Social and Genomic Constructions of Chimera

Arthur Saniotis
The University of Adelaide
Australia

Abstract

The use of chimera in medical science has been both controversial and highlights how life categories are reconstrued and constructed. Chimera have been popular in ancient and cross cultural mythologies and represent human/non-human boundaries. Chimera also reaffirm the concern with human and non-human animal relations which are prevalent in many indigenous cosmologies. At present, chimera in the form of "pharm" animals are being commercialised for their medical benefits. While such animals are show pieces of the new biotechnologies, there is growing concern about the future directions of chimera and their implications for human society. In this paper, I identify chimera at three sites with a view of providing an overview of chimera; their past and present constructions, and future human/animal transgenic possibilities.

Key words: Chimera, Transgenics, Mythology, Commerce, Embodiment

H.G. Well's novel *The Island of Dr. Moreau* (1896) is based on a brilliant but mad scientist who explores the "plasticity of life" via recombinant human and non-human DNA (Brem and Amjar, 2003). While the consequential chimera[1] (transgenics) are endowed with human reason their proclivity towards reverting to their previous "animal" selves remains an insurmountable dilemma for Dr. Moreau. In the 1997 movie the problem of animal reversion is controlled by a small chip which is placed in bodies of chimeras. When the chip is switched on by Dr. Moreau it causes excruciating pain, thus rendering the chimera into submission. In the final scene in the 1997 movie, one of the surviving chimeras, who is called "Sayer of the Law" intimates that the ontological distance between non-human animals and human beings cannot be bridged – each must follow its "natural" destiny. Wells novel and subsequent movies challenge societal constructions of human/animal interface. The notion of the chimera has significant currency in popular culture and the product driven world of biotech companies.

In this paper I will locate chimera at three various sites: mythological/anthropological; chimera and genetic commerce, and future chimeric embodiments. My intention is to provide some insight

into the nature of chimeric constructions and their significance in the human imagination and for current and future society.

Chimera: Mythological and Anthropological Constructions

In Greek mythology the chimera was a monster which was part lion, part snake and part goat and breathed fire. For the ancient Greeks the chimera was a creature which evoked both repulsion and awe. "Its form was symbolic of its nature: a monstrous unnatural body signified a monstrous unnatural disposition" (Karpowicz, Cohen, & Kooy 2005: 109).[2] Chimera such as the Sphinx, Minotaur, Gorgons, Centaurs, Harpies, Sirens, Mermaids and a litany of others pervade ancient Greek mythology, as well as the mythologies of other cultures. The plethora of chimera found throughout the world testifies to their imaginative power and our primal connection to the non-human world. In addition, their unnatural forms personified the capricious and ambiguous power of nature.

Chimera had multiple roles and served as mentors, teachers, villains, heroes and figments of horror. In Greek mythology Chiron the centaur was noted for his wisdom and mentored Jason and other notable Greek heroes. In ancient Iranian cosmology the god Ahura Mazda sent a cow to instruct Mithra on the manner of animal sacrifice. The popular religion of Mithraism which probably has its roots in Iran had the bull as its central symbol. The bull cult and its human/animal interface was also evident in Minoan and other Mediterranean civilisations. Hinduism is abundant with various human/animal hybrids which are considered to be divine such as the wisdom god Ganesh. In Hindu cosmology the principle god Vishnu is believed to have incarnated himself nine times. Four of these manifestations (*avatar*) were "hum-animal" hybrids: Matsya Avatar - Fish Incarnation Kurma Avatar - Tortoise Incarnation, Varah Avatar - Boar Incarnation, and Narasimha Avatar - Man-Lion Incarnation.

Arguably, the centrality of the chimera in human cultures may be understood in relation to human cultural evolution. Some five million years ago our ancestors split from the lines of our cousin simians, paving the way for human evolution, first by inhabiting the savannahs, harnessing fire, and via the transition from biological to culturally programmed behaviour, a time development which took thousands of generations. Evolution is a highly creative and opportunistic process that led to the development of various types of humans, Homo Habilis, Homo Ergaster, Homo Erectus, Homo Heidelbergensis, Homo Neanderthalis, Homo Florensis, and Homo Sapiens. Their genomes spread throughout the world and adapted to their environments. While Homo Sapiens became distinct from the rest of the animal kingdom its predilection towards cultural evolution was its outstanding hallmark, unparalleled by any other species. However, the distinctiveness of Homo sapiens should not overlook its similarity with non human animals. As Ehrlich rightly points out, our species has co-evolved with many other species which have had a marked influenced on human evolution (Ehrlich 2000: 44). Early humans understood that co-dependency with non human animals was vital to their survival. The high level of co-dependency with non human animals eventually led to an efflorescence of symbolic behaviours.

Prehistoric shamans were the first ritual specialists who had a crucial role in mediating between humans and non human animals. These shamans were the earliest forms of transgenic humans who symbolically fused human and the non human. Shamans communed with the animals and wore an array of animal parts in order to invoke the spirits of certain animals. Later on, shamans became known for their shape shifting ability, and were believed to turn themselves into animals.[3] The alleged shape shifting ability of shamans was interlaced with the mythopoeitic understandings of our early ancestors.

In his book *Personhood and Agency: The Experience of Self and Other in African Cultures* (1990), the anthropologist Michael Jackson interviews a modern day shaman who believes that he has the power to turn into an elephant (Jackson and Karp 1990). Jackson's interview unveils the mythopoietic penchant of our species for construing connections with the non-human world. Indigenous peoples often claim their origins to particular animals which has given rise to totemism. For example, the Mende tribe in Africa believe they have descended from elephants. Australian Aboriginal cultures assert to have originated from dreaming spirits which are embodied in animal and plant forms.[4] While mythological/anthropological understandings of chimera continue to inform many cultures' understandings of the human/non-human interface, genomics discourse and its increasing corporatisation is crucial in unpacking modern interpretations of chimera.

Chimera and Genetic Commerce

The biological use of the term chimera describes various kinds of "inter-species combinations at many levels, from molecules, to cells, to whole organs." A chimera is an animal which is composed of two or more genetically different cells. Recombinant DNA sequencing relates to the artificially combining of DNA from two distinct species which leads to a modification of a particular species. Through the use of biotechnology, recombitant DNA sequencing allows a gene to be expressed in novel ways which bypass natural selection processes. An example of recombinant DNA is "a gene from the winter flounder that produces an antifreeze protein" that is combined "into salmon in the hope of extending the farming range of the fish." (The State of Food and Agriculture 2003-2004). Recombinant DNA was successful "in 1974 when a simian virus was inserted into mice embryos, resulting in mice carrying this DNA" (Margawati 2003; Jaenisch and Mintz 1974).

Human to animal chimera (an area of transgenics) are presently being produced via "the addition of human cellular material such as stem cells "to a nonhuman blastocyst of embryo" Robert and Baylis 2003: 1). Examples of human to animal chimera include the transplanting of "human neural stem cells into the forebrain of a bonnet monkey in order to assess stem cell function and development" (Robert & Baylis 2003: 1).[5] In 2003 the Sheng University in China placed human skin cells into rabbit eggs in order to produce early stage embryos (Dennis 2002), while scientists at Stanford University created a mouse which contains "human stem cells in its brain" (Robert and Baylis 2003: 1; Krieger 2002). The complexity of these and many other transgenic creations are biotechnological showpieces that are being powered by

biotech corporations. For biotech critics like Jeremy Rifkin the biotech culture is currently informing our notions of "life as product" - a commodified form that is open to extensive patenting. Rifkin and Newman's failed attempt in patenting the "humanzee" (part human, part chimpanzee chimera) in 1998 was engineered to protest against the apparent abuses of transgenic technologies (Baylis and Scott 2006). While this kind of protest warrants public attention it tends to overlook the complex relationship between biotechnology and transgenic corporate culture. For Rifkin et al, biotech firms are aggressive international players that are using free trade agreements to privatise human, animal and plant genomes (King and Stabinsky). Their effective use of patenting represents a form of "privatisation of social resources" (King and Stabinsky).

Present indicators of aims and methods of transgenic technologies are relevant signposts for informing future transgenics. The present uses of animal to human transgenic combinations for human beings include:

1. The creation of transgenic animals for the harvesting of organs for xenotransplantation (Glenn 2004).
2. Replacement of cartilage, heart valves, collagen tubes and cerebrospinal shunts (Glenn 2004).
3. Skin, burns and wound healing (Glenn 2004).
4. Prospective research to manufacture transgenic milk for treatment of diseases such as cystic fibrosis, phenylketonuria (PKU) and hereditary emphysema (Margawati 2003; E.T.S.; Noor 1996; PPL Therapeutics).

Current transgenic uses are in reality part of a corporate process which includes a brand of genetic husbandry called "pharming", that aptly characterises the relationship between transgenics and commercialisation. "Pharming is the production of human pharmaceuticals in animals" for human use. Transgenic animals which include chimera and cloned animals have had their genetic composition altered to include the genes of other animal species (Breekveldt and Joost).

Transgenic animals are produced using three methods: microinjection, where a needle injects "foreign DNA (transgene) into a male pronucleus"; retroviral vectors, where a gene carrying virus is inserted into a genome; embryonic stem cell transfer, where cultured and modified embryonic stem cells are "injected into the blastocyst stage of a developing embryo" to create a chimera (Gavin et al. 1998). The first report of a transgenically created animal was a mouse in the early 1980's (Cummings 1999). In 1982 "Ralph Brinster of the University of Pennsylvania's School of Veterinary Medicine inserted human growth hormone genes into mouse embryos" (Rifkin 1998). Consequently, these mice grew twice as big than normal mice and were dubbed "super mice" (Rifkin 1998). Each generation of these mice could pass on the human growth genes (Rifkin 1998; Biotechnology Information Series 1995). In 1987, transgenic mice were able to produce "the human drug, tPA (tissue plasminogen activator to treat blood clots)" (Biotechnology Information Series 1995; The British Union for the Abolition of Vivisection 2004). Essentially, these mice and other livestock animals such as pigs, goats, sheep and cows are production sites for human proteins which form the basis for invaluable drug treatments. Some of their transgenic applications for pharmaceutical use are given in the following table:

Table 1: R&D of Medicine Production by Transgenic Animals

R&D of medicine production by transgenic animals			
Drug	*Disease/Target*	*Animal*	*Company*
alpha-lactalbumin	anti-infection	cow	PPL
alpha1 anti trypsin (AAT)	deficiency leads to emphysema	sheep	PPL
CFTR	cystic fibrosis	sheep, mouse	PPL
human protein C	Thrombosis	pig, sheep	PPL
tissue plasminogen activator (tPA)	Thrombosis	mouse, goat	PPL
human calcitonin	Osteoporosis	rabbit	PPL
factor VIII	Hemophilia	pig sheep	Pharming PPL
factor IX	hemophilia	pig, cow sheep	Pharming PPL
fibrinogen	Wound healing	cow sheep	Pharming PPL
alpha-glucosidase	Pompe disease	rabbit	Pharming
collagen I collagen II	tissue repair rheumatoid arthritis	cow cow	Pharming
lactoferrin	GI tract infection, infectious arthritis	cow	Pharming
antithrombin 3 (ATIII)	Thrombosis	goat	GTC
glutamic acid decarboxylase	type 1 diabetes	mouse, goat	GTC
human serum albumin (HSA)	maintains blood volume	mouse, cow	GTC
msp-1	Malaria	Mouse	GTC
Pro542	HIV	mouse, goat	GTC

Table found in Breekveldt, Jeroen and Joost Jongerden. (1998). "Transgenic Animals in Pharmaceutical Production." *Working Group Technology and Agrarian Development*, Wageningen Agricultural University. See: <http://www.biotech-monitor.nl/3609. htm>.

In the 1990's a number of biotech companies such as Pharming B.V., PPL Therapeutics and Genzyme Transgenics Corp, saw the commercial potential in extracting therapeutic proteins from the milk and the blood of transgenic animals (Gavin and May 2001). Currently there are numerous companies worldwide creating pharmaceutical drugs using transgenic animals (Kae 2006). Rifkin notes that commercial gain is increasingly turning domestic animal into "biofactories." The scale of biotech companies investiture in transgenic animals is evident in companies such as Genzyme Transgenics which had constructed a $10 million facility for creating drugs for Gaucher's disease (Rifkin 1998). Similarly, the 2006 GTC Biotherapeutics report indicates that there is a booming market for factor Vlla that is used for haemophiliacs that is reported to be $845 million in 2005, and with estimated future sales of $2 billion in 2012 (GTC Biotherapeutics 2006). The report also states that rhFVlla which is developed from transgenic rabbit's milk could supply the future needs of the market place (GTC Biotherapeutics 2006).

Table 2: Selected Proteins from Transgenic Animalsin the Pipeline

Product (indication)	Development stage	Animal	Company
Recombinant human antithrombin III (ATIII) (hereditary deficiency of ATIII)	Phase 2/3 (US)	Goats	GTC Biotherapeutics (Framingham, MA, USA)
Human C1 esterase inhibitor (angioedema)	In Phase 2	Rabbits	Pharming (Leiden, The Netherlands)
Lactoferrin (antibacterial/antiviral)	Phase 1 completed	Cow	Pharming
α-glucosidase (Pompe disease)	Phase 2/3, but production shifted to Chinese hamster ovary cells	Rabbits	Pharming/Genzyme (Cambridge, MA, USA)
Bile salt-stimulated lipase (pancreatic insufficiency)	Phase 2 completed	Sheep	PPL Therapeutics
α-1 antitrypsin (pulmonary disease/cystic fibrosis)	Phase 2 completed	Sheep	PPL Therapeutics/Bayer
Sources: Recombinant Capital and company websites			*LD*

Table found in *Nature Biotechnology*. Vol. 21: 839 - 842 (2003).
doi:10.1038/nbt0803-839
www.nature.com/nbt/journal/v21/n8/full/nbt0803-839.html

The use of transgenic animals is becoming increasingly popular since such animals have various advantages over cell culture and other kinds of pharmaceutical protein production (Business Communication Co. Inc). "High protein expression levels, concentrated raw material," and efficient purification make transgenic animals cost

effective (Business Communication Co. Inc).[6] Consequently, transgenically derived products may be substantially lower than cell culture products (Business Communication Co. Inc). For instance the private biotech company AviGenics states that a while a cell culture costs $100 per gram of protein, per gram of protein extracted from a transgenic animal costs between $2 and $20 (Kae 2006). This means much cheaper pharmaceutical costs for consumers. Although transgenic animals are expensive to produce, ranging from $20,000 to $300,000, each animal may produce substantial yields. For instance, one Wisconsin firm reported that one cloned calf could produce between $200 and $300 million of pharmaceutical products in its life time (Centre for Emerging Issues 1999).

A future direction of transgenic animals is in the area of increased immune resistance via introducing specific genes into animals. So far there is little information regarding the role of specific genes in immune systems of livestock animals (Wheeler et al. 2003). Manipulation of genes from the major histocompatibility complex (MHC) could produce future benefits in improved immunity in livestock animals (Wheeler et al. 2003). Although attempts in producing influenza resistance in pigs have so far been unsuccessful, it does suggest one way in which transgenic technologies may decrease disease in the future (Wheeler et al. 2003). The production of chimera via the augmentation of desirable alleles or the removal of undesirable alleles that are associated with disease susceptibility may in the future lead to resistance against diseases such as bovine pseudorabies virus, leukemia virus, foot and mouth virus, clostridium and streptococcus, and genetic diseases such as bovine leukocyte adhesion deficiency (BLAD) and deficiency of UMP synthase (DUMPS) (Wheeler et al, 2003). In the future transgenes could be designed which result in animals becoming self immunised. Such transgenes could also respond to antibiotics that would produce antigens that could "raise protective antibody titers" (Wheeler et al. 2003).

Future transgenic applications may produce visual indicators in animals during estrus. In animals such as baboons the female posterior regions turns bright red indicating increased estrogen levels (Wheeler et al. 2003). Seidel states that pigs could be produced to have red posteriors during estrus, thereby saving production time, money and improving conception rates (Seidel 1999; Wheeler et al. 2003).

Future "Chimeric" Embodiments

The noted physicist Stephen Hawking claims that there will come a time when Homo sapiens will need to change their DNA. He is probably right. His concern is that artificial intelligence will progress to such a degree in the future that it may threaten the human species. Hawking's solution is for humans to create a connection between brain and computer so that the two will interact symbiotically rather than in opposition (Greenfield 2004: 46). Hawking's call for a symbiosis between carbon and silicon organisms will be pre-empted by living DNA recombinant beings, humans with genetically modified sensory perceptions. Trans-species gene splicing will probably also work in combination with an array of neural implants which will further enhance sensory perceptions (Kurzweil 2000: 221). By the end of the 21st century there will be available designer DNA gene splicing for a variety of purposes.

Notwithstanding Robert & Baylis's opposition to creating "trans-species chimeras" on the grounds that it will somehow compromise human dignity (Johnstone and Eliot 2003).

Savulescu (2003) argues that trans-species gene splicing may proffer a new stage in human evolution. Rather than effacing our humanity, Savulescu argues that trans-species gene splicing is an expression of our humanity. According to Savulescu, it is theoretically possible to combine "pluripotent or totipotent stem cells" from various animals and introduce them into the human embryo (Savulescu 2003: 22).

What would be the justification for this kind of experimentation? Firstly, recombining human and non-human animal DNA may enhance desirable human immunological properties and increase human longevity (Savulescu 2003: 22). In this way, trans-species gene splicing could in the near future combat against a litany of age related genetic disorders such as dementia, heart disease, osteoporosis and loss of vitality. As Savulescu notes:

> *Suppose that we were to find that animals that have a significantly longer lifespan than human beings, such as turtles, contained genetic sequences that reduced the rate of telomere degradation. It might then be possible to transfer these sequences into the human genome, radically prolonging life or compressing aging. (Savulescu 2003: 22)*

Secondly, Savulescu foresees trans-species gene splicing as a method for enhancing human sensory perceptions. For instance, transferring the gene for night vision in nocturnal animals into the human genome may benefit humans to see better at night, thereby decreasing car accidents at night, and increasing the rescue capabilities of night searches (Savulescu 2003: 22). Furthermore, improved night navigation would greatly benefit pilots. The socio-economical benefits would override moral caveats as purported by Robert & Baylis. The push towards trans-species gene splicing may be prompted by aging societies throughout the developed world and a concomitant need to improve life capacities. While longevity has substantially increased in the developed world in the last one hundred years, mobility among the elderly in general has been problematic. Telomere degradation during middle to late middle age (50-65) inevitably reduces human mobility. A reduction of telomere degradation (a product of trans-species gene splicing) may offer a viable alternative to those countries experiencing falling birth rates but which need viable workforces. Therefore, it is possible that trans-species gene splicing might improve a nation's economic productivity in the future, while redefining the parameters and capacities of aging.

This new kind transgenic human will not necessarily simulate the marvel comic "X-Men"; for all given purposes they will probably look "normal" and inconspicuous. Alternately, gene manipulation may give rise to future speciation of humans into distinct lines, " 'enhanced' and 'natural' " (Greenfield 2004: 143). While such anthropogenetic evolution coincides with "the non-negotiable hierarchy" of Aldous Huxley's *Brave New World*, Gregory Stock argues that different people will always value different phenotypical traits, thereby preserving species diversity (Greenfield 2004: 142).

The point here is that given the rate of ecological destruction on the earth the promise of trans-species gene splicing may lead to the possible creation of a new kind of embodiment which is more environmentally friendly. Ehrlich claims that there is a

"need for a novel evolutionary approach" due to the impact of future climate change which will affect the planet for centuries (Ehrlich 2000: 326). More precisely, evolutionary changes need to be in the area of the human perceptual system which has problems comprehending the immediacy of environmental problems (Ehrlich 2000: 327). In short, human sensory perceptions have evolved to experience the world in a limited way, and are unable "to equip the human species with the ability to detect gradual alterations" of environmental climate change (Ehrlich 2000: 327). Here, transspecies gene splicing may lead to the cultivation of a greater range of sensitivities to environmental conditions. Having enhanced sensory perceptions may actually promote more ecologically sound attitudes and practices. If humans had the ability to see ultra light frequencies, Ehrlich tells, then we would be aware of the ozone crisis, prompting corrective steps much sooner (Ehrlich 2000: 328).[7] Furthermore,

> *Had we evolved the chemoreceptive capabilities of dogs, we would be much more concerned about issues such as the presence of hormone-mimicking synthetic chemicals in the environment* (Ehrlich 2000: 328).[8]

In other words, an enhanced sensory embodiment would work concomitantly with what Ehrlich refers to as "slow reflexes" – an ability to detect ecological threats in both the short and long-term future. Eventually, the combination of slow reflexes and enhanced sensory perceptions could "lay the groundwork for a conscious evolution" (Ehrlich 2000: 327). Certainly, enhanced sensory perceptions would transform our experiential understanding of the non-human world to such a degree as to render scientific Cartesian based models untenable. In comparison to the miniscule "nanolevel mandates" (Greenfield 2004: 6), which may possibly threaten the human species, transgenic humans may in actuality promote an ecological awareness which has so far eluded the human species in general. Transgenic humans may provide a way towards climate change adaptation and for evolving advantageous innovations.[9]

Conclusion

Due to the prolific work in transgenics this paper has intentionally examined chimera in three areas. While chimera play a part in the mythopoiesis of cultures, chimera as commercial life products are at the vanguard of innovative biotechnology. Current transgenic technology is invaluable in increasing biological knowledge and biomedical science (Wheeler et al. 2003). New developing biotechnologies such as transformation of "ES/EG cells with the 'foreign' gene(s)" (Wheeler et al. 2003), may lead to more efficient livestock production as well as animals which could have the ability to become self immunised.

Future directions of human to animal transgenics are wide ranging and may take a similar form to "reliable germline technology" that focuses on increasing longevity, health improvements, and disease prevention (Stock 2002: 3). Germ line enhancements which retard the aging process in human beings by "altering cell senescence" (Loftis: 59-60), and improving the immune system are probable future directions for biotech companies (Loftis 2005).[10] Considering the aging populations in first world and countries such as China, this kind of biotechnology may subsequently alter societies.

Another future direction will be towards developing human sensory enhancements. Development of anti-aging and sensory enhancement gene technologies may effect changes in the human gene pool and transform human evolution. Questions may arise regarding whether sexual reproduction between transgenic humans and non-transgenic humans might lead to various other cognitive and sensory enhancements, or cause negative and long lasting mutations in the human gene pool.

Correspondence

Arthur Saniotis
Visiting Research Fellow
Discipline of Anthropology
School of Social Sciences
The University of Adelaide
SA 5005, Australia
Email: saniotis@yahoo.co.uk

Notes

1. The term "chimera" includes singular and plural.
2. See also Bazopoulou-Kyrkanidou (2001).
3. A shape-shifter is a "creature or natural entity ... able to change its outward form at will and that eschews any fixed identity." (Slater 2001: 16).
4. Each Aboriginal person is a living embodiment of a particular animal or plant spirit which is believed to have germinated in the female womb.
5. See also Ourednik, Ourednik, and Flax (2001).
6. See also Femandez.
7. See also Roan (1989).
8. See also Colborn, Dumanoski and Myers (1996).
9. Cavin (2006: 86) asserts that, "The evolution of anatomic adaptations in the hominids could not have kept pace with the abrupt climate changes which would have occurred within the lifetime of individuals." Trans-species chimeras might prove to be anatomically better suited to global warming than ordinary human beings.
10. See also Walters and Palmer (1997: 103), and Rose (2000).

References

Baylis, Francoise and Robert Jason Scott. (2006). "Primer on Ethics and Crossing Species Boundaries." Available at <http://www.actionbioscience.org/biotech/baylis_robert.html>.

Bazopoulou-Kyrkanidou, Euterpe. (2001). "Chimeric Creatures in Greek Mythology and Reflections in Science." *American Journal of Medical Genetics.* 100: 66-80.

Biotechnology Information Series. (February 1995). "Pharmaceutical Production from Transgenic Animals." Available at <http://www.biotech.iastate.edu/biotech_info_series/bio10.html>.

Breekveldt, Jeroen and Joost Jongerden. (1998). "Transgenic Animals in Pharmaceutical Production." *Biotechnology and Development Monitor.* 36: 19-22. Available at <http://www.biotech-monitor.nl/3609.htm>.

Brem, Sarah and Karen Anijar. (2003). "The Bioethics of Fiction: The Chimera in Film and Print." *The American Journal of Bioethics.* 3(3).

Business Communication Co. Inc. Norwalk, CT. USA. "Therapeutics from Transgenic Sources." Available at <http://www.bccresearch.com/bio/sampleBIO048A.pdf>.

Calvin, William. (2006). "The Emergence of Intelligence." *Scientific American.* 16(2): 84-92.

Centre for Emerging Issues. December (1999). "Animal Pharming: The Industrialization of Transgenic Animals." Available at <http://www.aphis.usda.gov/vs/ceah/cei/bi/emergingmarketcondition_files/animal_pharming.htm>.

Colborn, Theo., Dumanoski, Diane and John Peterson Myers (1996). *Our Stolen Future.* New York: Dutton.

Cummings, David. (December 1999). "Animal Pharming: The Industrialization of Transgenic Animals." Available at <http://www.aphis.usda.gov/vs/ceah/cei/>.

Dennis, Carina. (2002). "China: Stem Cells Rise in the East." *Nature.* 419: 334-36.

Ehrlich, Paul. (2000). *Human Natures: Genes, Cultures, and the Human Project.* Washington D.C. & Covelo, California: Island Press.

E.T.S. (Emerging Technology Series). (1997). "Genetic Engineering and Biotechnology." Part E. Applications. 4: 62.

"Biotech in the Barnyard: Implications of Genetically Engineered Animals." *Pew Initiative on Food and Biotechnology.* Available at <http://pewagbiotech.org/events/0924/proceedings1.pdf>.

Garvin, Wilbert., Ute. Harms, Caroline Shearer and Laurence Simmoneaux (1998). "Transgenic Animals." *European Initiative for Biotechnological Information.* Available at <http://www.ipn.uni-kiel.de/eibe/UNIT11EN.PDF>.

Gavin, William. (2001). "The Future of Transgenics." *Regulatory Affairs Focus,* Available at <http://www.transgenics.com/images/May2001Gavin.pdf>.

Glenn, Linda McDonald. (2004). "Ethical Issues in Genetic Engineering and Transgenics." *ActionBioscience.org.* June. Available at <http://www.actionbioscience.org/biotech/glenn.html>.

Greenfield, Susan. (2004). *Tomorrow's People: How 21st-Century Technology is Changing the Way We Think and Feel.* London: Penguin Books.

GTC Biotherapeutics "GTC Biotherapeutics Reports Third Quarter 2006 Financial Results." Available at <http://www.gtc-bio.com/pressreleases/pr110206.html>.

Jackson, Michael and Ivan Karp, eds. (1990). *Personhood and Agency: The Experience of Self and Other in African Cultures.* Stockholm: Almqvist & Wiksell.

Jaenisch, Rudolf and Beatrice Mintz. (1974). "Simian Virus 40 DNA Sequences in DNA of Healthy Adult Mice Derived from Preimplantation Blastocysts Injected with Viral DNA." *Proceedings of National Academic Science USA.* 71: 1250-1254.

Johnston, Josephine and Christopher Eliot (2003). "Chimeras and 'Human Dignity'." *The American Journal of Bioethics.* 3(3).

Kae, Helmut. (2006). "The New Macdonald Pharm." *The Science Creative Quarterly.* 2. September/November. Available at <http://www.scq.ubc.ca/?p=471>.

Karpowicz, Phillip, Cohen, Cynthia, B and Derek J. Van der Kooy. (2005). "Developing Human-Nonhuman Chimeras in Human Stem Cell Research: Ethical Issues and Boundaries." *Kennedy Institute of Ethics Journal*, 15(2): 107-134.

King, Jonathan and Doreen Stabinsky. (1998). "Biotechnology Under Globalisation: The Corporate Expropriation of Plant, Animal and Microbial Species." *Race and Class: A Journal for Black and Third World Liberation*. October. Available at <http://hornacek.coa.edu/dave/Reading/race.class.html>.

Krieger, L. M. (2002). "Scientists Put a Bit of Man Into a Mouse." *Mercury News*. December 9. Available at <http://www.bayarea.com/mld/mercurynews/4698610.htm>.

Kurzweil, Ray. (2000). *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*. New York: Penguin Books.

Loftis, Robert. (2005). "Germ-Line Enhancement of Humans and Nonhumans." *Kennedy Institute of Ethics Journal*. March. 15(1): 57-76.

Margawati, Endang, Tri. (2003). "Transgenic Animals: Their Benefits to Human Welfare." *ActionBioscience.org*. January. Available at <http://www.actionbioscience.org/biotech/margawati.html>.

Noor, R. R. (1996). *Genetika Ternak. Penebar Swadaya*. Jakarta; Available at <http://www.ppl- therapeutics.com/>.

Ourednik, V., J. Ourednik, and J. D. Flax, et al. (2001). "Segregation of Human Neural Stem Cells in the Developing Primate Forebrain." *Science*. 293: 1820-24.

PPL Therapeutics company web site. Available at <http://www.ri.bbsrc.ac.uk/library/research/cloning/archive/benefits.html>.

Rifkin, Jeremy. (May-June 1998). "Future Pharming - Genetic Engineering of Animals." Available at <http://www.finddarticles.com/p/articles/mi_m0FRO/is_n3_v131/ai_20601078>.

Roan, Sharon. (1989). *Ozone Crisis: The Fifteen-Year Evolution of a Sudden Global Emergency*. New York: Wiley.

Rose, Michael. (2000). "Aging as a Target for Genetic Engineering." In G. Stock and J. Campbell, eds., *Engineering the Human Germ Line*. Oxford: Oxford University Press. Pp. 49-57.

Savulescu, Julian. (2003). "Human-animal transgenesis and chimeras might be an expressions of our humanity." *The American Journal of Bioethics*. Summer. 3(3): 223-25.

Scott, Robert Jason and Francoise Baylis. (2003). "Crossing Species Boundaries." *The American Journal of Bioethics*. 3.3: 1-13.

Seidel Junior., George. (1999). "The Future of Transgenic Farm Animals." In J. D. Murray, G. B. Anderson, A. M. Oberbauer, and M. M. Mc Gloughlin eds., *Transgenic Animals in Agriculture*. New York: CABI Publishing. Pp. 269-283.

Slater, Candace. (2001). *Entangled Edens: Visions of the Amazon*. Berkeley: University of California Press.

Stock, Gregory. (2002). *Redesigning Humans: Our Inevitable Genetic Future*. New York: Houghton Mifflin.

The British Union for the Abolition of Vivisection. (December 2004). "Animal Pharming." Available at <http://www.buav.org/pdf/G5GenePharming.pdf>.

The State of Food and Agriculture 2003-2004. FAO Corporate Document Repository.

Available at <http://www.fao.org/docrep/006/y5160e/y5160e00.HTM>.
Walters, LeRoy and Julie Gage Palmer. (1997). *The Ethics of Human Gene Therapy.* New York: Oxford University Press.
Wheeler, Matthew, Eric Walters, and Sheree Clark. (2003). "Transgenic Animals in Biomedicine and Agriculture: Outlook for the Future." *Animal Reproduction Science.* 79(3-4): 265-289. December.