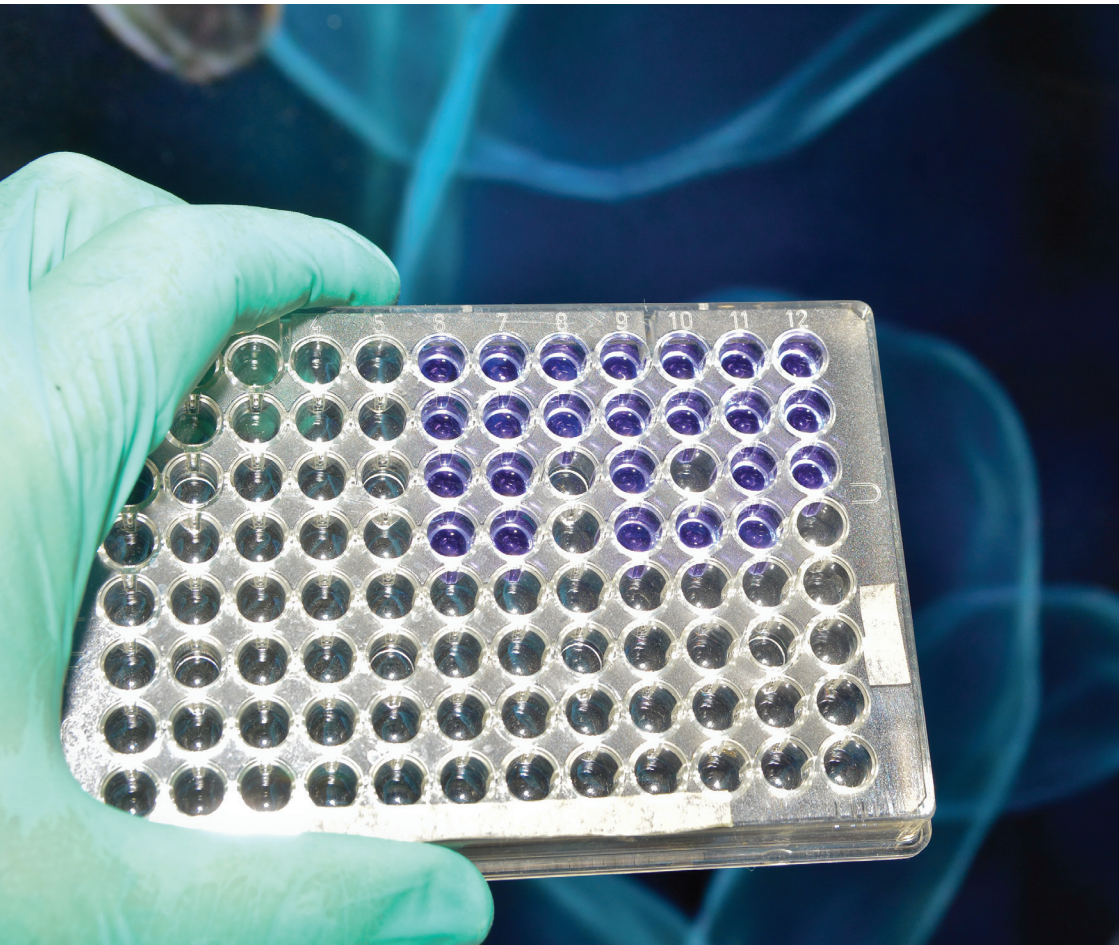
BIOCHEMICAL SOCIETY

DIY BIOLOGY

BIOHACKING, CITIZEN SCIENCE, AND COMMUNITY LABS



Science is not just for scientists. In fact, the emergence of the 'professional' scientist is relatively recent, being a mostly 20th Century phenomenon. Before this, science was the domain of the amateur, the enthusiast, and the passionate. Darwin himself was never employed as a biologist or botanist; his self-funded work was a personal pursuit which he was free to follow as he saw fit. He was not unusual; the Victorian passion for collecting and classification was widespread across many different areas of society. The formation of the British Association for the Advancement of science (latterly the British Science Association) in 1831 demonstrates how Science was seen as an activity in which every citizen could take part.

It was only towards the end of the 19th Century that universities and other institutions started to dominate scientific research with their larger labs, better facilities and formalised training and qualifications. During the 20th Century, large projects and international collaboration have brought about about fundamental shifts in our understanding of the Universe and our place within it. However, along the way, the practice of doing science has moved away from the everyday and become something that many people will have little contact with.

The re-emergence of 'citizen science', aided in part by online communities and new technologies, has brought back the ability for everyone to take part in scientific research. Large online collaborative projects such as Zooniverse (www.zooniverse.org) offer the opportunity to 'lend a hand' to researchers and contribute to analysing large data sets. Increasing access to and reduction in the price of scientific equipment now allows people to carry out molecular biology experiments at home. Reduced sequencing costs and online ordering of specialised materials means that many people can now carry out basic genetic analysis and take the first steps into learning about how genetic manipulations are carried out. Community labs and groups offer a sharing of expertise and experience, as well as an alternative entry point into scientific research. The potential for collaboration between disciplines and the opportunity for everyone to take part in experimentation offers a chance to return to the glory days of citizen science.

But with this increased accessibility comes worries about the safety of handing over molecular biotechnology tools to those with little training or oversight. Are there certain areas of science which should be off limits?

#DIYBio #DIYBiochem

COMMUNITY LABS

Around the world a number of spaces are opening up which allow people to explore molecular biology outside of the traditional world of academia. Places like the London Biohackspace, La Paillasse in Paris, or GenSpace in New York, offer a community-run molecular biology and microbiology lab which aims to give access to a wide range of people from different backgrounds.

The London Biohackspace is a containment level 1 laboratory with a wonderfully eccentric collection of recycled lab equipment, home-made solutions and even a re-purposed pasty oven being used as an incubator. The emphasis is firmly on providing open access to lab equipment and bench space, for use in a safe manner, for individual or collaborative projects, following the DIYBio code of ethics (see box). There's a strong sense that the techniques and the experiments that they are offering should be available to as wide an audience as possible – that everyone should be able to pursue their curiosity about the natural world.

Draft DIYBIO code of ethics from 2011 DIYBIO European Congress

Transparency
Emphasise transparency and the sharing of ideas, knowledge, data and results.

Safety
Adopt safe practices.

Open Access
Promote citizen science and decentralised access to biotechnology.

Education
Help educate the public about biotechnology, its benefits and implications.

Modesty
Know you don't know everything.

Community
Carefully listen to any concerns and questions and respond honestly.

Peaceful Purposes
Biotechnology must only be used for peaceful purposes.

Respect
Respect humans and all living systems.

Responsibility
Recognise the complexity and dynamics of living systems and our responsibility towards them.

Accountability
Remain accountable for your actions and for upholding this code.

Figure 1. The DIYBio code of ethics, from https://diybio.org

BioBricks™

BioBricks™ are stretches of DNA which have been created to a set of standard criteria. This makes them easier to combine together into systems which can be inserted in living cells, often *E.coli*, to produce a useful device. In much the same way that standard electrical components allowed people to experiment creating circuits and electrical engineering at home, BioBricks allow easier genetic engineering and hence a whole raft of new innovative solutions to old problems.

The registry of standard parts now has over 20,000 parts including protein generators, reporters, measurement devices and sensing parts. Every year, the iGEM (International Genetically Engineered Machine) competition sees student teams from around the world use these standard parts to create a dizzying array of projects.

Zooniverse

The Zooniverse is the world's largest and most popular platform for people-powered research. This research is made possible by volunteers – hundreds of thousands of people around the world who come together to assist professional researchers. Their goal is to enable research that would not be possible, or practical, otherwise. Zooniverse research results in new discoveries, datasets useful to the wider research community, and many publications.

You don't need any specialised background, training, or expertise to participate in any Zooniverse projects. They make it easy for anyone to contribute to real academic research, on their own computer, at their own convenience. You can study authentic objects of interest gathered by researchers, like images of faraway galaxies, historical records and diaries, electron microscope images of cells or videos of animals in their natural habitats. By answering simple questions about them, you help contribute to our understanding of our world, our history, our Universe, and more.

(Taken from www.zooniverse.org/about)

OPINIONS

Dr Mark Erickson is Reader in sociology, at the School of Applied Social Science, University of Brighton. He has a long-term interest in cultural representations of science and technology, and public engagement with science and technology. Using a combination of sociological, anthropological and cultural studies research methods his research studies microbiology and molecular biology laboratories, focusing on the relationship between the 'esoteric' world of formal science and the 'exoteric' world of society and culture.

Sociologists of science have identified the problem of the 'democratic deficit' in the production of scientific knowledge for a long time but perhaps we should be careful what we wish for. Allowing members of the general public access to powerful biotechnologies that can be deployed in their own homes raises a number of social, ethical and political questions that cannot be 'contained' within our standard frameworks of institutional ethical approval.

Professor Laura Bowater is the Associate Dean for Enterprise and Engagement in the Faculty of Medicine and Health at the University of East Anglia. Laura has recently been appointed as a Professor of Microbiology Education and Engagement at the Norwich Medical School. She is leading a brand new, interdisciplinary research project focused on public engagement with the global problem of antibiotic resistance (ARM).

The democratisation of science has its roots in a past where citizen science was the norm: members of the public undertook science long before it became a paid 'science profession' and the gap between scientists and citizens emerged. The wealth of information available on the Internet, including the breadth and depth of open access data, combined with purchase opportunities on sites like Amazon and Ebay have created the perfect environment for a new age of science to emerge. Across the globe, citizens feel empowered to develop their own research programmes and to conduct experiments in hack spaces, garages, kitchens and garden sheds. This emergence of this new science forum raises interesting possibilities and important questions for professional scientists. Should scientists celebrate, support and welcome the contribution of these new citizen scientists? Do these new citizen scientists offer society and scientists exciting opportunities for new collaborations and novel perspectives? Or are we witnessing the emergence of a hidden underworld of unregulated, unethical science and should society be concerned? I haven't made my mind up yet, have you?

Dr Helen Spiers is Postdoctoral Associate in biomedical research and citizen science at the University of Oxford. She is also the Biomedical Research Lead within the international research group responsible for the Zooniverse, the world's largest and most popular platform for online citizen science. To date, over 100 research projects across multiple academic disciplines have been launched on the Zooniverse, allowing anyone with an internet connection to make an authentic contribution to real research, and for researchers to do studies that would not be possible otherwise.

Science is a way of learning about the world around us, a reliable process where our ideas are accepted or rejected on the basis of evidence. The technological innovations of recent decades have catalysed a resurgence of citizen science, re-empowering non-professional researchers with the opportunity to make authentic contributions to science. There are more ways than ever to be involved, from contributing to online projects from the comfort of your sofa, to performing experiments in biohacker spaces. Both non-professional and professional researchers can benefit greatly from this increased interaction; it can enable research impossible to conduct otherwise, facilitate serendipitous discovery, provide an opportunity for further education, and encourage deeper engagement with research. The production of evidence-based knowledge and practice of critical, scientific thought will become increasingly important as we enter this era of fake news. Aren't there far greater dangers in keeping science just for the scientists?

Alex Pearlman is a digital journalist and bioethicist. She will complete her Master's Degree in Bioethics & Society at King's College London in 2018. Alex's work breaks down the complex ethical issues facing our society with the advent of under-regulated and misunderstood biotechnology, and reports objectively and accurately for the general public. Most recently, her own reporting has been focused on stories related to innovation and regulation of emerging science.

"Questions about the ethics of biohacking can no longer be focused on whether we should unleash a mass of changes on our natural world or bodies. The question is not "should" we hack our environments and ourselves. We have already passed the point in the evolution of this technology for those questions to be relevant – once something is out of the box, you can't put it back in. We have already begun the process of being hacked, and now we must focus on "how" to regulate biohacking to preserve equal access, transparency, and safety.

The possible impact of making even the slightest changes to our bodies and our environments is obvious. But, as climate change makes living in once-temperate areas more difficult, and as technology merges further with our minds and bodies, biohacking will soon be more than a hypothetical: it will be an imperative.

When it comes to ethics of biohacking, two things matter: the "why" and the "how". Intent and methodology. If the intent is to create technology that extends the biological limits of the natural world in a way that is helpful, safe and accessible, and it is done within a regulatory framework that protects innovators, consumers, and other stakeholders, we will be able to successfully implement biohacking into our lives. Lessons can be learned from the corporate and governmental co-option of early computer technology and the internet, and an early insistence on transparency and ease of access will guarantee that biohacking maintains its ethical intentions."

Dr Jenny Molloy is the Coordinator for both OpenPlant and the Synthetic Biology Strategic Research Initiative at the University of Cambridge. She is deeply interested in the role and impact of open science and open IP in research and innovation and frequently speaks on these topics at local and international meetings. In addition to her role in the University, she is a founding Director of the Cambridge-based non-profit organisation Biomakespace (a community laboratory for engineering with biology) and she co-organises the international Gathering for Open Science Hardware.

"We're now getting better and smarter at designing and engineering living systems, to the extent that 'Biology is Technology' (Robert Carlson, 2011). Unfortunately, our shared bio-future rests on a platform of hardware, materials and reagents that are typically only accessible to those in well-resourced academic or industrial laboratories. I'm interested in community biolabs because they aim to address this inequity and to create new futures for science – a big ambition with a big hype surrounding it. I keep two concepts in mind while I watch the community I'm involved with grow – mundanity and equity. Mundanity, in that I'd like biology to become an everyday technology – community labs can foster in-depth participatory public engagement in a way that whizz-bang demonstrations can't and that has potential to shape perceptions. However, I also really hope that projects emerging from these labs show benefits, however small, from moving science towards communal, bottom-up, and collaborative practices that strive for equitable and open participation and access to the resulting outcomes. I'm excited by the journey that these communities and spaces are embarking on and I have a lot of questions that I hope will get answered along the way about the nature of science, collaboration, innovation, ownership, public benefit and more!"

Dr Brenda Parker is a Lecturer in biochemical engineering based at University College London. Her doctoral research investigated how proteins could be artificially evolved for green chemistry. However, her postdoctoral work at the University of Cambridge took her to a new shade of green: microalgae. Since then her research has focussed on how we can use photosynthetic microorganisms for sustainable industrial biotechnology. Her particular interest lies in bioremediation, and she is currently working on an EPSRC-funded project investigating how microalgae can be used to clean up heavy metal pollution.

"Questioning the value of community labs is to question the value of play and curiosity. Increasingly, as scientists in academia or industry we find ourselves constrained, driven by impact or outputs from our research. We have fewer opportunities to indulge ourselves with a Friday afternoon experiment. Makespaces and biohacklabs draw a diverse set of people who want to separate the scientific enquiry process from the machinery associated with academia. Universities are recognising this and creating such spaces for informal collaboration, and in future I believe the boundaries will become more porous.

These intermediate spaces are fertile ground for interdisciplinarians. Designers, biologists, engineers, artists have the opportunity to interact. As the tools to work with molecular biology become more affordable or accessible – take for instance the fantastic Bento Lab – we challenge the previous practical limitations associated with this this type of work. This aspect of freedom and cooperation could be applied to solve some of our more "wicked problems" to borrow from design terminology. As the movement goes hand-in-hand with open source information, we explode the traditional models of commercialising knowledge and discovery.

However, in the simplest form, perhaps community labs and biohacking are actually a return to a form of exploration that we associate with scientists such as Darwin. In an age of readily available information, I would argue that community labs have the potential to restore a sense of wonder. How beautiful to discover something fundamental about the world around us, via our own independent observation?"

Bethan Wolfenden is the co-founder of Bento Bio, the makers of Bento Lab, an all-in-one miniature DNA laboratory. She has a background in biochemistry and synthetic biology, and is passionate about widening access to genetic technologies.

"Genetics and molecular biology are the fundamental technologies of life, but only a small number of experts have access to laboratories and specialist knowledge. At Bento, we are building tools and content to make learning hands-on genetics as accessible as using a Raspberry Pi computer. We are part of a global movement nurturing curiosity and diversity in genetics, and making sure the future of biotechnology is open to all."

BIOCHEMICAL SOCIETY

The Biochemical Society works to promote the molecular biosciences; facilitating the sharing of expertise, supporting the advancement of biochemistry and molecular biology and raising awareness of their importance in addressing societal grand challenges.

We achieve our mission by:

- bringing together molecular bioscientists;
- supporting the next generation of biochemists;
- promoting and sharing knowledge;
- and promoting the importance of our discipline.

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