Etica & Politica / Ethics & Politics, XX, 2018, 3, pp. 35-52.
ISSN: 1825-5167

CRISPR PIGS, PIGOONS AND THE FUTURE OF ORGAN TRANSPLANTATION.
AN ETHICAL INVESTIGATION OF THE CREATION OF CRISPR-ENGINEERED HUMANISED ORGANS IN PIGS

SILVIA CAMPORESI
Department of Global Health & Social Medicine
King's College London
silvia.camporesi@kcl.ac.uk

ABASTRACT
Bioethics operates on two dimensions: one is the future, i.e. the temporal subject of bioethicists' speculations, and one is the present, the point of influence of bioethics. In order for bioethics to operate on two dimensions, bioethicists have to resort to biofutures, or imaginaries of possible futures populated by extrapolations of uses of emerging biotechnologies. This paper discusses the possible biofuture in which we are able to grow humanised organs in pigs for the purposes of human transplantation, which has brought xenotransplantation closer to the present thanks to experiments conducted by George Church at MIT, which use CRISPR genome editing technologies to edit out a number of retroviruses that are endogenous in pigs and can pose a risk of human infection in xenotransplantation. This paper juxtaposes the biofuture imagined by Church, where organ transplants become routine and are customized on the basis of the recipient, with the biofuture imagined by Canadian author Margaret Atwood in her 2003 novel *Oryx and Crake,* who in a sense predicted the advent of CRISPR pigs with her 'pigoons', engineered pigs with multiple organs also for the purpose of human transplantation. Although feeding on the same material or elementary building blocks, Church and Atwood end up with opposing outlooks on the moral implications of using animals as biofactories. While bioethicists often rely on biofutures imagined by scientists, with the possible risk of buying into epistemic scientism and reinforcing socio-technical expectations, in this paper I argue that science fiction, or speculation fiction, has an important role to play in providing narrative fodder for alternative imagined biofutures.

KEYWORDS
Xenotransplantation, organ transplantation, organ transplants, biofutures, speculative bioethics, science fiction, CRISPR, genome editing, George Church, Margaret Atwood

1. INTRODUCTION

If I say "organ transplant", you will probably think of an emergency rescue – a scene featuring a helicopter transporting an organ from the scene of a tragic accident to a sterile emergency room where a, hopefully skilled, surgeon will transplant the organ from the deceased to a recipient who had been on a waiting list and has days if not hours left to live. As is well known, there is a very narrow window of opportunity [from 6 hours for hearts or lungs to 12 hours for pancreas and liver and up to three days for kidneys] for an organ to be transplanted from a cadaver, and because of this limited window of opportunity, it is very challenging to retrieve organs viable for transplant. Statistics on the number of people dying while waiting for an organ transplant are objectively very grim: according to the organdonors.gov, the official website of the US government branch providing information on organ donation and transplantation, 20 people die each day waiting for an organ in the US. This is referred to as the "waitlist mortality" and is the official measure to record the frequency at which patients listed for transplant at a program die before undergoing transplant. These and similar figures for other countries are often cited to demonstrate the urgency of research in this year. Inso Hyun, bioethicist, refers to organ shortage as a "humanitarian" concern (Hyun 2016), something I will go back to in section 3 of this paper. In sum, the shortage of organ donors in the first place, the messy reality of tragic accidents, and the shock of family members who might not have been aware or do not agree with the decision of the deceased to donate the organs compound the difficulties of retrieving an organ even when the deceased had clearly given their consent for use of organs for donation after their death. (Morgan et al 2002; Rithalia et al 2009)

However, this need not be the future of organ transplantation, or so goes the narrative imagined by two visionaries, or -as I refer to them below - strange bedfellows: George Church and Margaret Atwood. In the biofutures imagined by Church and Atwood, organ transplants become a routine procedure that can be planned in advance, where customized organs can be manufactured and tailored to the recipient. Not only will they not be rejected by the recipient's body, but they will also be able to be customized to the recipient's immunoprofile and be genetically engineered so that they can be immune from diseases.

Bioethics operates fundamentally on two dimensions: one is the future, i.e. the temporal subject of bioethicists' speculations, and one is the present, the point of influence of bioethics. (Shick 2016; 2017) Xenotransplantation is perfect foil for speculations on the future, and has fascinated humanity for

centuries. The figure of the chimera dates back to ancient Greek mythology, where we find it in paintings dating to 6th century before Christ a compound monster with head of a lion, body of a goat and tail of a snake. Today, 'chimerism' is the technical word used in biology to refer to an individual with cell lines from two different embryos that have fused at an early stage of development. (Malan et al 2016) It can also be found used as a lay-term in many academic and popular references to experiments which involve some degree of mixture of human-animal elements, and are often associated with fears of transgressing species boundaries or subverting the natural status. As Brennan and Anijar among others have noted, the use of chimeras in popular culture such as film and print can help explain some of the arguments, and of the 'queasiness' towards such experiments, that we can find in the academic literature. (Brennan and Anijar 2003) It is probably the case that the arguments found in bioethics literature and in popular culture co-produce and reinforce each other. Academics are not immune to pop culture influence, quite on the contrary! We now have many analysis of the use of metaphors and of morally loaded language in bioethics. (cfr O'Keefe et al 2015 for a study applied to genome editing)

This paper discusses the possible biofuture imagined by Church, in which we are able to grow humanized organs in pigs and edit them with CRISPR genome editing technologies so that they are free of porcine endogenous retroviruses that pose a risk for human transplant, and juxtaposes it with the biofuture imagined by Atwood in her 2003 novel *Oryx and Crake*. I adopt Ari Shick's critique of speculative bioethics to show how an over-emphasis on the urgency of the experiments may overshadow other non-medical solutions to the problem of shortage of organs for transplantation. In the end, I draw some reflections on the role that science fiction and speculative fiction play in the construction of biofutures for bioethics.

2. WHICH BIOFUTURES? CRISPR PIGS AND PIGOONS

The domestic pig, or *Sus Scrofa*, is considered the best candidate for transplant of biological material to humans, and valves from pigs are routinely used in heart surgeries. (Manjii et al 2015) However, currently the holy grail of xenotransplantation is the possibility of growing humanized organs in pigs[1]. Two main challenges hinder the search for this 'holy grail': the possibility of

1 Although John Harris has rightly noted in a personal communication that a 'holier grail' in this context might be growing synthetic organs!

rejection to due immune-incompatibility between species; and, the possibility of xenozoonosis, or the transfer of viruses from animals to humans, although the actual risk of the latter remains unknown. (Fisher et al 2014) This 'holy grail', which until recently was only the subject of speculations about a possible (bio)future, seems to be closer now to reality thanks to two main complementary strategies that have been developed over the last ten years. The first strategy, developed by Kobayashi et al in 2010, with the first demonstration of graft survival in vitro in 2017 (Yamaguchi et al 2017) is called blastocyst complementation. Blastocyst complementation means that animals' organ-specific developmental genes are repressed at the embryonic stage of blastocyst, which includes a cavity full of fluid and two different cell components. When the chimeric embryos are implanted into a host animal, the developmental genes that had been repressed are activated, or 'complemented' by the host animal. The result is that organ-specific embryos can be generated, with the potential for the creation of recipient-tailored organs. The main limitation of this process is that cells of the ectoderm are still of animal origin and can lead to rejection of the organ.

The second strategy, which addresses the concerns of xenozoonosis mentioned earlier, is the one developed by the group led by George Church at MIT. What Church and his group succeeded in doing was the multiple inactivation, for the first time in vivo, of porcine endogenous retroviruses (PERVs) using CRISPR technology. (Niu et al 2017) PERVs are endogenous retroviruses found in the pig genome, which can be found inserted in various loci in the pig genome in a dormant state. However, it has been demonstrated in cell lines in vitro that PERVs can be reactivated in human cells. (Wilson et al 1998; Martin et al 1998) Although this has never been demonstrated in vivo in patients that have received xenotransplanted biological material from pigs, the proof of principle in vitro has been considered a serious limitation to the possibility of xenotransplantation. (Yang et al 2007; Denner et al 2012). The work has led the journal *Science* to title the cover of the 2017 fall issue as 'CRISPR pigs' and captioning it as work that brings us "one step closer to reliable pig-to-human organ transplants".

Church is a visionary scientist. By this I mean that he has the capacity to imagine far-reaching societal implications of existing technologies well before his time. He is perhaps on a par with Craig Venter, the Celera Genomics CEO who co-signed the official completion of the Human Genome Project with NIH Francis Collins in 2001, and who has since worked on synthetic biology, creating life from scratch, and has been one of the very first scientists sequencing his own genome. Church has also spearheaded research in a

variety of areas, from the Personal Genome Project projectlaunched in 2005 and aimed at converting the lower costs of genome sequencing for the use by single consumer in a mix of preventative and recreational medicine, to synthetic biology, to research on telomeres aimed at reversing the ageing process, to now making waves genome editing. In an interview released for *The Atlantic* in August 2017, Church said:

> If it happens, routine pig-to-human transplants could truly transform healthcare beyond simply increasing the supply. Organs would go from a product of chance - someone young and healthy dying, unexpectedly - to the product of a standardized manufacturing process. [...] (Zhang S, 2017)

In Church's imagined biofuture, human organs are mass-manufactured in pigs and transplantation becomes a routine surgical procedure. As noted above, the manufacture of organs in pigs would completely subvert our perception about needing an organ for transplant, as it would eliminate the urgency and randomness/luck elements of the transplant. Not only that, but Church also speculates that the creation of humanized organs in pigs will make them superior to organs that can be retrieved from humans, as CRISPR tools would be able to engineer them so that they become resistant to disease. Quite unexpectedly, the scenarios imagined by Church share many elements with to the ones envisioned by Atwood in her novel *Oryx and Crake*, although the two could not be farthest in terms of their outlooks towards the future (the former imagines a rosy utopia; the latter a dim dystopia). Although the Canadian writer is more famous for her *Handmaid's Tale* (Atwood, 1985) novel which depicts a grim future in which the human species is close to being sterile post a nuclear disaster and the continuation of the species hinges on the enslavement of a portion of society, hence the handmaids, who are bound to live as surrogates, the novel I would like to focus on in this paper is *Oryx and Crake*, which is at the time of writing (August 2018), 15 years old. *Oryx and Crake* [2003] is the first of a trilogy with the same protagonists and could be classified like many of her other works as a 'dystopia', although not a work of science fiction proper. Atwood refers to her book as a work of speculative fiction. She writes:

> *Oryx and Crake* is a speculative fiction, not a science fiction proper. It contains no intergalactic space travel, no teleportation, no Martians. As with *The Handmaid's Tale*, it invents nothing that we haven't already invented or started to invent. Every novel begins with a what if, and then sets forth its axioms. The what if of *Oryx and Crake* is simply: *What if we continue down the road we're already on?* (Atwood 2011)

Atwood is also, like Church, a visionary. She feeds on science to imagine the far-reaching societal implications of existing technologies. The "medium" for the construction of her biofuture is imagination and words, while Church's is imagination and cells. However, many elements of the biofutures that they share are the same.. Mindful of the fact that the domestic pig is the best candidate for the transplant of tissue and biological material, Atwood imagines an 'enhanced pig', for which she coins the neologism '*sus multiorganifer*'. In her novel though, the enhanced pigs are commonly referred to as 'pigoons':

> The goal of the pigoon project was to grow an assortment of foolproof human-tissue organs in a transgenic knockout pig host-organs that would transplant smoothly and avoid rejection [...] A rapid maturity gene was spliced in so the pigoon kidneys and livers and hearts would be ready sooner, and now they were perfecting a pigoon that could grow five or six kidneys at a time. [...] *Pigoon* was only a nickname: the official name was *sus multiorganifer*. (Atwood 2003, pp 22)

In her biofuture, Atwood stresses the efficiency, safety, and reliability of the procedure, similarly to what Church does. She writes: "The organs were frozen until needed". However, contrary to Church, Atwood imbues her novel with moral concerns about the use of animals for biofactories, the relationships between species (where the human species uses animal species only for our own benefit), and also within species (she imagines that the human species is divided into those that are technologically advanced and live in gated communities, separated from the rest of the population). In Atwood's biofuture, the chimerization of the animals with human cells leads to the enhancement of their cognitive capacities – a concern that has been voiced in the bioethics literature regarding the possibility of off-target chimerization of embryos beyond the target organ e.g. Savulescu 2016 – and to the 'wickedness' of the pigoons, whose 'contamination' [using this morally loaded word on purpose here to represent the views of the author] by human cells has made them wicked like the human species. However, although this concern has been raised in the bioethics literature, in Atwood's novel her moral concern about the chimeric animals does not hinge on a speciesist assumption (i.e. the chimeras have an enhanced moral status because of the human cells they contain) but on a moral concern on the moral status of the animals which are used as a means to an end. As noted by Hansen in a recent paper, "an author includes her pro-attitudes in her story, i.e., moral, social, and epistemic desires that structure the fabula and the perspective from which she tells it. Thus, considering how a work of science fiction portrays a technology can reveal the

moral beliefs embedded in it" (Hansen 2018, p. 237) which is exactly what we see in place in Atwood's novel.

In Atwood's novel there are also concerns about the mass-manufacturing of animals for food consumption: these are the "chickee-nobs" without a head, although this is not the topic of this paper, the two concerns (of manss-manufacturing animals for research, and for food consumption, in ways that possibly bring to the fore the worst elements of our species) often go hand in hand.

Truly, Church and Atwood could not be more at polar opposites of the moral spectrum. The striking similarities of their biofutures are particularly interesting as while feeding on the same material, they end up with very different outlooks on the implications. In a sense, they can be seen as prototypes of the bioliberal and bioconservative bioethicist, where the bioliberals are those supporting in principle new emerging technologies aimed not only at treating conditions but also at enhancing human performance; and bioconservatives are those adopting a more cautious stance towards said technologies or outright opposing them. While for the former the future of growing organs in pigs is a rosy utopia where people do not die on waiting lists waiting for a transplant, and transplants cease to be emergency surgeries; for the latter it is a grim dystopia where humanity is exploiting animals for the mass manufacture of organs for the benefit of only a small portion of society, the technologically advanced, while the social inequalities have grown exponentially leading to violence, riots and widespread living in gated community. Church is an perfect prototype of a bioliberal insofar as he thinks that we have a moral duty not only to treat, but to enhance, if we can. Although not explicitly put by Church in these terms, this move is a classic example of crossing the therapy/enhancement divide, where something construed for therapeutic purposes can become 'better than the norm'. John Harris among others has been a vehement defender of the moral irrelevance of the therapy/enhancement distinction, citing vaccination as a prime example of a preventative measure (which falls under the rubric of 'therapy') that enhances our immune capacities. (Harris 2007; p.21,32,46,191) Along similar lines, the application of CRISPR genome editing technologies for the creation of humanized organs in pigs can go beyond the imperative to 'treat' those with failing organs and include enhancing human performances in terms of our organs' functions.

3. TEMPORALITY AND CAUSAL INVERSION IN BIOETHICS

Bioethics operates on a thin line: it is inescapably temporally focused on speculative futures, and necessarily includes an 'anticipatory' mode drawn to the imagination of biotechnological futures. In order to do so it has to rely on the futures imagines by scientists, to a good extent. This *modus operandi* can fall prey to the critiques that bioethicists are not critical enough, and end up reinforcing the sociotechnical expectations of scientists (or, put differently, fall prey to epistemic scientism). (Hedgecoe 2010) Imagining biofutures has important policy implications because it shapes what kind of ethical questions are asked regarding a certain technology, and the present uses of the technology. Also, as put by Ari Schick: "as bioethics has developed into an established field factoring into public policy deliberation, its speculative discourse has become a framework in which technological visions are transformed into sets of 'probable facts' demanding proactive ethical scrutiny. [...] and creating a causal inversion: it is now the future that makes the present, rather than the other way around". (2016, p. 225) Alfred Nordmann, in his prescient critique of speculative bioethics applied to nanoethics, wrote that "we should not squander our attention on incredible futures, when the present demands our attention". (Nordmann 2007) We can see this 'causal inversion' and 'dislocation of agency' at play in the biofuture imagined by Church. On the website of the company 'eGenesis', a spin-off of Church's laboratory based in China, we read:

> eGenesis is using innovative, safe and responsible technology to help end a global health issue. Our goal is to make xenotransplantation a routine medical procedure for the delivery of safe and effective human transplantable cells, tissues and organs for the hundreds of thousands of patients worldwide who are in dire need.

Another example comes from Inso Hyun, bioethicist at Case Western Reserve University in Cleveland Ohio already quoted at the beginning of this paper, who writes:

> The humanitarian importance of this research is both apparent and urgent. There is currently a dire shortage of organs for transplantation in the United States, leading to approximately 22 deaths per day among patients waiting. for organs. (Hyun 2016)

On both accounts, the research is being framed as a global health issue and juxtaposed with humanitarian concerns. When put it in these terms, the urgency of research cannot be disputed, and the promise of the research cannot but be welcomed or praised. It follows then that bioethics necessarily

falls into its anticipatory mode and needs to "act now" to develop guidelines on how pigs can be engineered ethically for human transplant. The causal inversion depicted by Shick (2016) has taken place. The imagined (bio)future is influencing the present. This has led to only certain types of ethical questions (i.e. "How to conduct this research?") being asked instead of others (i.e., "should this research be conducted at all?" or "What are the alternatives?"). In the case of CRISPR engineered pigs for human transplant, an "anticipatory" bioethics mode buys into the premises of the urgency of the research and dislocates moral agency from the present to a future in which we ask how we can ethically engineer animals for human transplantation.As a consequence, as predicted by both Shick and Nordmann, the present applications of the technology, and the alternatives in the present to shortage of human organs for transplantation are not properly considered. In the case of the (undisputed) shortage of organs for human transplant, those 'presents' amount to non-medical or non-techno-scientific alternatives to xenotransplantation, i.e. a discussion of social policies to increase organ donations (i.e. opt-out, or presumed consent) as implemented to varying degree of effectiveness in several countries, as I discuss in the next section.

4. REFLECTIONS FROM A BIOLIBERAL TURNED BIOCONSERVATIVE (?)

When reflecting on my own position regarding the experiments which are the focus of this paper, I find myself - to my own surprise – somewhat aligned with the bioconservative side of bioethics in being skeptical, or at least not so enthusiastic, about growing humanized organs in pigs[2]. In the past, however, I have often aligned with the bioliberals in supporting scientific research on consequentialist grounds. (Camporesi and Boniolo 2008; Camporesi and Bortolotti 2008; Camporesi 2014).

Prompted to inquire about my own change of mind, I have come to the conclusions that my alignment with bioconservatives is not motivated – at least not only! – by me 'getting older', or by my sharing any of their moral concerns on transgressing nature or species boundaries, or on the moral status of the chimeric animals. On the contrary, I am still of the opinion outlined in

2 While I do not plan to turn vegetarian or vegan any time soon, I believe there are strong rational reasons to reduce the number of animals in research (what it is technically called 'reduction and refinement' in research on non-human animals, cfr NCB 2005) and in parallel to consume less meat, and consume only sustainably grown meat.

Camporesi and Boniolo 2008 when the fear was the creation of human/animal cytoplasmic hybrid embryos, or 'cybrids', that such fear is irrational and should be discounted, although I am more skeptical than I was then about the supposedly lack of alternatives of creating human embryonic stem cell lines for research. Instead, I find myself adopting a somewhat cautious, possibly 'bioconservative' stance towards the experiments on two grounds. First, I think the risks/benefits ratio of using animals in research is heavily if not totally skewed towards benefits to our species, and to the detriment of the animal species. This is nothing new and an accepted cost-benefit evaluation in scientific research on non-human animals. (NCB 2005) This is often referred to as the "on balance justification" view, where it is argued that the benefits to the human species outweigh the costs to the animal species. Although we often find recommendations aimed at reducing the costs on the animal species, the framing itself of benefits to one species and costs on another makes the two difficult to measure, or commensurate (a point also noted by Wolff 2011). I myself have conducted experiments in animals in my previous life before turning bioethicist, and I am not denying their necessity. To the contrary, I believe in the necessity of carrying out experiments in animals and amassing scientific evidence in animals before proceeding to clinical trials in humans, and I always skeptical when I read on some products "This has not been tested in animals". (I ask myself: where has this been tested before landing on my skin?) However, I believe that the use of animals as biofactories, as would be the case for using pigs to grow humanized organs, could and often does reveal and reflect the worst tendencies of our species (past, and present), namely: using other species, or supposed "races" in the human species, as easily expandable labour; and, the seemingly inevitable tendency towards factory farming, where economic efficiencies are prioritized over environmental and safety concerns. Meanwhile, there are non-medical alternatives to growing organs in animals, such as social policies to increase human to human organ donations. Spain is a notable example of a successful country (at the time of writing, the most successful in the world) in retrieving organs for human transplant thanks to a presumed consent or opt-out law. (Baraniuk 2018)

In his seminal paper "The Survival Lottery", John Harris imagined a biofuture – we could say – in which citizens have entered a "social contract" and are given a number as part of a lottery which, when called, requires them to donate their organs to save an X number of people[3] from dying of organ

3 According to statistics from UNOS, one person can save up to 8 people (accessed September 29, 2018)

failure. (Harris 1975) Of course, the 'donation' of their organs means that they themselves would die, but this is an accepted part of a system which is fair for everybody – all people are subjected to same rules – and justifiable on utilitarian ground where a higher number of people is benefitted by the sacrifice of a smaller. Of course, Harris was the first one to write later that his Survival Lottery was not meant as a 'white paper' with policy implications, quite the contrary, it was meant to be a provocative thought experiment that could point out to some weaknesses in our reasoning when it comes for organ transplantation. (Harris 2012) For example, to weaknesses in our defective social policies which do not support presumed consent for human to human cadaver donation. Harris has always been a strong supporter of the idea – this time, something that could be implemented in policy, and not only a thought experiment - that dead people do not have interests and that their organs should be by default conscripted for donation, and I agree with him that most societies are not investing nearly enough in making possible human to human transplants, when organ conscription from the dead would seem to be a moral imperative.[4]

Second, I am increasingly growing more skeptical of trying to find biological solutions to social problems. Instead of trying to solve social issues like shortage of organs for transplantation, inequalities in education attainment, health disparities and huge different in life expectancy of different ethnic minorities (I am not using the term 'race' on purpose since race has no ontological status as a concept, cfr Lorusso 2012), we try to 'explain them' away with 'just so stories' and sociobiological explanations. As put by the late American evolutionary biologist and historian of science Steven Jay Gould, biological determinism appears to come and go in cycles, and re-emerges in times of political retrenchment. (Gould 1981; 1996)

We are again in the midst of such times, when the latest advancements of science are used as a means to explain social differences, and [purportedly] to dissolve away, or cure, social problems.

To conclude, I believe that other possibilities beyond the creation of humanised organs in animals should also be considered when it comes to solving the problem of shortage of organs for human transplantation. As

4 John Harris has for many years suggested that "death" is a complicated concept and that to insist that organ donors are dead by many of the normally accepted criteria would make cadaver donation close to impossible. He has therefore suggested that "cadaver" donors should be "dead enough". See for example John Harris "Doing Posthumous Harm" James Stacey Taylor, ed., The Ethics and Metaphysics of Death, New York: Oxford University Press, 2013. 213-222.

argued in (Camporesi and Cavaliere 2016), "While we do not necessarily believe that the existence of viable alternatives should be used to ban humanised animal models outright, it is certainly a matter that deserves ethical attention. We need reflect on the fact that, by ignoring other potential solutions – or at least prematurely supporting one solution over another – we are actively privileging a medical/scientific solution over a political solution of devising and implementing policies to facilitate human-to-human transplants". These non-medical solutions are often obscured in a bioethics discourse that relies heavily on biofutures imagined by scientists[5].

In the end, I am not so sure why I find myself to be less enthusiastic towards these experiments that I would have been in the past. I think part of the reason towards my skepticism and caution is due to the influence over the past six years of my colleagues in the Department of Global Health & Social Medicine at King's, who have prompted me to reflect on the hype often surrounding new emerging biotechnologies, and the uncritical acceptance of the promises of research that many bioethicists – including myself!- fall prey of. Secondly, I think it must be the influence of my Master's and PhD students at King's[6] – while I am not a vegetarian or a vegan myself, many of my Master's and PhD students are, and have with very good reasons argued in seminar-based class discussions that as a bioethicist we have added reasons – on ethical grounds towards respect for animals, and the environment, including long-term responsibility towards our planet and for future generations– to become one. One final consideration was that I find that the labels in bioethics bioliberals and bioconservatives represent a over-simplifying way of categorizing scholars which does not capture the nuances of the arguments in between, and risks flattening them out for wanting two create two opposing camps, where the former is supposedly relying on rational arguments and the latter on emotions and intuitions. However, as it has been rightly pointed out in the context of the enhancement debate by Giubilini, the reliance on intuitions and emotions is "not necessarily antithetic to reason and rationality",(Giubilini 2015, 40) and both bioconservative and bioliberals rely on both, albeit appealing to different sets of emotions and intuitions. Not only this, but I believe that the representation of bioethics scholarship in terms of

5 John Harris has pointed out to me in a personal communication that the existence of alternatives to Church's research is at all to the point. The point is what is the best permissible/ethical way to reduce the loss of human lives caused by organ shortages. However, I believe that bioethics discourse that compartmentalises the discussion of medical and social solutions to the same problem (organ shortage) falls prey of biological determinism.

6 In particular, Giulia Cavaliere!

bioliberals and bioconservatives is not a particularly useful way of representing bioethics scholarship because it risks exacerbating the polarization between the two camps. It also risks aligning scholars with political values in a way that it is not necessarily accurate. For myself, I would like not to be labelled as a 'bioliberal' or 'bioconservative', but to be able to make up my mind about the latest technology on the basis of a contextual assessment thereof. But of course, what I may be labelled is not up to me, but to the rest of the bioethics community.

5. CONCLUSIONS

In this paper I have chosen to focus on one of CRISPR genome editing applications beyond reproduction, i.e. growing humanized organs in pigs. This paper is also, at least in part, a response to what I among others see as an excessive locus of concern on genome editing applications in reproduction. (Camporesi and Cavaliere 2016) In 2016, the UK's Nuffield Council on Bioethics identified in their report on genome editing three areas in which CRISPR genome editing may have a "transformative impact": cellular therapy; gene therapy; and, xenotransplantation. (NCB 2016) However, two areas have been identified as "priority areas" to be addressed urgently: human reproduction and applications to livestock (i.e., engineering animals for food consumption). I believe, however, the case study of xenotransplantation to be particularly interesting and deserving ethical attention for being positioned at the convergence of a tangled web of scientific pathways and ethical issues that make it a key locus of ethical and political concern.

In this paper I have juxtaposed two possible biofutures, the former imagined by a visionary life scientist, George Church, and the latter imagined by a visionary novelist, Margaret Atwood whom I have referred to as 'strange bedfellows'. I have shown that, despite being built with many strikingly similar 'building blocks', the biofutures imagined by Church and Atwood could not be farther apart in terms of their outlook towards the future. As noted by Hansen earlier in this paper, an author imbues her novel of the moral concerns. That means that although fiction is not, and cannot be, normative in the way that bioethics is (i.e. it does not directly or explicitly answer questions of what ought to be done, or whether we should grow organs in pigs, or not), fiction is often able to imagine things before we can. It can also help us identify moral concerns, which might be obscured when bioethics feeds only on biofutures imagined by scientists. In this paper I have also put forward some reflections by a bioliberal turned -perhaps! – bioconservative, because of growing age or

other matters. While I do not deny the necessity of using animals for research, and the potentiality of research conducted by Church and others aimed at growing humanized organs in pigs for human organ transplantation, I believe there are good reasons -which I have highlighted above - that should prompt us to consider other non-medical alternatives to human transplantations. To conclude, science fiction or speculative has an important role to play in bioethics by depicting possible biofutures, which can serve as alternative, often complementary, narratives and biofutures imagined by scientists. In turn, this can provide a countermeasure to the tendency of bioethics of buying in into epistemic scientism and reinforcing socio-technical expectations.

ACKNOWLEDGMENTS

This paper is the result of some reflections that I made in preparation for a workshop on Health Biofutures organised by John Gardner and Samuel Taylor-Alexander of Monash University and held at the Monash University campus in Prato on June 11-12, 2018. Many thanks go to John Harris and Giulia Cavaliere for their critical comments on a draft of this paper, and for pointing out some of the weaknesses of my arguments. I take full responsibility for all remaining weaknesses!

REFERENCES

Atwood, M. (2011) *In other worlds: SF and the human imagination*. New York: Random House

Atwood, M. (2003). *Oryx and Crake*. New York: Anchor.

Atwood, M. (1985). *The Handmaid's Tale*. New York: Anchor.

Baraniuk, C (2018) *Spain leads the world in organ donation. What's stopping other countries catching up?* Mosaic, August 6, 2018 https://mosaicscience.com/story/spain-uk-organ-donation-transplants-liver-kidney-heart-lungs-surgery-nhs/ (accessed September 29, 2018)

Brem, S. K., & Anijar, K. Z. (2003). *The bioethics of fiction: The chimera in film and print*. American Journal of Bioethics 3:3, 22-24

Camporesi and Cavaliere (2016) *Shortage of organs for transplantation – is more research on human–animal chimeras the right approach?* Bionews September 12, 2016 https://www.bionews.org.uk/page_95685 (accessed September 29, 2018)

Camporesi, S. (2014). *From bench to bedside, to track & field: The context of enhancement and its ethical relevance*. University of California Medical Humanities Press.

Camporesi, S., & Boniolo, G. (2008). Fearing a non-existing Minotaur? The ethical challenges of research on cytoplasmic hybrid embryos. Journal of Medical Ethics, 34(11), 821-825.

Camporesi, S., & Bortolotti, L. (2008). *Reproductive cloning in humans and therapeutic cloning in primates: is the ethical debate catching up with the recent scientific advances?*. Journal of medical ethics, 34(9), e15-e15.

Camporesi, S., & Cavaliere, G. (2018). *Eugenics and enhancement in contemporary genomics*. Routledge Handbook of Genomics, Health and Society.

Camporesi, S., & Cavaliere, G. (2016). *Emerging ethical perspectives in the clustered regularly interspaced short palindromic repeats genome-editing debate*. Personalized medicine, 13(6), 575-586.

Choi, Hyuk Jin, Jiyeon Kim, Jae Young Kim, Hyun Ju Lee, Won Ryang Wee, Mee Kum Kim, and Eung Soo Hwang. *Long-term safety from transmission of porcine endogenous retrovirus after pig-to-non-human primate corneal transplantation.* Xenotransplantation 24, no. 4 (2017).

Denner, J., & Tönjes, R. R. (2012). *Infection barriers to successful xenotransplantation focusing on porcine endogenous retroviruses*. Clinical microbiology reviews, 25(2), 318-343.

Fishman, J. A. (2014). *Assessment of infectious risk in clinical xenotransplantation: the lessons for clinical allotransplantation*. Xenotransplantation, 21(4), 307-308.

Gould, S. J. (1996) *The mismeasure of man* (Rev. ed.) WW Norton & Company

Giubilini, A. (2015). *Don't mind the gap: intuitions, emotions, and reasons in the enhancement debate*. Hastings Center Report, 45(5), 39-47.

Hansen, S. L. (2018). *Family Resemblances: Human Reproductive Cloning as an Example for Reconsidering the Mutual Relationships between Bioethics and Science Fiction*. Journal of bioethical inquiry, 1-12.

Harris, J. (2012) *John Harris clarifies his position on infanticide*. Journal of Medical Ethics blog, February 29, 2012. https://blogs.bmj.com/medical-ethics/2012/02/29/john-harris-clarifies-his-position-on-infanticide/ (accessed September 29, 2018)

Harris, J. (2007). *Enhancing evolution: The ethical case for making better people*. Princeton University Press.Princeton and Oxford. pp 21,32,46, 191.

Harris, J. (1975). *The survival lottery*. Philosophy, 50(191), 81-87.

Hedgecoe, A. (2010). *Bioethics and the reinforcement of socio-technical expectations*. Social Studies of Science, 40(2), 163-186.

Hyun, I. (2016). *What's wrong with human/nonhuman chimera research?*. PLoS biology, 14(8), e1002535.

Kobayashi, Toshihiro, Tomoyuki Yamaguchi, Sanae Hamanaka, Megumi Kato-Itoh, Yuji Yamazaki, Makoto Ibata, Hideyuki Sato et al. *Generation of rat pancreas in mouse by interspecific blastocyst injection of pluripotent stem cells*. Cell142, no. 5 (2010): 787-799.

Lorusso, L. (2011). *The justification of race in biological explanation*. Journal of medical ethics, 37(9), 535-539.

Malan, Vekemans, M. Vekemans, and C. Turleau. *Chimera and other fertilization errors*. Clinical genetics 70, no. 5 (2006): 363-373.

Manji, R. A., Lee, W., & Cooper, D. K. (2015). *Xenograft bioprosthetic heart valves: past, present and future*. International Journal of Surgery, 23, 280-284.

Martin, U., Kiessig, V., Blusch, J. H., Haverich, A., Von der Helm, K., Herden, T., & Steinhoff, G. (1998). *Expression of pig endogenous retrovirus by primary porcine endothelial cells and infection of human cells*. The Lancet, 352(9129), 692-694.

Morgan, S. E., & Miller, J. K. (2002). *Beyond the organ donor card: The effect of knowledge, attitudes, and values on willingness to communicate about organ donation to family members*. Health communication, 14(1), 121-134.

Morozov, V. A., Wynyard, S., Matsumoto, S., Abalovich, A., Denner, J., & Elliott, R. (2017). No PERV transmission during a clinical trial of pig islet cell transplantation. Virus research, 227, 34-40.

Niu, Dong, Hong-Jiang Wei, Lin Lin, Haydy George, Tao Wang, I-Hsiu Lee, Hong-Ye Zhao et al. "*Inactivation of porcine endogenous retrovirus in pigs using CRISPR-Cas9.*" Science357, no. 6357 (2017): 1303-1307.

Nordmann, A. (2007). *If and then: a critique of speculative nanoethics*. Nanoethics, 1(1), 31-46.

Nuffield Council on Bioethics (2016) Report "Genome Editing: An Ethical Review"

http://nuffieldbioethics.org/wp-content/uploads/Genome-editing-an-ethical-review.pdf

(accessed September 29, 2018)

Nuffield Council on Bioethics (2005) Report "*The ethics of research involving animals*" http://nuffieldbioethics.org/wp-content/uploads/The-ethics-of-research-involving-animals-full-report.pdf (accessed September 29, 2018)

O'Keefe, M., Perrault, S., Halpern, J., Ikemoto, L., Yarborough, M., & UC North Bioethics Collaboratory for Life & Health Sciences. (2015). "Editing" genes: A case study about how language matters in bioethics. The American Journal of Bioethics, 15(12), 3-10.

Paradis, K., Langford, G., Long, Z., Heneine, W., Sandstrom, P., Switzer, W. M., ... & Otto, E. (1999). *Search for cross-species transmission of porcine endogenous retrovirus in patients treated with living pig tissue*. Science, 285(5431), 1236-1241.

Rithalia, A., McDaid, C., Suekarran, S., Myers, L., & Sowden, A. (2009). *Impact of presumed consent for organ donation on donation rates: a systematic review*. Bmj, 338, a3162.

Savulescu, J. (2016) *Should a human-pig chimera be treated as a person?* AEON July 14th, 2016 https://aeon.co/ideas/should-a-human-pig-chimera-be-treated-as-a-person (accessed September 29, 2018)

Schick, A. (2017). *Bioethics and the legitimation/regulation of the imagined future. In Imagined Futures in Science*, Technology and Society (pp. 27-56). Routledge.

Schick, A. (2016). *Whereto speculative bioethics? Technological visions and future simulations in a science fictional culture*. Medical Humanities, 42(4), 225-231.

Scientific Registry of Transplant Recipients, https://www.srtr.org/about-the-data/the-srtr-database/ (accessed September 29, 2018)

United Network for Organ Sharing (UNOS), https://unos.org/data/ (accessed September 29, 2018)

Wilson, C. A., Wong, S., Muller, J., Davidson, C. E., Rose, T. M., & Burd, P. (1998). *Type C retrovirus released from porcine primary peripheral blood mononuclear cells infects human cells*. Journal of virology, 72(4), 3082-3087.

Wolff, J. (2011). *Ethics and public policy: a philosophical inquiry*. Routledge.

Yamaguchi, Tomoyuki, Hideyuki Sato, Megumi Kato-Itoh, Teppei Goto, Hiromasa Hara, Makoto Sanbo, Naoaki Mizuno et al. "Interspecies organogenesis generates autologous functional islets." Nature 542, no. 7640 (2017): 191.

Yang, Y. G., & Sykes, M. (2007). *Xenotransplantation: current status and a perspective on the future*. Nature Reviews Immunology, 7(7), 519.

Zhang, Sarah (2017) Genetically engineered pigs to grow organs for people. The Atlantic August 10, 2017, https://www.theatlantic.com/science/archive/2017/08/pig-organs-for-humans/536307/ (accessed September 29, 2018)