Genomics,
Society and Policy

VOLUME 3, NUMBER 2 (AUGUST 2007)

SPECIAL ISSUE:
ANIMAL GENOMES, BODIES AND TISSUE IN SCIENCE AND SOCIETY

GUEST EDITOR:
MATTHEW HARVEY

Genomics, Society and Policy, Vol.3 No.2 (2007) ISSN: 1746-5354

GSP online Genomics, Society and Policy
2006, Vol.3, No.2

Contents

Genomics, Society and Policy
2007, Vol.3, No.2, p.ii

Editorial: Animal Genomes, Bodies and Tissue in Science and Society

The papers in this issue address the field of animal biotechnology and, particularly, animal genomics. Together they seek to understand the context and shaping of the science of animal genomics, reflect on connections between this science and the social position and cultural construction of animals and human-animal relationships, and explore current and future regulation and policy. Each paper emerged from a multi-disciplinary workshop convened by the ESRC Genomics Policy and Research Forum, University of Edinburgh to discuss animal genomics in April 2006. Some participants at the workshop, and some authors here, have long been interested in animal genomics and biotechnology, whilst others were asked to bring knowledge developed in other fields and with other case studies.

Underpinning the workshop, and followed through in this issue, was a recognition that genomics uses and studies a lot of animals, combined with concern that the otherwise flourishing social science of genomics has passed them over. The strength of concern is variously expressed. In my own editorial essay, I ask only that the animal becomes more conspicuous. Others call for something stronger: Donaldson, for example, argues that we need to rethink our idea of society or the social in such a way that the inclusion of nonhuman animals becomes obvious.

Whichever route is adopted, a handful of themes recur, including: whether animal genomic science is reductive; the extent to which it aligns with narratives of instrumentalism; the potential for animal genomics to render animals efficient sources or accumulators of capital; whether animal genomics functions as an instrument of biopower; and whether animal genomics alters both what we can and do know about an animal, and the animal that is known. On the way we visit the farmyard (Donaldson, Holloway & Morris, Twine), the laboratory (Harvey, Hauskeller), and the sea (Costa & Carvalho), although as Twine points out, genomics means that it is increasingly difficult to separate such spaces.

Although final judgement rests with the reader, I hope this issue makes a valuable contribution both to the social scientific and philosophical analysis of genomics, and to the growing field of animal studies. It also contains a new venture for the journal. The issue includes a broadly technical paper on DNA barcoding by molecular ecologists Filipe Costa and Gary Carvalho. Inclusion of a technical paper is new in itself, but moreover, this is followed by three short commissioned responses from John Dupré, a philosopher, Pete Hollingsworth, a conservation geneticist, and Petter Holm, a social scientist. Costa and Carvalho provide a final response and together these papers make for a very interesting discussion. Many aspects of animal genomics have been discussed before within social science journals, and sometimes from multiple perspectives in this way, but probably not DNA barcoding.

Matthew Harvey
ESRC Genomics Policy and Research Forum, University of Edinburgh, UK
Guest Editor

GSP online Genomics, Society and Policy
2007, Vol.3, No.2, pp.1-28

Animal Genomics in Science, Social Science and Culture

MATTHEW HARVEY[1]

Abstract

Animals are commonplace in genomic research, yet to date there has been little direct interrogation of the position, role and construction of animals in the otherwise flourishing social science of genomics. Following a brief discussion of this omission, I go on to suggest that there is much of interest for the social sciences and the humanities in this field of science. I show that animal genomics not only updates and extends established debates about the use of animals in science and society, but also raises novel issues and promotes new ways of thinking about what animals are, and the social and biological relationships between animals and humans. Organising the science of interest into six themes (sameness, difference and classification; crossing boundaries; the maintenance of borders; farmyard supermodels; laboratory supermodels; knowing, relating and looking at animals), for each I review some of the science that is being done, some of the conceptual issues that are raised, and some of the social science that is or could be done. I conclude by briefly considering the development of socially responsive policies for animal genomics.

Introduction

Animals are commonplace in genomic and biotechnological research, as principal objects of study or conduits and models for understanding human biology. This work connects with longstanding debates about the use of animals in science and society, extending and updating these with new techniques for understanding and using animals. But further, the science of genomics and the manipulation of animal genomes raises novel issues and promotes new ways of thinking about what animals are, how they evolve and relate to each other, and the social and biological relationships between animals and humans. Yet there is little direct interrogation of animal genomics in the social science literature, particularly if genomics is conceived only as the DNA sequencing of the entire genome. There is a growing literature for research agendas within the broader field of biotechnology, in particular xenotransplantation and genetically modified animals,[2] and human-animal chimeras and cloning have also received some attention.[3] But to date, the key arena for discussing developments like these remains ethics and bioethics.[4]

Following a note on the meaning of "animal genomics", this review briefly discusses the broad omission of animals from social science. The paper then goes on to consider the context and shaping of the science of animal genomics, a range of questions and issues for which genomic solutions have been proposed, and how this work might reconfigure the social and cultural position of animals and human-animal relations. Suggesting there is much here of social scientific interest, the paper finally considers policy issues for regulating and governing animal genomics and exploiting animal genomic research.

Animals, genomics and social science

Although the term genomics might be restricted to the sequencing of the entire genetic complement of an organism, and so animal genomics might refer only to the genome sequencing of animals, in practice sequencing alone is of little interest. It is what follows that is significant, such as how that knowledge connects with what else is or can be known; how the knowledge so obtained might be applied; or how that animal is better understood in itself or in comparison to others. Sequencing may further be married with other techniques such as genetic modification or selective breeding, and the animal genome worked on and with in new or more intense and efficient ways.

This marriage probably marks the disciplinary boundary of "animal genomics". But for this paper I will conceive the field of interest more broadly still, for there are now practices where the genomes, genes and tissue of particular species turn up in novel and unexpected places, such as in xenotransplantation and stem cell research. For example, human embryonic stem cells have recently been implanted into, and have then integrated with, mice brains.[5] The transplanted tissue is then a metonym for the animal or species from which it came, and the power of the connection is hard to erase, perhaps notably so if that animal's genome has moved too. If animal genomics is thought of in these terms, broader than mere sequencing to encompass working on and with animal genomes, then as I go on to show and explain, the depth and significance of activities within animal genomics is extensive.

This science uses and impacts on a lot of animals, including ourselves. Despite this, and with work reported in the present volume excepted, there is little direct work within social science on animal genomics as a topic in its own right. The work published so far has concentrated on certain hard cases – xenotransplantation, genetic modification, cloning – that have been opened up to public debate or seem particularly problematic in terms of ethics or regulation. Moreover, this research has usually been limited to what these practices might mean for people. For example, Michael argues that the 'technoscientific bespoking' of animals by making them 'ready-to-order … might catastrophically curtail the symbolic role of animals in human identities, and thus provoke a general anxiety toward new genetics'.[6] What is happening to *the animal* is inconspicuous.

This omission, perhaps, reflects a broader circumstance within social science, for animals remain in the social science literature largely invisible and 'to read most sociological texts, one might never know that society is populated by non-human as well as human animals'.[7] There is substantial work within other related disciplines such as moral philosophy[8] and history,[9] and some of this crosses with sociological accounts[10] and has considered the impact of biotechnology.[11] But, historical accounts aside, this work has generally been balanced toward an animal rights or ethical frame. Tester, for example, explores the way that society and individuals relate to animals, but his primary concern is with special claims made for animal rights.[12]

Recently, some social scientists have attempted to account for animals' invisibility, suggesting that animals tend to be embedded and treated within the broad category

---

"nature" or that social science is person-centred and animals, considered not part of society, are of little interest.[13] Moreover, a social science of human-animal relations has recently expanded,[14] and there is a large and developed literature on relations between humans and companion animals.[15] But this attention has not yet transferred to the otherwise flourishing social science of genomics[16] and the general lack of attention becomes all the more interesting given the integral position of animals in the genomics revolution (assuming there is such a revolution) and many other social and scientific practices.[17]

Paula offers some of the clearest examples of published research with an explicitly animal-genomic orientation, considering the impact of genomic approaches in the context of food production and policy development.[18] However, a broader research agenda that captures a wider range of genomic sciences and which considers the human, the animal, and the human-animal conceptual coupling is required, one which is unlikely to emerge simply from the aggregate of those individual projects currently represented in the literature. In the following section I outline six themes emerging from the science of animal genomics, broadly defined, of interest to social science (and to the arts and humanities).

1. Sameness, difference and classification

'Much of nature', comments Stephen Jay Gould, 'is messy and multifarious, markedly resistant to simple mathematical expression'.[19] But rather than being an obstruction to science, this amounts to its challenge, and genomics has become part of the scientific project that tries to turn nature, by which I mean here the plants, animals and other features and products of the earth, into something orderly and simple. Two particular and stubborn types of problem, presented by the mess and complexity of nature as well as by its size and spread, now have apparent genomic solutions and even mathematical articulation. The first concerns the recording and cataloguing of biodiversity, the second its classification.

Species identification and recording biodiversity

How does one determine of which known species a particular specimen is an example, or indeed if that specimen is "new to science"? Species identification is primarily based on visible morphology but the technique remains problematic. For example, Hebert et al point out that even the best taxonomists can identify just a tiny percentage of the estimated 10-15 million species on Earth, and morphological keys used in identification require such a high level of expertise that misdiagnoses are common. Further, variation between individual members of a species can lead to misidentification, and morphology can differ significantly across the life-span making correct identification difficult. Some species are morphologically cryptic, that is, so similar that it is nearly impossible to distinguish between them, and even if other factors like internal anatomy, behaviour and geography can be taken into consideration, Hebert et al note that 'although much biological research depends on species diagnosis, taxonomic expertise is collapsing'.[20] To resolve the problem, they propose that short DNA sequences known as "barcodes" offer the best approach to a sustainable identification system.

DNA barcoding assumes that a simple and unique DNA sequence can distinguish and therefore identify any given species, and the search is underway for a sufficiently standardised yet discriminatory section of DNA. Early attempts resulted in some failures, classifying ladybird beetles as wasps, for example,[21] but a 648 base pair region of the cytochrome *c* oxidase I (COI) mitochondrial gene has been shown to be particularly promising in tests with birds, fishes and some orders of insects.[22]

Barcoding every species would help field scientists identify specimens, but social scientists might note that the technique has social and policy implications. For example, barcoding may facilitate the monitoring of species, feeding into current societal and policy concerns over conservation, the maintenance of biodiversity and the tracing of foodstuffs (on the latter, see section 3 below). For example, a group attempting to barcode all fish argue that such data would assist sustained fisheries management and consumer confidence.[23]

But the promissory future for barcoding transcends identification and monitoring, and the vision is for nothing short of a barcoded world. There is now a strong and developing research network – the Consortium for the Barcode of Life[24] – and reports suggest that a Canadian team will have barcoded every known bird in the world by 2010.[25] Once a comprehensive species catalogue has been compiled, it could then be made instantly accessible. Paul Hebert, barcoding's chief protagonist, envisions a day 'when every curious mind, from professional biologists to schoolchildren, will have easy access to the names and biological attributes of any species on the planet'.[26] This will have implications for public understanding and engagement with science, and sociologists of science may also note that barcoding has generated debate within scientific circles on its economic and technical footing as well as its consequences for traditional taxonomy and taxonomists.[27] There is presently no social scientific interest in this fascinating and growing field, but if realised, the claims of the barcoding community will be socially, politically and conceptually significant.[28]

Species and classification

For Will et al, 'DNA barcoding has both new and good elements, but unfortunately no elements that are both'.[29] Ebach and Holrege are similarly dismissive, arguing that barcoding generates only information not knowledge, and tells us little more than we know already: 'life is complex'.[30] In particular, whilst barcoding may lend itself to identification under conditions of uncertainty, it has less application to some other goals of taxonomy such as classifying organisms and describing relations between them. Classifying and relating are particularly hard problems, but where the limits of barcoding are reached, other genome-based solutions are encountered.

Ritvo notes a persistent paradox: it is obvious that human beings are different from non-human animals but it is not obvious what the kind and degree of difference is.[31] This problem of determining sameness and difference extends to all other relations between members of the animal kingdom, and Ritvo records some of the many ways that, historically, these differences have been discussed and turned into systems of classification.[32] As a systematised scientific endeavour, classification – the practical

---

activity of assigning the vast numbers of organisms in the world to particular kinds – can trace its roots to the enlightenment and has turned up many competing schemes. But that there have been (and are) competing schemes and taxonomies supports Ritvo's general point that classification, and description of sameness and difference, reflects intellectual, social and political commitments as much as, or more than, what differences there "really" are.

For some, any difficulty in a satisfactory final classification scheme of all animals should be circumvented (and explained) by considering classification as a pragmatic and pluralist practice. Dupré argues that diverse sets of people – biologists, ecologists, foresters, gamekeepers, wildflower enthusiasts, members of the public and so on – require workable classifications, but classifications that need not necessarily align.[33] No particular scheme should be privileged, and Dupré argues that ordinary-language or folk taxonomies can be treated on a par with, and in the same way as, scientific classifications. For example, Dupré suggests there is no sound reason to exclude whales from the category fish, except the consensual agreement that they are not. Prior to science, whales *were* fish but folk were 'duped into changing that belief for bad reasons'.[34]

Dupré acknowledges that this claim is controversial, but to say that there is no unique and privileged biological (ie, within science) classification is less so. An underlying difficulty (but one that does not trouble barcoders) is that there is no current solution to the 'famously difficult' species problem; that is, the failure of biologists to agree on how we should define the word "species" and therefore the grounds on which we should make species discriminations.[35] A popular solution is to consider two populations of sexually reproducing organisms as different species if they cannot interbreed with each other. But this only accounts for *sexually reproducing* organisms, of which many living organisms including many plants are not, so a different concept is needed for them. Also, as Hey points out, some breeds of dog can mate but some cannot (because of extreme size differences) leaving it open whether 'dog' is a term for many different or one species. These, and other problems, mean that there are some two dozen different definitions of "species".[36]

For Hey, much of the difficulty comes in the deployment of rival and fuzzy linguistic categories, all of which are assumed to mirror patterns found in nature. But into this uncertain arena, genome sequencing might offer empirical, clarifying data. Comparing DNA sequences and whole genomes offers the promise of an objective concept for the relationship between organisms,[37] yet as I will show, it might be just as troubling.

Humans and other animals

Although there are certainly groups and individuals who would say otherwise, in scientific and much popular parlance humans *are* animals, even if we might think that humans are particularly distinctive animals. This view is maintained in the current consensual scheme of biological classification and through the theory of evolution. But as already indicated, whilst it is easy to say humans are particularly distinctive

---

animals, this is the start of many conceptual and empirical difficulties. From a conceptual perspective, Herrnstein Smith writes:

> *'Once the straightforward truth of our human distinctiveness is unsettled by the straightforward truth of our animal identity, there is no point, or at least no more obviously natural point, beyond which the claims of our kinship with other creatures – or, indeed, beings of any kind – could not be extended; nor, by the same token, is there any grouping of creatures, at least no more obviously rational grouping, to which such claims might not be confined'.*[38]

For Herrnstein Smith, this invokes a 'chain of animate being', a continuum that can't sensibly be broken up into discrete units toward which different rules of conduct apply. But people frequently *act* as if it can. Herrnstein Smith refers, for example, to an 'ethical taxonomy' where our sensed and practised responsibilities to horses, butterflies, walruses, oysters, wasps, lice and microbes are quite different.

Extending our moral responsibility to microbes seems absurd, but Herrnstein Smith's point is that there is no obvious point on the continuum to make the break and divide the sensible from the silly. This is a policy as well as a philosophical conundrum, and one discussed in the UK Parliament during a debate on the proposed animal welfare bill. One Member of Parliament noted considerable problems with the definition of "animal" in the bill. For the purposes of the bill, the category "animal" contains only vertebrates, but the Member argued that if the bill was designed to alleviate the suffering of animals, then it should be extended to those non-vertebrates that scientific evidence suggests are capable of suffering, including cephalopods such as octopus and cuttlefish.[39] Perhaps then the scientific criteria of "suffering" should replace the scientific category of "vertebrate".

Genome analysis cannot speak directly to such ethical and political questions, but it does have something empirical to say about *degrees of difference* and *relatedness* between organisms; a quantitative knife so to speak. One of the less celebrated findings of the human genome project is how few genes humans have. Early estimates suggested up to 200,000 with a concomitant theory that the more complex an organism the more genes it would have (and obviously *we* would have the most). But this number has steadily dropped to the current estimate of about 25,000, making humans around 3,000 genes different to a worm, 2,000 different to a fruit fly, and 17,000 different to rice, which has more.[40] This fall required some re-working of the notion of complexity: if humans were to remain the most complex, mere numbers of genes could not be the key. Attention shifted from structure to function and meaning. For example, Enard et al report that human and chimp genomes are 98.7% identical in their DNA sequence, yet there are many clear differences between the species.[41] Hypothesising that the underlying basis of these differences is likely to be altered gene expression, they go on to show that large numbers of quantitative changes in gene expression can be detected between closely related mammals. Such changes, they argue, have been particularly pronounced during the evolution of the human brain.[42]

Human complexity is thus saved, but 98.7% still seems to suggest that humans and chimps are mostly the same, a figure that rises to 99.4% for functionally important sites. ‘Chimps are human, gene study implies’ read the headline on *NewScientist.com* when the latter figure 99.4% was announced,[43] and for Morris Goodman and colleagues data like this challenges the anthropological view that has traditionally emphasised how very different humans are from all other forms of life.[44] For Goodman et al, whilst traditionally chimps are classified with gorillas and orang-utans in the family *pongidae*, separate from the human family *hominidae*, the DNA data means that chimps must be moved over to the human family: ‘The accumulating DNA evidence provides an objective non-anthropocentric view of the place of humans in evolution. We humans appear as only slightly remodelled chimpanzee-like apes’.[45] That doesn’t make us sound particularly special or even distinctive, and Goodman claims anthropologists have their own vested interests for making us seem otherwise.[46]

But what does it *mean*, based on DNA data, to say that ‘chimps are human’? Anthropologist Jonathan Marks argues that similarity in DNA is being casually translated into similarity of “us”, but this is just metonymy – replacing one part of us for “us”. Moreover, why describe us as a remodelled chimp-like ape? As Marks points out, this is just because we interpret a figure like 98.7% identity in DNA to mean we are 98.7% chimp, but on that basis we are also 35% daffodil, and to say we’re quite extensively remodelled daffodils ‘is more ludicrous than profound’.[47]

For Marks, to read anything into this is to reduce life to genetics, and genetics has nothing important to say about the differences between humans and animals. A figure like 98.7% or 99.4% ‘bears the precision of modern technology [and] carries the air of philosophical relevance’ but this emperor really has no clothes.[48] Marks takes to pieces the methodologies of comparative genomics and shows how assumptions stack up to error. He then claims that anyway, there is nothing profound about saying that we are genetically similar yet different to chimps: this is entailed by the theory of evolution. Moreover, there are so many ways that humans are so obviously different to other animals, including the chimpanzee, that what needs explaining is why we are currently bewitched by genetic similarity.

There is no space here to look deeper into the ongoing debate on the significance of DNA comparisons between humans and other animals, save to raise three of many points of interest for the social sciences and humanities. The first is conceptual, for the debate amounts to a struggle for the right to define humanness. Since the 1960s, old questions pertaining to describing and conceptualising the similarities and differences between humans and other animals have begun to be colonised by genome-based sciences and the implications of this for understanding humanness need to be fully worked out. The second and third points, not unrelated, are sociological.

This struggle is as much conceptual as it is territorial, with traditional anthropology, molecular anthropology, molecular biology and comparative genomics amongst those disciplines claiming the right to define what amounts to humanness. This struggle will be of interest to sociologists of science and different techniques, materials and forms of evidence (palaeontology, genomics, ethnography, bones, DNA and so on) are mobilised by different groups in support of one position or another. But, as suggested, molecular techniques appear to be emerging as markers of the dominant paradigm, and so the third and final question asks *why*.

With Marks, the colonisation of humanness by genome science might most simply be viewed as an extensively generalised example of the narrative of geneticisation, a term first used by Lippman to refer, in the context of health and disease, to 'an ongoing process by which differences between individuals are reduced to their DNA codes'.[49] When applied to an understanding of the demarcations between humans and animals, this certainly sounds like what we are talking about. To illustrate, Armand Leroi, a biologist at Imperial College London, explained in a documentary on UK television that we can cast aside all other previously mooted demarcation criteria and simply point to particular genes:

> *'Ever since Aristotle, philosophers have wondered what makes us different from the beasts. Their answers – that man is a political animal, a thinking animal, a tool making animal – can now be discarded. Now, when we ask what makes us human, we can answer this gene, and that one and that one. We can begin to write the recipe for making a human being'.*[50]

Accordingly, a research effort is underway to pinpoint the telltale genes.[51] But to say we now view such differences as genetic because we see everything as genetic is not saying much, and to understand the hold and power of DNA in this case we need to look at something else.

The essence of DNA, no matter how it can be described in biochemical terms, is that it is information.[52] The drift to information began in 1965 when Zuckerkandl and Pauling stated that the essence of the organism is located in informational macromolecules, particularly DNA.[53] For them, the only reason we see discrete living forms at all is because of the relatively fixed information passed from generation to generation, information contained in DNA. This encourages a particular view of humanness, an ontological shift perhaps, but Zuckerkandl and Pauling would and probably could not have predicted the transformations in information technology that would come in the following decades, and which would bring DNA to the foreground.

An impressive international effort devoted to the sequencing and digital storage of animal genomes now relies on information technology. Many outputs are made available on publicly accessible databases, and the DNA codes of African savannah elephant, the nine-banded armadillo, the domestic cat, the European rabbit and the northern white-cheeked gibbon were just a few of those to begin to be sequenced in 2006.[54] Tentatively then, the particular attraction of DNA for conceptualising humanness and relations between animals might be that DNA presents, indeed is, a code that can be read, collated, stored, sorted, compared, manipulated, categorised and accessed in a way not offered by other sources of data. Of all the possible types of data that have or could be used as demarcation criteria between animals – bone, hair, communication, tool use, art, culture, consciousness, reflection, whatever – it is DNA

---

that has been selected and harvested, and through the interconnection with information systems, humanness and the essence of animals is quantified and digitized.

The sheer volume of information generated presents significant practical problems: genomes sequenced to date range in size from 100 to a thousand million bytes and just storing genomic information and the results of comparisons is a challenge.[55] Yet the effort is considered worthwhile, not just because cross-species genome comparisons offer a tool for understanding the genetic factors involved in human health and illness, but that they also offer the chance to complete the annotation of the “tree of life”.

The tree (or ring or net) of life

Phylogenetic trees are schemes that represent evolutionary relationships between organisms, and molecular phylogenetics infers these relationships through comparing DNA sequences. Molecular phylogenetics expanded with DNA sequencing techniques and more so in the 1990s with the rapid sequencing and availability of whole animal genomes. Two basic assumptions are that all species, present and past, share a single common ancestor, and that as time passes new species evolve from earlier ones. If genomes evolve by the gradual accumulation of mutations, then the amount of difference in nucleotide sequence between two genomes indicates how recently those genomes shared a particular common ancestor, with two recently diverged genomes having fewer differences than two that diverged further back in time.[56] By comparing three or more genomes, the evolutionary relationship between them can be inferred, and in principle, if you carried on doing this for everything it would be possible to construct the universal tree, ‘an image that unifies all life through its shared histories and common origin’.[57]

But at the same time as showing promise for completing the universal tree, genomics might ultimately undermine this goal. First, different research objectives, methodologies and practices produce different trees, meaning that the (re)construction of evolutionary time, events and relationships remains indeterminate. Second, genomic research suggests that at its very deepest roots, the tree metaphor has to give way to a ring or a net. Darwin made his first (but not *the* first) sketch of something like an evolutionary tree in his 1837 *Notebook on Transmutation of Species*, and “tree” is the standard metaphor for evolutionary relationships.[58] But comparative genomics and the subsequent demonstration of horizontal gene transfer (the transmission of DNA between species) suggest that the “tree of life” depiction of evolution is misleading, or perhaps even meaningless.[59] Research by Rivera and Lake suggests that the relatively complex genome of eukaryotes (cellular non-bacterial life) arose from the fusion of two simple prokaryote genomes. This, they argue, means that at the deepest levels there is a ring of life with no start and no end.[60] Alternatively, Kunin et al and Doolittle prefer to talk of a net of life.[61] Trees only represent linear and vertical relationships, but the net metaphor better captures the transmission of DNA between organisms.

The increase in resolution afforded by genome analysis therefore challenges orderly, tree-like representations and confirms that nature is messy all along. Doolittle summarises the general situation like this:

> *'Biologists came to think that … the ultimate natural order is a single inclusively hierarchical, "universal phylogenetic tree", without reticulation … If, however, different genes give different trees, and there is no fair way to suppress this disagreement, then a species (or phylum) can "belong" to many genera (of kingdoms) at the same time: There really can be no universal phylogenetic tree of organisms based on such a reduction to genes'.*[62]

Doolittle suggests that to save the tree concept, organisms could be defined as more than the sum of their genes, having some sort of 'emergent reality' which permits once more expression of relationships to be maintained at the species/organismal level. But if we need to turn to extra criteria, the increasingly technical and quantitative investigation of the relationships between animals from molecular phylogenetics and comparative genomics has brought us no closer to conceptually defining borders between organisms. There is no better demonstration of these emergent realities than when ordinary language classifications, expressed through sensed kinship, are revealed in genomic breaching experiments; that is, scientific practices where borders are transgressed.

2. Crossing boundaries

Robert and Baylis list seven examples of 'novel creatures', real or imagined, which mix biological material across conventional species boundaries, be they animal-to-animal transgenic organisms or nuclear-cytoplasmic hybrids, or human-animal chimeras created by inserting human cellular material into a nonhuman embryo or nonhuman material inserted into adult humans.[63] What happens when scientists mix tissue from different species into a new whole? Perhaps moral and ethical confusion, queasiness, revulsion, affront to nature, a challenge to humanness and animal integrity?[64] Perhaps all of these, but perhaps also the betterment of human and animal health, improved animal welfare, or better animal products.[65]

For Cohen, recent technologies that enable the insertion of human cells into animals and vice-versa require the development of a standard for determining where the conceptual boundary between humans and animals lies, and when it has been crossed.[66] But as we have seen, conceptually delineating that boundary is a difficult matter. An alternative approach might be to turn the study of boundaries from a conceptual issue to an empirical one. Franklin argues that the site for rehearsing boundaries and transgressions is sociological, and that the process has in some senses begun.[67] For example, research on cultural constructions of new reproductive and genetic technologies like IVF and preimplantation diagnosis might offer an analogue for discussion about human-animal chimeras. Franklin notes that anthropological research has shown notions such as relationality, kinship, affinity and inheritance are frames of reference within which people work through the desire both *to* and *not to* limit genetic technologies. It might be reasonable to guess that these concepts might also frame reactions to genetic technologies that cross animal boundaries, particularly

---

if it is easier to demonstrate essential continuity between animals and humans than to define difference. Franklin concludes that it is necessary to understand and explicate the sociological principles through which our 'genomic future' is being shaped, allowing us to predict and rehearse when technologies like those that make animal-human chimeras are most likely to become problematic.

Experience already tells us that ethical or other arguments against such technologies are challenged by the chance that they might save someone's life, and otherwise "repugnant" technologies become acceptable or even imperative. Bailey for example urges the use of infant baboons as heart donors for infant humans. Bailey performed such an operation in 1984, the human infant Baby Fae living for 20 days before the heart was rejected. For Bailey, the argument for such a procedure is clear:

> *'baboons are a plentiful, unthreatened, largely homologous, versatile donor resource that should be further investigated for this purpose. They are utilized widely in laboratory research … Immature baboons should not be dismissed as potential donors for young infants unless, or until, they are proved through laboratory or clinical research to transfer infections'.*[68]

That baboons are numerous and already subjects of scientific procedures are not *reasons for* their exploitation as organ donors, yet all the same it is not straightforward to argue against the saving of an infant's life, even if a baboon's is lost. But Franklin's point is that we should seek to explore these ethical and moral conundrums *before* we face stark imperatives, before we even know, for example, if it is technically possible to create hybrid embryos by fusing human cells with rabbit eggs, a proposal widely discussed in the press.[69] Some of the necessary sociological work will be to look at the positioning and construction of scientific research that crosses given species boundaries by those proposing to do it, those who challenge it, those who regulate it, and those who might have to live with the consequences of it. In this vein, several studies have begun to investigate lay and expert practical reasoning around technologies that transgress species barriers.

Although Bailey recommends the baboon as donor, scientific research and the weight of consensus focuses on the pig. Brown and Michael investigated the criteria used by scientists to legitimate this selection, and the way that they defended their work against negative representations.[70] They found that scientists drew asymmetrically on the resources of sameness and difference when justifying using pigs rather than the more immediately obvious nonhuman primates. For example, the scientists emphasised that culturally and ethically, pigs are different to humans in a way that other primates are not, and so pigs can be categorised differently, ethically speaking. But technically speaking, they stressed that pigs are the better candidate because they are *more* similar; for example their organs are of more similar size throughout the lifespan than are those of primates. Brown and Michael show how scientists moved between these scientific and cultural discourses in order to present their work as unproblematic.

An underlying assumption of social science research of this type is that declarations of sameness and difference are rhetorical achievements, not “natural” categories: they are contingent, tied to the historical moment or an actor’s social location and could therefore be otherwise. The political (and policy) edge to this work is that if this is the case, then on what grounds can any one account be privileged? Brown and Michael suggest that experts *qua* experts assume the facticity of their accounts and present their knowledge as wholly unproblematic to public groups. But public groups are not straightforwardly receptive. In a later work, Michael and Brown analyse conversations between lay people discussing xenotransplantation.[71] Noting that much expert assessment of technologies is couched in terms of cost-benefit analysis (Bailey above compares the benefit of transplant to the cost of zoonoses) they show that for lay people, cost-benefit is a highly contingent concept. For example, participants reasoned that they needed to trust experts providing information on which any cost-benefit analysis could be made, and moreover, needed to make a discriminatory judgement regarding whose costs and benefits to believe.

This asymmetry between expert and lay assessment can have significant consequences for the future trajectory of a given technology, and the science community is not unaware that mixed-species embryos might provoke public disquiet.[72] Grove-White et al argue that that the late 1990s’ public backlash against GM crops developed from areas of tension between the public on the one hand, and industry, Government and “sound science” on the other.[73] Now research by Macnaghten suggests similar tensions for GM animals. [74] Macnaghten observed public mistrust toward those institutions seen as responsible for such work combining with a view that GM animals are not ‘natural’ and that our ‘moral’ responsibility toward animals is being breached. Macnaghten warns that for GM animals, public controversy is likely.

If something positive came out of the intense and often acrimonious public debate on GM crops and foods in the UK, it is that it catalysed the current interest in upstream public engagement in science policy,[75] and for animal genomics there is some prospect for the development of new participatory modes of regulatory development. For example, the regulatory status of different human-animal chimeras is not yet wholly fixed and the human-rabbit experiments mentioned above exposed a regulatory grey area centred on whether the resulting embryos could or would be considered “human”. The situation is complex too for human-mice chimeras, and the legal and regulatory landscape is as unclear as the moral and the ethical.[76] Yet this lack of clarity could be turned into an opportunity for the creation of a socially robust policy and regulatory agenda. This will require “social intelligence” on public and expert opinion, and so becomes an opportunity for social science.

3. The maintenance of borders: genomics, traceability and surveillance

Haraway locates the “problem” of transgenic organisms in a challenge to the ‘sanctity of life’ maintained in Western cultures, which historically have been obsessed with racial purity, categories authorised by nature and the well-defined self.[77] Whilst this diagnosis sensitises us to the contingency of common unease at GM animals, it does not remove the sociological fact that by showing how permeable they are, these

---

technologies problematise received borders between species and between individuals. In contrast, other genomic technologies are concerned not with crossing borders, but with maintaining and policing them.

The movement of animals and animal products within and across nations presents significant challenges for control. Mitchell et al report that within Britain alone, there are around 19 million farm-to-farm cattle movements annually.[78] In the search for improved tools for tracing movements, genomics can now be applied to the identification of individual farm animals, herds or animal products. For example, DNA sequence variation between individual animals, the principle behind the barcoding approach discussed above, allows the traceability and certification of animal products at any point from farmyard to consumption, to verify the quality and the breed origin of meat or to verify pedigree.[79] Several companies now offer these services, such as Pyxis Genomics in the United States and the Irish company IdentiGEN, whose 'TraceBack' system uses DNA profiles to track meat back to the individual animal of origin, guaranteeing 100% traceability.[80] In one particular case, Sygen developed DNA tracing technology to verify meat from a rare English pig. Meat from Berkshire pigs sells for up to three times more than other pork in Japan, but more pork claiming to be Berkshire was on the market than animals available to supply it. The DNA test exploits variation involved in colour and other physical characteristics between Berkshire and other pigs.[81]

A particularly urgent utility for DNA fingerprinting technology lies with the traceability and containment of disease. "Biosecurity" (the attempt to ensure the health of animals, humans, ecologies etc.) in the form of "surveillance" arrived on the farmyard in the wake of the UK foot and mouth disease epidemic in 2001[82] and surveillant genomic technologies are now being presented as solutions to biosecurity issues. For example, within the EU, high value is placed on accurate and secure animal identification for the monitoring and eradication of disease, but Cunningham and Meghen argue that current technologies, based largely on ear tagging and national databases, are flawed.[83] They point out that tag switching can disguise a diseased animal for sale, or identify a healthy animal as diseased for compensation. Animal theft and smuggling also challenge conventional tracing procedures. They conclude that DNA technology offers a powerful means of authenticating and controlling animal identification.

The application of genomics to matters of surveillance and control is clearly a policy issue, but currently there is little social scientific input or research. The design and implementation of policy requires a complex set of processes as well as processors, and social scientists can usefully "get amongst" these to facilitate successful policy implementation and to investigate intended and unintended social and economic consequences. For example, from an industry perspective, the need for genomic based technologies is sometimes framed as a means to restore consumer confidence in meat foodstuffs.[84] But I have already noted that trust is a sufficiently complex sociological phenomenon that, if there is a lack of confidence in meat production, mere technical solutions may not be adequate for its restoration.

There is also an opportunity for more theoretical and conceptual social scientific work concerning the ordering and re-ordering of social relations, the control of space and movement, and the translation of animal bodies into information and data. Some grounds for this can be found in Donaldson and Wood who show the social dimension of disease management through a case study of foot and mouth disease.[85] The authors point out that disease control and surveillance strategies are rooted in economic and political systems more than the material nature of the disease. They argue that surveillance manifests as a mode of ordering that controls space and movement through the construction of bounded categories, and that the primary unit of control is not bodies (animal or human) but information and activity.

Consider for example the UK National Scrapie Plan (NSP).[86] This involves a series of breeding strategies intended to increase the number of sheep genetically resistant to scrapie, and the hope is that eventually the disease will be eradicated from the national sheep flock. Genomics has been recruited into this scheme as a tool of categorisation. Surveillance, Donaldson and Wood note, depends on the purity of categories and the cleanest possible demarcations between them. Genomics, in the form of genotyping, is used in the NSP to determine a sheep's resistance or susceptibility to scrapie, generating clear demarcations between desirable and undesirable genotypes. These distinctions are captured in tables and diagrams where sheep are translated into one of 15 possible genotypes. For instance, the 'NSP Ram Genotyping Scheme Consequences Table' for purebred rams displays 15 genotypes ordered into 5 'types'.[87] For a genotyped ram falling into types 1-3, no restrictions apply and that ram can be placed on the Ram Register, a facility to aid the sale or loan of resistant rams. But if a ram turns out to be type 4 or 5, then an immediate restriction is placed on the sale, transfer or breeding of that animal and it must be slaughtered or castrated within 90 days.

Although the disappearance of type 4 and 5 rams from the gene pool will be considered economically advantageous, the consequences for each ram of the translation of its corporeality to data and back by and through a network of actors and centres of calculation can be fatal.[88] Yet this represents more than a disregard for that animal. The NSP shows how genomics can facilitate the translation of animal bodies into information and, by making them simply data stored at centralised locations remote from that animal or traditional agents of control (eg, farms and farmers), the instrumental or mechanistic representation of animals is complete. This representation is clearly seen in the industrial application of animal genomics on the farmyard.

4. Farmyard supermodels

In his article *A Short, Meat-Oriented History of the World*, Cockburn notes that the meat industry is Cartesian in outlook and considers animals merely machinery.[89] He quotes an executive from a meat company saying that sows should be thought of, and treated as, valuable machines whose function is to pump out baby pigs like sausages. This casting of animals in instrumental and mechanistic terms fits seamlessly with the language and practice of farm animal genomics.

Genomics, in the form of genome analysis, marker assisted selection and genetic modification, offers an opportunity to intensify the industrial productivity of animals. Raadsma and Tammen neatly encapsulate this materialist objective when they note that genomic technologies will (social factors permitting) lead to the development of 'novel and high value *products*' and 'opportunities for the *mass production* of elite males for use in extensive animal *production systems*'.[90]

For example, the identification of genes associated with particular traits enables informed selection and breeding strategies and/or genetic modification to create animals with new or improved characteristics, or to remove undesirable traits. To illustrate, pork contributes 43% of the worlds consumed red meat and research at the genomic level attempts to identify candidate genes for efficient growth rates, reproduction, litter size, disease susceptibility, carcass merit (eg, intramuscular fat) and meat quality (eg, tenderness, colour). Using marker-assisted selection, this information is being used within the pig industry to improve pig production.[91] A recent World Health Organisation report outlines many other examples in production or planning, including transgenic salmon that grow 3-5 times faster than their non-transgenic counterparts, cows that produce protein-rich milk to increase the efficiency of cheese production, and chickens with two active ovaries for increased egg production.[92]

These "farmyard supermodels" are something of an achievement for farm animal genomics. The phrase "farmyard supermodels" came from an aside made by a presenter at an international farm animal genomics conference. Following presentations on progress in chicken and bovine genomics, this presenter showed that pig scientists too had their own 'supermodels' with a picture of a sow suckling a particularly large number of piglets. In terms of 'farm level performance' and the production of progeny this sow was exceptional, and throughout the conference many other examples of high performers – pigs with minimal back fat, chickens with extra strong legs to hold extra large bodies, cows with exceptional 'carcass merit' and so on – were displayed.

The continuity between modern breeding informed by genomics and ancient animal breeding is often stressed.[93] But it was with the rise of market economies, when animal products become commodities, that selection started to focus on productivity,[94] and it is likely that, informed by the knowledge of the action of thousand of genes,[95] industrial interest and the weight of private finance will focus on production traits. Yet farm animal genomics is not concerned only with such traits. The centrally funded UK Biotechnology and Biological Sciences Research Council lists product quality and efficiency as only one of three applications of farm animal genomics alongside farm animal health and welfare, and human health.[96]

For the latter, the BBSRC and Roberts argue that farm animals offer particular advantages over the more typical mouse for understanding fundamental biology and for furthering biomedical research (although see section 5 below).[97] More directly, over twenty companies worldwide are involved in the production and harvesting of therapeutic proteins from transgenic animal "bioreactors" in a process known as pharming.[98] In June 2006, the European Medicines Agency announced approval of

---

the first drug produced in an animal bioreactor.[99] GTC Biotherapeutics' ATryn is an anti-clotting agent for use in people who lack the natural anticoagulant protein and is harvested from transgenic goats. As in this case, proteins are usually gathered from the animal's milk, but attention is also turning to eggs, urine and semen.[100]

In terms of animal health and welfare, research can involve identifying at the genome level disease susceptibility or resistance (such as in the NSP),[101] but genomics also targets less obvious concerns. Researchers at the Roslin Institute have used genome analysis to investigate genetic variation in nitrogen and phosphorous excretion by poultry, and the feasibility of reducing this by genetic selection. This would address terrestrial and aquatic pollution as well as improve the environment for poultry, farm personnel and nearby residents.[102] Genetic selection or modification is also being used to select against behaviour that contributes to welfare problems, and genomics holds promise for "improving" welfare by, for instance, enabling animals to better "tolerate" unfavourable conditions, or removing behaviours that lead to distress or increased rates of mortality. For example, piglet mortality is a major welfare and economic problem in the pig industry. Around 12% of deaths are the consequence of crushing by the sow, and some sows crush more piglets than others. Observing these differences could be used to support a culling regime, or if differences between sows could be shown to have a genetic component, a selective breeding programme. This could involve genomic research, identifying and selecting specific genotypes.[103]

This work is indicative of an increased attention to animal welfare and a considerable body of European and UK legislation, together with popular concern and action toward welfare (eg. growing demand for free range animal products, demonstrations against farm animal transportation) suggests the growth of an 'animal welfare consciousness'.[104] Whilst this consciousness might be threatened by any increase in animal research or intensification of agriculture flowing from genomic research, genomics can, like for the pigs and chickens, address welfare problems. There are however at least two reasons to suggest that, again, mere technical solutions may be unsatisfactory.

First, it is a utilitarian or cruel-to-be-kind welfare solution that eliminates or slaughters some animals so that "better" ones may survive. Roberts points out that flowing from animal genomics will be 'no major effort to coax a genetically infertile sow to reproduce, for example. Flocks and herds will likely be screened for undesirable alleles and affected animals culled from the population'.[105] This is a human- not animal-centred mode of ordering, a mode organised on economic principles legitimised by appeal to moral concern. This connects to the second reason. Buller and Morris argue that the gradual pervasiveness of animal welfare policy and regulation legitimates the continued subjugation of animals founded in modernity:

> *'Farm animals, those 'docile bodies', have become vehicles for capitalist accumulation through processes of selection, breeding, intensive husbandry and now genetic modification'.*[106]

In the face of this 'modernism re-embedded', Buller and Morris urge two things: the recognition of animals as sentient beings with 'individual animalian distinctiveness';

---

and a new and more individualistic approach to welfare and farming that takes account of the affective and interactive relations between humans and non-humans. The first proposition argues for the reorientation of relations toward the horizontal over the hierarchical, whilst the second suggests that on-farm as well as other relations are psychological and social first, technical second. As Tisdell, and Schakel and van Broekhuizen show, breeding is not merely a technical matter, but a socio-economic and cultural one, too,[107] and this, perhaps surprisingly, holds for the laboratory animal.

5. Laboratory supermodels

Some of the hardest working and most numerous animal supermodels are in laboratories. According to a report in *Nature*, animal research facilities are overflowing with 'mutant mice' and face a multi-million dollar logistical nightmare. For this, 'overworked animal technicians can blame genomics'.[108] The mouse genome was completed in draft in 2002 and excitement within the science community has been as difficult to contain as the mice.[109] Garanga describes the completion as a 'watershed that forces us to re-consider our conceptual tools and the way we do research', and Gunter and Dhand suggest that for many, the mouse genome 'holds more promise for our future than even the human genome itself'.[110] This is because the mouse is *the* experimental model for human biology, and in 2003 mice were involved in around 65% of all animal experiments in the UK.[111] The completion of the mouse genome reinforces and extends this distinguished position:

> *'there can scarcely be a major area of mammalian biology or medicine to which mouse studies have not contributed in some way, often as surrogates for human studies … Much of this power has come from technologies to manipulate the mouse genome, but until now we have in effect been shooting in the dark. The genome of Mus musculus will provide the necessary illumination'.*[112]

The study of genetic disease using mice can be based on natural variants, natural mutants, chemical- or radiation-induced mutants, or engineered mutants, and can be used to understand the role of specific genes in monogenic and multifactorial diseases such as type 2 diabetes and sensorineural deafness.[113] Particular interest is focused on the utility of "knockout" mice, and a project recently announced will "knockout" or disrupt each of the 20,000 protein-coding genes in the mouse genome.[114] Mice are also important in stem cell research, broadening the utility of the mouse to mammalian development and physiology. Recent advances in this field, attributable to the mouse, are presented with equal enthusiasm. Smith claims that 'the faculty for propagating pluripotent stem cells from mouse and human embryos' is a 'gift from nature [that] has provided unparalleled research tools'.[115] I noted above, for example, that researchers have experimented with injecting human embryonic stem cells into mouse brains, providing new models for studying neural development which might advance understanding of neurodegenerative and psychiatric diseases.

This enthusiasm and the technical advance of animal models is tempered and constrained by legislation in ways that can usefully be explicated by social science.

The regulatory and legislative position on animal experimentation seeks to satisfy the requirements of industry and science whilst protecting animals from avoidable suffering and unnecessary use.[116] This inevitably leads to cost-benefit thinking, but the UK Animal Procedures Committee, which advises the Home Secretary on matters that fall under the Animals (Scientific Procedures) Act, points out that cost-benefit analyses involve judgements that encode values and are therefore contestable and contingent.[117] They do not, for example, encode the judgements of those who argue for the complete end to animal experimentation in any form.

When grounded ethically, the argument for the end to animal experimentation lacks *force*, in Burkhardt's terms, in that those involved in the practice of biotechnology will never be persuaded; not, that is, until ethics becomes a legitimate and routine part of the 'scientific attitude'.[118] This seems to imply that animal scientists don't have ethics, but of course this is not the case. Social scientists are not often directly involved in philosophical analysis of ethics, but they certainly are interested in the ethical and moral reasoning and activities of those engaged on both sides of Burkhardt's binary: with animal rights activists and with animal scientists.[119] Yet to report, the *Reconfigurations of Human/Animal Relations in Genomics and Beyond* project at Cesagen, Lancaster University, engages with animal scientists as part of its work, exploring how they frame their research and work through moral dilemmas.[120] Similarly, the *Use of Animals in Science* project based at the Institute for Science and Society, University of Nottingham, aims to investigate arguments used by scientists and animal activists and whether and how boundaries are drawn between "ethical" and "scientific" claims.[121]

Other social scientific studies, notably at Innogen, University of Edinburgh, have begun to investigate the commercial activities of the animal genomics sector, the likely socio-economic impacts of new developments, and the international regulatory climate for GM and cloned animals.[122] The social scientific investigation of laboratory animal genomics is then beginning to hit its stride. There remains however a tendency to orient to the production of human and institutional practice, agency, cognition and so on. But taking a small step from social science toward the history of science, there have been projects that have focused on, and sought to account for, the construction of *the animal* in scientific research.[123]

In *Making* Mice, Rader considers the construction of standardised laboratory mice.[124] Rader points out that scientists tend to produce a laundry list of material features that make the mouse appear without question the most suitable experimental model for human disease states. Garanga lists high fertility, genetic tractability, short gestation and susceptibility to disease, to which Cox and Brown add numerous genetically well-defined lines, modest cost and short generation times.[125] To this can now also be added the many sophisticated technologies for manipulating the mouse genome and the availability of the genome sequence.[126] Yet, just as with the pig in xenotransplantation, Rader contends that these justifications need to be understood as the outcome of a historical and sociological process more than the material nature of the mouse. This is not to say that high fertility, modest cost and so on are not valid reasons for choosing the mouse, but that to speak only in these terms decontextualises the mouse and "black-boxes" the places, values, politics and practices that led to its

---

development and use as *the* experimental model. Rader argues that the very notion of a "standardised" laboratory organism required intense negotiation over material, organisational and conceptual categories that are now taken for granted:

> *'Standardized organisms, therefore, need to be reconceived within a broader sociology of technoscientific work. These animals are the result, rather than the cause, of consensus among early twentieth-century experimental biologists'.*[127]

In discussing the various developers, producers and users of the laboratory mouse, Rader focuses primarily on the role of individuals, especially the 'passion and drive' of Clarence Cook Little. Little founded the Jackson Laboratory in the 1920s which is now home to around 2800 mouse varieties as breeding mice, frozen embryos or DNA samples.[128] These inbred mice, and all the others in labs across the world, are an allegory of animals under the human gaze.

6. Knowing, relating and looking at animals

The position of animals in the human gaze is ambiguous, and these ambiguities function at individual as well as societal and cultural levels. Animals are at times considered companions, members of the family even, and significant resources are deployed in saving particular species, especially when threatened by human activity. At the same time, research that ultimately destroys animals is conducted to better human health, and animals are destroyed or exploited for food, clothing and pleasure. Rats exemplify ambivalent identity, being loveable pets, detestable pests and scientifically 'neutral' laboratory animals.[129] On an individual level, hobby-farmers experience animals as both friends and sources of food, and those working in the meat industry need to manage both emotional attachment and detachment to the animals with which they work.[130]

It is tempting here to use the conjunction *but* not *and* to better capture the apparent paradox in these relationships: to the hobby farmer, animals are friends *but* also food; rats are pets *but* also killed for research; some species are conserved *but* others are hunted as pests. Berger suggests that our temptation to see *but* here is a vestige of a shift in human-animal relations during the industrial period.[131] At that time, a previous intimate and proximal relationship where animals were, and meant, many things (…*and*…) became one of distance, and *some* animals and *some* species were reduced to productive units (…*but*…). Yet following the collapse of modernism and the rise of late modernity/post-modernity, Franklin argues that we must return to seeing the *and*: 'The possibility of consistency in the realm of human-animal relations', writes Franklin, 'is less likely than differentiations'.[132] Genomic research needs to be understood in the context of this inconsistent and ambiguous landscape, reinforcing the need to think through and talk about human-animal relationships, representations, understandings, practices and so on.

Consider companion animals. Serpell cautions against aligning the companion animal genome with a human aesthetic that disregards effects on the animal. Serpell particularly targets negative consequences arising from genetic selection, noting that

---

selection for traits that appeal to our anthropomorphic perceptions has led to animals with painful or disabling conditions, citing the English Bulldog which suffers physical deformities and nasal and respiratory disorders. If the Bulldog had been produced through genetic engineering in agriculture, Serpell suggests, then there would be public protest, but it has been generated by 'anthropomorphic selection' and is accepted because it is part of a social, rather than economic or industrial, inter-species relationship.[133]

Serpell's analysis suggests that if technologies like genetic modification or marker-assisted selection become tools of the pet trade, then a different reaction might be expected than to their use in farming or agriculture.[134] But a reaction would be elicited only if these practices became common knowledge: breeding in agriculture *has* produced Bulldog-like horrors. Selection for production traits has generated diseases and disabling deformities in poultry that are not seen in animals that have not been selected for rapid growth,[135] and perpetuating the massive double-muscling cattle breed Belgian Blue, initially the outcome of a 'natural' genetic mutation, presents significant welfare problems. For example, 90% of Belgian Blue calves have to be delivered by caesarean section and Webster suggests that this runs close to contravening British law and the Protection of Animals Act. Webster argues that 'the whole [Belgian Blue farming] system depends absolutely on the deliberate production of a population of fundamentally unfit breeding animals, lethal recessives in fact'.[136]

It may be, therefore, that Serpell's observed lack of public disquiet over such horrors is a consequence of the persistent separation in Western culture of the food we eat from the means of its production, and that we don't really "know" our food animals at all.

However, the rise of the "welfare consciousness" is leading industry and farm animal scientists to consider trade-offs between maximising production whilst at the same time attending to welfare concerns, a process in which functional genomics may have a role.[137] But whether this solution fits with the needs and demands of the perceived target group – consumers – is a space for social scientific research. It may be that without this research, the technical drive to balance profits and ethics assumes too much about the social world to which it believes it is responding, the type of blind spot sociologists feel led, in part, to the current unstable position of GM crops and food.

Genomics might then be used as a conduit for explicating the varied understandings and relationships which we have with animals, but there are more immediate ways that current genomic practices and technologies change our understandings of animals. For example, by interfering in inherited characteristics, it is sometimes claimed that we are changing the animal that is known, what that animal "is", its "natural" form of life, its purposes and ends ("telos"). Whilst "traditional" animal farming works with those ends, genomic knowledge and biotechnology means that we can manipulate these ends to the point that they are disregarded.[138] The extent to which this principle is new to biotechnology can be overplayed. Sixty years ago Collingwood commented that for a cattle-breeder, an improved form is one better suited to that breeder's interests, and these are not identical to that of the cattle.[139] But

---

the projection of animals from genomic science is different. For example, Grasseni argues that biotechnology has shaped farmers' perception of animal nature and their practice of animal breeding to fit its patterns.[140] From ethnographic research at cattle fairs and farms in Italy, Grasseni shows how the 'science' of biotechnology has completed the industrialisation of animal bodies by shaping the 'art' of animal breeding and the 'vision' of cattle breeders. Standardised practices, expert advice and biotechnology now mediate breeders' more direct knowing of their animals and has shifted their concern from 'longevity' and 'sturdiness' to 'productivity' and 'statistical hazard control'.

The central organising principle is that biotechnology and genomics encourages a reductionist view of the animal. Michael argues that 'off the peg' genetic design reduces the animal to the sum of its genes, and the knowing of an animal's genetic make-up becomes enough to comprehensively know that animal.[141] For Bowring, this breaking up of animals into collections of genes and traits, whose relationship to the organism in which they reside is wholly contingent, and then manipulating genetic material accordingly, threatens the integrity and autonomy of animals on which the human-animal social relationship is based. Bowring argues animal companionship points toward the cultural position of animals as providers of 'aesthetic, affective and cognitive nourishment' in a way that genes clearly cannot, and he argues that a farmer's respect 'for organisms *as organisms*' is threatened by the genetic engineer and their laboratory.[142]

Concluding remarks: Policies in the genomic era

For Franklin, the anthropocentric separation of humans and animals is no longer tenable at either the social or theoretical level.[143] Through its various forms, genomics and associated biotechnologies offer new levels of analysis and new practices for the continued revision of the human-animal conceptual coupling, for the meaning of humanness, and for the representation of animals. Comparative genomics speaks confidently of concepts and tools to quantify the similarity and difference between animals where we might previously have seen predominantly qualitative (human–other) distinctions; stem cell research and cross-species transplantation mix material and make indeterminate hybrid beings; mice are bred to express human genetic defects and become humans by proxy; animals are reduced to information, genes, proteins, etc. temporarily assembled in valuable machines; and so on. For some, these are not only conceptual and sociological issues, but policy issues too.

Paula argues that genomics extends discomfort over the use of animals in science and food production beyond welfare and the "Three Rs" paradigm (replacement, reduction, refinement). Paula suggests that a constellation of intrinsic (eg, tampering with nature) and extrinsic (eg, food safety) citizen concerns, coupled with societal demands for regulatory transparency and accountability, requires a more open and inclusive discussion of animal genomics, which continually moves with technological developments, freely conceiving and discussing them and shaping the research agenda.[144]

A challenge for this evolving view of policy is to build mechanisms into decision-making by which conceptual framings that fall outside the dominant technical discourse can at least be entertained and thought through. For example, some scientists have been pressing for a 'whole-animal' approach to farm animal welfare. This treats animals as integrated and experiencing beings, and looks at animals' expressive body language in order to understand the "inside" of their experience. Wemelsfelder et al have no hesitation in making theirs an anthropomorphic approach, even inviting lay persons to evaluate animal welfare and validate their approach by considering how an animal seems to be feeling or reacting.[145] Crucially, these people are only "lay" in the sense that they are not scientists, not in the sense that they cannot understand or know how an animal "feels". This approach contrasts sharply with the currently accepted "scientific" and "objective" assessment of suffering which, for example, counts skin lesions or maladaptive behaviours. It also contrasts sharply with reductionist visions encouraged by genomics.

But notions of species integrity and telos fall outside current regulatory frameworks, and so too do some new scientific animal objects. There are now technologies, practices and products that traverse or transcend the boundaries between regulatory authorities and their terms of reference.[146] For example, there is no specific UK regulation with regard to the transplant of human stem cells into animals, but depending on the precise procedure and the precise materials, one or more of four different agencies might be involved in granting approval (Home Office, Animal Procedures Committee, Human Fertilisation and Embryology Authority (HFEA), Stem Cell Bank Steering Committee). Although complicated, at least the regulatory procedure is defined. This was not the case when in November 2006 the HFEA received two applications for a licence to derive stem cells from 'human' embryos created from animal eggs instead of human eggs. The embryos would contain animal and human DNA, and an HFEA spokesperson commented that 'we need to decide whether the law prohibits this research [and] whether it falls under our remit at all', clearly illustrating the challenge to existing structures posed by novel creatures.[147] In January 2007, after 'careful consideration', the HFEA determined that 'under current legislation, these sorts of research would potentially fall within the remit of the HFEA to regulate and license, and would not be prohibited by the legislation'.[148] But the HFEA decided that the legality of the research alone should not determine the granting of any licence. Rather, the HFEA decided to organise a public consultation on hybrid and chimera research in order to help determine the best way to proceed.[149] Stephen Minger, head of one team that wants to make the embryos, stated that they were 'happy with [the] decision to consult both public and scientific opinion regarding cloning of human cells using non-human eggs',[150] perhaps reflecting the new mood for dialogue on science policy issues.[151] This is a positive development, and I mentioned earlier that animal genomics may be a useful test bed for new ways of developing socially sensitive policies, for it is neither so new that its social consequences cannot be known or predicted, or so established that it is very resistant to change.[152]

Any new process of policy development would need to be anticipatory and reactionary, taking account of developments as they arise. After all, there will always be developments that just a few months or years before were not within the regulatory

---

gaze or were considered science fiction, and genomics has one more surprise. For a while there has been discussion on the possibility of using cloning techniques to resurrect extinct animal life.[153] Adding fuel to the discussion, the sequencing of Mammoth DNA[154] and the finding of the best preserved mammoth yet[155] led to inevitable media speculation on the possibility of 'growing' a woolly mammoth.[156] Discussion continues on whether cloning will allow us to come to "know" extinct animals. But perhaps a more important question is: what would we do with a Woolly Mammoth?

---

[1] The research for this paper was conducted at the ESRC Genomics Policy and Research Forum, University of Edinburgh, UK. Correspondence matthew.harvey@royalsoc.ac.uk The views expressed in this paper are the author's own.

[2] Eg, M. Michael. Technoscientific Bespoking: Animals, Publics and the New Genetics. New Genetics and Society 2001; 20 (3): 205-224; M. Michael and N. Brown. The Meat of the Matter: Grasping and Judging Xenotransplantation. Public Understanding of Science 2004; 13: 379-397; P. Macnaghten. Animals in Their Nature: A Case Study on Public Attitudes to Animals, Genetic Modification and 'Nature'. Sociology 2004; 38 (3): 533-551; N. Brown and M. Michael. Switching Between Science and Culture in Transpecies Transplantation. Science, Technology & Human Values 2001; 26 (1): 3-22.

[3] Eg, S. Franklin. Drawing the Line at Not-Fully Human: What We Already Know. The American Journal of Bioethics 2003; 3 (3): W25-W27.

[4] Eg, J. Robert and F. Baylis. Crossing Species Boundaries, American Journal of Bioethics 2003; 3 (3): 1-13; A. Holland and A. Johnson (eds.). 1998. Animal Biotechnology and Ethics, London: Chapman and Hall; F. Bowring. 2003. Science, Seeds and Cyborgs: Biotechnology and the Appropriation of Life, London: Verso (especially chapter 5); M. Hauskeller. Telos: the Revival of an Aristotelian Concept in Present Day Ethics. Inquiry 2005; 48 (1): 62-75.

[5] A. Muotri et al. Development of Functional Human Embryonic Stem Cell-Derived Neurons in Mouse Brain. Proceedings of the National Academy of Sciences 2005; 102 (52): 18644-18648.

[6] Michael, op. cit. note 2, p.205.

[7] H. Tovey. Theorising Nature and Society in Sociology: the Invisibility of Animals. Sociologia Ruralis 2003; 43 (3): 196-215, p197.

[8] Eg, S. Clark. 1982. The Nature of the Beast – Are Animals Moral? Oxford: University Press.

[9] Eg, A. Manning and J. Serpell. 1994. Animals and Society: Changing Perspectives, London: Routledge; H. Ritvo. 1997. The Platypus and the Mermaid and Other Figments of the Classifying Imagination, Cambridge: Harvard University Press.

[10] Eg, K. Tester. 1991. Animals and Society: the Humanity of Animal Rights, London: Routledge.

[11] Eg, Holland & Johnson, op. cit. note 4.

[12] Tester, op. cit. note 10.

[13] cf. Tovey, op.cit. note 7.

[14] Eg, A. Franklin. 1999. Animals and Modern Cultures: A Sociology of Human-Animal Relations in Modernity. London: Sage; L. Holloway. Pets and Protein: Placing Domestic Livestock on Hobby-Farms in England and Wales. Journal of Rural Studies 2001; 17: 293-307; R. Wilkie. Sentient Commodities and Productive Paradoxes: The Ambiguous Nature of Human-Livestock Relations in Northeast Scotland. Journal of rural studies 2005; 21: 213-230.

[15] Eg, A. Podberscek, E. Paul and J. Serpell. 2000. Companion Animals and Us: Exploring the Relationships Between People and Pets, Cambridge: University Press.

[16] See I. Diamond and D. Woodgate. Genomics Research in the UK – the Social Science Agenda, New Genetics and Society 2005; 24 (2): 239-252.

[17] There is a joke doing the rounds that there are more social scientists studying stem cell scientists than stem cell scientists studying stem cells. But for sure, few, if any, of those social scientists are investigating the role of animals in stem cell research.

[18] L. Paula. 2003. Genomics and Man's Attitude to Animals: Towards a Sustainable Relationship? In Genes For Your Food – Food For Your Genes: Societal Issues and Dilemmas in Food Genomics, R. van Est, L. Hanssen and O. Crapel, eds. Working Document 92, The Hague: Rathenau Institute; L.

Paula. Effective Policies in the Animal Genomics Era: How Best to Involve Ethics, Expertise and the Public. ATLA 2004; 32 (1): 383-389.

[19] S.J. Gould. 1996. Dinosaur in a Haystack: Reflections in Natural History. London, Jonathan Cape: 3.

[20] P. Hebert et al. Biological Identifications Through DNA Barcodes. Proceedings of the Royal Society of London B 2002; 270 (1512): 313-321.

[21] B. Holmes. Barcode Me. New scientist 2004; 26 June: 32-35.

[22] Eg, M. Hajibabaei et al. DNA Barcodes Distinguish Species of Tropical Lepidoptera. Proceedings of the National Academy of Sciences of the United States of America 2006; 103 (4): 968-971.

[23] R. Hanner et al. 2005. FISH-BOL Workshop Report (available at http://www.fishbol.org).

[24] See http://barcoding.si.edu/index_detail.htm.

[25] Holmes, op. cit. note 21.

[26] P. Hebert and R. Gregory. The Promise of DNA Barcoding for Taxonomy. Systematic Biology 2005; 54 (5): 852-859.

[27] Eg, K. Will, B. Mishelr and Q. Wheeler. The Perils of DNA Barcoding and the Need for Integrative Taxonomy. Systematic Biology 2005; 54 (5): 844-851; M. Ebach and C. Holdrege. DNA Barcoding is no Substitute for Taxonomy, Nature 2005; 434: 697.

[28] See Costa and Carvalho, this issue: F.O. Costa and G.R. Carvalho. The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics, Society and Policy 2007; 3 (2): 29-40.

[29] Will et al, op. cit. note 27, p.844.

[30] Ebach and Holdrege, op. cit. note 27, p.697.

[31] H. Ritvo. Border Trouble: Shifting the Line Between People and Other Animals. Social Research 1995; 62 (3): 481-499.

[32] Ibid; Ritvo, op. cit. note 9; H. Ritvo. Our Animal Cousins. Differences 2004; 15 (1): 48-68.

[33] J. Dupré. In Defence of Classification. Studies in the History and Philosophy of Biology and Biomedical Science 2001; 32 (2): 203-219.

[34] J. Dupré. 2002. Humans and Other Animals. Oxford: Clarendon Press: 46.

[35] Cf. J. Hey. 2001a. Genes, Categories and Species: The Evolutionary and Cognitive Causes of the Species Problem. Oxford: University Press; J. Hey. The Mind of the Species Problem. Trends in Ecology and Evolution 2001b; 16 (7): 326-329.

[36] J. Hey 2001a, op cit. note 35.

[37] B. Charlesworth and D. Charlesworth. 2003. Evolution, Oxford: University Press.

[38] B. Herrnstein Smith. Animal Relatives, Difficult Relations. Differences 2004; 15 (1): 1-23 (p.2).

[39] Hansard, 10 January 2006, column 171.

[40] L. Stein. End of the Beginning. Nature 2004; 431: 915-916.

[41] W. Enard et al. Intra- and Interspecific Variation in Primate Gene Expression Patterns. Science 2002; 296: 340-343.

[42] For a detailed analysis of the gene-number story and the human genome project, see T. Holmberg. Questioning 'The Number of the Beast': Constructions of Humanness in a Human Genome Project (HGP) Narrative. Science as Culture 2005; 14 (1): 23-37.

[43] J. Hecht. Chimps are Human, Gene Study Implies. New Scientist 2003; 19 May (available at http://www.newscientist.com/article.ns?id=dn3744)

[44] D. Wildman et al. Implications of Natural Selection in Shaping 99.4% Nonsynonymous DNA Identity between Humans and Chimpanzees: Enlarging genus *Homo*. PNAS 2003; 100 (12): 7181-7188.

[45] Ibid, p.7181.

[46] M. Goodman. Epilogue: A Personal Account of the Origins of a New Paradigm. Molecular Phylogenetics and Evolution 1996; 5 (1): 269-285.

[47] J. Marks. 2003. 98% Chimpanzee and 35% Daffodil: The Human Genome in Evolutionary and Cultural Context. In Genetic Nature/Culture: Anthropology and Science Beyond the Two-Culture Divide. A. Goodman, D. Heath and M. Lindee, eds. London: University of California Press: 132-152 (p.139).

[48] Ibid, p.132.

[49] A. Lippman. Prenatal Genetic Testing and Screening: Constructing Needs and Reinforcing Inequities. American Journal of Law and Medicine 1991; 17: 15-50.

[50] What Makes us Human? Channel 4, 12 April, 2006.

---

[51] Eg, P. Gagneux and A. Varki. Genetic Differences Between Humans and Great Apes. Molecular Phylogenetics and Evolution 2000; 18 (1): 2-13; E. McConkey and A. Varki. Thoughts on the Future of Great Ape Research. Science 2006; 309: 1499-1501.
[52] I. Van der Ploeg. 2003. Biometrics and the Body as Information: Normative Issues of the Sociotechnical Coding of the Body. In Surveillance as Social Sorting: Privacy, Risk, and Digital Discrimination. D. Lyon, ed. London: Routledge: 57-73.
[53] E. Zuckerkandl and L. Pauling. 1965. Evolutionary Divergence and Convergence in Proteins. In Evolving Genes and Proteins. V. Bryson and H. Vogel, eds. London: Academic Press: 97-166.
[54] http://www.medicalnewstoday.com/medicalnews.php?newsid=47782
[55] A. Ureta-Vidal, L. Ettwiller and E. Birney. Comparative Genomics: Genome-Wide Analysis in Metazoan Eukaryotes. Nature Review Genetics 2003; 4: 251-262.
[56] T. Brown. 2002. Genomes. Oxford: BIOS.
[57] C. Woese. Interpreting the Universal Phylogenetic Tree. PNAS 2000; 97 (15): 8392-8396.
[58] For an image of Darwin’s first tree, see R. Winters. The World Through Darwin’s Lens. Science 2006; 311: 179.
[59] E. Koonin, L. Aravind and A. Kondrashov. The Impact of Comparative Genomics on Our Understanding of Evolution. Cell 2000; 101 (6): 573-576.
[60] M. Rivera and J. Lake. The Ring of Life Provides Evidence for a Genome Fusion Origin of Eukaryotes. Nature 2004; 431: 152-155.
[61] V. Kunin et al. The Net of Life: Reconstructing the Microbial Polygenetic Network. Genome Research 2005; 15 (7): 954-959; W. Doolittle. Phylogenetic Classification and the Universal Tree, Science 1999; 284: 2124-2128.
[62] Ibid, p.2127-2128.
[63] Robert and Baylis, op. cit. note 4.
[64] Eg, Ibid; Hauskeller, op. cit. note 4; F. Bowring. Animal Wrongs. New Humanist 2004; 119 (2) (available at http://newhumanist.org.uk/724); Michael & Brown, op. cit. note 2; Franklin, op. cit. note 3; Macnaghten, op. cit. note 2.
[65] Eg, P. Karpowicz, C. Cohen and D. van der Kooy. Is it Ethical to Transplant Human Stem Cells into Nonhuman Embryos? Nature Medicine 2004; 10 (4): 331-335; L. Bailey. Candid Observations on the Current Status of Xenotransplantation, Xenotransplantation 2005; 12 (6): 425-426.
[66] C. Cohen. Creating Human-Nonhuman Chimeras: of Mice and Men. The American Journal of Bioethics 2003; 3 (3): W3-W5.
[67] Franklin, op. cit. note 3.
[68] Bailey, op. cit. note 65, p.428.
[69] Eg, The Guardian, The Daily Telegraph, The Independent 13 January 2006.
[70] Brown and Michael, op. cit. note 2.
[71] Michael and Brown, op. cit. note 2.
[72] N. DeWitt. Biologists Divided Over Proposal to Create Human-Mouse Embryos. Nature 2002; 420: 255.
[73] R. Grove-White, P. Macnaghten and B Wynne. 2000. Wising Up: The Public and New Technologies. CSEC: Lancaster University.
[74] Macnaghten, op. cit. note 2.
[75] Eg, ESRC. 1999. The Politics of GM Food: Risk, Science and Public Trust. Special Briefing no. 5. ESRC: Swindon; R. Grove-White et al. 1997. Uncertain World: Genetically Modified Organisms, Food and Public Attitudes in Britain. London: CSEC & Unilever; C. Marris et al. 2001. Public Perceptions of Agricultural Biotechnology in Europe (PABE). Final Report to the European Commission FAIR CT98-3844 (DG12-SSMI) (see www.pabe.net).
[76] DeWitt, op. cit. note 72; Karpowicz et al, op. cit. note 65; E. Check. Biotech Critic Tries to Sew Up Research on Chimaeras. Nature 2003; 421: 4.
[77] D. Haraway. 1997. Modest-Witness@Second-Millennium.FemaleMan©_Meets_OncoMouse™: Feminism and Technoscience. London: Routledge.
[78] A. Mitchell. Characteristics of Cattle Movements in Britain: An Analysis of Records from the Cattle Tracing System: Animal Science 2005; 80 (3): 265-273.
[79] G. Plastow. The Changing World of Genomics and its Impact on the Pork Chain. Advances in Pork Production 2003; 14: 67-71; E. Cunningham and C. Meghen. Biological Identification Systems: Genetic Markers. Revue Scientifique et Technique 2001; 20 (2): 491-499; J. Vázquez et al. Practical

Application of DNA Fingerprinting to Trace Beef. Journal of Food Protection 2004; 67 (5): 972-979; A. Eggen and J-.F. Hocquette. Genomic Approaches to Economic Trait Loci and Tissue Expression Profiling: Application to Muscle Biochemistry and Beef Quality. Meat Science 2003; 66 (1): 1-9.

[80] http://www.pyxisgenomics.com; http://www.identigen.com

[81] See http://news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/3751535.stm

[82] A. Donaldson and D. Wood. Surveilling Strange Materialities: Categorisation in the Evolving Geographies of FMD Biosecurity. Environment and planning D: society and space 2004; 22: 373-391.

[83] Cunningham & Meghen, op. cit. note 79.

[84] Eg, Eggen & Hocquette, op.cit. note 79.

[85] Donaldson & Wood, op. cit. note 82.

[86] DEFRA. 2006. National Scrapie Plan for Great Britain. London: DEFRA (available at http://www.defra.gov.uk/corporate/regulat/forms/ahealth/nsp/nsp1.pdf)

[87] Ibid, p.22

[88] It is possible however that that ram might continue to “exist” in some sense. Rams that have scrapie-susceptible genotypes can be nominated to contribute toward a semen archive. Whilst the slaughter will still be carried out, if accepted, that ram’s genotype will be stored and might be used in the future for breeding. This is because selecting only for scrapie-resistant genotypes might compromise important health and production traits and there may be a time when other political and economic factors will change the constellation of elements desirable in the particular mode of ordering enforced.

[89] A. Cockburn. A Short, Meat-Oriented History of the World: From Eden to Mattole. New Left Review 1996; 215: 16-42.

[90] H. Raadsma and I. Tammen. Biotechnologies and Their Potential Impact on Animal Breeding and Production: A Review. Australian Journal of Experimental Agriculture 2005; 45 (8): 1021-1032 (p.1021), emphasis added.

[91] Eg, M. Rothschild. From a Sow’s Ear to a Silk Purse: Real Progress in Porcine Genomics. Cytogenetic Genome Research 2003; 102: 95-99; K. Kim et al. A Missense Variant of the Melanocortin 4 Receptor (MC4R) Gene is Associated with Fatness, Growth and Feed Intake Traits. Mammalian Genome 2000; 11 (2): 131–135.

[92] WHO. 2005. Modern Food Biotechnology, Human Health and Development: An Evidence Based Study, Geneva: WHO.

[93] Eg, F. Nicholas. Breeding By Numbers: An Ancient Endeavour That Still Resonates in the Exciting Era of Functional Genomics. Australian Journal of Experimental Agriculture 2005; 45: 735-737; BBSRC. 2005. Review of Farm Animal Genomics in Relation to BBSRC-Funded Research. Swindon: BBSRC.

[94] J. Mason and P. Singer. 1980. Animal Factories, New York: Crown Publishers.

[95] Nicholas, op. cit. note 93.

[96] BBSRC, op. cit. note 93.

[97] Ibid; M. Roberts. The Place of Farm Animal Species in the New Genomics World of Reproductive Biology. Biology of Reproduction 2001: 409-417.

[98] R. Das. Production of Therapeutic Proteins From Transgenic Animals. Biobusiness 2001; February: 60–64.

[99] C. Schimdt. Belated Approval of First Recombinant Protein from Animal. Nature Biotechnology 2006; 24: 877.

[100] M. Dyck et al. Making Recombinant Proteins in Animals – Different Systems, Different Applications. Trends in Biotechnology 2003; 21 (9): 394-399.

[101] See also J. Clark and B. Whitelaw. A Future for Transgenic Livestock. Nature Review Genetics 2003; 4: 825-833.

[102] Roslin Institute. 2005. Reducing Nitrogen and Phosphorous Excretion by Poultry, Annual Report 03/04. Edinburgh: Roslin Institute.

[103] S. Jarvis, R. D'Eath and K. Fujita. Consistency of Piglet Crushing By Sows. Animal Welfare 2005; 14 (1): 43-51.

[104] M. Winter, C. Fry and S. Carruthers. European Agricultural Policy and Farm Animal Welfare. Food Policy 1998; 23 (3/4): 305-323.

[105] Roberts, op. cit. note 97, p.414.

[106] H. Buller and C. Morris. Farm Animal Welfare: A New Repertoire of Nature-Society Relations or Modernism Re-Embedded? Sociologia Ruralis 2003; 43 (3): 216-237 (p.218).

---

[107] C. Tisdel. Socioeconomic Causes of Loss of Animal Genetic Diversity: Analysis and Assessment. Ecological Economics 2003; 45: 365-376; J. Schakel and R. van Broekhuizen. Breeding and Society: The Art of Creating New and Multiple Equilibria. Proceedings of the SEFABAR Final workshop 2003 (available at http://www.sefabar.org/).

[108] J. Knight and A. Abbott. Full House. Nature 2002; 417: 785-786 (p.785).

[109] R. Waterston et al. Initial Sequencing and Comparative Analysis of the Mouse Genome. Nature 2002; 420: 520-562.

[110] S. Garanga. Preface to Mouse Genetics After the Mouse Genome. Cytogenetic Genome Research 2004; 105 (2-4): 165; C. Gunter and R. Dhand. Human Biology By Proxy. Nature 2002; 420: 509.

[111] Home Office. 2004. Statistics of Scientific Procedures on Living Animals, London: HMSO.

[112] M. Boguski. The Mouse That Roared. Nature 2002; 420: 515-516 (p.515).

[113] R. Cox and S. Brown. Rodent Models of Genetic Disease. Current Opinion in Genetics and Development 2003; 13: 278-283.

[114] http://www.medicalnewstoday.com/medicalnews.php?newsid=51467

[115] A. Smith. Embryo-Derived Stem Cells: Of Mice and Men. Annual Review of Cell and Developmental Biology 2001; 17: 435-462 (p.456).

[116] APC. 2001. Report on Biotechnology. London: APC.

[117] APC. 2003. Review of Cost-Benefit Assessment in the Use of Animals in Research, London: APC.

[118] J. Burkhardt. 1998. The Inevitability of Animal Biotechnology? Ethics and the Scientific Attitude. In Animal Biotechnology and Ethics. A. Holland and A. Johnson, eds. London: Chapman and Hall: 114-132 (p.130).

[119] Eg, N. Taylor. In it for the Nonhuman Animals: Animal Welfare, Moral Certainty, and Disagreements. Society and Animals 2004; 12 (4): 317-339; R. Einwohner. Motivational Framing and Efficacy Maintenance: Animal Rights Activists' Use of Four Fortifying Strategies. Sociological Quarterly 2002; 43 (4): 509-526; E. Paul. Us and Them: Scientists' and Animal Rights Campaigners' Views of the Animal Experimentation Debate. Society and Animals 1995; 3 (1): 1-21.

[120] http://www.cesagen.lancs.ac.uk/roar/

[121] http://www.nottingham.ac.uk/iss/research/Current-Research-Projects/Staff_projects/Hobson-West_animals.php

[122] http://www.innogen.ac.uk/Research/

[123] Eg, R. Kohler. 1994. Lords of the Fly: Drosophila Genetics and the Experimental Life. London: University of Chicago Press; K. Rader. 2004. Making Mice, Princeton: University Press.

[124] Ibid

[125] Garanger, op.cit. note 110; Cox & Brown, op.cit. note 113.

[126] J. Rossant and S. Scherer. The Mouse Genome Sequence: The End of the Tail, or Just the Beginning? Genome Biology 2003; 4 (4): article 109.

[127] Rader, op. cit. note 123, p.15.

[128] See http://www.jax.org/index.html

[129] B. Edelman. 'Rats are People, Too!': Rat-Human Relations Re-Rated. Anthropology Today 2002; 18 (3): 3-8.

[130] Holloway, op. cit. note 15; Wilkie, op. cit. note 15.

[131] J. Berger. 1980. About Looking. New York: Pantheon Books.

[132] Franklin, op. cit. note 15, p.2.

[133] J. Serpell. Anthropomorphism and Anthropomorphic Selection: Beyond the "Cute Response". Society and Animals 2003; 11 (1): 83-100.

[134] Advances in genomic medicine (or more accurately, post-genomic medicine) are now being readied for use in veterinary practice. Mian et al describe how genetic bio-profiling and biomarker technology will improve diagnostic and treatment services for pets, personalising treatment for companion animals. S. Mian, K. Slater and T. Cave. The Future of Biomarkers and Personalised Medicine in Companion Animal Practice. EJCAP 2006; 16 (1): 1-9.

[135] R. Julian. Rapid Growth Problems: Ascites and Skeletal Deformities in Broilers. Poultry Science 1998; 77: 1773-1780.

[136] A. Webster. Rendering Unto Caesar: Welfare Problems in Belgian Blue Cattle. The Veterinary Journal 2002; 163: 228-229 (p.229).

[137] Eg, D. Burt. Applications of Biotechnology in the Poultry Industry. World's Poultry Science Journal 2002; 58: 5-13.

---

[138] A. Holland. 1990. The Biotech Community: A Philosophical Critique of Genetic Engineering. In The Bio-Revolution. P. Wheale and R. McNally, eds. London: Pluto.

[139] R. Collingwood. 1965/1945. The Idea of Nature. Oxford: University Press.

[140] C. Grasseni. Designer Cows: The Practice of Cattle Breeding Between Skill and Standardization, Society and Animals 2005; 13 (1): 33-49.

[141] Micheal, op. cit. note 3.

[142] Bowring, op. cit. note 5, pp.139 & 138.

[143] Franklin, op. cit. note 15.

[144] Paula, op. cit. note 19.

[145] Eg, F. Wemelsfelder et al. Assessing the 'Whole Animal': A Free Choice Profiling Approach. Animal Behaviour 2001; 62 (2): 209-220.

[146] N. Brown and M. Michael. Risky Creatures: Institutional Species Boundary Changes in Biotechnology Regulation. Health, Risk and Society 2004; 6 (3): 207-222.

[147] http://news.bbc.co.uk/1/hi/health/6230945.stm

[148] Angela McNab, chief executive of the HFEA, quoted in the New Scientist, issue 2564, 11 January 2007, p.7.

[149] http://www.hfea.gov.uk/docs/HFEA_Final.pdf

[150] New Scientist, issue 2564, 11 January 2007, p.7.

[151] House of Lords Select Committee on Science and Technology. 2000. Science and technology – third report. House of Lords: London.

[152] Paula, op. cit. note 19.

[153] R. Lanza et al. Cloning of an Endangered Species (*Bos Gaurus*) Using Interspecies Nuclear Transfer. Cloning 2000; 2: 79–90; R. DeSalle and G. Amato. The Expansion of Conservation Genetics. Nature Review Genetics 2004; 5 (9): 702-712.

[154] H. Poinar et al. Metagenomics to Paleogenomics: Large-Scale Sequencing of Mammoth DNA, Science 2006; 311: 392-394.

[155] http://news.bbc.co.uk/1/hi/sci/tech/6284214.stm

[156] Eg, Ibid; BBC News 19 December 2005.

GSP online
Genomics, Society and Policy
2007, Vol.3, No.2, pp.29-40

The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of Fish

FILIPE O. COSTA AND GARY R. CARVALHO[1]

Abstract

Almost 250 years after the publication of the taxonomy-founding work *Systema Naturae*, by Carl Linnaeus, the inventory and catalogue of the planet's biodiversity is still far from complete: only *ca* 1.5 to 1.8 million of an estimated 10+ million species are so far described. Notwithstanding the remarkable merits of the Linnean system, the task is too vast ever to be completed using current conventional approaches. Such a staggering reality, and the customary difficulty that the scientific community and society in general experience to access taxonomic knowledge, has prompted the search for novel tools or approaches for species identification. Such a tool has been recently proposed in the form of a standardised short DNA sequence from an agreed-upon region of the genome, which is expected to ultimately provide a means of fast and robust identification of any species on the planet: the DNA barcode. Received with as much enthusiasm by some as skepticism by others, this novel tool was set in motion on a worldwide scale by means of an international consortium of organisations (the Consortium for the Barcoding of Life), thus becoming a large-scale horizontal genomics project. While anchored within the knowledge and principles of taxonomy, DNA barcoding possesses unique characteristics which anticipate a diverse scope of new applications and benefits for society. Notably, it places the completion of the biodiversity catalogue within the reach of a single generation, with the promise to assist greatly in the discovery of new species. Alongside long-term, ultimate goals, such as democratisation of access to taxonomic knowledge and assistance in writing the encyclopaedia of life, there are several more prosaic applications that may also impact society, not only in certain scientific fields, but also in a range of social and economic activities. Here, we will use DNA barcoding of fish as an example to illustrate foreseen applications, and as a basis to stimulate reflection on potential societal impacts of this horizontal genomics project.

Synopsis of the Barcode of Life Initiative

DNA barcoding: why and what for?

The realisation of the paucity of our knowledge about the world's biodiversity, together with the limitations of current approaches to biodiversity diagnosis, are the main driving forces behind new approaches to species identification. Estimates of the number of existing eukaryotic species range from the most conservative 3.6 million up to 100+ million, with 10 million favoured by most analysts as the nearest order of magnitude.[2] Circa 1.5 to 1.8 million species have been described to date.[3] Even considering the lower estimates, we still know only a minor fraction of the immensity of life's diversity. The current rates of discovery - about 10,000 new species are described per year[4] - are inadequate if such a huge gap is to be closed in the near

---

future. Moreover, no more than 5% of the named organisms are known in any biological detail.[5]

Taxonomists and systematists constitute the scientific frontline for addressing issues of life’s diversity. They have the central role of delineating species, naming, classifying and describing, and unravelling their phylogenies and placement in the tree of life. Ideally, these experts should make use of multiple sources of evidence and follow a hypothesis driven approach to resolve species identities and relatedness. Hence taxonomy and systematics are disciplines with high and pivotal intellectual content[6] that depend on only a few taxon-specific experts.

However, intervention of experts is frequently required beyond species delineation and goes as far as routine species identification, the very basis of most research involving organisms. For those who work in other areas of science this will likely come as a surprise. In fact, learning the nuances that separate closely-allied species assemblages is so complex that few biologists, even those who have devote their careers to taxonomy, can critically discriminate more than 1000 species. This serious constraint to the diagnosis of biodiversity is exacerbated by various peculiarities of current taxonomic protocols. Many such protocols rely heavily on phenotypic characters, and frequently require lengthy and detailed inspection of the specimens, and even dissection. There is no master key that could work for different groups of taxa, or even for a single species across its different life stages. Reliable identification depends on experts who have climbed a long learning curve and who are focused on a specific group of organisms. There is also a bias of focus in particular groups such as vertebrates and insects. Taxonomic literature is often difficult to locate, and the description of a new species does not assure its future recognition.[7] The compounded outcome of these difficulties, together with the shortage of taxonomic experts and resources allocated to taxonomy, impose a taxonomic impediment to understanding, utilising and conserving biological diversity.[8,9] Indeed, this taxonomic impediment extends to the whole scientific community and society in general, which experience a customary difficulty to access taxonomic knowledge.

In 2003, Hebert and co-authors introduced the concept of a DNA barcode, and proposed a new approach to species identification,[10] which offered great promise to counter many of the limitations above. The new approach is based on the premise that the sequence analysis of a short fragment of a single gene (eg, cytochrome c oxidase subunit 1), enables unequivocal identification of all animal species. Hence, analogously to the barcodes used in commercial products, the DNA barcode would provide a standardised tool for fast, simple, robust and precise species identification. Such a ‘barcode region’ would also have to evolve at a rate that would distinguish species from each other while remaining more or less identical for all members of the same species. Finally it would have to be flanked by conserved DNA regions so as to make the polymerase chain reaction (PCR), a method of targeted gene replication, practical.[11]

DNA barcoding differs in many ways from conventional taxonomic identification tools and approaches, over which it offers several advantages. It permits the identification of species from fragments, and from any life-history stage, as well as

---

the standardisation of a universal master key in a format that reduces ambiguity and enables direct comparison of specimens to a global reference database.

Before the introduction of DNA barcoding, various molecular methods were already applied to species identification,[12] though often these were of limited scope. None had the ambition, scale and, most importantly, the degree of standardisation of barcoding. Soon, it was proposed that the DNA barcoding concept be expanded in order to embrace all eukaryotic life forms, and promised to revolutionise taxonomy and influence other allied disciplines.[13] The emergence of controversy among the scientific community was not, however, unexpected.[14] Some critics are concerned about known limitations of the approach (see next section), and question the ability of a single gene to provide sufficient information for such an ambitious project.[15,16] Others fear that DNA barcodes will overrule conventional methods and become the unique standard for species delineation (which is different from species identification, as explained above). Or even that this fashionable and democratic tool will make species identification a frivolous, apparently straightforward task, leading to the abandonment of conventional methods, and the gradual demise of the whole scientific discipline of taxonomy and its essential intellectual input into the biological sciences.[17,18,19] As explained in the next section, some of this criticism may result from misconceptions about the rationale and approach of DNA barcoding.[20,21,22]

Rationale and approach

Hebert and co-authors[23] suggested a 650 base pair (bp) sequence of mitochondrial gene cytochrome *c* oxidase subunit 1 (COI) as the reference DNA barcode for all animal life. This gene occurs in the mitochondria of all eukaryotic organisms, and the initial appraisal revealed consistent resolving capability at the species level for many animals. There are a few recognised limitations of this barcoding region, namely the possible lack of resolution for recently diverged species or for particular animal taxa (eg, cnidarians), or the inability to detect cases of introgressive hybridisation. These exceptions are thought to represent only a minor percentage of the target species on a global scale. Moreover, it is expected that these limitations can be tackled using additional or alternative barcoding regions in a comparatively small number of exceptional cases. Thus, while COI has been elected as the prime DNA barcode for identification of animals (and probably for macroalgae, too[24]) the pursuit of regions of the genome appropriate for use as DNA barcodes in other eukaryotic life forms (eg, plants,[25] fungi[26,27]) is in progress.

The rationale and approach of DNA barcoding are essentially the same whichever region of the genome is selected. The basic premise is that for each currently known species an unequivocal match can be established with the DNA barcode obtained by reading a selected region of its genome. The DNA barcode sequence is not necessarily invariable within a species. Instead, the rationale is that individuals of a species share very similar sequences and that the barcode arrays for different species are usually distinct. This "matching hypothesis" constitutes the key starting point for launching and implementing the new bioidentification system. Every known species must be checked for the validity of this hypothesis. In doing so, a database linking a given species and respective DNA barcode array will be built. Reference barcoded

---

specimens of each species that have been identified by experts are deposited in a museum and therefore available for double-checking and for long-term study. Once this reference database is complete, it can be used to assign an unknown sample to a known species.

In comprehensive DNA barcoding studies conducted so far with Lepidoptera,[28] birds,[29] fish[30] and crustaceans,[31] a match between a DNA barcode and a known species has been found in more than 95% of the cases. Failure to obtain an unambiguous match may result from insufficient resolution of the DNA barcode (which can be the case when screening recently diverged species). However, as is the case with the studies above, ambiguities may also flag the presence of potentially unrecognised species that were overlooked by conventional methods. It is precisely in this type of setting that DNA barcoding can be of great assistance in the discovery of new species; it provides a molecular basis to test species hypotheses when data are not congruent with known species boundaries.[32,33]

It should be emphasised that DNA barcoding does not substitute the conventional protocol for delineating new species.[34,35,36] A hypothesis-driven approach should be followed to address potential new species supported by DNA barcoding screening. Ideally, new species hypotheses should be tested against various sources of evidence (morphological, ecological, reproductive, other molecular evidence, etc.)[37,38] which will continue to rely on the input of the taxonomic expert. Indeed, this novel tool will assist taxonomic experts greatly in their research efforts, and not only by releasing them from routine identifications; it also provides a fast means of screening and triage for large numbers of samples, enabling quick detection of potential new species, with consistent identification of morphologically distinct or cryptic life history stages and gender. Most importantly, the efforts of experts in the delineation and description of new species will have an immediate effect, since the new species can be readily tracked down using DNA barcoding. As new species are discovered and identifications revisited by experts, voucher specimen identifications and the global reference database can be updated and immediately effective.

Organisation and framework

In May 2004, little more than a year after the publication of Hebert and colleagues' seminal paper,[39] an international consortium of organisations - the Consortium for the Barcoding of Life (CBOL)[40] - instigated the worldwide implementation of DNA barcoding, thus launching a unique large-scale horizontal genomics project. CBOL's mission is to explore and develop the potential of DNA barcoding for research and as a practical tool for species identification. Consortium members include museums, herbaria, zoos, biodiversity research institutes, universities, conservation organisations, government agencies and private companies.

Since its inauguration, CBOL has experienced rapid development, which was particularly intense after the First Conference for the Barcoding of Life, held in February 2005 at the Natural History Museum, London. This conference constituted the first large forum for discussing DNA barcoding, and the proceedings were compiled in a special issue of *Philosophical Transactions of the Royal Society*.[41,42]

There was also progress in organisational aspects of CBOL with the establishment of five working groups to target specific aspects of DNA barcoding.

Currently CBOL counts more than 150 organisations from 45 countries in its membership. The first global DNA barcoding campaigns - the Fish Barcode of Life (FISH-BOL)[43] and the All Birds Barcoding Initiative (ABBI)[44] - have been launched, with the intention of assembling a reference database of DNA barcodes for all fish and bird species respectively. FISH-BOL expects to complete most of the inventory of all known fish species of the world by 2010. More recently, a campaign was launched for DNA barcoding all Lepidoptera, which already exceeded 8 600 species barcode records.[45] Finally, a thematic international network, Barcoding of Invasive and Pest Species,[46,47] is also in operation.

CBOL coordinates and promotes DNA barcoding on a worldwide scale, and endorses public access to DNA barcoding data. Both the Barcode of Life Database (BOLD)[48] and existing public genomic repositories (namely the GenBank of the National Center for Biotechnology Information (NCBI), the European Molecular Biology Laboratory (EMBL) and the DNA Data Bank of Japan (DDBJ)) will provide free access to DNA barcoding data. The Barcode of Life Initiative intends also to be both integrative and integrated with other worldwide taxonomic initiatives[49] such as the global Taxonomic Initiative for the Convention for Biological Diversity and the Global Biodiversity Information Facility (GBIF).

Currently DNA barcoding is a fully established approach, as recognized for example by the setting up of a ‘Barcode’ keyword for the identification of standard DNA barcodes in public genomic repositories[50] and by the creation of a specific theme-section for submission of DNA barcoding studies in the journal *Molecular Ecology Notes.*[51] There is also ‘The Barcode Blog’[52] at Rockefeller University, which, since June 2004, has been alerting the community to new studies on barcoding.

The promise of DNA barcoding

> *‘Imagine a world in which any person, anywhere, at any time can identify any species at little or no cost. That world is technologically upon us.’*[53]

By contributing to a break up of the ‘taxonomic impediment’, DNA barcoding promises to open doors to a diverse array of scientific and social applications and for a variety of end-users, from the scientific expert, to the individual citizens. Our improved ability to recognize existing and cryptic species will be of benefit to environmental sciences, forensics,[54] pharmaceutics, agriculture, conservation, biological and molecular evolution, to countermeasures to biological warfare, to name but a few.[55] We describe some of the applications to fish biology and fisheries in the next section, but first we shall deal with more general impacts.

The scientific field of taxonomy itself may well be one of the most immediate beneficiaries from DNA barcoding. With this new and powerful tool, taxonomists can be freed from maintenance and routine tasks, and focus instead on the description and

---

investigation of newly discovered species,[56] thus greatly accelerating the rate of new entries in the encyclopaedia of life. However, crucially for addition of any species' DNA barcode to BOLD, it will remain necessary to deposit a voucher specimen,[57] a requirement that emphasises the intended integration of DNA barcoding with the Linnean system.

Benefits will likely extend to more than purely technical aspects, and many view DNA barcoding as a key opportunity to revitalize the scientific discipline of taxonomy,[58] which has progressively become one of the most underfunded within biological sciences.[59] In fact, different views on the potential impacts of DNA barcoding in taxonomy have been a source of lively debate:[60] some critics suggest it will sound the death knell for a moribund but vital discipline,[61] while for others it is a valuable opportunity to revolutionise and revitalise the subject.[62,63,64]

Such a debate might soon become a redundant one, since the prime concept and current practice of DNA barcoding is built upon establishing a match between a known vouchered species and a DNA sequence. Thus, the success of DNA barcoding is a corollary of progress in taxonomy and biodiversity inventories. The Barcode of Life Initiative has already started to draw attention to the value of taxonomy and the key role of taxonomists, and has attracted new sources of funding for the discipline. DNA barcoding has prompted unprecedented large-scale biodiversity inventories, which will provide new raw materials for taxonomy and systematics. It is raising standards for incorporating taxonomic information into genomic data repositories.[65,66] Moreover, it is establishing a new and valuable type of genetic bank (by means of archiving tissue samples or DNA extracts) from which the genome of each species can be accessed in the future.[67,68] Hence, benefits start to emerge, not only for taxonomy, but also for other disciplines within biological sciences and related scientific fields.

The impacts of the Barcode of Life Initiative are expected to extend beyond the scientific arena and ultimately influence society as a whole. Through improved knowledge of the planet's biodiversity, societies will be able to manage biological resources in a more sustainable and responsible manner. Ironically, the taxonomic impediment is most acute in developing countries, where biodiversity is highest.[69] Features of DNA barcoding such as rapid, accurate and cost-effective specimen identification have the potential to democratize access to taxonomic information in all regions of the globe, and open the gates of biodiversity information to the ordinary non-expert citizen.

One of the most emblematic visions of the Barcode of Life Initiative is the ultimate creation of a handheld device that could be used to identify any life form anywhere and anytime at little or no cost.[70,71] Such a 'Bio-pod'[72] would not only provide a species identification, but would also enable an Internet link with the corresponding entry in the encyclopaedia of life, with images and related information about that species. Below is a commentary on an article about DNA barcoding posted in a free access website.[73] It synthesises in a rather spontaneous fashion the type of reaction that the ordinary citizen may have to the idea of a Bio-pod:

> *This could be fantastic. If there's something in it for the end user, millions of people will be turned into field taxonomists. A known plant gives ID; a weird one means you contribute to science. Upload your location at the same time, and you have new types of data: scientists could get plant coverage. With such data useful in climate research, a person could feel good everytime they ID a plant.*
>
> *Reading through Jamais' previous post, I can see this opens up a whole pandora's box of problems with patents and the openness of the whole model.*
>
> *Hopefully there's a wikipedia like model for this. Are these machines available now to non-researchers? What is their cost?*

This comment also captures many of the hopes for the societal benefits of the Barcode of Life Initiative, in particular the high expectations for improvements in bio-literacy.[74] In this respect, DNA barcoding could become to biodiversity what the printing press was to literacy.[75] A more bio-literate society as a whole would be able to take better and more responsible decisions about the management of our planet's biological heritage. The ordinary citizen would have the opportunity to become familiar with the surrounding biological diversity, and acquire a different perception of its relevance.[76] It may trigger a curiosity for living organisms, and improve awareness of biodiversity threats, and the perception of how human actions can have a detrimental impact on rates of species extinctions and ecosystem change. Eventually, a more bio-literate society could produce 'greener' individuals, who are more environmentally-responsible in their daily actions, and willing to undertake pro-active measures to minimize their own impact on the planet's biodiversity.

The example of fish DNA barcoding

Fish provide a suitable model for testing the implementation of DNA barcoding at a worldwide scale. Although they constitute the largest vertebrate group (about 50% of all vertebrate species), they have a manageable number of species: c.20,000 marine species (15,648 in Fish Base; 91 with subspecies); c.15,000 freshwater species (13,544 in Fish Base; 152 with subspecies) (705 species occur in both marine and freshwater systems); and c.80 brackish species (82 in Fish Base; 1 with subspecies). They are very diverse systematically, comprising three major groups of organisms: the jawless fish (Superclass Agnatha), such as lampreys hagfish; the cartilaginous fish (Class Chondrichthyes), including sharks and rays; and the immense variety of the bony fish (Superclass Osteichthyes) which include lungfishes, eels, tunas, sea horses, etc.[77]

Fish are also of economic value as a food source. Global figures for the value at first sale in 2000, is circa US$81 billion for capture fisheries and about US$52 billion for aquaculture (excluding plants).[78] In the same year the estimate for retail trade for ornamental fish in the USA alone was US$3 billion, and in 1984 in Australia the value of recreational sports fishing was estimated in US$2 billion.

Fish and fisheries resources comprise a key target group from which it is anticipated that DNA barcoding will bring larger and more immediate benefits.[79] Such a system

---

will offer a simple – and increasingly rapid and inexpensive – means of unambiguously identifying not only whole fish, but fish eggs and larvae, fish fragments, fish fillets and processed fish. This capability will yield more rigorous and extensive data on recruitment, ecology and geographic ranges of fisheries resources, and improved knowledge of nursery areas and spawning grounds, with evident impacts at the fisheries management and conservation levels. For example, the possibility of rigorous identification of fish species from eggs and larvae could be particularly fruitful, since phenotypic identification of early life stages can be especially difficult.[80] A study testing the application of molecular techniques in species identification of fish eggs revealed that over 60% of the eggs were misidentified when phenotypic characters were used.[81] Eggs from haddock and whiting may have been reported as cod's eggs in previous surveys, possibly leading to an inflation of stock assessments of cod in the Irish Sea. Moreover, early stage haddock eggs were detected in the Irish Sea, indicating the presence of a spawning stock of this species previously unknown to that region.[82] In a context of environmental change, induced, for instance, by global warming, the ability to rigorously identify fish species at all life history stages from egg to adult is particularly useful to assess changes in geographic distribution ranges, spawning grounds and nursery areas.

Another valuable application envisaged for DNA barcoding is the identification of prey-remains from predators' stomach contents. This could provide more detailed information about aquatic trophic chains, revealing which fish species are preyed upon by other fish species[83] or seabirds.[84] This type of information could then be incorporated into ecological models and provide new data for use in management and conservation.

Potential forensic applications of fish DNA barcoding include the monitoring of fisheries quotas and by-catch, inspection of fisheries markets and products, the control of trade in endangered species, and improvements in the traceability of fish products. In Australian waters, for example, sharks are illegally captured, largely for their fins alone. Quality sharks' fins can sell for $6,000-$8,000/kg in Hong Kong, and it is estimated that globally more than 100 million sharks are killed every year. Sharks are a particularly susceptible animal, since they are slow growing, long lived, undergo a long gestation and have low fecundity. Many species are morphologically very similar, and many are protected.[85] A tool enabling precise identification of shark species from fins, from the fisheries boat to the soup in the restaurant, could be of great utility for law enforcement and conservation of endangered species.[86] Such a tool could also be used for detection of fraudulent species substitutions in fish markets and fish food products, a practice that is generating concern among consumers.[87] A striking example comes from the Red Snapper (*Lutjanus campechanus*), which is one of the most economically important fisheries in the Gulf of Mexico, and which has been subject to stringent fishing restrictions due to stock depletion. Marko and colleagues[88] used sequences of the mtDNA gene cytochrome b, in an approach very similar to DNA barcoding, to show that as much as 77% of the *L. campechanus* fillets were mislabelled in USA markets. This level of mislabelling may adversely affect estimates of stock size and contribute to the false impression among consumers that the supply of fish is keeping up with demand.

In this section we have illustrated several potential and actual applications of fish DNA barcoding, which can have direct impacts on various activities from fisheries management to traceability of products in the food supply chain. These are in addition to the scientific applications mentioned in previous sections, such as detection and tracking of undescribed species, clarification of taxonomic uncertainties (eg, cryptic species) and identification of historical, archived and museum material.[89]

Conclusions

Humankind's outstanding technological and scientific achievements during the late 20th century include space exploration, the unravelling of the human genome, and the cloning of mammals. In the face of such accomplishments, the paucity of our knowledge of the world's biodiversity is both puzzling and disappointing.

Tackling the inventory of the planet's biodiversity is in itself a colossal task. The Barcode of Life Initiative promises to accomplish that task in the timescale of a single generation. Only time will tell if it succeeds. Like the Human Genome Project, DNA barcoding is not free of controversy. While in the aftermath of the Human Genome Project it became evident that information *per se* does not generate knowledge, there is today broad recognition of the value and relevance of that project, to the extent that various genome projects of other organisms have followed.

Among other virtues, DNA barcoding has already focused attention on problems of biodiversity. There is little doubt of the worth of the numerous applications of the technology, as for example described in the context of fish and fisheries. The success of various wider and more ambitious historical, philosophical, and sociological goals of barcoding will depend initially on the approach of the scientific community, but also on current and future recognition, investment and support from society.

Perhaps the decisive test for DNA barcoding will be the ability to effectively convert the immense information to be collected into tangible scientific knowledge - the completion of the encyclopaedia of life. Accomplishing this task will improve citizen bio-literacy of the world's biodiversity, and possibly engender a new vision and attitude towards non-human life-forms and their conservation and sustainable utilisation. The role of the classical amateur naturalist so typical of the Victorian era, would become extended to those with limited taxonomic knowledge, although taxonomic expertise would still underpin all barcoding applications. Should DNA barcoding succeed in its mission, the concurrent progress in taxonomy may rank among the most important scientific legacies of the early 21st century.

---

[1] The authors are at the School of Biological Sciences, University of Wales, Bangor, UK. Correspondence to f.o.costa@bangor.ac.uk.

[2] E.O. Wilson. Taxonomy as a fundamental discipline. Philosophical Transactions of the Royal Society of London Series B 2004; 359 (1444): 739.

[3] Wilson op. cit. note 2

---

[4] R.M. May. Tomorrow's taxonomy: collecting new species in the field will remain the rate-limiting step. Philosophical Transactions of the Royal Society of London Series B 2004; 359 (1444): 733-734.
[5] P.H. Raven. Taxonomy: Where are we now? Philosophical Transactions of the Royal Society of London Series B 2004; 359 (1444): 729-730.
[6] Wilson op.cit. note 2.
[7] K.J. Gaston and M.A. O'Neill. Automated species identification: why not? Philosophical Transactions of the Royal Society of London Series B 2004; 359 (1444): 655-667.
[8] J.E. Rodman and J.H. Cody. The taxonomic impediment overcome: NSF's partnerships for enhancing expertise in taxonomy (PEET) as a model. Systematic Biology 2003; 52 (3): 428-435.
[9] Q.D. Wheeler, P.H. Raven and E.O. Wilson. Taxonomy: Impediment or expedient? Science 2004; 303 (5656): 285.
[10] P.D.N. Hebert et al. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London Series B 2003; 270 (1512): 313-321.
[11] D.E. Schindel and S.E. Miller. DNA barcoding and the Consortium for the Barcode of Life. In: Success stories in the implementation of the programmes of work on dry and sub-humid lands and the Global Taxonomy Initiative. Convention on Biological Diversity Technical Series 2005; 21: 144-146 (available at http://www.cbd.int/doc/publications/cbd-ts-21.pdf).
[12] J.C. Avise. 2004. Molecular Markers, Natural History, and Evolution. 2nd edition. Massachussets, Sinauer.
[13] Hebert, P.D.N. and T.R. Gregory. The promise of DNA barcoding for taxonomy. Systematic Biology 2005; 54 (5): 852-859.
[14] V.S. Smith. DNA barcoding: Perspectives from a "Partnerships for Enhancing Expertise in Taxonomy" (PEET) debate. Systematic Biology 2005; 54 (5): 841-844.
[15] C. Moritz and C. Cicero. DNA barcoding: Promise and pitfalls. PLoS Biology 2004; 2 (10): 1529-1531.
[16] D. Rubinoff, S. Cameron and K. Will. Are plant DNA barcodes a search for the Holy Grail? Trends in Ecology & Evolution 2006; 21(1): 1-2.
[17] M.C. Ebach and C. Holdrege. More taxonomy, not DNA barcoding. Bioscience 2005; 55 (10): 822-823.
[18] M.R.de Carvalho et al. Revisiting the taxonomic impediment. Science 2005; 307 (5708): 353-353.
[19] M.C. Ebach and C. Holdrege. DNA barcoding is no substitute for taxonomy. Nature 2005; 434 (7034): 697.
[20] Hebert and Gregory, op.cit. note 13.
[21] R. DeSalle. Species discovery versus species identification in DNA barcoding efforts: Response to Rubinoff. Conservation Biology 2006; 20 (5): 1545-1547.
[22] D. Rubinoff. DNA barcoding evolves into the familiar. Conservation Biology 2006; 20 (5): 1548-1549.
[23] Hebert et al. op. cit. note 10.
[24] G.W. Saunders. Applying DNA barcoding to red macroalgae: a preliminary appraisal holds promise for future applications. Philosophical Transactions of the Royal Society B 2005; 360 (1462): 1879-1888.
[25] R.S. Cowan et al. 300,000 species to identify: problems, progress, and prospects in DNA barcoding of land plants. Taxon 2006; 55 (3): 611-616.
[26] X.J.I.A. Min and D.H. Hichey. Assessing the effect of varying sequence length on DNA barcoding of fungi. Molecular Ecology Notes 2007; 7 (3): 365-373.
[27] S. Yang. Researchers barcode DNA of 6,000 fungi species in Venice museum. UCBerkeley News. 2006 (available at http://www.berkeley.edu/news/media/releases/2006/12/13_fungi.shtml).
[28] M. Hajibabaei et al. DNA barcodes distinguish species of tropical Lepidoptera. Proceedings of the National Academy of Sciences 2006. 103 (4): 968-971.
[29] P.D.N. Hebert et al. Identification of birds through DNA barcodes. PLoS Biology 2004; 2 (10): 1657-1663.
[30] R.D.Ward et al. DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society Series B 2005; 360 (1462): 1847-1857.
[31] F.O. Costa et al. Biological identifications through DNA barcodes: the case of the Crustacea. Canadian Journal of Fisheries and Aquatic Sciences 2007; 67 (2): 272-295.

[32] P.D.N. Hebert et al. Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly *Astraptes fulgerator*. Proceedings of the National Academy of Sciences 2004; 101 (41): 14812-14817.
[33] A. Gomez et al. Mating trials validate the use of DNA barcoding to reveal cryptic speciation of a marine bryozoan taxon. Proceedings of the Royal Society Series B- 2007; 274 (1607): 199-207.
[34] DeSalle, op. cit. note 21.
[35] Wheeler et al, op. cit. note 9.
[36] M. Hajibabaei, G.A.C. Singer and D.A. Hickey. Benchmarking DNA barcodes: an assessment using available primate sequences. Genome 2006; 49 (7): 851-854.
[37] DeSalle, op. cit. note 21.
[38] A.P. Vogler and M.T. Monaghan. Recent advances in DNA taxonomy. Journal of Zoological Systematics and Evolutionary Research 2006; 45: 1-10.
[39] Hebert et al., op. cit. note 10.
[40]CBOL homepage: http://barcoding.si.edu/
[41] V. Savolainen et al. DNA Barcoding of Life. Themed issue of the Philosophical Transactions of the Royal Society B 2005; 360: 1803–1980.
[42] Reviewed in H.C.J. Godfray. To boldly sequence. Trends in Ecology & Evolution 2006; 21: 603-604.
[43] Fish-BOL homepage: http://www.fishbol.org
[44] ABBI homepage: http://www.barcodingbirds.org/
[45] All Leps homepage: http://www.lepbarcoding.org/
[46] K.F. Armstrong and S.L. Ball. DNA barcodes for biosecurity: invasive species identification. Philosophical Transactions of the Royal Society Series B 2005; 360 (1462): 1813-1823.
[47] S.L. Ball, K.F. Armstrong and G. Roderick. INBIPS: The International Network for the Barcoding of Invasive and Pest Species. In: Success stories in the implementation of the programmes of work on dry and sub-humid lands and the Global Taxonomy Initiative. Convention on Biological Diversity Technical Series 2005; 21: 160-162 (available at http://www.cbd.int/doc/publications/cbd-ts-21.pdf).
[48] S. Ratnasingham and P.D.N. Hebert. BOLD: The Barcode of Life Data System (http://www.barcodinglife.org). Molecular Ecology Notes 2007; 7 (3): 355-364.
[49] DeSalle, op. cit. note 21. Discusses the value of DNA barcoding to facilitate integration and interaction of current large scale biodiversity databases initiatives.
[50] R. Hanner et al. Data standards for DNA barcode records: indexing an encyclopaedia of life. Submitted, 2007. Currently available as: R. Hanner. Proposed standards for barcode records in INSDC (BRIs), 2005; http://barcoding.si.edu/protocols.html.
[51] http://www.blackwellpublishing.com/journal.asp?ref=1471-8278&site=24
[52] http://phe.rockefeller.edu/barcode/blog/
[53] Report of the Workshop ‘Taxonomy, DNA and the Barcode of Life’. Banbury Center, Cold Spring Harbor Laboratory, NY September 10-12, 2003.
[54] N. Dawnay et al. Validation of the Barcoding gene COI for use in forensic genetic species identification. Forensic Science International 2006; (in press).
[55] V. Savolainen et al. Towards writing the encyclopaedia of life: an introduction to DNA barcoding. Philosophical Transactions of the Royal Society Series B 2005; 360 (1462): 1805-1811.
[56] Ibid.
[57] C. Schander and E. Willassen. What can biological barcoding do for marine biology? Marine Biology Research, 2005; 1 (1): 79-83. Underlines the need to link DNA barcodes with museum vouchers.
[58] CBOL, op. cit. note 40.
[59] Wilson, op.cit. note 2.
[60] Smith, op. cit. note 14.
[61] Will, K.W., B.D. Mishler, and Q.D. Wheeler, The perils of DNA barcoding and the need for integrative taxonomy. Systematic Biology, 2005. 54 (5): 844-851.
[62] Hebert and Gregory, op. cit. note 13.
[63] D.E. Schindel and S.E. Miller. DNA barcoding a useful tool for taxonomists. Nature 2005; 435 (7038): 17.
[64] T.R. Gregory. DNA barcoding does not compete with taxonomy. Nature 2005; 434 (7037): 1067.
[65] Hanner et al, op. cit. note 50.

---

[66] R.H. Nilsson et al. Taxonomic reliability of DNA sequences in public sequence databases: a fungal perspective. PLoS One, 2006. 1: (e59). This paper raises the issue of the taxonomic reliability of DNA sequences in public sequence databases in a fungal context, but in fact this is currently a concern for all taxa. The strict conditions demanded for DNA barcoding records are helping to raise the bar for taxonomic reliability of sequences deposited in public databases.
[67] The Ocean Genome Legacy: http://www.oglf.org/
[68] P.R. Becker et al., Environmental specimen banking. Journal of Environmental Monitoring 2006; 8 (8): 776-778. For discussion on the importance of environmental specimen banking for different uses, including access to the genomes.
[69] Schindel and Miller, op. cit. note 11.
[70] Savolainen et al, op. cit. note 55.
[71] D.H. Janzen. Now is the time. Philosophical Transactions of the Royal Society of London Series B 2004; 359 (1444): 731-732.
[72] The expression 'Bio-pod' is taken from http://www.flmnh.ufl.edu/cowries/barcoding_intro.pdf.
[73] Posted by: Daniel Haran at October 20, 2005 05:37 PM at http://www.worldchanging.com/archives/003655.html.
[74] Janzen, op. cit. note 71.
[75] M. Holloway. Democratizing taxonomy. Conservation in Practice 2006; 7: 14-21.
[76] Savolainen et al, op. cit. note 55.
[77] R.D. Ward et al. DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society B 2005; 360 (1462): 1847-1857.
[78] FAO. The state of world fisheries and aquaculture, part 1: world review of fisheries and aquaculture. 2002, Rome: Food and Agricultural Organization, Fisheries Department.
[79] J. Lleonart, M. Taconet and M. Lamboeuf. Integrating information on marine species identification for fishery purposes. Marine Ecology-Progress Series 2006; 316: 231-238. Underlines the challenges of species identification of marine fisheries and the need for a global database network to share taxonomic knowledge. DNA barcoding would be of great assistance to such an approach.
[80] G.G. Pegg et al. MtDNA barcode identification of fish larvae in the southern Great Barrier Reef, Australia. Scientia Marina 2006; 70: 7-12.
[81] C.J. Fox et al. TaqMan DNA technology confirms likely overestimation of cod (*Gadus morhua* L.) egg abundance in the Irish Sea: implications for the assessment of the cod stock and mapping of spawning areas using egg-based methods. Molecular Ecology 2005; 14 (3): 879-884.
[82] Ibid.
[83] M.F. Sigler, et al. Diet of Pacific sleeper shark, a potential Steller sea lion predator, in the north-east Pacific Ocean. Journal of Fish Biology 2006; 69 (2): 392-405. Molecular techniques were used to identify some of the prey in stomach contents of the Pacific sleeper shark.
[84] R.A. Phillips et al. Diet of the northern fulmar *Fulmarus glacialis*: reliance on commercial fisheries? Marine Biology, 1999; 135 (1): 159-170. Availability of a DNA barcodes library of fish would have helped identify prey species of the northern fulmar.
[85] R. D. Ward, pers. comm.
[86] R.W.K. Chan, et al. Application of DNA-based techniques for the identification of whaler sharks (*Carcharhinus spp.*) caught in protective beach meshing and by recreational fisheries off the coast of New South Wales. Fishery Bulletin 2003; 101 (4): 910-914.
[87] M. Trotta et al. Multiplex PCR method for use in real-time PCR for identification of fish fillets from grouper (*Epinephelus* and *Mycteroperca* species) and common substitute species. Journal of Agricultural and Food Chemistry 2005; 53 (6): 2039-2045.
[88] P.B. Marko et al. Mislabelling of a depleted reef fish. Nature 2004; 430 (6997): 309-310.
[89] M. Hajibabaei et al. A minimalist barcode can identify a specimen whose DNA is degraded. Molecular Ecology Notes 2006; 6 (4): 959-964.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.41-43

Commissioned response to Filipe O. Costa & Gary R. Carvalho, 'The Barcode of Life Initiative: Synopsis and Prospective Societal Impacts of DNA Barcoding of Fish'

Real but modest gains from genetic barcoding

JOHN DUPRÉ[1]

Costa and Carvalho[2] make a compelling case for the practical utility of barcoding fish. Essentially the barcode, the precise sequence of a carefully chosen few hundred base pairs of a mitochondrial gene found in all eukaryotes, is intended as a definitive taxonomic criterion that can be added to the existing description of a species, but that has the enormous advantage of being applicable to any part of the organism. No existing part of most taxonomic descriptions can be applied to a fish finger, remains of animals in a fish's stomach or, probably, a detached shark's fin. Since, as they explain, there are important practical contexts in which it is desirable to relate such objects to their species of origin, detecting fraudulent fishmongers or violations of fishery preservation law, for example, the potential benefits are clear. They might also, in imaginable future circumstances, come to be of considerable benefit in providing definitive classifications for field biologists without easy access to relevant kinds of taxonomic expertise.

It is much more difficult to understand how the introduction of this technique will revolutionize the practice of taxonomy or enable the 'completion of the biodiversity catalogue within the reach of a single generation'. I'll leave aside for a moment the fact that this project is explicitly limited to eukaryotes (and in practice has only so far been applied with much success to animals), and therefore that this hypothetical catalogue will be missing out the very large majority of organisms and probably the majority of *kinds* of organisms. My first point is merely that the limiting factor in cataloguing life will surely continue to be the number of properly trained taxonomists.

Perhaps the most important theoretical point is that the introduction of genetic barcodes does nothing to solve the traditional problem of determining what a species is. A few decades ago, partly due to the effective advocacy of Ernst Mayr, it was widely believed (if by no means universally by professional systematists) that species could be defined as reproductively isolated groups—the so-called Biological Species Concept. Unfortunately it became increasingly clear that reproductive isolation was neither a necessary nor a sufficient condition for maintenance of the morphologically stable kinds generally agreed to be species. That reproductive isolation was not necessary was classically illustrated by the case of oaks,[3] in which distinct species appeared to have existed for long periods of time despite continuous and substantial interbreeding, but it now appears that many other groups of organisms might have been chosen to make the point. Lack of sufficiency was demonstrated by the existence of species dispersed among isolated populations, physically unable to interact and mate, yet showing no significant divergence.[4]

Genomics, Society and Policy, Vol.3, No.2 (2007) ISSN: 1746-5354

The biological species concept assumed a picture of evolution as consisting of a branching tree in which the initiation of a branch could be defined by reference to the establishment of reproductive isolation between the organisms represented by the new and the originating branches. If a group of organisms conforms to this model, and a reasonable period of time has passed since the occurrence of the speciation event marked by the branch in the tree, an appropriate mitochondrial gene sequence is likely to provide a good criterion for species membership.[5] However, a likely explanation for the problems with the biological species concept is that local diversity within a genus or even higher taxon is maintained by ecological differentiation rather than reproductive isolation. A compelling reason for believing this is the fact that interspecific hybridization is proving to be far more common than had for a long time been thought, even in groups such as birds, which have been widely taken to be a paradigm for application of the biological species concept.[6] Hybridization involves, by definition, exchange of genetic material, and hence makes the use of a genetic test for species membership unreliable. Using reproductive isolation as a definition of species will effectively deny the existence of a great deal of diversity that has traditionally been captured by descriptions of species.

Putting the matter another way, the Mayrian vision sees the cutting edge of evolution as isolated populations—incipient species—forging off into the future to find their unique destiny. A different view, made increasingly likely by the growing evidence of hybridization, proposes that many evolving groups will consist of a set of more or less hybridizing, though ecologically separated, kinds—but kinds sufficiently stable and robust to meet most traditional understandings of the species. Which of these pictures is correct is, at any rate, surely an empirical matter, and judging where and to what extent the latter situation obtains will again require the continuing engagement of taxonomists. And of course if it is not to be wholly question-begging, the relevant judgments will need to be based on a variety of criteria—morphological, behavioural, reproductive, etc. So the usefulness of genomic (barcode) taxonomy will be subject to the judgments of taxonomists, and the limiting factor on ‘cataloguing life’ will remain the availability of this expertise.

Costa and Carvalho also make the much more speculative suggestion that barcoding might greatly increase the interest in taxonomy among the general public, and thereby provide impetus for conservation measures. The basis for this suggestion is the vision of a hand-held barcoder—something that anyone could buy for $10, according to one of the websites Costa and Carvalho reference for this proposal—connected by wireless link to a central databank. Though it is certainly easy to underestimate the rate of technical change in an area such as this, I am a little sceptical about this prediction. Still, let us assume for the sake of argument that such a thing is indeed forthcoming in a few years time. I remain sceptical as to whether such a product would find a mass market. As a (very) amateur taxonomist of wild plants, it is my experience that most people find the identification of flora and fauna decidedly uninteresting. And I suspect that those who do not, find the acquisition of the (currently) necessary skills a large part of the attraction of the practice. But more interestingly, and paralleling my point about professional taxonomy, it strikes me that the sort of knowledge people already interested in such matters have had to acquire would be necessary to make the use of the barcode reader rewarding. The great

---

majority of plants, say, are, by definition, common. It is the expertise that enables one to pick out the uncommon or difficult-to-classify specimens that would make access to such a machine attractive. Constantly identifying brambles and stinging nettles would soon become tiresome.

I certainly don't wish to deny that the barcoding project has potential value to many kinds of users from professional taxonomists to enforcers of fishery protection legislation and amateur botanists and no doubt many others. It may even be a good investment of the very substantial resources it has attracted. But as with so many novel scientific projects nowadays, it has also attracted its fair share of hype. Suggestions that it will bring about the rapid cataloguing of all biodiversity, or that it will create a wave of popular excitement about taxonomy seem to me to belong in this category.

Acknowledgements

I am grateful to Maureen O'Malley for very helpful comments on an earlier draft of this paper. I gratefully acknowledge support from the Economic and Social Research Council (ESRC) and the Arts and Humanities Research Council (AHRC). The research in this paper was part of the programme of the ESRC Centre for Genomics in Society (Egenis).

---

[1] ESRC Centre for Genomics in Society (Egenis), University of Exeter, UK J.A.Dupre@exeter.ac.uk
[2] F.O. Costa and G.R. Carvalho. The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics, Society and Policy 2007; 3 (2): 29-40.
[3] L. Van Valen. Ecological Species, Multispecies, and Oaks. Taxon 1976; 25: 233-239.
[4] P.R. Ehrlich and P.H. Raven. Differentiation of Populations. Science 1969; 165: 1228-1232.
[5] As a matter of fact success to date has been limited to animals. It has proved more difficult to find a suitable barcoding sequence for plants, and currently it appears that several sequences may be needed. See W.J. Kress and D.L. Erickson. A Two-Locus Global DNA Barcode for Land Plants: The Coding rbcL Gene Complements the Non-Coding trnH-psbA Spacer Region. PLoS ONE 2007; 2(6): e508.
[6] J. Mallet. Hybridization as an Invasion of the Genome. Trends in Ecology and Evolution 2005; 20: 229-237.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.44-47

Commissioned response to Filipe O. Costa & Gary R. Carvalho, 'The Barcode of Life Initiative: Synopsis and Prospective Societal Impacts of DNA Barcoding of Fish'

DNA barcoding: potential users

PETER M. HOLLINGSWORTH[1]

The current popularity of DNA barcoding relates to its potential power coupled with its intuitively pleasing simplicity. It is based on the premise of using a standard short region of DNA as a universal tool for identifying organisms.[2] The aim is to establish a large-scale reference sequence database against which unknown samples can be queried for identification. Where sequences are found that are divergent from others in the database, the corresponding specimens are flagged up as potential new species warranting further investigation. Costa and Carvalho[3] describe some of the potential societal benefits of DNA barcoding in the context of fish identification and also summarise some of the potential benefits to the discipline of taxonomy itself.

Who will benefit most from DNA based identification?

Table I lists some examples of people who identify organisms and some of the approaches they may use. Much of the debate around DNA barcoding has focused on its implications for taxonomists and taxonomy. However, if DNA barcoding can be made accessible and cheap, arguably the greatest beneficiaries will be the many professionals whose work involves biological identifications, but whose job is not to carry out taxonomy *per se*. For this category of people, DNA identification can potentially offer a direct route to the knowledge generated by taxonomists, and avoid them having to spend their time learning how to identify organisms. The opportunities here are immense, given the range of professions that involve biological identifications, and particularly with the growing importance of biodiversity conservation. Of course, there will be limitations. Resource constraints will limit application in some circumstances. A pre-requisite for user confidence is validation of the approach in the taxonomic group of interest, and even a perfectly functioning DNA barcoding system will be dependent on the samples that are fed into it. For example, in field-based surveys targeting the appropriate habitats to sample can require considerable expertise, and the untrained field collector may miss some key species by not knowing where to sample in the first place. Nevertheless, once a sample is available, many professions would benefit from access to automated identification systems (Table I).

The likely use of DNA identification by the broader public is more difficult to quantify. Amateur naturalists are potential beneficiaries in that a cheap and easily accessible DNA identification service could represent a useful training/feedback tool as they are 'getting their eye in' on a given group of organisms. However, given that their enthusiasm is underpinned by an interest in morphological and ecological aspects of biodiversity, there are likely to be limitations as to the extent of uptake and their perceived relevance of DNA barcoding technologies.

Table I. Some examples of users of taxonomic information and their potential interest in DNA-based identification.

	User	**Identification need**	**Typical source of information for identification**	**Identification skills**	**Interest in taxonomy**	**Potential direct beneficiary of DNA identification?**
	Taxonomist	Assessments of diversity and distributions	Specialised literature, museum collections, field guides, databases, colleagues	High	High	Yes (for routine identification & sub-optimal specimens)
Non-taxonomic professionals	Ecologist/life scientist	Assessments of diversity and distributions, verification of research sample identity	Specialised literature, museum collections, field guides, databases, taxonomists, colleagues	Variable (low-high)	Variable (low-high)	Yes
	Conservationist	Assessments of diversity and distributions, identification of specimens to conserve	Field guides, images, databases, taxonomists, colleagues	Variable (low-high)	Variable (low-high)	Yes
	Legal (police, customs)	Identifications based on fragmentary material, forensic samples, wildlife crime/illicit trade	Field guides, images, targeted key, databases, taxonomists	Variable (low-high)	Variable (low-mid)	Yes
	Human/animal health	Identification of species with harmful attributes or medicinal properties	Field guides, images, targeted key, databases, taxonomists	Variable (low-high)	Variable (low-mid)	Yes
	Environmental protection	Identification of indicator species, identification of invasive/pest species	Field guides, images, targeted key, databases, taxonomists	Variable (low-high)	Variable (low-mid)	Yes
	Biodiversity utilisation (e.g. agriculture, fish management, forestry, horticulture)	Identification of species with useful attributes, identification of species that impede utilisation (pests/invasives etc)	Field guides, images, targeted key, databases, specialist colleagues, taxonomists	Variable (low-high)	Variable (low-mid)	Yes
Public	Amateur naturalist	Assessments of distributions and diversity	Specialised literature, museum collections, field guides, databases, taxonomists	High	High	Yes (as a training/feedback tool)
	Passively interested public	Occasional curiosity driven interest	Field guides, images	Low	Low	Possibly (may encourage interest in biodiversity)
	Uninterested public	-	Nothing	Low	Low	No

For the more general public, by improving accessibility to information, there is the potential to generate interest and to instil a greater degree of environmental responsibility.[4] Costa and Carvalho follow up this point and discuss the potential impacts of easy access to DNA barcoding for the 'ordinary citizen' and note that:

> *It may trigger a curiosity for living organisms, and improve awareness of biodiversity threats, and the perception of how human actions can have a detrimental impact on rates of species extinctions and ecosystem change. Eventually, a more bio-literate society could produce 'greener' individuals, who are more environmentally-responsible in their daily actions, and willing to undertake pro-active measures to minimize their own impact on the planet's biodiversity.*

However, it remains to be seen whether a simple technological solution to identifying organisms will have a major impact on public awareness of biodiversity. Access to a hand-held DNA 'barcorder' might lead to an increased interest in biodiversity, but this may be transient as technological developments in other walks of life compete for attention. In considering how society responds to resources available for identification, it is worth reflecting on situations where a high density of information already exists. In well characterised regions of the world which have comparatively low numbers of species such as the British Isles, there are many easy-to-use illustrated field guides which enable the identification of organisms from a range of taxonomic groups. However, this has not led to comprehensive bioliteracy.[5] In cases such as this, access to taxonomic information *per se* is not the limiting factor. Rather it is more likely to be attributable to the level of interest/enthusiasm/need being insufficient to acquire the knowledge, even with the necessary tools at hand. A hand-held DNA 'barcorder' may make identifications and access to associated information easier, but it still requires an inclination for use in the first place. The main drivers for environmental awareness for the general public seem likely to remain day-to-day contact with biodiversity[6] and exposure to captivating environmental reportage in the mainstream media.

The future use of DNA barcoding

DNA barcoding represents the key foundation step in the process of coordinating the use of DNA for taxonomy at the species level.[7] It has already accelerated the routine establishment of 'DNA ready' collections for herbaria and museums. It has triggered a formalisation of links between sequence data and voucher specimens in Genbank, and the development of informatics systems linking specimens, sequences, names and associated information. It has without doubt stimulated biologists using DNA data at the species level to pay much greater attention to coordinating activities and to think beyond producing local solutions for individual studies.

The vision put forward by Herbert et al,[8] Janzen[9] and colleagues for DNA barcoding has in turn prompted considerable debate. Several biologists have questioned both the scientific validity of the approach, and its broader implications for the future of taxonomy.[10] However, given the general benefits that have emerged from the

---

coordinated use of genetics in other disciplines and the societal need for biological identifications, it seems difficult to imagine that an appropriately implemented coordinated use of genetics in species level taxonomy can be anything other than beneficial. The exact form of this approach can be expected to evolve as technologies develop, and the future will undoubtedly involve approaches that go beyond single gene sequencing. But as long as there is a demand for the conservation and utilisation of species (eg, Table I), there will be a need for their identification. A system which enables this to be automated has to be worth developing.

Acknowledgements

I am grateful to Toby Pennington, David Harris, Mark Watson, Michelle Hollingsworth and Rebecca Ellis for helpful discussions on this article.

---

[1] Royal Botanic Garden, Edinburgh, UK P.Hollingsworth@rbge.org.uk

[2] P.D.N. Hebert et al. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London, series B 2003; 270: 313-321.

[3] F.O. Costa and G.R. Carvalho. The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics, Society and Policy 2007; 3 (2):29-40.

[4] M. Holloway. Democratizing taxonomy. Conservation in Practice 2006; 7: 14-21; D.H. Janzen. Now is the time. Philosophical Transactions of the Royal Society of London, Series B 2004; 359: 731-732.

[5] (c.f. Holloway, op. cit. note 4; Costa and Carvalho, op. cit. note 3.

[6] J.R. Miller. Biodiversity conservation and the extinction of experience. Trends in Ecology and Evolution 2005; 20: 430-434.

[7] Hebert et al, op. cit. note 2.

[8] Ibid

[9] Janzen, op. cit. note 4.

[10] M.C. Ebach and C. Holdrege. DNA barcoding is no substitute for taxonomy. Nature 2005; 434: 697; Q.D. Wheeler. Losing the plot: DNA "barcodes" and taxonomy. Cladistics 2005; 21: 405-407. K.W. Will, B.D. Mishler and Q.D. Wheeler. The perils of DNA barcoding and the need for integrative taxonomy. Systematic Biology 2005; 54: 844-851.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.48-51

Commissioned response to Filipe O. Costa & Gary R. Carvalho, 'The Barcode of Life Initiative: Synopsis and Prospective Societal Impacts of DNA Barcoding of Fish'

The Book of Life goes online

PETTER HOLM[1]

A walk in the park

It's a beautiful day for the great outdoors. You have decided to take a break from city life. Sunny fall weather; it's drying up from the rain last week. Perfect for picking mushrooms. You bring a basket, small brush, sharp knife. And the biopod, the latest generation life barcoder, 'Tricorder' edition.[2] After a short walk to your own secret mushroom place, you spot a patch of nice-looking specimens. Caps are 5–10 cm across, with slightly depressed centres. Slightly sticky. Colour brownish to dark brick-red. Gills close together. It could be the delicious 'Flirt' (*Russula vesca*). Or is it the poisonous 'Sickener' (*Russula emetica*)? You quickly scan it with the barcoder. There is a barely-audible hum as the device goes online. A few seconds later, the display shows *Russula vesca*. Great! Scrolling down the tiny screen, you're informed that its mild flavour goes well with lamb stew. Serve with a light red Italian. You fill the basket, and head to the supermarket for the rest of the ingredients you need to prepare a fine meal.

Linnaeus in the sky

This sort of scene becomes possible to envisage from Costa and Carvalho's synopsis on the Barcode of life initiative.[3] At first glance, it has a Star Trek feel to it: a landing party is beamed from the safety of the starship onto some planet 'where no one has gone before', equipped with tricorders serving as lifelines and generalised information gadgets. Whereas a real-life version of this scenario might have been dismissed as pure fiction a few years ago, the rapid rise of GSP and mobile 'phones have made it more realistic. The Barcode of Life Initiative extends just slightly what is now a familiar scene. Instead of dispensing with a map, compass and navigation skills, as the GPS did, the life barcoder promises easy access to the identity of the wildlife along your track. When one is equipped with such a hand-held device, it is as if the mushroom comes fixed with a label. Instead of the cumbersome task of teaching yourself how to be a taxonomist, or bringing one along from the local museum, you simply consult the virtual Linneaus in the sky.

From Costa and Carvalho's fine review, we already know how the Barcode of Life pulls off this feat. The barcoder analyses DNA from a tissue sample taken from the target specimen and links it to a barcode. With this barcode, the identity of your specimen is fixed as a specific location in a DNA-based species classification system, which also provides easy access to other relevant information, be it, in the mushroom case, the appropriate antidote or the wine that best brings out its flavour.

Barcoding and the Encyclopedia of Life

A virtual Linnaeus would be a wonderful thing. Such a system, fully operational, comes with a number of advantages. It can identify species from tissue fragments and regardless of life-history stage. Ambiguity is reduced and identification of look-alikes becomes straightforward. The identification of known species can now be safely left to amateurs, allowing the experts to focus on unknown species.

While Costa and Carvalho are excellent guides to the advantages of a fully functional barcode-of-life system, they are less explicit when it comes to the investment required before the system can go online. How much and what kind of work does it take to make a virtual Linnaeus? The key here is the classification system by which the DNA sequence from a specific genome region is linked to some (hierarchically ordered) list of named species. For a lay person to use a barcoder to identify species, the databases by which these links can be made must already be in place. There must be an 'Encyclopedia of Life', with information linked to barcodes. If a specimen's barcode is not registered, the amateur will remain uninformed.

This problem is comparable with one commonly encountered in supermarket checkout queues, when an item - usually from the fruit and vegetable section - lacks a barcode. When the cashier is confronted with a species exotic to him – is this a cantaloupe or a galia? – he must become an old-fashioned taxonomist, consulting, first, the super-market version of a field-guide. If this is unsuccessful, he must call up a real expert from the back of the shop somewhere to identify it. Only then can you pay for your merchandise and take it away with you.

A sizable supermarket contains around 50,000 items. Here, classification is reasonably easy: not only are there relatively few species, but all have been classified and priced prior to sale. The problem is not one of knowing the identity of your species, but making that information available at the checkout. Nature, by comparison, is a far grander kind of supermarket, storing many millions of items. Here, the inventory is not pre-established, but must be built from scratch. While the barcoder allows the lay person easy access to the labelled checked entries, there remains a problem with the un-labelled species. Since the barcode is encoded in the specimen itself, you will of course always get a reading. But if the species in question has not already been named and entered into the Encyclopedia of Life, your query will remain unanswered.

Setting up an Open Writing Workshop

A complete Encyclopedia of Life is not the only advantage of the Barcode of Life Initiative. Another major attraction is the ease by which entries can be added. To use Costa and Carvalho's vocabulary, barcoding will speed up species *delineation* as well as species *identification*.

Assume the Initiative produces the first draft of a DNA barcode ‘Encyclopedia of Life’ by adding the relevant DNA key to the list of all conventionally named and classified species. In the process, improvements such as the definition of the true identity of similar species will already have been made. Nevertheless, the basic problem is much the same as before, namely that most species remain unclassified. How could the DNA barcoding technology help fill in the blanks?

The first point emphasised by Costa and Carvalho concerns the economy of expertise. Since barcoding makes identification of labelled species easy, the professional taxonomists can concentrate their work on the uncharted territories. However, the taxonomist community should perhaps not rely on this, since the number of taxonomists in society is not a constant. Can we assume that resources freed up by an efficient species identification technology will be allocated to the task of species delineation? Given the tight budgets of the organizations employing taxonomists, and the constant struggle among worthy causes, the answer to this is unclear.

Another, perhaps more interesting point, concerns how a barcode classification system allows for the process of species delineation to be organised differently. Imagine that a cluster of unknown barcode readings has been reported by reliable sources, which leads to the formulation of a hypothesis of a new species. While the rejection or confirmation of such hypotheses will still require expert opinion, the barcoding technology invites broad participation in the collection of the information required to test it. Working from the fixed point of DNA-based identification, a protocol on data collection can be set up and distributed. In this way, authorship of the Encyclopedia of Life changes. Instead of the expert taxonomist working alone in the dusty dungeons of the museum, the Encyclopedia becomes a collaborative effort involving many different people.

A related point here concerns the status of the conventional taxonomist as expert. Initially, as underlined by Costa and Carvalho, the barcode classification of a given species is a hypothesis to be checked against the conventional classification. The conventional taxonomist’s expertise with the tools of the trade mean that he remains first author and gate keeper for DNA-based classification. If and when the technology proves itself, however, this is turned on its head. The conventional classification changes status, and becomes the hypothesis that must be checked against the barcode classification. The real experts, set to judge between true and false Linnean classification, are those who master DNA-based technologies. While this may look problematic from the point of view of today’s taxonomy profession, such is the normal destructiveness of progress. Indeed, the re-organisation of the taxonomy profession is an important feature of barcode technology. With the DNA barcode as classification key, folk taxonomy becomes, just as the Linnean classification did before, a new and interesting source of hypotheses for species identity.

A few dark possibilities

Will the world become a happier and more just place with the success of the Barcode of Life initiative? As always, new technologies produce both winners and losers when

---

they are let loose on the real world. A major question here is how barcoding might affect the balance of power in an already unfair world. Who stands to gain: the resource-rich of the North or the impoverished of the South?

Wouldn't it have been nice if the DNA barcoding, on top of everything else, also helped the poor and powerless? But this is not the case. The Encyclopedia of Life – in both its conventional and DNA-barcode versions – is more complete for the North than the South. The broad, democratic access to species identification by way of barcoding technology will therefore be of most relevance in the North. In the South, where most unlabelled species are to be found and the lack of resources to fill the blanks are most obvious, its usefulness is less clear. It could be argued, of course, that the efficiency of DNA-based delineation will give developing countries a chance to make inventories of their natural riches. Another, darker possibility is that such inventories will be of most interest to capitalist firms on bioprospecting excursions. While DNA barcoding may allow indigenous people to be co-authors of the Encyclopedia of Life, it may be the modern pharmaceutical giants that stand to reap the financial rewards.

Do you want to live in a supermarket?

The rich stand to gain while the poor lose out. In the face of this, the have-nots should organise and fight as best they can. Not to ban the technology, of course, but to reformat it in a way that can serve their interests. While we wait for this upcoming struggle, we can take time to consider whether a barcoded world is desirable. A romantic might put it thus: 'Do you really want to live in a supermarket - a world where every species comes pre-labelled for reading with a handheld device?' To the romantic, the answer is 'no', of course. To him, barcoding is but an extension of the iron cage of rationality, a place where the disenchantment of the world has reached an extreme, and all wilderness has been emptied of mystery and turned into yet another supermarket.

While I acknowledge this fear, however, I do not share it. The wilderness of the world simply cannot be contained in a classification scheme. Just like a map, classification does not really reduce the complexity of the world, but allows you to travel more effectively within it. The barcoder offers a fine meal of 'Flirt' mushrooms instead of violent vomiting induced by the 'Sickener'. Just like Star Trek's tricorder, the barcoder will not prevent the adventure, but serve as a valuable companion for your travel to places where 'no one has gone before.'

---

[1] Norwegian College of Fishery Science, University of Tromsø Petter.Holm@nfh.uit.no

[2] A tricorder is a handheld device used for scanning an area, interpreting and displaying data from scans to the user, and recording information. A tricorder is a prop in the Star Trek Universe. See www.startrek.com

[3] F.O. Costa and G.R. Carvalho. The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics, Society and Policy 2007; 3 (2): 29-40.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.52-56

The Barcode of Life Initiative: Reply to Dupré, Hollingsworth and Holm

FILIPE O. COSTA AND GARY R. CARVALHO[1]

We are grateful to John Dupré, Peter Hollingsworth and Petter Holm for their insightful and constructive responses to our article.[2] As with any new and increasingly applied approach, DNA barcoding has provoked considerable discussion, even though the basic technology employed is essentially a refinement of existing molecular approaches to systematics.[3] What characterises DNA barcoding is the attempt to standardise the molecular approach by focusing on one or a few genes with appropriate levels of among-species divergence, and to secure global accessibility to a common database. Additionally, although one gene, cytochrome oxidase I (COI), has proven to be informative across diverse taxa, the aim of DNA barcoding has not been to identify a single common gene, but rather to maximise standardisation across related taxa to ensure high comparability. DNA barcoding is essentially a practical tool that can be applied to compare a target DNA sequence with a reference DNA sequence that may confirm species identity or generate alternative hypotheses of species delineation. It is crucial therefore to appreciate that rather than replacing conventional approaches to taxonomy, which rely heavily on ecological, morphological and behavioural characteristics, DNA barcoding can in many cases render the Linnaean system more accessible. A recent cover of *Nature*[4] illustrating a modern-age Linnaeus wearing a contemporary naturalist's outfit and holding a barcode in his hand could not be more paradigmatic.

Rather than rehearse many previous discussions and articles on the merits and limitations of DNA barcoding, here we focus on just a few of the key points raised by Dupré, Hollingsworth and Holm. One of the initial points raised by John Dupré is the relative bias of existing DNA barcoding databases towards eukaryotes, especially animals. While the balance of current information is indeed skewed toward animals, the utilisation of alternative standardised gene sequences is being increasingly used in other groups, including land plants,[5] fungi[6,7] and other protists.[8] The driving characteristic of such inventories of biodiversity is to ensure high comparability and quality of reference databases. While it is clear, as with any technology, that certain taxa may remain recalcitrant to standard barcoding approaches, occasional combination of additional sequences, might be anticipated to disclose species identity for many organisms.

A major point made by Dupré is the link between DNA barcoding and the biological species concept. Although DNA barcoding may provide novel insights into the species concept,[9] it is certainly not the primary aim. While there may be direct concordance between presumed species status and reproductive isolation,[10] barcoding is potentially a practical tool that may facilitate the classification of ecological or morphological diversity within a taxonomic framework. It is not disputed that closely related species experiencing intermittent or frequent hybridisation will not be detected using conventional DNA barcoding approaches. However, where there appears to be

---

an uncoupling between observed ecological, behavioural or morphological heterogeneity and reproductive or molecular divergence, DNA barcoding can serve to facilitate the testing of alternative hypotheses or the application of alternative species concepts. Thus, rather than being constrained by or restricted to only those taxa conforming to Mayr's vision of biological species, DNA barcoding can extend taxonomic approaches to test evidence obtained at other biological levels.[11]

A further point raised by Dupré is the necessary limitation of any molecular taxonomy by the availability of high level taxonomic expertise. Coincident with the inclusive biological nature of DNA barcoding, is the recognition that highly trained taxonomists remain a crucial component of the species identification procedure. However, James Hanken,[12] in an historical overview of the rates of species discovery, suggests that, indeed, taxonomy should rely on technological innovation rather than expecting an improbable substantial enlargement of the community of taxonomic experts. Thus, a more realistic solution would be the implementation of innovative technologies into an integrative taxonomy framework, including digital imaging, high resolution X-rays, information technologies, DNA barcoding and other genomic approaches.

It is expected, however, that barcoding may extend the taxonomic process to those individuals lacking such skills, depending of course on the availability of a matching DNA sequence in the reference database. This point is linked to the more general issue of how DNA barcoding may facilitate interest in taxonomy among the general public, thereby serving to promote a case of conservation measures. It is accepted that many people, including the interested amateur naturalist, are motivated by an innate interest in the nature and patterns of biological diversity that will not necessarily be enhanced by molecular taxonomy. However, non-specialists within conservation bodies, museums and various government laboratories where molecular expertise might not exist can still submit samples to commercial companies for DNA sequencing, enhancing access. Such accessibility will enhance public awareness through the disclosure of new species, as well as increasing the profile of threatened species or risks posed by invasive species. The availability of the so-called 'Tricorder', although a seductive and distinctive vision for the future of DNA barcoding , is only one aspect. The recent discoveries of new species in what are considered well-documented taxa, such as birds,[13,14] lepidopterans,[15] and fish,[16] enhance the awareness of biodiversity among the general public that may relate more readily to the discovery of new species in easily recognisable and familiar taxa. Such disclosures can then serve as a framework for emphasising the much higher levels of hidden biodiversity and cryptic speciation in less familiar organisms, especially among microbes.

Peter Hollingsworth points out that one of the main drivers for environmental awareness for the general public is likely to remain the day-to-day contacts with biodiversity. While this is undoubtedly true, it is not necessarily exclusively so. As indicated above, increased awareness of environmental issues, which has been driven by such things as climate change and habitat destruction, has focused increasingly on the role of species in ecosystems. Thus, a more precise cataloguing of the levels and distribution of species diversity across the globe can only help to generate a case for public engagement in environmental and conservation policies.

While Petter Holm promotes many of the virtues of DNA barcoding, he questions the level of investment necessary to generate ‘a virtual Linnaeus’. Considerable global effort is already underway with various DNA barcoding campaigns and other biodiversity surveys (eg, Census of Marine Life[17]). However, there were two recent and important developments that will have a major impact in accelerating the availability of the ‘virtual Linnaeus’. One of them is the International Barcode of Life (iBOL),[18] an international consortium that aims to generate DNA barcodes for 500,000 species over a period of five years, starting in 2009. While such efforts will of course take time and considerable manpower and funding, they will be rewarded by gains in efficiency - in terms of both time and expenditure - by the scale of activity, the high throughput analysis and automation. It is difficult to envisage how such efficiencies could be generated by the hitherto taxonomic and geographically fragmented efforts to log biodiversity, especially where quality assurance and access to curated voucher specimens is more variable. Another recent salient development, The Encyclopedia of Life (EoL),[19] brings together the currently scattered global biodiversity initiatives, thereby ‘materializing’ the virtual Linnaeus. The EoL is conceived as an ‘ecosystem of websites that makes all key information about life on Earth accessible to anyone, anywhere in the world’. Ten years is the estimated time for the completion of the species pages for the 1.8 million known species, the first pages are expected to be available sometime in 2008. Inspired by Wikipedia, EoL intends also to consider the contribution of individual citizens, though all published information will be subject to authentication by scientists. DNA barcoding will dovetail well with this project, playing a key role, for instance, in providing unequivocal links between different source databases, such as between museum specimens and genomic databases (eg, GenBank). It is precisely the combined influence of such expansive biodiversity projects that we expect to have a significant impact in the bioliteracy and appeal for biodiversity of future generations.

Holm also raises the ethically important and timely issue of balancing such access and value to DNA barcoding efforts with geographic variability in biodiversity and infrastructure. The Consortium for the Barcode of Life aims to catalogue global biodiversity through the existence of various regional working groups associated with particular taxa. Obtaining and describing such diversity where it is at its greatest in the tropics, for example, but where infrastructure and expertise may be more variable, is a particular challenge. While such issues will serve to constrain overall activity, it is only through the generation of a global effort that sufficient resources and manpower might be mobilised to address such imbalance. The existence of what Holm refers to as ‘dark possibilities’, whereby DNA barcoding inventories may be exploited by capitalist firms or bio-prospecting excursions, is a possibility where information is available to all. Such activities are of course not new, and although the ethos of DNA barcoding would be counter to such exploitation, scenarios can be envisaged where useful products or species may be disclosed for use not just by the developed world. A case in point is the current DNA barcoding efforts in mosquitoes,[20] which of course are associated with considerable distribution of disease and mortality.

Concluding remarks

It is a useful exercise to critically evaluate the application and implications of new approaches to tackling well established problems such as taxonomy and species identity. DNA barcoding has often been regarded as an alternative or exclusive approach to generate a “new taxonomy”. As seen from many published studies on DNA barcoding, it is an approach that is by its nature dependent upon comprehensive reference to other biological levels of organisation. Genes evolve in individuals that often aggregate into populations that live in specific habitats, and it is crucial therefore to examine the extent to which biological heterogeneity may coincide with recognisable species groupings. Where a convenient genetic tag (stable, heritable and discrete) can be developed to recognise such entities, such as a DNA barcode, then this can be a useful practical tool that may, or may not, be used in conjunction with other independent corroboratory information. The integration of molecular approaches with conventional Linnaean taxonomy has in many cases stimulated new levels of investment in taxonomy.[21] While the prognosis for DNA barcoding appears sound, there will continue to be a need for conventional taxonomic expertise, though one might hope for increased integration and communication across the molecular and non-molecular divide. The key is not to claim exclusivity for DNA barcoding, but rather to promote awareness of the complexity and in some cases the fragility of diversity in the natural biological world.

---

[1] The authors are at the School of Biological Sciences, University of Wales, Bangor, UK. Correspondence to f.o.costa@bangor.ac.uk.

[2] F.O. Costa and G.R. Carvalho. The Barcode of Life Initiative: synopsis and prospective societal impacts of DNA barcoding of fish. Genomics, Society and Policy 2007; 3 (2): 29-40; and commissioned responses in same issue.

[3] A. Ferguson. 1980. *Biochemical Systematics and Evolution*. Blackie, Glasgow & London.

[4] Nature 2007; 446 (7133): 231-342, 15 March. Issue dedicated to the celebration of the 300th anniversary of Linnaeus’s birth.

[5] W.J. Kress and D.L. Erickson. A two-locus global DNA barcode for land plants: the coding rbcL gene complements the non-coding trnHpsbA spacer region. PLoS One 2007; 6 (e508): 1-10.

[6] X.J.I.A. Min and D.H. Hichey. Assessing the effect of varying sequence length on DNA barcoding of fungi. Molecular Ecology Notes 2007; 7 (3): 365-373.

[7] All Fungi DNA Barcoding Planning Workshop http://barcoding.si.edu/fungi.html.

[8] Report of the Workshop on ‘Protistan Barcoding, Reference Material and Cultures’, November 6-7, 2006, Portland, ME USA. Protist here are defined as ‘mostly microscopic eukaryotic organisms commonly referred to as algae, aquatic fungi, and protozoa’. Available at http://www.barcoding.si.edu/PDF/Protist%20Workshop%20Report%20-%20FINAL.pdf

[9] S.E. Miller. DNA barcoding and the renaissance of taxonomy. Proceedings of the National Academy of Sciences 2007; 104 (12): 4775-4776.

[10] A. Gomez et al. Mating trials validate the use of DNA barcoding to reveal cryptic speciation of a marine bryozoan taxon. Proceedings of the Royal Society Series B- 2007; 274 (1607): 199-207.

[11] P.D.N. Hebert et al. Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly *Astraptes fulgerator*. Proceedings of the National Academy of Sciences 2004; 101 (41): 14812-14817.

[12] J. Hanken. Taxonomy and Species discovery. DNA Barcoding for CoML Workshop, 15-17 November 2006, The Netherlands Royal Academy of Arts & Sciences, Amsterdam. Available at http://www.barcoding.si.edu/coml_agenda_2006.htm.

---

[13] P.D.N. Hebert et al. Identification of birds through DNA barcodes. PLoS Biology 2004; 2 (10): 1657-1663.

[14] K.C.R. Kerr et al. Comprehensive DNA barcode coverage of North American birds. Molecular Ecology Notes 2007; 7 (4): 535-543.

[15] Hebert et al., op. cit. note 11.

[16] B.C. Victor. *Coryphopterus kuna*, a new goby (Perciformes: Gobiidae: Gobiinae) from the western Caribbean, with the identification of the late larval stage and an estimate of the pelagic larval duration. Zootaxa 2007; 1526: 51–61.

[17] Census of Marine Life (CoML): http://www.comlsecretariat.org/

[18] The International Barcode of Life (iBOL) http://www.dnabarcoding.org/

[19] The Encyclopedia of Life (EoL) www.eol.org

[20] N. Kumar Pradeep et al. DNA Barcodes can distinguish species of Indian mosquitoes (Diptera: Culicidae). Journal of Medical Entomology 2007; 44 (1): 1-7.

[21] Miller, op. cit. note 9.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.57-69

Socialising Animal Disease Risk: inventing Traceback and re-inventing animals

ANDREW DONALDSON[1]

Abstract

Through a discussion of how the inventive practices of farm animal genomics interact with animal disease and food risk, this paper aims to expand our notion of what constitute the social dimensions of animal genomics, and why attention to animals and the contemporary issues surrounding them can offer us insights into genomics in general. Through a case study of the circumstances surrounding the invention of the DNA TraceBack technology in the midst of the BSE crisis, I argue that, rather than just examining genomics in and of itself, we should follow the inventions of genomics and their inseparable informational material environments. Then we can see the need for a social science approach that is more attentive to the inseparability of politics and science at the material level and can invent new, more inclusive, problems and research questions.

Contemporary connections

First, a confession: although I study agriculture, farm animal genomics[2] does not form a central empirical focus of my research. But in April 2001, when an epidemic of foot and mouth disease (FMD) was raging through farmed cattle, sheep and pigs in the UK, the field did come into contact with my own. That month, the BBC documentary series, Panorama, screened a polemic that focussed less on the impacts of FMD and more on the modern history and contemporary situation of British agriculture. With the cost of handling FMD to be a further drain on the public purse,[3] the documentary set out to question whether farming served the public interest well enough to justify its continued public subsidy. If left to trade un-supported in a liberalised global market, British farming would surely have to change in order to remain competitive. We were shown precursors to an evermore technologically intensive agribusiness, culminating in a brief interview with Graham Bulfield, then director of the Roslin Institute. He outlined the importance of genomics-based innovations in animal breeding to increase production efficiency and resistance to disease.[4] In that moment several of the objects of my research – animals and their diseases, expertise and the global agri-food system – were brought together with genomics.

At first glance, though, this is an association that seems to make little difference to the logics of animal production. The development of genomics-based approaches to breeding for improved productivity and disease resistance does nothing to alter the fact that farmed animals are being bred, as they always have been, for improved efficiency and utility. The introduction of quantitative genetics and now genomics into animal breeding has simply improved the detail and efficiency of the breeding process. Certainly some of the issues for social scientists around genomics identified

---

by Michael Banner and Jonathan Suk[5] are present. Current concerns around genomics and globalisation, governance and regulation, and future concerns about the role of social science in genomics policy and interdisciplinary work, could all find illuminating case studies within farm animal genomics. But what do these tell us about farming, about animal production, rather than genomics? Banner and Suk also highlight that social scientists should be concerned about the meaning of genomics for human identity.[6] But humans are not the only (or even the most numerous) animals encountered by genomics, and surely *social* scientists should also (if not more so) be concerned about the meaning and consequences of genomics for the identity or form of ‘the social’ or ‘society’. In this paper I tackle what that shift in perspective might entail and take a case study which does tell us something about animal production and about its shifting form.

My starting position is that the question of how to respond to the continual innovation of science and technology is a question of the contemporary and so must be a question for social scientists. The emergence and continual development of genomics and its associated fields is a contemporary phenomenon in the usually understood sense, in that it is novel and current, and this raises social issues as discussed by Banner and Suk. But the contemporary takes on other connotations when we try to pin down exactly what is contemporary about a given situation. Take the example of a new model of car.[7] Car design has changed over many years, but the various technologies and components of a car can be dated to different periods in the past. What is contemporary about a new car is its overall design, the way in which its components are currently assembled together and packaged. For anthropologist Paul Rabinow, the social question of the contemporary is all about the form that various interconnected elements take at any given point in time – literally about the shape of events.[8] In a similar vein, Nick Bingham has outlined a way of thinking that might “stop us from fetishising or becoming fixated on the objects, techniques, and processes of our newest scientific ‘revolution’”.[9] He suggests that we ask “what do particular biotechnologies materialise next to, in the neighbourhood of, connected with, and so and so on and so forth?”.[10]

Following Bingham’s logic, the position of genomics in the hinterland of my research becomes something of a virtue. By examining a genomics-based technology as only part of a set of contemporary connections – in this case of animal disease and food risk – I illuminate the potential scope of the ‘social aspects’ of animal genomics. In order to do this, in the following section I outline a particular understanding of ‘the social’ and then present a cognate account of invention that provides us with the key concept of the ‘informational material environment’. The next section goes on to outline the informational material environment of TraceBack, a technology for meat traceability.

Socialising and inventing

Whilst nonhuman animals have always figured in human culture,[11] they have had little direct presence in sociological concerns.[12] In recent years a number of researchers, in geography in particular, have sought to address this lacuna.[13] The position I start from here is that it is not enough to simply acknowledge animals as

---

sociological actors within a conventional view of society. Rather, it is better to rethink our idea of society or the social in such a way that the inclusion of nonhuman animals (or any other nonhuman thing for that matter) becomes obvious. The particular saliency of the concepts of 'socialising' and 'invention' that I am going to outline can be traced in part to the philosophy of Alfred North Whitehead. With his focus on reality as process, Whitehead used the term society in a way rather different to the now conventional sociological understanding. For Whitehead, a society, rather than being a bundle of 'social relationships' between people, was any composite entity (whether it involved humans or not) that endured over time.[14] To describe something as 'social' designates only that there is something interesting about the way that it is assembled and held together over time and space, whilst saying nothing about what it is, or how it is held together.[15] These ideas resonate strongly with the spatial and temporal understandings of form, interconnection and association that Rabinow and Bingham espouse.

Practitioners of Science Studies, particularly those now associated with Actor-Network Theory (ANT), have explored such ideas though studies of laboratories and technological development processes. They have arrived at a view contrary to the usual sociological position that society can be introduced as an explanatory factor, suggesting instead that society itself is always what requires explanation. This position has been termed a 'performative' view of society.[16] What this means is that society is not a permanent, solid backdrop to actions. Instead, society is that which those actions continually produce. Which begs the question: what constitutes those productive activities? They are variously constituted through different "modes of existence"[17] such as religion, law, family, the state, commerce, the sciences etc. – all of those things which we assign to the domain of the 'social' as long as we think society is behind them, structuring them. Society is made up from all of those types of activity which provide us with ways to talk about, experience and order the world, activities which make reference to an outside world and which provide some commonality, however fleeting. The conventional view of society could be termed 'extensive' (society is all-encompassing and exists outside of action) and the performative view 'intensive' (society is situated and created through action).

Perhaps because the originators of ANT explicitly examined the intensive practices – the actual doing – of science and technology, rather than just the purported philosophies or outcomes, they also took note of the importance of nonhuman things in the continual creation and maintenance of society. All the description, measurement and standardisation of the world and the performance of identity would not endure collectively if it were not for the material technologies that are more durable than face-to-face human interaction. Some of these technologies also permit more diverse forms of interaction with the other nonhuman things that make up the biophysical world. Paralleling Whitehead's usage, the performative view of society is also a view of society as 'more-than-human'.[18]

From this perspective, what do the natural sciences bring to more-than-human society? They are among the ways in which nonhumans are 'socialised'.[19] This literally means that the sciences make nonhumans amenable to being part of the more-than-human society, part of the ever-changing collection of negotiated associations

---

that bind together entities. New members of society (which we often think of as the discoveries of science) are identified, classified, measured, formatted, understood and made available to existing members of society through those understandings.[20] So the sciences that make nonhuman animals their object are a way in which nonhuman animals are socialised – although they are far from the only way, as nonhuman animals have clearly been part of more-than-human societies for a very long time. A performative understanding of this process suggests that socialising is not merely a process of bringing things that are ‘out there’ ‘in here’. Rather than the discovery of already existing objects in the world, the sciences are engaged in invention.[21] And rarely, in the age of molecular biology and particle physics, are the nonhuman objects of the natural sciences as readily identifiable by the layperson as a whole animal. A social conceptualisation of invention, as I will outline it here, can also tell us more about the nature of nonhuman entities as they are socialised.

Invention is an essential element of the sciences’ capacity to socialise and is also the key to their capacity to drive technological innovation. As Whitehead stated with regard to the increased professionalisation and institutionalisation of scientific research: “the greatest invention of the 19th century was the invention of the method of invention”.[22] In outlining some important features of invention in science-driven pharmaceutical development, Andrew Barry[23] draws on the work of both contemporary philosopher Isabelle Stengers (herself influenced by Whitehead) and 19th Century sociologist Gabriel Tarde[24] to give a performative view of invention. Tarde conceptualised interaction amongst humans in terms of imitation and invention. Imitation is the process by which ideas, practices, technologies and so on spread, whilst invention is the creation of new configurations of elements, new composite entities which will go on to be part of ever more complex composites. In a manner analogous to Whitehead’s societies and the notion of the contemporary outlined in the introduction to this paper, these new composite entities are not simply reducible to their original elements.

Such a notion of invention infuses the work of Stengers on modern science, as she focuses on the invention of questions, new composites and the experiments that put them to the test.[25] In his analysis of pharmaceutical R&D, Barry makes use of a history of chemistry written by Stengers and Bensaude-Vincente.[26] He takes the term “informed materials” to describe more specifically what is invented in pharmaceutical R&D processes if Tarde’s sociological perspective is adopted. The composite nature of the invented molecule is evidenced in its “informational material environment” – the accumulated data on the molecule and its action, the legal information about intellectual property rights, computer models and databases and so on.[27] The perception and comprehension of the invented molecule are inseparable from this informational material environment.[28]

These insights add extra potency to Bingham’s suggestion that we examine what new biotechnologies *materialise* with. The process of invention results in more than just a novel object, technique or process. It produces complex composites, informed materials inseparable from their informational material environment. Informational material environments are a way of conceptualising the socialised form of an object. They are shorthand for the many practices of observation, measurement, recording and production that are necessary to make an object mobile and interactive. In the informational material realm of genomics, the molecules of genes themselves literally encode information about their potential interactions and the further informational material environment such interactions will generate. And it has become increasingly apparent that this information is embedded in the wider material interactions of genome, proteome and other biological systems. The problem we have now is that, with such complex composites, it becomes difficult to isolate exactly what is being socialised/invented – introduced in a novel way – and what the ramifications may be within contemporary events. The next section of the paper examines a specific invention and aims to place it within its informational material environment.

Risk and traceability

Identigen's DNA TraceBack™ technology makes use of key elements of contemporary genetic/genomic science: single nucleotide polymorphisms (SNPs - consistently located small variations in the genome of a species) an ultra-high throughput genotyping platform and integrated information technology interfaces.[29] Identigen was founded in 1996 by researchers from Trinity College Dublin's Institute of Genetics with the intention of providing guaranteed traceability of beef products through genotyping. The Irish supermarket Superquinn participated in the technology proving and became the first supermarket chain in the world to guarantee the traceability of its beef through the use of TraceBack "to identify not only the farm the animal has come from, but the actual animal of origin as well"[30] and to present this information to customers in its product labelling. SuperQuinn claimed an 11% increase in beef sales from 1999 to 2000, following the introduction of TraceBack.[31] In 2001 Superquinn won the Unilever Award from the International Grocery Distributors in recognition of its use of TraceBack in response to customer needs[32]. The success of TraceBack continued when, in 2006, Tesco announced that it would also use the technology for beef traceability in its Irish operation. Taken by itself this story of an innovative biotechnology raises questions. Why do supermarkets need to be able to trace their beef products? Why is this a customer need? What are the circumstances that led to the invention of TraceBack? These all concern animal diseases.

We need to take a small diversion. Much of my research has focused on the development of discourses and technologies of biosecurity in agriculture, during and after the 2001 FMD epidemic. More complete stories about biosecurity can be found elsewhere;[33] for the purposes of this paper it is necessary only to note the analytical direction it points us in with respect to animal diseases. In relation to agriculture, biosecurity is usually taken to refer to the environmental elements of disease prevention and control, a range of hygiene procedures and management techniques that can maintain a separation between crops or livestock and pathogens. In the UK, biosecurity used to be confined largely to technical discussions and was not widely used amongst farmers. During the 2001 FMD epidemic, biosecurity became a watchword for disease control policy, a discourse to shift responsibility for the epidemic and its mismanagement from government to farmers, and a reason for the surveillant control of people.[34] In wider scientific circles, it is acknowledged that biosecurity entails more than just on-farm hygiene; it "involves all sorts of things like

---

the testing of animals, the vaccination of animals, isolation facilities, and so on."[35] And, to further muddy the waters, outside of mainstream political and agri-food industry understandings of biosecurity, preliminary findings in some recent research have suggested that we should also conceive of biosecurity as involving both animal welfare and the health and safety of consumers with respect to disease in the food chain.[36] Adding yet another dimension, Bruce Braun has characterised biosecurity as a geopolitical strategy that seeks to deal with the unpredictability of the biological world. He defines this unpredictability in terms of the 'virtuality' or continual emergence that marks biological systems and situates the debate in terms of the 'molecularization of life', emphasising the collective plunge into uncertainty and insecurity that has resulted from "advances in molecular biology, genetics and biochemistry" and the view of the world they provide.[37]

In short: the increased discursive focus given to biosecurity marks an increased attention to biological *risk*[38] in various forms. The rise of biosecurity discourse in UK agriculture is not primarily about disease management, but about *risk* management and about the new forms that this might necessitate.[39] And risk has received a lot of attention from social scientists in recent years. For instance, in 1999, Sheila Jasanoff gave an overview of two decades of research and noted that risk had "become *the* organising concept that gives meaning and direction to environmental regulation"[40] (italics in original). More recently it has been noted that standardised methods of risk assessment and risk management have become major drivers in every sphere and level of public and private sector decision-making.[41] Risk thinking is a key component of all contemporary modes of organisation and regulation, and social scientists have, throughout the rise of modes of risk thinking and risk-based regulation, attempted to demonstrate that risk denotes more than just the probability of something bad happening.[42] Jasanoff sums this work up as demonstrating that risk is "the embodiment of deeply held cultural values and beliefs … concerning such issues as agency, causation and uncertainty."[43]

Although risk is not a new way of thinking or ordering,[44] many commentators note that new categories of risks are emerging, especially with respect to food and agricultural production.[45] It has become common for social scientists to assert, following Ulrich Beck,[46] that we now live in a 'risk society'. Wealth production, through technological development, has led to the production of new risks. Using risk in this sense denotes the production of material circumstances that could have potentially widespread detrimental effects on the environment and human beings. As they evidence in food scares, these new types of risk follow more complex pathways, further distanciated in time and space and less visible to a consuming public.[47] All of which highlight the importance of Jasanoff's observation about the contingent construction or 'embodiment' of risk.

Another way to think about these modernisation risks, following an ANT approach, is in terms of an increased 'entanglement' in the world.[48] In terms of the conceptual framework outlined in the previous section this would consist of a multiplication of new social composites through technoscientific invention. From a similar conceptual starting point Stassart and Whatmore[49] have argued that these types of food risk are 'transacted' as a property of both the growing distance between producer and

---

consumer – both physically and in terms of knowledge and practices – and the enduring physical/bodily and emotional closeness that people have to food. Such is the strength of these connections that even animal disease episodes that do not pose great risks to human health (such as FMD) can have an impact on consumer confidence as they demonstrate the vulnerabilities of complex agri-food systems.[50]

One of the key animal disease/food scare episodes of recent years determined the informational material environment – the set of entangled relationships of production technologies and consumption practices –which gave rise to TraceBack. The crisis surrounding Bovine Spongiform Encephalopathy (BSE) has been held up as having the same impact on agriculture as Beck’s favourite example of a modernization risk, radiation as epitomised by the Chernobyl disaster, did on the nuclear power industry.[51] The story of BSE is now widely known and researched, but I will rehearse the key elements here.

BSE is caused by an abnormal form of a prion protein found in the nervous system of cattle. It was first identified in cattle in England in 1986, but it is thought that the disease may have developed, unclassified, during the 1970s.[52] The rapid spread of the disease amongst cattle in the late 1980s was attributed to the widespread use of cattle feed containing meat and bone meal (MBM) from rendered carcasses, which in turn could contain remnants of brain and spinal tissues of BSE infected cattle. The use of MBM had been seen as a symbol of modern efficiency within agriculture. It recycled more easily metabolised animal protein, of which there was surplus production, and led to a reduction in dependency on US soya producers for animal feed.[53] Nevertheless, the emergence of BSE led to a ban in the use of MBM (though this was by no means a straightforward process[54]). Worse was to come though when, in 1996, a link was announced between BSE and a new variant of a human disease, Creutzfeldt-Jakob Disease (vCJD). This turned what had been a big problem for the beef industry into a public food scare. BSE came to epitomise the view of industrialised, intensive agriculture as a source of risk and harm that had been building through controversies about water pollution and concerns over animal welfare and widespread biodiversity and habitat loss.

The crisis in the UK involved controversial science over the nature and transmissibility of the disease and failings amongst policymakers to fully take into account the uncertainty of the science.[55] Across Europe BSE, as it spread to the beef herds of other countries, threw food safety politics into disarray.[56] In fact, Knowles et al.[57] note BSE as a key factor in shifting the food safety policy of the EU from a product-based approach to a consumer-orientated one. BSE had huge economic impacts on the beef sector, both as a result of import bans from BSE free countries and a loss of consumer confidence. In an attempt to combat the latter component of the risk ‘transacted’ by BSE, the EU Council of Ministers introduced a requirement for cattle registration and the labelling of beef to indicate its origins.[58] There was debate within the European parliament as to whether this be classed as a market measure (to restore consumer confidence and improves sales) or as a consumer safety measure. Ultimately it was classed as both, with the aim of creating an “uninterrupted chain” between producer and consumer.[59] According to the website of the European

---

Commission's Directorate General Agriculture "these rules enable full traceability of cattle, and the meat they produce, from stable-to-table".[60]

At this point, TraceBack re-enters the story. DNA identification for pedigree breeding is a well-established feature of livestock production, providing a basis for the extension of genetic identification techniques into animal and meat traceability.[61] So the conceptual and material basis for TraceBack existed when Ciaran Meghen was conducting his doctoral research into the molecular genetic relationships between cattle breeds at Trinity College Dublin.[62] When the BSE crisis emerged, Meghen turned his research towards commercial application and co-founded Identigen to develop the technology that would become TraceBack. As Meghen noted, during the BSE crisis "most commentators were suggesting that traceability was a major issue. That's what inspired the idea".[63] EU regulations around labelling and the emergence of similar requirements for demonstrating the provenance of beef by other beef importing countries have ensured a ready market for Identigen's product.[64]

Does the invention of TraceBack entail only the technical sampling and testing processes? The social conceptualisation of invention outlined above would suggest there is more in play.[65] A pointer to what else is part of the informational material environment of TraceBack lies in the very issue that gives rise to the need for genetic traceability: "Conventional animal identity is lost once the carcass is divided up".[66] Once an animal is slaughtered and the carcass butchered it becomes next to impossible to retain traceability of its various products through the industrialised food chain using conventional labelling techniques. However, the animal's genotype remains a constant identifier; it can be extracted from the whole live animal, the carcass or the various parts of the divided carcass. First, the animal or carcass is sampled. Identigen has specific proprietary sampling tools for use in either abattoirs or when an animal is tagged (ear tagging is another requirement of the EU regulation). Then the genetic profile is stored centrally and TraceBack's rapid genotyping permits a reconstruction of the animal's unique genetic identity, and hence its origin and point of entry to the food chain, from any part of its body. Although the materiality of the animal body is not literally invented by TraceBack, part of the invention of the technology is certainly the translation of animal bodies into informed materials. In doing this, TraceBack re-invents animal identity into a more manageable format. The informed materials of the animal bodies themselves join the sampling, genotyping and data handling devices as part of the TraceBack technology. But the informational material environment of TraceBack extends still further.

Using TraceBack, any animal disease or other food risk incident could be quickly traced to source. But, as noted previously, the introduction of labelling and traceability are not only (perhaps not even primarily) concerned with the materiality of consumer safety. Although we have now arrived at a situation where the meat supply chain is driven by the consumer demand for safe food, it is not enough to simply produce safe and wholesome food. The production process must be communicated to consumers, prompting a range of methods of providing consumers with information about their food products.[67] Quality assurance schemes and their associated labels communicate to consumers that their meat has been produced under certain standards of animal health and welfare or consumer safety. As well as being a

---

signifier of provenance in itself, the guaranteed traceability that Identigen promotes TraceBack as offering also provides a reliable means for supermarkets to audit the quality assurance schemes they have in place along their supply chains, cross-checking their suppliers and ensuring their ability to back up their claims to consumers. TraceBack's brand can be added to food labels alongside the retailers own quality branding. Some research, however, suggests that quality assurance labelling has little impact on consumer perceptions, relegating such schemes to little more than production-focussed modes of supply chain management.[68] As a final note here, TraceBack itself is a product with a rich environment of marketing information. It is this element of the informational environment which makes TraceBack's 'offer' to retailers.

Ultimately, TraceBack's informational material environment, from which it is inseparable, extends backward and forward in time from the moment of its invention. Its action is informed by not only the science that has gone before, but also by the relations of risk in which it intervenes. Its invention is also informed by the claims it will permit its users to make about the safety and traceability of their food as it shift the ways in which risk is transacted. Yet for all this, TraceBack is only as innovative a solution as the forward elements of its complex environment (in this case the consumers being communicated with) enable it to be by their response.

Concluding Remarks

Braun sees our current focus on biological risk (under the auspices of biosecurity) as a political response to the increasingly prominent vision of life on a molecular scale and the relative unpredictability that being immersed in such a molecular world seems to heighten. This observation, whilst true on a particular scale, presents the science that leads to a molecularization of life and the politics that result from it as distinct and related in a linear fashion: "biosecurity today names a set of *political responses*"[69] (emphasis added). Others have argued that, rather than a progressive molecularization of life, we are now witnessing the "re-biologization" of life.[70] This re-biologization is encapsulated in the current experimental and exploratory efforts to obtain biologically useful information from the massive amount of genomic data collected.[71] The application of systemic approaches from genome mapping through to functional genomics and so on, generates informational material environments that incorporate the social and political elements of dealing with risk, the entanglement of heterogeneous materials (including re-invented animal bodies) and the raising of difficult choices. In the practice of contemporary biology and its application in biotechnologies, politics and science are inextricably linked at a material level.

TraceBack exemplifies this situation as it contributes to the socialisation of disease risk in novel ways. It is an invented technology that is nothing without the already existing animal body, which it then in turn re-invents in the light of an inseparable genotypic identity. Yet TraceBack also could not exist in the form it takes without the complex social composite (of regulation, politics and risk) engendered by BSE. Moreover, TraceBack's interaction with risk is not simply on a molecular level. It is part of a wider informational material environment in which animal identity might have been rendered temporarily more stable, but in which consumer behaviour does not have to comply. A focus on genomics alone cannot bring out these types of interactions. It is through the juxtaposition of risk and TraceBack – comparable only as social forms in the abstract – that they become apparent in this case. Bingham asserts that insights about the living world can be best gained "from the muddle of the middle",[72] where our ideas of nature and society (or indeed science, technology and politics) do not come apart easily. This brings us to what we might mean by the social dimensions of animal genomics.

I would suggest that we need to get away from thinking about social questions or issues as being those that belong in some hazily visualised domain designated 'the social'. The various related ideas of collectivity put forward here – the contemporary, the enduring composite, the performative view of society, invention as the production of complex composites and informed materials – all present a view of 'the social' as nothing more than a description of interaction, of more-or-less enduring associations. None of them offers any explanation; they exist only as methodological aids to focus the attention and assist in the description of the world. They implicitly reject the totalising, explanatory character of such earlier concepts as 'culture' and 'society', concepts that many feel no longer have any purchase in our entangled and always shifting contemporary moment.[73] Social issues are something all together broader in definition: they are all of those concerns generated through the production and interaction of new composite entities. If we want to have a social science that is attentive to nonhuman as well as human animals, that can say something novel and useful about animal genomics, then we have to have a social science that is also attentive to molecules, genomes and the whole array of technical and scientific objects, techniques and tools that constitute informational material environments. I have attempted to illustrate and adopt just such a perspective in this paper. Extending it further leads me to two more general conclusions that remain pertinent to studying genomics.

A focus on the inseparability of objects, their informational material environments and their perception by others leads to an interesting set of concerns. The categories of farmed animals, wild animals and companion animals differ from each other in ways that have less to do with easily made distinctions such as 'domestication' and 'food production' and more to do with the many and varied informational material environments that those processes create. Farmed animals in particular are informed materials, embodying varying degrees of information and inhabiting more-or-less complex informational environments depending on the levels of research and intervention that have gone into their development. The new ways of seeing and understanding raised by genomics both highlight this feature of their existence and extend its potential complexity and richness.

Putting concepts together in the ways that I have done could be seen as an endless set of word games. However, it can also serve a useful function. Borrowing from Isabelle Stengers[74] I would term this process the invention of problems. Problems are not a given, they are brought into play through many and varied interactions[75] and it is the job of the scientist (social or otherwise) to actively engage in their framing and invention. This active perception of invention and intervention can lead us to make problems that are more inclusive in their articulation,[76] an issue of particular saliency

---

when considering the relative paucity of studies that fully engage with more-than-human society.

---

[1] Centre for Rural Economy, Newcastle University andrew.donaldson@ncl.ac.uk

[2] I follow the BBSRC in its definition: "we use the term Farm Animal Genomics to encompass a range of genomics and genetics approaches it is defined as: 'Science that promotes the understanding of genetics and gene function in livestock animals and the application of this knowledge to life sciences in general, in particular to farm animal health and welfare, product quality and efficiency, and human health'." (BBSRC. 2005. Review of Farm Animal Genomics in relation to BBSRC-Funded Research: 4).

[3] The eventual cost of the epidemic would be in the region of £8 billion, with greater losses occurring in tourism and other sectors outside of agriculture that had not become apparent at the time of the documentary. See A. Donaldson, R.P. Lee, N. Ward & K. Wilkinson. 2006. Foot and Mouth – Five Years On: The Legacy of the 2001 Foot and Mouth Disease Crisis for Farming and the British Countryside. Centre for Rural Economy Discussion Paper 6.

[4] This sense of import is echoed by the BBSRC, op. cit. note 2, p.31.

[5] M. Banner & J.E. Suk. Genomics in the UK: Mapping the Social Science Landscape. Genomics, Society and Politics 2006; 2:1-27.

[6] Ibid, p.23.

[7] This exposition of 'the contemporary' originates with Michel Serres in M. Serres & B. Latour. 1995. Conversations on science and technology. Michigan. University of Michigan Press.

[8] See P. Rabinow. 1999. French DNA. Chicago. University of Chicago Press; P. Rabinow 2003. Anthropos Today: Reflections on Modern Equipment. Princeton. Princeton University Press.

[9] N. Bingham. Bees, butterflies and bacteria: biotechnology and the politics of nonhuman friendship. Environment and Planning A 2006; 38: 483-498.

[10] Ibid.

[11] For a recent overview see L. Kalof & A. Fitzgerald. Eds. 2007. The Animals Reader. Oxford. Berg.

[12] H. Tovey. Theorising nature and society in sociology: The invisibility of animals. Sociologia Ruralis 2003; 43: 196-214.

[13] Eg, C. Philo & C. Wilbert. Eds. 2000. Animal Spaces, Beastly Places: New Geographies of Human-animal Relations. London. Routledge.

[14] See A.N. Whitehead. 1929. Process and Reality. Corrected Edition. Macmillan USA [1979].

[15] B. Latour. 2005. Re-assembling the Social. Oxford. Oxford University Press.

[16] B. Latour. The Powers of Association. In J. Law (Ed). 1986. Power, Action and Belief: a new Sociology of Knowledge? London, Routledge and Kegan Paul. For recent accounts of Science Studies' lessons for sociology in general see Latour, op. cit. note 15; J. Law. 2004. After Method: Mess in Social Science Research. London. Routledge.

[17] B. Latour. A Plea for Earthly Sciences. Presented to the Annual Meeting of the British Sociological Association. East London. 2007.

[18] The phrase as used here belongs Sarah Whatmore, eg, S. Whatmore. Materialist returns: practising cultural geography in and for a more-than-human world. Cultural Geographies 2006; 13: 600-609.

[19] See B. Latour. 2003. The Politics of Nature. London. Harvard University Press. In a similar vein, the social sciences are a way in which humans are socialised. For a commentary on the performativity of the social sciences in the modern state and their role in the constitution of the society they purport only to describe, see J. Law & J. Urry. Enacting the Social. Economy and Society 2004; 33: 390-410.

[20] The classic ANT examples of the socialisation of nonhuman entities are Latour's account of Pastuer and his microbes and Callon's Scallops in St Brieuc Bay (see B. Latour. 1988. The Pasteurization of France. Cambridge, Massachusetts. Harvard University Press; M. Callon. Some elements of a sociology of translation: Domestication of the scallops and the fishermen of Saint Brieuc Bay. In Power, Action and Belief: a new Sociology of Knowledge? J. Law, ed. London. Routledge and Kegan Paul: 196-233.) Steve Hinchliffe provides an excellent account of the fractured and resisted attempts to isolate, and make amenable to political intervention, a causal agent for BSE (S. Hinchliffe. Indeterminacy in-decisions: science, policy and politics in the BSE crisis. Transactions of the Institute of British Geographers 2002; 26: 182-204).

---

[21] This point, variously expressed, is central to an ANT approach. In this paper it will have to take the status of an axiom, but for further discussion see J. Law. op. cit note 16; I. Stengers. 1997. The Invention of Modern Science. Minneapolis. University of Minnesota Press.

[22] A.N. Whitehead. 1925. Science and the Modern World. New York. Free Press [1967].

[23] A. Barry. Pharmaceutical Matters: The Invention of Informed Materials. Theory, Culture and Society 2005; 22: 51-69.

[24] Tarde's work has also been repeatedly cited by Bruno Latour as a forgotten precursor to ANT.

[25] Stengers 1997, op. cit. note 21; I. Stengers. 2002. Power and Invention. Minneapolis. University of Minnesota Press.

[26] A. Bensaude-Vincente & I. Stengers. 1996. A History of Chemistry. Cambridge, Massachusetts. Harvard University Press.

[27] Barry, op. cit. note 23, p.59.

[28] For more on this view of perception see A.N. Whitehead. 1920. The Concept of Nature. Cambridge. Cambridge University Press.

[29] See http://www.identigen.com/dna_brand.php

[30] http://www.superquinn.com/Multi/default.asp?id=301&itemId=301&Section=Nutrition%20Forum

[31] Identigen press release March 14th 2001.

[32] Identigen press release October 12th 2001.

[33] A. Donaldson. Biosecurity after the event: Risk politics and animal disease. Forthcoming in Environment and Planning A; A. Donaldson & D. Wood. Surveilling strange materialities: categorisation in the evolving geographies of FMD biosecurity. Environment and Planning D: Society and Space 2004; 22:373-391; B. Braun. Biopolitics and the molecularization of life. Cultural Geographies 2007; 14:6-28.

[34] Donaldson & Wood, op. cit. note 33.

[35] D. Black, Select Committee on Environment, Food and Rural Affairs. Minutes of Evidence, October 16, 2002.

[36] E. Roe and A. Evans. Animal Welfare: A form of bio-security? Paper presented to the Annual Meeting of the Association of American Geographers in Chicago 2006.

[37] Braun, op. cit. note 33, p.6. Braun's argument is essentially about offering an alternative view on the political outcomes of the molecularization of life to that put forward by Nikolas Rose (N. Rose. The politics of life itself. Theory, Culture and Society 2001; 18: 1-30).

[38] A. Donaldson. Biosecurity and the re-ordering of risk. Presented to the Annual Meeting of the Association of American Geographers. Chicago 2006. Donaldson, op. cit. note 33; Braun, op. cit. note 33.

[39] The Department for Environment, Food and Rural Affairs has a number of public/private partnership groups working on the best ways to facilitate improvements in animal health and farm management for both industry and public benefit.

[40] S. Jasanoff. The Songlines of Risk. Environmental Values 1999; 8: 135-152.

[41] M. Power. 2004. The Risk Management of Everything. London. Demos. H. Rothstein, M. Huber & G. Gaskell. A theory of risk colonization: the spiralling regulatory logics of societal and institutional risk. Economy and Society 2006; 35: 91-112.

[42] See, for example, S. Lash, B. Szerszynski and B. Wynne. Risk, Environment and Modernity. London. Sage.

[43] Jasanoff., op. cit. note 40, p.135.

[44] P. O'Malley. Introduction: configurations of risk. Economy and Society 2000; 29: 457-459.

[45] A.P.J. Mol and H. Bulkley. Food Risks and the Environment: Changing Perspectives in a Changing Social Order. Journal of Environmental Policy & Planning 2002; 4: 185–195.

[46] U. Beck. 1992. Risk Society. London. Sage.

[47] Mol & Bulkley op.cit. note 45.

[48] B. Latour. Is re-modernization occurring – and if so, how to prove it? Theory, Culture and Society 2003; 20: 35-48.

[49] P. Stassart and S.J. Whatmore. Metabolising risk: food scares and the un/re-making of Belgian beef. Environment and Planning A 2003; 35: 449-462.

[50] E.P. Cunningham. 2003. After BSE - A future for the European livestock sector. European Association for Animal Production, scientific series, vol. 108.

---

[51] P. Oosterveer. Reinventing Risk Politics: Reflexive Modernity and the European BSE Crisis. Journal of Environmental Policy & Planning 2002; 4: 215 – 229.
[52] The BSE Inquiry. Volume 1: Findings and Conclusions. London. The Stationary Office.
[53] Oosterveer, op. cit. note 51.
[54] See Hinchliffe, op. cit. note 20.
[55] Hinchliffe, op. cit. note 20. The BSE Inquiry, op. cit. note 52.
[56] Oosterveer, op. cit. note 51.
[57] T. Knowles, R. Moody & M.G. McEachern European food scares and their impact on EU food policy. British Food Journal 2007; 109: 43-67.
[58] Initially in 1997 under Council Regulation (EC) 820/97 which was later replaced with Regulation (EC) 1760/2000 Of The European Parliament and of The Council.
[59] Knowles et al. op. cit. note 57.
[60] http://ec.europa.eu/agriculture/foodqual/beef/label_en.htm
[61] E.P. Cunningham and C.M. Meghen. Biological identification systems: genetic markers. Scientific and Technical Review of the Office International de Epizooties 2001.
[62] http://www.identigen.com/leadershipteam.php
[63] Moo Tech Fingerprints Mad Cows. Wired Med-Tech Section, November 6th, 2001. Available at http://www.wired.com/medtech/health/news/2001/11/48005?currentPage=1.
[64] The poor traceability from slaughterhouse to retail identified by the EU Food and Veterinary Office (FVO Special Report DG(SANCO) 9505/2003) is utilised by Identigen Chairman, Patrick Cunningham – also Chief Scientific Advisor to the Irish Government – to highlight the importance of TraceBack. See P. Cunningham. Food, Livestock, Health - some applications of biotechnology. Paper presented to EU-India Workshop on Biotechnologies. New Delhi 23-24 April 2007.
[65] We could also look back in the innovation process to note how previous inventions are being imitated in the invention of TraceBack. For example, genome sequencing has identified many SNPs as by-products (see BBSRC, op. cit. note 2), which can then be utilised in new projects and technologies.
[66] Cunningham & Meghen, op. cit. note 61, p.497
[67] X. Gellynck, W. Verbeke & B. Vermeire. Pathways to increase consumer trust in meat as a safe and wholesome food. Meat Science 2006; 74:161–171.
[68] Ibid.
[69] Braun, op. cit. note 33, p.15.
[70] P. Rabinow and C. Caduff. Life – After Canguilhem. Theory, Culture and Society 2006; 23: 329-331.
[71] Ibid.; See also M. O'Malley and J. Dupre. Fundamental Issues in Systems Biology. Bioessays 2005; 27: 1270-1276.
[72] Bingham, op. cit. note 9, p.496.
[73] Rabinow 1999, op. cit. note 8. See also Latour 2005, op. cit. note 16; Law 2004, op.cit. note 16.
[74] Op. cit. note 21.
[75] See also Rabinow (2003, op. cit. note 8) on Foucault's idea of problematisation as the process by which elements are constituted as objects of thought.
[76] See Law 2004, op. cit. note 21; Latour 2007, op. cit. note 18.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.70-81

The Reification of Life

MICHAEL HAUSKELLER[1]

‘What’s wrong – fundamentally wrong – with the way animals are treated (…) isn’t the pain, the suffering, isn’t the deprivation. (…) The fundamental wrong is the system that allows us to view animals as our resources, here for us – to be eaten, or surgically manipulated, or exploited for sport or money.’[2]

Tom Regan made this claim 20 years ago. What he maintains is basically that the fundamental wrong is not the suffering we inflict on animals but the way we look at them. What we do to them, what we believe we are allowed to do to them, is dependent on how we perceive or conceptualize them. We not only *treat* them as resources but prior to this we already *think* of them as resources, and when we look at them, all we tend to *see* is resources. In our perception of them they exist not for themselves but ‘for us’. But obviously it can only be fundamentally wrong in a moral sense to view them that way if it is wrong in a factual sense, that is, if animals are in fact *not* ‘for us’. But is it wrong?

Animals as ends in themselves

According to Immanuel Kant, our moral duties to our fellow human beings can all be traced back to the one rule never to treat each other (and oneself) merely as means but always at the same time as ends. The reason for this is that human beings, by virtue of their being capable of acting out of respect for the moral law and thus autonomously, have an intrinsic or absolute value that Kant calls dignity. That human beings have such an absolute value means, for Kant, that they (and in general all rational beings) by their very nature *exist* as ends in themselves.[3] Thus the imperative always to treat them as ends and never merely as means is only an acknowledgement of their true nature. In contrast, all other beings have only a relative, extrinsic value and do not exist as ends in themselves. All value they can possibly have they do have by reason of their being valued by humans. It does not matter whether or not they are alive or conscious or sentient: they can never be ends in themselves unless they possess reason and are capable of acting out of respect for the moral law. Since animals lack this ability they are, again by their very nature, *not* ends in themselves, and we have no direct moral obligations towards them and are free to treat them, if it suits us, *merely* as means to our ends. Rational beings that exist as ends in themselves are called *persons* (the word ‘person’ being a *nomen dignitatis*), whereas all other beings, including all animals, are most appropriately called, and regarded as, *things*.[4]

The idea that animals might literally *exist* as means (thus justifying their being treated as means) is reminiscent of the Stoics’ claim that the whole purpose of their existence is their usefulness to human beings.[5] Kant, however, did not go quite that far. He merely made the negative claim that animals do not exist as ends, but not the positive claim that they actually do exist as means. The Stoics tended to think of animals as predisposed for human use, as natural born instruments,[6] whereas Kant conceptualized them as ‘things’ because in his view they lack the necessary

---

requirements for moral considerability. So in all practical, that is, moral respects, animals are just like any other non-rational thing. Their existence, their needs and desires, cannot be the basis for moral obligations. Morally speaking their lives and their well-being are a matter of indifference and there is no answer to the question how they *ought* to be treated. They do not have dignity (that is, an absolute value) but only a *price*, which means that they 'can be replaced by something else which is equivalent'.[7] Thus, according to Kant, replaceability is the hallmark not only of inanimate things but of all living beings except humans.

However, replaceability is, contrary to what Kant suggests, not a property an object can possess as such, intrinsically, but only in relation to someone to *whom* it is replaceable and in relation to a certain aspect under which it is viewed. Anything can be replaceable for us if what matters to us is not the thing in its particularity, individuality, and uniqueness, but rather the thing as a representative of its *kind*. Because only then another thing of the same kind will do just as well. But *what* kind a thing is, again is not a question of its intrinsic properties but, instead, of our interest in it. To use a fairly trivial example, a coffee machine is not a coffee machine because it makes coffee (since it does many other things as well, and sometimes it does *not* make coffee). Rather, it is a coffee machine because it is *designed* to make coffee, we *expect* it to make coffee, and we primarily *use* it to make coffee. If it breaks we can either get it repaired or buy a new one, and it doesn't really matter which, because it is, to us, replaceable. We can replace it precisely because it does not matter to us which coffee machine we have as long as it does what it is supposed to do, that is, make coffee. Similarly, when it is suggested that animals are by their very nature replaceable they are already thought of as performing a certain function or having a certain use. We have an idea of what we want from them, how they should be like, what makes them good representatives of their kind. And this idea *makes* animals replaceable. That is why it is quite wrong to argue that we have no moral obligations to animals *because* they are, by their very nature, replaceable. Rather, we *define* them as replaceable because that provides us with a convenient justification not to pay any attention to what is good for them. Being a mere thing means being replaceable in the sense that there is no moral reason why we should not replace it. This is intuitively plausible with respect to inanimate objects like coffee machines. Although they are not *in themselves* replaceable there is also nothing about them that puts us under an obligation not to replace them. In that respect, however, animals are not mere things. They are different. They do have a good, and this good is *their* good and not anyone else's.

Judging by the way they behave, if animals could talk they would certainly disagree with both Kant and the Stoics. Their actions, and that is the only thing we can judge them by, are far from suggesting that they view themselves as replaceable, on the contrary. They are primarily oriented towards their own survival and to the attainment and defence of their own individual good. They clearly care for what happens to them. There is nothing in the way animals behave or in the way their bodies are shaped and organized that supports the idea that the purpose of their existence is anything but their own good. It certainly is not our good. And they would also regard themselves and their existence as ends in themselves. They may in fact be treated as means but they *exist* as ends in themselves. Regarding them merely as means, as things that can be used and replaced at will, is therefore not adequate to what they are. It is a practical denial of their independent existence and their biological integrity as a realization of their own good.

As the British philosopher William Wollaston has pointed out, a ‘true proposition may be denied, or things may be denied to be what they are, by deeds, as well as by express words or another proposition.’[8] Since our actions are expressive of the beliefs we have we can declare that things are not as they are simply by acting in a certain way. If I, for instance, break a promise, I act as if such a promise has never been made and by acting that way (wrongly) declare that it has not been made. If I steal from somebody I treat someone else’s property as my own and thereby declare that it is mine while in fact it is not. Wollaston believed that this fact explained the difference between good and evil or morally right and wrong actions. He gives the following illustration:

> *To talk to a post, or otherwise treat it as if it was a man, would surely be reckoned an absurdity, if not distraction. Why? because this is to treat it as being what it is not. And why should not the converse be reckond as bad; that is, to treat a man as a post; as if he had no sense, and felt no injuries, which he doth feel; as if to him pain and sorrow were not pain; happiness not happiness. This is what the cruel and unjust do.*[9]

However, it is not quite clear why it should be more morally wrong to treat a human being like a post than to treat a post like a human being, or more wrong to treat an animal as if it were a mere thing than to treat a mere thing as if it were an animal or a human person. Whereas the former seems to be morally wrong the latter just seems crazy. Somebody who is treating a post as if it were alive and sentient is out of their right mind, but their actions do not seem morally reprehensible. Wollaston realized that it would not be plausible to consider all actions that are expressive of a false proposition as equally morally wrong and tried to account for the different degrees of wrongness by distinguishing between actions with respect to the ‘importance’ of their consequences. Some actions are more wrong than others because certain things matter more than others. When, for instance, the happiness, welfare or life of a creature is at stake, denying their being what they are is more important than if their happiness, welfare and life were not affected. Now, it may seem that, by acknowledging that the degree in which an act is morally wrong depends on its consequences, Wollaston seriously undermines his claim that acts are morally wrong because they somehow deny the truth. However, Wollaston could defend his view by arguing that if an action causes suffering but does not deny the truth then it is not morally wrong despite the suffering it causes. For instance – as both Plato and Kant have argued – punishing someone for their crimes is not only justified (and perhaps advisable for the good of society) but also something that is literally owed to them. By being punished they are acknowledged as morally responsible beings, (in Kantian terms) as autonomous agents and thus as beings that possess intrinsic value and dignity. Did one refrain from punishing them one would in effect deny them their humanity, that is, deny them to be what they in fact are. Hence, since they are treated as morally responsible human beings no moral wrong is being committed even though suffering may be inflicted on them. It would appear then that even though a practical denial of the truth

---

may not be sufficient to declare an act to be (seriously) morally wrong it may still be a *necessary* condition of moral wrongness.

Reification

Generally speaking, our practices influence and change the way we look at the objects involved in them. Conversely, the way we look at things determines the role we assign to them in our practices. Biotechnology is a human practice that has (and reflects) a tendency to transform living beings into scientific objects and into mere things. I call this process of transformation ‘reification’. The term ‘reification’ is often used when abstract concepts are being treated *as if* they represented concrete things which can act and be acted upon. Reification in this sense is a fallacy, very similar in kind to the fallacy that Alfred North Whitehead called the ‘fallacy of misplaced concreteness’.[10] To give an example, ‘pleasure’ or ‘happiness’ tend to be reified in traditional utilitarian thinking when they are disconnected from the individual beings that are happy and feel pleasure and treated as if they had an existence of their own so that they can meaningfully be quantified, added and subtracted. The term ‘life’ is also a good candidate for this kind of reification. Life gets reified when, for instance, in the eyes of those who think of themselves as pro-life activists life acquires the status of an entity that has a value independent of those whose life it is. The status of being alive, which in fact qualifies a substance, is regarded and treated as if it were itself a substance: life as such.

However, this kind of reification is not what I wish to talk about here, at least not primarily. When I speak about the ‘reification of life’ I want the term ‘reification’ to be understood in the old Marxist sense of treating a subject as if it were a mere thing. The German word is ‘Verdinglichung’, which literally means ‘turning [something that is not a thing] into a thing’. What the term addresses is the practical tendency to make a commodity (i.e., something that has a price but no intrinsic value) of an entity by disregarding every aspect of it other than those that can be utilized. Following the Kantian lead, this tendency is regarded particularly offensive when it is exhibited towards human beings, because humans should never be treated only as means but always as ends. But if animals, as I have pointed out above, are also ends in themselves in the sense that they aim at the fulfilment of their own being and do not primarily serve any other ends than their own by holding on to their lives and their particular kind of existence,[11] then we may just as well adopt the Kantian imperative and conclude that animals, too, should never be treated merely as means but always at the same time as ends.

The concept of reification originates in Marx’s critique of Capitalist society and was elaborated by Georg Lukacs.[12] Only recently it was given a book-length treatment by Axel Honneth,[13] who interpreted reification in a much wider context as an expression of ‘Anerkennungsvergessenheit’, which literally means forgetfulness of recognition. Honneth cites Adorno and Horkheimer who once remarked that all reification is a forgetting. What is forgotten is that the other is a subject just like oneself or, in more general terms, that the world outside does not exist exclusively for our convenience. This forgetting is expressed in a certain lack of emotional involvement or indifference – ‘Teilnahmslosigkeit’. Reification is the effect of habitually adopting the perspective of a distant, neutral observer, a perspective that makes all objects appear as mere things. A certain primary relatedness to the world is lost.

The adoption of this neutral perspective is generally supposed to be a precondition of good science. Thus reification is required in order to conduct a scientific inquiry. In H.G. Wells's novel *The Island of Dr Moreau* we find this idea perfectly expressed by Dr Moreau himself when he remarks to his involuntary guest Prendick:

> *Pain! Pain and pleasure – they are for us, only so long as we wriggle in the dust (...) You see, I went on with this research just the way it led me. That is the only way I ever heard of research going. I asked a question, devised some method of getting an answer, and got – a fresh question. You cannot imagine what this means to an investigator, what an intellectual passion grows upon him. You cannot imagine the strange and colourless delight of these intellectual desires. The thing before you is no longer an animal, a fellow-creature, but a problem.*[14]

This particular way of looking at animals is the result of what Michael Lynch called the 'transformation of the animal body into a scientific object'.[15] After having observed the behaviour and language of neuroscientists performing electron microscopic studies of regenerative processes in the brain of mammals, Lynch described the tension between mutually exclusive representations of laboratory rats, which on the one hand were initially perceived and throughout the experiments implicitly assumed to be naturalistic creatures, but were on the other hand spoken of and eventually treated as analytic products of research. The 'naturalistic animal' is the animal of our ordinary perception and interaction. Its presence is necessary but remains systematically unacknowledged in the research products. 'The 'analytic animal' therefore becomes the *real* animal in a scientific system of knowledge, while tacitly depending upon the naturalistic animal for its practical foundation.'[16] There is no indication in the way those experiments were conducted and the way the results were expressed that the entities being used were actually living beings. Every aspect that is supposedly irrelevant to the purpose of the experiment is systematically ignored. By gradually transforming the naturalistic animal – the living, conscious, and sentient creature – into an analytic entity and identifying the former with the latter, modern experimental science exemplifies forgetfulness. The knowledge is actually there but it is systematically suppressed and never openly acknowledged although implicit in the way researchers prepare the animals to yield the results they wish to attain: 'Animals are treated as holistic, living, reactive subjects to be soothed, cajoled, tricked, and gently led through procedures that transform them into analytic subjects.'[17] In the articles that were published after the experiments, animals were no longer present as living beings but as cases 'which demonstrated an abstract regenerative process in a generalized brain.'[18]

Animal Models

Various companies offer so-called research models for purchase. Sinclair, for instance, offer 'miniature swine as Models for Human Diabetes'. On their website, Sinclair first state what a serious problem the disease poses, and that for the lack of

---

suitable large animal models, diabetes research has not sufficiently developed. Then, the product is presented:

> *Miniature swine have many characteristics similar to humans that make them a suitable species to model human diseases. Miniature swine are omnivores, easy to handle, raise few ethical considerations, offer similar size to adult humans, have several organ systems very similar to humans in term of anatomy, physiology and metabolism, and test compounds can be administered through all routes of delivery, including trans-cutaneous delivery systems (patches). (…) Sinclair offers a new induced model of type 2 diabetes with dyslipidemia in miniature swine. The dyslipidemia observed is very similar to the one of diabetic humans and early atherosclerosis lesions have also been detected. The similarities of the lipid metabolism, vascular anatomy, capacity and collateral circulation of the coronary arteries between swine and humans make this animal model even more attractive.*[19]

What is being offered here is not a conscious living being that cares for its own existence and strives to attain and preserve its own kind of good, but a *model*. A model is a kind of representation. It stands for something else. Normally it is a simplified version of a complex process or state which can be used to facilitate understanding of, or increase knowledge about, that process or state. If we want to know how something works or what effects certain actions have on it, and we cannot get hold of the real thing, or do not, for one reason or another, want to use it, a model is needed that is likely to provide the same information. A model may even be better suited for the purpose of gaining information because it can be constructed in such a way that many irrelevant aspects of what it is meant to represent are eliminated. However, an animal that is being used as a model for a human disease is not in itself a simplified version of that disease. It is, even when it is used a model, still a living being that cares for itself and has its own particular good. So instead of being eliminated, all those details that are deemed irrelevant for the purpose of gaining a certain kind of information are simply ignored - as much as this is possible. The properties that are explicitly acknowledged and highlighted are not properties of what Lynch called the naturalistic animal but either properties of the analytic animal or properties that facilitate their being turned into analytic animals. Being omnivores they can be fed almost anything, so feeding them will not be a problem. They are easy to handle, so no inconveniencies or surprises that might force their user to acknowledge their naturalistic side are to be expected. Their organ systems, metabolism and anatomy are similar to those of humans. The disease affects their bodies in the same way it affects the bodies of humans.

An animal model is perceived and used as a representation. Although a representation need have no similarity with what it represents (just as, conversely, a thing can be similar to another without representing it),[20] in the case of animal models a certain similarity is necessary. The similarity is needed in order to achieve the research goal: it is the primary reason for using it as a model. On the other hand, the model also needs to be different, for if there weren't any difference between the representation and what it represents, one could just as well use the real thing. In this case the real thing would be a human being suffering from Diabetes. Yet experimenting on humans

---

is thought to be unethical. In contrast, swine allegedly ‘raise few ethical considerations’, so the reason for not using human beings does not apply to animals. Ethical concerns appear to weigh less or not exist at all in the case of animals, and this justifies their being used as a model. In fact, however, it is the way they are represented that allows us to lower their moral status to a negligible degree.

In every act of representation there is an object (that which is represented) and a mode of representation (that *as* which the object is represented). Every representation involves a certain characterization of an object. In the case of animal models, the animal represents a human as the bearer of a certain disease. It is meant to exemplify this human disease. Being meant to exemplify, the animal model is, *qua* model, a reduction. Similarity is important only in a certain respect, whereas in other respects the dissimilarity is equally important, namely dissimilarity in respect to everything that might be considered ethically relevant, such as life, sentience, conscience, an inner perspective, a subjective existence. These properties are not positively absent in animal models but they are systematically overlooked. Hence the dissimilarity is not intrinsic to the object but a mental, linguistic and social construction. It is a result of what Honneth calls forgetfulness (of a prior recognition). Everything that is not relevant to the purpose (and that may possibly create a meaningful relationship between the animal and its user) is pushed into the background, is suppressed. The animal is regarded and, more importantly, subsequently treated as a mere model or, in more general terms, a tool. Its intrinsic value is concealed and its instrumental value emphasized. At the same time the instrumentalization is being hidden. The fact that the animal only *becomes* a model by virtue of the way humans relate to it (conceptualize and treat it) is forgotten, and what is essentially the result of an interest-guided contraction of one’s visual and mental focus is transformed into an ontological fact. Awareness that one is using an animal *as* a model is lost and replaced by the belief that one is actually using an *animal model*.

The process of reification passes through several stages. The starting point is an individual living, conscious, and sentient animal. This is initially recognized but eventually forgotten (Honneth’s *Anerkennungsvergessenheit*). A selective use of language is then employed to deflect attention from those properties that tend to be regarded as giving rise to intrinsic value and thus moral status, and simultaneously to confine attention to properties that are most likely to be instrumentally valued. The next and most important step is the transformation of an instrumental perspective into an ontological fact: the animal now appears to not only be *used* as a model but to *be* a model, thereby retroactively justifying its being used as a model. As a result, the animal appears to be an indefinitely usable thing that is completely at our disposal.

Incidentally, this crucial transformation of an instrumental perspective into an ontological fact can be seen as an instance of reification in the first sense of the word, which I mentioned briefly at the beginning of this paper. It is an instance of treating an abstract concept *as if* it represented a concrete thing. Not only the animal is reified (by being conceptualized and treated as a mere thing) but also the term ‘model’ is being reified by using it as if it represented the whole reality of the object it refers to instead of a certain use this object can be subjected to.

Language helps to sustain this crucial deception. The way we speak about a thing not only reflects but also shapes our perception of it and facilitates the process of reification. Just as it is important in warfare to verbally dehumanize the enemy and all potential victims of one's own aggression in order to dissolve possible moral scruples and instinctive inhibitions towards killing fellow human beings,[21] animals are being transformed verbally in order to deflect attention from the fact that they are individual living creatures that care for their lives and have a good of their own just as we do. What needs to be forgotten is that animals are not made for our convenience, do not exist as means to our ends, but are ends in themselves. Only natural beings can be ends in themselves. Pure (non-living) artefacts, on the other hand, are never ends in themselves because they are made for a certain purpose. By employing a certain terminology natural beings are for all practical purposes turned into artefacts. 'To speak of organisms as machines legitimizes our treatment of them as artefacts, as completely knowable and transparent objects and of their lives as having no ethical significance.'[22]

Super-reification through genetic modification

A further step in the reification of living creatures is reached when animals are genetically manipulated in such a way that those features that, for some reason or other, hamper our use of them are eliminated and other features that are conducive to their intended use are accentuated or added. Quite rightly Lynch remarked that 'the genetic design and domestication of laboratory animals anticipates their use as analytic subjects.'[23] Animals are not only spoken of as tools and treated as tools, they are quite literally being created as tools. Instead of putting up with the naturalistic animal and trying to ignore it as best as we can, gene technology allows us (or promises to allow us) to create animals that are less and less naturalistic and more and more analytical – increasingly perfect research tools. Mice, for instance, have been used for almost a century to model human diseases because they are cheap, easy to hold, and, most importantly, develop conditions similar to those of humans such as cardiovascular disease, cancer, or diabetes. However, by specific gene targeting (homologous recombination in embryonic stem cells) genes can now be inserted, deleted, modified or substituted so that other human diseases can be modelled that do not normally strike mice, such as cystic fibrosis or Alzheimer's. Knockout mice, knockin mice, and transgenic mice can be specifically designed according to the needs of the customer. They are custom-made by various companies that offer their services to the requiring researcher: Tell us what you want and we will get it for you. The U.S. National Institutes of Health (NIH) advertise Knockout mice as a resource that 'will serve to further the value of the mouse as a powerful and important tool in the study of human health and disease.'[24] Ozgene, a company specializing on the fabrication and marketing of genetically modified mice and rats, advertise their products as 'the most sophisticated and valuable tools in functional genomics and drug target validation.'[25]

The instrumental value of the mouse as a research tool is thus not only emphasized but it is effectively raised. Although its intrinsic value is thereby not diminished but in fact remains the same it gets even harder to recognize this and not to forget it. Genetically modified mice are still living, 'naturalistic' creatures but they have also become artefacts into whose very being a purpose has been introduced that is not their own. This external purpose is the sole reason for their existence. It is not that, like animals raised for food, they owe their existence to the fact that we have discovered how to use them for our purposes but rather that they owe their very *nature* to what we are planning to do with them. Their utility is the reason not only for the fact *that* they are but also for *what* they are. They already enter the world as human inventions and consequently are increasingly regarded as the intellectual property of their inventors, as products for which it is thought proper to claim and award a patent.

The first patent on an animal was issued in 1988 for a mouse genetically engineered to susceptibility for breast cancer, the so called Harvard oncomouse. Since then more than 500 patents on animals have been issued, including cats, dogs and primates. The patent was awarded despite the fact that the U.S. law prohibited that naturally occurring organisms be patented. But of course it was argued that the oncomouse was *not* a naturally occurring organism. It was not a product of nature but a human product. Although genetically modified animals may not be entirely artificial they are no longer entirely natural either: they are something like living artefacts or, to use the very fitting term that was introduced into the debate by Nicole Karafyllis, 'biofacts'.[26]

But doesn't the successful creation of such biofacts mean that we have finally managed to bring animals into existence that actually *do* exist as means (to our ends)? We could then concede that Kant was wrong to claim that only human beings exist as ends in themselves and accept that most animals do too, and may still want to hold that animals that are specifically designed for a certain purpose do clearly *not* exist as ends in themselves but truly as means. They are not only used as instruments, they *are* instruments. And if they do exist as means, if they are instruments, then it seems it can hardly be inadequate to treat them as such. We would, after all, only use them the way they are meant to be used and treat them exactly as what they are. Our actions would be truthful, would be adequate to their nature and therefore morally justified.

However, even a biofact is still a living creature that pursues its own ends despite the fact that it has been created to serve our ends. It is not in itself meant to be used in any way, ie, it does not *exist* as a tool, and its being designed as a tool does not provide sufficient moral justification for its exploitation. The fact that our children owe their existence to us does not give us the right to treat them as our property. And if we had conceived them for a certain purpose (eg, to take over the family business or to donate bone marrow to a sibling suffering from leukemia), we would still be morally obligated to let them live their own lives and pursue their own ends, which might turn out to be very different from what we intended them to be. Even if we had used gene technology to render them more suitable for our purposes, that would not entitle us to treat them as our property. The same holds for animals. We may design them at our convenience but that does not give us the right to treat them any way we please. It would if animals were things, but living beings cannot be turned into things. The process of reification is never complete and remains largely conceptual and perceptual. Biotechnology just gives us the means to consolidate our blindness towards the independent reality of an animal's existence.

Instrumentalisation and Integrity

Alan Holland once remarked that if it could only be shown that the genetic modification of animals is incompatible with showing *respect* to them then this would be the best case against it.[27] Now, as we have seen, the genetic modification of animals is an attempt to turn a living organism into an instrument that is perfectly adapted to its intended use. The process of reification that has started as a specific way of looking at, thinking and talking about, and treating a living organism, is pushed to its limits by actually re-modeling the organism so that its instrumental value is raised. Thus the animal's instrumental value becomes so prominent for our perception of it that its intrinsic value is effectively buried underneath it. Does this constitute a violation of the animal's integrity?

Biological integrity consists in the ability to live according to one's own natural ends or *teloi*. Instrumentalization, or what I have called reification, is a process or an act that aims at either ignoring or eliminating these ends and replacing them with artificial, human-made ends. If those human-made ends are achieved at the expense of the animal's natural ends then clearly its biological integrity is impaired. However, it is at least theoretically possible (although not very likely) that an animal is viewed and used as a tool without this having any effect on its ability to live according to its own natural ends. In other words, it could be nothing but a tool for us and not be any worse for it. Would its use then still be a violation of its integrity and, therefore, morally wrong? Or is reification morally wrong only because of what we are likely to *do* to the animal as a result, but not wrong *in itself*, as a specific human attitude towards animals, a certain way of thinking about and looking at them?

It is difficult to separate an attitude from its practical application and expression. And indeed, if the conceptual and perceptual transformation of a living animal into a resource, an instrument, or a mere thing, had no effect whatsoever on the way we treat animals, Tom Regan would hardly have regarded it as the 'fundamental wrong'. So perhaps we should concede that the instrumental attitude towards animals is not *in itself* a violation of their integrity. However, it seems that the respect we owe them (due to their being living creatures with a good of their own and their leading lives that we can recognize as intrinsically valuable) covers more than just our actions. It does not only demand that we not restrict their ability to pursue their natural ends but also that we acknowledge their true nature (according to which they are *not* things) in our thinking.

The Kantian imperative that we never treat each other merely as a means but always at the same time as an end does not primarily command a certain kind of behaviour towards others but first of all a certain kind of mental attitude. In our daily lives we often treat others as means to our ends. For instance when we go to a shop and buy a newspaper the shopkeeper is being used by us as a means to acquire what we want. There is nothing wrong with that, as long as we don't forget that the shopkeeper is also a human being who does not exist for our convenience and who deserves our respect. This respect is something we expect from others even where it doesn't make much difference to what actually happens. The shopkeeper would be deeply offended if he learned that we regarded him as a mere instrument without any intrinsic value whatsoever. And he would be offended even if we treated him no differently. The point is that we do not want to be 'used' even when we *are* used, that is, we expect others not to think of us *merely* as a means but always also as an end. If we find out that we have in fact been treated merely as a means we are not only disappointed but morally outraged. We feel that it is morally wrong to 'use' someone like this, to relate to people as if they were tools. We are not primarily concerned about the possible or actual *effects* of being used but about the fact itself. Neither do we think that the wrong consists in our *feeling* used. Rather, we object very strongly to our *being* used. Even if we never learned about it we would still not want it to happen. Even if nothing in the actual course of events had been different it would still make a difference to us. We feel that by being regarded merely as an instrument our individual reality is being denied. We are living, conscious beings that exist for their own sake and not for anyone else's, and we want this fact to be acknowledged and our identity as not-things to be respected. Yet animals, too, are living, conscious beings that exist for their own sake, and although they cannot demand respect for it they do deserve it just as much as humans do.

---

[1] Department of Sociology and Philosophy, University of Exeter, UK m.hauskeller@exeter.ac.uk

[2] T. Regan. 1985. The Case for Animal Rights. In In Defense of Animals. Peter Singer, ed. New York: 13-26.

[3] I. Kant. 1883. Fundamental Principles of the Metaphysic of Morals. Kant's Critique of Practical Reason and Other Works on the Theory of Ethics, translated by Kingsmill Abbott. London: 46.

[4] Ibid.

[5] Cicero, De Natura Deorum: II.37. Although humans have a purpose, too, they do not serve any other creature's (nor the Gods') interests. Humans are meant to contemplate and imitate the universe and thereby to actualize their rational nature (ibid.). All other living beings exist in order to aid this purpose. Even though reason permeates everything, including animals, it is only in humans that reason exists in a pure form. Therefore animals are not of "primary importance" (Epictetus. 1916. The Discourses and Manual. Together with fragments from his writings. Translated with Introduction and Notes by P.E. Matheson. 2 vols. Oxford: II.8). For a more detailed discussion of the Stoics' view on animals cf. M. Hauskeller. 2007. Biotechnology and the Integrity of Life. Aldershot. Ashgate: ch. 8.

[6] This does not mean that they are meant to be used for a particular purpose only. Although horses are said to be for riding, cattle for ploughing, etc., it is their general purpose that is morally relevant, and that is to serve human needs and wants. In the Stoics' view there is no reason (for instance, no Aristotelian intrinsic telos and according natural good) why we should not find new uses for animals as long as it benefits us and thus reason itself. On the contrary, reason *demands* to use them any way they can be used. Again, for more detail cf. Hauskeller. 2007. ch. 8.

[7] Ibid, p. 53

[8] W. Wollaston. The Religion of Nature Delineated, 8th ed. 1750. London: 6.

[9] Ibid, p. 20

[10] A. N. Whitehead. 1926. Science in the Modern World. Cambridge. Whitehead defines this fallacy (p. 72) as the 'error of mistaking the abstract for the concrete'.

[11] It might be objected that this is not Kant's sense of 'ends in themselves' since Kant explicitly rests his claim that humans are ends in themselves, ie, have intrinsic value, or dignity, on their alleged (potential) moral autonomy, which animals lack. But autonomy was not part of Kant's *concept* of dignity. Rather, autonomy was thought to be the only possible (or legitimate) *source* or *ground* for dignity. That the necessary requisite for being an end in oneself is moral autonomy was Kant's personal conviction. However, the close link that Kant intended to establish between moral autonomy and intrinsic value is far from compelling and it is by no means clear why there should not be other grounds for intrinsic value beside moral autonomy, for instance the existence of a good of one's own.

---

[12] G. Lukacs. 1971. History and Class Consciousness. Cambridge, Mass.
[13] A. Honneth. 2005. Verdinglichung. Frankfurt/M.
[14] H.G. Wells. 1921. The Island of Dr. Moreau. London: 93.
[15] M. Lynch. Sacrifice and the Transformation of the Animal Body into a Scientific Object: Laboratory Culture and Ritual Practice in the Neurosciences. Social Studies of Science 1988; 18 (2): 265-289.
[16] Ibid, p.267
[17] Ibid, p.281
[18] Ibid. p.266
[19] http://www.sinclairresearch.com/diabetes.htm
[20] For the concept of representation cf. N. Goodman. 1976. Languages of Art. Indianapolis.
[21] Cf. M. Hauskeller. 2001. Versuch ueber die Grundlagen der Moral. Munich: 165-189.
[22] T. Warkentin. 2006. Dis/integrating animals: ethical dimensions of the genetic engineering of animals for human consumption. AI & Society 2006; 20: 82-102, p.100.
[23] Lynch, op. cit. note 12, p.274.
[24] http://www.nih.gov/science/models/mouse/deltagenlexicon/theresource.html
[25] http://www.ozgene.com
[26] N. Karafyllis. 2001. Biologisch, natuerlich, nachhaltig. Philosophische Aspekte des Naturzugangs im 21. Jahrhundert. Tuebingen and Basel.
[27] A. Holland. 1990. The Biotic Community: a philosophical critique of genetic engineering, p.170. In The Bio-Revolution. Cornucopia or Pandora's Box. Peter Wheale and Ruth McNally, eds. London: 166-174.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.82-98

Exploring Biopower in the Regulation of Farm Animal Bodies: Genetic Policy Interventions in UK Livestock

LEWIS HOLLOWAY & CAROL MORRIS[1]

Abstract

This paper explores the analytical relevance of Foucault's notion of biopower in the context of regulating and managing non-human lives and populations, specifically those animals that are the focus of livestock breeding based on genetic techniques. The concept of biopower is seen as offering theoretical possibilities precisely because it is concerned with the regulation of life and of populations. The paper approaches the task of testing the 'analytic mettle' of biopower through an analysis of four policy documents concerned with farm animal genetics: the UK's National Scrapie Plan (2003); the UK National Action Plan on Farm Animal Genetic Resources (2006); the Agriculture and Environment Biotechnology Committee's report on Animals and Biotechnology (2002); and the Farm Animal Welfare Council's report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture (2004). Of interest is whether and how the four policy case studies articulate a form of biopower in relation to human-livestock animal relations in the context of genetic approaches to livestock breeding, and how biopower is variably expressed in relation to the different policy issues addressed. In concluding, the paper considers the overall applicability and relevance of biopower in the context of regulating animal lives within livestock breeding, highlighting both possibilities and limitations, and offers suggestions for taking forward research on livestock populations from a neo-Foucaultian perspective.

Introduction

Genetic techniques[2] became increasingly important in livestock breeding during the second half of the twentieth century. They include statistical calculations of animals' 'genetic merit', identification of marker genes associated with particular qualities such as enhanced productivity or reduced disease susceptibility, and the possibilities of creating genetically modified livestock.[3] Such is the significance of these developments that they have been labelled a 'genetics revolution' by the scientists involved.[4] Livestock breeding has long been the subject of scientific interventions of various kinds, concerning selective breeding, nutrition and health. However, genetic techniques represent a more fundamental intervention in the lives of agricultural animals, based on the notion of genes and genomes, phenomena that are partly embodied within individual animals and identification of which has other implications for the bodies of these animals. Indeed, these techniques suggest that the lives of animals, as individuals and as populations, are being understood, regulated and managed in new and complex ways, a process that demands examination.[5] One means of approaching this task is through Foucault's 'biopower'[6] which offers theoretical possibilities precisely because it is concerned with the regulation of life and of populations. However, because this concept was developed in relation to human lives and populations its legitimacy needs to be established in the non-human

---

context. The overall objective of this paper, therefore, is to test the ‘analytic mettle’[7] of biopower in the context of livestock agriculture and specifically the breeding of livestock through genetic interventions.

We do this through an analysis of policy issues which engage with farm animal genetics, an engagement which has increased in recent years in parallel with the development of genetic breeding techniques. Four specific policy documents have been selected as a vehicle for our exploration of the relevance of biopower in understanding the regulation of agricultural animal lives. The first of these is the UK’s National Scrapie Plan (NSP),[8] which has, since 2001, used genomic testing as the basis for attempts to eradicate scrapie from the UK national sheep flock, while the second, the UK National Action Plan on Farm Animal Genetic Resources (FAnGR),[9] establishes a strategy for conserving UK livestock biodiversity. Both represent significant policy developments: the NSP is the only policy initiative to date that has actually deployed genomic testing in the national level management of the sheep population, while FAnGR is a national response to an international policy drive founded on the use of genetic knowledge in the quest for biodiversity conservation. The third policy document is the Agriculture and Environment Biotechnology Committee’s (AEBC) report on Animals and Biotechnology,[10] which examined the regulatory implications of biotechnological developments for agriculture and the environment, and the fourth, the Farm Animal Welfare Council’s (FAWC) report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture,[11] includes discussion of genetic methods in breeding stock. Again, both reports are significant as they have been produced by independent organisations appointed to provide strategic advice to the UK government on the regulation of agricultural biotechnology and all aspects of farm animal welfare respectively. Although other policy-informing reports on agricultural biotechnology and its regulation have been published over the last decade, the two selected for analysis here represent the most recent statements that deal with the issue and, in the case of the FAWC report, build from and bring together the findings from earlier reports.[12]

We begin by outlining Foucault’s conception of biopower and how this has been usefully reworked as the basis of further empirical enquiry by two Foucaultian scholars, Paul Rabinow and Nicolas Rose.[13] Discussion follows of several issues relating to the use of biopower for making theoretical sense of the regulation and management of non-human populations. The paper next explores the four policy case studies in more detail, outlining their scope and purpose and then examining them through Rabinow and Rose’s reconceptualisation of biopower. Of interest is whether and how the four policy case studies articulate a form of biopower in relation to human-livestock animal relations, and how the expression of biopower is different in relation to the different policy issues addressed. Finally, we consider the overall applicability and relevance of biopower (as reformulated by Rabinow and Rose) in the context of regulating animal lives within livestock breeding, highlighting both possibilities and limitations, and offer suggestions for developing research on livestock populations from a neo-Foucaultian perspective.

Policies, power and biopower

Foucault's notion of biopower represents an important theorization of power as this relates to (human) life.[14] All of the policies outlined above are concerned with the lives of farm animals - increasingly defined in terms of their genetic content - and how these lives should be regulated and managed. It is the regulation of life that concerned Foucault who used the general term biopower to describe forms of power focused upon the vital characteristics and capacities of human bodies and the conduct of individuals and collectivities.[15] For Foucault biopower centred "on the body as a machine: its disciplining, the optimisation of its capabilities, the extortion of its forces, the parallel increase of its usefulness and its docility, its integration into systems of efficient and economic controls…"[16] Within the field of biopower, Foucault distinguished between two forms of 'biopolitics'. The first, 'anatomopolitics', referred to "the disciplinary techniques that sought to maximize the body's forces and integrate it into efficient systems, such as through proper training, or through rationally organizing workplaces, armies and domestic economies".[17] Biopolitics is the term used to describe the second form and refers to specific political mechanisms, strategies and technologies that take as their object "the biological existence of the nation…understood as a 'population' imbued with the mechanisms of life and knowable in statistical norms".[18] 'Population' is the key word here since this notion had a very different meaning prior to the eighteenth century. From this time, however, population becomes "the ultimate aim of government".[19]

For Foucault, therefore, the emergence of biopower was historically contingent and closely tied up with nation states as these emerged in post-Renaissance Europe. Biopower came to overlay, but not completely replace, the previously dominant mode of 'sovereign power', the power to "curtail life in periodic, spectacular manner".[20] In contrast, biopower represented a more "dispersed form of disciplinary or 'pastoral' power … [the] power to make live or let die".[21] The reason for this shift in the operation and form of power, so Legg suggests, was tied up with decline of feudalism and, more specifically, the establishment of the agricultural and industrial revolutions, both of which led to a mass movement of people into cities and the subsequent need for their 'management'.[22] Furthermore, the emergence of competitive nation states required healthy and well-disciplined 'populations' to ensure their survival[23] Foucault envisaged the human sciences, together with a set of administrative institutions associated with the nation state, as central to the production and operation of biopower during the eighteenth and nineteenth centuries. Policy interventions in the birth rate and morbidity, and measures to coordinate medical care were the primary focus of biopower.

In spite of the formulation of biopower in relation to a particular historical period and set of phenomena associated with that period, the notion of biopower clearly has resonance and analytical potential in understanding the operation and distribution of power in contemporary society. Indeed, Marks claims that biopolitical processes are part of the fabric of everyday reality in advanced capitalist economies.[24] A more cautious approach is suggested by Rabinow and Rose, who dispute the notion of an "omnipotent and all-pervasive" biopower, suggesting that while some applications of Foucault's ideas on biopower and biopolitics have many merits they also "entail

---

highly general philosophical deployments of the terms which are totalizing and misleading".[25] They also argue that Foucault himself made limited reference to biopower and so the concept "remains insufficiently developed" and has yet to demonstrate its "analytic mettle in sufficient cases".[26] In an attempt to provide further conceptual clarity Rabinow and Rose suggest that the concept of biopower must, at a minimum, include three elements. The first is "one or more truth discourses about the 'vital' character of living human beings, and an array of authorities considered competent to speak that truth".[27] Truth discourses can have their origins in a number of disciplines, including the biological and the sociological. The second is strategies for intervention upon collective existence in the name of life and health. These strategies are directed at populations often, although not necessarily, identified at the scale of the nation state, and "emergent biosocial collectivities"[28] such as those based on race or gender. The third element is 'modes of subjectification', which refers to the means by which individuals come to regulate themselves and their own sense of self and body in relation to truth discourses. In any particular instance of biopower, it is important to understand that it is not that one or other of the three elements is dominant, causing or producing the others as effects. Instead, truth discourses, strategies for intervention and subjectivities are co-constitutive and co-emergent within relations of biopower. The three elements of biopower and the way in which these are co-constituted in diverse ways require further "detailed, empirically grounded enquiry", according to Rabinow and Rose,[29] for example in examining the ways in which, in particular instances, intervention strategies might be seen as attempts to realise the ideas for collective existence immanent in particular truth discourses, or in exploring how emergent truth discourses might be used to legitimise particular forms of intervention.

Policy developments relating to genetic approaches to livestock breeding offer one potential empirical context to further test the 'analytic mettle' of biopower. As Marks observes "the conceptual resources of thinking on biopolitics have been seen by many as a useful and analytical tool for looking in particular at the ways in which the post-war development of molecular biology has provided new pathways for politics to penetrate the material components of life".[30] He goes on to argue that many recent biotechnological issues such as gene therapy and the human genome project all raise significant biopolitical issues. Also relevant is research that explores the operation of biopower through policy developments, both contemporary and historical. For example, Legg utilises an analytical scheme derived from the Foucaultian literature on governmentality (the conceptualization of which is bound up with the related notions of biopolitics, population and discipline) to examine three reports that dealt with Delhi's congestion problem in the colonial period.[31] In a contemporary context Gilbert examines a recent political document (the Security and Prosperity Partnership) drawn up in 2005 by the US, Canadian and Mexican governments in an attempt to redefine the nature of cross-border relationships.[32] Reading this document through the lens of the Foucaultian governmentality literature, Gilbert finds evidence of a biopolitical rationality that refocuses political attention on the needs and wants of the 'citizen' and away from the management of the 'population'.

Reading policies through a Foucaultian lens, therefore, has some useful precedents that legitimise and inform the analysis herein. But before we undertake this task we

---

need to consider the implications of utilising what is essentially an anthropocentric theory of power within the context of animal lives and populations.

Biopower and animals

Limited efforts have been made to apply Foucault's ideas to the study of animals and human-animal relations, and within this already small body of work the specific area of biopower has received very little attention. In relation to Foucault's wider theorisation of power, for example, some attention has been paid to conceptions of disciplinary power in human-animal relationships. Novek, for instance, explores this in relation to intensive forms of livestock husbandry, and Williams explores how the recognition of animal sentience is used to deepen the disciplining of animals in and around meatpacking plants in order to elicit particular behaviours useful to the plant management. Work by Palmer and Holloway, in contrast, examines Foucault's understanding that disciplinary power is not simply repressive, but is a productive phenomenon within human-animal relationships, associated for instance with the emergence of particular sorts of human and animal subjectivity.[33] Holloway also discusses biopower as a useful concept in exploring human-animal relationships which involve the active intervention by people in the lives and bodies of livestock animals in contemporary agriculture; here, he examines the operation of biopower in relation to the deployment of robotic and information technologies in dairy farming. In this context, Holloway, drawing on Rabinow and Rose's three elements of biopower which we drew attention to above, acknowledges that there are problems associated with applying these to animals. Here, we consider these problems in a little more detail, suggesting that they need to be borne in mind in assessing the concept of biopower in examinations of human-animal relationships in general, and genetic policy interventions in livestock agriculture in particular.

First, the extent to which human-animal relationships exemplify biopower rather than 'sovereign' (or indeed some other mode of) power needs consideration. Above, we outlined Foucault's description of a biopower which came to overlie sovereign power in post-Renaissance Europe. The particular form of power exemplified by sovereign power is the power to curtail life, and clearly in relation to livestock animals the power to closely confine, control and end the lives of the animals concerned is strongly evident. However, the ways in which this power is expressed in livestock agriculture is in some important ways different to the expression of sovereign power as described by Foucault in relation to human populations. First, power over the life of livestock is, at least in contemporary Western contexts, particularly mundane, in contrast to the spectacular events periodically associated with the exercise of sovereign power over the life of humans. The slaughter of thousands of animals is daily routine in livestock systems which have effectively objectified animals, and far from acts of slaughter being public events, most in the West have become progressively distanced from the farming and killing of the animals they eventually consume, although spectacular and very public events such as the mass slaughter of animals resulting from the 2001 outbreak of Foot and Mouth Disease in the UK served as a reminder of the deaths of animals which underpin meat-based diets.[34] Second, alongside the power over life exemplified by the act of slaughter, the exercising of human power over the life of livestock animals has proceeded in other,

---

more subtle ways, through processes of domestication, selective breeding, and, increasingly, the application of genetic knowledge-practices.[35] These interventions represent attempts to direct and regulate life, to integrate that life into the technologies and economics of what have become industrialised agricultural systems. As such, overlying the powerful relations of domination which unarguably subtend contemporary livestock agriculture is a set of relations which, we argue, constitute a form of biopower operating between humans and livestock animals.

This argument that biopower is relevant in considering human-livestock animal relations raises two further issues. First, for Foucault, the notion of biopower was constituted in relation to an idea of population - an idea that took on particular meanings from the late 18th Century, and in particular was associated with the idea of the nation state. With regard to livestock, there is perhaps a number of different ‘populations’ at different scales, which might be considered the subject of relations of biopower. These include, for instance, the ‘national herds/flocks’ of the different species of livestock animal, but also a herd or flock on an individual farm. Further types of population are the different breeds of livestock within a national territory, or even international populations of animals related through their common membership of a breed.[36] In some ways, the differentiated effects of biopower in relation to how different groupings are defined parallel the way that Rabinow and Rose argue that categories of race or gender have formed the basis for different sorts of interventions in human populations. In assessing biopower in relation to policy interventions, it is clear that an understanding of how they constitute particular notions of population is necessary. The terminology of ‘biosocial collectivities’ adopted by Rabinow and Rose is particularly valuable here, allowing a move beyond the limitations of geographically proximate populations of the same species (ie, humans), to take into account non-proximate and heterogeneous groupings which might be constituted by members of different species (both human and nonhuman).

Second, Foucault’s biopower was, as concerned with national populations and the nation state, necessarily connected to state-level interest and interventions in populations. Yet, as Rabinow and Rose imply, from the later part of the 20th century, strategies for interventions have involved an array of state, quasi-state and non-state institutions, particularly in relation to genetic truth discourses. Similarly, in relation to livestock, a network of different types of institution can be understood as implicated in the formulation and implementation of strategies for intervening in the collective existence of livestock populations. Such institutions include those of the state (such as the relevant government departments), those sponsored by the state (such as government-funded agricultural research institutes), as well as private sector organisations (eg, commercial breeding companies) and the voluntary sector (eg, UK breed societies[37]). Here then, in relation to livestock breeding, biopower is distributed across networks of related institutions, including at the micro-scale the individual breeding unit or farm at which many interventions in farm-scale populations are conducted, and is related to the particular forms of institutionalisation which have come to characterise livestock breeding from the late 20th Century.

Policy interventions in the life of livestock animals

To further examine the issues raised above, we return now to our four case studies. Although all are concerned with genetic approaches to livestock breeding, they represent two distinct types of policy intervention. The first (NSP and FAnGR) surrounds concerns relating to, for example, specific animal health, disease and welfare issues, and ecological notions of biodiversity. Here, intervention has increasingly been articulated through an understanding that it is the genetic characteristics of livestock populations which should be the focus of attention, and specific policies and consultation documents have, to a greater or lesser degree, been formulated around a sense that livestock genetics can be managed in order to achieve desirable outcomes. The second type of intervention (the AEBC and FAWC reports) has emerged, somewhat ironically, in response to concerns about the effects of an increasing 'geneticisation'[38] of livestock breeding practices. In this case, policy-influencing activity has centred around debates about the extent to which policy intervention is required in order to mitigate some of the potentially negative implications of regarding livestock increasingly as the products or bearers of genetic material. The first type of policy intervention can be understood as promoting *opportunities* arising from the potential insights into livestock provided by genetic/genomic science, while the second form seeks to address (through regulatory changes) the potential *threats* associated with biotechnological and other developments in livestock breeding.

After outlining the four policy interventions, we focus in particular on the ways in which they articulate a form of biopower, as theorised by Rabinow and Rose, in operation in relation to livestock, and explore how biopower is expressed differently in relation to the different issues addressed in these interventions.

National Scrapie Plan

Scrapie is a Transmissible Spongiform Encephalopathy, fatal to sheep. Concerns that the presence of scrapie in sheep might mask the presence of BSE in such animals, with consequent health implications for humans who consume infected sheepmeat, led to the establishment of the NSP, which aimed to eradicate scrapie from the national flock through a Ram Genotyping Scheme. The NSP is underpinned by claims that 'conventional' methods of disease control, "traditionally based on the diagnosis of infected animals and the prevention of transmission to other stock" cannot be applied in the case of scrapie.[39] The NSP's strategy for intervention is instead predicated on a *genetic* understanding of the relationship between livestock animals and the disease. Key to the NSP is the fact that sheep with different genotypes are more or less susceptible to scrapie. The NSP thus centres on the identification of marker genes from sheep blood samples, a testing process referred to as Prion Protein (PrP) Genotyping, which allocates sheep to one of five categories (their PrP Genotype): the strategy thus focuses on retaining as breeding stock those animals which are theoretically genetically more resistant to scrapie, and culling those which are more susceptible. Initially a voluntary scheme, as a result of EU legislation, the NSP developed into a compulsory programme in 2004 for those flocks which experienced

---

a case of scrapie, and in 2006 it focused on pedigree flocks and other flocks breeding rams to be used in breeding.[40]

Farm Animal Genetic Resources

The second case study is the recent UK National Action Plan on FAnGR. The Action Plan, published by the UK's Department for Environment, Food and Rural Affairs,[41] was prepared by the National Steering Committee for FAnGR, an advisory committee consisting of scientists and expert representatives of a range of other organisations, which was established in 2004 by the UK government as part of its official response to the UN Food and Agriculture Organisation's global strategy for the protection of the world's animal genetic resources,[42] a product of the Convention on Biological Diversity drawn up at Rio de Janeiro in 1992. The plan identifies 38 Recommended Actions, together constituting its strategy for conserving farm animal genetic resources. Several are particularly relevant here. Two call for greater levels of 'scientific' and 'molecular' characterisation of livestock breeds. Two others directly relate to concerns about the narrowing of genetic diversity potentially associated with new genetic techniques of livestock breeding (including, specifically, the NSP), while a fifth raises concerns about the potential effects of such techniques on the health and welfare of animals, relating this to the FAWC report, returned to below.

Agriculture and Environment Biotechnology Committee

The Biotechnology Commission (AEBC) was established in June 2000 with a remit to provide the UK Government and Devolved Administrations with independent, strategic advice on developments in biotechnology and their implications for agriculture and the environment. A sub-group was constituted to produce a report on Animals and Biotechnology (published in 2002[43]) which considered whether current and future developments in animal biotechnology could be addressed through the existing regulatory and advisory machinery. Adopting a deliberately open and consultative approach to its work, the Commission held a series of meetings with experts and the general public and commissioned two research studies into public attitudes to biotechnology with animals. Its report refers to and builds on earlier publications dealing with animal biotechnology.[44] Drawing attention to both the positive and negative potentialities of the application of genetic biotechnology to animals, the AEBC comes to the view that "the practical differences between genetic biotechnology and conventional practices are not such as to suggest that GM or cloned animals should be governed separately in every aspect from conventional animals in the regulatory system".[45] However, it does recognise that GM and cloned animals present a number of potential problems that are not currently addressed in the regulatory system: eg, adequate monitoring of the long term stability and welfare of cloned and GM farm animals if and when they enter conventional production, ensuring consumer choice, and preventing any adverse environmental impacts. As such, it presents a set of seven recommendations for overcoming existing regulatory shortcomings, key among which is a new, independent and *strategic* advisory body "to examine issues raised by the use of genetic biotechnology on farm animals in the context of its use on other animals and current livestock farming practices".[46]

The Farm Animal Welfare Council

FAWC has, since 1979, provided independent advice to the UK Government on the welfare, and associated legislation, of agricultural animals on farm, in transit and at the place of slaughter. The Council comprises animal and agricultural scientists, economists, representatives of animal breeding companies, veterinary surgeons, farmers, and representatives of consumer interests. Its 2004 report on the welfare implications of animal breeding and breeding technologies in commercial agriculture aimed "to provide clear and practical advice to Government on the establishment of an appropriate framework within which developments in animal breeding and breeding technologies, and the outcome of such processes, may be considered".[47] The report identifies a number of shortcomings in existing legislation and other (eg, private sector) initiatives relating to animal welfare in the UK, and makes recommendations to address them, key among which is the creation of a Standing Committee to consider animal breeding in agriculture and its welfare consequences. Among its proposed roles the new Committee was expected to oversee a significantly increased level of surveillance of the welfare consequences of current breeding strategies and new breeding technologies, an activity requiring the collection and analysis of existing as well as new data from a variety of sources. The Government subsequently rejected the formation of the new Committee on the grounds of cost, a lack of a clear role for it in the absence of statutory powers, its threat to innovation and trade, and the global nature of animal breeding, which makes a UK-specific body largely redundant.[48] Instead, the Government sees FAWC itself as well placed to tackle many of the concerns raised and proposes a number of roles it might perform in relation to breeding including building good relationships with UK breeding companies and advising on a code of good practice for these companies (ie, an advisory and voluntary approach to regulation). By and large the Government views existing legislation as sufficient to protect animal welfare in relation to breeding and breeding technologies but it partially agrees with FAWC's call for enhanced surveillance, albeit with emphasis on a voluntary approach to data collection.

'Truth', authority and interventions in the life of livestock animals

Having outlined our four policy issues, we return now to Rabinow and Rose's three elements of biopower: the existence of truth discourses about the essence of life; strategies for intervention in the collective existence of living beings; and processes of subjectification which produce self-regulating individuals. Here, we focus on the first and second elements, returning to the third in the concluding section.

In all four policy documents, truth discourses about life are fundamental to the development of strategic interventions in the life of livestock animals. In all four cases, a genetic understanding of life is accepted; animal life is regarded as essentially genetically manipulable. For instance, the NSP states that "Studies of the genetics of sheep have … shown that it is possible to identify whether sheep are resistant or susceptible …",[49] and FAWC argues that "genotype associated welfare problems are recognised".[50] Genetic truth discourses thus run through all of the documents, but are articulated in different ways and are related in different ways to other simultaneous 'truths'. This suggests that different modes, or particular types, of biopower can be

---

identified in different instances, in relation to the very different issues addressed by the various policy documents. Different modes are thus related to particular combinations of, or relationships between, the different 'truths' associated with them.

In the NSP, the 'life' of sheep is reduced to a genetically-dependent susceptibility to scrapie, so that it is solely the PrP Genotype which is the focus of policy intervention. It is allied, however, with arguments that, first, scrapie poses a threat to human health; second, that as such, it should be 'eradicated'; and third, that genetics is the key to disease susceptibility in this case and that genetic testing is thus the key to eradication. Genetics here thus provides the opportunity of addressing a perceived animal and human health issue. In the case of FAnGR, there is a similar understanding that livestock animals can be 'known' through molecular characterisation. These 'truths' are here allied to, first, an argument that livestock 'biodiversity' should be conserved, and second, an understanding that genetic biodiversity stands alongside other measurements of livestock biodiversity (especially the diversity of livestock breeds) as an appropriate target for policy. As with scrapie, a knowledge of livestock genetics relates to a possible mode of intervention, yet in this case regarding the conservation of genetic diversity, in contrast to the narrowing of diversity which is a possible outcome of attempts to eradicate scrapie.

The other two policy documents address some of the potential consequences of genetic techniques in agriculture, although in common with the first two there is an assumption that such techniques will become increasingly prevalent in livestock breeding. Both the AEBC and FAWC reports draw on different understandings of the essence of life; in particular scientific truths relating to a genetic basis for life become entangled with other truths drawn from moral philosophy which, first, accept an essentially instrumentalist or utilitarian perspective on human relations with animals, but, second, represent animals as sentient beings with their own integrity or 'nature', such that animal lives need to be protected from the possible excesses of human intervention.

These emergent truths about the life of livestock animals gain legitimacy in the current policy context through the recognised expertise of the constituent members of the committees they are associated with, and by their intertextual relations with other reports (including each other) and institutions. In particular, authority is constructed and reproduced within the four cases by a common reference to scientific authority and expertise, used to legitimise the suggested policy interventions in the life of livestock. The NSP, for example, states that "The use of genetics to tackle scrapie has been recommended by the Spongiform Encephalopathy Committee (SEAC), the EU Commission's Scientific Steering Committee and has been endorsed by the Food Standards Agency".[51] The committees and agency referred to are seen as competent authorities as they too embody scientific expertise. Similarly, FAnGR is chaired by a leading agricultural scientist, with committee members drawn from a range of scientific institutions alongside those with specialised commercial and agricultural knowledge of particular species. Authority in this case is also constructed by reference to the internationally recognised authority of the FAO. In the cases of the AEBC and FAWC, their constitutional concerns with ethical issues associated with genetic interventions in the life of livestock require that alongside scientific expertise,

---

authority is simultaneously drawn from other fields. The AEBC is, for example, informed by various scientific disciplines, but at the same time it includes the perspectives and authorities of law and moral philosophy, while FAWC asserts that it "takes account of scientific knowledge and the practical experience of those involved in the agriculture industry … [and takes] a broad-ranging approach, taking into account all relevant views".[52] Collectively, then, and using Rabinow and Rose's terminology, the policy reports drawn on here can be seen as representing an interlinked array of authorities considered competent to speak truths about the life of livestock animals and the appropriateness of particular types of intervention in that life. Our point here is that although these authorities may in some ways contradict each other, and become allied in different ways to other, sometimes also competing, truth discourses, in specific contexts and at particular moments they are regarded as authoritative, and as such, are associated with effects such as policy responses and changes in the practices of animal agriculture.

A clear strategy for intervention is demonstrated in both the NSP and FAnGR although the strategy and its associated intervention is much more targeted in the case of the NSP where the eradication of a disease represents a singular and very clear aim to be realised through genetic testing. In contrast, the strategy identified by FAnGR is relatively broad in scope – the conservation of the UK's farm animal genetic resources – and relies on genetic interventions (scientific and molecular characterisation) alongside a range of other actions to realise its objective, including the establishment of institutions and reporting structures, the establishment of inventories and recording systems to improve data collection and accessibility, and strategies for genetic conservation. Meanwhile, the strategy for intervention that is called for by the AEBC and FAWC reports is the regulation of agricultural biotechnology and breeding technologies respectively. The strategy here is, primarily, to protect farm animals from the excesses of biotechnological and other breeding developments with the recommended intervention an extension and deepening of livestock governance. While the AEBC calls for the establishment of a new statutory advisory body and FAWC recommends a new Standing Committee, both advocate *increased* monitoring and surveillance (also endorsed by FAnGR) at a number of scales: individual animal bodies subject to breeding strategies; and the nation state, where flows of genetic material and genetically modified animals (may) cross national borders. The AEBC, informed by a wider constituency of interests, also calls for *further* means of extending public engagement in decisions about genetic biotechnology, and arranging the means to maintain consumer choice about whether to purchase GM products. All of these recommendations imply the devising of new, or the revision of existing, policy and regulatory instruments relating to the management of livestock populations.

The strategies in all four policies call for intervention in the lives of farm animals both to protect those lives (eg, from disease, loss of genetic diversity, and the welfare consequences of breeding technologies), and also to guarantee the interests of associated human populations (eg, through sustaining the livelihoods of sheep farmers and the health of consumers (in the case of the NSP) and ensuring consumer choice when and if genetically modified animal products are made available commercially, in the case of the AEBC's report). In this way they can be seen to be intervening in,

---

and attempting to manage, simultaneously the lives of animal and human populations whose interests are inextricably intertwined.

There are multiple populations at which the strategies for intervention are targeted. Two relatively tightly defined populations, at different geographical scales, are the focus of the NSP: the national sheep flock (a population which should be free of scrapie) and the individual farm flock as the population where intervention through genetic testing, culling etc. occurs. Cutting across both of these populations is another - breed - with some breeds identified as being less susceptible to scrapie than others and therefore of increased economic interest. The populations that are the focus of intervention within FAnGR are somewhat more loosely defined. Population here is, in one sense, all livestock in the UK, but differentiated according to species, breed and ‘strains’ within breeds. Alongside these populations ‘biosocial collectivities’ provide an additional focus for the strategies for intervention. Such a notion evokes assemblages comprising both human and non-human entities. In the case of the NSP, therefore, the targeted biosocial collective comprises sheep (as individuals), genetic material, individual humans including farmers and breeders, disease vectors and a variety of institutions including Defra, SEAC and breed societies. Similarly, the biosocial collective identified through FAnGR comprises all livestock in the UK (categorised as species, breed and strain), their ‘genetic resources’, humans (as, *inter alia*, breeders, policymakers, scientists) and institutions (eg, breed societies, species organisations, governments). The targeted populations identified by NSP and FAnGR can be seen to both pre-exist, but also be reproduced through, these interventions (eg, breed is a long-standing and accepted way of understanding livestock). In contrast, the biosocial collectives appear to be rather more emergent and contingent, brought into being through the policy interventions and potentially associated with new political activities.

The populations that are the focus of the strategies for intervention in the AEBC and FAWC reports are, like those of the NSP and FAnGR, multiple and broadly conceived. In the case of the former, it is ‘animals’ in the UK that is the primary population of interest, categorised as farm animals, companion and sporting animals and those involved in xenotransplantation. Individual (cf. populations of) animals outside the UK are mentioned (eg, the production of high-value farm animals through cloning in Australia and the US), as are flows of genetic material and genetically engineered animals across national boundaries. Given the AEBC’s remit of *national* regulation it is inevitable that a national population of ‘animals’ - broadly conceived - should be the focus of its strategies for intervention. The more specialist concerns of FAWC may explain the focus of its strategies for intervention on populations similar to those identified in the NSP and FAnGR. Here, then, population is defined primarily in genetic terms, as farm animal ‘genotypes’ produced through conventional breeding strategies and ‘new’ breeding technologies. Alongside this, species of farm animals, breeds, and also types of animal such as dairy cows and broiler chickens are further populations of interest. As with the AEBC, international animal populations are recognised, eg, through reference to the international effort involved in animal genetic engineering and of flows of genetic material and genetically engineered animals across national boundaries. However, the ultimate focus of FAWC’s primary strategy of intervention is *national* farm animal genotypes, a scale of intervention in animal populations that is subsequently rejected by the Government as redundant in the face of the international nature of farm animal breeding.

Suggestions of biosocial collectivities are apparent in the AEBC and FAWC reports. In broad terms, this is evident in the AEBC's relational vision. When discussing *farm* animals (and how biotechnology may impact them) the report emphasises that these should not need to be viewed in isolation, but in relation to *other* animals. This reinforces its assertion that biotechnology has to be understood and approached in relation to other livestock farming practices (something that FAWC also advocates) and that both need to be situated in the context of society's attitudes to animals more broadly. This highly relational vision is one that is likely to reflect the social scientific expertise on the AEBC and the social scientific research it commissioned.[53] More specifically, and evident in both the AEBC and FAWC reports, is their combined calls for enhanced monitoring and surveillance of farm animal populations that are the subject of breeding strategies and technologies. In both cases the imagined biosocial collective comprises farm animals (as breeds, species, types and genotypes), individual humans such as farmers, breeders and veterinary surgeons, biotechnological and other breeding interventions (some of which are not yet commercially available), and a variety of institutions including the government (its various advisory bodies – existing and new - and departments), breeding companies and breed societies. The public may be seen to comprise an additional member of this biosocial collective in the vision of the AEBC where greater public engagement with animal genetic biotechnology is advocated and reflects a wider trend towards greater public consultation and engagement in decision-making.

In summary, analysis of the four policies provide evidence for at least two of Rabinow and Rose's three dimensions of biopower in the context of livestock breeding through genetic techniques, albeit variably expressed. The concluding part of the paper considers the third dimension and makes suggestions regarding the need for further conceptual and empirical research in this domain.

Conclusion

Rabinow and Rose summarise their understanding of what is necessary to biopower as follows:

> *…knowledge of vital life processes, power relations which take humans as living beings as their object, and the modes of subjectification through which subjects work on themselves qua living beings…*[54]

We conclude by assessing the relevance of such an approach to the study of livestock animals and their breeding through genetic techniques, explored through the medium of policy, and by raising some questions associated with thinking about human-livestock relations through the lens of biopower.

The first two of Rabinow and Rose's elements seem strongly applicable to the case of agricultural animals and genetic interventions in their lives. The emergence of 'truth discourses' which locate vital life processes at the level of genetic material has

---

become increasingly evident in livestock breeding,[55] just as they have in the context of medical interventions in human life.[56] Scientific and political authorities increasingly considered able to speak that truth have become prominent in agriculture and livestock breeding. Similarly, the policy and consultation documents examined in this paper are evidence of power relations involving strategies for intervening in the lives and existences of groups of living beings - although here it is livestock animals rather than humans which are the immediate focus of such interventions. What emerges from our assessment of the four policy issues is that the notion of what constitutes the livestock population to be intervened in is far from straightforward. Populations defined at different *scales* (eg, national or farm scale), and of different *types* (eg, species, breed or genotype), are identified and co-exist within individual documents. As such, rather than policies simply targeting pre-existing populations, multiple and entangled populations are constituted through the truth discourses and interventions associated with policy documents. Further, differently circumscribed populations draw heterogeneous others (eg, humans, genetic material, or organisations) into relational associations with them. Definitions of population as a result form the basis of the particular heterogeneous bio-social collectivities which are intervened in. Policy interventions which constitute and engage with such collectivities thus effectively extend the purview of biopower to include animals (*inter alia*) in their relationships with humans.

The third of Rabinow and Rose’s elements is rather more problematic. Animals’ subjectivity is, to an extent, addressed by those aspects of the policy interventions which are concerned with issues of ‘animal welfare’ in agriculture. Yet throughout, it is difficult to comprehend how livestock can be understood as ‘working on themselves’ in the way Rabinow and Rose, and Foucault, imply, and yet this is absolutely crucial to the concept of biopower since the “process of producing ‘docile’ minds and bodies is not (indeed cannot be, on grounds of cost) confined to state institutions and discourses watching over, regulating and controlling people’s thoughts and behaviour. The basic idea of biopower is to produce self-regulating subjects”.[57] In other words, once (human) bodies and minds have been shaped in particular ways by truth discourses then the individual ‘takes over’, to regulate themselves so that they continue to function in healthy ways and as ‘good subjects’. The most economical form of surveillance, as Danaher et al[58] argue, is self-surveillance. It is this dimension of biopower that is a stumbling block to the acceptance of biopower, as Rabinow and Rose define it, in relation to human interventions in the lives of livestock animals.

In response, we suggest that an extended notion of the relations which constitute subjectivity might offer a way to explore how biopower is articulated through human-animal relationships. Specifically, and in relation to the four policy interventions examined here, we argue that ‘geneticised’ truth discourses and interventions are associated with the production of modes of *human* subjectivity which have the effect that (some) humans work, not only on themselves, but on the bodies and experiences of livestock animals as other living beings. This is not to downplay the importance of the animals themselves. Instead, the theoretical challenge is to explore how, within particular modes of biopower, heterogeneous relationships between humans and nonhumans are structured and played out, recognising the significance of both the

---

bodily materiality and the subjectivity of humans *and* animals in relation to particular sets of power relations. As such, by relocating and distributing the focus of biopower, a more relational conception of biopower in which individuals work on nonhuman others alongside their work on themselves, might begin to be formulated. Thus, for example, much of the intervention suggested or required by the policy documents we have examined demands the enrolment of livestock breeders and farmers into practices of surveillance and monitoring of livestock animals, and into bureaucratic processes of record keeping, reporting and communication, all of which are associated with the exercise of biopower in relation to animal lives and bodies. In arguing for this more distributed sense of biopower and biosocial collectivities, we begin to look towards the poststructuralist perspectives offered by, for instance, science and technology studies and actor-network theory,[59] in order to develop understandings of biopower (and, indeed, other modes of power) which more adequately account for trans-species relationships. At the same time, we argue that detailed empirical work within networks of breeders, scientists and others is demanded in order to fully examine the modalities and complexities of biopower as they are expressed and performed in particular circumstances.[60] Thus, our initial assessment of the usefulness of biopower as an analytical concept sets an agenda for further theoretical and empirical work which will greatly enhance our understanding of the implications of genetic techniques for livestock agriculture.

---

[1] Lewis Holloway, Department of Geography, University of Hull, UK l.holloway@hull.ac.uk; Carol Morris, School of Geography, University of Nottingham, UK Carol.Morris@nottingham.ac.uk.

[2] We acknowledge that there is an important distinction between genetics and genomics. However, for the sake of clarity and ease of reading the term 'genetic' is used in this paper to include both 'classical' quantitative genetics and 'modern' genomics as these have developed in the context of breeding livestock. G. Bulfield. Farm animal biotechnology. Trends in Biotechnology 2000; 8: 10-13.

[3] Bulfield, op. cit. note 2. A. Archibald and C. Haley. What can the genetics revolution offer the meat industry? Outlook on Agriculture 2003; 32: 219-226. S. Bishop and J.A. Woolliams. Genetic approaches and technologies for improving the sustainability of livestock production. Journal of the Science of Food and Agriculture 2004; 84: 911-919. D. Elstein, J. Comis and A. Flores. Unraveling the genome of the honey bee, pig, cow and chicken: an agency effort to sequence genomes. Agricultural Research 2005; January: 4-9. E.A. Maga. Genetically engineered livestock: closer than we think? Trends in Biotechnology 2005; 23: 533-535.

[4] Archibald and Haley op. cit, note 3.

[5] See, for example, the work of Sarah Franklin on new forms of 'biocapital' and 'bioprospecting' related to genetic technologies. S. Franklin. Mapping Biocapital: new frontiers of bioprospecting. Cultural Geographies 2006; 13: 301-304. S. Franklin. Sheepwatching. Anthropology Today 2001; 17: 3-9. S. Franklin. Dolly: a new form of transgenic breedwealth. Environmental Values 1997; 6: 427-437.

[6] M. Foucault. 1990. The History of Sexuality, Volume 1: An Introduction. Penguin. Harmondsworth. M. Foucault. 2004. Society Must Be Defended. Penguin. London.

[7] P. Rabinow and N. Rose. 2003. Thoughts on the Concept of Biopower Today http://www.molsci.org/files/Rose_Rabinow_Biopower_Today.pdf (accessed 01.02.2005).

[8] Defra. 2003. National Scrapie Plan for Great Britain: NSP Programme Brief. London. Defra.

[9] Defra. 2006. UK National Action Plan on Farm Animal Genetic Resources. London. Defra.

[10] Agriculture and Environment Biotechnology Commission. 2002. Animals and Biotechnology: a Report by the AEBC. London. AEBC.

[11] Farm Animal Welfare Council. 2004. FAWC Report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture. London. FAWC.

[12] MAFF. 1994. Report of the Committee to Consider the Ethical Implications of Emerging Technologies in the Breeding of Farm Animals (the 'Banner Report'). London. HMSO. Farm Animal

Welfare Council.1998. Report on the Implications of Cloning for the Welfare of Farmed Livestock. London. FAWC. AEBC, op. cit. note 10. Royal Society. 2001. The Use of Genetically Modified Animals. London. The Royal Society. Animal Procedures Committee. 2001. Report on Biotechnology. London. The Animal Procedures Committee.

[13] Rabinow and Rose, op. cit. note 7.

[14] Foucault, op. cit. note 6.

[15] Rabinow and Rose, op. cit. note 7. B. Braun. Biopolitics and the Molecularisation of Life. Cultural Geographies 2007; 14: 6-28.

[16] Foucault. 1990, op. cit. note 6, p.139.

[17] Braun, op. cit. note 15. p.9.

[18] Braun, op. cit. note 15. p.9.

[19] M. Foucault. 1978 [2001]. The politics of health in the 18th century. In Essential Works of Foucault, 1954-1984: Power (Vol. 3). J. D. Faubion ed. London. Penguin pp. 90-105. E. Yoxen. 1982. Giving Life a New Meaning: The Rise of the Molecular Biology Establishment. In Scientific establishment and heirarchies: sociology of the sciences, vol. VI. N. Elias, H. Martins and R. Whitley, eds.: 123-143.

[20] J. Marks. Biopolitics. Theory, Culture and Society 2006; 23: 333-335. p.333.

[21] Braun, op. cit. note 15. p.8-9.

[22] S. Legg. Foucault's Population Geographies: Classifications, Biopolitics and Governmental Spaces. Population, Space and Place 2005; 11: 137-156.

[23] Rabinow and Rose, op. cit. note 7.

[24] Marks, op. cit. note 20.

[25] Rabinow and Rose, op. cit. note 7. p.3.

[26] Ibid, p.23

[27] Ibid, p.2

[28] Ibid, p.3

[29] Ibid, p.23

[30] Marks, op. cit. note 20. p.333.

[31] S. Legg. Governmentality, Congestion and Calculation in Colonial Delhi. Social and Cultural Geography 2006; 7: 709-729.

[32] E. Gilbert. Leaky Borders and Solid Citizens: Governing Security, Prosperity and Quality of Life in a North American Partnership. Antipode 2007; 39: 77-98.

[33] J. Novek. Pigs and People: Sociological Perspectives on the Discipline of Nonhuman Animals in Intensive Confinement. Society and Animals 2005; 13: 221-244. A. Williams. Disciplining Animals: Sentience, Production and Critique. International Journal of Sociology and Social Policy 2004; 24: 45-57. C. Palmer. 'Taming the Wild Profusion of Existing Things'? A Study of Foucault, Power and Human/animal Relationships. Environmental Ethics 2001; 23: 339-358. L. Holloway. Subjecting Cows to Robots: Farming Technologies and the Making of Animal Subjects. Environment and Planning D: Society and Space 2007; 25.

[34] I. Convery, C.Bailey, M. Mort, J. Baxter J. Death in the Wrong Place? Emotional Geographies of the UK 2001 Foot and Mouth Disease Epidemic. Journal of Rural Studies 2005; 21: 99-109.

[35] H. Ritvo. 1987 The Animal Estate: The English and Other Creatures in the Victorian Age. Cambridge MA: Harvard University Press. K. Anderson. A Walk on the Wild Side: A Critical Geography of Domestication. Progress in Human Geography 1997; 21: 463-485. L. Holloway. Aesthetics, Genetics and Evaluating Animal Bodies: Locating and Displacing Cattle on Show and in Figures. Environment and Planning D: Society and Space 2005; 23: 883-902. L. Holloway and C. Morris. Animal Bodies and Genes: Contested Expertise in the Fields of Breeding for Beef and Disease Eradication. Paper presented at the session 'Spaces of knowledge, communities of knowing', RGS-IBG annual conference, London, September 2005.

[36] The definition of breed is problematic. Most simply, for authors such as Clutton-Brock, it refers to a group of animals which can be distinguished from other groups on the basis of appearance, so that when members of a group breed their offspring reproduce their particular 'type'. However, we find this type of definition quite limited, and for our purposes it might be more helpful to see breed as a more complex set of relationships, a bio-social collectivity which includes breeders and breed societies, and discourses and practices of livestock breeding, along with the animals themselves. J. Clutton-Brock. 1994. The Unnatural World. In Animals and Human Society: Changing Perspectives. A. Manning and J. Serpell, eds. London. Routledge pp. 23-35.

---

[37] Breed societies are organisations which promote their particular breeds of livestock, and attempt to guide the development of the breed in particular directions. In the UK they tend to be registered charities

[38] L. Gannett. What's in a Cause?: The Pragmatic Dimensions of Genetic Explanations. Biology and Philosophy 1999; 14: 349-374. N. Rose. The Politics of Life Itself. Theory, Culture and Society 2001; 18: 1-30.

[39] Defra, op. cit. note 8. p.19.

[40] J. Long. Scrapie Scheme Advance. Farmers Weekly 2005; 25 March: 38

[41] Defra, op. cit. note 8.

[42] FAO. 2007. First Report on the State of the World’s Animal Genetic Resources. Rome. FAO.

[43] AEBC, op. cit. note 10.

[44] MAFF, op cit. note 12. FAWC, op cit. note 12.

[45] AEBC, op. cit. note 10. p.29.

[46] Ibid, p.4

[47] FAWC, op. cit. note 11. p.5.

[48] Defra. 2006. Government Response to the FAWC Report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture. Consultation Document. London. Defra.

[49] Defra, op. cit. note 8. p.19.

[50] FAWC, op. cit. note 11. p.5.

[51] Defra, op. cit. note 8. p.19.

[52] FAWC, op. cit. note 11. p.7.

[53] See, for example, P. Macnaghten. 2001. Animal Futures: Public Attitudes and Sensibilities Towards Animals and Biotechnology in Contemporary Britain. A Report by the Institute for Environment, Philosophy and Public Policy for the Agricultural and Environmental Biotechnology Commission.

[54] FAWC, op. cit. note 11. p.7.

[55] See also C. Grasseni. Designer Cows: The Practice of Cattle Breeding Between Skill and Standardisation. Society and Animals 2005; 13: 33-50. Holloway, op. cit. note 33.

[56] see, for example, E. Yoxen. 1982. Giving Life a New Meaning: The Rise of the Molecular Biology Establishment. In Scientific establishment and hierarchies: sociology of the sciences, vol.VI. N. Elias, H. Martins and R. Whitley, eds. Doerdrecht: D. Reidel Publishing Co.: 123-143. L. Kay. 1993. The Molecular Vision of Life: Caltech, the Rockefeller Foundation and the Rise of the New Biology. Oxford. Oxford University Press. E. Keller. 2000. The Century of the Gene. Cambridge, Mass. Harvard University Press. D. Haraway. 1997. Modest_Witness@Second_Millennium.FemaleMan©_Meets_OncoMouse™: Feminism and Technoscience. London. Routledge.

[57] G. Danaher, T. Schirato and J. Webb. 2000. Understanding Foucault. London, Sage.

[58] Ibid

[59] Eg, B. Latour. 1999. Pandora’s Hope: Essays on the Reality of Science Studies. London. Harvard University Press. B. Latour. 2005. Re-assembling the Social: An Introduction to Actor-Network Theory. Oxford. Oxford University Press. J. Law and A. Mol, eds. 2002. Complexities: Social Studies of Knowledge Practices. London. Duke University Press.

[60] Such empirical research is at the heart of our forthcoming research project, ‘Genetics, genomics and genetic modification in agriculture: emerging knowledge-practices in making and managing farm livestock’ funded by the UK Economic and Social Research Council (ref. RES-062-23-0642).

Genomics, Society and Policy
2007, Vol.3, No.2, pp.99-117

Animal Genomics and Ambivalence: A Sociology of Animal Bodies in Agricultural Biotechnology

RICHARD TWINE[1]

Abstract

How may emergent biotechnologies impact upon our relations with other animals? To what extent are any changes indicative of new relations between society and nature? This paper critically explores which sociological tools can contribute to an understanding of the technologisation of animal bodies. By drawing upon interview data with animal scientists I argue that such technologies are being partly shaped by broader changes in agriculture. The complexity of genomics trajectories in animal science is partly fashioned through the deligitimisation of the productivist paradigm but continue to sit in tension around particular conceptions of sustainability in farm animal production.

In spite of this deligitimisation process genomics is now being framed in the context of a new productivism (termed the livestock revolution) bound up in projected global changes in animal consumption during the first half of the 21st century. This potentially jars against both social trends that seek to re-enchant animal life and sustainability discourses which include social and environmental contexts. Nevertheless the possibility of a new productivism is supported by various interconnected trends including the emergence of a discourse of the ‘bioeconomy’ and a liberal regulatory apparatus for farm animal breeding technologies. Ultimately an understanding of the possibility of emerging new bio-capitalisations on animal life should be set in a broader context of competing agricultural paradigms as well as ongoing tensions over ‘naturalness’ in human/animal relations.

Introduction

Much of the sociological literature speaks of contemporary Western human/animal relations as characterised by an ambivalence which came to cultural prominence during the twentieth century.[2] Animal Genomics I shall argue sits productively within the nexus of this ambivalence. On the one hand we can note a historical move toward less instrumental human/animals relations; and the emergence of ethics of care which have inspired hubris challenging reflexivity within modern intensive agriculture and other areas. Yet significantly animals remain real conduits for bio-capitalisation and targets of human consumption at the outset of the 21st century. Biotechnological elaborations of animal life, be they through genomics or bio-pharmaceuticals or, perhaps in the longer term, cloning[3] or GM, extend the modernist mastery of nature, now for some more properly understood as a refashioning or ‘bespoke’[4] made to order nature. Whilst this may indicate an historical continuity with the modernist mastery of nature (constructed as separate to the human), transitioning now to a reality wherein nature becomes properly an externalised object of re/design, biotechnological impacts remain unclear owing to uncertainties over their social

---

reception and technical viability. The ability of biotechnologies to further embed hybrid forms is partly dependent upon the continued erosion of the 'natural' in domains such as food and health.[5]

My focus in this paper is on animal biotechnologies in *agriculture* rather than medicine. However this choice of focus necessitates that I make clear a few points related to scope of coverage. I have argued elsewhere[6] of the need to take into account the way in which developments in the biosciences promote a convergence between agricultural and biomedical domains but also that in terms of knowledge transfer there is a much longer history at play here.[7] When trying to think through sociological explanations of animal biotechnologies it is cogent if possible to be attentive to these interconnections, newly emerging or otherwise. For example, it's important to appreciate that database information covering the sequenced genomes of both mice and the human is used routinely in comparative genomics in order to try and pinpoint gene function and economically interesting chromosomal loci for the farm animal sciences. Thus huge investments which in the main had the rationale to investigate human disease are also made useful to those working in farm animal science and investigations into animal gene function also feed back into human medical research. Recognising such interconnections is as yet under-theorised in the social science literature. Although the last ten years have seen a significant increase in research into the ethical, legal and social aspects of genetics this has been predominantly human centred in focus. To an extent this reflects the general invisibility of animals in Sociology[8] as well as the failure to attribute sociological import to the place of animals and animality within the social. In the social science and bioethics of this area there is a specific division of labour between the false demarcation of 'red' (human, medical) and 'green' (environmental) biotech. In this unreflected repetition of the society/nature dualism it is rather unclear where animals are accommodated. Consequently sociologists are at the early stages of thinking through the biotechnological construction of human/animal relations and here I offer some signposts.

Ideally then an analysis would be broader than that imposed by space constraints here. For example *most* of the research that could be taken to underline Michael's[9] claim of *bespoke* animals takes place in biomedicine. Thus the vast majority of animal research using genetically modified (GM) animals is in the area of creating animal models to study disease. There are a small number of research projects investigating both cloning and GM technologies for applications in agriculture. The company Aquabounty may be successful in commercialising the first GM animals (salmon) for human consumption in a few years' time, and cloned animal products for human consumption may be commercialised by 2010.[10] The point here is that if one was to base an analysis *solely* on either agriculture or biomedicine without any reference to their interconnection, one might well come up with a particularly partial representation of the biotechnological shaping of human/animal relations. The unsurprising discrepancy in funding between the sequencing of the human and mouse genomes vis-à-vis those of 'agricultural' animals means that the latter lag someway behind. However due in part to its interest as a model for developmental biology the chicken genome sequence is complete and mapping projects for other major farm animals are well underway. These efforts are adding significant knowledge to the

---

understanding of gene function and promoting the adoption of molecular solutions to particular problems in farm animal breeding.

My approach in this paper to producing an understanding of the biotechnological shaping of human/animal relations in the context of agriculture centres around two main aspects. First I am interested in transnational discourses which serve to frame the role of animal science in farm animal breeding in various ways. Of particular importance here is the emergence of the knowledge-based bioeconomy discourse generally and the prescribed role for animal science within this. I will argue that pivotal to the successful uptake of a new technology such as genomics is its own negotiation of its relationship to ideas of *sustainable* agriculture within the bioeconomy discourse. Here I also draw upon empirical research; a series of semi-structured interviews with UK based animal scientists conducted in 2006. This debate on sustainability is also germane to that of global food paradigms and the future of animal ethics within food production. The second aspect I wish to focus upon is the actual work that animal science does upon animal bodies. Here I apply a Foucauldian analysis to the disciplinary power of animal sciences acting to break down and interrogate the efficiency of animal bodies in farm animal production. I argue that due to the taken-for-granted ethical lacunae around animal life, Foucault's analysis of biopower actually works better when applied to farm-animal animals. I also briefly consider how the arguments mapped out are positioned in relation to wider social theory terrains on the role of ambivalence in debates around modernity and postmodernity.

Ambivalent animal futures in the 'bioeconomy'

Although it is prudent to avoid being drawn into a teleological and linear view of progress where 'prior' instrumental views of nonhuman animal life have been gradually problematised, and to an extent discredited in parallel with the denaturalisation of gender and race relations, it is nevertheless clear that in the West the political status of animals has indeed emerged during the last thirty years. We can note a broad cultural interest in animal behaviour and interiority and, on the fringe, a rise in vegetarian and vegan practices of the self that announce a posthuman engagement with the world. In farm animal breeding itself animal welfare is a much more important issue and area of funded research compared to thirty years ago.

But even before we introduce a biotechnological slant on the discussion, we are already in the realm of contradiction and ambivalence. As Buller & Morris point out, "*while postmodernity has encouraged us to see the individuality and subjectivity of nonhumans as beings, modernity continues to put them on our plates as meat*".[11] Historically our emergent dissonance at the processes of animal production has been partly managed by the spatial sequestration of the sites of rearing, slaughter and preparation. Arguably our cultural tendency to disengage with animal ambivalence also makes it harder to bring animals into academic study and to encourage public engagement on the social and ethical aspects of farm animal breeding. If we think of biotechnological approaches to animals as at least partly *re-embedding* modernist values of control and mastery then it is not difficult to see why, emotionally, it may be a difficult subject for people to explore.

In this section I want to try and explain animal biotechnology in terms of this recent history of partial animal subjectification. In fact I want to suggest that animal science is in tension and is best understood as being shaped by both ‘postmodern’ values as well by the ‘re-embedding’ of modernity.[12] By drawing upon semi-structured interview data carried out with animal scientists I will point to the ways in which this tension is expressed and how the productivist paradigm has been partly diluted. New molecular techniques such as animal genomics are being partly shaped by a strong discourse of sustainability in contemporary agriculture complimented - and sometimes contradicted – by their framing within the emerging idea of the bioeconomy. It is within the bioeconomy discourse and the related rejuvenation of the anatamopolitics of animal bodies to be discussed later that we can potentially point to the re-embedding of modernist values in animal science.

Although I have referred to a broader cultural ambivalence in our human/animal relations expressed through a tension between explorations of animal subjectivities and explorations of genomic control we can focus this down into the fields of animal science. Although it is tempting to say that behavioural and animal welfare science map onto the former and quantitative genetics and new molecular techniques map onto the latter this would be to simplify. For example genetics and genomics are being given a significant role in animal welfare and sustainability generally, and more critically, for some, a welfare approach to animal ethics would anyway be seen as complicit with instrumentalism. Indeed welfare has been quite successfully converted into a new value for the commercialisation and consumption of supposedly ‘happier’ animals. In spite of this caution the language and framing of animals within these branches of animal science *can* be strikingly different, pointing to the contested nature of the animal in contemporary animal sciences. I will revisit this point later. For the time being I want to show how the productivist paradigm in farm animal breeding has been partly diluted and deligitimised.

During 2006 I conducted semi-structured interviews with 22 UK-based animal scientists including those working on genetics, genomics, welfare and agricultural economics. These provided strong evidence for a turn against productivism. It is important to note that in the post-war period quantitative genetics and other efficiency measures had been very successful in adding to farm animal productive output. Although molecular techniques can be used to refine genetic selection it is not clear that greater productivity traditionally conceived as quantitative output is constructed as a societal need in the way it once was. Furthermore it would be accurate to say that social opposition to an emphasis on productivism is located around concerns over the industrialisation of farm animal production and so implies that a partial paradigm shift has occurred prior to and irrespective of biotechnological innovation. (Whilst it would be naïve to suggest that animal welfare has become the number one concern for UK meat consumers we *can* point to a 150% increase in organic meat sales between 2000 and 2005.[13] Clearly concerns over industrialisation can also pertain to human health consequences.) What also became clear from the interviews is that further drivers of change have been the unforeseen consequences of pursuing narrow breeding goals. For example, selecting for high milk production has produced significant problems

---

such as mastitis and declining fertility in cows.[14] Here are some extracts from interviewees to illustrate the decline of productivism:

> *"I think people would be concerned if the product, if … productivity was pushed much further, in terms of milk production or egg production. As I say to a large degree breeders are backing off of those traits and looking for robustness or longevity in milk production, longevity in egg production and certainly in terms of government funding for that sort of research has become more important*"
>
> "*It's changed certainly I think quite dramatically. I would say up until the mid-1970s, a bit longer than that, the emphasis was on output amount. Then it became an issue of quality and efficiency and now there's a lot more emphasis on animal health and welfare and robustness*"
>
> *"Oh yes, dramatically. Two changes I suppose. One has been the shift from research that's relevant to production agriculture to supporting developments in more fundamental biology. And the other shift, something more recently, is to say well, yes, we're interested in sustainable production agriculture but the only things we're really interested in are the impact on the environment or an impact on society which tends to be the DEFRA view, look at DEFRA's forward look, the emphasis on environment and sociological perspectives is enormous"*
>
> *"I guess about 10-12 years ago I was seeking to find wider options in sheep breeding, basically in trying to get away from simply making sheep grow faster and have less fat. And it became apparent that there were a lot of issues to be addressed in terms of diseases and specifically genetic sort of disease resistance"*

Given this historical and social context which also includes the emergence of sustainability as a key principal in agriculture and animal science funding, it is not surprising to see both quantitative genetics and newer molecular techniques partly orientated to this agenda. One interesting consequence of this is that breeding goals now include 'socially and environmentally important traits' alongside the traditional focus on selection for economic output.[15] Molecular techniques *can* be used to optimise output (as in markers for growth and litter size) but also they are currently thought to be of best use for difficult to measure traits which can fit well with a de-emphasis on production. These include disease resistance in animals and *qualitative* changes such as meat quality. Research in this area is accompanied by philosophical deliberation on breeding goals which now should be 'long term' and 'biologically, ecologically, and sociologically sound'.[16] Similarly in their discussion of the role of genetic technologies (traditional and molecular) in improving sustainable farm animal production Bishop & Woolliams also stress the importance of social, biological, environmental and economic viability.[17] These represent interesting shifts where animal scientists are now compelled to think broadly and across disciplines about their work.[18] I shall return to this point later. In their summation of current breeding goals Bishop & Woolliams point out that increased product output and efficiency of

---

production will continue to be important, but notably stating "*within economies such as Western Europe, where output already exceeds requirements, such a breeding goal may be questioned*".[19] For them disease resistance and animal health now pose the greatest challenge to farm animal geneticists, pointing out that the cost of disease in the UK alone stands at £1.7 billion. Genomics has already been applied in this area and is expected to make further contributions. A further contributory factor here to the shaping of genomics is the recent controversy over genetic modification. That GM proved so contentious in the case of crops would tend to inspire the belief that it would be even more so in the case of animals. Thus genomics, which although a molecular technique, is being framed as an ethical and more publicly acceptable alternative[20] offering the benefits of more precise controlled selection minus the extra step of transgenics.

Within the discourse of animal science the broadening out of genetic technologies to include social, environmental and animal welfare considerations finds expression in the idea of the 'win-win'. This refers to the idea of a selection that incorporates *both* productivity and post-productivist values such as animal welfare. In a way it might be seen as the perfect response to animal ambivalence, an attempt to satisfy both trends of instrumentalisation and subjectification in Western human/animal relations simultaneously. It's a notion that came up several times during the interviews as illustrated here by extracts, each from a different scientist:

> *"So in a way what we're doing is a win-win situation. If we breed animals that are more resistant to disease the farmers spend less time and less money on preventative treatments but also the welfare of the animals is improved as well in that they are inherently more healthy than, you know, had we picked the wrong sire".*
>
> *"I think many farmers would believe that pushing for very high standards of welfare that perhaps people who are detached from animals aspire to, is going to cost a lot of money. But in fact a lot of our research on larger species at least shows that they can be win-wins here. In diary cattle for instance we've shown that by expanding selection away from just milk production alone to include resistance to mastitis and lameness and to include fertility is expected to increase the economic returns as well as reduce welfare problems".*
>
> *"Which has, you know, obviously some diseases are of major economic importance, and if one could make animals are basically fitter, healthier and more able to resist disease, then you're benefiting the animal, you're reducing the need to treat them with drugs and antibiotics so there's a potential downstream benefit for the human food chain. And so there's a sort of a potential for a win-win situation if you can do that effectively"*
>
> *"I don't see production and welfare as being equivalent, but I don't see there being a problem with working on a project in which both production and welfare are improved. And it's certainly more likely to be taken up by industry if you can show that you have invented something that's going to improve both welfare and production and everybody wins"*

One point to make about the ‘win-win’ is that it is a genetic solution to welfare centred on the selection of the animal before it is born. There may not be anything inherently problematic with this. In fact one example that came up was that of animals that due to being selected for intensive environments over several generations had to now be ‘re-selected’ if they were to cope with better welfare environments. Moreover it is no doubt dubious for the social scientist to unreflectively favour the environmental fix over the genetic fix for that must surely contain its own mistaken duality. Nevertheless problem-solving choices are set in an economic context and may serve to further particular ontological assumptions about, in this case, animals. The concern here may be that the partial geneticisation of welfare is also an instrumentalisation of welfare where aspects such as health and robustness may be seen as bound up in productivism as much as they are in welfare. Additionally they could be seen as invested in an overly biologistic account of farm animals, as was the concern of one animal welfare scientist interviewed:

> *“On the other hand there’s also a trend, a parallel trend where it’s almost like we’re going backwards in time and welfare is becoming more and more an issue just of health, you know physical health. And that is partly this what we’re talking about, you know its like metabolic stress because it’s, because they’re in the first place conceptualising animals as complex production systems and then they’re talking about the health of that system. I see it as my own task and other colleagues is to counterbalance and to develop concepts that are close to the subjectivity of the animal. And to also, I mean how could you possibly talk about boredom and depression you know in a complex metabolic system? It’s not going to happen is it?”*

If one thinks of a major defining modernist assumption about animals as that which over biologises and denies their sociality as vital to a human/animal dualism then one could interpret this geneticisation of welfare as a re-embedding of modernity as it denies a space for the very subjectifying language that could subvert it. The idea that welfare is becoming more and more an issue of health may also speak to its co-option by a genetics-focused ethos. The re-embedding argument is stronger once one analyses the framing of the future of farm animal breeding within the transnational idea of the bioeconomy.

I will begin by tracing the formation of the bioeconomy discourse and then consider its relation to farm animal breeding. During the last 5-10 years the idea of the bioeconomy has emerged in European and global economic discourse as a concept which is intended to signify a new epoch of post-industrial capitalist accumulation. It encapsulates genomics and biotechnology generally in a narrative of progress that purports to address both challenges of Fordist economic decline as well as environmental limits to growth. Although the contribution of the bios to the economy (as well as that of peoples seen as closer to nature) has traditionally been ‘backgrounded’[21] here we have an explicit manifesto that puts the generative powers of biology at the centre of economic progress.

In the European context, Europa-bio – The European Association of Bioindustries[22] - is taking a lead in shaping the meanings around the bioeconomy. It expresses a naturalising teleology in its idea of different epochs stating on its bioeconomy web portal:

> *"In the 18th and 19th Centuries, European society was transformed by the Industrial Revolution and the steam engine. This was the Age of Engineering. In the 20th Century, the developed world reaped the benefits of chemistry, which provided the materials, productive agriculture and medicines which make our lives so comfortable and safe. The whole world is now in transition from the Age of Chemistry to the Age of Biotechnology. Biotechnology will drive expansion of the global economy, increasing wealth while reducing Humankind's environmental footprint. We have the potential to be world leaders in innovation; the most dynamic region in the developing bio-based economy".*

The European Commission is actively promoting this idea on a number of levels. These include the formation of new European Technology Platforms - essentially vision documents on an array of technologies over the next 25 years - and the inclusion of the bioeconomy in the new Framework 7 Programme; an Environmental Technology Action Plan (ETAP); and a Biofuels Directives and Biomass Action Plan. Yet this discourse is certainly transnational. China saw the first international conference on the bioeconomy in 2005 and the Organisation for Economic Co-operation and Development (OECD) is currently working up a policy agenda on the bioeconomy between now and 2030. The OECD defines the bioeconomy as

> "*the aggregate set of economic operations in a society that uses the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations....made possible by the recent and continuing surge in the scientific knowledge and technical competences that can be directed to harness biological processes for practical applications*"[23]

Our new capacities to possibly harness biological labour, for example, through novel material hybrids or immortal stem cell lines or bio-remediation can, it is hoped, encourage the exploitation of newly 'liberated' biological value, arguably as a corrective to past technological excess or lifestyle mistakes. Cooper has offered one of the first historical accounts of the bioeconomy discourse arguing that it emerged out of 1970s debates on post-fordism and limits to growth. She posits a coming together of a notion of life as autopoiesis, as self-generative, with the emergence of debt finance - "*the production of money from money*" - as a key mode of economic power.[24] The point is more than merely to underline the role that promissory venture capital plays in funding biotechnological start ups but that, for Cooper, there has been a significant discursive exchange between theoretical biology and neo-liberal theories of economic growth which has come to shape a bioeconomic vision.[25] It is within environmental science and the ideas of ecological modernisation that Cooper locates this discursive exchange. I would also add that the emergence of bioeconomic modelling within agricultural economics should be seen as a significant influence.[26] Essentially constituting an adaptive moment of post-industrial capitalism, ecological

---

limits to growth are converted into valuable opportunities for capital accumulation, thus bio-remediation can clean up pollution and GM food can feed a growing global population. In one sense this is unsurprising given that the alternative would have been to properly reflect upon the ecological contradiction of positing progress in terms of continual economic growth.

Putting the spotlight on animal inflections of the bioeconomy discourse adds to the analysis and provides further contextual explanation for animal biotechnology trajectories. One of the aforementioned EU technology platforms is titled Sustainable Farm Animal Breeding and Reproduction[27] and scopes out the research agenda until 2025. The TP working group is made up of leading figures in research and industry. Its 'vision for 2025' document illustrates how its ideas for this area are contextualised by the notion of the knowledge-based bioeconomy. Although there is little doubt that new molecular techniques should be developed at least as basic research (in part it argues because Europe must remain competitive within a knowledge-based bioeconomy), this is stressed with the proviso of transparency and public engagement.[28] The bioeconomy language of sustainability is also to the fore here defined in terms of "*The three pillars – people, planet and profit...sustainable breeding and reproduction means balancing food safety and public health, product quality, biodiversity, efficiency, environment, animal health, animal welfare in an economically viable way*".[29] Overall sustainability is given an economic slant and there is no mention of the several ways in which large-scale animal breeding is environmentally unsustainable.[30] There are breeding options here, for example, in developing techniques for selecting animals that produce less phosphates or emit less ammonia and methane or selecting for disease-resistant animals, but it's unclear how viable or effective these could be.

Perhaps the most significant section of the TP vision paper refers to what is termed in the broader literature as the 'livestock revolution'. Global consumption of animal products is forecast to rise significantly over the next 20 years mostly due to increasing levels of consumption in developing countries. Whilst the FAO has expressed concern over rising levels of animal consumption in developing countries on the grounds of public health and environmental impact,[31] the TP vision paper frames it as both a challenge and opportunity. Although it may be countered, as indicated above, that new genetic techniques are under investigation that could improve the healthiness of animal products and restrict their environmental impact, such changes, if viable, may well come too late. Thus while we have seen a partial deligitimisation of productivism in the UK context, it becomes apparent that in global terms animal breeding allied to an emergent transnational discourse of the bioeconomy provides the opportunity for a return to a productivist mode. Whereas molecular techniques in the UK and to an extent the wider Europe are being shaped by a turn against productivism, it will not necessarily be the case in other parts of the world. Moreover I would suggest that further research is required on the deployment of 'sustainability' within debates on farm animal breeding and new technologies in order to provide a better understanding of the extent to which they can make a real contribution to enhancing the environmental and social dimensions of agriculture.

The intention in this section has been to explore some of the ways in which new molecular techniques in animal breeding are being contextualised by broader socio-economic change. We are, it should be noted, still in the early days of such technologies, with only limited commercialisation of genomics and remaining doubts within significant areas of animal science communities over the ethics and technical viability of cloning and genetic modification. However, many possibilities are being pursued that would cast animals as significant actors within global relations of bioeconomic exchange. These span and intertwine the agricultural and medical domains including GM models, biopharmaceutical animals, persistent attempts to develop animals for xenotransplantation and selection for farm animals using both quantitative genetics and newer molecular techniques. Cloning is also being applied to companion animals,[32] racing animals and in the hope of conserving threatened species. For much of the remainder of this paper I want to focus on the processes which are key to constructing animals as bioeconomic actors. This necessitates giving attention to the processes that do work upon animal bodies that convert them into newly mobile sources of value and exchange.

Animals, biovalue and biopolitics

Since they have for a very long time borne the imprint of human directedness, farm animals may be considered some of the first hybrid forms. But the new capacities for control, manipulation and possible redesign introduced by molecular techniques entails that this hybridity is intensified. Such work upon animal bodies takes place alongside human genomics. Research, whether it is centred on animal breeding or human disease, employs comparative work between databases of human and animal genomic information. The knowledge transfer now taking place echoes that which took place during the earlier part of the twentieth century between animal and human reproductive science.[33] Yet a monolithic analysis that posits advancing trends of body rationalisation risks missing the differences that are taking place between the human and the animal, notably how human/animal relations and the moral value of nonhuman animal life are being constructed in the process.[34] Animal biotechnology is potentially controversial given that it suggests various ways for extending the instrumentalisation of animals precisely at a time when the moral value of animals is being contested.

Here I want to outline how animal biotechnology contains commonalities and differences with the human case and so try and flesh out some specificity for thinking about the rationalisation of animal bodies. Many authors[35] have attempted to theorise the rise to cultural prominence of genomics and have drawn upon Canguilhem's idea of the notion of biological life as informational code and Foucauldian theories of biopolitics. Some, notably Haraway and Thacker,[36] have incorporated animals into their thinking but have not especially pursued the notion of biopolitics and 'life as information' in the animal case. Consequently this is what I shall do here.[37]

What is it then that is crucial to commodification processes around animal bodies? If we recap Cooper's idea of autopoiesis, "*a self-engendering of life from life*",[38] we can augment this with Waldby's idea of 'biovalue" which she refers to as:

> "*the yield of vitality produced by the biotechnological reformulation of living processes. Biotechnology tries to gain traction in living processes, to induce them to increase or change their productivity along specified lines, intensify their self-producing and self-maintaining capacities...biotechnology finds insertion points between living and nonliving systems where new and contingent forms of vitality can be created, capitalizing on life*"[39]

These are useful concepts for thinking about innovation in animal biotechnologies and one can see how they provide good definitions for some in particular, notably the use of animal bodies as 'machines' for the production of biopharmaceuticals. Biovalue is also created by freeing animal DNA from its original context and recombining it in a new site. Moreover biovalue is not inherent to biotechnology but should be applied to the year-on value creation we have seen in animal breeding using quantitative genetics to produce what animal scientists refer to as 'genetic progress'; the cumulative enhancement of the herd.

Some features of animal biotechnology are already potentially useful for the construction of biovalue in a globalising economy. If globalisation is partly about the compression of time and space as well as commodity standardisation then biotechnology introduces a novel malleability, narrowing distance between species and reorganising evolutionary time. If the aim of animal breeding has been to produce healthy high quality animals as products then cloning may potentially offer a new level of optimal standardisation. Although the debate on human cloning has been aired through concerns about individuality and concepts of dignity, a desocialised view of animals has contributed to the absence of a similar degree of ethical concern for cloned animals. Generally the significant difference between the cultural application of ethical frameworks related to human biotechnology vis-à-vis animal biotechnology means a more liberal licence for optimising biovalue in the animal case. Whilst scientific projects for enhancing reproduction extend across the human/animal dichotomy, what we do upon animal bodies continues in a manner to structure what is morally *unacceptable* in the human case. The closest we get to controlled breeding in the human case are technologies such as pre-implantation genetic diagnosis (PGD) or perhaps sex selection.[40] Comprehensive human germline breeding remains at this point in time within the blue-skies deliberations of bioethicists.

In spite of these differences I do want to argue that biopolitics, so remarked upon in the human case by social scientists, are just as relevant in farm animal breeding.[41] Indeed, due to different ethics the analysis works better. Although Foucault did not apply his theory of biopolitics to animals, in his discussion of pastorship as the mode of modern individualising power he does historicise biopower in terms of human/animal relations: "*It isn't enough to know the state of the flock. That of each sheep must also be known*".[42] Here he taps into Christian themes of shepherdry and providential care as important antecedents of biopower. Foucault's theory of biopower is of course understood as the management of human life and subjectivities through knowledge/discourse that broadly serve the economic and social regulation of modern rationalised societies. He defined it specifically as the "*endeavour, begun in the 18th Century, to rationalize problems presented to governmental practice by the*

---

phenomena characteristic of a group of living humans beings constituted as a population: health, sanitation, birth rate, longevity, race".[43] This concept is then specified with two inter-related aspects, first an anatomopolitics of the body, "*centred on the body as a machine: its disciplining, the optimization of its capabilities, the extortion of its forces, the parallel increase of its usefulness and its docility, its integration into systems of efficient and economic controls*" and a biopolitics of the population, "*focused on the species body, the body imbued with the mechanics of life and serving as the basis of the biological processes: propagation, births and mortality, the levels of health, life expectancy and longevity, with all the conditions that can cause these to vary*".[44] I think there is a reading of Foucault that can make a strong argument for the agricultural animal as representing a biopolitical ideal type. But to begin with there are two ways in which this may not be the case. First, Foucault's point was that biopower supersedes sovereign power, but in the animal case sovereign power is obviously very much still operative,[45] and, second, biopower is a technology that constructs subjectivity and it's unclear that we can talk about this in the animal case.[46] Nevertheless, post-war animal science especially has exerted a considerable degree of biopower over agricultural animals for it is not merely that the animal body must be primed to be economically productive but that the body itself must work toward its own consumption. The 'genetic progress' made on animal bodies during this period together with increased availability and the decreased price of animal products also shows how this biopower was in a sense subservient to the overarching project of constructing healthy human bodies.[47]

Animal science has and continues to put much labour into both anatamopolitics and population biopolitics. Docility has been selected for across all agricultural species in that disruptive or aggressive animals will tend to be selected out. A whole array of animal science sub-disciplines work to ensure that animal bodies are disciplined to be at the optimum for production. These include but are not limited to meat science, behavioural science, reproductive science and a focus on feed efficiency, physiology, development, nutritional quality, immunity and disease, biometrics, environmental impact as well as methods of slaughter. The notion of 'genetic progress' could be taken as an annual measure of biopower success but genetics is only a part (although increasingly so) of animal biopolitics. Here optimization projects strike deeper due to the absence of human norms of privacy, autonomy[48] and justice. Normatively dystopian fears about encroaching biopolitical management of society are informed by this legitimated animal shadow biopower. Thus ethical objections to new technologies on the grounds of human dignity not only encourage reflection on the 'human' but also upon the human/animal distinction by which it is partly constituted.

An important facet of both forms of biopower for the further production of *biovalue* is the genetic view of life as informational code. Animal genomics for example is in certain important ways an information science. This is evidenced by the material practices of animal scientists which involve less and less lab based work and more time in front of a computer screen doing work on database molecular information representations of animal bodies. Following earlier work by Canguilhem on the coming together of information theory and molecular biology[49] several authors have analysed this as a part of emergent biopolitics. It is a vital process in the conversion of biology into biovalue. At this point it's worth quoting an interview extract from a

---

discussion on transgenics. On the question of moving DNA from one species to another one scientist said:

> “*If you think about it it boils down to the identity of that little piece of sequence. Now my personal view is that it’s just a piece of DNA sequence. Whether it has, it could be isolated from, it could have a pig gene and you want to put it into a mouse lets say. You could go to a pig, you could take some blood, you could isolate some DNA from that blood, you could isolate that gene from a sheep and you could put it into the mouse. Or you could say I know that sequence, I’m going to go to a machine and I’ll make that sequence and it’s a pig sequence and I’ll put it into a mouse. Now are they both pig genes? They’re just a piece of DNA, to me its just a piece of DNA*”

This raises interesting questions for genetic identity but for the purpose of this discussion it illustrates how DNA can come to be seen as mobile information largely detached from its original context. It is Thacker who has probably analysed this in most detail, writing on the movement of biological material from the ‘wet’ lab to become ‘dry’ information, a new media. He writes:

> “*Biological exchange, in conceiving of biology as information that exists – and persists – across media, radically widens the possibility of what can be exchanged within the biological domain. Not only is the biological commensurate with the economic (e.g., microbes, cells, or DNA that is patented or purchased for research), but the biological can be internally exchanged in ways that are not limited by the division between the material and the immaterial*”[50].

An example of this would be the transfer of DNA onto a chip which can then enter into relations of economic exchange as a biovaluable research tool. Although it is as if life as information code has gradually come to lose its metaphorical content, Thacker argues that the dematerialisation of biology can only go so far. Information is both immaterial *and* material,[51] the former allowing for its entry into global relations of exchange and the latter ensuring either biovalue or promissory biovalue.

Another contributory process to the codification of DNA and biological abstraction is the generation of statistical data around genetic knowledge. In animal science this developed alongside quantitative genetics. Statistics are pressed into service in order to try and calculate the economic advantage of going for a particular genetic selection, and of combining particular genetic and environmental adjustments. If animals are converted, abstracted and valorised as economically relevant genes, markers and quantitative trait loci within their codification as DNA, then within associated statistical estimates they can be said to become elements within complex mathematical equations. For Foucault statistics were an important element of biopolitical management.[52] In the animal context we can think of animal breeding as a highly controlled state of its own. One modelling technique in animal science is known as bioeconomic modelling. Indeed bioeconomic modelling techniques emerged in the 1980s within agricultural economics[53] and provide an augmentation to Cooper’s historicisation of the bioeconomy discussed earlier. Bioeconomic approaches are a convergence of animal genetics, economics and statistical modelling

---

and are used across all agricultural species.[54] The development of such techniques has been catalysed by the corresponding development of information technology. Best Linear Unbiased Prediction (BLUP) is a sophisticated statistical software program that geneticists use to estimate breeding values of animals. Moreover it aims to separate out genetic factors from environmental factors and so yield accurate knowledge of the value of selection alone. A focus on the productive performance of an animal inevitably constructs a partial view of the value of the animal. Holloway notes this surge in statistical modes of animal evaluation, arguing that they sit in tension with vernacular visual judgements of the animal by farmers which are now deemed to be scientifically unreliable. In an analysis that chimes with that of Thacker above, he states

> “*As data are made and studied, particular forms of knowledge of the animal body are gained, but the totality of the animal is lost. There is an iterative process of abstraction, as ‘raw’ data from related animals are processed to construct individual’s estimated breeding values (EBV) for specific traits, generalised indices for beef or calving values, and an index comparing animals with others of their breed. Ultimately, an abstract, simplified yet comprehensible representation of the complex reality of nature is put onto paper or computer disks, forms which can then themselves be transported and examined in places and times away from the sites of data collection*”[55]

Indeed ‘nature’ is constructed in such a way as to make it malleable and useful. The abstraction process opens up the possibility for human intervention and ‘enhancement’ of ‘nature’.

A unifying theme running through many commentaries on biopolitical constructions of human embodiment is a concern with reductionism. Thus to what extent do, for example genetic databases, in their extraction of genetic knowledge put forward a de-socialised view of the body? A common criticism of UK Biobank, the project to take sample DNA from 500,000 people, has been that it valorises a genetically determinist view of health.[56] What may be seen as absent or insufficiently accounted for includes public health perspectives and a broader theorisation of the body as socially, politically and ecologically embedded. A similar tension between reductionism and complexity is played out in the context of farm animal breeding. However this takes place within a Cartesian historical context which has naturalised a biologically determinist view of animals. As Burke points out, it is often scientific research on animals that is then employed to project such determinism onto human behaviour.[57] The tension between complexity and reductionism was also evident from respondents interviewed. This took two forms. First, it was clear that the challenge of genomics is considerable. Although genome sequencing is producing more ‘information’, it remains complex to actually discover the underlying gene/s involved in traits of interest. Gene interactions also complicate matters as does a renewed interest in epigenetics which may make it more difficult to predict animal performance. Second, it became obvious that the tension was evident in the differing conceptions of the animal between geneticists and welfare scientists. Unsurprisingly the latter want to put an emphasis on animal subjectivity and sociability which can clash and sit rather

---

oddly with an overly genetic model of animal behaviour. One animal welfare scientist said in relation to genetic selection:

> "*Primarily my stance is that that whole paradigm is heavily reductionist obviously. So it is based on the purity reductionist approach to animals which and my problem with that is, you know it's not wrong but it's a huge imbalance. And a claim of the objective science paradigm that it's the only objective paradigm*"

Thus sociologists who wish to re-socialise the human within genomic discourse have a shared concern with animal welfare scientists who wish to do the same with animals. But in the animal case it's arguably more of a challenge due to our tendency not to think of animals in terms of sociality and subjectivity, and because of the historical ideological investment of thinking about animals in this way. Our inheritance of dualistic modes of thinking about society and nature have entailed that in the distinctions of subject/object, mind/body, culture/nature, reason/emotion animals have tended to be associated with the second set of terms.[58] As well as excluding 'animal' from 'human', this has been part of a modernist technology that has enabled many human groups to be associated with animality, a historically consistent and persistent mode of conceptualising human difference. Consequently attempts to start emphasising animal sociality and subjectivity have a considerable degree of discursive heritage to contend with. In addition what has been of specific use to biopower and is now reproduced in both medical human genomics and animal genomics is the mapping of the culture/nature distinction with that of mind/body. This underlying assumption of biopower appears to allow bodies of whatever species to be apprehended in an asocial manner which can then encourage an overestimation of the malleability of bodies. It is this decontextualisation move that is often behind the production of risk and in the case of animal breeding, surfaces in the unintended consequences of biopolitical control such as a narrowly productivist selection focus impacting welfare or the appearance of unexpected disease.

Conclusion

Although we can note differing 'animals' at play within animal genetics and animal welfare science it is clear that the former animal remains the dominant conception. The dominance of the biopolitically amenable animal is unsurprising given its inter-relation with the commercial production of biovalue. The animal favoured within animal welfare science (and I would not want to suggest this is unitary or unanimous in either field of science) on the other hand represents both an economic cost and an ontological challenge. Therefore it is not surprising that many animal welfare scientists work pragmatically with geneticists in order to try and secure some change in the conditions of farm animals. It could be argued that by underemphasising animal sociality and subjectivity, animal genetics implicitly expresses overconfidence in knowledge of human/animal difference, a question that is fluid in various areas of scientific knowledge including genomics itself.

I have sought to analyse emergent technologies in animal breeding in terms of the interconnections between biopolitics, biovalue and the idea of the bioeconomy.

Within these relations we find the ambivalence of contemporary human/animal relations in the form of contested truths about what an animal is and a broader struggle over the place of sustainability in future agricultures.[59] Although I and others have alluded to the cultural tension between instrumentalism and subjectification at play within our human/animal relations, genomics itself amplifies this once more with its intimations of human/animal similarity *and* its intensification of the biopolitical interrogation of animal bodies. These relations would seem to fit Bauman's conception of postmodernity not as something that temporally supersedes modernity but as the instigation of ambivalence and uncertainty as defining themes of our times.[60] This is a rather different account to the postmodern politics of difference alluded to at the outset but complimentary in the sense that for Bauman postmodernity is also a *reflection upon* ambivalence. It is then a political act to name the ambivalence and contradictions with which we treat animal others, as opposed to merely living with unaccounted incongruity.

Any counter narratives of progress wishing to explore new ethical dimensions of human/animal relations must encounter the usefulness that modernity has found for the symbolic category of the 'animal' in structuring difference and identity. Although it is itself uncertain how cultural tensions will shape animal biotechnologies and farm animal breeding generally, in the future it is likely that the increasingly global context in which these industries operate will lead to fragmented and diverse outcomes. As highlighted above, global population trends are also being used as an argument for a new productivism.[61] The globalisation of animal production encourages more liberal regulation[62] and could open up new spaces for the promotion of biotechnological innovation. If, as seems possible, the 'livestock revolution' becomes the stage on which we revisit a productivist focus upon animal breeding (potentially in tandem with new molecular technologies) then it will have to answer comprehensively the real challenge of environmental sustainability as well face ongoing alternative posthuman voices for animal ethics.

Acknowledgements

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. The work was part of the programme of the ESRC Centre for Economic and Social Aspects of Genomics (CESAGen). I would also like to thank scientists and administrative staff working at the Roslin Institute and the Scottish Agricultural College for their co-operation and engagement with my work.

---

[1] ESRC Centre for Economic and Social Aspects of Genomics (CESAGen), Lancaster University, UK r.twine@lancaster.ac.uk

[2] K. Thomas. 1983. Man and the Natural World: A History of the Modern Sensibility. London: Routledge; A. Franklin. 1999. Animals and Modern Cultures : A Sociology of Human-Animal Relations in Modernity. London: Sage; P. Macnaghten. Animals in their nature: a case study of public attitudes on animals genetic modification and 'nature'. Sociology 2004; 38 (3): 533-551.

[3] At the time of writing (April 2007) the EU's European Food Safety Authority (EFSA) and the European Group on Ethics (EGE) as well as the US's Food and Drug Administration (FDA) are considering the subject of the human consumption of cloned farmed animals.

---

[4] M. Michael. Technoscientific bespoking: animals, publics and the new genetics. New Genetics and Society 2001; 20 (3): 205-224.

[5] See MacNaghten, op. cit. note 2.

[6] R. Twine. Ma(r)king Essence: Ecofeminism and Embodiment. Ethics and the Environment 2001; 6 (2): 31-58.

[7] See A. Clarke. 1998. Disciplining Reproduction: Modernity, American Life Sciences, and the Problems of Sex. Berkeley: University of California Press.

[8] H. Tovey. Theorizing nature and society in sociology: The invisibility of animals. Sociologia Ruralis 2003; 43 (3): 196-215.

[9] Michael, op. cit. note 4.

[10] See http://news.bbc.co.uk/1/hi/sci/tech/6431229.stm

[11] H. Buller & C. Morris. Farm animal welfare: a new repertoire of nature-society relations or modernism re-embedded? Sociologia Ruralis 2003; 43 (3): 216-237, p.217.

[12] The idea of modernity being re-embedded in farm-animal farming is taken from Buller & Morris, op. cit. note 11.

[13] This statistic comes from Mintel, the consumer and market research group, as reported by the BBC here: http://news.bbc.co.uk/1/hi/uk/4551304.stm

[14] See W.M. Rauw et al. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livestock Production Science 1998; 56; 15-33.

[15] Eg, E. Kanis et. al. Breeding for societally important traits in pigs. Journal of Animal Science 2005; 83: 948-957.

[16] I. Olesen et. al. Definition of animal breeding goals for sustainable production systems. Journal of Animal Science 2000; 78: 570-582. See also P. Thompson & A. Nardone. Sustainable livestock production: methodological and ethical challenges. Livestock Production Science 1999; 61: 111-119.

[17] S. Bishop & J. Woolliams. Genetic approaches and technologies for improving the sustainability of livestock production. Journal of the Science of Food and Agriculture 2004; 84: 911-919, p.911.

[18] I thank one of my referees for pointing out that interview responses here "could be treated as rhetoric, as less about the doing of animal genomics, and more about the talk that constructs/legitimates it in this given context". I think this is something to remain reflexive to. Here I would argue that there has been a limited change in animal science. It is of course germane to consider whether such changes get translated into agricultural practice.

[19] Bishop & Woolliams, op. cit. note 17, p.913.

[20] This framing is evident in animal science discourse as well as in emergent company public relations in breeding companies such as Aviagen and Cherry Valley, for example.

[21] See V. Plumwood. 1993. Feminism and the Mastery of Nature London: Routledge.

[22] Europa-Bio http://www.europabio.org/ represents Europe's leading biotechnology companies. It has created its own Bioeconomy portal here - http://www.bio-economy.net/

[23] OECD. 2006. The Bioeconomy to 2030 – designing a policy agenda. Paris: OECD Publications: 1.

[24] M. Cooper. Life, Debt, Autopoiesis – Inventing the Bioeconomy. Distinktions – Journal of Scandinavian Social Theory 2007; May (Special Bioeconomics Issue): 2.

[25] Ibid. p.12

[26] I discuss this in more detail later.

[27] The web-site for this Technology Platform can be found here: http://www.fabretp.org/

[28] FABRE-TP. 2006. Sustainable Farm Animal Breeding and Reproduction – A Vision for 2025 Brussels: FABRE Technology Platform: 16.

[29] Ibid. p.9

[30] See FAO. 2006. Livestock's Long Shadow -Environmental Issues and Options. LEAD/FAO. Available online at http://www.virtualcentre.org/en/library/key_pub/longshad/A0701E00.pdf (last accessed 10 April 2007). To this one should also add deleterious human health impacts of over-consuming animal products.

[31] See http://www.fao.org/WAIRDOCS/LEAD/X6115E/x6115e03.htm

[32] The pet cloning company Genetic, Savings and Clone went out of business in late 2006.

[33] Clarke, op. cit. note 7.

[34] See M. Foucault. 2001. Power: The Essential Works, Vol.3. London: Allen Lane: 299; P. Rabinow. 1992. Artificiality and enlightenment: from sociobiology to biosociality. In Incorporations. J. Crary & S. Kwinter, eds. New York: Zone: 234-53, p.237.

---

[35] Eg. D. Haraway. 1997. Modest Witness@Second Millenium. FemaleMan Meets OncoMouse: Feminism and Technoscience. London: Routledge; N. Rose. The politics of life itself. Theory, Culture and Society 2001; 18 (6): 1-30; C. Waldby. 2000. The Visible Human Project – Informatic Bodies and Posthuman Medicine. London: Routledge; E. Thacker. 2005. The Global Genome – Biotechnology, Politics and Culture London: The MIT Press.

[36] Haraway, op. cit. note 35; Thacker, op. cit. note 35.

[37] An aspect of animal biopolitics which space prevents me from discussing here is animal biometrics. Biometrics are increasingly important in agriculture in order to try and prevent the spread of disease.

[38] Cooper, op. cit. note 24, p.9.

[39] C. Waldby. Stem cells, tissue cultures and the production of biovalue. Health: An Interdisciplinary Journal for the Social Study of Health 2002; 6 (3): 305-323, p.9.

[40] Only the former is legal in the UK. Some authors would certainly wish to construct a continuum here between these and contraception as well as assisted reproduction technologies (ARTs). But my point here is about technologies that make a *qualitative* modification to bred populations.

[41] Foucault has been drawn upon before by social scientists and humanities scholars interested in human/animal relations. Examples are C. Palmer. 2004. Madness and Animality in Michel Foucault's Madness and Civilization. In Animal Philosophy: Essential Readings in Continental Thought. M. Calarco & P. Atterton, eds. Continuum International; D. Wadiwel. Cows and Sovereignty: Biopower and Animal Life. Borderlands 2002; 1 (2): 1-8; L. Holloway. Subjecting cows to robots: farming technologies and the making of animal subjects. Environment and Planning D: Society and Space (forthcoming). To quote Wadiwel (p.1): "*That...nonhuman animals are not clearly eligible for consideration within a discussion of biopolitics is not due to any poverty in the potential scope of Foucault's term. Rather, the deficiency relates to the tradition of politics itself, at least in the West, which has, by and large, exempted the nonhuman animal from agency as a political being*".

[42] Foucault, op. cit. note 34, p.309.

[43] Rabinow, P. ed. (2000) Ethics: Subjectivity and Truth (Essential Works of Michel Foucault). Harmondsworth: Penguin: 73.

[44] M. Foucault. 1990. The History of Sexuality: Care of the Self Vol.3. Harmondsworth: Penguin: 139.

[45] For a lengthy discussion on animals and sovereign power see Wadiwel, op. cit. note 41. For Foucault's example of a society "*which has generalised biopower in an absolute sense, but which has also generalized the sovereign right to kill*", see M. Foucault. 2003. Society Must Be Defended – Lectures at the College de France, 1975-1976. London: Penguin.: 259-60.

[46] For a fascinating discussion and possible refutation of this point see Holloway, op. cit. note 41.

[47] The negative health impact of over-consuming animal products notwithstanding.

[48] Interestingly as Holloway (op. cit. note 41) points out, the introduction of robotic milking systems are predicated around allowing for cow autonomy.

[49] In F. Delaporte, ed. 1994. A Vital Rationalist – Selected Writings from Georges Canguilhem. New York: Zed Books: 316-7.

[50] Thacker, op. cit. note 35, p.10.

[51] Ibid. p.21

[52] Foucault, op. cit. note 45, p.246; Thacker, op. cit. note 35, p.22.

[53] Statistical methods of determining the economic value of selection choices have a much longer history.

[54] Eg, T. Roughsedge, P.R. Amer & G. Simm. A bio-economic model for the evaluation of breeds and mating systems in beef production enterprises. Animal Science 2003; 77: 403-416; J. Conington et al. A bioeconomic approach to derive economic values for pasture-based sheep genetic improvement programs. Journal of Animal Science 2004; 82: 1290-1304.

[55] L. Holloway. Aesthetics, genetics, and evaluating animal bodies: locating and displacing cattle on show and in figures. Environment and Planning D: Society and Space 2005; 23: 883-902, p.892.

[56] Eg, Genewatch. 2006. UK Biobank gets go-ahead: GeneWatch UK response. Press release. Available at http://www.genewatch.org/article.shtml?als[cid]=507674&als[itemid]=541998 (Last accessed 10 April 2007.)

[57] L. Burke. 1994. Feminism, Animals and Science – The Naming of the Shrew. Buckingham: Open University Press: 106.

---

[58] For critiques of dualism see literatures in feminist philosophy, feminist geography and ecofeminist theory. For example, in ecofeminism see Plumwood, op. cit. note 21; G. Gaard. Toward a Queer Ecofeminism, Hypatia 1997; 12 (1): 114–37; and Twine, op. cit. note 6.

[59] See T. Lang & M. Heasman. 2004. Food Wars – The Global Battle for Mouths, Minds and Markets. London: Earthscan.

[60] Z. Bauman. 1991. Modernity and Ambivalence. Cambridge: Polity Press: 271-2.

[61] FABRE-TP, op. cit. note 28, p.12.

[62] Please refer to the recent UK Department for Environment, Food and Rural Affairs (DEFRA) response to the Farm Animal Welfare Council's (FAWC) call for a new body to assess new technologies in animal breeding. DEFRA's opinion was that regulation might stifle innovation and should be better dealt with at an EU level or by an international body: DEFRA. 2006. Government response to the FAWC report on the welfare implications of animal breeding and breeding technologies in commercial agriculture London: DEFRA: 5.

Genomics, Society and Policy
2007, Vol.3, No.2, pp.118-119

Author Biographies

Gary Carvalho is Professor of Molecular Ecology, School of Biological Sciences, University of Wales, Bangor and heads the Molecular Ecology and Fisheries Genetics Laboratory. He undertakes research on the population genetics and evolutionary biology of aquatic animals, with a particular focus on the origins and significance of population diversity. He is currently member of the ICES Working Group on the Application on Genetics in Fisheries and Mariculture, is Chair, European Regional Working Group of FISH-BOL- (DNA barcoding of fishes), and past Vice-President of the Fisheries Society of the British Isles.

Filipe Costa is a Marie Curie Fellow at the School of Biological Sciences, University of Wales, Bangor. He is a team member of the Molecular Ecology and Fisheries Genetics Laboratory, and is currently involved in various research projects concerning DNA barcoding, phylogeography and phylogeny of aquatic animals. He was formerly Deputy-Chair of the European Regional Working Group of the Fish Barcode of Life (FISH-BOL) initiative, and he is also Co-Chair of the Research Network ‘Barcoding Aquatic Life – Portugal’.

Andrew Donaldson is Lord Richard Percy Research Fellow at Newcastle University’s Centre for Rural Economy. He studied biology as an undergraduate but since completing his PhD in 2001 he has established himself as a human geographer. His research focuses on knowledge and expertise in rural land management and the agri-food system, especially around issues of animal health and disease.

John Dupré is a philosopher of biology who has held posts at Oxford, Stanford, and Birkbeck College, London. In 2006 he held the Spinoza Visiting Professorship at the University of Amsterdam. He is currently Professor of Philosophy at the University of Exeter and Director of the ESRC Centre for Genomics in Society (Egenis). His publications include *The Disorder of Things* (Harvard, 1993), *Human Nature and the Limits of Science* (Oxford, 2001), *Humans and Other Animals* (Oxford, 2002) and *Darwin's Legacy: What Evolution Means Today* (Oxford, 2003).

Matthew Harvey is currently manager of the Science in Society Programme at the Royal Society, UK. Previously he led a work package on animal genomics at the ESRC Genomics Policy and Research Forum, University of Edinburgh.

Michael Hauskeller is Associate Professor at the Department of Sociology and Philosophy, University of Exeter. His latest monograph *Biotechnology and the Integrity of Life* will be published by Ashgate in November 2007.

Peter Hollingsworth is Head of Genetics and Conservation at the Royal Botanic Garden Edinburgh. His research focuses on genetic approaches to study plant population biology and taxonomy.

Lewis Holloway is Lecturer in Human Geography in the Department of Geography, University of Hull. His research interests revolve around the relationships between technologies, livestock animals and humans in the context of agricultural practices and knowledges. With Carol Morris he is currently undertaking a research project entitled ‘Genetics, genomics and genetic modification in agriculture: emerging knowledge-practices in making and managing farm livestock’ funded by the ESRC.

Petter Holm is a professor of fisheries management at the University of Tromsø. His publications include *The Dynamics of Institutionalization: Transformation Processes in Norwegian Fisheries* (*Administrative Science Quarterly*, 1995), *Which Way is Up?* (in D. MacKenzie et al (eds.), *Do Economists Make Markets? On the Performativity of Economics*, 2007), and, with Kåre Nolde Nielsen, *Framing Fish*, *Making Markets: The Construction of Individual Transferable Quotas* (in M. Callon et al (eds), *Market Devices*, forthcoming).

Carol Morris is Lecturer in Human Geography in the School of Geography, University of Nottingham. Her research is broadly concerned with the relationship between society and rural nature(s), including agricultural animals. With Lewis Holloway she is currently undertaking a research project entitled ‘Genetics, genomics and genetic modification in agriculture: emerging knowledge-practices in making and managing farm livestock’ funded by the ESRC.

Richard Twine is a principle investigator at the ESRC Centre for Economic and Social Aspects of Genomics at Lancaster University. He works on the project ‘Reconfigurations of Human/Animal Relations in Genomics and Beyond’. His work has previously appeared in journals including *Body and Society*, *Ethics and the Environment* and *Medicine, Healthcare and Philosophy*.