The ethics of synthetic biology research and development: a principlist approach

Kevin Smith

The Ethics of Synthetic Biology Research and Development: A Principlist Approach

Abstract A principlist approach is adopted to analyse the ethical status of synthetic biology (synbio) research and development. The principle of nonmaleficence generates precaution-driven conclusions that are excessively restrictive to the field of synbio. The principle of beneficence is best served by permitting synbio research to flourish, and not have it treated as a special case warranting the imposition of a high degree of external and self-regulation. Synbio may offend the principle of justice in certain circumstances, however such issues are largely restricted to the initial stages of synbio innovation, while in the longer term the development of the field can be expected to promote just ends. The principle of respect for autonomy entails that scientists ought to be afforded a broad scope to freely pursue synbio research and development in a curiosity-driven fashion. In balancing the various conclusions under the four principles, the author concludes that society has an ethical obligation to support the development of synbio research and development and not restrict this important nascent field by the imposition of stern regulation.

Keywords Autonomy • Beneficence • Bioethics • Justice • Nonmalificence • Principlism • Synthetic biology

1. INTRODUCTION

This chapter explores the question: what is the ethical status of research into synthetic biology (synbio) and its attendant development? Ethics is a domain where it is essentially impossible to achieve absolute truth. Ethical laws and practices are inevitably open to questioning, and the aphorism "there are as many ethical positions as there are individuals" contains some truth. However, to hold that subjectivity reigns supreme in the ethics domain and that there are 'no correct nor wrong responses' would be a depressing position. Fortunately, while ethics can never yield the same levels of (provisional) near-certainty as can scientific research, rational ethical analysis can yield important conclusions. This is just as well, because ethics is crucial: there would inevitably be much societal, individual and environmental damage and exploitation in the absence of ethics-driven restraints; and, in the absence of ethical imperatives to act, many negative consequences would flow from omission.

To facilitate a rational exploration of the ethics of synbio research and development, this chapter will utilise a well-established approach to ethical analysis known as *principlism* (Beauchamp, Childress 1994). The principlist approach is based on four core ethical principles:

- *Nonmaleficence*
- *Beneficence*
- *Justice*
- *Respect for autonomy*

As a tool of ethical analysis, principlism entails that each of the four principles (in turn) is applied to the issues raised by an ethical conundrum – namely, synbio. Accordingly, this chapter will proceed by reviewing the ethical claims that have been made by various

ethicists, with the material organised into each of the five categories listed above. Finally, an overall conclusion will be presented, in which the present author will seek to integrate and balance the individual conclusions under each of the four principles.

2. NONMALEFICENCE

The principle of nonmaleficence can be summarised as a normative rule: 'do no harm'. This notion is somewhat problematic on strictly logical grounds, as it would be virtually impossible to do anything in biomedical research that could be entirely guaranteed free from any conceivable risk of causing (even very slight) harm. A more common-sense interpretation of the concept is as follows: it should be considered unethical to do something that has a high risk of causing serious harm. While this latter interpretation lacks precision (when is a risk 'high' enough to count; when is a harm 'serious' enough to count?), it has resonance with the kind of everyday ethical outlook commonly employed by individuals – including many scientists and laypeople.

While promising major benefits, it has been asserted that synbio has the potential for catastrophic consequences, including some which are far more severe –and unpredictable– than most associated with most forms of bioscience, and some which may be unstoppable once underway. These disastrous potential outcomes include runaway environmental degradation and abuse of the products of synbio for malign ends. For example, the prominent bioethicist Savulescu, Director of the Oxford Uehiro Centre for Practical Ethics, has claimed that synbio "introduces new jokers into the pack" so that among other dystopian scenarios, "one mistake or abuse could be catastrophic", as Savulescu alleges that synbio carries "unprecedented risk to natural ecosystems and human health" (Savulescu 2012). On a similar vein, Stabinski of Greenpeace International has claimed that "…synthetic biology is like genetic engineering on steroids"; "Tinkering with living organisms that could be released in the environment poses a grave biosafety threat to people and the planet" (Stabinski 2006). Such siren calls have been heeded and, dating from the earliest days of synbio research, these concerns have led to various national regulatory responses to control synbio research and development (Rager-Zisman 2012).

Does synbio research contain intrinsic features that render its proscription or heavy regulation ethically desirable? The notion synbio represents a special case in bioethics is highly contentious (Newson 2015). Synthetic organisms may be designed to reproduce autonomously, and major concerns have been raised as to the biosafety aspects of such organisms. What is they should escape from the laboratory? The environmental and health-related negative consequences of such escape could be considerable. However, numerous biomedical laboratories (most of which are not specifically involved in synbio research) routinely deal with highly pathogenic organisms, including potentially lethal viruses and bacteria, as well as genetically modified organisms. In such work, standard safety procedures are successfully employed to prevent accidental release of the organisms. Thus, it would appear to be a fundamental error to place synbio in a special category in which the normal safety approaches of biomedical laboratories are deemed insufficient.

The concept of 'dual-use' (or 'dual-use complexity') has been particularly prominent in the ethical discourse surrounding synbio. The concept refers to research aimed at

improving human well-being having the potential for misappropriation by bioterrorists. A fairly substantive body of published work exists that explores this notion (Drew, Mueller-Doblies 2017, Evans, Selgelid 2015, Rager-Zisman 2012, Wimmer 2018). The published work on dual-use, taken in toto, has been broadly negative in its conclusions (though a minority of authors take a contrary view), and has in general tended to suggest that the risk of harm or disaster warrants strong regulation or proscription of much synbio research, or at least placing obligations (sometimes of an onerous nature) on synbio researchers to become aware of possible harmful uses of their work and thence take responsibility for averting the anticipated harmful misuses.

However, a problem with the concept of dual-use is that, taken literally, it appears to be so widely applicable that it offers little of value. Almost all technologies could in some way be misused such as to cause harm; and all forms of synbio research have at least some potential for dual-use. Thus, the concept of dual-use can logically only apply in cases where the risks are high and the dangers are of a very serious sort. Such experiments, where the scope for malign uses of a given technology are clear, have been termed 'experiments of concern' (Miller, Selgelid 2007). In such cases, the dual-use concept appears undisputable, and the ethical disapprobation of pursuing such research without due safeguards inevitable and irrefutable. Nevertheless, in such clear-cut cases the researchers involved are likely to recognise the potential for misuse and act accordingly – with no need for complex ethical theorizing around concepts of dual-use. (This assumes they are not corrupt: but ethical injunctions will not prevent corrupt individuals from carrying out their immoral activities.) In terms of regulatory control or proscription, it is not clear that this is necessary at the research phase of development of (say) a synthetic microorganism for medical use that could also be put to use as a weapon by bioterrorists. External regulation would be appropriate at a future developmental stage – ie when a clearly dangerous product (such as the synthetic microorganism in the above example) is ready for use, as opposed to when the initial research is being conducted. Thus, in cases where the dangers of misuse are obvious and realistic, the concept of dual-use ethics as a normative tool would appear to be somewhat redundant.

Yet is clear that many advocates of dual-use ethics would not restrict the approach to scenarios in which the risks of misapplication of synbio were credible and severe, as in the foregoing example. The literature on dual-use ethics tends to suggest that a dual-use ethics approach should apply universally to the field. Thus, synbio researchers would be obliged to be permanently vigilant in respect of potential misuses of all aspects of their work. In general, proponents of dual-use ethics suggest that *education* should be the tool for engagement with dual-use concerns. Dual-use proponents have argued that research communities ought to provide substantive educational provision for researchers – preferably incorporating the involvement of laypeople– aimed at raising awareness of the possibilities for technological misuse. Sadly, professional ethics education more often than not falls far short of its well-meant goals for enhancing ethical behaviour (Bazeman, Tenbrunsel 2011), and it seems almost inevitable that efforts to inculcate dual-use ethics amongst researchers will be similarly futile. One might argue that such education, although of minimal benefit, is at least harmless. But this assumption is questionable: the costs of dual-use education could be substantial. An obligation for such education be time

consuming, and would tend to distract researchers from their primary work, thus impacting negatively upon scientific progress. Moreover, because synbio is multidisciplinary, and dual-use ethics entails that any activity of potential relevance to synbio ought to be considered for its abuse potential, these costs would potentially be shouldered by an extensive range of bioscientific disciplines and a very large number of researchers.

It has been claimed that ethical attention should be paid not only to the research processes underlying synbio, but also to *knowledge* itself: namely, what knowledge should be pursued, and how much of it ought to be disseminated (Douglas, Savulescu 2010). The underlying contention is that it is desirable to control and limit synbio knowledge in order to avert bad outcomes accruing from the misuse of such knowledge by bioterrorists or other malign actors.

The argument for widening ethical consideration to include knowledge has prima facie appeal. However, it carries substantial danger of unintended consequences. It is indisputable that the application of bioscientific knowledge to various domains, such as agriculture and medicine, has led to major gains for humanity. Hence, it is dangerous –and ethically fraught– to restrict bioscientific enquiry, lest the flow of improvements to human wellbeing be impeded. While authors favouring such restrictions on knowledge want to limit such control exclusively to synbio-associated knowledge with the potential for serious misurse, in practice this position is highly problematic. It is generally impossible to discriminate *a priori* those forms of research and knowledge so produced that will lead to catastrophe versus those that are either neutral or will lead to improvements in human wellbeing; additionally, it is necessary to ask the question: *who decides* which types of knowledge (and underlying research) ought to be prohibited? To which there are no uncontentious or unproblematic answers (Pierce 2012). Biocientific research may reasonably be viewed as the process by which reliable knowledge about biology is accumulated and deposited in the public domain. Some of this knowledge will then be used for technological ends, thus improving human wellbeing. On this basis, it appears ethically correct to proceed on the default assumption that any given piece of synbio knowledge, and the research entailed in its discovery, ought not to be restricted. Of course, it would be ethically required to prohibit dissemination of truly dangerous knowledge (for instance, instructions for the construction of a synthetic microorganism capable of being unleashed as a potent bioweapon). However, this type of knowledge is an end-product: by contrast, most research knowledge is not a product: its potential future uses –good or ill– cannot be known with any accuracy, and attempts to restrict such knowledge would be impractical and damaging to the bioscientific enterprise. To employ a non-biological analogy, from physics: while it would be ethically necessary to prevent public dissemination of a detailed set of instructions for building a 'dirty' nuclear bomb, it would be ethically problematic to prevent public access to the fundamental physics knowledge underpinning such a weapon. Attempts to restrict generation of (through research) or public access to such basic physics knowledge not only be manifestly impractical and highly intrusive for the research communities involved, such restrictions would impede development of valuable future technologies (such as medical devices based on material physics knowledge, etc).

Aside from the spectre of bioterrorism, it is a truism that accidents happen, and fears about extremely undesirable or catastrophic consequences from mishaps involving synbio

have led to some opponents of technological progress to posit the theoretical risks from synbio –particularly unidentified risks– as grounds for a complete ban on synbio research and development. More subtly, there have been declarations from many in society calling for the use of a *precautionary principle* to regulate the field. This principle holds that until all possible risk has been identified and eliminated, one ought not to proceed. Originally devised in the context of environmentalism, the precautionary principle has been applied to many types of scientific endeavour including synbio. A precautionary approach is intuitively appealing to many, as it chimes with the tendency towards caution innate in the human psyche. The precautionary principle, however, means unacceptably adverse or ridiculous implications, at least in the case of synbio. Taken literally, it maintains *any* degree of danger unacceptable *regardless* of the future advantages. Unfortunately, without some danger, it is impossible to do anything innovative in biomedicine, or to conduct any research that could ultimately produce some undesirable results, however remote or minor. For instance, owing to unexpected impacts of engineered virus-based agents used in clinical studies for somatic gene therapy, a (small) number of patients have died or become seriously ill. If the strong precautionary principle had been implemented in the field of somatic gene therapy, accidental deaths and morbidity would have been prevented, but this would have been to the detriment of the increasing number of patients who have so far benefited from somatic gene therapy, and would have excluded benefits for potential patients who stand to be successfully treated in increasing numbers as the technology matures. Therefore, if implemented, the precautionary principle in its strong form would allow nothing to be accomplished at all!

In response to this problem, alternative or attenuated variants of the precautionary principle have frequently been posited, and are of relevance to the ethics of synbio. The ways in which the principle has been interpreted are many, and include a means to recalibrate the onus of proof, a means of focusing on certain types of risks, and as a rule-of-thumb reminder to 'err on the side of caution' (Smith, Chan et al. 2012). For example, in the specific context of synbio, Wareham and colleagues have outlined a systematic approach for arriving at a threshold below which potential dangers can be disregarded (Wareham, Nardini 2015). Their approach includes a Bayesian tool to assign probabilities to deleterious outcomes. These authors argue that their proposed approach effectively rehabilitates the precautionary principle as a feasible policy tool to deal with the unknowns of future synbio research.

This approach may be of practical worth; however, it is intellectually difficult to defend the concept of a threshold. The problem lies in the essentially arbitrary nature of a danger threshold. More broadly, the use of any attenuated form of precautionary principle will tend to contribute irrational considerations – such as an obligation to give arbitrary weight to certain kinds of danger (such as unknown dangers, or environmental dangers) – that will tend to skew an otherwise rational analysis of risk.

In conclusion, applying the principle of nonmaleficence to synbio research and development is problematic if the principle is interpreted in a literal manner. While harm is certainly possible from the abuse of synbio knowledge or products, an ethic that literally demanded 'do no harm' would entail undue restriction to the field, and would thus slow

down, limit or prevent the developments of applications of synbio that would otherwise deliver major benefits.

3. BENEFICENCE

The principle of beneficence can be summarised as an ethical onus to create as much good as possible. This naturally begs the question, what is 'good'? While there are of course a wide range of claims of what is good, made by philosophers over the centuries, in the context of principlism the good refers to *utility* – namely the existence of positive mental states (or, more simply, 'happiness'), in aggregate across all affected individuals. Thus, beneficence is a *consequentialist* ethical principle, in that it requires evaluation of the consequences of actions. Actions having the best consequences – ie, those producing the greatest quantity of utility – are ethically praiseworthy. This approach is also known as *utilitarianism*.

Claims of good consequences do not need to be explicitly linked to the maximisation of utility in order to fall within the scope of the principle of beneficence. For example, suppose a plausible claim is made that a particular synbio development is likely to enable pharmaceutical scientists to produce a new, highly effective family of antibiotic drug. While it would be possible and valid to morally praise the associated synbio work on the explicit grounds that the outcome would likely be an increase in utility, through boosting happiness and reducing suffering as a result of saving lives and minimising the duration of infectious illness, such description is somewhat superfluous. Rather, it would be sufficient simply to establish that the synbio work would lead to the ability to create such drugs in order for the activity to count as ethically desirable under the beneficence principle.

The possible practical applications of synbio, and their effectiveness, cannot be foreseen with any accuracy. This is a general issue for any nascent technology: there are plentiful instances of this in the history of science and technology. For example, at the time that the ability to artificially transfer genes from one organism to another became an experimental possibility (in the 1970s), it could not be accurately predicted that this basic work would lead to the major applications that have –and continue– to revolutionise key aspects of medicine. For example, we have seen a follow-on revolution in the production of vital therapeutic agents such as insulin, together with successful gene therapy attempts and, most recently, gene edited human cells for successful anticancer therapy. To take another example, early experiments with bacteria eventually led to the discovery of penicillin, and thus to the development of the powerful antibiotics that have become invaluable to modern medicine. It is clear that such benefits could not have been anticipated by the pioneers of bacteriology working on basic research questions back in the 19th century.

synbio is clearly at a relatively early stage of development as a field; for example, only fairly recently (2010) was the production of the first semi-synthetic organism achieved (Gibson, Glass et al. 2010). It is entirely possible that in the future synbio could allow the generation of artificial cells of great medical importance. Such potential synbio products might allow the production of synthetic microorganisms designed to exterminate cancer cells within the patient's body, or artificial stem cells able to replace cells lost to disease in neurodegenerative conditions. However, at present there is no way of predicting with any

accuracy when or whether which of these or similar valuable products may be obtained from synbio (Heavey 2017). Nevertheless, simply because it is not possible to predict the exact benefits of synbio certainly does not imply that major benefits –and the beneficence that will flow from them– ought not to be factored in to the evaluation of the value of synbio. Innumerable examples of the accretion of fundamental knowledge leading to technologies that substantially benefit humankind can be discerned in the history of science. Thus, fundamental scientific research tends to leads to major gains in utility; and this is a feature of the scientific enterprise that can applies across all major fields. Accordingly, to the extent that synbio research is permitted to develop in an unrestricted manner, ultimately much utility will flow from such endeavours, as the products of synbio emerge, and help inter alia to combat disease and solve other human problems. Elsewhere in this book, other authors describe current research in the field of synbio, as well as alluding to nascent products the development of which is of course based on basic research knowledge. All this counts as positive according to the principle of beneficence, and as such lends strong ethical support to research scientists working in the field of synbio.

In conclusion, the principle of beneficence places an ethical duty on society to support synbio research, and to refrain from unduly impeding its progress through excessive caution and unduly onerous regulation. A rational approach would seek to balance the possible harms of synbio (as described in the previous 'nonmaleficence' section) with the potential benefits.

4. JUSTICE

The principle of beneficence can be summarised as the ethical duty to fairly distribute benefits, risks, and costs. For example, if a form of synbio were to benefit only one part of society, particularly one comprising privileged individuals, this would be considered unjust and therefore ethically problematic.

Justice issues are frequently raised as objections to scientific and technological developments, including synbio. An important issue in terms of the principle of justice arises where governance of synbio imposes onerous and protracted regulatory requirements on synbio: this leads to a situation in which only rich countries or multinational corporations can participate. (Schmidt 2016). This threatens to limit the potential benefits from synbio for poorer nations. A parallel concern exists in terms of harms: if a synbio product were to harm a specific societal group, and not other sectors of society, this would be unjust (ETC Group 2007). Indeed, popular opinion holds that social justice concerns provide reason to proscribe the investigation and development of radical new technologies such as (at least some forms of) synbio, a societal perspective that is to a large extent mirrored by government agencies and policy forums (Kaebnick, Gusmano et al. 2014).

However, such concerns tend to focus on the initial stages of the introduction of the technology, and neglect the more important long-term patterns of distribution (Hunter 2013). An analogy with mobile phones is apposite to illustrate this tendency: initially, research into mobile telephony was restricted to laboratories in rich countries, and was frequently conducted by moneyed Western corporations; and when the first products were marketed, only rich individuals and prosperous companies could afford them. Now, we see

mobile phones permeating all countries, rich and poor, and in the latter nations they are a huge force for good, permitting impoverished peoples to communicate and access information to their marked benefit. Yet a strong justice-based ethical objection to mobile telephony research could have been mounted, and had it been heeded two negative consequences would have arisen: [a] the technology would have been stunted in its development (or not developed at all); and therefore [b] impoverished people would have had the benefits of mobile phones – which would have impacted their lives to a much greater degree than wealthy people.

From this analogy, a general ethical rule may be discerned: justice-based concerns imply that restrictions ought to be placed on the investigation of new technologies, yet these restrictions lead to reduced justice I the long run. This paradoxical situation clearly applies to synbio research, as much as it does to the investigation of any radical new technologies.

In conclusion, while the application of future synbio technologies needs to take social justice into account, the principle of justice is best served by permitting synbio research and development to proceed without stern regulatory impositions and restrictions.

5. RESPECT FOR AUTONOMY

The principle of respect for autonomy holds that a competent, informed person ought to have the freedom to choose whether or not to participate in, or consent to be part of, a proposed course of action. Any violation of such freedom is, under the respect for autonomy principle, unethical.

The autonomy of synbio researchers counts in this regard. Those who wish to exercise their freedom to explore this field of science are prima facie morally entitled to do so, according to the autonomy principle. Of course, any demonstrably negative impacts of their work, of the sort described previously in this chapter, would serve as good reason to restrict the autonomy of synbio researchers. However, as argued above, while applications of synbio may be misused by malign actors, and accidents may occur, stern restrictions to synbio at the level of research are generally not warranted on ethical grounds. Similarly, concerns over autonomy do not morally justify proscription of synbio research and development. Thus, insofar as synbio does not amount to a net negative in the foregoing terms, synbio researchers ought to be free to continue their endeavours.

Social science research has indicated that where patients are presented with the idea of being treated with synbio-based medical technologies, they frequently display excessive fear concerning the technology, for instance worrying unnecessarily that ‘something uncontrollable’ could be created. It is ethically necessary that such patients be adequately informed about the actual risks and benefits of the synbio application in question if they are to be able to exercise their true autonomy. Under the principle of autonomy, it is ethically important that patients be accorded the information to allow them not only to declines treatment if they so desire, but also the ‘right to try’ (Rakic, Wienand et al. 2017, Heidari, Shaw et al. 2017).

Another autonomy-related concern arising from synbio is the notion that the technology could lead to fundamental changes in our understanding of life, and what it

means to be human – particularly if developments in synbio proceed in parallel with developments in robotics (Nasuto, Hayashi 2016, Murillo-Sanchez, Ruiz-Mirazo 2016).However, such concerns are clearly of a very distant-future nature; to some extent they are at the cusp of what can reasonably be evaluated within the methodology of principlism, and begin to enter into the realms of metaphysics. As such, these claims and concepts lie beyond the scope of the present chapter.

6. CONCLUSIONS

There are many ways to look at the ethical issues raised by radical new technologies. This chapter has considered the issues raised by synbio through the normative lens of principlism. In terms of the first principle addressed above, nonmaleficence, many ethicists and other critics have raised fears about harms –some of them catastrophic– arising from the misuse of synbio, or accidents associated with it. The common (although by no means universal) view amongst such commentators has been that the risks require a precautionary approach, entailing at least heavy regulation, if not proscription, of much synbio research and development. However, adherence to the implications of the nonmaleficence principle is generative of problematic outcomes: primarily a hindering of the development of synbio products. Because such products will include tools that have the potential to deliver substantial human improvement in the future, the principle of nonmaleficence is fraught in the context of synbio, since its application would lead to less utility (human happiness) had it not been invoked.

In this regard, the principle is in direct conflict with the second principle addressed above, beneficence. While the commentariat, including ethicists (with some notable exceptions), have generally been unwilling to emphasise the upsides of synbio, preferring instead to concentrate on the potential risks or other negatives, this chapter has argued that these upsides are very substantial for the future. This implies that a resolution to the tension between these two principles, of nonmaleficence versus beneficence, must depend upon a rational cost-versus-benefit evaluation. Such an analysis is outside the scope of the present chapter: it would be appropriate only for specific aspects or instances of synbio research and development, as opposed to having applicability to the overall question of the ethical status of synbio. Nevertheless, it is clear that the potential benefits of synbio are very large, albeit that their exact shape cannot be discerned with much clarity at the present point in time. This means that a maleficence-driven focus on more clearly identifiable dangers can easily, but irrationally, serve to downplay the beneficence-promoting aspects of synbio. Readers must make up their own minds as to which direction the balance lies – this is, after all, an ethical question, requiring judgement of a sort different to scientific analysis. However, the present author suggests that the balance is in favour of synbio being permitted to be investigated and developed without special regulation or proscription beyond the normal standards of safety that apply to bioscientific research in general.

The third principle addressed above, justice, is intrinsically harder to evaluate than either of the two preceding principles, in any given context such as synbio research and development. The notion of justice is commonly held to be axiomatically valid and important as an ethical principle, and all else being equal it is difficult to argue against this principle. However, in certain contexts, including synbio, justice can be in tension with the

first two principles. This is so because a strict application of the principle would, as discussed above, frequently mean that scientific progress and the attendant delivery of products that boost human welfare will be stymied. How is this tension resolved? To a large extent this depends on the basic ethical outlook of the individual who is judging: someone who holds justice to be the most important principle will not be swayed by considerations arising from other principles, such greater utility. By contrast, someone who holds beneficence to be the most important principle will only support appeals to justice insofar as maximising justice also yields greater human happiness; where the two principles conflict, this individual will prefer an unjust situation with greater utility to the converse. Philosophers continue to argue about the relative merits and demerits of particular ethical principles (an academic field known as meta-ethics), but this debate lies beyond the scope of the present chapter, and the reality is that most individual's come to the ethics table with pre-established ideas which principle(s) they hold dearest. The present author considers the principle of justice to be subordinate to that of beneficence, and accordingly is not swayed by appeals to justice where the outcome would be a reduction in utility.

Aside from far-future possibilities that might arise from synbio, involving synthetically generated people, the principle of respect for autonomy is taxed less by questions around synbio that the other three principles. The greatest issue that synbio (presently) raises in respect of autonomy resides in the domain of the freedom of scientists to conduct their research in an open-ended, curiosity driven manner. Those who hold autonomy to be the most important principle will agree that it is intrinsically right to accord such autonomy to individual researchers. Others will be happy to accede to the notion that such freedom be accorded, to the extent that it does not impact negatively in respect of the other principles. So, the present author supports synbio researcher freedom, not primarily because it is an intrinsic good, but rather because it aids the synbio enterprise and thus will help deliver benefits in terms of enhanced human happiness.

In overall conclusion: while synbio research and development may lead to knowledge and products that could cause harm accidentally or by deliberate misuse, and may impact negatively in terms of societal justice in the short term, the promise of this emergent arena of bioscientific progress offer so much potential that researchers in the field out supported by society in their endeavours. To do otherwise would be ethically unacceptable.

BAZEMAN, H. and TENBRUNSEL, A.E., 2011. *Blind spots: why we fail to do what's right and what to do about it.* New Jersey: Princeton University Press.

BEAUCHAMP, T.L. and CHILDRESS, J.F., 1994. *Principles of Biomedical Ethics.* New York: Oxford University Press.

DOUGLAS, T. and SAVULESCU, J., 2010. Synthetic biology and the ethics of knowledge. *Journal of medical ethics,* **36**(11), pp. 687-693.

DREW, T.W. and MUELLER-DOBLIES, U.U., 2017. Dual use issues in research - A subject of increasing concern? *Vaccine,* **35**(44), pp. 5990-5994.

ETC GROUP, 2007. *New Directions:The Ethics of Synthetic Biology and Emerging Technologies report.* Washington: Presidential Commission for the Study of Bioethical Issues.

EVANS, N.G. and SELGELID, M.J., 2015. Biosecurity and Open-Source Biology: The Promise and Peril of Distributed Synthetic Biological Technologies. *Science and Engineering Ethics,* **21**(4), pp. 1065-1083.

GIBSON, D.G., GLASS, J.I., LARTIGUE, C., NOSKOV, V.N., CHUANG, R., ALGIRE, M.A., BENDERS, G.A., MONTAGUE, M.G., MA, L., MOODIE, M.M., MERRYMAN, C., VASHEE, S., KRISHNAKUMAR, R., ASSAD-GARCIA, N., ANDREWS-PFANNKOCH, C., DENISOVA, E.A., YOUNG, L., QI, Z., SEGALL-SHAPIRO, T.H., CALVEY, C.H., PARMAR, P.P., HUTCHISON,CLYDE A.,,III, SMITH, H.O. and VENTER, J.C., 2010. Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome. *Science,* **329**(5987), pp. 52-56.

HEAVEY, P., 2017. Consequentialism and the Synthetic Biology Problem. *Cambridge Quarterly of Healthcare Ethics,* **26**(2), pp. 206-229.

HEIDARI, R., SHAW, D.M. and ELGER, B.S., 2017. CRISPR and the Rebirth of Synthetic Biology. *Science and Engineering Ethics,* **23**(2), pp. 351-363.

HUNTER, D., 2013. How to Object to Radically New Technologies on the Basis of Justice: The Case of Synthetic Biology. *Bioethics,* **27**(8), pp. 426-434.

KAEBNICK, G.E., GUSMANO, M.K. and MURRAY, T.H., 2014. The Ethics of Synthetic Biology: Next Steps and Prior Questions. *Hastings Center Report,* **44**, pp. S4-S26.

MILLER, S. and SELGELID, M.J., 2007. Ethical and philosophical consideration of the dual-use dilemma in the biological sciences. *Science and Engineering Ethics,* **13**(4), pp. 523-580.

MURILLO-SANCHEZ, S. and RUIZ-MIRAZO, K., 2016. Synthetic biology as a challenge to understand the autonomy of the living. *Isegoria,* (55), pp. 551-575.

NASUTO, S.J. and HAYASHI, Y., 2016. Anticipation: Beyond synthetic biology and cognitive robotics. *Biosystems,* **148**, pp. 22-31.

NEWSON, A.J., 2015. Synthetic Biology: Ethics, Exceptionalism and Expectations. *Macquarie Law Journal,* **15**, pp. 45-58.

PIERCE, R.L., 2012. Whose ethics of knowledge? Taking the next step in evaluating knowledge in synthetic biology: a response to Douglas and Savulescu. *Journal of medical ethics,* **38**(10), pp. 636-638.

RAGER-ZISMAN, B., 2012. Ethical and Regulatory Challenges Posed by Synthetic Biology. *Perspectives in biology and medicine,* **55**(4), pp. 590-606.

RAKIC, M., WIENAND, I., SHAW, D., NAST, R. and ELGER, B.S., 2017. Autonomy and Fear of Synthetic Biology: How Can Patients' Autonomy Be Enhanced in the Field of Synthetic Biology? A Qualitative Study with Stable Patients. *Science and Engineering Ethics,* **23**(2), pp. 375-388.

SAVULESCU, J., 2012. Master the new loom before life's tapestry unravels at our hands. *Times Higher Education,* **2046**, pp. 32-33.

SCHMIDT, J.C., 2016. Prospective Technology Assessment of Synthetic Biology: Fundamental and Propaedeutic Reflections in Order to Enable an Early Assessment. *Science and Engineering Ethics,* **22**(4), pp. 1151-1170.

SMITH, K.R., CHAN, S. and HARRIS, J., 2012. Human germline genetic modification: scientific and bioethical perspectives. *Archives of Medical Research,* **43**(7), pp. 491-513.

STABINSKI, D., 2006-last update, Synthetic Biology - Global Societal Review Urgent!. Available: http://www.etcgroup.org/node/8.

WAREHAM, C. and NARDINI, C., 2015. Policy on Synthetic Biology: Deliberation, Probability, and the Precautionary Paradox. *Bioethics,* **29**(2), pp. 118-125.

WIMMER, E., 2018. Synthetic Biology, Dual Use Research, and Possibilities for Control. *Defence Against Bioterrorism: Methods for Prevention and Control,* , pp. 7-11.