Crossing Species Boundaries

CROSS-SPECIES CHIMERAS: EXPLORING A POSSIBLE CHRISTIAN PERSPECTIVE

by Neville Cobbe

Abstract. Various entities that combine material from humans and other animals at either the cellular or subcellular level have attracted growing public interest. I explore the controversy by considering both the scientific rationale behind creating various entities that have prompted the greatest public concern and possible ethical implications. I note a number of potentially relevant biblical passages and reflect on the *imago Dei* and considerations of *telos* in order to prompt wider discussion regarding how Christians might respond to such emerging bioethical issues.

Keywords: chimera; cloning; embryo; ethics; humanity; *imago Dei* (image of God); nuclear transfer; research; *telos* (end); welfare

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The creation of living entities that are a mixture of material from humans and other animals has gained increasing attention in the media. Previously, the injection of human embryonic stem cells into mouse embryos to create interspecies chimeras had divided the scientific community, with some biologists arguing that this may be required to test the pluripotency of existing human cell lines while others questioned the necessity of such experiments and feared that the expected public disquiet would encourage further opposition to research involving human embryos (DeWitt 2002). However, much of the recent interest in Britain has been fuelled by proposals to use eggs from other species to supposedly clone human embryos (Henderson 2007a, b). Nevertheless, many other sorts of human-nonhuman mixtures may also be envisaged, including extant practices such as

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transplanting pig valves into human hearts or grafting human tumors into mice for study purposes (Karpowicz et al. 2004). Each of these different entities containing mixtures of human and nonhuman biological material has been variously described as a *chimera*—a term that originally designated a mythological fire-breathing monster with a lion's head and foreparts, a goat's head and abdomen, and a serpent for a tail.

Much confusion in the public debate concerning cross-species entities has arisen due to inconsistency in usage of nomenclature. For example, cloned animals created by nuclear transfer were initially described as "genetic chimaeras" because they possessed "somatic cell–derived nuclear DNA in combination with oocyte-derived mitochondrial DNA" (Evans et al. 1999, 90). However, the term *hybrid* also has been used to describe the product of cross-species nuclear transfer due to the possession of nuclei and mitochondria from different species (Loi et al. 2001). In addition, the term *cybrid* or *cytoplasmic hybrid* has been used to describe cells containing nuclear DNA and mitochondrial DNA from different species, though previously published studies referring to a *cybrid* have generally involved fusions between cultured cells such as fibroblasts (Kenyon and Moraes 1997; Barrientos, Kenyon, and Moraes 1998; McKenzie et al. 2003) or mouse embryonic stem cells used to generate chimeric mice (Levy et al. 1999; Sligh et al. 2000) rather than interspecies embryos as currently proposed. While each of the different terms arguably has some merit in describing interspecies nuclear transfer, reference to a *hybrid* may be misleading if one is normally used to restricting this term to the progeny resulting from sexual reproduction (Lawrence 2005), while the term *chimera* may be misleading if one normally associates this only with an organism containing genetically distinct populations of whole cells originating from different embryos (Rossant and Spence 1998). By contrast, the descriptions *chimeric* and *hybrid* may be used interchangeably by molecular biologists when the subject under discussion is an engineered protein or DNA construct (Smith et al. 1997; Lawrence 2005), while all eukaryotic cells have been described as chimeric in discussing their possible evolutionary origins via endosymbiosis (Margulis, Dolan, and Guerrero 2000). As a result, it is hardly surprising that there has been much confusion over the nature of entities described by such terms (Select Committee 2007, 5–6, 44–46).

In a report prepared by the U.K. House of Commons Science and Technology Committee in 2005, it was argued that human/nonhuman embryonic mixtures would be less human than fully human embryos and therefore pose fewer ethical problems for research, despite revulsion in some quarters that such creations appear to blur the distinction between the species concerned (Select Committee 2005, 32). The report went on to recommend that new legislation should therefore define the nature of such entities and prohibit their implantation in a woman but authorize their creation for research purposes if they are destroyed in line with the current four-

teen-day rule for human embryo experimentation (prior to appearance of the primitive streak and subsequent development of the nervous system). By contrast, the Department of Health in the U.K. then produced a Government White Paper recommending that the creation of human/nonhuman chimeric or hybrid embryos should be prohibited for the time being, while leaving open the possibility that this might be legalized by Parliament in the future and made subject to appropriate regulation (Department of Health 2006, 24–25). Such proposals for future legalization following public debate might be viewed as a relaxation of previous Government recommendations that the mixing of adult human somatic cells with the live eggs of any animal species should not be permitted (Department of Health 2000, 47). However, an initially small group of researchers seeking to use cow or rabbit eggs for cloning strongly objected to any further delays supposedly caused either by apparent public unease[1] or desires for more extensive Parliamentary debate, vociferously complaining about such matters to the media.

The ensuing lobbying and hype then promoted claims that a hybrid embryo ban "would cost patients' lives" (Fleming 2007) or that such research was "vital" (Moss 2007) since cloning "can beat disease" (Henderson 2007a) and may offer "the first effective treatments" (Henderson 2007b), while also specifically blaming "religious groups" (Henderson 2007c) for their alleged influence in impeding such research. This in turn led to criticism of the resulting clamor by at least one church representative, questioning the merits of the underlying science and urging caution regarding ethical implications (Bruce 2007). Despite the impression given by the furor in the British press (Henderson 2007b, c), it actually seems that there had previously been relatively little detailed examination of the relevant issues from a predominantly theological perspective (though more specifically faith-based objections may have subsequently become apparent in response to public claims). On the other hand, it still remains to be seen how "therapeutic cloning" might uniquely promise the future treatments in which so much confidence has been expressed (Knight 2004; Check 2005; Cobbe 2006; Cibelli 2007).

In this essay, I attempt to move beyond some of the more polarized claims and the deep-seated revulsion that many people seem to instinctively feel about crossing species boundaries by critically examining the scientific basis for various proposed human/nonhuman entities that have provoked such controversy and then exploring the possible implications of potentially relevant biblical texts. Although most of the ensuing discussion is devoted to research involving significant transfer of human material into eggs or embryos of other species, it is curious that the British Government subsequently has striven to regulate the reciprocal insertion of nonhuman animal cells into human embryos and genetic modification of human embryos to carry transgenes from other species (Department of

Health 2007, 9–10, 98–99). However, it remains to be seen what scientific demand there may actually be to perform such experiments and what the fate of these dubious proposals might be.

So, what are the key issues in the current debate about chimeras, and how might Christians respond thoughtfully to all of this?

Animal Eggs for Human Cloning?

Long before demonstrations of fraud cast serious doubt on the efficiency with which stem cell lines might be derived from cloned human embryos (Cyranoski 2006), and before the sheer number of women's eggs that had actually been used in such attempts was revealed (Nature staff 2006), Ian Wilmut (2004) had suggested that the eggs of other species might be used to reprogram gene expression. In a subsequent newspaper article, Stephen Minger (2006) asserted that "if we want future treatments for today's diseases, a better source of eggs needs to be found," arguing that it would be more ethical to use eggs from domesticated livestock that are already killed for their meat and can provide a large pool of eggs than to encourage women to undergo risky and invasive procedures for which they receive no direct medical benefit and where most of the donated eggs are wasted. Although the use of cows' eggs in this way may seem relatively unobjectionable to many when phrased in these terms, problems may arise when excessive or premature confidence is placed in the outcomes of such experiments. Naturally, any proponent of such work would be keen to assuage fears that anyone is trying to create a monster like the mythical Minotaur. Instead, Minger described in that article how his group in London is interested in creating cloned human embryonic stem cell lines from individuals with conditions such as Alzheimer's disease, in order to better understand how the disease develops.

Such research proposals sharply contrast with previous attempts at cross-species nuclear transfer, in which the apparent aim was "to correct various diseases through cellular transplantation" (Chen et al. 2003), despite outstanding concerns about whether such cells derived from components of divergent species would even be tolerated by a human patient's immune system (Wakayama 2004). However, one may still be left wondering how feasible it is to model various noncongenital and late-onset conditions with a variable penetrance simply by studying cells from embryos in vitro when most of the genes or proteins responsible for the condition of interest remain unidentified (Wilmut 2004; Eggan 2007). This would seem especially difficult given the additional complications due to unpredictably variable yet significantly elevated disruption of gene expression associated with nuclear transfer[2] and the question of how such complications would not be exacerbated by the use of eggs from more distantly related species.

Of course, skepticism regarding allegedly unique benefits is not in itself a sufficient argument against permitting research, at least if no obvious

harm is apparent and no significant risks are foreseeable. Nevertheless, failure to adequately account for the strongest claims about purported outcomes would seem unwise in the face of recognized doubts. It is hard to see how one can ultimately have it both ways: claiming that a cow's egg would contribute virtually nothing to any embryo produced by nuclear transfer in order to derive stem cells (Minger 2006; Henderson 2007a) and arguing that the use of cows' eggs might be essential to such research (Minger 2006). Similarly, it is not immediately obvious how one can insist that interspecies embryos would probably be unable to develop very far and even be legally prevented from surviving to develop a nervous system (Select Committee 2005, 32) yet also suggest that such embryos would be essential for studying neurological conditions such as Alzheimer's disease or motor neuron disease, which primarily affect humans in late adulthood (Minger 2006; Rose 2007). Such claims may appear mutually exclusive, especially if the affected genes or proteins of interest are largely unknown (Wilmut 2004; Eggan 2007) and in light of currently limited abilities to predict the developmental outcome of embryonic clones (Jaenisch and Wilmut 2001; Rhind et al. 2003). It seems that one must either accept that some viable human/nonhuman mixtures are also conceivably possible in order for the proposed research to offer such clearly predictable and uniquely guaranteed clinical benefits or conclude that such research alone does not necessarily guarantee the currently assured promise (and also does not obviously pose any comparable moral threat other than unfairly raising the expectations of affected patients and the wider public). Therefore, unless seemingly extravagant claims can be otherwise substantiated or satisfactorily explained, it should be realized that irresponsible hype may simply reinforce opposing expressions of horror.

As it happens, it is doubtful that most such mixed-species embryos and stem cells derived from them will survive particularly long, because it appears that host mitochondrial function is not properly supported by donor nuclei from more distantly related species (Zuckerman et al. 1986; Kenyon and Moraes 1997; Barrientos, Kenyon, and Moraes 1998; Moraes, Kenyon, and Hao 1999; Barrientos et al. 2000; Dey, Barrientos, and Moraes 2000; McKenzie and Trounce 2000; McKenzie et al. 2003). Although reports differ regarding the preferential replication of donor or recipient mitochondria,[3] it is nonetheless conceivable that supplying more donor mitochondria may alleviate some incompatibility problems over time. However, known differences in the reprogramming of gene expression during the earliest stages of embryonic development in different mammalian genera (Beaujean et al. 2004a, b; Chen et al. 2006) and similarities between defects in cloned animals and interspecific hybrids (Vrana et al. 1998; Vrana et al. 2000; Hiendleder et al. 2004; Singh et al. 2004; Zechner et al. 2004) together suggest that use of eggs from more distantly related species would lead to even more defects in reprogrammed gene expression. Importantly,

Wilmut himself recently endeavored to acknowledge some of the associated technical difficulties in a laudably candid newspaper article, describing how oocytes from other species are expected to be less suitable for reprogramming human nuclei because of differences in the corresponding proteins (Wilmut 2007).

Indeed, most attempts so far to clone mammals using eggs from distantly related species have permitted only limited embryonic development as far as the blastocyst stage (Dominko et al. 1999; Lee et al. 2003; Ikumi et al. 2004; Lu et al. 2005; Murakami et al. 2005; Li et al. 2006; Zhao et al. 2006; 2007). Although one research group (Chen et al. 2003) reportedly has derived embryonic stem cells following transfer of nuclei from human skin cells into rabbit eggs, doubt apparently remains within the research community regarding the feasibility of this approach (Dennis 2006), presumably aggravated by fraudulent claims about the derivation of stem cells from cloned human embryos (Cyranoski 2006). Moreover, development to the blastocyst stage (in order to derive embryonic stem cells) is not necessarily equivalent to full reprogramming even when performing nuclear transfer with eggs from the same species (Boiani et al. 2005). Even parthenotes and androgenetic embryos are able to form blastocysts, despite the fact that such embryos lack differential maternal and paternal gene expression patterns and thus are unable to yield viable offspring (Lagutina et al. 2004). As development to term has been described as the only effective guarantee of complete nuclear reprogramming (Kind and Colman 1999) and viable cloned offspring have yet to be obtained when using eggs from distantly related mammals representative of separate orders, the use of embryonic cells derived in this way to study otherwise unidentified subtle differences associated with late-onset human disease conditions therefore seems all the more questionable.

Despite such considerable technical obstacles, it is nevertheless conceivable that the use of eggs from other species might be used in more basic research to advance understanding of the factors in an egg required for reprogramming gene expression (Byrne et al. 2003; NAS Guidelines Committee 2005, 41), although a growing body of data now suggests that much of the desired information concerning early developmental potential could be obtained without actually cloning embryos at all (Ivanova et al. 2006; Silva et al. 2006; Takahashi and Yamanaka 2006; Cyranoski 2007). Furthermore, if the ultimate goal of cross-species nuclear transfer is simply basic research to advance understanding of the cloning process or to improve its efficiency, it is not clear what advantages this offers over more conventional approaches using donor nuclei from the same species as that from which eggs are obtained (Blelloch et al. 2006; Kishigami et al. 2006). However, this has not deterred mavericks elsewhere from trying to use cows' eggs for another ultimate goal of human reproductive cloning (Illmensee, Levanduski, and Zavos 2006; Zavos and Illmensee 2006).

Alternatively, it is possible that eggs from our closer relatives might be used to clone human or humanlike embryos where eggs from more distantly related mammals (such as cows or rabbits) would not suffice and sufficient numbers of human eggs are unavailable. For example, there is far greater compatibility between human nuclei and chimpanzee mitochondrial function (Barrientos et al. 2000), and the genomes of these species are known to be remarkably similar (Chimpanzee Consortium 2005). Furthermore, nuclear transfer between closely related mammalian species has been shown to yield at least some viable offspring (Loi et al. 2001; Gómez et al. 2004; Kim et al. 2007) and other reports of pregnancies (White et al. 1999; Lanza et al. 2000; Sansinena et al. 2005; Yin et al. 2006), indicating that successful reprogramming of gene expression may sometimes be possible using such an approach. Nevertheless, additional unforeseen complications may still be conceivable in view of the altered developmental reprogramming of donor nuclei following cross-species nuclear transfer in fish (Sun et al. 2005). After all, if nuclear transfer between a common carp and a goldfish reportedly results in fish that more closely resemble rare hybrids between these species than either the nuclear parent or egg donor (Sun et al. 2005), and if many observed differences between humans and chimpanzees are essentially thought to reflect differential regulation of gene expression (Cáceres et al. 2003; Gilad et al. 2006; Prabhakar et al. 2006), then what sort of entity might result if human nuclei were reprogrammed by the eggs of a chimpanzee?

Professor Lee Silver describes in a recent book how he was approached by a young student who was keen to do an unusual experiment for her undergraduate thesis: fertilize one of her eggs with chimpanzee sperm and follow the development of the embryo inside her uterus. When asked what she would do with the baby after it was born, she responded, "I guess I was thinking that I would abort it right before it was born, because my senior thesis would be done, and I'd want to finish the experiment and graduate" (Silver 2006, 87). Silver relates how he was appalled at the time but could not figure out why, and that most pro-choice friends and colleagues had a similar reaction when he told the story, rationalizing their consternation by pointing to the cavalier manner in which the young woman was willing to treat her own body as well as other forms of life.

Nevertheless, it seems that the Soviet Government and the Academy of Sciences sent an expedition to Africa in February 1926 with the main goal of artificially inseminating chimpanzee females with human sperm so as to obtain a viable hybrid of the two species (Rossiianov 2002). The effort was directed by Professor Il'ya Ivanovich Ivanov, who inseminated three chimpanzee females with human sperm during the first half of 1927 but failed to obtain a hybrid. He apparently also wanted to inseminate native women with chimpanzee sperm at a hospital in the Congo without the women's knowledge and consent, although it is doubtful that these experiments

actually took place. Ivanov subsequently attempted to arrange further experiments on the artificial insemination of women volunteers with the sperm of an orang-utan. His efforts stopped when he was arrested by the Soviet secret police in December 1930 (Rossiianov 2002).

These accounts of Silver's student and Ivanov's work show that there has been at least some interest in generating chimp-human hybrids and that an apparent lack of respect for the experimental subjects is a common theme. If previous attempts to create such hybrids are already known (albeit rare and seemingly unsuccessful), could the eggs of other primates be used in future human cloning efforts?

Although cloning by nuclear transfer has been attempted repeatedly in nonhuman primates (Meng et al. 1997; Mitalipov et al. 2002; Simerly et al. 2004; Yang et al. 2007), I should stress that I am not aware of any current proposals to use chimpanzee or other primate eggs in cross-species embryo experiments. However, this in itself does not rule out the possible use of eggs from such species in future human nuclear transfer attempts. One can imagine how there could be demand for more faithful reprogramming than that provided by eggs from other mammals, especially if patient lobby groups and the wider public are led to believe that future therapies depend on such work. Nevertheless, if the use of numerous eggs from women for cloning research is presently considered unjustifiable because of the risks involved and the lack of personal or guaranteed benefit (Cobbe 2006; Minger 2006), it is questionable how the use of eggs from nonconsenting members of any sentient, highly intelligent, and endangered nonhuman ape species could be considered any more justifiable.

In conclusion, the currently available evidence does not provide sufficient reason to suspect that the transfer of human nuclei into eggs from other species is likely to yield viable offspring and thus raise ethical concerns associated with their treatment (assuming that eggs from closely related primates are not used). However, the underlying incompatibilities between more divergent mammals may cast doubt on why experiments with eggs from less closely related species had been touted as offering patients their "only hope of a cure" (Rose 2007).

Animals with Human Brains?

More challenging issues may be raised through the creation of some chimeric animals in which distinct populations of cells are derived from human embryos and those of other species. The use of embryonic and fetal chimeras between quails and chickens was used to study neural development as far back as 1969 because it was possible to clearly distinguish the cells of each species (Le Douarin 1969), subsequently leading to a series of dramatic experiments in which small sections of brain from developing quails were transplanted into the developing brains of embryonic chickens (Balaban, Teillet, and Le Douarin 1988; Balaban 1997). The resulting

chickens exhibited vocal calls and behavioral head movements unique to quails, proving that the transplanted parts of the brain contained the neural circuitry for the corresponding quail behaviors (Balaban et al. 1988; Balaban 1997). Meanwhile, attempts to combine cells from embryos of clearly different mammals resulted in 1984 in the creation of the first viable chimera containing a mixture of goat and sheep cells, popularly known as the "geep" (Fehilly, Willadsen, and Tucker 1984). Because complex behaviors could clearly be transferred across species in chimeric birds and it was also possible to create some viable cross-species chimeric mammals, it became apparent that the creation of some chimeras might raise serious ethical questions if the majority of the brain should consist of human tissue. For example, would any resulting creature exhibit characteristics that would be considered ethically unacceptable if found in an experimental animal? For those who might otherwise accept research with nonhuman species in preference to analogous experimentation on humans, how should scientists treat a chimeric animal with conceivably similar potential for higher cognitive capacities?

In light of such questions, the National Academy of Sciences in the U.S.A. recommended that research in which human embryonic stem cells are introduced into nonhuman primate embryos should not be permitted for the time being (NAS Guidelines Committee 2005, 40–41). Similarly, in a "Policy Forum" article in the journal *Science*, Ruth Faden and colleagues concluded that it would be unacceptable to graft human neural cells into closely related species at an early developmental stage if the human cells potentially constituted a large proportion of the host animal's brain (Greene et al. 2005). Nevertheless, the guidelines formulated by such groups are largely voluntary in nature (rather than legally binding) and do not preclude the production of chimeras involving human cells and embryos from either mice or larger nonprimates, so long as such work is subject to careful review. Indeed, a group of researchers at the Rockefeller University recently showed that human embryonic stem cells that were engrafted into mouse blastocysts could proliferate and differentiate within the embryos when cultured in vitro (James et al. 2006). However, after implantation in the uterus of foster mice, the vast majority of these mouse/human chimeric embryos subsequently failed to retain derivatives of the slower-dividing human cells or displayed developmental abnormalities. Despite such incompatibilities between the developmental programs of more divergent species, one of the implanted embryos appeared morphologically normal and also contained several small patches of human-derived cells (James et al. 2006). This raised the possibility that more substantial engraftment of human cells in chimeric embryos surviving to later developmental stages could provide valuable animal models for human development or disease. After all, others had shown how injection of human embryonic stem cells into the ventricles of developing embryonic

or fetal mouse brains could generate functional human neurons that successfully integrated in the forebrains of mature animals (Muotri et al. 2005), while human embryonic stem cells were reported to rapidly produce neurons even in early chicken embryos following transplantation next to partially differentiated tissue (Goldstein et al. 2002). The potential outcomes of transplanting substantial numbers of human embryonic stem cells into the developing embryos of larger mammals are far less certain at present. It also remains to be seen whether injection of human embryonic stem cells into mutant embryos might result in greater contributions to organismal development, as with tetraploid complementation in mice (Rossant and Spence 1998).

Meanwhile, an informal ethics working group at Stanford University had already endorsed a separate proposal to create mice in which the neurons of their brains would be almost completely human in origin (Scott 2006; Greely et al. 2007). In this case, the proposed experiments differed from recommendations by the National Academy of Sciences pertaining to chimeric embryos, as the intention was to transplant human neural progenitor cells into the brains of fetal mice. By using a mutant mouse strain in which most or all of the developing neurons die (otherwise leading to the prenatal death of affected mice) it was anticipated that neurons derived from the transplanted human cells might colonize the brains of such mice just before their own neurons disappeared and thereby enable survival to term. Because the proposed experiments involved transplanting relatively differentiated cells from disaggregated tissue into a preexisting brain structure rather than transplanting intact and developing tissue, as in the aforementioned quail-chicken chimeras, the Stanford group was satisfied that the significantly different size and structure of the mouse brain would prevent the human cells from contributing traits that might reflect human consciousness. Therefore, it was concluded that the ethical questions raised by conferral of humanlike mental characteristics on nonhuman animals would not obviously apply to the proposed experiments (Greely et al. 2007). Nevertheless, a lack of certainty surrounding the outcome of such experiments prompted recommendations that the work should proceed cautiously and remain subject to further review at different stages. If the human cells looked as if they were organizing themselves into a mouse brain architecture, the resulting animals could be used for research involving increasing proportions of human neurons or later developmental stages. But, just in case, the working group recommended closely monitoring the developmental behavior of such chimeric mice and immediately terminating the experiment if any displayed unexpected or humanlike traits.

Similarly, Robert Streiffer (2005) has recommended an early-termination policy for human-nonhuman chimeras, prior to the onset of cognitive capacities, because of uncertainty surrounding which transplants of human stem cells into embryonic or fetal animals may result in a creature

with the moral status of a normal adult human. However, such precautions could inadvertently expose a curious discrepancy if killing is considered more justifiable when increasingly human qualities are observed rather than according increasing respect or rights with increasing signs of humanity. As Jason Scott Robert recently pointed out (2006), there can be an important tension between moral and biological humanization when the most scientifically defensible studies (such as those that involve transplanting human cells into closely related nonhuman primates) are also the most ethically controversial. On the other hand, studies that are more questionable scientifically, that involve either negligible numbers of human neurons or combinations of human cells with those of more distantly related animals, are also those that may be less likely to pose significant ethical concerns (notwithstanding objections to vivisection in general).

Species Boundaries and Scriptural Views of Humanity

How might Christians view such experiments in the light of biblical teaching? Some may appeal to passages such as Leviticus 19:19 for guidance, where interbreeding of different kinds of animals is explicitly forbidden by Mosaic law. Note, however, that the same verse prohibits planting one's field with two kinds of seed and wearing clothes made of two kinds of material. So, if one already wears mixes of cotton, wool, nylon, and polyester, or if one has a mixed herbaceous border in the garden, it would obviously be inconsistent to simply say No to the creation of entities that contain genetic material from different species on the basis of this passage alone. One can, however, view such commandments as being reminders to the children of Israel to be pure, holy, and set apart by God in all aspects of life, as implied by Leviticus 19:1. Others may point to passages such as Leviticus 18:23, in which sexual relations with other animals are forbidden, in order to argue against the creation of any human/nonhuman hybrids. After all, prohibition of other sexual practices seems to be reinforced in the New Testament (see Matthew 5:27–28; Mark 10:19; 1 Corinthians 6:9–18), and therefore such rules are not necessarily restricted to the former nation of Israel. However, it is debatable how relevant such passages would be to the creation of mixed-species chimeric embryos in which no obviously prohibited sexual act is involved.

Instead, it would seem that most objections to the creation of human-nonhuman embryonic and fetal mixtures arise from fears that such entities will undermine the unique status of humans and universal human rights. In the secular world, this often is encapsulated by an ill-defined concept of "human dignity" (Karpowicz et al. 2004; Robert 2006), which may incorporate respect for autonomy of persons as rational and free agents but appears too multifaceted to permit simple identification of all requisite criteria (Karpowicz, Cohen, and van der Kooy 2005). On the other hand,

Christians may base the unique status of humanity on biblical references to the creation of "man," male and female, in the image of God, or *imago Dei* (Wyatt 1998, 51–56; McGrath 2001, 441). Therefore, if Christians are to make helpful contributions to discussions about the creation of human-nonhuman chimeras or hybrids, it is imperative that they try to better understand what it actually means to be created in the "image" (*tselem,* צלם) or "likeness" (*d ᵉmut,* דמות) of God. Unfortunately, as John Calvin noted ([1554] 1993, 93), interpreters have not agreed about what is implied by these words, although understanding such references nowadays obviously is of theological relevance to perspectives on human evolution (Ruse 2000, 74) as well as in trying to seek a definition of human dignity that is both reasonably coherent and not unfairly discriminatory.

Although various Christians throughout history have equated the image of God with human intellectual capacities for reason, conscience, or spirituality,[4] it may not be immediately clear what distinguishes all members of our species as special on this basis alone. Such a distinction becomes especially problematic in the absence of a radical discontinuity between the mental attributes of humans and those of related species or when observable differences appear to be primarily quantitative and graded in nature (Southgate and Negus 1999, 168–69; Case-Winters 2004). From a biblical perspective, it is nevertheless apparent that human life is somehow considered especially sacred (Genesis 9:5–6, Matthew 6:26, 12:11–12), while comments by the apostle Paul seem to associate God's likeness with aspects of the mind (Ephesians 4:23–24) or growth in knowledge (Colossians 3:10). Thus, recognizing the remarkable tool use, cunning, and linguistic abilities in other living apes (along with evidence of intelligence in extinct species of advanced hominids), subsequent attempts have been made to identify the image of God in terms of the first "true" human appearing as "a responsible moral agent, as a spirit-possessing person" (Archer 1982, 64–65). This view is based on a particular interpretation of Genesis 2:7, which understands the creation of human beings as distinct from the rest of creation in the bestowal of God's "breath" or "spirit" so that only such bodies are supposedly animated by "a true human soul" (p. 65).

Yet it is doubtful that the creation of humans in the image of God should therefore imply that humans differ qualitatively from all other living animals in having a divinely imparted "spirit,"[5] especially in light of passages such as Psalm 104:24–30 and the rhetoric of Ecclesiastes 3:18–21 (cf. Ecclesiastes 12:7). Indeed, all living animals, whether human or nonhuman, are described in Genesis 7:22 as having the "breath of the spirit of life" or *nishmat-ruach chayyim* (נשמת-רוח חיים). Similarly, the Hebrew term *nephesh chayyah* (נפש חיה) used in reference to the creation of the human as a "living soul" in Genesis 2:7 is exactly the same term used when referring to other animals and their creation (Genesis 1:21, 1:24, 2:19). By the same token, there is seemingly little in the Bible to suggest that the

imago Dei is exclusively predicated on the inherent rational faculties of human beings. Although comments by Elihu in the book of Job suggest how God endowed humanity with superior understanding (Job 32:8, 35:11), it is made clear elsewhere that the rationality of humans is completely dwarfed by the supreme knowledge of God (Job 38–40:5, Isaiah 55:8–9, John 16:30), yet the wisdom of supposedly lowlier species is also praised (Numbers 22:22–33, Proverbs 30:24–28). Therefore, although understanding and wisdom are undoubtedly valued, it would seem that a simple consideration of human mental attributes in isolation is insufficient to encapsulate God's image.

Conversely, it would seem that the creation of humanity in the image of God does not mean that God must be like humankind physically, especially since we are informed that God is spirit (John 4:24, 2 Corinthians 3:18) and is usually invisible (John 1:18, 1 Timothy 1:17, 6:16, 1 John 4:12) or does not necessarily have any physical form (Deuteronomy 4:15). The notion that the *imago Dei* should necessarily represent physical properties seems all the more questionable when we are informed that God is not a man (Numbers 23:19, 1 Samuel 15:29, Isaiah 31:3, Hosea 11:9). To suggest otherwise runs the risk of trying to create an overly anthropomorphic vision of God in one's own image rather than providing greater understanding of human nature in relation to God. Indeed, it has been argued that biblical references to the creation of humanity in God's likeness tend to contrast with ancient Mesopotamian traditions in which humanity was supposedly created from "divine blood" (Miller 1972). Nevertheless, it also is made apparent that God was willing to reveal himself to the faithful in human form prior to Christ's incarnation. For example, the early text of Genesis 18 describes how God appeared as a man when visiting the tent of Abraham and Sarah, accompanied by two angelic traveling companions. Similarly, God appeared to Jacob in human form as described in Genesis 32:24–30. Anthropomorphic visions of God are recorded by several Old Testament prophets (Isaiah 6:1–5, Ezekiel 1:26–28, Daniel 7:9), though their descriptions suggest one who is ineffably glorified rather than simply human in form. Although relatively few accounts of God's appearance to humans give an indication of bodily form, it does seem that a human form rather than that of other species is indicated in all such instances (Dearman 2002, 34). This may not be surprising if the intended audience in question was exclusively human. Therefore, it is not so much that the God of the Old Testament has an essentially human form as that God can voluntarily assume such a form, so there is little to suggest that biological material of human origin is intrinsically divine.

Going back to the point where humanity's creation is first mentioned in the Bible (Genesis 1:26–28), it seems clear that the image of God is somehow connected with the authority of humans over the rest of creation and the role of stewardship. The two concepts of God's image and dominion

are clearly linked in Genesis 1:26, and the connection is repeated in the first commandments to humankind in 1:28, while humanity's role in caring for creation is subsequently clarified in 2:15. The unique position of humanity as rulers over the rest of creation yet subordinate to God is also reflected clearly in Psalm 8:4–8. Similarly, when God became incarnate as "the Son of Man" in the person of Jesus Christ, one of the most striking hallmarks of his deity that initially impressed onlookers was his authority (Mark 1:27, Luke 4:36, 5:24) and especially his authority over creation (Mark 4:41, Luke 8:25). Indeed, such authority as a characteristic of "the Son of Man" appears to be a specific fulfillment of Old Testament prophecies (Isaiah 9:6–7, Daniel 7:13–14). The image of God is also clearly connected with authority in Paul's discussion of culturally appropriate head attire for public worship (1 Corinthians 11:7–11).

Such a functional interpretation of the *imago Dei* would be consistent with inferences drawn from Assyrian and Aramaic inscriptions on a ninth-century B.C. statue discovered in 1979 at Tell Fekheriyeh (Millard and Bordreuil 1982). According to the bilingual inscription, King Hadad-yis'î placed this statue of himself in a city to remind his subjects of his rule even when he was physically absent, and the statue is referred to as both the "image" and "likeness" of the king. Consequently, if the use of an image or likeness represents the exercise of authority by proxy in such cultures, it would seem reasonable for the *imago Dei* to be similarly connected with a stewardship role.

Such authority over creation was noted by John Chrysostom as a key feature of the *imago Dei* (Chrysostom [c. 390–98] 1994, 372) and is also reflected in Philip Hefner's description of human beings as "created co-creators," in which humans may fulfil God's purpose by acting as free agents to create a wholesome future for the nature of our origins (Hefner 1993, 264). Similarly, in his 1981 encyclical *Laborem Exercens* Pope John Paul II described how "man, created in the image of God, shares by his work in the activity of the Creator" (paragraph 25). Importantly, as Andrew Linzey has stressed (1994, 54–57, 71; 2004, 81), Christian views of human dominion over other creatures should emphasize responsibility and follow the example set by Christ of lordship manifest in service (Mark 10:42–45, Philippians 2:5–8). Some may view the role of a co-creator as distinct from that of a steward (Case-Winters 2004), but it has been pointed out that responsibility to God entails that "the good steward will be called to creativity and the responsible co-creator will be called to preserve existing goods" (Verhey 2003, 161–62), just as creativity in stewardship is apparently valued in two of Jesus' parables (Matthew 25:14–30, Luke 19:12–24). Even from a purely secular perspective, the remarkable ability of humans to manipulate nature is hard to dispute, although the present environmental and conservation crises point toward selfish abuse of authority in a manner inconsistent with good stewardship.

Nevertheless, from a Christian perspective it is only in Christ that the image of God is truly apparent (Athanasius [c. 319] 1996, 41; Calvin [1536] 1989, 164–65), even though fallen humanity may imperfectly reflect God's image and is described as increasingly reflecting it through transformation of one's mind by God's Spirit (2 Corinthians 3:18, Ephesians 4:23–24, Colossians 3:10). Whereas humanity is generally referred to as being created *in* the image of God (Genesis 1:26–28), Christ is described as one who actually *is* the image of God (John 12:45, 14:9, 2 Corinthians 4:4, Colossians 1:15, Hebrews 1:3). Furthermore, if true righteousness is required to display God's likeness, as implied by Ephesians 4:24, it would appear from various passages that these qualities are displayed in Christ alone (Ecclesiastes 7:20, Luke 18:19, Hebrews 4:15, 1 Peter 2:22). Consequently, the relationship humans hold with God appears essential to reflection of God's image; it is only through being engrafted in Christ that humanity and any associated human authority or power truly reflect God's image and likeness (John 15:4–5, Romans 8:29, Hebrews 2:8–11). As Karl Barth has described, the *imago Dei* may therefore be comprehended in terms of humanity sharing in the divine likeness of the man Jesus and as being created in the image of God who "exists in relationship and fellowship" (Barth 1960, 323–24). Just as the Creator is recognized by Christians as a relational triune God of love,[6] so humanity created in God's image apparently was intended for companionship whereby conjugal union (Genesis 2:18–24, Ephesians 5:31–32) or communal unity in love (John 17:23, 1 John 4:12) would echo the relationship with God. Moreover, faith and prayer are portrayed as essential in order for Christ's followers to demonstrate at least some of the miraculous authority associated with Christ himself (Matthew 17:19–20, Mark 9:28–29). So, although the unique features of the *imago Dei* may be primarily related to the responsibilities of dominion in a stewardship role, it also seems that the fulfillment of God's image is ultimately realized only through Christ's example and hence also in relationship with God (Wyatt 1998, 53–55).

Notably, the status of humans created in God's image does not seem to be limited by outward evidence of defined characteristics in particular individuals. Instead, various biblical passages suggest that all humans are equally valued from the Creator's perspective, regardless of apparent differences (Proverbs 22:2, Acts 10:34–35, Galatians 3:28, Colossians 3:10–11) and should be treated accordingly (Job 31:13–15, Proverbs 14:31, Ephesians 6:9, James 3:9–10). Similarly, the emphasis that both male and female were created in the image of God (Genesis 1:27, 5:1–2) indicates how it is our species as a whole that should reflect God's image, and we read that all nations thus descended were likewise intended to seek God (Acts 17:26–27). Such egalitarian perspectives could reflect how the community of humanity in general, rather than isolated human individuals,

might be supposed to reflect something of God's nature. Indeed, the exercise of authority over creation was originally expressed in the plural (Genesis 1:26, 28), while redemption and restoration similarly seem to depend ultimately on the saving relationship between Christ and humanity as a whole (Romans 5:19, 1 Corinthians 15:22). As Noreen Herzfeld has argued in her discussion of parallels between views of God's image in humanity and the Turing test for artificial intelligence (2002), perceived cognitive capacities may also be better appreciated in a relational context. Interestingly, Barth commented on how the image and likeness of God "is revealed in God's dealings with Israel and therefore in the history of Israel," yet he viewed Christ as "the fulfilment of Israel's own existence" (1958, 200–203). Thus, the creation of humanity as the species chosen by God to be stewards of creation arguably may be similar to the sense in which the nation of Israel is portrayed as having been chosen by God to serve as a nation of priests and to be the means of blessing the world (Genesis 12:2–3, 28:14, Exodus 19:5–6, Isaiah 41:8–9, John 4:22), which Christians may see as ultimately being fulfilled in the saving work of Christ (Torrance 1999, 116–19).

The *imago Dei* may therefore be seen as the potential for authority associated with the human species as a community of stewards and co-creators in relation to God, although it is Christ alone who is described as truly bearing God's image as the Creator incarnate (and in relation to whom humanity may ultimately reflect God's image). This authority over creation may include some license for experimentation, since the pursuit of knowledge and wisdom is frequently praised in the book of Proverbs (10:14, 15:2, 15:14, 18:15, 23:12, 24:3–5), and Paul himself may even be said to have indirectly provided us with one of the best summaries of the scientific method (1 Thessalonians 5:21). Furthermore, Paul repeatedly emphasizes the freedom of believers (1 Corinthians 6:12, 10:23, Galatians 5:1, 5:13), which may include, among other things, considerable freedom in research. However, a role as stewards of creation does not provide license to exploit other creatures in any way that is cruel (Proverbs 12:10), especially since the special status of humanity is included among the individual care shown by God for all other creatures (Psalm 104:21–28, Matthew 6:26, John 10:11–15), and all creation is described as belonging to God (Psalm 24:1).

So, does the creation of humanity in the image of God mean that clear boundaries must be maintained between species in order to preserve the special status of humans, or could the judicious creation of human-nonhuman chimeras and hybrids be an example of humanity exercising God-given authority over creation? Indeed, if we are "created co-creators" (Hefner 1993, 264), do we have an obligation to "play God" in at least some respects, as Ted Peters has argued (2003, 213), or would this be dangerously presumptuous given our comparative lack of foresight and wisdom?

Consequences for Cross-Species Clones and Chimeras

The extent to which we are permitted to exert control over or "interfere" with nature is not always clear, largely because of limitations in isolated human understanding (Job 38:1–40:5, Proverbs 3:5) and possibly our failure to recognize how human creative activity differs from that of God who created everything out of nothing (Nehemiah 9:6, Hebrews 11:3) and sustains all creation (Psalm 104:10–30, Colossians 1:17, Hebrews 1:3). However, in considering whether or why some unnatural alterations to the makeup of a creature may intrinsically be wrong, some philosophers make use of the Aristotelian concept of *telos* (τελος), meaning "end" or "goal." Although *telos* has various interpretations, it often is understood as referring to intrinsic value or integrity and associated interests. David de Pomerai describes this intrinsic nature of an organism "as the sum of its realised and potential genetic capabilities, both what it is and what it could become" (de Pomerai 2002, 93). Similarly, *telos* has been described by Bernard Rollin as the "pigness" of the pig—"the way of living exhibited by that animal, and whose fulfilment or thwarting matter to the animal. The fulfilment of telos matters in a positive way and leads to well-being or happiness; the thwarting matters in a negative way and leads to suffering" (Rollin 1998, 162).

Importantly, it is not the *telos* itself but the interests that flow from it that authors such as Rollin consider to be sacred, as he himself casts doubt on the idea that species are immutable in light of modern biology (Rollin 1995, 36–38). Consequently, engineering animals with a slightly different *telos* may not be objectionable so long as the interests of that particular creature's *telos* are still respected. For some Christians, however, interfering with the *telos* of humans or other animals may be viewed as wrong not simply from the perspective of individual welfare but rather if one thereby presumes to improve on what God created, which God considered very good (Genesis 1:31). Yet, as the rest of creation has been suffering alongside fallen humanity (Romans 8:20–22), it is not clear that what is natural is necessarily always for the best. Others may point to the description of how God created all living things to reproduce "after their kind" or "according to their kinds" (Genesis 1:12, 21, 24–25), such that the integrity of species' *telos* should be preserved. Such a view is not restricted to "special creationists," as it also may be held by theistic evolutionists who recognize God's activity as continuing (John 5:17, Colossians 1:17, Hebrews 1:3) rather than completely finished in creation and would view the reproduction of species "according to their kinds" not in absolute terms but rather as a statement about the most commonly observed patterns of heredity. Even those with no particular belief in God but deep respect for nature may worry about the consequences of unnaturally crossing what seem to be long-maintained boundaries between species.

Nevertheless, the broader definition of species concepts can be far from simple, as different criteria have been used for different classes of organism (Mishler and Donoghue 1982; Hey 2006; Marris 2007), so some caution needs to be exercised in the extent to which definitions of species boundaries are applied to questions of species integrity or *telos*. For example, the most widely accepted definition of *species* (at least for extant sexually reproducing organisms) is probably Ernst Mayr's biological species concept, according to which "species are groups of interbreeding natural populations that are reproductively isolated from other such groups" (Mayr 1996, 264). This definition suggests that most human-nonhuman entities would not be members of the human species so long as such creatures were otherwise fertile yet unable to successfully reproduce with humans on reaching sexual maturity and thereby produce fertile offspring. However, would anyone be prepared to permit various chimeric or hybrid entities to engage in sexual activity with humans, thereby risking bestiality, simply for the sake of determining species membership on this basis? Although complementary use of an evolutionary species concept (Wiley 1978) may rule out the classification of some chimeras as human because of their overall lack of common ancestry, especially if only a relatively small fraction of cells is entirely human, this begs the question of how many cells must be of human origin, and in which bodily organs, in order for a creature's *telos* to be essentially human. As Streiffer (2005) has noted, both anthropocentric and cognitive-capacity views of moral status raise questions about what proportion of human cells or which mental capacities in a chimera are morally significant, so perhaps it should not be surprising that a theological view of humanity may still encounter the same questions if significant moral status is associated with both particular functional attributes and a particular species membership but not necessarily limited by one or the other.

Even when all or most cells should be genetically identical following transfer of human nuclei into the eggs of other species, the status of any resulting entity may still be open to question. Despite a frequently quoted refrain that such embryos would be more than 99 percent human in terms of DNA content (Fleming 2007; Moss 2007; Henderson 2007a, b), one should be aware that this figure deals only with relative numbers of unique protein-coding genes but assumes that each is present in the cell with an equal copy number. This figure therefore provides only a rough estimate of the genetic diversity contributed by different species rather than the overall fraction of total DNA or coding sequences from different species in such an embryo. However, when the number of mitochondria typically present in an unfertilized egg is also taken into account,[7] conservative estimates of the nuclear fraction of total DNA in the resulting product of nuclear transfer may drop to under 70 percent and estimates of the nuclear fraction of protein coding gene copies to less than 2 percent. To contend that the greater diversity of coding sequences in a cell's nucleus is necessary

and sufficient for determining species identity on the basis of overall "information content" would imply that human blood is predominantly nonhuman because of the absence of any nucleus in mature red blood cells. As such a conclusion is clearly nonsensical, it is doubtful that the mere presence of a human nucleus should be the sole determinant of species identity. How might an entity containing a human nucleus but primarily nonhuman mitochondria be classified as human using conventional species concepts (Wiley 1978; Mayr 1996), especially if it is presumed to be intrinsically nonviable due to incompatibilities between divergent species? Moreover, since even a sloughed human skin cell is recognized as human in terms of both its specific origin and corresponding genetic identity rather than its *telos* (which is non-organismal), what status should the mere presence of a human nucleus confer in the absence of any intrinsic potential for further significant and organized development?

If the entity produced by cross-species nuclear transfer is neither a human nor a potential person (in contrast to viable human embryos generated with human eggs), many of the currently voiced ethical concerns as well as some purportedly specific research benefits may appear somewhat overstated. Indeed, if one primarily objects to cross-species nuclear transfer because of concerns that it seemingly violates the *telos* of a nonhuman egg in combination with a human somatic cell nucleus, might this be twisted to suggest that cloning with human eggs would be more justifiable in teleological terms, despite the potential for abuse of recognizably human life (Cobbe 2006; Wilmut and Highfield 2006, 220–31)? Although some may object to cloning by nuclear transfer primarily as an "unnatural perversion" or remote distortion of human reproduction, objecting to cross-species nuclear transfer on the same basis alone may imply that human reproductive cloning is somehow accepted as more natural. Alternatively, objections to cross-species nuclear transfer may be construed as disgust at the supposedly remote distortion of what is already considered by some to be a kind of remote distortion in itself, absurd though this seems. As others have pointed out, teleological speculation about whether or not things are "natural" may also be problematic, as this could easily lead to rejection of all medical technology if consistently applied in the strictest possible sense (Karpowicz et al. 2004). Given that Jesus himself apparently recognized the value of medical intervention (Matthew 9:12, Mark 2:17, Luke 5:31), any absolutist rejection of anything deemed "unnatural" would therefore be questionable from a Christian perspective. Natural-law theorists may argue that the proper end of human beings differs radically from that of other species (Kass 1985, 272), but does this mean that modifying *telos* is necessarily immoral? Or, as Thomas Berg asks (2006, 107), could the creation of some human-nonhuman chimeras be "at the service of the human person, of his true and integral good, and in conformity with the plan and the will of God?"

It is important to note that the fact that something is permissible does not necessarily mean that it is always beneficial or constructive, while a primary aim of Christians should always be to seek the good of others (1 Corinthians 10:23–24, Philippians 2:4–7). Leaving aside the unique position of humans as stewards of creation and any potential health or welfare risks concerning chimeric individuals, one could argue that there are no societal or ethical concerns with the creation of mature human-nonhuman chimeras if all species are freely accorded full and equal consideration with corresponding rights (Singer 1989). In theory, this could entail elevating the status of other species rather than diminishing that of our own and thereby threatening human rights. However, a host of practical constraints together with vested interests may conspire against the broader realization of such goals (Frey 2003, 161–68), and it is certainly clear that we do not presently live in a society in which all species hold equal status (Singer 1989). In particular, animal research oversight committees tend to differ from those overseeing research involving human subjects in considering that valid research objectives may justify sacrificing even the fundamental interests of the research subject, while those regulating research involving human embryos are primarily concerned with informed consent only on the part of adults providing gametes or embryos (Streiffer 2005). Under any such regulatory system, it is therefore difficult to see how adequate protections could be guaranteed for any chimeric research subject with enhanced moral status without also undermining research objectives.

Some have suggested that ethical difficulties related to cognitive capacity may be avoided by destroying human-nonhuman chimeric embryos at an early preimplantation stage or prior to formation of a rudimentary nervous system (Select Committee 2005; Streiffer 2005), but it is unclear what scientific benefit there would be in creating chimeras in which observations of the fate of transplanted human cells in a developing organism were extremely limited. Indeed, in a recent paper describing early development of implanted human-mouse chimeric embryos (James et al. 2006), the authors pointed to the need for more significant contributions of human cells in chimeric embryos, stressed the need to examine later developmental time points, and concluded by affirming that live chimeric animal models would be a much more valuable research tool.

Given such constraints, we have no way of evaluating a priori the level of humanity of some human-nonhuman chimeric entities with potentially enhanced mental attributes, and hence the extent to which they arguably should be accorded human rights, unless they are permitted to develop to term and mature. We could therefore have various injustices, as we may either discriminate against certain chimeras that potentially should be accorded human rights as they develop by killing them prematurely out of personal convenience and prejudice, or else allow them to develop to term and mature only to subsequently decide that they should never have been

created in the first place due to developmental defects or societal inequalities and prejudice. Either way, it is hard to see how this can be viewed as righteously caring for the needs of an animal in the manner suggested by Proverbs 12:10 and how it might also be beneficial and constructive in the manner suggested by 1 Corinthians 10:23.

As Derek Parfit has commented from a purely secular perspective (1982; 1986, 487–90), if it cannot be shown that it is intrinsically bad for a particular being to ever live, it may be said to benefit such a being by bringing about or preserving its existence once it has been created. However, if the moral status of a particular interspecies chimera cannot presently be determined without first creating such an entity, this in itself may be sufficient argument against creating such an entity on the basis of a precautionary principle, especially when the purported benefits do not seem to be adequately supported by available evidence on the basis of a proportionality principle. Even if it should become possible to accord similar moral status to all sentient beings regardless of species membership, such that physically healthy human-nonhuman chimeras were permitted to survive to term and otherwise treated with due respect, they still could suffer as a result of the denial of other freedoms and possible identity crises resulting from their unique natures. Such potential difficulties arguably are similar to those described in the Bible, where no suitable companion was available for the man among all the other creatures placed in Eden until he was introduced to a woman, who completely shared his fleshly origin and nature (Genesis 2:18–24).

In addition to issues raised by the conferral of human mental traits, there is the possibility of pluripotent human stem cells contributing to the germline of some chimeras, particularly if such cells are incorporated sufficiently early in development. This raises the hypothetical risk of a human fetus being trapped in the uterus of another species if the resulting creatures are allowed to interbreed, prompting recommendations that this should be prohibited (NAS Guidelines Committee 2005, 39–40; Greely et al. 2007). However, if a chimera with apparently human mental faculties should be either created in isolation or unable to reproduce with similar creatures because of enforced prohibitions against breeding, this would amount to denial of what many would see as a fundamental right. Whereas humanity is described as having been created in God's image as male and female so as to reproduce and presumably provide mutual support (Genesis 1:27–28, 2:20–24), denial from the outset of such relational opportunities or other freedoms to creatures that may share human mental attributes seems deeply unjust (Karpowicz, Cohen, and van der Kooy 2005).

Such denial of interests from the outset may already be apparent when it is argued that human-nonhuman embryonic mixtures would be less than fully human and therefore pose fewer ethical problems for research, despite uncertainty regarding particular developmental outcomes and recognition

that determining moral status may require speculation about the status of individuals once born (Select Committee 2005). Here we glimpse some of the gravest ethical concerns—over the conferring of potential for cognitive traits predominantly associated with humanity followed by a systematic denial of both the freedoms and sense of community otherwise associated with a species supposed to reflect something of God's nature. As Rollin comments (2007), the real ethical issues arise not so much in the mere creation of an organism as in its expected treatment, especially if it potentially could be self-aware. Although it would be naive to suggest that such concerns are necessarily limited to the interests of human-nonhuman chimeras, the creation and treatment issues may converge if one intentionally creates an organism with not only the potential for significant cognitive status but also severely compromised welfare.

Conclusion

The possible creation of various chimeric animals with the potential for what may be viewed as hitherto uniquely human faculties raises profound questions concerning rights and responsibilities, making it imperative that such issues are properly discussed in full before racing ahead to perform what others may see as poorly substantiated experiments. This does not necessarily mean that one should rule out all possible transfer of human cellular material into other species (Karpowicz et al. 2004; Berg 2006; Editorial 2007). Rather than advocating either absolute prohibition or acceptance of all conceivable human-nonhuman mixtures, each kind of proposed experiment needs to be evaluated separately in a manner that seeks to uphold both the highest standards of animal welfare and truly beneficial scientific advances. Where uncertainty surrounds the potential outcomes of experiments involving human-nonhuman chimeras, work may either be preceded by analogous experiments involving transplantation of stem cells from other species (NAS Guidelines Committee 2005, 41; Streiffer 2005), or preliminary experiments that carry less risk of significantly altering higher brain functions should be prioritized (Greely et al. 2007).

It remains to be seen how a cautious approach might satisfy the most diametrically opposed views, with some consumed by utter disgust at any thought of creating human-nonhuman mixtures but often hard pressed to convincingly articulate all of their objections in non-intuitionist terms, and others who seem not to question the supposed specific benefits of proposed research and appear heedless to genuine concerns. Anyone opposed to the creation of any human-nonhuman entity on the grounds that this somehow diminishes human rights or demeans the image of God probably ought to consider how this issue compares with the abuse of freedoms already apparent in the modern-day slavery of human trafficking, other

wilful and destructive exploitation of human life, and extant concerns about unjustified abuses of other species elsewhere. Those who would try to combat public fears by holding out high hopes of medical marvels may be wise to better account for the source of any uniquely placed confidence or else consider the harmful effects of hype in the longer term. For those wishing to make grandiose claims, it may be worth considering which would eventually pose the greater professional threat: facing delays in conducting currently controversial research or bearing personal responsibility for unduly elevated public expectations.

NOTES

1. According to the Department of Health in the United Kingdom, considerable public unease with the possible combination of human and nonhuman animal material was strongly represented among the 535 responses to their public consultation on regulation of fertility treatment and human embryology. The Government described how submissions were received over the summer and autumn of 2005 from a wide range of stakeholders, including license holders, patient's representatives, professional bodies, and individual members of the public. However, responses specifically dealing with "the creation of human-animal hybrid or chimera embryos" were later described as unrepresentative by proponents, who protested that the consultation had been hijacked by pressure groups. Remarkably, it seems that relatively few of the subsequent complainants had responded to the Government's previous consultation themselves. Actual responses to the relevant public consultation were published at *www.dh.gov.uk/en/Consultations/Responsestoconsultations/DH_4132358*.

2. Relevant examples of epigenetic dysregulation associated with nuclear transfer are described in Bourc'his et al. 2001; Daniels et al. 2001; Dean et al. 2001; Kang et al. 2001; Humpherys et al. 2002; Bortvin et al. 2003; Chung et al. 2003; Mann et al. 2003; Santos et al. 2003; Beaujean et al. 2004c; Boiani et al. 2005; Somers et al. 2006; and Yang et al. 2007.

3. Neutral transmission of bovine mitochondria originating from either the nuclear donor or enucleated recipient egg was described by both Ralf Steinborn and colleagues (2002) and Stephan Hiendleder and colleagues (2003). The final proportion of mitochondria from different sources generally reflected initially reduced levels in somatic cells relative to oocytes. Coexistence of donor and recipient mitochondria in cloned interspecies embryos is also described in Liu et al. 2004 and Li et al. 2006. However, it is reported that donor mitochondrial DNA ceased to be detectable in morulae and blastocysts generated by interspecies nuclear transfer (Chang et al. 2003). Preferential replication of mitochondria from the recipient egg is similarly described in Yang et al. 2004. By contrast, preferential replication of mitochondria corresponding to the same species as the cell's nucleus is described in Moraes, Kenyon, and Hao 1999 and Chen et al. 2002.

4. For examples see Origen [c. 248] 1994; Athanasius [c. 319] 1996, 28, 38; Augustin [c. 413–26] 1994, 241; [c. 400–416] 1994, 185–86; Aquinas [c. 1265–72] 2006, 57, 59, 67, 75; and Graham 1955, 10.

5. The term s*pirit* in the Bible is denoted by the same words as for breath or wind in both Hebrew (רוח or נשמה) and Greek (πνευμα).

6. God's creative command is described as being addressed in the plural (Genesis 1:26), and creation apparently included the activity and presence of Christ (John 1:1–14, Colossians 1:16) as well as the Spirit of God (Genesis 1:1–2). Such references may be collectively understood in terms of the loving relationship within God as Father, Son, and Spirit (Matthew 3:16–17, John 14:31, 15:26).

7. Oocytes from several different mammalian species are variously described as typically containing hundreds of thousands of mitochondria in Michaels, Hauswirth, and Laipis 1982; Steuerwald et al. 2000; Reynier et al. 2001; Barritt et al. 2002; May-Panloup et al. 2005; El Shourbagy et al. 2006; and Santos, El Shourbagy, and St. John 2006. Additional statistics used to calculate conservative estimates referred to in the text were derived from data currently available for the human genome (*www.ensembl.org/Homo_sapiens/mapview*).

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