Report of the Synthetic Biology, Politics, and Philosophy Workshop

University of BRISTOL

BrisSynBio
biomolecules to biosystems
from understanding to design

UWE BRISTOL University of the West of England

Workshop Report from June 8, 2017 at University of Bristol, Life Sciences Building, Tyndall Avenue, UK BS8 1TQ

Report of the Synthetic Biology, Politics, and Philosophy Workshop

Introduction and Summary:

This report summarises the outputs of a workshop that took place at the University of Bristol, UK, in conjunction with the Social Science Research Group at the University of West England, Bristol and the BrisSynBio[1] Synthetic Biology Research Centre on the 8th June 2017.

The workshop brought together a number of social scientists, philosophers, computational biologists, genetic engineers, and artists working on synthetic biology to stimulate multidisciplinary deliberation and insights into the political challenges and philosophical ideas emerging at the cutting edge of innovation in synthetic biology.

The event was coordinated by Darian Meacham (Director for Responsible Research and Innovation at BrisSynBio) and Miguel Prado Casanova in conjunction with BrisSynBio. BrisSynBio is a multi-disciplinary research centre that focuses on the biomolecular design and engineering aspects of synthetic biology, and has been established as one of six Synthetic Biology Research Centres in the UK. BrisSynBio is funded predominantly by the BBSRC and EPSRC, and has a number of other academic, industrial and public-facing partners. Responsible Research and Innovation (RRI) is a cross-cutting theme in the centre. Its offices are at the University of Bristol Life Sciences Building, Tyndall Avenue, UK BS8 1TQ. As a BBSRC/EPSRC Synthetic Biology Research Centre, BrisSynBio is one of the leading research centres in the UK on synthetic biology. The event was organised as an activity of the NAPSTER Project[2] (New Anthropology in Philosophy, Science, Technology and Engineering Research), funded by the University of the West of England, Bristol.

This report has been adapted to inform the deliberations taking place on synthetic biology at the UN **Convention on Biological Diversity (CBD)**, and as such we focus primarily on presenting the morning sessions of the Bristol Workshop. In particular this report, and the conclusions drawn from it, responds to the call for information to be submitted in **document SCBD/SPS/DC/DA/MW/86375** on "Research, cooperation and activities noted in the sub-paragraphs (a) through (c)" below, and taking into account "socio-economic, cultural and ethical considerations" as stated in the preamble:

(a) To conduct research on the benefits and adverse effects of organisms, components and products of synthetic biology technologies and approaches on biodiversity, with a view to filling knowledge gaps and identifying how those effects relate to the objectives of the Convention and its Protocols;

(b) To promote and enable public and multi-stakeholder dialogues and awareness-raising activities on the potential benefits and potential adverse effects of organisms, components and products of synthetic biology technologies and approaches on biodiversity, involving all relevant stakeholders and with the full and effective engagement of indigenous peoples and local communities; and

(c) To cooperate in the development of guidance and capacity-building activities with a view to assessing the potential benefits and potential adverse effects of organisms, components and products of synthetic biology technologies and approaches and, if necessary, updating and adapting current methodologies for risk assessment of living modified organisms to organisms resulting from synthetic biology, as appropriate.

**Summary Conclusions of the workshop can be found on page 8.*

[1] http://www.bristol.ac.uk/brissynbio/
[2] www.newanthropology.eu

Morning session:

Responsible Research and Innovation and the Politics of Synthetic Biology

Chaired by Prof. Julie Kent (University of West England and BrisSynBio)

10:00-11:00 Michael Reinsborough (BrisSynBio Research Fellow, University of Bristol and University of West England)

Title: *Social science and philosophy within the context of developing Responsible Research and Innovation: integrated AREA*

Summary

Since the discussions of the workshop were bringing together philosophers and social scientists the opening speaker proposed to describe the context of this possibility to work together. 'Responsible Research and Innovation' (RRI) was a new policy term to describe a changing approach to the relationship between science and society. The old linear model had been "pay for basic science and leave scientists alone and this will, in the long run, generate applications that will benefit to the economy and society". But this rhetoric justifying funding was now largely being replaced. The new model "Grand Challenges – research should be useful to society and address grand challenges in society and/or global society". Large corporate research laboratories, example Bell Labs, have largely disappeared in the changing (post-Fordist) structure of the economy. There has also been a long term recognition of the Collingridge Dilemma: that with new technologies we haven't enough knowledge to effectively regulate them; but by the time we have enough knowledge the technologies are well established (path-dependency) and therefore difficult and expensive to change. Thirdly, there is a growing recognition that what begins in the lab (if it is successful) becomes a generalized product, technique, or knowledge outside the lab. And therefore how is it that we might pull society into the lab so that what comes out of the lab is integrated to the needs of communities.

While there are several models for integrating social/societal concerns to research agendas this presentation focused on the so-called AREA model promoted in the UK by the Environmental and Physical Sciences Research Council (EPSRC). AREA stands for Anticipate, Reflect, Engage, Act. The qualities of being anticipatory (being aware of how expectations of the future influence the present; using a multiple scenarios approach), reflexive (researcher awareness of their own position within the greater research economy), inclusive (broadly inclusive as a deliberative, responsive (mutually responsive to dialogue with others within and outside of the immediate research community) are to be integrated into research agenda. While this does not guarantee consensus from all the various parties it is hoped that the integration of science will be improved and research trajectories will begin to better reflect societal concerns.

Discussion with Workshop Participants

Questions after the presentation focused on anticipation of benefits and risks of synthetic biology, and how a multiple scenarios approach to anticipating possible futures could be more accurate (by developing researcher and community capacity). The presenter maintained a position that while more speculative methods and ideas about the future were inevitable, it was important to remember that images and visions of the future are often mobilized to justify resources for research. In this context, it seems more important that future claims about benefits and risks are plausible and to adhere to the precautionary principle.

One participant shared an example where serious consequences of a new vaccine trial for swine flu had not been anticipated, but which possibly could have been avoided if scientists had been required to consider possible multiple scenarios and outcomes.

Slides and references to this presentation are in the appendix 2.

11:15-12:00 Lewis Coyne (Department of Sociology, Philosophy, & Anthropology, University of Exeter; member of www.ethicsandgenetics.org)

Title: *Questions about Responsibility in Synthetic Biology*

Summary

This talk assessed the pros and cons of the responsible research and innovation agenda (RRI), as a way of regulating the development of synthetic biology. Two broad reasons were given why RRI, which involves the public and civil society in the early stages of the innovation process, is preferable to peer-regulation (or self-governance) by researchers and innovators alone. The first reason was the greater understanding of risks that RRI can allow for. The second was the greater degree of ethical scrutiny that it allows. It was argued that the involvement of the public and civil society will allow us to make better informed decisions about synthetic biology, and better understand the ethical concerns it raises.

To show how this might work in practice, the talk gave the hypothetical example of a synthetic biology coffee plant that could grow in temperate climates such as the UK's. This led to a discussion regarding the socio-economic condition of developing world farmers, as their livelihoods would likely be negatively affected by the introduction of a patent-protected crop such as this to the global marketplace. Since synthetic biology could raise such issues of global justice, it was argued that an ideal regulatory framework would be able to accommodate them, and RRI, at least in principle, allows for this.

However, it was also argued that RRI is neither rigorous nor comprehensive enough. Two problems were raised with the agenda. The first was that there is no necessary link between legislation and any concerns raised by the public and civil society. The second problem was that RRI is only able to accommodate concerns about certain undesirable consequences of synthetic biology, and cannot accommodate any fundamental objections to it.

The overall argument was that, to be truly responsible, research and innovation in synthetic biology should be subject to national and international legislation following from public deliberation. In particular, if the public and civil society overwhelmingly raise fundamental objections to synthetic biology, then national and international legislation ought to reflect this.

The text of this presentation is given in the appendix 3.

Discussion with Workshop Participants

One participant raised the issue of the precautionary principle and whether governance ought to abide by it. The presenter argued that national and international governance should be in accordance with the precautionary principle where there are credible risks of major ecological harm or negative socio-economic consequences for the globally disadvantaged.

Another participant asked whether issues of global justice were too ambitious for legislation at the national and even regional levels (for example, the European Union). The presenter accepted this criticism, and argued that national and regional legislation might help build support and consensus for international legislation at the level of the United Nations.

12:00-:12.45 Molly Bond (School of Geographical Sciences, University of Bristol)

Title: *Synthetic Biology Assemblages: Friction at the Interface of Diversity*

Summary

This talk addressed one aspect of the speakers' research on the governance of synthetic biology and the network of actors, ideas, and economic agendas which contribute to knowledge-making and decision-making about the future of synthetic biology. The network that has formed around synthetic biology was conceptualised as an assemblage. The synthetic biology assemblage incorporates governments and regulators from around the world: NGOs, and CSOs, a variety of social, ecological, and physical scientists; industry associations, businesses, and venture capitalists; farmers and farmer organisations; Indigenous peoples and associated organisations; trade unions; the UN and other international and financial agencies. Within these groups dominant and influential discourses circulate, such as 'disruptive innovation', 'responsible research and innovation', 'human rights', the 'rights of Nature', and 'living in harmony with Nature'. Many in this assemblage are guided by different economic agendas or visions, including the 'Bioeconomy', 'Green Economy', 'Buen Vivir', 'Circular economy', and 'Sustainable Development'.

Each actor, discourse, and economic agenda within this assemblage carries different interpretations of sustainability, risk, and the 'good life', as well as the type of relationship envisaged between society, economy, nature, and natural resources. Between this diversity of world-views, knowledge-systems, sciences, and relations, 'friction' is generated. Friction, in a physical and metaphorical sense, is the result of diverse elements interacting, interrupting, colliding, connecting, or encountering one another. Friction is a force that can be reactive or erosive, but always productive. Friction then, produces both positive and negative outcomes for different elements in the assemblage. The main argument of the talk was that instead of avoiding or fearing friction, as many in the synthetic biology assemblage do, it should be embraced as a reality. Friction reveals deep ontological conceptions of the way the world is and ethical commitments about the way it should be, including what constitutes human progress. Friction is a result of diversity, occurring at the interface of diversity, and it is diversity and plurality that makes society more resilient to future challenges.

Discussion with Workshop Participants

One participant suggested that the main purpose of the responsible research and innovation agenda is to iron out 'friction', or the diversity of worldviews and perspectives on synthetic biology, so that eventually the public would accept genetic engineering or synthetic biology. Another participant agreed that the big issue for the future of synthetic biology was public consent to this new science and that would be highly frictious.

The ensuing discussion highlighted how some parties at the Convention on Biological Diversity were advocating the idea of 'sciences *for* life', where sciences and technologies deriving from traditional knowledge are being put forward as alternatives to synthetic biology. It was also noted that other parties advocate a moratorium on synthetic biology until there is greater clarity on all likely socio-economic, ethical, and cultural consequences. It was argued in response, that such strongly held views about the way the future could be shaped by synthetic biology inevitably had to be taken into account at the CBD in order to respect different agendas and to govern democratically.

Afternoon session:

Concepts of Nature and Science

Chaired by Dr Maria Fannin (University of Bristol)

14:00-14:45 Thomas Gorochowski (BrisSynBio, University of Bristol)

Title: *Automation and Synthetic Biology*

Summary

This talk introduced the complexity of biology, and the many challenges scientists face in precisely engineering and scaling up innovations in synthetic biology. Increasing automation and the combination of artificial intelligence and 'deep learning' however, are rapidly making biology easier and faster to engineer, with productivity increasingly outpacing Moores law. The talk summarised the array of new techniques and capabilities of cutting edge synthetic biology tools and automated systems, including MAGE (multiplex automated genetic engineering) to accelerate evolution and optimise metabolic pathways; 3D printing technologies capable of bioprinting using biological living ink; as well as new distributed manufacturing technologies, such as 'Digital to Biological Converters' (DBC) capable of transmitting DNA sequences digitally to manufacture RNAs, proteins or viral particles outside normal laboratory conditions such as in Outer space. These distributed manufacturing technologies are also being promoted by companies such as Transcript to enable so-called DIY Bio or the 'democratisation of synthetic biology', where portable lab space can be moved around in containers and rented out for synbio start-up companies.

Discussion with Workshop Participants

One participant asked whether framing synthetic biology and other emerging technologies in terms of 'democratisation' was misleading. The reason was that although synthetic biology is highly accessible to the public, since it can be practiced at a minimal cost outside professional research institutes, this means that it easily falls outside of public scrutiny and oversight, and that if the effects of synthetic biology are not publicly accountable, then it might in fact be less democratic than traditional biology. Further discussion centred around the question of how automation technologies were changing or could potentially change the methods of science and the traditional role of the scientist in the scientific endeavour. Specifically, there was discussion of how automation technologies in synthetic biology were impacting (decreasing) the idea of the biological sciences as hypothesis driven.

15:15-15:50 Katy Connor (BrisSynBio Artist in residence)

Title*: "Blood Culture": Reimagining Life at the Cellular level*

Summary

This talk presented some of the early work emerging from an art, science and social science collaboration, exploring how artistic research can bring new insights to the practice of cell culture - in particular to culturing red blood cells, synthetic blood - currently being produced in the lab by researchers at BrisSynBio.

As a starting point, the artist considered the aesthetics of blood at the cellular level; contrasting the black and white images derived from microscopy technologies and the instrumental use of colour for lab research purposes, with a cultural (and visceral) understanding of blood - particularly in relation to its liquidity. The talk also considered what potentialities creative practice, art and science had for public deliberation, engagement and exploration of diverse views and values.

Discussion with Workshop Participants

Participant discussion focused on the ways in which artistic practice can be informative to scientists and collaborators, in revealing how their own work depends on particular (often unexamined) visual strategies.

15:50-16:25 Miguel Prado Casanova (Department of Health and Social Sciences, University of West England)

Title: *Functional Noise and Synthetic Biology*

Summary

This talk presented a critique of the concept of noise in bioinformatics frameworks for synthetic biology where the biological system is to be reduced to the signal from various background noise in the bioinformatics method. The aim is to develop, an understanding of the theoretical and practical role of "noise'", as a form of randomness, in biological organization and evolution within the context of synthetic biology. Phrases such as 'junk DNA' give a sense that foreground information not understood by geneticists does not have a biological meaning. According to some ideas from evolutionary biology, beginning with Darwin, and including recent work by Giuseppe Longo, Cristian S. Calude (2015), and Barbara Bravi (2016), physical randomness, if properly understood, should not be seen as "noise" in complex systems. This is particularly true of living systems, where randomness has a functional role that contributes, in an essential way, to the structural stability of system dynamics. Thus, it is important to recognise the development of a biological organism in relation to background noise; noise has a functional role in the development of organisms, perhaps in the same way that the development of an child's immune system requires an adequate background of germs/microbial threats in order to initially form and then develop into a healthy immune system.

Discussion with Workshop Participants

Participant discussion explored the ways in which informational frameworks for understanding biology were adapted from thermodynamic frameworks (signal/noise) for making communication systems functional. And subsequently, whether or not this was an appropriate manner of conceptualising noise in biological systems which had evolved within 'noisy' environments anyway, and wherein noise could play a developmental role.

16:25-17:00 Massimiliano Simons (University of Leuven, Belgium)

Title: *Synthetic biology as ready-made nature in the making*

Summary

This talk presented a typology of constructivist philosophies (that in some way our knowledge of the world is constructed/constructs that world), emphasizing that not all constructivist philosophies are the same. The increased use of computers and engineering methods in biology (computational biology) is in many ways consonant with constructivist philosophies. The central claim was that, although earlier periods of molecular biology (such as genetic engineering) can clearly be seen as constructivist as well, within the last decades there is a shift. The author introduces the notion of 'postcomplex life sciences' that implies that new approaches do not deny the complexity of nature, but imply a desire to transcend it by an open constructive act. This constructive attitude is expressed in different ways: if nature is too complex for our models … then (1) … make models more complex, e.g. systems biology; or (2) … make nature less complex, e.g. synthetic biology. In synthetic biology the construction process is in the open, in the sense that synthetic biologists argue that even if biological systems do not have standard parts, are not modular, perhaps we can make them so.

Discussion with Workshop Participants

Participant discussion examined the ways that critique of constructivist social theory might also apply to constructivist biology. The discussion also considered what an 'open' science was and if there are more than one form of an 'open' science made possible in the new biology.

Conclusions of workshop:

The conclusions drawn below reflect key considerations and outputs of the workshop that were most relevant to the ongoing work on synthetic biology at the CBD and the recent call for information. These considerations included:

Responsible Research and Innovation and the Politics of Synthetic Biology

- The importance of Anticipation, Reflection, Engagement and Action in R&D processes can be emphasized. The beginning point of all innovation is in the lab and therefore research is an early location to consider societal outcomes.
- The responsible research and innovation agenda is a step in the right direction for governance of synthetic biology, as the formal involvement of civil society organisations and the public can allow for better-informed and more accountable policy making.
- Considerations of environmental and global justice, including socio-economic, cultural and ethical considerations are unavoidable, and so should be incorporated into any ideal international governance framework for synthetic biology.
- The precautionary principle has been and remains foundational for all risk assessment frameworks governing new technologies, including synthetic biology. Such that activities which pose a significant risk to planetary ecology, or a risk to human dignity *simpliciter*, shall be preceded by an exhaustive examination; their proponents shall demonstrate that expected benefits outweigh potential harms, and any potential harms should be fully understood and mitigated.
- Continuing levels of politics, conflict and 'friction' amongst different economic agendas, world views, systems of knowledge and vested interests within parties to the CBD and across relevant organisations, Indigenous peoples and Local communities will not be easily aligned, therefore a system must be found to accommodate and govern fairly and equitably for all.

Concepts of Nature and Science

- Synthetic biology combining with artificial intelligence, and increasingly capable automation technologies, makes biology easier and faster to engineer, with companies increasingly capable of producing bespoke chemicals, compounds and products on demand.
- Some conflicts were identified around DIY bio and the idea of the 'democratisation' of genetic engineering. Giving more actors access to all technologies is not the same as having a dialogue about how we want to use them, or what types of uses might be appropriate; greater access to technologies and wider proliferation does not automatically equate to greater democratic oversight or legitimation of technologies, and could in some cases lead to the inverse.
- The development of a biological organism is always in relation to background noise. So some metaphors (taken from communication theory) for noise reduction in synthetic biology may be inappropriate to biological systems.
- There are a number of ways in which biology is becoming 'constructivist' which is to say humans are actively making with their biological knowledge.
- *Postcomplex* life sciences are not necessarily a denial of the complexity of nature, but a desire to transcend it.

List of workshop speakers & organisers

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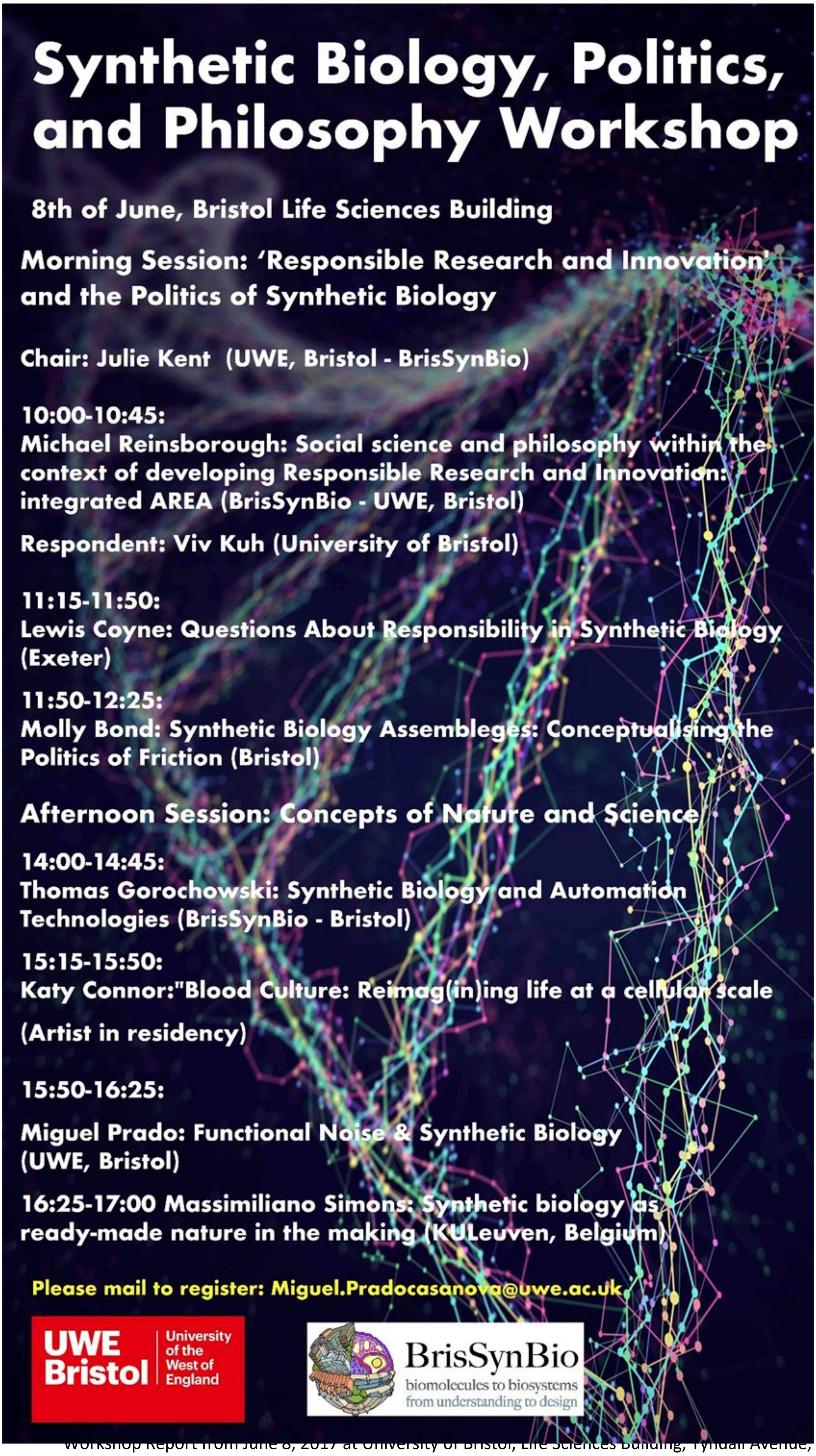
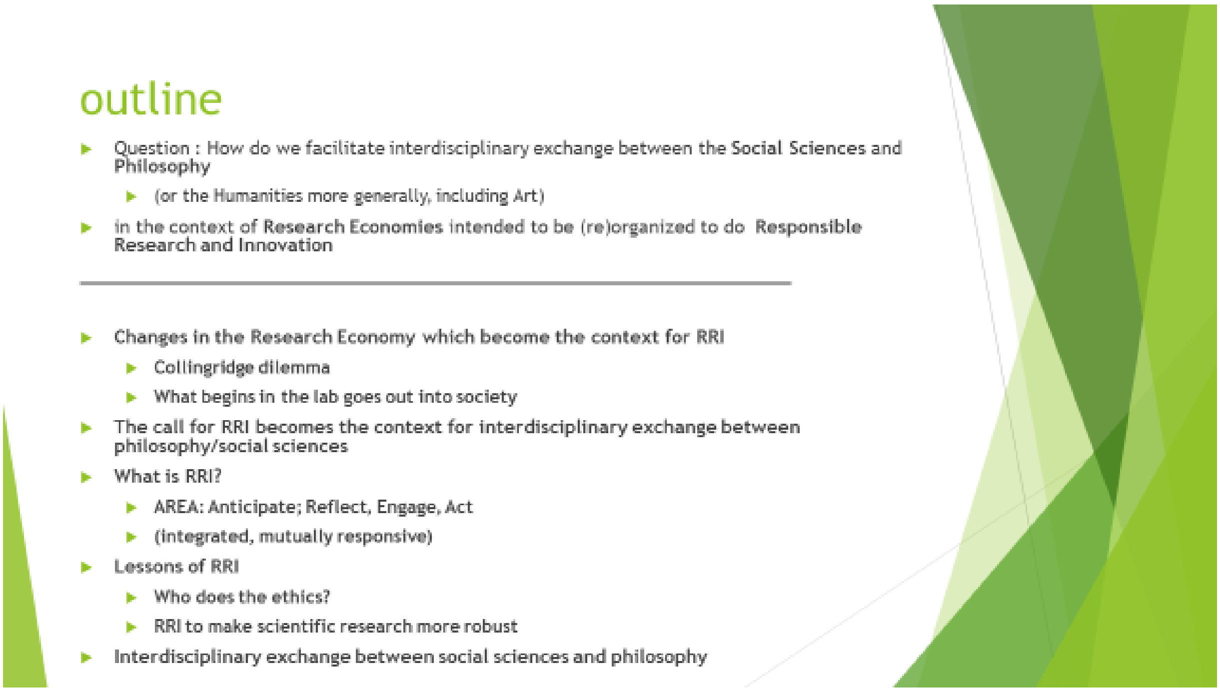
Appendix 1 **Workshop Poster**



Appendix 2 Slides of Presentation on RRI (AREA Model)



Why RRI?

- RRI as a product of a changing relationship between science and society; a change in the historical relations of science
- Old linear model: "pay for basic science and leave scientists alone and this will, in the long run, generate applications that will benefit to the economy and society"
  - But this rhetoric is largely being replaced
- New model: Grand Challenges - research should be useful to society and address grand challenges in society and/or global society

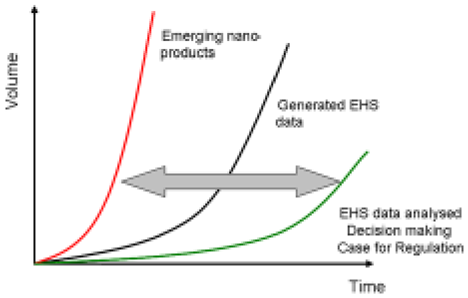
Changing Research Economies

- Large corporate research laboratories have largely disappeared in the changing (post-fordist) structure of the economy
- Recognition of the Collingridge Dilemma
  - new technologies not enough knowledge to regulate them; But by the time we have enough knowledge the technologies are well established (path-dependency) and therefore difficult and expensive to change
- Growing recognition that what begins in the lab (if it is successful) becomes a generalized product, technique, or knowledge outside the lab
  - So how is it that we might pull society into the lab so that what comes out of the lab is integrated socio-technical or biological knowledge (biosocial)

Collingridge Dilemma

Temporal Gap in Technology Assessment

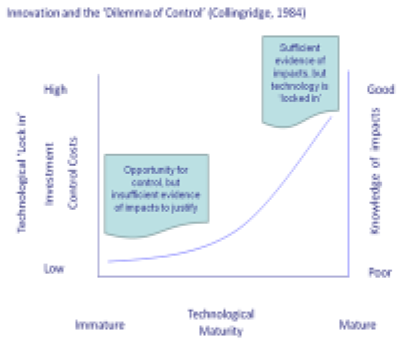
- Figure 1



source: (Owens 2011)

Dilemma of Control

- Figure 2



The call for Responsible Innovation

- RRI is a product of these changing relations of science
  - Including research - Not just RI because what happens in the lab goes outside the lab (so RRI)
  - Can we get society into the laboratory
- Many claims on what 'responsible' might mean
  - This is a pretty generic term
  - In some ways 'RRI' is a fraught term- quite politically neutral in a political realm where there are commercial and civil society interests in how technological innovation establishes the framework for what is and isn't possible in society, how decisions are made, and how resources are distributed, i.e the basis for politics is the technical infrastructure of society
    - or even (in some cases) an influence on what can be thought (Basis for Philosophy)
  - Also worth looking at implicit claims in the term 'innovation' which is part of RRI
    - For example, some have asked might we choose Responsible Research and Stagnation (in a world where innovation driven growth puts the economy on a collision course with the planetary boundaries

Putting Society into the Lab: Integration happens across different interdisciplinary and cross-sectoral exchanges

- Developing interdisciplinary and cross-sectoral cooperation as basis for RRI
- Publics, Policy, Business, Civil Society

[Society]

<---------> Cross-Sectoral

- Social Sciences, Humanities, Philosophy, Art <-> Natural Sciences [The Academy]

[The Lab]

- <------(close)-----> (far)

- Cross Sectoral = cooperation between different sectors (ie. academic and commercial, civil society, or policy)
- Interdisciplinary = cooperation between academic disciplines
  - Interdisciplinary close (example philosophy, sociology)
  - Interdisciplinary far (example bioinformatics, literature)
- All this happens in the context of a call for RRI: Responsible Research and Innovation

What is RRI?

- So RRI is the context within which social scientists and philosophers might work together
  - And work together with synthetic biologists
- Various different models for Responsible Research and Innovation?
- EU model
- UK Research Councils Model: A.R.E.A.
  - But also RRI might be
- A existing and evolving tradition within sciences and humanities ELSI/ELSA/Technology Assessment/ (Constructive Technology Assessment, Parliamentary Technology Assessment, Real Time Technology Assessment, etc.)
- A reflection of political disputes (actors who oppose particular technologies or call for democratization of existing technologies & research trajectories)
- Commercial recognition that design of technology matters
- ... or something else that someone else wants it to mean (?)

RRI European Union

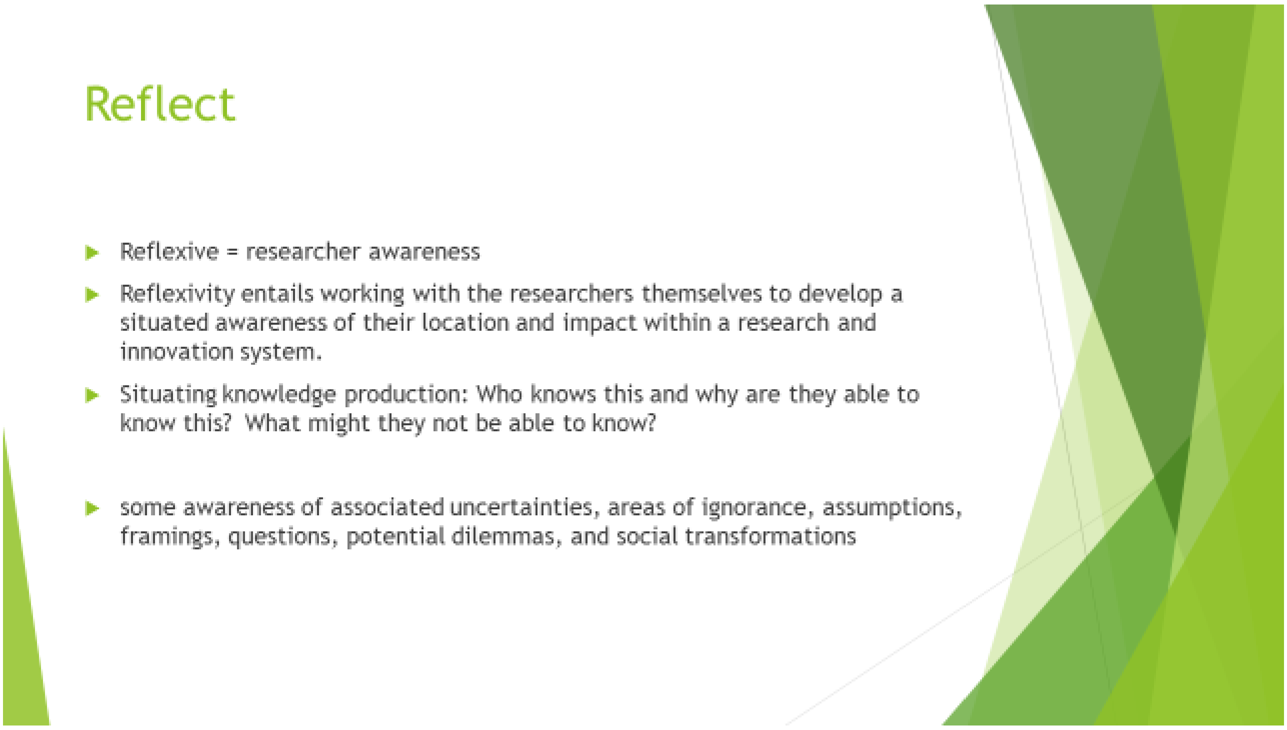
- RRI is an 'interactive process by which societal actors and innovators become ***mutually responsive*** to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process' (von Schomberg 2012)
- thematic elements of RRI EU model:
  - public engagement,
  - open access,
  - gender,
  - ethics,
  - science education
- via integrated actions that for example promote institutional change, to foster the uptake of the RRI approach by stakeholders and institutions.

RRI UK research councils

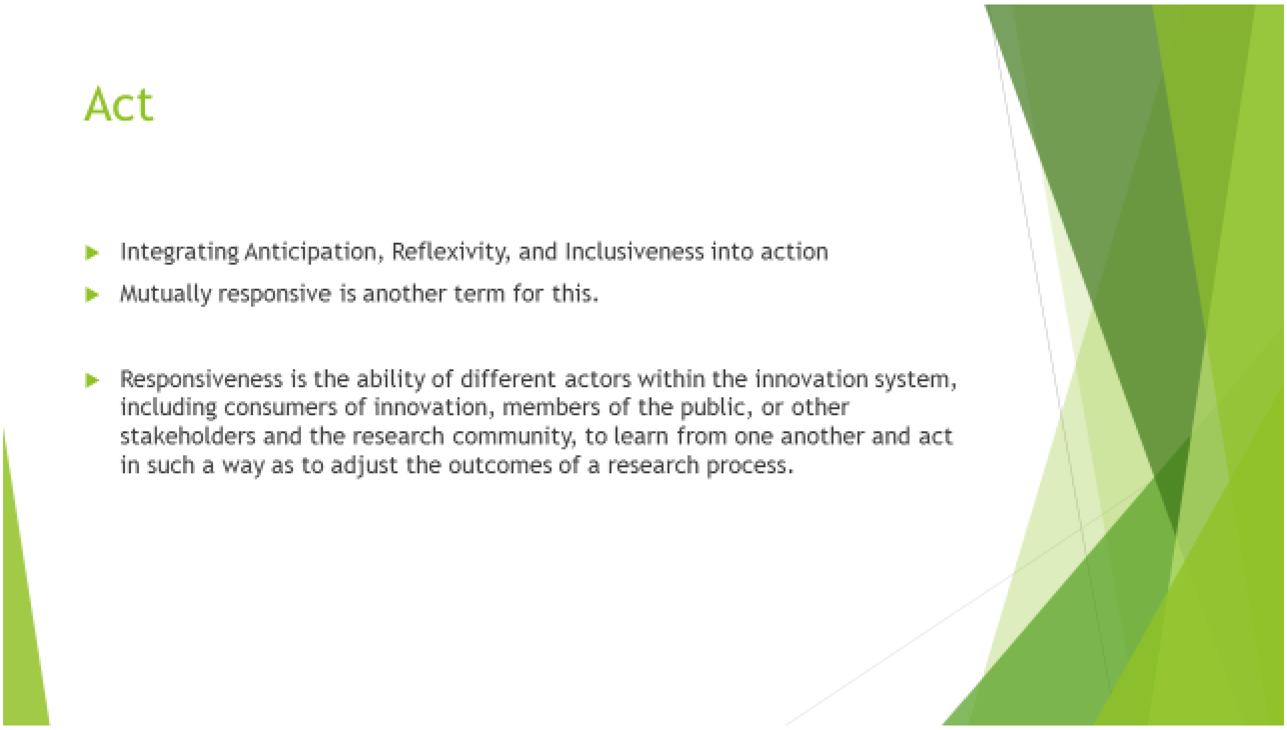
- AREA model by the EPSRC

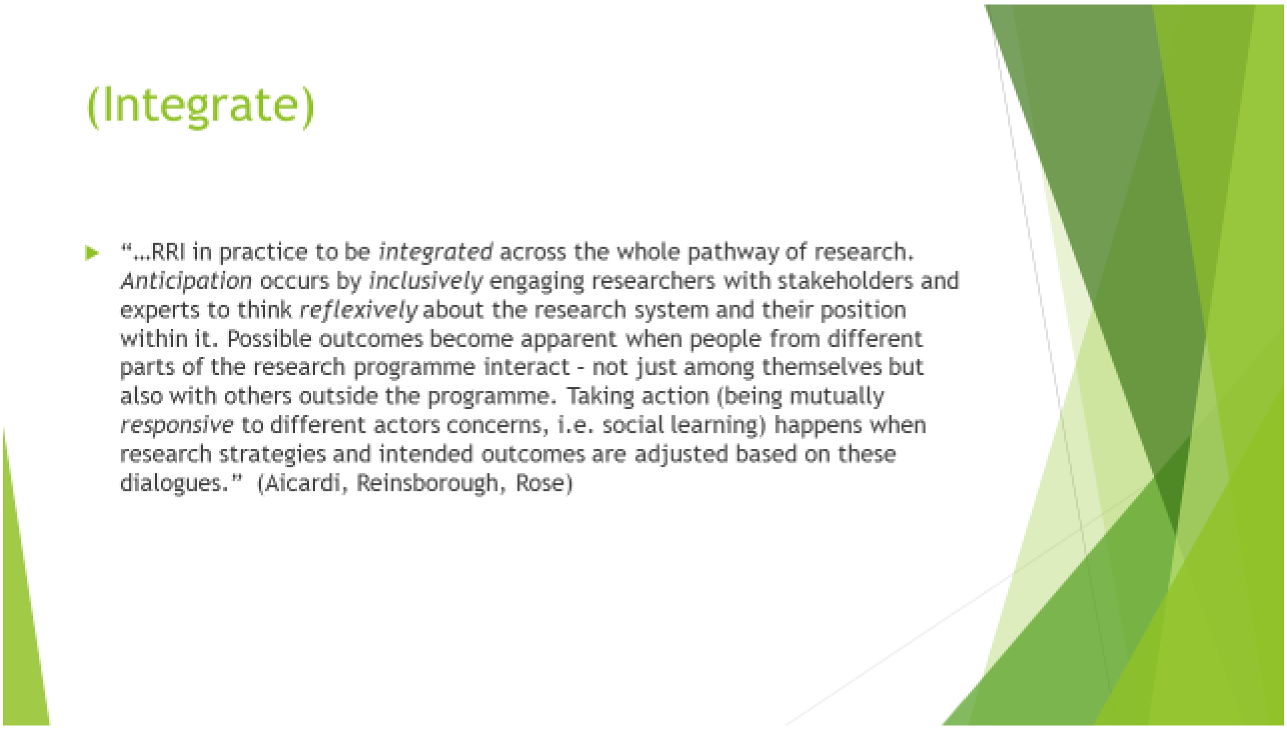
- Anticipate
- Reflect
- Engage
- Act
  - Anticipatory, reflexive, inclusive, responsive (qualities from paper by Stilgoe et al.)

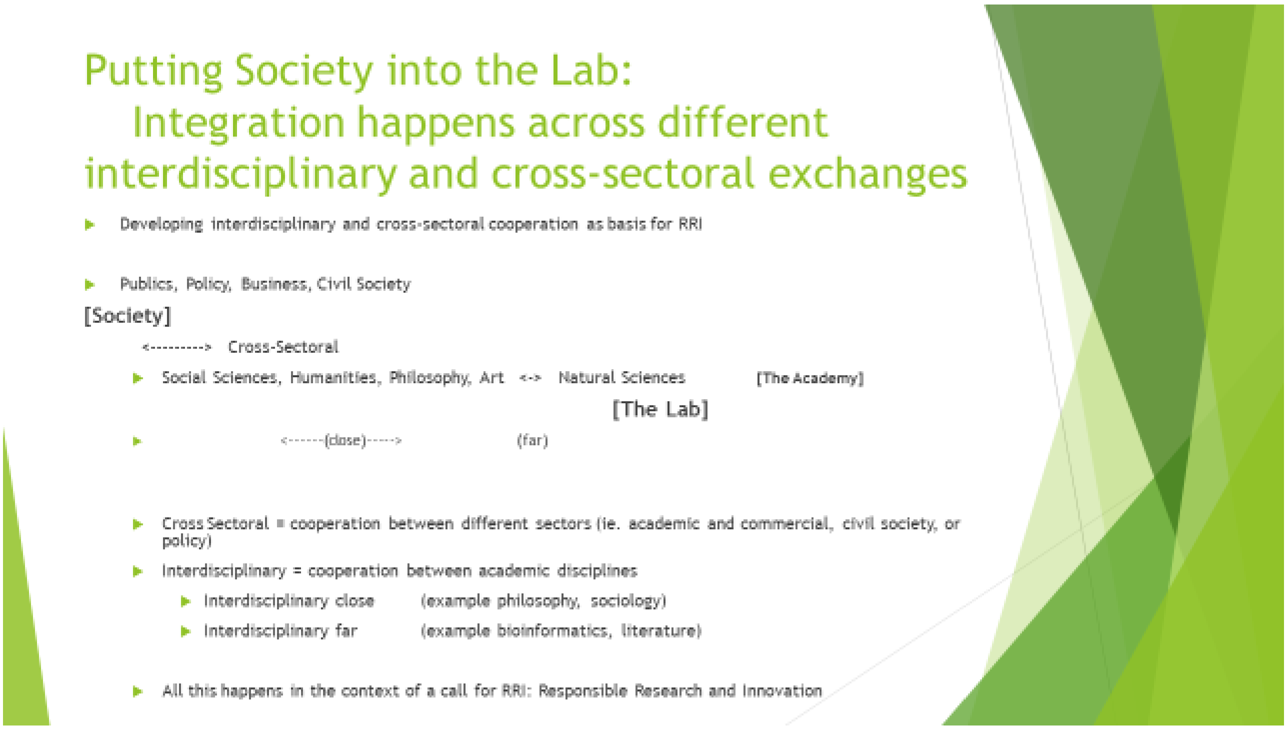

Anticipate
Consider potential impacts, intended or otherwise (e.g. economic, social, environmental), that might be outcomes of research,
not to predict a single most probable outcome but to explore possible (and plausible) outcomes
Scenarios approach: consideration of alternative ***scenarios*** may improve the capacity of various actors to deal with both expected and unexpected possible futures.


Reflect
Reflexive = researcher awareness
Reflexivity entails working with the researchers themselves to develop a situated awareness of their location and impact within a research and innovation system.
Situating knowledge production: Who knows this and why are they able to know this? What might they not be able to know?
some awareness of associated uncertainties, areas of ignorance, assumptions, framings, questions, potential dilemmas, and social transformations


Engage
Inclusive
Inclusion is the opening up of visions, impacts and questioning to broader deliberation, dialogue, engagement, and debate in an inclusive way.
Asking whose knowledge shapes research agendas?


Act
Integrating Anticipation, Reflexivity, and Inclusiveness into action
Mutually responsive is another term for this.
Responsiveness is the ability of different actors within the innovation system, including consumers of innovation, members of the public, or other stakeholders and the research community, to learn from one another and act in such a way as to adjust the outcomes of a research process.


(Integrate)
“…RRI in practice to be *integrated* across the whole pathway of research. *Anticipation* occurs by *inclusively* engaging researchers with stakeholders and experts to think *reflexively* about the research system and their position within it. Possible outcomes become apparent when people from different parts of the research programme interact - not just among themselves but also with others outside the programme. Taking action (being mutually *responsive* to different actors concerns, i.e. social learning) happens when research strategies and intended outcomes are adjusted based on these dialogues.” (Aicardi, Reinsborough, Rose)


Putting Society into the Lab:
Integration happens across different interdisciplinary and cross-sectoral exchanges
Developing interdisciplinary and cross-sectoral cooperation as basis for RRI
Publics, Policy, Business, Civil Society
[Society]
<---------> Cross-Sectoral
Social Sciences, Humanities, Philosophy, Art <-> Natural Sciences
[The Academy]
[The Lab]
<------(close)----->
(far)
Cross Sectoral = cooperation between different sectors (ie. academic and commercial, civil society, or policy)
Interdisciplinary = cooperation between academic disciplines
Interdisciplinary close (example philosophy, sociology)
Interdisciplinary far (example bioinformatics, literature)
All this happens in the context of a call for RRI: Responsible Research and Innovation

Some lessons of responsible research and innovation

- Who does the ethics?
  - Common misconception that the sociologist/philosopher/embedded humanist is supposed to "do the ethics part" for the scientific research community
    - The researchers in synthetic biology are responsible for RRI
    - Anticipatory knowledge: The researchers in synthetic biology are the source of ethical consideration for the work that they do (first to discover an invention in the lab = first to consider it's future application in society). I learn from them
    - Role of a social scientist/philosopher/artist is to do research/philosophy/art (within and in support of an RRI context)
    - Supporting communities (biologists, publics, commercial enterprise, etc.) to develop the collective capacity for a responsible research system
  - Common misconception that the social scientist/artist is supposed to "do the public communication part" for the scientific research community
    - To be mutually responsive means that communication is always two ways
- Ultimately, the purpose of RRI is to make scientific research more robust by integrating various forms of knowledge into (mutually) responsive action
  - Better science by/for responding to the context of society/environment

Have I answered the question that I proposed at the beginning?

- Question : How do we facilitate interdisciplinary exchange between the **Social Sciences** and **Philosophy**
  - (or the Humanities more generally, including Art)
- in the context of **Research Economies** intended to be (re)organized to do **Responsible Research and Innovation**
- Well probably not… but I have tried to describe the specific context of the research economy at this historical moment which provides an opportunity for interdisciplinary exchange

Interdisciplinary exchange across epistemic communities

Synthetic Biology

- Biologists, mathematicians, computer scientists, engineers, physicists, etc.

Science and Technology Studies

- Social sciences, philosophy, art, history, etc.

	Natural sciences	Social sciences	philosophy	art
Epistemology: how do we know?	natural laws	social laws/or descriptive	reasoning/or logic	Aesthetics as a way of knowing?
Epistemic Culture	Varies by discipline			
Ontology	oriented towards certainty: "objective"	Varies even within disciplines		

Some Resources for philosophical thinking within the context of RRI as described by sociology

- **A**nticipate/Anticipatory
  - Temporal
    - Bergson/ Nathan Widder
- **R**eflect/Reflexive
  - Located knowledge
    - Donna Haraway/ Feminist epistemologies/ Situated knowledge
- **E**ngage/Inclusive
  - Social
    - Political philosophy /deliberative democracy / Levinas (?) /theories of technocracy
- **A**ct/Responsive
  - "Knowledge vs Power" or "Knowledge production as a form of power"
    - Foucault/ Latour/ Joseph Rouse

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- Stilgoe, Jack, Richard Owen, and Phil Macnaghten. 2013. "Developing a framework for responsible innovation." *Research Policy* 42(9): 1568-1580. doi: http://dx.doi.org/10.1016/j.respol.2013.05.008


Synthetic Biology, Politics, and Philosophy Workshop
Title and abstract
Social science and philosophy within the context of developing Responsible Research and Innovation: integrated AREA
Socially useful outcomes from computational biology will in part be dependent upon the ability of research programmes to anticipate potential needs and concerns of user communities and integrate these into their research agenda. This presentation outlines the AREA framework (promoted initially by the UK Engineering and Physical Sciences Research Council (EPSRC)) for doing this, emphasizing research being anticipatory, reflexive, inclusive and mutually responsive. The integration of these qualities into contemporary scientific research modes is often supported by work of social scientists, humanists, philosophers and artists. The role of research in this task (by philosophers and social scientists) is discussed as well as opportunities and challenges in interdisciplinary collaboration.
BrisSynBio
Thank You!
UWE BRISTOL
University of the West of England

Appendix 3 **Text of Presentation *Questions about Responsibility in Synthetic Biology* (Lewis Coyne, University of Exeter)**

Questions about Responsibility in Synthetic Biology

1. Introduction

The Responsible Research and Innovation (RRI) agenda, as defined by the European Commission, has two broad functions: to (a) build public trust in research and innovation by (b) recognising the legitimacy and necessity of public and civil society groups influencing scientific and technological development, particularly in its early stages. I will here set out some reasons why RRI – in this form – is preferable to peer-regulation by researchers and innovators which does not subscribe to (b). I will also, however, ask whether RRI is rigorous and comprehensive enough.

Since this is a conference on RRI and its relation to synthetic biology, I assume that all of us present accept that the latter ought to be subject to *some* sort of ethical scrutiny – the only questions being what form that takes and who does it. But occasionally people ask, partly in jest, why humanities scholars enjoy a right to unrestricted research while scientists do not. The answer, of course, is that while freedom of *expression* is conceivably an absolute right, there is no equivalent right to freedom of *action*. We regulate action where there is the risk of wrongdoing and harm to others.

Modern natural science (i.e., since the 16th century) is distinguished from pre-modern science by its emphasis on experimentation, from which theory subsequently follows. *Doing something in the world*, and deriving knowledge therefrom, is its hallmark. As such, modern science – both natural and social – is inseparably tied to action. If this is true for the research stage, it is self-evidently the case for that of development, and, since synthetic biology is intended for industrial application, it falls under the remit of ethical scrutiny in both respects.

2. Epistemic Expertise

The question, then, is what *sort* of regulation is proper to an innovation like synthetic biology. One option is peer-regulation, which is roughly the function of university ethics panels. Of course, these tend to operate within individual institutions. However, for an example of this model working across institutions we may point to the 1975 Asilomar Conference on Recombinant DNA – an early form of genetic engineering – where practitioners drew up a voluntary set of regulatory guidelines. Or, for a more contemporary example, we could point to the 2015 International Summit on Human Gene Editing. (It should be clear that I am using 'regulation' here in a very broad sense, covering even voluntary ethics codes and guidelines).

Let's take these latter examples as ideal forms of peer-regulation because of their inter-institutional composition. Such an approach appeals to what we could call *epistemic expertise*. In other words, expert practitioners might be seen as best placed to perceive any possible risks, dangers, and misuses of a new technology, since they have the greatest understanding of what are after all complex innovations. The obvious next step of the argument is that this would lead to the best-informed regulation, and can be confidently adopted on a voluntary basis. In some cases, those who refuse to do so might be considered irresponsible, and subjected to social sanctions within the scientific community.

One concern we might have with this argument is the questionable appeal to epistemic expertise. Take, as another example of this approach, the financial sector. Wall Street and the City of London have in recent decades been increasingly allowed to regulate themselves partly on the assumption of epistemic expertise: that those who know most about complex financial instruments are best placed to identify risks and avoid harms. But after the financial crisis we are not inclined to take such an argument seriously.

Why is this? Partly there is the suspicion of moral corruption: that bankers were willing to take high-risk decisions in pursuit of a quick buck. But even if we assume absolute moral integrity on the part of the actors, the problem is that epistemic expertise of a *part* – sub-prime mortgages, say – does not equate to epistemic expertise of the *whole* in which they are embedded: in the case of banking, national and global economic activity. And it is precisely the risk of adverse effects on others within that whole which concerns us.

Now, something similar might also prove to be true of synthetic biology. Those who best understand it are not *necessarily* best placed to understand the wider effects it might have – ecological or socio-economic – and whether those wider effects include the risk of harm. If this is the case, or at least a distinct possibility, then we would have reason to be dubious about peer-regulation alone.

So how might we eliminate, or at least decrease the likelihood of, the possibility of harm to others? As stated, the RRI agenda holds that a variety of public voices and civil society organisations should be invited to inform the innovation process. The immediately obvious strength of this approach is that it better corresponds to the contextual whole within which innovation takes place. If, for example, agricultural synthetic biology risks adverse ecological effects, then a variety of perspectives might be better placed to capture this: wildlife organisations, and so on. And if they are wrong, and fears are ungrounded, they can be publicly proven so – possibly building greater trust in the innovation.

According to the criterion of epistemic expertise, then, RRI would seem, at face value, to be superior to peer-regulation alone.

3. Optimising Ethical Scrutiny

A second advantage relates to what we might call the *optimisation of ethical scrutiny*.

Let's look at peer-regulation in this regard. An advocate of this model would have to assume that either 1) the scientific community in question is sufficiently able to identify and act in accordance with the appropriate ethical standards, or 2) that ethics is not its concern. The latter is clearly untenable: if what is good and right is what we *should* do, then we cannot say that we needn't worry about it. (None of us, I hope, really want to see innovation which flouts academic integrity, physically harms others, or violates human dignity.)

The former assumption is also questionable – and not a slight on synthetic biologists, since we should be sceptical that any one group can perceive all ethical concerns relevant to a particular issue, and act appropriately in response. For the record, I take this to be true even of applied ethicists: being an expert in moral philosophy doesn't amount to being a moral saint. We might – and I stress *might* – be good at identifying what we should do, but we aren't necessarily good at doing it!

How does the RRI agenda fare in this regard? RRI explicitly seeks to align innovation with widely-held values and standards, by opening the process up to a range of voices from the public and civil society. Once again, this looks more promising than peer-regulation. Allowing for scrutiny by a variety of perspectives seems likely to strengthen critical reflection through challenging assumptions, and highlighting possible consequences.

On this basis we might then be better able to locate areas of ethical concern, particularly, I would suggest, regarding marginalised groups and those who are not easily able to represent themselves. And again, if those fears are unfounded they can be publicly proven so.

Let's take, as an example, the economic interest of agricultural labourers in the developing world. Some might dispute the notion that we have any *obligations* toward, for example, a coffee farmer in Ethiopia. But if most of us want to see those in the developing world live dignified lives, as I assume we do, and if self-sufficiency and prosperity generally contribute to such a life, as I believe they do, then we should be concerned with the fortunes of farmers in the developing world.

Now, let's say that a synthetic biologist working with a food company develops a coffee plant which can grow in a greater range of climactic conditions, such as the UK's temperate climate. (I don't know if that's biologically feasible, but for the sake of argument let's assume it is.) The genome is patented with the hope of being brought to market. Our Ethiopian farmer would then be in competition with a more economical strain, potentially undercutting his ability to sell to us. Moreover, if he wanted to grow that crop he would presumably have to do so with permission of the intellectual property holder.

One can probably imagine the kind of complex legal and socio-economic questions raised here. Should we allow both traditional and synthetic strains of coffee to compete on the market, letting consumer preference run its course? Or should we protect the Ethiopian farmer's interests by, say, taxing synthetic products? Should we allow the synthetic coffee to be sold like any other coffee, or should we clearly demarcate its origin on the packaging, allowing for informed consumer decision-making? If the Ethiopian farmer wanted to grow the synthetic strain, for whatever reason, what would he owe to the company who owns the patent? What will *that* do for his autonomy? And so on.

I don't pretend to have definitive answers to these questions. But RRI at least makes it possible for our Ethiopian farmer, and others like him, to be taken seriously during the innovation process and its application to the market. We would have a better chance, at least, of taking his well-being into account than we do courtesy of the peer-regulation model.

So on two counts – epistemic expertise and optimising ethical scrutiny – the RRI agenda appears preferable to peer-regulation alone.

4. Limitations of RRI

I don't want to give the impression, based on what I have said so far, that I think RRI is an ideal regulatory agenda – on the contrary, there are serious limitations to this approach, some in principle and others more practical. For the sake of time I will pick just two objections, the first practical in nature, the second more of principle.

(α) The Legislative Gap

Firstly, there is the issue of how RRI could inform appropriate legislation. At present, the RRI agenda is simply a 'tool kit' with no obvious way of feeding into law; indeed, it makes no claims to do so. Although some funding for innovation might be withheld by major funding bodies if practitioners refuse to engage with the agenda, this is only a soft kind of power rather than an enforcement.

Why is this a problem? Well, as I suggested earlier, being responsible involves not just knowing what we *should do*, but also actually *doing* it. Even if we all agreed that there were ways in which an innovation ought not to be employed, this is, of course, no guarantee that practitioners would act accordingly. Regulation by national law and international treaties, however, are usually better able to ensure this. To be sure, legislation is not a panacea: regulating in one nation or geopolitical region – the EU, say – risks 'ethics dumping', where companies and researchers simply go to states with more favourable regulatory conditions. Following Brexit one can easily see the UK taking on such a role in Europe.

But does this mean that we should simply give up on regulation otherwise deemed appropriate? Obviously not: firstly, because if, hypothetically, we think we should regulate an innovation in a particular way then that is what we *should* do! And secondly, on a slightly less idealistic note, attempting to generate standards on an international level can at least avoid a race to the bottom. It is hard to do so, no doubt, but not impossible, and the difficulty of international co-ordination does not mean we should not try.

It is of course the case that peer-regulation also suffers from the same problem of the legislative gap, so I am not claiming that RRI is *worse* than peer-regulation in this regard – merely that it, too, is not ideal.

(β) Fundamental Objections

My second concern is to do with the ethical scope of the RRI agenda. As stated, RRI seeks to draw on widely-held values and standards, partly to build public trust in scientific and technological innovations such as synthetic biology. This might be adequate if we only have *partial* concerns about the consequences of an innovation, and which can be addressed through appropriate regulation. So with the example I gave earlier, of an Ethiopian coffee farmer's prosperity and autonomy, it is conceivable that the RRI agenda could lead to some consideration of his interests (although, as I say, there is no obvious way these would be reflected in legislation).

But what if an overwhelming majority of the public have *fundamental* objections to an innovation? What do we do then? Could *these* objections be incorporated? I would suggest that they cannot. Here we find a tension in the underlying aims of the RRI agenda, which *assumes* that the innovation is going to take place and asks only for the public to shape its development so as to avoid specific consequences. But this means that if the public and civil society don't want a certain technology to develop at all their objections fall outside the scope of the RRI agenda. And in that case, public trust in innovation will presumably be undermined, rather than enhanced.

It seems to me that good democratic governance does not lightly override public opinion (though it may do on occasion), and if the public does have well-founded, fundamental objections to an innovation then these ought to be taken into account. And if our regulatory agenda cannot capture and respond to such objections

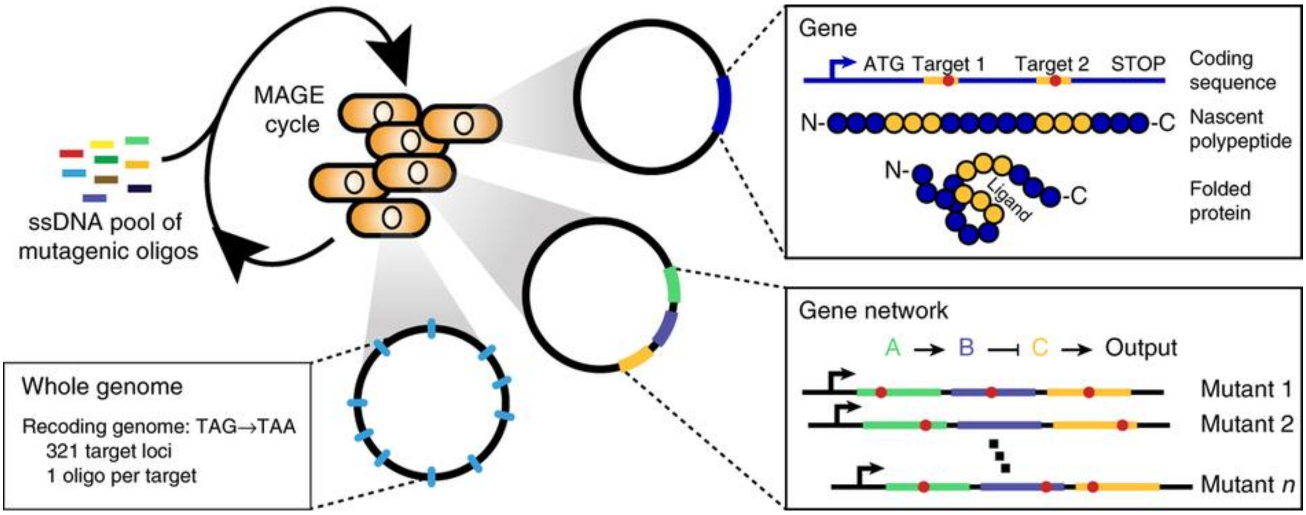
– and it seems RRI cannot – then there is something wrong with the regulatory agenda, not with the objections.

Now, it might be that synthetic biology doesn't elicit such a response from the public, or not on a significant scale. If that is the case, then the demands placed on synthetic biology by the RRI agenda might be sufficient. But we at least need to find out first – so I will end by posing some questions of principle which require answers, answers which can only come from deliberation in the public realm.

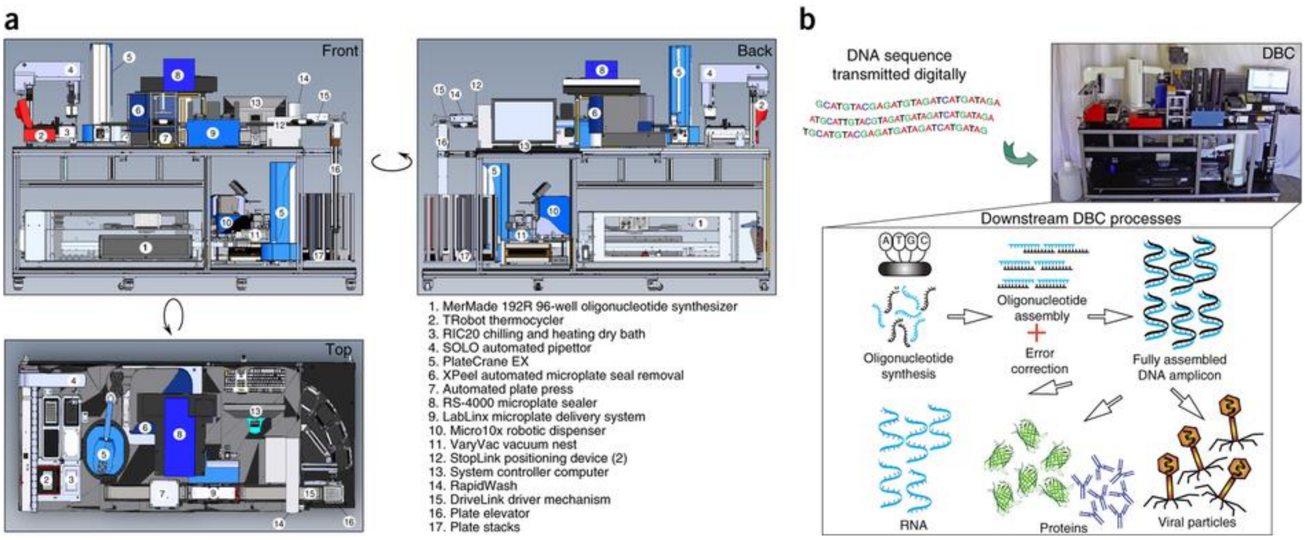
Is it *hubristic* to create new organisms (the 'playing God' charge)? Is synthetic biology unacceptably 'unnatural' in some sense? Does patenting the genome of a living being violate its dignity? Would synthetic organisms have lower moral status than natural counterparts, by virtue of their artefactual status? If it was thought that synthetic organisms were not worthy of moral consideration, and we were able to utilise them as we wished, what would this say about *us*, their creators? And do all or any of these constitute sufficient reason not to permit it?

These are even bigger questions than those I posed earlier, and again, I do not pretend to have definite answers. Perhaps the best we can do is work them out publicly, and legislate accordingly. That, to me, would be truly responsible research and innovation.

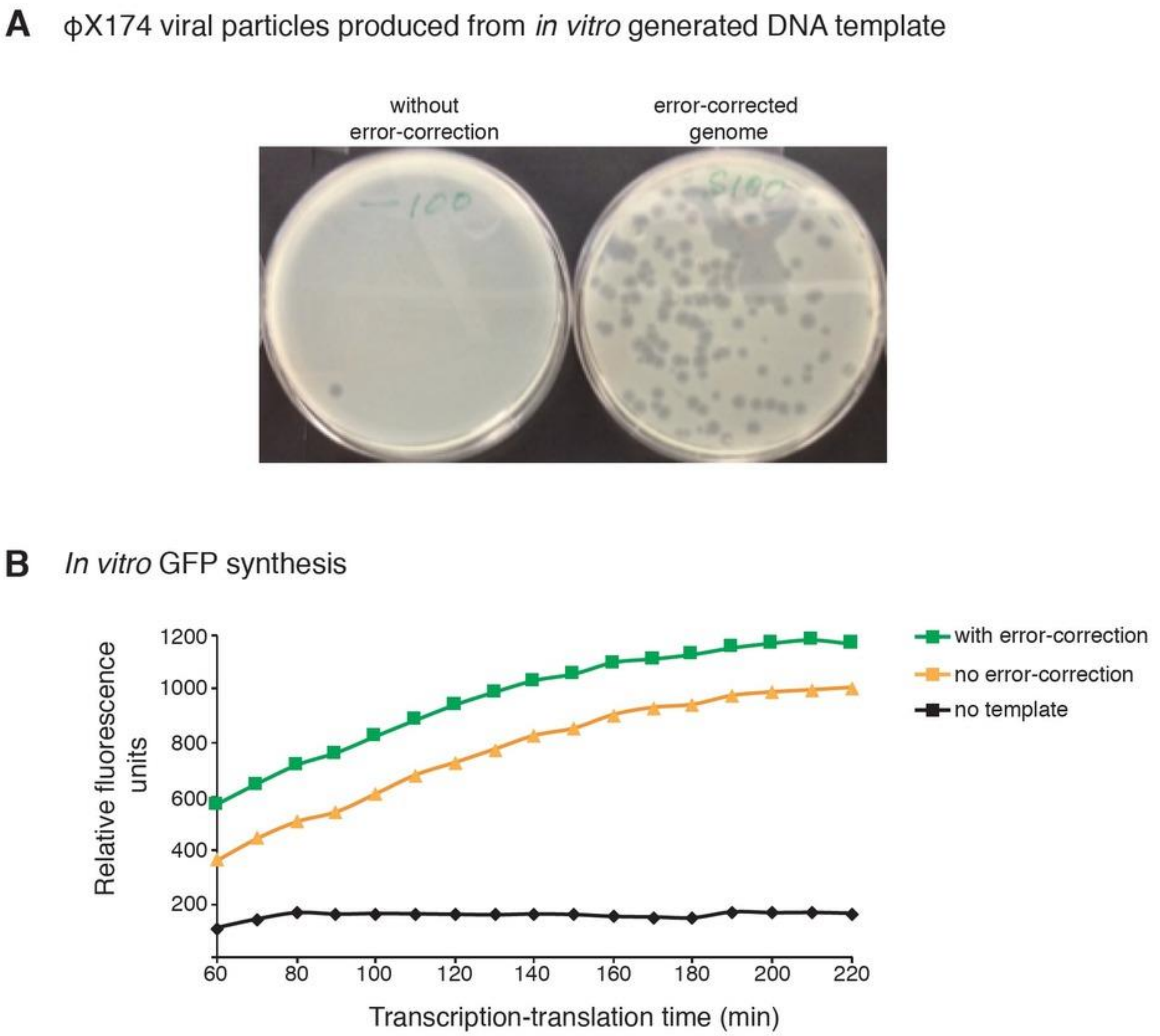
Appendix 4 **Images of Automation Technologies in Synthetic Biology**



Source: "Figure 1: Multiplex automated genome engineering (MAGE) processes and applications." From Rapid editing and evolution of bacterial genomes using libraries of synthetic DNARyan R Gallagher, Zhe Li, Aaron O Lewis & Farren J Isaacs, *Nature Protocols* 9, 2301–2316 (2014) doi:10.1038/nprot.2014.082 Published online 04 September 2014



Source: "Figure 1: Concept of on-demand production of biologicals on the DBC." from Digital-to-biological converter for on-demand production of biologics, Kent S Boles, Krishna Kannan, John Gill, Martina Felderman, Heather Gouvis, Bolyn Hubby, Kurt I Kamrud, J Craig Venter & Daniel G Gibson, *Nature Biotechnology* (2017) doi:10.1038/nbt.3859 Published online 29 May 2017



Source: “Supplementary Figure 3: Importance of error-correction reaction to produce functional DNA amplicons.” from Digital-to-biological converter for on-demand production of biologics, Kent S Boles, Krishna Kannan, John Gill, Martina Felderman, Heather Gouvis, Bolyn Hubby, Kurt I Kamrud, J Craig Venter & Daniel G Gibson, *Nature Biotechnology* (2017) doi:10.1038/nbt.3859 Published online 29 May 2017

Source: “Supplementary Figure 1: Prototype of the digital-to-biological converter (DBC).” from Digital-to-biological converter for on-demand production of biologics, Kent S Boles, Krishna Kannan, John Gill, Martina Felderman, Heather Gouvis, Bolyn Hubby, Kurt I Kamrud, J Craig Venter & Daniel G Gibson, *Nature Biotechnology* (2017) doi:10.1038/nbt.3859 Published online 29 May 2017

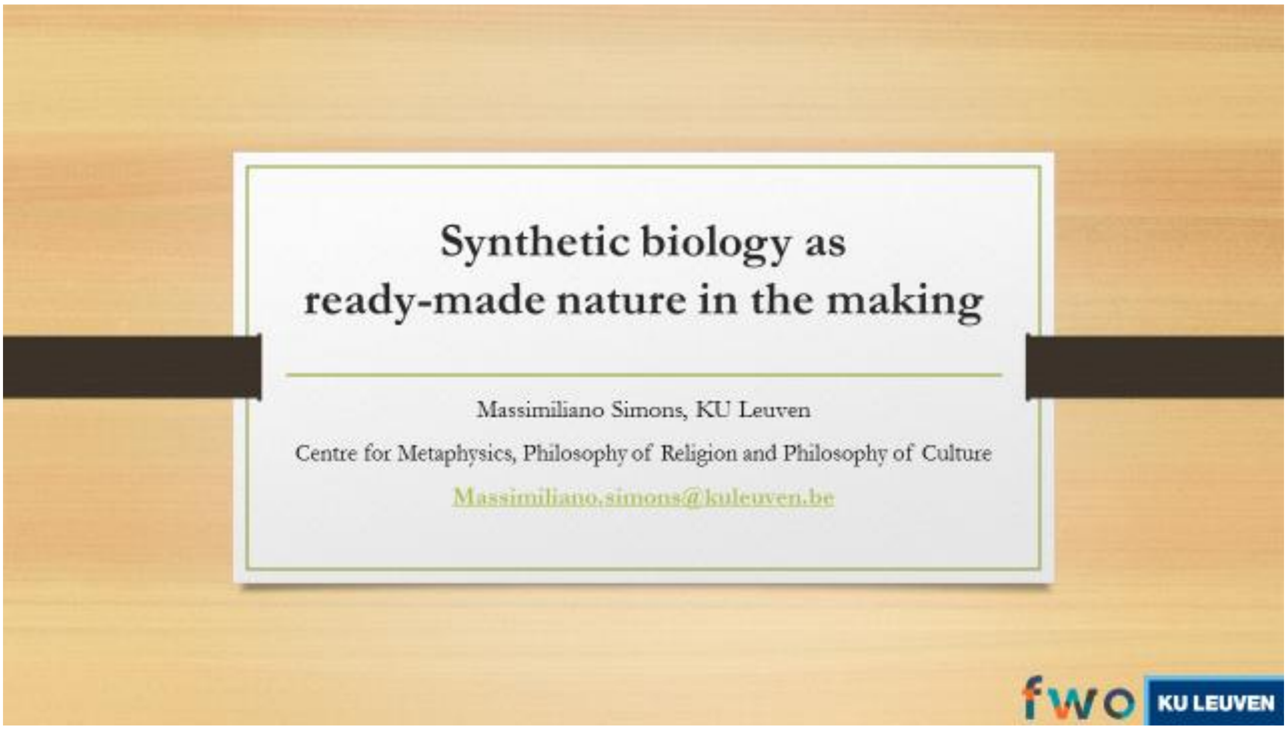
Appendix 5 Artist Images *"Blood Culture": Reimagining Life at the Cellular level* (Katy Connor, Artist in Residence, (BrisSynBio/ University of Bristol)

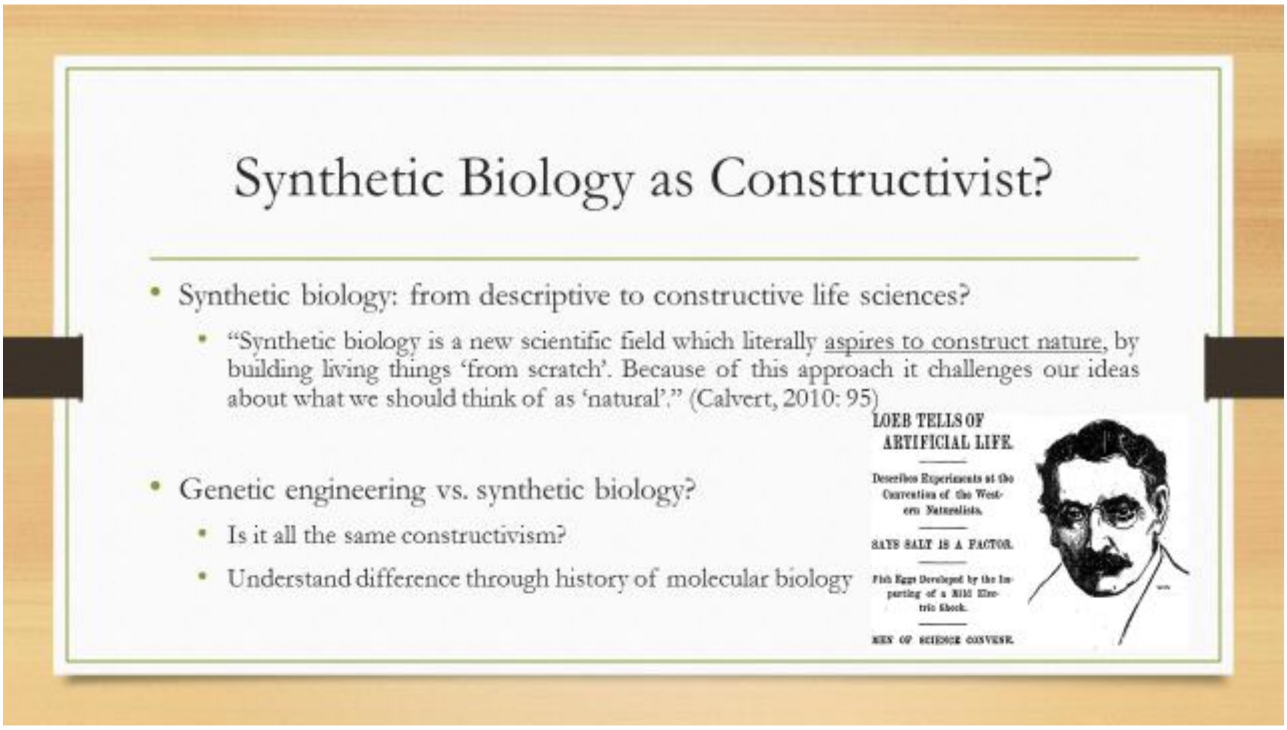
Image: Katy Connor *Language of Liquidity*: Screen mono print on paper (2017)

I use the process of screenprinting, as a vehicle to explore a physical response to being in the lab, where red blood cells are routinely cultured in a liquid medium of highly instrumental colour (phenol red). Here in these prints, the viscous media of paint, colour and chance become an antidote to containment.

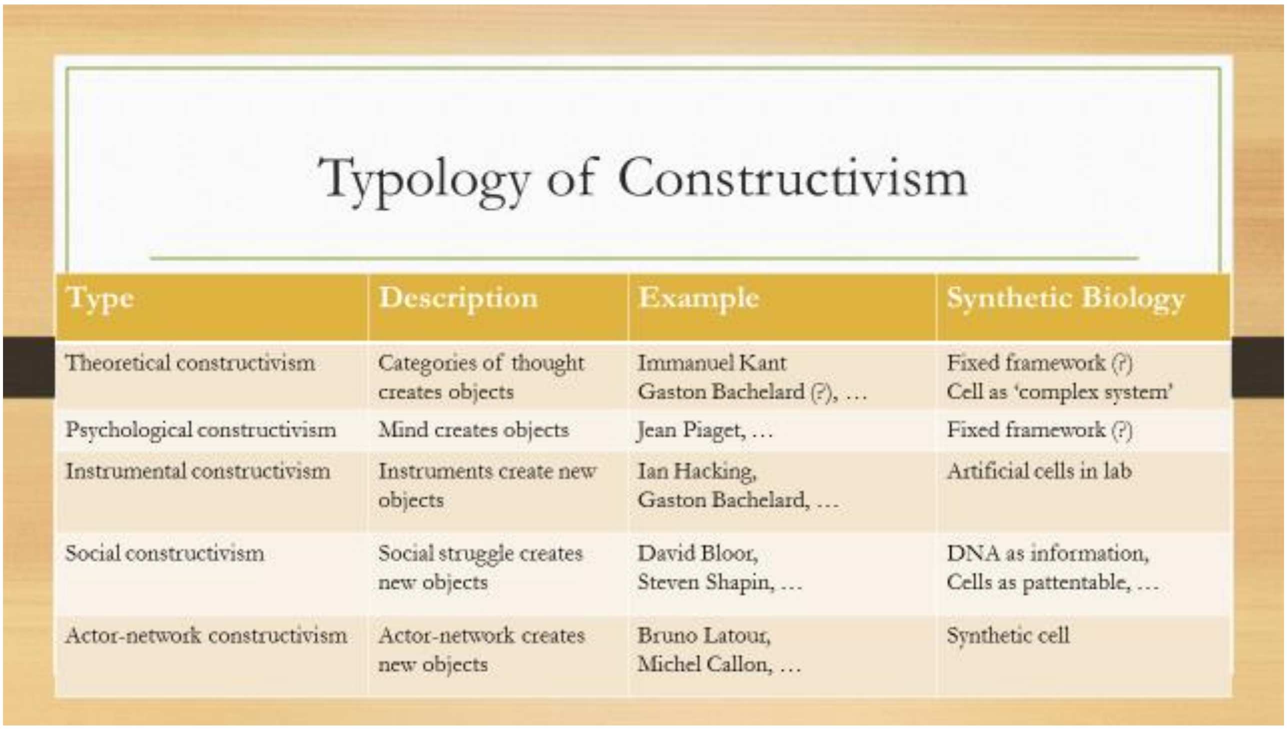
Image: Katy Connor *Language of Liquidity*: Screen mono print on paper (2017)

Appendix 6 Slides of Presentation on Constructivist Biology

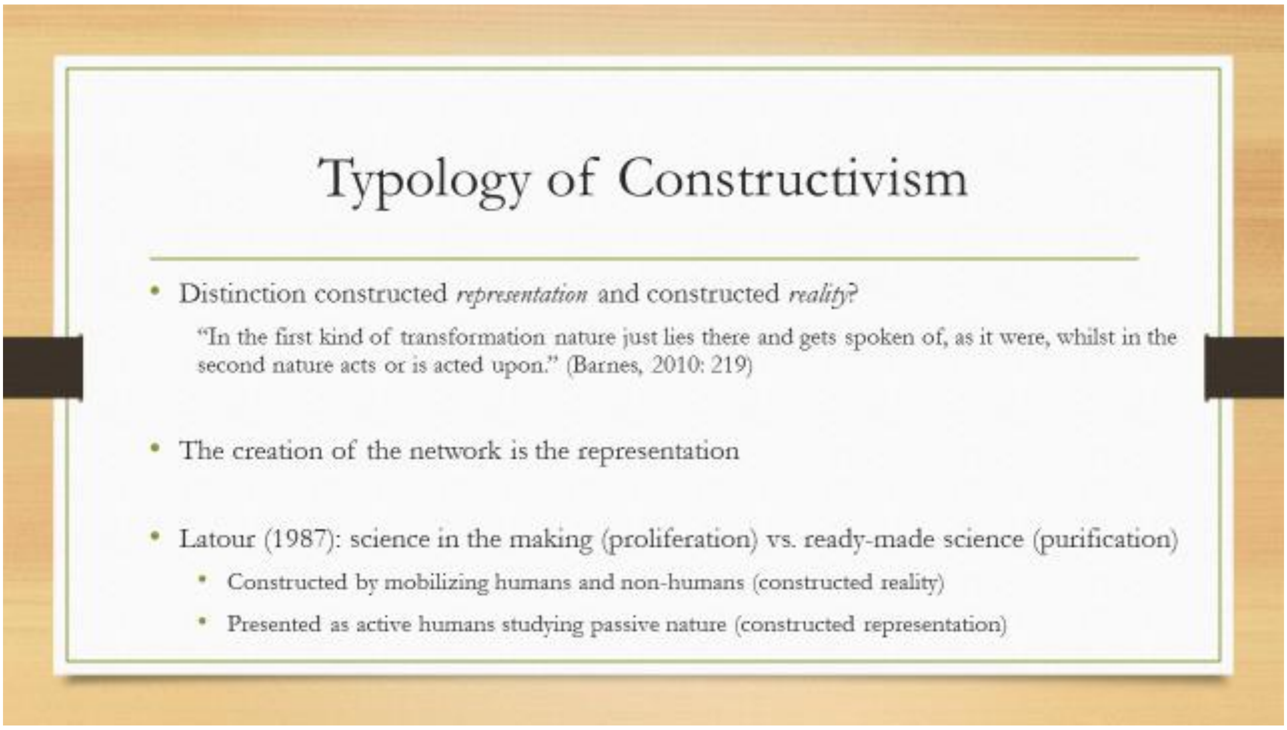


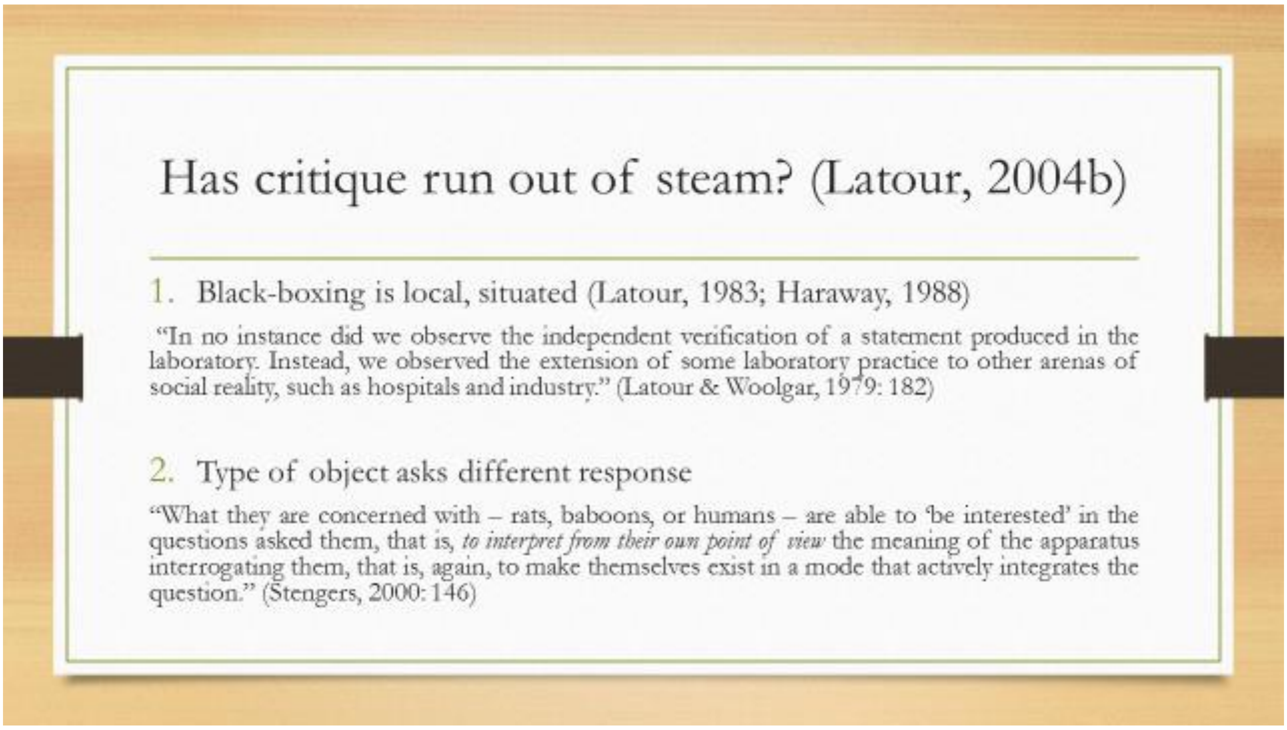


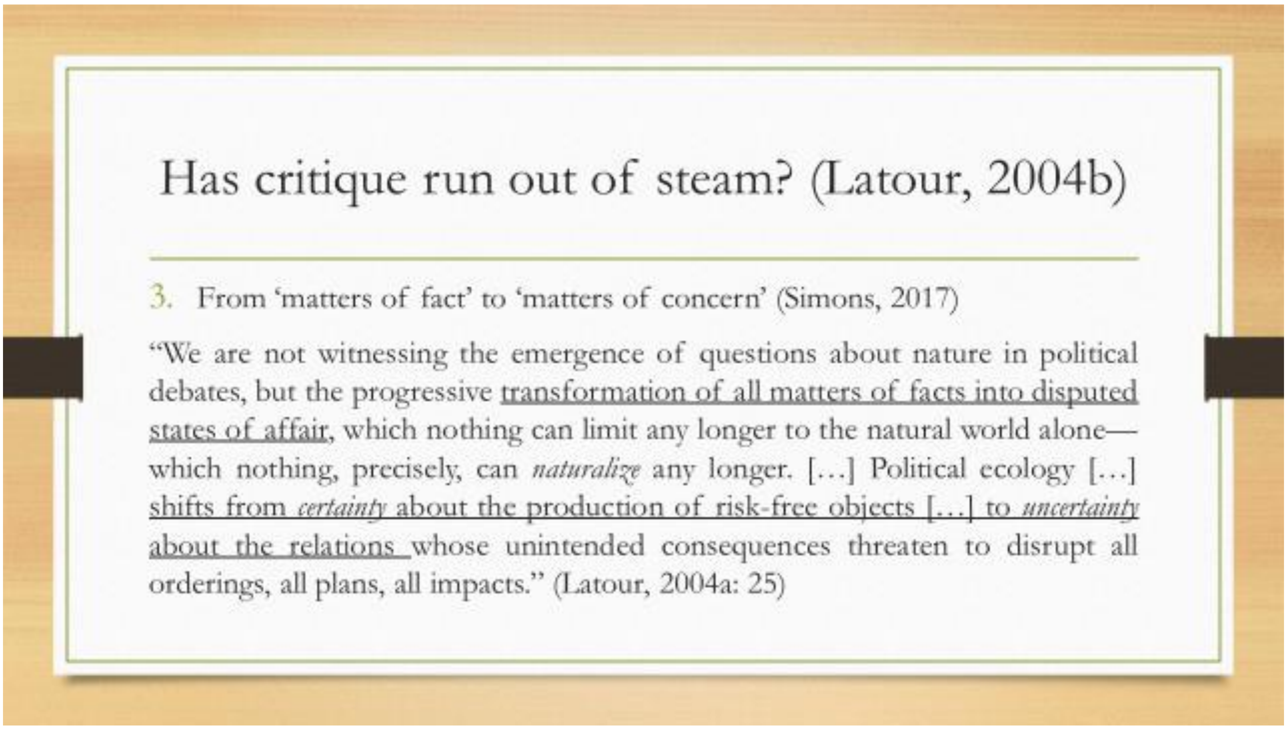

What is 'constructivism'?
Nowadays everything seems to be constructed…
Seaford, R. (2012). *Cosmology and the polis: The social construction of space and time in the tragedies of Aeschylus.*
Tänzler, D. et al. (2012). *The social construction of corruption in Europe.*
Van Brussel, N. (2014). *The Social Construction of Death: Interdisciplinary Perspectives.*
…
Sources of constructivism idea
Semiology – poststructuralism – postmodernism (Lacan, Foucault, Derrida, Lyotard, …)
Sociology of knowledge: Strong Programme, SSK, SCOT, STS, ANT, … (Bloor, Pickering, Latour, …)
Ethnomethodology, conversation analysis, interpretative sociology, …
Berger, P. & Luckmann, T. (1966). *The social construction of reality : A treatise in the sociology of knowledge.*

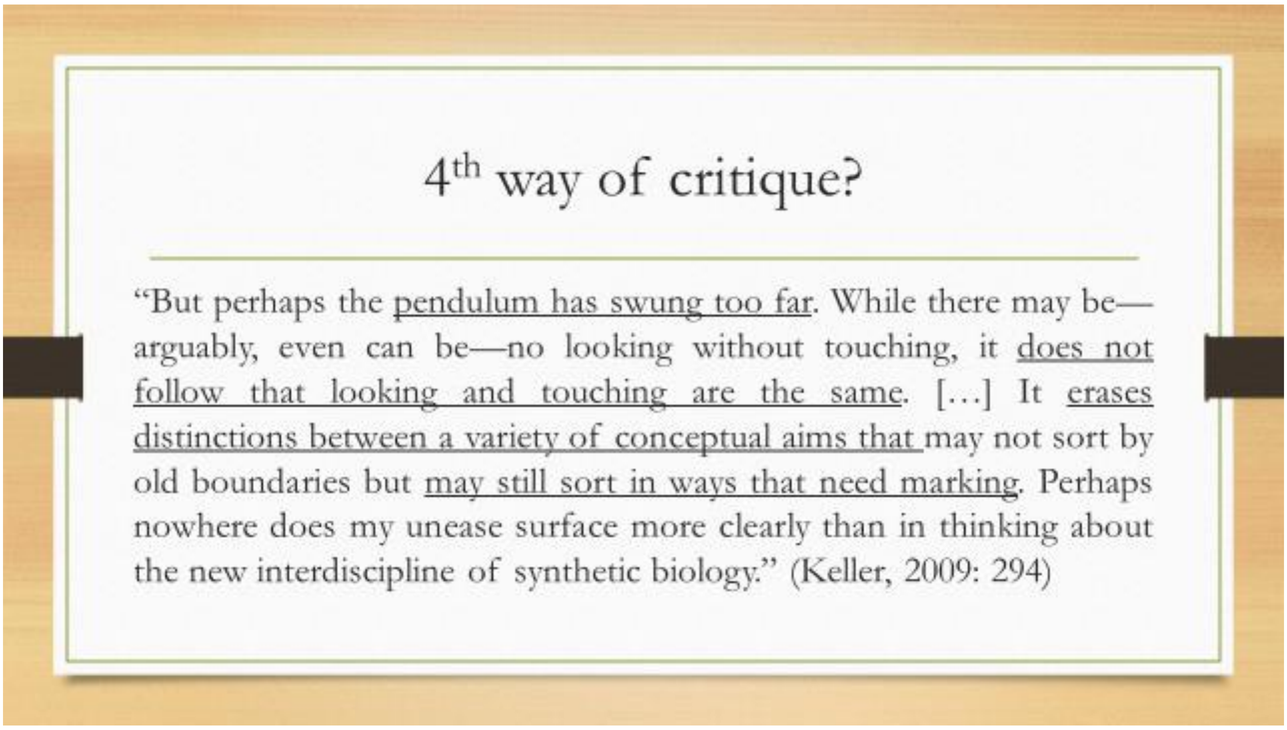

Typology of Constructivism

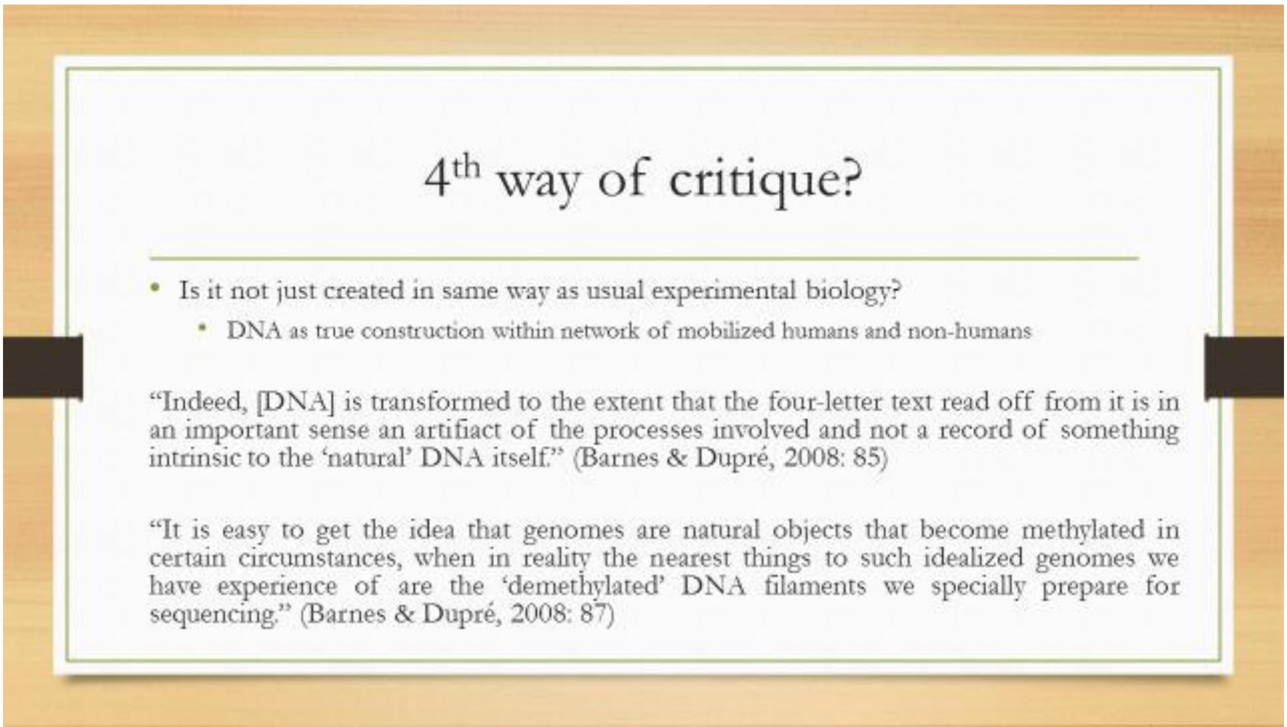
Type	Description	Example	Synthetic Biology
Theoretical constructivism	Categories of thought creates objects	Immanuel Kant Gaston Bachelard (?), …	Fixed framework (?) Cell as 'complex system'
Psychological constructivism	Mind creates objects	Jean Piaget, …	Fixed framework (?)
Instrumental constructivism	Instruments create new objects	Ian Hacking, Gaston Bachelard, …	Artificial cells in lab
Social constructivism	Social struggle creates new objects	David Bloor, Steven Shapin, …	DNA as information, Cells as pattentable, …
Actor-network constructivism	Actor-network creates new objects	Bruno Latour, Michel Callon, …	Synthetic cell

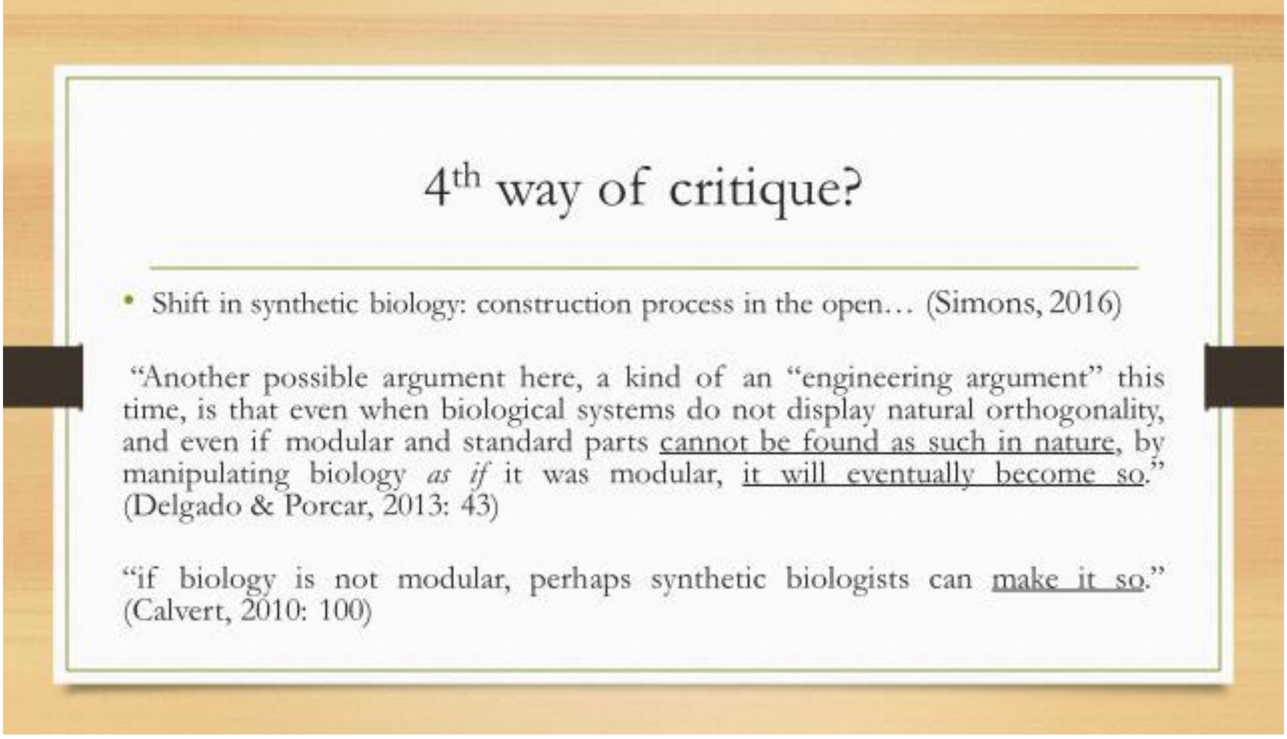

Typology of Constructivism
• Distinction constructed *representation* and constructed *reality*?
"In the first kind of transformation nature just lies there and gets spoken of, as it were, whilst in the second nature acts or is acted upon." (Barnes, 2010: 219)
• The creation of the network is the representation
• Latour (1987): science in the making (proliferation) vs. ready-made science (purification)
• Constructed by mobilizing humans and non-humans (constructed reality)
• Presented as active humans studying passive nature (constructed representation)

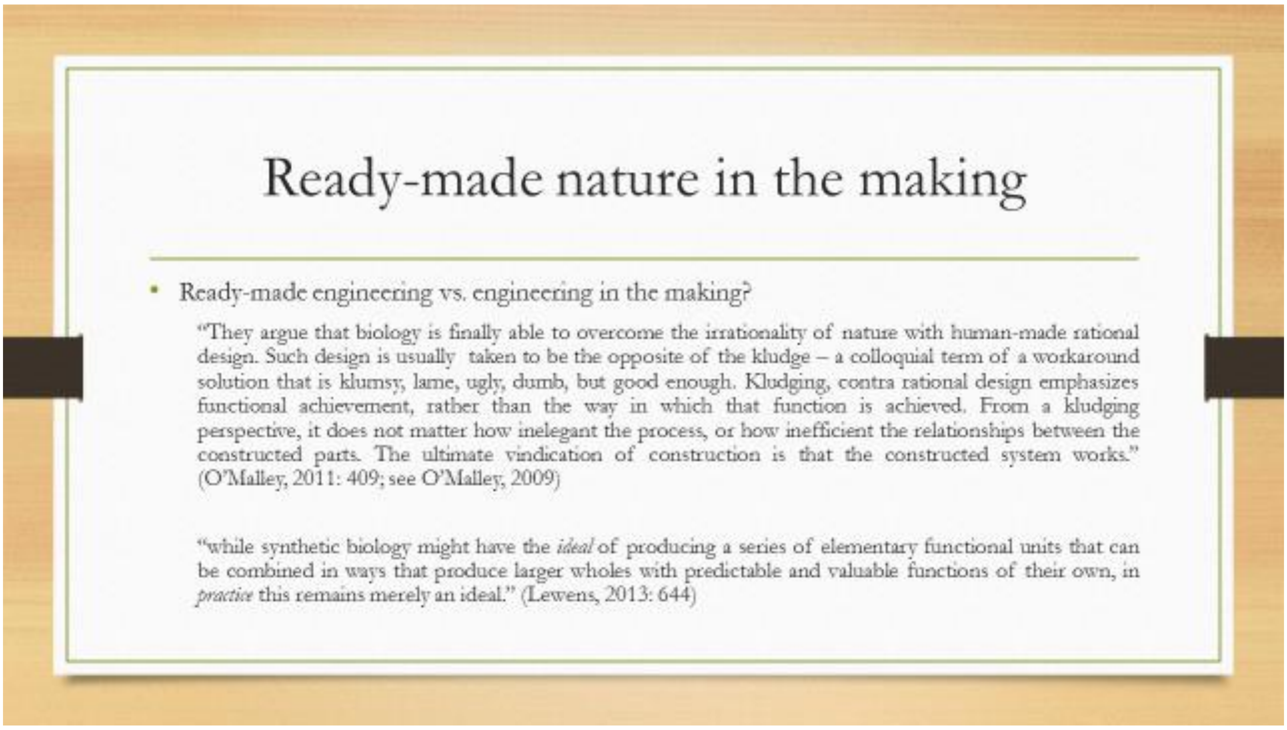

Has critique run out of steam? (Latour, 2004b)
1. Black-boxing is local, situated (Latour, 1983; Haraway, 1988)
"In no instance did we observe the independent verification of a statement produced in the laboratory. Instead, we observed the extension of some laboratory practice to other arenas of social reality, such as hospitals and industry." (Latour & Woolgar, 1979: 182)
2. Type of object asks different response
"What they are concerned with – rats, baboons, or humans – are able to 'be interested' in the questions asked them, that is, *to interpret from their own point of view* the meaning of the apparatus interrogating them, that is, again, to make themselves exist in a mode that actively integrates the question." (Stengers, 2000: 146)

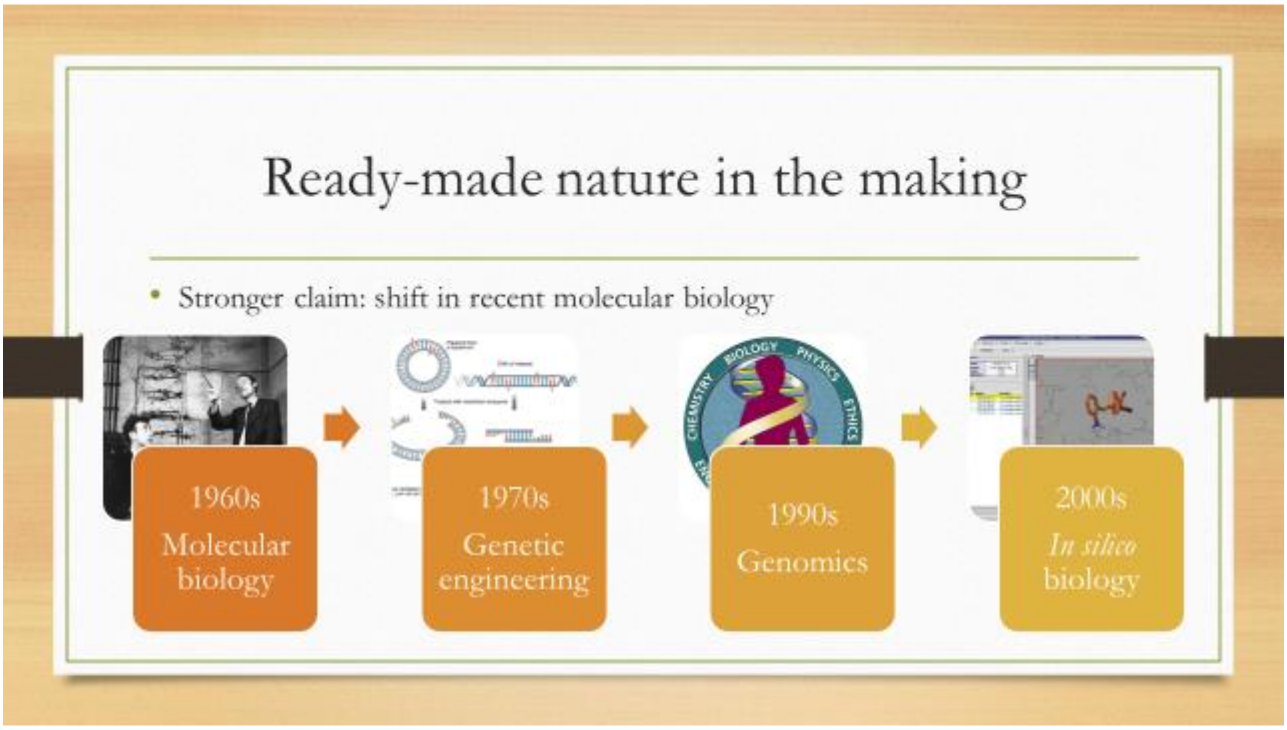

Has critique run out of steam? (Latour, 2004b)
3. From 'matters of fact' to 'matters of concern' (Simons, 2017)
"We are not witnessing the emergence of questions about nature in political debates, but the progressive transformation of all matters of facts into disputed states of affair, which nothing can limit any longer to the natural world alone—which nothing, precisely, can *naturalize* any longer. […] Political ecology […] shifts from *certainty* about the production of risk-free objects […] to *uncertainty* about the relations whose unintended consequences threaten to disrupt all orderings, all plans, all impacts." (Latour, 2004a: 25)

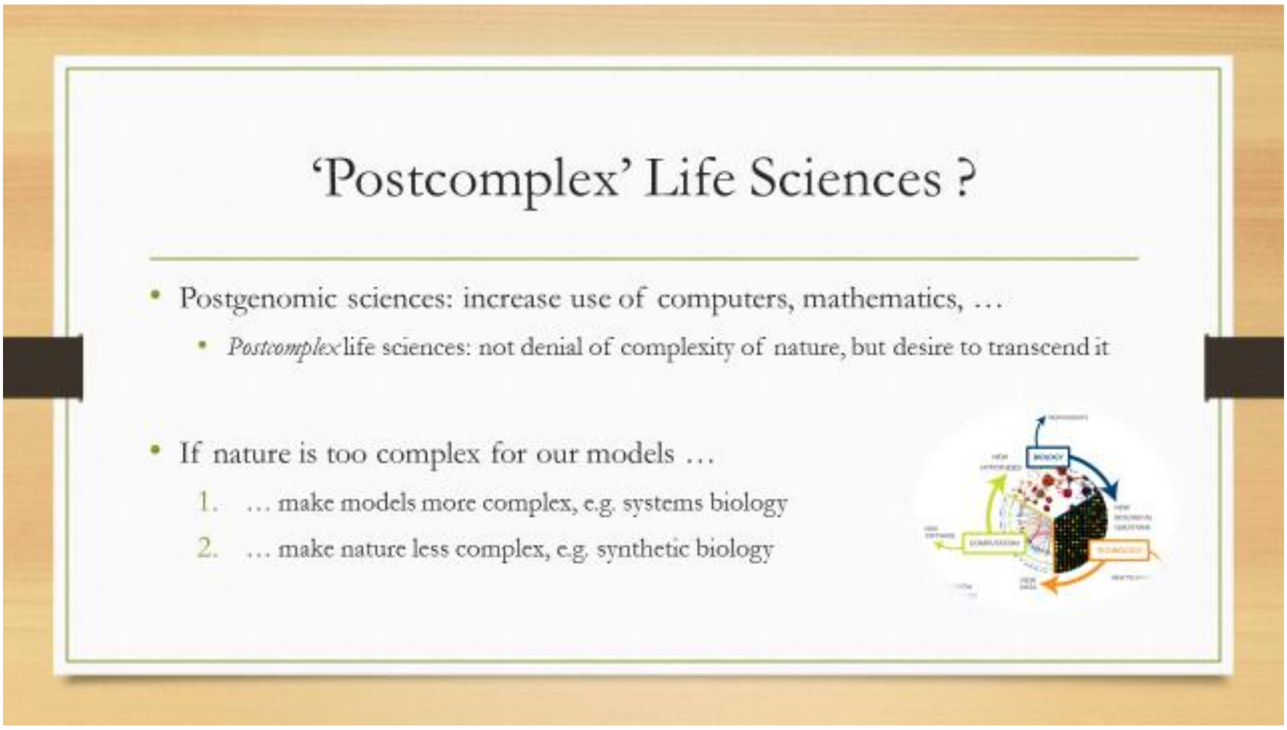

4th way of critique?
"But perhaps the pendulum has swung too far. While there may be—arguably, even can be—no looking without touching, it does not follow that looking and touching are the same. […] It erases distinctions between a variety of conceptual aims that may not sort by old boundaries but may still sort in ways that need marking. Perhaps nowhere does my unease surface more clearly than in thinking about the new interdiscipline of synthetic biology." (Keller, 2009: 294)

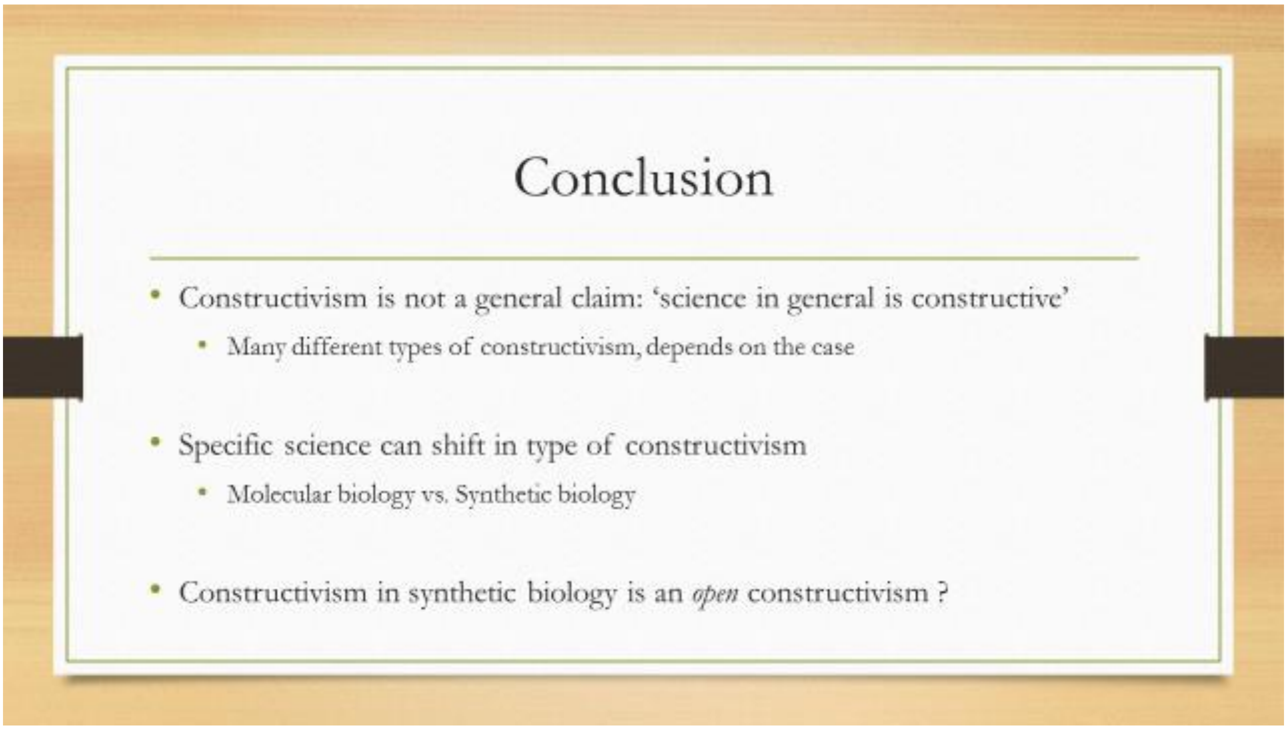

4th way of critique?
Is it not just created in same way as usual experimental biology?
DNA as true construction within network of mobilized humans and non-humans
"Indeed, [DNA] is transformed to the extent that the four-letter text read off from it is in an important sense an artifiact of the processes involved and not a record of something intrinsic to the 'natural' DNA itself." (Barnes & Dupré, 2008: 85)
"It is easy to get the idea that genomes are natural objects that become methylated in certain circumstances, when in reality the nearest things to such idealized genomes we have experience of are the 'demethylated' DNA filaments we specially prepare for sequencing." (Barnes & Dupré, 2008: 87)


4th way of critique?
Shift in synthetic biology: construction process in the open… (Simons, 2016)
"Another possible argument here, a kind of an "engineering argument" this time, is that even when biological systems do not display natural orthogonality, and even if modular and standard parts cannot be found as such in nature, by manipulating biology *as if* it was modular, it will eventually become so." (Delgado & Porcar, 2013: 43)
"if biology is not modular, perhaps synthetic biologists can make it so." (Calvert, 2010: 100)


Ready-made nature in the making
• Ready-made engineering vs. engineering in the making?
"They argue that biology is finally able to overcome the irrationality of nature with human-made rational design. Such design is usually taken to be the opposite of the kludge – a colloquial term of a workaround solution that is klumsy, lame, ugly, dumb, but good enough. Kludging, contra rational design emphasizes functional achievement, rather than the way in which that function is achieved. From a kludging perspective, it does not matter how inelegant the process, or how inefficient the relationships between the constructed parts. The ultimate vindication of construction is that the constructed system works." (O'Malley, 2011: 409; see O'Malley, 2009)
"while synthetic biology might have the *ideal* of producing a series of elementary functional units that can be combined in ways that produce larger wholes with predictable and valuable functions of their own, in *practice* this remains merely an ideal." (Lewens, 2013: 644)


Ready-made nature in the making
• Stronger claim: shift in recent molecular biology
1960s Molecular biology
1970s Genetic engineering
1990s Genomics
2000s *In silico* biology
BIOLOGY
PHYSICS
ETHICS
CHEMISTRY


'Postcomplex' Life Sciences ?
Postgenomic sciences: increase use of computers, mathematics, …
Postcomplex life sciences: not denial of complexity of nature, but desire to transcend it
If nature is too complex for our models …
1. … make models more complex, e.g. systems biology
2. … make nature less complex, e.g. synthetic biology


Conclusion
Constructivism is not a general claim: 'science in general is constructive'
Many different types of constructivism, depends on the case
Specific science can shift in type of constructivism
Molecular biology vs. Synthetic biology
Constructivism in synthetic biology is an *open* constructivism ?

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fwo KU LEUVEN

Actor-network constructivism

" Take a corner of the world, say, the Himalayas, and think of it as it was prior to the existence of any human beings. Now imagine that humans come along and represent the facts in various different ways. [...] Next, imagine that eventually the humans all cease to exist. Now what happens to the existence of the Himalayas and all the facts about the Himalayas in the course of these vicissitudes? Absolutely nothing. Different descriptions of facts, objects, etc., come and went, but the facts, objects, etc., remained unaffected. (Does anyone really doubt this?)." (Searle, 1995: 164)

- We can never say anything about this external reality except by representations (*pace* Searle)
  - Also existence claim of reality is itself part of construction
  - "Realism could not be a theory asserting the existence of Mt. Everest, for example, because if it should turn out that Mt. Everest never existed, realism remains untouched." (Searle, 1995: 156)
  - Realist constructivism: our constructed reality implies that there are *realities* over which we have no control
- Our representations do no leave world indifferent, we create relations with objects
  - Only way to know anything about objects is by interacting with them, changing them, …