr 15 min	Spanish
Red	Southeast Asia	18	Male	B.Sc. in Medicine	B.Sc. student	6 months	7:00 hrs 28/06/2014	2 hrs	English
Orange	Southeast Asia	22	Female	B.Sc. In Southeast Asian Studies	B.Sc. student	6 months	03:00 hrs 29/06/2014	2 hrs 20 min	English

APPENDIX F REVIEW OF THE INTERVIEWS

The full transcripts of the interviews are to remain private and confidential in the possession of the author of this paper up to one year after this publication and will then be destroyed, same for the recorded audio. The following information represents *verbatim* quotes that aid in the analysis of this thesis.

F.1. DIYBIO AND BIOHACKING, THE SAME?

The following are sections that reflect on how DIYbio is defined:

> For me the word DIYbio is very conflicting and there are a lot of dualisms for me as well. Because I know a lot of people use it and know the whole history of DIYbio, and at the same time people use it to label transhumanism, and quantified self, and sometimes they mean molecular biology, and sometimes just biology. So, in your opinion is brewing beer at home DIYbio or not? For me in a way it is. But at the same time those people do not feel associated with DIYbio at all.

> As soon as things start to get seriously then a lot of companies can spin-off DIYbio, and the moment it becomes professional it starts to become conflicting to be a part of the movement. Because how much DIYbio are you if you are a professional. Is it really Do-it-yourself if you are doing it professionally? And also the words, the sound of DIY is also working against you, dealing in a professional world.

> Well I think that at a glance they may look more scared if you say "Hello, I am a biohacker" But I think that is more related to the connotation this word has with the software world. Hackers have been depicted in this sort of Frankenstein way. So that is why they are a bit more weary if you present yourself as a biohacker. So I present myself as a DIYbio'er. In my opinion, in my mind, these two words are the same thing. I don't really see a difference.

> What is the common background of these people is the interest in science in general, the interest in technology, informatics, electronics, all these different backgrounds, and they come together and give rise to the DIYbio idea; it is a mix in DIY, and the hacker movement, and biology and science.

F.2. DEFINITIONS ON BIOHACKING

The following quotes reflect on some of the understandings of what biohacking is and what is not.

F.2.1. COMMON DEFINITIONS ON (BIO)HACKING

The following quotes are the answers from the informants on the meaning of biohacking:

> Hacking means just being creative with technology, using it in different ways that it was intended to be used for. Not so much in the dark side of hacking, as in breaking things, or sabotaging.

> Hacking just means discovering... it just means disassembling something to understand how it works inside, it just means you are doing it relating to biology.

> Well it is part of the DIYbio movement. Because the ground mentality is the hacker mentality, or philosophy lets call it. And it is there is something that you don't know how it works, and you want to disassemble it, and assemble it again to understand how it works, that is the hacking progress. And this can also be applied to biology and it is actually what molecular biology was since the beginning

> For me a hacker is someone who wants to understand how things work. You can take something and take apart and see how it works.

> Hacking is the sort of about studying a function and use that for alternative functions. changing a toast maker to do something else. so using that for biological purposes. But DIYbio and biohacking, there are some elements of DIY in biohacking but I think that biohacking is of changing a function and using it for another purpose.

F.2.2. WHO IS A BIOHACKER

This following quotes were prompted to define whether iGEM'ers and Craig Venter is a biohacker.

> [iGEM'ers are not biohackers because they] completely comply in the competition by the system. They don't try to break it or to change it, they are following the same rules. Very dogmatic. No. iGEM'ers are not biohackers.

> I think I could define a fellow biohacker as a person who is spending or investing a certain amount of time in their life contributing to the community. And you can contribute to the knowledge, or you can just show up any once in a while and help people with your knowledge. Also for instance someone who decides to donate money to the community in my opinion that is also a way of helping and investing, developing the community.

> IGEM is something very similar but I guess all the biobricks are not really free. But generally what you have are undergraduate students playing with pieces of genetic material and put them together to make a synthetic organism that is able to do something and this is biohacking.

> I consider [Craig Venter] a biohacker too but then we have to differentiate if we want to count the patent things. But Venter is also a biohacker, he started from an idea that mainstream science doesn't accept the artificial cells for example and he just wanted to do it. I would say in general that a good scientist is a hacker by definition. Because they look at nature with interest and disassemble pieces to understand how it works.

> When you see someone from iGEM that does something interesting in the sense that that person has a lot of potential and wants to really do something, so they start learning and can become a biohacker. (…) There are different levels to knowledge like in martial arts you have white, yellow or a black belt. So it is not that people cannot consider themselves as biohackers, but they are just people that are starting the path to learning that knowledge.

> [Being a biohacker] is a very subjective thing and should not be exclusive. Each person will take a different path in the movement but taking the initiative towards doing/building something is the first step if you want to call yourself a biohacker

> I think biohacking is more linked with science fiction, with the biopunk genre and with the the union between biological and electronics and with modification. It also relates more to synthetic biology and systems biology which is the genetic modification of an organism.

> DIY envelops biohacking, but DIYbio is more focused on making technologies more accessible regardless of what technology it is.

> I would consider [iGEM'ers] biohackers, although that word I have heard it used often with certain groups that are against GMOS, against biohackers.

> For me [DIYbio and biohacking] is not the same. Biohacking is more of a bioinformatics kind of activity where you can change DNA and how it works, know out genes and and things like that. Because I think that Craig Venter is also a biohacker but he is not very DIY is he?

> [iGEM'ers are biohackers] because they are people who change how something works, like how the biology is a biohacker. Not only change but how they improve it, they just want to know how to characterize it; what does that gene do, what does this gene do, it is all called biohacking

> [Craig Venter is not a biohacker] because to be a biohacker ultimately you have to want to distribute that knowledge and also not so entirely for commercial purposes but to make it more accessible, so i don't consider him a biohacker.

F.3. MOTIVATIONS AND EXPECTATIONS

The following quotes reflect some of the reasons on why they decided to join the movement and why they think others have joined:

> I would say that most of [other DIYbio members] are interested in the social change. How is biotechnology going to change because of these technologies they all do it in a different way, and I kind of define it as social innovation. Yeah social innovation through biotechnology, and it can be either science, business, philosophy, activism, it can be art, it all has certain impact on how people perceive the world and how they behave. But their attitude is the same.

> DIYbio is sometimes very similar to what is done in institutions, but people do it for different reasons. They are not for example aiming for publications or creating new knowledge, but more for their curiosity. For some kind of political goal, or communicating science and similar goals.

> [DIYbio] really has changed how I see the world, really how I see my future, I said "Ok you have academy, and there is company work, and I am basically going to fall in one of these two places". And know I see this third room. And yes you can ask me "well, you don't really earn money with it, it will never become your full time activity" But still for me it is a place, a community to be. To inspire innovation if you want to put it like that. But really inspire new ideas to be developed and enable anyone to really do it

I can say that for me on the personal level [DIYbio] is rewarding and also was moved in the beginning by curiosity. (…) What really attracted me about this movement was the open aspect of it. Make something that can be used by anyone else. And for me it was a great opportunity to interact with all these different disciplines (…) Everybody can learn something from the other.

The consequence of DIYbio I can see freedom of using the knowledge and freedom to pursue your own idea and project and I think also empowerment. Allowing the individual to realize more about the tools and the things he could do.

When I am doing [DIYbio] I feel I am changing something. I feel like we are doing something together and we are changing science has been done so far because you can imagine of course that industry always has done science, universities have always done science but not everyone, the citizens were not involved, and I think we are building this—it may be a confident statement—but we are building the foundations for this to happen. So that really anyone in the future years will be able to pursue their own biological project or pursue their own projects. And what I like also, what I see often now is that it is the community, the citizens, the people that are not say actively involved in our group, who are shaping how the community is building. So we really respond to the need and to the input and feedback that we receive from people. And this is due I think to our structure, our openness, because we don't have a really defined goal that we want to reach.

From my side I wanted to do some experiments. Just to satisfy my curiosity. But again, I can do them only in the lab, and in my lab for now I have to do what my professor wants me to do. So I don't have all this freedom of experimenting with biology that I would like to do.

I was doing interesting work in bioinformatics, like basic research, but I wanted to do something that had an impact in society.

When I learned about the DIYbio movement I saw an opportunity to make a change with my knowledge.

But for me, maybe it is because I always wanted to do science but then took another path, and I wasn't allowed to get back into that.... So i see it as an opportunity to do science.

F.4. SIMILAR VALUES AND PURPOSE OF THE MOVEMENT

The following quotes reflect some of the values exposed and opinions on whether DIYbio is a movement:

Creativity is one of the main values of DIYbio and openness enables that.

I think it is a social movement, because I think that it is changing the way people are interacting with each other.

I think we share certain values. Which are fulfilled doing what we are doing, like keeping things open to everybody and releasing open-software, open-hardware. And these are from the personal level, these are values. Trying to—I don't like to say it like this—but really trying to make the world a better place. These kinds of values, of freedom, trying to empower people with knowledge.

But usually if it is public research there will be immediately a wiki, or have place where you publish the updates of your research and you freely release everything online. There can be something else like an entrepreneur who has an idea, and wants to keep it for him. Then in that case the entrepreneur is just using the lab space of the DIYbio group. It is not philosophically the same as DIYers

[Values] curiosity for science, and openness, and open-source, and sharing.

Lots of people—it is a common feature that I experience, not all, but many—of the DIYbio people are also skilled in informatics so they really have this hackish mentality. Now one side is to open and understand and the other side is to share whatever you learn. This is another important thing and something that can differentiate between companies or universities, towards the citizen science

I think there is no common project or common goal. It is very diverse. It really depends on a local community. They only thing I see is the interest of people that participate in these meetings and events for technology and DIY movement in general is they like to get their hands dirty in things that interest them.

I call it a movement because I don't think the direction of DIYbio is clearly defined but rather DIYbio is a concept that we are continuously constructing all together. Different groups give their points of view and then they do what they want and what they believe in. There are some basic rules though that are part of the philosophy of the movement. Like things being Libre and Open source but focused on biological sciences, biotechnology. Those concepts are still so broad that it allows for people to make their own interpretation that depend on the social and cultural circumstances that person is in, as well as the financial means available. I don't think there is one definition.

Just learn more and explore, imagination and think about what makes you curious, just continue your curiosity like that.

The first value of DIYbio is access and opportunity and the second one is just creativity

I do think it is a movement because people do so think similarly and are obsessed with open source and open knowledge which enables us to approach things with creativity

First [biohackers] have to have a common set of rules that we all agree upon. We all have to agree on a common set of values that we commonly check and make sure it is DIY, really no sexism, racism, really like a punk community in the past. when you have common rules that you share it is not only about DIYbio but of also being more inclusive

When you think about DIYbio you have to be civic minded. So when I say civic minded I mean sharing and opening access to civic society and people regardless of their age and other social classes.

I think [people] say [it is a movement] as a way that there is some agenda, but there is no agenda. It changes depending if you are from a third world or a first world. Not everybody has the same starting point, it can change depending on your gender, race and class.

F.5. CONCERNS OVER BIOSAFETY

The following quotes reflect issues over biosafety:

> If you start regulating something there will be no difference between amateurs and professionals. So if there are more rules they should apply to everyone, and it is already pretty good regulated.(…) I don't think that self-regulating is an option that is pretty naive. You really need an external group of people that really reviews you and the accredits certain licenses that is how it works in the world (…) The regulations are already there and they are pretty strict.

> I guess the community could allow to deliver the knowledge to someone who could misuse it. The community is just an open book, an open space and everyone can come in and out. So you could get some knowledge you could misuse

> I have talked to people who are a bit scared by the fact of bringing for example DNA technologies to the citizens. They start saying something like "There is a problem with bioterrorism, you can contaminate, you can make some dangerous virus or bacteria, and then everything dies". But I think those are mostly fears, not realistic scenarios. You could make a bomb or something like that with everything you find in the supermarket and practically nobody is going to the supermarket and make a bomb. It is the same thing. There is the possibility that you can do it but in practice you don't do it. And in fact this is very difficult to do. It is hard to make a good virus that can survive once it escapes from the lab. It is almost impossible. But it is a concern some people ask

> We all want to do something good, constructive, we don't want to create bioweapons for example. No one is talking about that in the community and no one is interested in the topic. I want to create things, better things, things that help something. I don't want to destroy. I think that is something very clear in the movement. They all want to make something—create a solution

> The most important thing is regulation. That is why it is important to do this with experts on biotechnology and bioethics and therefore it also has to be transparent.

> By bringing science to society, making biology accessible for everyone is like teaching everyone how to make existence. You need responsibility to make it alive. You may fulfill your curiosity and imagination but if you make something like a weapon, you make a bacteria more virulent and you forgot about the biosafety, then you could be very harmful to society. You let a biological weapon into the ecology and

> When you think about DIYbio you have to be civic minded, rather than just focusing on changing some formula or bacteria cells. You have to really think what you are doing. Handling living creatures is entering a very different techno-sphere. But then I guess that the focus in DIYbio for most artists is to do things that are unethical, and maybe cross the line, but they are making a statement or something like that.

F.6. SIMILARITY WITH COMPUTERS

The following quotes represent a similarity between computers and biotech:

> I like to compare this movement to the informatics movement at the beginning of the 60s 70s, when a group of people inside university working with computers they started to push the technology far from the university to the house of the people. So again, at the time the establishment was that to use a computer you have to be a scientist so someone who is working in the university related to that and there was no chance to have a computer at home. It was something to specific for those things. And then everything changed with the invention of the personal computer, and you know how it goes. The same right now should happen with biology. So at the beginning to make a PCR, to work with bacteria, to see some cells you need to follow the university degree and everything. And right now you can just connect online find a

> group of people close to your place, go there and start experimenting immediately

> How I understand DIYbio is with comparing it with happened in the 50s when computers were big machines in university labs and very few people had access to the technology as it was already starting. But then people starting to create their own computers that were not maybe as powerful as the ones in universities but it allowed access to people to the technology. [DIYbio] is something similar with genetic engineering, biotechnology in that it is trying to take the technology out of the laboratories and start putting it in the hands of the people so they can start creating new things, new industries, new solutions, they can create various things that might not be possible if we maintain research solely to the labs. If users have access to technology, they know exactly what their necessities are and they can then use the technology and apply it to their needs. It is very similar of what happened with computers

> It is wonderful to see how the planet changed once the technology was put in the hands of the people, and yes they built good things and bad things. There are a lot of issues that will emerge once people have access to genetic engineering. But these questions have appeared before in the area of systems engineering and computing. I think we are reliving that transition that happened in that area and how at the beginning there were a lot of fears but in the long run we find solutions and then the benefits outweigh the risks and the prejudice.

> The best way people can understand what is happening [with biotechnology] is to understand is similar to what happened in the 50s with computers. Then people thought they were going to build a terminator and everybody was scared that it could end with humanity, and it has not happened. Now, 30 years later we have created smartphones instead.

> [In the future DIYbio] maybe is no longer a movement. I think it will be like this; it will become very common in the next years. I see biotechnology and the life sciences like what happened with computers in the 60s. It was a group of people that decided to move that technology to the masses.

F.7. DEMOCRATIZATION OF BIOLOGY

The following quotes represent the goals of the DIYbio movement.

> Most of the time is creating more open and more creative biotechnology sector. Yeah, I think openness and creativity are the main goals. And then other goals in order to achieve that for example educational aspects to it, but its not really a goal but more of a side-effect. And one of the goals is also to make people more aware of what biotechnology is going to do in society.

> Most of DIYbio is aimed at social innovation. Like using certain technology to drive changes in society. And that is what DIYbio can easily do. Create new tools that for example make people more aware of their environment, and gives them a sense of responsibility, and maybe they can change their behaviors. There is a whole different kind of impact value of DIYbio that is not academic or business value.

> DIYbio for me is a community which basically wants to bring science beyond academy and companies. The idea is to basically bring biology specifically to the public, to anyone, to the citizens And for doing this of course you need more open-hardware, open-software, and also people who are experts. [The vision of DIYbio is] explained in the DIYbio website, they say it is basically to bring biological knowledge to the citizens and empower the citizens with these tools and knowledge.

[The vision of DIYbio is] explained in the DIYbio website, they say it is basically to bring biological knowledge to the citizens and empower the citizens with these tools and knowledge

[DIYbio] is a movement first of all, that tries to bring science to everyone. It is open to everyone but it is mostly for people that are outside academia, outside of the usual places where you can find biological knowledge, and experimental stuff

Well everything is an approach towards the democratization of science and technology. And this is the important thing

Since the movement is very open, every person takes their own idea and have their own goals. My personal goal inside the movement is to democratize the technology. To put the technology in the hands of people. But others might seek to do innovation, come have other ambitions of entrepreneurship or to advance more rapidly fields like genetic engineering, or create new industries. I think it fits into some of the movements of open source. Each person has a different interest and the try to join the group with that particular interest that they have

The movement is about bringing science and technology together to come up with solutions to real social problems.

The goal is to bring more access to science. As we know, molecular biology and genetic engineering are very expensive and not a lot of people have the opportunity to do serious things in their homes. But when you input DIYbio you can bring the science to the people, they could make so many things, and they can learn much more from actually doing it than reading it from a book. Molecular biology is something that you have to practice by making it yourself.

DIYbiology is about opening access to knowledge about science for people that are not trained scientifically but for people who are interested.

F.8. ACCESS TO SCIENCE VS EXCLUSIVE SCIENCE

The following quotes reflect an imperative to open access to science, and the contrast with academic or industrial science which requires academic degrees.

[Democratizing science is important] because it is important that people can express themselves with biotechnology and can then find new applications for it. The things to be able to achieve that; cheap tools, sharing designs, those are all side-effects of that

In democratizing you have democracy in it, and one of the fundamental things about democracy is that you should educate people because they should be able to make their own decisions, and you have to trust that they make good decisions. If you have everyone involved then maybe everyone could be happy. So one of the fundamental things in democratizing science is educating people about technology so they can make good decisions about it.

First of all you need a degree to come inside the academia. So let's say there is a friend of yours who is interested in what you are doing and want to give effort to spend his time to do something in science, but he really cannot. Maybe your friend has a degree in philosophy or in law. So it is automatically outside of science, they cannot even dream to do be allowed to do some experiments So to do that you need to go outside the academia, in an environment where anybody is welcomed. Everybody is free to join and do thing, to experiment without taking the degree and taking years and years to study.

Basically what is the establishment until now in science and to do experiments, especially with biology you need to follow university courses, bachelor, master, PhD, and like that. And then when you are very skilled then you can start to experiment yourself, and you can start playing with cells and bacteria all stuff that you cannot find in the house of common people. So that is why you have to go to university to start working with that. What is going to change now with DIYbio approach is that we want to bring this kind of technology to everyone.

At the end of the day if you want to experiment with electronics, you can do that. If you want to do some chemical experiments with stuff you find in the supermarket you can do it. If you want to play with informatics you can do it. But biology it still not (…) and it is a 40 year old technology, but now it is impossible to do it for common people. We really see that there is distance between the technology and the potentials beyond the technology and the people. They don't use it, it is not there for them., it is just for universities and other laboratories

I hope that DIY will do something for everyone. Start teaching, start experimenting, start seeing what a bacteria is, what the DNA is, or what a GMOs is. And really play with that and be conscious of that, and then your fear will be gone as soon as you understand what it is. Until know there is a huge load of ignorance about these topics.

Maybe doing science doesn't have to be science in labs and I think that as social beings we need to do science. I think this has to do with the dichotomy of people thinking that science is for scientists. No! I think we can all do science in a way and not just in universities but in your house.

I think that was is interesting about the movement is transferring knowledge into society. That they can understand what is DNA, understand that their cells have DNA, that they understand a scientist can produce a GMO to produce bioplastics and that they understand what risks does that involve; what are the ethical and biosafety implications that it entails.

Biotechnology is a field that is going to be very important in this century, in the next 20 and 30 years, but all it is waiting is to reach to the masses. And for now high-tech biotechnology is still in the laboratories and that is why people don't understand it

People don't understand biotechnology that is why for example there are the movements against GMOS here and around the world. In my personal opinion a lot of fears around biology and many of these movements are unfounded. They think that putting a gene in a bacteria makes it toxic and t is not toxic. That is one of the things that the movement wants to change.

Because for now you need a science degree or you have to be an engineer or have even higher graduate studies to be able to access a laboratory with those tools and develop technologies. And this is even limited, because in your bachelor or master you still don't research your own interests you research those of your supervisor.

This kind of movement opens the possibility for people to pursue their own interests. That is the reach I see in the movement. It gives people the tools to solve their own social problems

I think that [DIYbio is making] a small change, but it is really about viewing biology as something that only the rich people in labs can do it.

> Society could contribute to science, like science is only accessed by a few people of very rich people. If for example only the king and queen have access to all of the science in the world but not the others nothing would improve in science but if you let more people to do it it could be more creativity, it would be faster to do.

> I think that the first change is at the people's point of view, because right now the point of view is very afraid. They think genetic engineering is scary so when they have access to it, when they can explore it scientifically at first they can know how it works. This is the first change that I hope what will happen to DIY.

> So the first [positive consequence] deals with education with the people. How DIY can change the point of view of how people think about ethics about biology; how to use the biology for good things. You are not playing God you are making something that could be good for the future, because maybe they can cure malaria, maybe someone will create something there. This is what DIYbio could give you the tools to explore you curiosity. I think of the good possibilities.

> For some the institutional framework has not been enough so they have to move into this subculture movement were marginalized people don't have the privilege to receive education from institutions. So i think the goal of DIYbio is increasing access to those who are marginalized

F.9. EXPENSIVE TOOLS VS CHEAP TOOLS AND OPEN-SOURCE

The following quotes reflect a discontent with the high cost is takes to do research

> [Open-Source is important] because of course it is more accessible if it is open. In my opinion one of the reasons why these technologies are hard to reach for the common citizen is because they are way to expensive. So making them open-source is the first step to enable anyone to actually build the machine they need to run an experiment or use a protocol that is open for anyone to try.

> Your PCR machine is costing $20,000EUR, and you need a PCR machine. Why does a PCR machine cost $20,000EUR? it is just an easy device. It is more complex to make a microwave and you can buy them at $20 in the supermarket. Why can't I buy a PCR in the supermarket for $20? There are quite a lot of linkage between academia, and companies, and money establishment.

> The community itself doesn't have any regulation, so there isn't written anywhere that you cannot patent. Even the opposite, some of the first laboratories around the world also open up a bench for entrepreneurs, whether they can come and test their idea and build up a company and do it. So there is a possibility inside the DIYbio community to make patent and this is not strictly forbidden. I think, and maybe this is my personal thinking that since it is an open community, everything should remain open. But nowadays there are so many ways to do business, that they community should really be open to these kinds of business opportunities

> There will be things that people want to share and things they don't. (…) Some will share everything gratis and open-source, which will be important in Latin America while others will prefer to patent and make an industry which is also important to create jobs and infrastructure and so on.

> Not everything has to be open source, but I think it is important that it is; it is one of the main philosophies of the movement. Mainly because it allows people to have more access to it in the first place

> I think it is very important to be open source. Why? Because you can decide to patent and then make a lot of money but then we return to the premise of DIYbio of opening access to knowledge to create more opportunities for people and so it becomes the initial problem again

> We do DIYbio in the lab because we don't have a lot of equipment, or the infrastructure, or the the money to the the experiments that we want, and DIYbio is all about doing research at a very low cost.

> I think that DIYbio is a friend to society and a foe to big companies because we may harm their economies. If you there is a cheaper way to do something why not just make it like that? They make things too expensive sometimes.

> DIYbio allows some people with very low resources in developing countries to have access to biohardware and things like that that are sometimes not even present in college laboratories, and DIYbio tools have given them tools to work with like scientific communities

> I think that everything should be open source, because the goal is to increase access to marginalize communities that don't have the privilege to receive formal education from institutions

> Everything should be open source. The sense of ownership that some people have has no place in the community, because ownership in a sense restricts access. But open source provides the resources for people to do it, especially marginalized communities that don't have access to these resources, either because they are not privileged enough or because they don't have the resources. What open-source also allows, is that with the knowledge you can actually localize it to your own needs which makes it more inclusive. People can adapt it and hack it to things that are relevant to their communities and their culture

F.10. A SLOW MODEL VS AN INNOVATIVE MODEL

The following are quotes reflect a grievance with a science that is slow to change and to update itself with new ideas, and that it is difficult to to exert curiosity:

> Science is of course a very dogmatic practice. In science you have to create hypothesis and design experiments and actually do them, analyze them and publish them. It is very dogmatic, there is no model of fun. So it is completely different from doing something as a hobby or doing something out of a personal endeavor or exploring what you are capable of. Thinking of future perspectives that are more of a creative process. And in science creativity is very limited. You have to of course deal with these dogmas all the time. So I think this is what is driving the difference between geeking out and working in society.

> These DIYbio communities and places I think they sprout, the allow the innovation to sprout, to happen basically, and this is due to the lack of requirement that you need to enter. Because basically anyone is allowed to try it. It is interesting because the person is not confined at all, and they can really explore what she or he wants.

I mean with DIYbio you could spin off from a DIYbio project towards a company or a start up thing. But most of the projects are more.. not for fun, but they are not worthy economically. That is how I can define them. Most of them are an idea that you want to try out. And it is mostly out of curiosity or because it is interesting for some reason. I think this kind of room can be taken by the DIYbio, because in this community you allow people to have ideas, any idea can come in. And I think these ideas would be turned down mostly by companies and universities because there is no profit for one and for the other, there is no, scientific questions (…) In academy if you want to try something—it is true that there is a lot of free environment you can try a lot but—still you are focused on, we can call it knowledge profit.

Another advantage [of DIYbio] is that since it is local and usually small, it is very easy and fast adaptable. Some new technology, new things come out you can just take it and repeat it. While in big institutions it takes more time; since you are that big.

I think [academia] is behind because it is too big. It is an establishment and it takes them much more time to follow a new direction. They are big institutes with thousands of people working in a pyramidal structure with a ready defined path. Up to now I see that academia is coming from this history so it is trying to conserve a lot of the details from this history a lot of the features of academia from the past. At the end of academia you usually have very old professors, people with a lot of experience but at the end old. And at the end of these movements you usually find young people. People that just want a new approach, I think it is normal.

You understand that before you have the freedom to have your own research, to satisfy your own curiosity, it will take a very very long time. And I am now in the position of "Will I go for a post-doc, or will I change?" But what are the opportunities? For now the opportunities are in academia or in some company. It more or less doesn't change so much of working for someone and do what is expected.

Nowadays, no matter of my preparation of my background in academia, if I want to propose a project it's a hell, to just get the project done, to get a fund, to get the money to start it. It is just a hell. There are lots of bureaucracies and lots of networking. While in this way I finally have an easy way to do projects and if one idea, someone likes it we just meet up and start right away. You don't need to write grants, you don't need to wait for authorization or anything.

I think that some biotech research is done at a big scale but with a very limited level of innovation, because a company already has its market chains well established. They don't really want to create something new, their innovations are incremental. Innovations really come from start ups

In DIY you can find a new way to do some things. That's what makes DIY different and more diverse from academia which is more about technical.

I think that many people that have been in research institutes and have practiced science for a long time, some of them are so sick of having to do that experiment or this experiment, when some of these research institutes do not necessarily do something that is good for society

F.11. COMPETITIVE VS COLLABORATIVE SCIENCE

The following reflect opinions on science and its reward systems of publishing which are competitive and secretive vs the collaborative science of DIYbio:

I want to do a PhD but every time I think about it is "What is the point how many papers I write?" I have this feeling of "Let's do something different", more like DIYbio. Because when I think about academy, it is just about being recognized for the work you have done for the 20 years of your life.

I maybe admire a professor because they have a very specific view, that studies a specific thing. But I also think this guy only knows, really within his own specific little, little tiny field. And his knowledge is not used by the whole community that supports it

Usually if you work in a lab, whether it is in a university or a company, usually what you work on is rather closed-source if you want to have a patent or if you want to publish, most of the time you don't say anything about your research until the moment you wish to publish. There is even a kind of competition among groups, they don't release their own techniques, their information. While in the DIYbio movement it is completely the opposite, usually they open a wiki, or a website before starting their research, and whatever data or new idea is coming out it is immediately shared for free and open-source and open-commons, ready for everyone, and this is really the mentality behind the open-source movement in the beginning. So again, you have software made by companies, closed-sourced and you have the hackers that are trying to open the software and understand how it works and make it open-source for everyone. So there is really on this side no money-driven interest in doing things. It really is for curiosity.

To publish open data, or open-access journal you need to pay the publisher, and it is quite expensive, and have your publication open in this way. While for DIY you just publish for free in this media and it is already open from this point of view. It is really a different approach. But I am happy that it exists and it is a kind of citizen science movement, and open source data, also for the academia. I hope academia will move towards this direction more and more.

Well this peer review is another thing wrong. Because now you have some editors, that really just evaluate what you write, they do not repeat the experiments. And you cannot really comment on the journals on the articles. That is completely different approach that the Internet community has. If you do something you post it in the forum and it is automatically commentable and people can put stars like in applications.

In a romantic way of doing science it should be only curiosity but right now the truth is that in academia they need to get grants. They need to publish. And to publish something, the research needs to be accepted from the journals. And the journals don't accept research with negative results. I mean to innovate continuously you need to avoid people who can get your idea that they could publish before you. So there is all this kind of competition, because at the end you need money to run your research.

I think anyway that the academic model has to change. We have a lot of problems like fast-food science. I think the image of the scientists is misunderstood. I don't want to be a scientist to be a professor in a university. I want to be a scientist because I want to understand things and create things, and academia demands scientific papers so they can give you funding and so on. I think that scientists have lost a lot of freedom in academia to practice their profession

Scientists compete with each other because ultimately they want the recognition to get the grants to have their own laboratory to have the freedom to do their own experiments and people when they get to academia that is what they aspire for. Many scientists start with the intention to make something that will have a positive impact in society and to create change, but slowly while they continue into their education into a masters, and a PhD they got dragged into a the culture of publish, publish, publish. The more you publish the better, the more difficult it is the better

> Scientist have now do all sorts of tricks to increase their citations, I am very aware of that and I have seen it been done. I think there are a lost of scientists with a lot of scientific vocation but a very poor social vocation

F.12. REACTIONARY VS PROACTIVE

The following display the thoughts behind whether industry and academia are allies or foes:

> Its complimentary it is not an alternative. I don't think it replaces academic sciences, at all, no. I think it really extends it, investigates it, or uses it in a way. But it is not an alternative. Because most work that is done in DIYbio is not scientific. It does not create new scientific knowledge. For example certain people do projects for their own good, or they create certain tools or applications. There are not many examples really of new scientific insights or knowledge that has been created by DIYbiologists.

> There is a bit of dualism in [the relationship between DIYbio and academia]. Because in one sense it tries to oppose academic sciences and at the same time people are trying to collaborate. Also when I come into these discussions, or collaborating with some academic group for example I think “What a minute, aren't you against us?”. So that is kind of tricky.

> Science is very deterministic. It tries to limit variables instead of creating as much as situations as you can. In science you kind of try to limit possibilities and in art you explore as many possibilities as you can. But both can lead to new knowledge and insights and truth. So that is why I think they both are important. I think DIYbio has a values next to academic science it will not replace each other. They are complementary to each other.

> Now research can only be done within the academy or within industry. And I don't think for instance the DIYbio movement is going to replace these two realities, because they are there, they must be there and they are producing a lot, but there is some kind of space, a gap in between companies and academy were there is still something to discover and try. Companies do it more on the money level, so they just want to make a profit. The academy is more about producing knowledge. But then there is a kind of room in between somewhere and this room can be taken by any DIYbio project in my opinion

> I think people develop things and discover things in a different way than we are doing it now with DIYbio So I think it is also at a social and economical level are a bit merging because it is really a problem about "OK I need to develop a product, and make money, and then I have to deliver the results". So DIYbio is more like saying "OK we don't need lots of money, it is not that hard once we share the knowledge, and you can actually try to develop, and try out your experiment” basically. I think it is more like in a company it is like "OK I am paid and I use the knowledge for this company" and then everything remains within it. Tthe same thing for the university it is more like "I research, I ask this question, and then I don't see applications because I just want to understand how this process works and that's it, and I stop there". But DIYbio is creating a place where knowledge can come in and develop freely

> I think academy likes [DIYbio]. Mainly because from the academy point of view we are teaching people. So actually we are helping them. For the industry I also think that they like us, because we can be the seed for new ideas to develop and of course the industry could take theses ideas and take it to the next level, like developing a product. So I think both can benefit from DIYbio.

> If you study a bit of the history of science. The biggest revolutions they all came from outside the academia. Maybe from people that are formally inside the academia, but in a way are outside mainstream academia. For centuries it was like that. All the big ideas they came from outside and then with time they get accepted by the mainstream and another mainstream is formed, and then when someone says something else, again the history repeats. Someone will be isolated at first and then maybe after 10-20 years it will be normal knowledge.

> [People in academia] mostly they don't know anything about the movement. The people who know the movement they are excited to see that there are problems in academia and they like the idea that someone is trying to do something different. Nobody in academia, almost nobody in academia think that scientifically the DIYbio movement can contribute in a determinate way. They think that we do more basic science, and playing around, and not really doing interesting things. But actually it is not true. Because from different groups all around the world are coming out nice technology, open-source reactors, and machines and people who are experimenting. and it really depends on the group. At the beginning the DIYbio group are really small and cannot do too much. Again there are realities in which a lab is already established are starting to do research. Moreover, they manage much more than what academia is doing to promote citizen science. So there are lots of projects in science in which the amount of data is important and a single lab in academia cannot manage to get data around the world. While a single group, a DIY group can organize to get data from citizens all around the world and get massive research done. So basically they like it, but they don't take it seriously. It is like kid play. But when you have several thousands of kids playing then something will come out.

> This is what the type of initiatives that we see [in the movement]; how to make things that at this moment are very expensive, we know they are very difficult, and we know that not all things work [they way we want them to]. I think that some people are trying to do that, after seeing that to a point universities and industry have created advancements, but we want to be part of the solution and see if we can advance better and faster. Some of these people at one point got together to do this and they called it DIYbio.

> I think that one problem is to give blame responsibility to academia, the government or society. I think that one thing about being a biohacker or DIY is precisely doing it yourself, it is taking that responsibility. (…) The second is that these changes happen all the time. A few people get out of the university and create new ideas, and those ideas then come back to the university and create new things. So it is a normal cycle in technology.

F.13. INFORMAL NETWORKS

The following quotes reflect characteristics of biohackerspaces:

> DIYbio is a more open and creative space and there are no restrictions. If you want to be a part of DIYbio there is no requirement. You can sign up for a mailing list and now I am a part of it. So that makes it pretty easy. And you can freely browse around and try new things without justifying it in any way. So that makes it very easy to start with.

> You can easily become part of DIYbio there is no official requirement for it. You can just send me an email and you can come here, and that's what a lot of people do. It makes it very easy for people to engage, often times they don't have to pay for it they don't have to do any exams, they don't need any qualifications.

Like other movements nowadays it is Internet-based. It is based mainly in a community that communicates and exchanges information continuously. And it is completely decentralized, you don't have a central headquarter Mostly it is people from all over the world that are interested in DIYbio movement, try to build up their own community

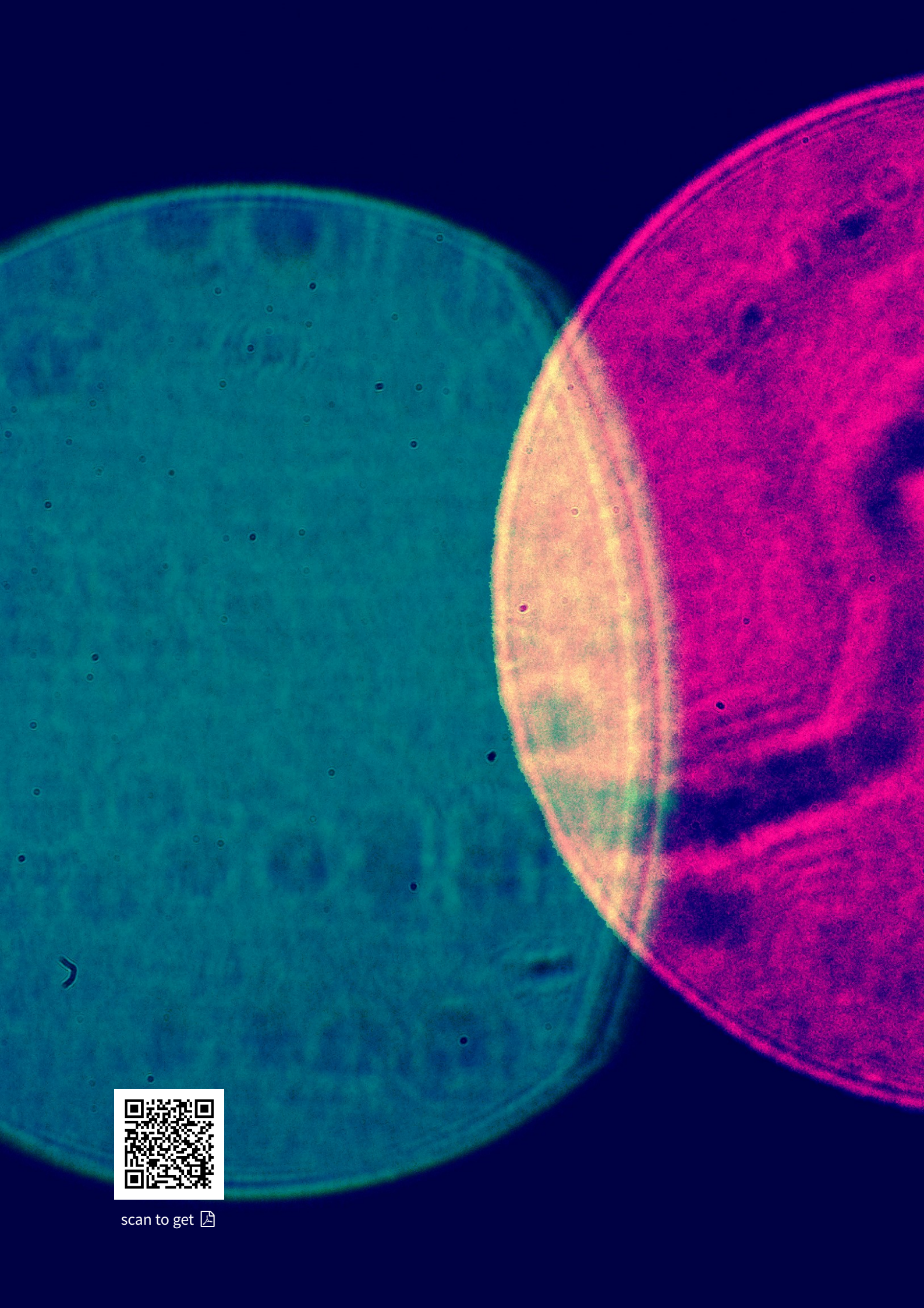
I think it is really about how as soon as money comes in you have to give in some of your ideals, in exchange for money you will lose freedom for sure.

I mean because especially at a European level ask money they will require something from you. This requirement can threaten your freedom. And also for me I really like remaining open as possible, so for me it will be very important. If money comes in, it doesn't have to restrict my freedom in any sense

I think DIYbio aims for a change in ideology. Mainly because we are trying to change the mentality of people by showing them that there are different ways to do research and development, and we are doing this by creating new spaces of opportunities

I think that the [discontent with academia and industry] is why hackerspaces are trying to remove themselves from the system a bit but are also being co-opted by the system, so it is not strange to see hackerspaces with private funding.

“Be curious, read widely. Try new things.
What people call intelligence just boils down to curiosity”
– Aaron Swartz



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