GRAPPLING WITH THE UNIVERSAL PROTOPLASM

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INTRODUCTION

Progress in the biological sciences continue to amaze. Barely a month goes by without some remarkable new discovery being announced. Many of the most astounding results announced in recent years concern our newfound power to reset and control the development of cells due to dramatic improvements in our understanding of genetics and stem cell biology. The creation of Dolly the sheep demonstrated that, in the right environment, somatic cells could develop into a whole organism (Wilmut et al. 1997). The creation of induced pluripotent stem (iPS) cells via direct nuclear reprogramming (Takahashi and Yamanaka 2006) along with associated advances in understanding the molecular signalling processes which guide the differentiation of cells has opened up exciting possibility for cell therapies as well as for fundamental science: one of the most interesting therapeutic uses of this technology would be as an assisted reproductive technology, should it prove possible to derive human gametes from stem cells (Mathews et al. 2009). Stem cell science has also greatly increased the prospects for chimeric organisms, which were already substantial owing to advances in developmental biology. At the same time, progress in the development of technologies of genetic modification has allowed the creation of more and more transgenic organisms. Lurking in the background — or, rather, in the more distant future — is the prospect of an entirely "synthetic" biology, which might allow scientists to design organisms from scratch using genetic sequences drawn from the entire living kingdom as building blocks (Kaebnick 2014).

While each of these discoveries has generated more than its fair share of alarm and ethical controversy, what is perhaps not yet adequately recognised is that, both separately and together, these discoveries have unsettled — or threaten to unsettle —a number of distinctions that were previously understood to be central to the ethics of the life sciences. The invention of iPS cells has undercut the distinction between differentiated and pluripotent cells and therefore— with the possibility of somatic cell nuclear transfer (SCNT) cloning or other manipulations of zygotes — the distinction between actual and potential individuals. Research into techniques of artificial gametogenesis from iPS cells threatens to undermine the distinction between somatic cells and gametes. Together, these two technologies would

profoundly unsettle our sense of the importance of genetic parenthood and the distinction between relatives and strangers as well as between generations. Finally, the creation of stem-cell chimeras and rapid progress in the technology of genetic engineering has blurred the boundaries between species.

In this paper I survey the messy moral landscape that is likely to result and the challenges it poses to our current ethical understandings and institutional practices regarding the treatment of human tissue, genetic parenthood, and the moral status of embryos. A number of these challenges have been noted previously and are the topic of a vigourous, if still comparatively small, literature in bioethics. However, I will argue that the ultimate significance of our new found technological power remains under appreciated. With a set of technologies that we can now imagine, if not actually glimpse on our technological horizon, given the right set of circumstances and the dedication of sufficient scientific ingenuity almost any cell could be transformed into any other cell — or indeed into a whole organism. In combination, then, these scientific and technological advances have brought us to the point where it becomes possible to consider all living things as variations or developmental stages of an endlessly protean "universal protoplasm". I will suggest that this new worldview would have radical implications for our understanding of the moral status of humans compared to other organisms and thus for our treatment of non-human animals.

TRANSFORMATIONS

It is impossible for the nonspecialist to keep up with the scientific literature nowadays and extremely difficult even to maintain an accurate sense of what the science makes possible or rules out at the current date — let alone is likely to allow in the near future. Nevertheless, if we are to properly understand our current ethical circumstances, it is essential to attempt this latter task. In this section, then, I will provide a brief overview of the various sorts of transformations science already makes possible or is likely to make possible in the near future, according to the testimony of researchers and informed pundits.

SOMATIC CELLS TO WHOLE ORGANISMS

That it is possible, given the right circumstances, for any somatic cell in a sheep to be transformed into a whole organism was demonstrated by the creation of "Dolly" the sheep (Wilmut et al. 1997). Dolly was a "clone" — a genetically identical copy — of another sheep from which a somatic cell was taken and inserted into a denucleated egg of another sheep. The technology used to create Dolly — SCNT — has since been applied to produce clones in a number of other mammalian species, including mice, rats, dogs, cats, monkeys, cows, pigs, and horses. Two research teams have recently announced success in deriving embryonic stem cells from human embryos created using SCNT (Chung et al. 2014; Tachibana et al. 2013). While both technical and ethical barriers stand in the way of the reproductive cloning of human beings, these barriers seem unlikely to be insurmountable.

The invention of iPS cells has also opened up new possibilities for transforming somatic cells into whole organisms via "tetraploid complementation" (Denker 2009). Induced pluripotent stem cells are cells with the capacity to develop into any cell in the body, which may be created by manipulating somatic cells via a number of techniques. "Tetraploid complementation", which has been demonstrated in mice, involves first combining two embryos together to produce an embryo with double the normal amount of chromosomes (a "tetraploid" embryo), and then adding iPS cells to this embryo and implanting the resulting chimeric embryo into the womb of a female of the species (Zhao et al. 2009). When this

technique is successful it produces an organism the entire body of which is descended from the iPS cells and is thus a clone of the original source of the somatic cells from which the iPS cells were created.

SOMATIC CELLS TO GAMETES

The invention of iPS cells also holds out the promise of allowing the creation of gametes from somatic cells (Mathews et al. 2009).If the correct set of molecular signals and culture conditions can be discovered it should be possible to produce both sperm and eggs from any somatic cell from a male organism and eggs from any somatic cell from a female organism. This has already been demonstrated in mice (Hayashi et al. 2011; Hayashi et al. 2012) research to produce human gametes from iPS cells is proceeding apace (Clark 2010). The capacity to produce "artificial gametes" will herald in a new era of reproductive technology, making it possible for any individual — living or dead — from whom a somatic cell can be sourced to become a genetic parent.

Once it is possible to produce both sperm and egg from human embryonic stem cells (hESc) it will also be possible to produce new human embryos — and thus hESc lines — by combining sperm and egg created from different hESc lines. These new cell lines could then be used to produce more sperm and eggs which could in turn then be used to create new embryos. This iterative process would allow what I have elsewhere termed "in vitro eugenics", which would involve the selective crossing of desirable genetic traits in humans in a laboratory system to produce children with "enhanced" genomes (Sparrow 2013).

TWO SPECIES TO ONE CHIMERA

A number of different scientific advances both separately and together have allowed the creation of organisms the species of which is unclear. Recombinant DNA technology ("genetic modification") has for many years now allowed researchers to create organisms containing genes from two or more species. This technology continues to improve and the recent invention of the "CRISPR" gene editing technology has made it more powerful still (Cong et al. 2013). Another procedure that transforms the species of organisms is the production of "stem cell chimeras," wherein pluripotent stem cells (either iPS or embryonic stem (ES) cells) from one organism are injected into the developing embryo of another organism to produce an adult individual with cells from both species. In theory, this procedure might allow the creation of human-pig chimeras with organs consisting entirely of human cells, which might then be used as a source of organs for transplantation (Rashid, Kobayashi, and Nakauchi 2014). Finally, "synthetic biology" aims to allow the design of organisms from the "ground up", using a toolkit of genes taken from across the animal (and plant) kingdom (Kaebnick 2014). Such organisms would not just be mixtures of existing species, rather they would be completely novel.

UNSETTLED BOUNDARIES

Each of the technological transformations I have described involves crossing or blurring a boundary once thought fundamental to the biological sciences. Yet, equally — or perhaps even more — importantly, each of them also threatens distinctions that are fundamental to our understanding of our current place in the world and of the ethical dilemmas we face in living in it. It is to the task of describing these unsettled boundaries and (some of) the implications of them becoming unsettled that I now turn.

BETWEEN BODIES AND BABIES I: SCNT CLONING AND IPS CELLS

The theoretical possibility of human cloning by SCNT provoked a flurry of excitement and activity in philosophy and applied ethics, which is yet to subside. Much of ensuing discussion related directly to the question of whether or not it would be ethical to bring a human clone into existence using this technique (see, for instance, the discussions in: Agar 2002; MacKinnon 2000; McGee 2000; Nussbaum and Sunstein 1998). However, the possibility of human cloning also prompted and equally vigourous — if smaller — debate about the implications of SCNT for the older but ongoing philosophical controversy about the moral status of embryos (See, for instance, Charo 2001; DiSilvestro 2006, Oakley 2006; Peters 2001). It is this latter debate — and its subsequent extension to an argument about the implications of direct nuclear reprogramming — that is my central concern here.

Many people believe that what makes abortion or IVF morally wrong is that these practices involve the killing of a "potential person". Human foetuses and human embryos are widely, if not universally, believed to have a different moral status to other groupings of human cells, which it seems plausible to attribute to the capacity they have to develop into an infant (and then an adult) human being. Because philosophers have struggled to explain why simply being a member of the species *Homo sapiens* rather than of another species should grant an individual a special moral status, philosophers have insisted that "person" should be conceived of as a term of art in this context, rather than a synonym for "human being", and refer to creatures of any species with the appropriate properties to grant them the moral status that we currently accord normal adult human beings (Harris 1985, 18-19; Tooley 1972).

However, various philosophers were quick to note once it becomes possible to produce a human infant via SCNT cloning, then, given the right circumstances every human somatic cell seems to have the same "potential" as a human embryo (Charo 2001; Peters 2001). Importantly, this potential might also be realised by turning the somatic cell into an induced pluripotent stem cell and then performing tetraploid complementation (Magill and Neaves 2009; Denker 2009).

The debate about the nature and significance of potential is large, complex, and ongoing and my remarks about it must perforce be brief in this context. It is worth noting at the outset that many philosophers are openly cynical about the significance of potential for moral status, observing that while we all have the potential to be dead, it would be an obvious mistake to treat us as such until we are (Harris 1985, 11). By and large, then, the argument that once these cellular manipulations become possible every somatic cell is a potential person is intended as a *reductio* of the argument that human embryos have moral status by virtue of this potential: it would be grossly implausible to hold that it would be morally impermissible to destroy or discard any somatic cell because of the potential it has to become a person (Charo 2001; Devolder and Harris 2007).

Those are inclined to resist this *reductio* must therefore identify a relevant dissimilarity between embryos and somatic cells when it comes to their potential in the context of SCNT cloning or tetraploid complementation of iPS cells. A number have been suggested: the potential of embryos is "active" (or "intrinsic" or "inherent") where that of somatic cells is "passive" (or "extrinsic") because somatic cells must be placed into the nucleus of an egg or genetically manipulated and combined with a tetraploid embryo before they have any potential (Condic, Lee, and George 2009); somatic cells rely on the conscious intervention of human agents in order to become a human being where embryos do not; and, somatic cells might *produce* a human being whereas an embryo would *become* one (Disilvestro 2006; Oakley 2006).

While reasons of space prevent me from settling the matter here, let me state my belief that it is unlikely that any of these various objections will be successful — at least against the argument about the implications of direct nuclear reprogramming for the potential of somatic cells. They all look to founder on a scientifically accurate account of the science of stem cells and the process of embryonic development (Denker 2009) and on the fact that the potential of human embryos is also dependent on a large number of contingent circumstances including the actions and goodwill of third parties (Charo 2001; Devolder 2009). That is to say, a human embryo created via IVF, for instance, will not become a person unless an IVF technician transfers it into a woman's womb. Even an embryo created by natural fertilisation within a woman's body will not become a person unless that woman makes various choices to nurture the new life growing inside her and to care for the infant after he or she is born so he or she may grow into an adult. While it may be plausible to insist that while SCNT cloning would allow a somatic cell to be used to *produce* a person, this cell would not *become* a person, this objection has much less force against the argument about the potential of somatic cells with the advent of direct nuclear programming. In this latter case, the somatic cell arguably would indeed become the individual who was eventually born because all of the body of the fetus derives from the cells in the inner cell mass of the embryo which in turn would be derived from a somatic cell, after it had been provided with the appropriate environment (being reprogramming factors plus a tetraploid embryo) (Devolder 2009). The procedures necessary to bring a person into existence via the production of iPS cells and then tetraploid complementation may be more baroque and less reliable than the "natural" process of gestation but do not appear to differ fundamentally from it when it comes to their contribution to the potential of the cell at the beginning of the process.

Even if we conclude — as I have argued is likely — that somatic cells do not acquire moral status with the advent of iPS cells, if somatic cells could be used to produce new individuals this would still require a significant revision of our attitudes towards the disposition of our tissues. In particular, the institutional processes governing consent to the taking and storage of tissue samples would need to take account of the possibility that these samples could be used to bring into existence an individual with the same genome as the original source of the tissues. Presuming that most individuals would not like to be cloned without their consent, sampling and donation processes would need to explicitly detail and regulate the circumstances in which tissue samples might — or, perhaps more importantly, might not — be made available for a cloning procedure.

That someone might wish to clone another person against their will might be thought to be unlikely. However, even barring cases where obsessive fans want to clone celebrities, there is at least one circumstance wherein an argument might be made for cloning independently of the DNA source's desires in this regard. Where a couple have (or have had) an existing child who is (or was) their genetic offspring and then have subsequently become unable to conceive children, cloning their first child would allow them the opportunity to become genetic parents again (Sparrow 2006; Robertson 1998, 1423). Given the importance that many people place on becoming a genetic parent this would seem to indicate that the couple have a strong interest in being able to clone their child. Indeed, the case where their first child has died but where a sample of their tissue is available has often been offered as the "poster case" for human cloning (Brock 1998, 148; Pence 2002, 59; Agar 2002, 148-9). Even in this scenario though, we might wonder whether this procedure would be ethical in the absence of consent for such posthumous use of the tissue, especially if the (deceased) child had reached their majority. Where their first child is still alive and an adult, it might be thought that their consent would be necessary in order to clone them even if the tissue sample which was to be used was taken while they were still an infant. Yet, if they deny their parents permission to

clone them, the child will threaten the reproductive liberty of the parents. Interestingly, in the larger debate about the ethics of human cloning, it has become popular to argue that clones suffer no harm by virtue of the fact that they are genetically identical to an existing individual: this seems to follow from the fact that few people think that the birth of identical twins raises any moral issues or harms either twin (Harris 1997). What is less often recognised is that if the clone suffers no harm then it is difficult to see how the existing person who is cloned is harmed by the creation of a genetically identical individual — and therefore why their consent should be necessary (Kass 1997, 23).

This brief discussion already suggests, then, that the question of the appropriate person to approach for consent to cloning, as well of the moral significance of that consent, is more complex than first appears. Moreover, there is another set of circumstances where our intuitions suggest that, in order to clone an individual consent would be required *from the genetic parents of that individual*. When it comes to the disposition of human embryos the genetic parents of the embryo are generally thought to have a special interest in its fate. In particular, we would typically deny that anyone has the right to bring a child into existence using an embryo without the explicit consent of at least one of the genetic parents. When it comes to the destruction of embryos, we also normally seek the consent of one or both genetic parents, except where such destruction is mandated by statute. Given that the genetic parents of a cloned embryo are the genetic parents of the DNA source, this suggests that individuals should have to seek the consent of their own genetic parents before they clone themselves (Sparrow 2006). This intuition gains extra force when we recognise that, at least in the case of reproductive cloning, an individuals' cloning of themselves without their parents' consent directly impinges upon the reproductive liberty of their parents (to whit, their right *not* to reproduce) by making them genetic parents against their will. However, its implications for therapeutic cloning are surprising, as it suggests that even therapeutic cloning (for instance, the creation of cloned embryos for the purposes of extracting ES cells for use in treatment of the DNA source) may not be ethical without the consent of the genetic parents of the individual being treated, on the grounds that such a procedure would involve the creation and then destruction of embryos in which the individual's genetic parents would have a significant interest (Sparrow 2009).

BETWEEN BODIES AND BABIES II: ARTIFICIAL GAMETES

Embryos are not the only type of human tissue that we currently think of as having more moral significance than somatic cells. We also tend to treat our gametes differently than somatic cells. Thus, for instance, consent procedures for the collection of gametes are typically more elaborate than those for other tissues and we view the storage of gametes as more ethically fraught than the storage of other types of cells. Our intuitions about the special significance of gametes come into stark relief when we imagine someone acquiring our gametes without our consent: the capacity of our gametes to be used to produce children who would be our genetic offspring means that other person's possession of our gametes places us in a special jeopardy.

Once it becomes possible to produce gametes from iPS cells generated from somatic cells, this distinction will no longer make sense. Any tissue sample will allow the person who possesses it to bring the genetic offspring of the tissue source into existence. Moreover, given that it is possible to acquire tissue samples noninvasively (for instance by sampling saliva or salvaging skin cells) individuals might even remain unaware that third parties had come into the possession of material that would then allow those third parties to bring that individual's children into existence (Smajdor and Cutas 2014).

The advent of artificial gametogenesis will therefore require us to think further about the moral significance of genetic parenthood and, in particular, the foundations and force of the right not to become a parent, which is an important part of reproductive liberty (Brock 1994; Robertson 1994). Practically speaking, given even the prospect of artificial gametogenesis, there is an urgent need for consent processes for the taking and storage of blood and tissue samples to record individuals' attitudes towards the possible future use of these samples for reproductive purposes. These processes should explicitly address the question of the destruction versus possible reproductive use of these samples in the event of the individual's death, given that the ability to produce gametes from somatic cells will greatly increase the opportunities for posthumous reproduction.

BETWEEN RELATIVES AND STRANGERS (AND BETWEEN GENERATIONS)

The discussion of the appropriate locus for consent to human cloning above has already touched upon some of the ways in which the new cell technologies unsettle the boundaries between generations, which have previously played an important role in shaping our thinking about the relations between children and their parents. Many discussions of human cloning have treated it as allowing a new way for individuals to become parents by bringing children into existence with the same genome as themselves (Strong 2000). According to this way of thinking, individuals who clone themselves would become the parents of their own genetically identical twins and the procedure would be justified by the moral significance of having a "genetic relationship" with one's children; indeed, they would be more "genetically related" to their clone then to their natural genetic offspring. This is already to blur the ordinary distinction between generations because the clone would be born in a different (historical, if not genetic) generation to someone who is their identical twin. However, as argued above, on another way of thinking, the genetic parents of clones are the genetic parents of the individual who is cloned. Thus, human cloning would make it possible for individuals to become the genetic parents of new individuals without them doing anything to bring this about. It also, of course, allows the possibility that individuals will be the genetic twins of other individuals years younger than themselves. While men have always been subject to the risk of being a genetic parent of children of whom they were unaware, cloning seems to blur the distinction between relatives and strangers still further.[1]

In so far as it would greatly expand the opportunities for posthumous reproduction, the technology of artificial gametogenesis would also unsettle the boundaries between generations, making it possible for people to have genetic parents who were long dead before they were even conceived. While artificial gametogenesis is usually envisioned as a technology to allow people who might otherwise be incapable of becoming genetic parents because they were unable to produce gametes to become genetic parents through the creation of sperm or eggs from iPS cell lines derived from that person, there is some discussion in the literature of the question of whether or not it would actually succeed in this given that the cell

[1] The claim that SCNT clones would be the identical twins of the DNA donor — and therefore the genetic offspring of the genetic parents of the donor — might be resisted on the grounds that SCNT clones will often have different mitochondrial DNA to the person cloned (Oakley 2006; Robertson 1998, 1392, footnote 97). The significance of mitochondrial DNA is also, of course, at the centre of the debate about both the science and ethics of "three parent babies", created using cytoplasmic or mitochondrial transfer (Baylis 2013). Yet, because mitochondrial DNA is transmitted in the cytoplasm of the egg — and therefore (more or less) unchanged down the matrilineal line — and because there are only a small number of mitochondrial genotypes, the fact that one has the same genetic relationship with one's maternal grandmother and great grandmother as with one's own mother and that each of us has the same mitochondrial DNA as millions of other people, suggest that any claim about the moral significance of mitochondrial genetic parenthood will blur the distinction between relatives and strangers further still.

donor's genes are not actually reshuffled (as is the case in normal genetic parenthood) in this process — rather, the genes of a cell that might become an identical twin of that person are reshuffled (Mertes and Pennings 2008; Mertes and Pennings 2010). Thus, artificial gametogenesis would also unsettle our concept of genetic parenthood and therefore between relatives and strangers.

One particular theoretical use of the technology of artificial gametogenesis would create people who arguably had no genetic parents whatsoever. As I have discussed elsewhere, once it becomes possible to create both sperm and eggs from human ES cells, it should be possible to use such sperm and egg to create new embryos from which new stem cell lines might be derived, from which more sperm and egg might be derived (Sparrow 2012). As long as one starts with a sufficient number of stem cell lines, this iterative process should allow researchers to embark upon a multigenerational process of selective crossing of human traits *in vitro* — a process I have characterised as "*in vitro* eugenics" (Sparrow 2013). Were one of the embryos produced by this process to be placed in the womb of a consenting woman and brought to term, the child that was born would not be able to identify any living individuals — or indeed individuals that had ever lived — as his or her genetic parents. They would be "orphaned at conception" (Sparrow 2012). Such a possibility further illustrates the potential of artificial gametogenesis to unsettle the boundaries between generations and between relatives and strangers.

BETWEEN SPECIES

The best way to delineate species and also the idea that species represent "natural kinds" are notoriously controversial. Nevertheless, in so far as we treat members of the human species at least as though they had a significantly different moral status from members of all the other species, the concept of species continues to play a crucial role in folk morality as well as in regulation of medical research (Robert and Baylis 2003). Thus, for instance, the killing of an infant human is murder where the killing of a mature chimpanzee is not; experimentation without consent is permitted in the case of the latter but not the former. Most jurisdictions also regulate research involving human embryos where they do not regulate research involving the embryos of non-human animals.

Recombinant DNA technology ("genetic engineering") unsettles the boundaries between species by enabling the creation of organisms with genes — and traits — from two or more species. A mouse which has been genetically modified so as to have human genes is not human but neither is it entirely mouse. A new gene editing technology, known as CRISPR (for "clustered regularly interspaced short palindromic repeats"), recently added to the toolbox of scientists, has greatly enhanced the potential power of genetic engineering by allowing very precisely targeted modifications of the genome (Cong et al. 2013). Thus, in the future we are likely to see many more organisms containing genes from a number of different species being created.

Because genetic modification begins with an organism of one species and adds genes from others, it might be argued that it unsettles the boundaries between species only to a limited extent. A mouse with human genes typically still looks like a mouse and most of its genes remain mouse genes. However "synthetic biology", which aims to allow the construction of new life forms from the ground up using genes taken from anywhere in the natural world, would produce organisms which had no clear natural antecedents. That is to say, while they would have traits derived from animals and/or plants of many different species, they would bear little if any relation to any of them. While, in one sense they would represent "new" species, in another sense they would represent the final dissolution of species boundaries: all

organisms would be revealed as the expression of a genetic code which itself is universal. Even though a practical synthetic biology remains a distant dream at the moment due to the complexity of the systems it is attempting to manipulate and construct, the mere prospect of such an endeavour already encourages scientists — and, eventually, the general public — to adopt such an attitude.

Perhaps the most viscerally disturbing blurring of species boundaries, though, occurs in the creation of stem cell chimeras. By introducing stem cells from one species into the developing embryo of another, researchers are able to create organisms, the bodies of which consist in cells from both species. Crucially, this research demonstrates the importance of cellular environment relative to DNA when it comes to the developmental trajectory of tissues: the cells of the first species will often integrate into the developing organism in accordance with the developmental schema typical to embryos of the second species (Karpowicz, Cohen, and Van der Kooy 2005, 123-125). By combining this technique with some clever genetic engineering, researchers have been able to produce animals wherein particular organs are made up of cells of a different species from that of the remainder of the animal (Kobayashi et al. 2010). First, animals are genetically modified so that the developing embryo fails to produce a particular organ and then pluripotent stem cells of a different species are introduced, which colonise the empty developmental niche within the growing embryo so that the organ does in fact develop but consists of cells of this second species. This technology has an exciting potential to be used to grow human organs for transplant within the bodies of genetically modified pigs or sheep (Matsunari et al. 2013; Rashid, Kobayashi, and Nakauchi 2014). Yet such chimeric animals would be composed of cells of two species at once and therefore are arguably entirely of neither species.

A UNIVERSAL PROTOPLASM?

I have been discussing the ways in which various scientific and technological advances in the life sciences each unsettle boundaries which have traditionally played a key role in moral and philosophical argument. The simultaneous development and combination of these technologies has a further implication, which I have thus far only touched upon.

We can already imagine combinations of the technologies I have been discussing which would produce quite dramatic reconfigurations of living things. Thus, for instance, injecting human iPS cells into a genetically modified pig embryo might bring into an existence an animal which not only contained some human organs but also produced human sperm, which then might be used to create new embryos for further manipulations. Stored tissue taken from a person now long dead might be turned into sperm and eggs to bring into existence their genetic offspring or to be used to creates cell lines which might then be genetically modified to include genes taken from anywhere in the living world. Exciting — and grotesque — scenarios of this sort in which one organism or tissue type is transformed into another may be multiplied endlessly. However, even if the more outlandish of the possible scenarios never eventuate, the advent and possible combination of these technologies has already begun to transform our attitude towards the living world on a deeper, philosophical, level: it encourages us to understand all living organisms and their cells as variations or developmental stages of an endlessly protean “universal protoplasm.” According to this new world view, every cell — and every organism — represents the realisation of a set of principles and instructions coded in DNA and its relations to its developmental and physical environment and is the product of a process of evolution and interaction which connects all living things. Modern science increasingly aspires to a power which would enable researchers

to control and manipulate this resource so as to be able to, in theory, transform any cell into any other cell or tissue, including whole organisms.

NON-HUMAN, ALL TOO HUMAN?

This is a breathtaking ambition — a "new alchemy" in the life sciences — which undoubtedly holds out significant benefits in terms of medical treatment, reproductive technologies, and environmental engineering even if it is ultimately only partially realised. Yet its philosophical implications are equally revolutionary and threaten to jeopardise the benefits that it might otherwise deliver.

Research in the life sciences relies heavily on animal models and animal experiments. Without "knockout mice", contemporary molecular biology and stem cell science would grind to a halt. The project of developing chimeric pigs as sources for human organs for transplant obviously relies upon our willingness to sacrifice the lives of pigs to this end. Even research into artificial gametogenesis involves the creation and destruction of animal embryos as well as animal suffering in the course of sourcing gametes and in the gestation of embryos and young that will then be dissected — many of which procedures would be prohibited were they to involve human gametes or embryos. The ethical framework for this research therefore presumes the distinction between the moral status of humans and non-human animals.

However, in radically unsettling both the distinction between human and non-human animals and between actual and potential individuals the new attitude towards the living world, which I have suggested is emerging in the life sciences, makes it much harder to ethically justify the (non-human) animal research that is necessary to realise its vision. Blurring these lines severely problematises the ethical frameworks that govern both embryo research and (non-human) animal experimentation.

Research involving human embryos is regulated in many, perhaps most, jurisdictions where research in the life sciences takes place. Obviously, the details of these regulatory regimes and the precise formulation of their motivation differs from nation to nation. Typically, though, these regulations require consent from the genetic parents of embryos for research on human embryos, restrict research on human embryos to the first 14 days after conception, prohibit the implantation of chimeric and/or genetically modified embryos, and mandate the destruction of embryos in certain circumstances; they often prohibit the creation of human embryos for research purposes. The justification for regulating such research varies from jurisdiction to jurisdiction but often rests on one or more of the following claims: individuals have an emotional attachment to their embryos and care about the fate; that, as the beginnings of human life, embryos are deserving of "respect"; and, that embryos have some moral status by virtue of their potential to become human being (for a survey, see Isasi and Knoppers 2006). By comparison — and in contradistinction — research involving the embryos of other species is typically not regulated at all.

Recent scientific interest in creating cloned and chimeric embryos has already begun to challenge these regulatory regimes by calling into question the precise definition of a "human embryo" (Magri 2005). However, this challenge takes place at the level of the *application* of the regulations. The scientific developments I have been surveying here challenge the *justifications* of such restrictions. As we saw above, arguments for the moral significance of embryos by virtue of their potential are called into question by the development of iPS cells, which grant any somatic cell the potential to become a human being. The more fundamental challenge, though, is posed by the blurring of species boundaries initiated by recombinant

DNA technology and extended by the creation of stem cell chimeras (Waldby and Squier 2003). As we saw in the discussion of stem cell chimeras above, scientific results in this area in particular call into the question the role and significance of DNA in the development of the organism. A human cell placed into the embryo of another species will develop in accordance with the developmental schema of the non-human animal rather than of a human embryo. Moreover, the program of research to develop replacement organs for human beings by making human-animal chimeras relies upon the idea that mere possession of cells with human DNA does not accord an organism the moral standing appropriate to a human being. It is therefore difficult to see why the mere fact that embryos contain human cells should be mark them out as having a distinctive moral status. Together, then, these developments call into question two of the main justifications for regulating human embryo research any differently than research on non-human embryos.

If this was the only implication of this new attitude towards the living world, we might well conclude that it was nothing to get too exercised about. Many philosophers and scientists already believe, I suspect, that human embryos should not be accorded any more respect or moral significance than any other bundle of cells. However, emphasising the fundamental interrelatedness and mutability of all living things also has radical implications for our understanding of the ethics of our treatment of non-human animals more generally, which may be very disruptive indeed.

There are (at least) two aspects of our treatment of non-human animals — including our treatment of them in the context of medical research — that are properly controversial. First, there is the matter of the moral weight of the suffering caused to sentient creatures by human activities. Second, there is the question of the moral value of the lives of the non-human animals that human beings kill independently of any suffering their deaths might involve. Each of these matters is the topic of the philosophical literature too large to survey here. Yet even a brief recap of the main conclusions of this debate is sufficient to demonstrate why the new world view I have been discussing might have radical implications.

In each context, a key issue is "What justifies us causing suffering to or killing non-human animals if we are unwilling to treat human infants in the same ways?" (Singer 1993, 55-62). When it comes to the moral weight of suffering, many philosophers have reached the conclusion that *nothing* justifies making this distinction and that we should therefore not cause sentient non-human animals pain where we would not be willing to cause human infants the same pain (Bentham 2006; Singer 2006). The question of the value of the lives of (non-human) animals is more complex and controversial. There are good reasons to think that certain sorts of creatures, including (healthy, adult) human beings, may be deprived of more by being killed than others. Thus, for instance, creatures that are able to perceive their lives as extending through time, to anticipate the future, and that have future-oriented desires, are harmed by being deprived of future life when killed where merely sentient creatures are not (Harris 1985, 17-19; Singer 1993, 90). Nevertheless, again the line between human and non-human animals notoriously fails to track this difference: some "higher" non-human animals, including primates, dogs, and pigs, clearly have these capacities, whereas human infants and some severely cognitively impaired human beings do not. A number of influential philosophers have therefore concluded that whether or not a creature is a member of the species *Homo sapiens* or not is, strictly speaking, irrelevant to whether it is morally permissible to kill it in any given circumstance (De Grazia 1996, 56-61; Harris 1985, 19-20; Singer 1993, 182).

However, few, if any, researchers — and no jurisdictions of which I am aware — are willing to be this consistent. In practice, then, species makes a huge difference to the way in which

organisms are treated. By unsettling our understanding of the distinction between species and its moral significance, the recent developments in the life sciences I have been discussing, make it even more difficult to explain why membership of the species *Homo sapiens* should matter so much for moral standing.

The literature on the ethics of creating (non-human) animal/human stem cell chimeras has struggled with this question. Once we begin creating such chimeras, the obvious question to ask is, how much of such a chimera would need to be composed of human cells before this creature should be granted the same moral status as we currently grant to human beings? The prospect of non-human animals with brains made up of human neurons is especially philosophically unsettling (White 2007). While we might be prepared to concede that there is nothing especially distinctive about human kidneys, livers, hearts, or lungs as compared to those of non-human animals, the superior cognitive capacities of the human brain are generally held to be crucial when it comes to explaining what justifies granting normal adult humans, at least, higher moral standing than non-human animals. If a genetically modified pig, for instance, had a brain consisting entirely of human cells, we might wonder whether it was more appropriate to describe this as a pig with a human brain or a human with the body of a pig. Admittedly, human neuronal stem cells introduced into the developing pig embryo would most likely adapt themselves to the structural blueprint provided by the larger embryonic environment so that the pig would develop a brain structured like a pig's but made up of human tissue (Karpowicz, Cohen, and Van der Kooy 2005, 123-125). It might then be argued that it was the structure of its brain rather than the type of cells in the brain that was important when it came to the moral status which should be granted to this chimera (Greely et al. 2007). However, the relative contribution of the distinctive features of human neurones and the distinctive features of the structure of the human brain when it comes to producing consciousness is scientifically controversial, while the contribution each makes to the special moral standing we grant human beings is philosophically controversial. Again, given that we typically grant a special moral standing to human infants and that an adult chimeric pig with a human brain might be capable of cognitive feats human infants could not achieve, in order to deny the chimeric pig the same moral standing as human infants it appears we would either need to draw on an argument about the pigs' (lack of) potential or risk being accused of fetishising the structure of brains over their capacities. Yet, as noted above, the moral significance of potential is doubtful; nor do we typically think that human infants with a genetic condition that will prevent them from living to adulthood lose the moral standing they have simply by virtue of being human.

For the most part, then, authors in this literature conclude that what matters is the moral status of the chimera that research might create rather than the structure of its brain or what percentage of its cells might be human (see, for instance, DeGrazia 2007; Hyun et al. 2007; Streiffer 2005). That is to say, their conclusions track — indeed, they draw upon — the larger philosophical debate about the grounds of moral status. What does not as yet seem to have adequately acknowledged in this literature is that these conclusions either license medical experimentation on healthy human infants and/or severely cognitive impaired adults — including painful experimentation and experiments which involve killing these human beings at the end of the experiment — or they rule out conducting such experiments on sentient non-human animals (Singer 1993, 68). Presuming that we are unlikely to embrace the first of these implications, we are therefore forced to consider the possibility that we must radically rethink our treatment of non-human animals in medical research and elsewhere.

CONCLUSION

The power to manipulate and transform cells, which modern science increasingly provides, promises many benefits. However, as I have attempted to show here, it is not without its complications and even costs. The more we come to understand all living things as parts of a larger pool of living matter— a universal protoplasm — shaped by DNA and environment and potentially manipulable so as to be capable of being transformed into any other living thing, the harder it will become to ground distinctions and intuitions that have to date been central to our understanding of the ethics of the life sciences; the moral significance of the distinction between human and non-human animals, in particular, is likely to become even more vexed than it already is, with significant implications for our treatment of non-human animals. Without these ethical signposts, we will struggle to orient ourselves in a world of rapidly expanding choices made possible by new technologies. For this reason, it is essential that research in the life sciences continues to be accompanied by research in ethics. I am therefore especially delighted to have had the opportunity to participate in the 2014 Uehiro Carnegie Oxford Conference on "Ethics for the Future of IPS/Stem Cells"; the founding of the Uehiro Research Division for iPS Cell Ethics, at the Centre for iPS Cell Research and Application, at the University of Kyoto, is also a valuable contribution to this vital project.

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