
Human Social Evolution and Animal Exploitation through Artificial Selection

Throughout the course of human history, humankind has exploited other animals for its own ends. Indeed, humans have tended to regard other species as a natural resource, since they are able to provide us with a reliable, continual and self-renewing supply of the protein, hide, natural fibres, manure and muscle power, etc., on which our own species depends (Swabe 1999, 7). For the past 10,000 or so years, our control and exploitation of other animals has become increasing sophisticated as we have domesticated and bred them selectively.

It was in fact this manipulation and use of other animals to meet human requirements that inspired Charles Darwin in his development of the notion of natural selection. The activities of animal breeders, who in the nineteenth century practised their art upon an empirical basis, revealed to Darwin that animal populations exhibit random variation from which useful characteristics can be selected and bred from. As he wrote in his autobiography,

I soon perceived that Selection was the key-stone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me. (...) Fifteen months after I had begun my systematic enquiry, I happened to read for my amusement 'Malthus on Population', and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved and unfavourable ones to be destroyed. The result of this would be the formation of new species (Darwin 1974).

The artificial selection of animals that humans had been practising for thousands of years thus formed the basis for Darwin's understanding of how species naturally change and develop in time.

Since the publication of Darwin's *The Origin of Species* in 1859, the theories of evolution and natural selection have provided a foundation for

our understanding of the existence and development of life on Earth. Unless one adheres to the notion of creationism (which curiously continues to be tendered by religious fundamentalists, even controversially being extended so far as to influence the current scientific curricula of schools in the US states of Kansas and Kentucky), the synthesis of Darwinian ideas of evolution with modern molecular biological science is generally taken to be received knowledge. The modern theory of evolution, commonly referred to as *neo-Darwinism*, views evolution as a two-step process. It combines the original Darwinian notion of selection with the idea of genetic change. To give a brief outline of the basic tenets of genetics for the uninitiated, a gene is basically understood as the physical unit of heredity. Geneticists generally perceive it as a length of DNA (i.e. deoxyribonucleic acid - the molecule that is the primary carrier of genetic information), which encodes for the amino acid chain that forms a protein. Due to mutation, a gene that takes up one place in a chromosome may in fact take on different forms. These are known as *alleles*, in other words, they are different versions - or expressions - of the same gene (Plotkin 1994, 247-8).

Returning to the neo-Darwinian theory of evolution, the two-step process may be summarised as follows:

the first step is the generation of variant phenotypes (i.e. the organism in flesh and blood form), at least in part because the genetical machinery ensures much variation. The second is the selection of phenotypes and their differential reproduction. These microevolutionary events, if confined within a breeding population, will lead to changes in the form of that population that might eventually lead to macroevolution, that is, the formation of a new species (Plotkin 1994, 37).

To clarify this further, it is, of course, pertinent to also define what is here exactly meant by *microevolution* and *macroevolution*. In this context, microevolution refers to the evolutionary changes that occur within a species or even a breeding population. Microevolution is generally measured by changes in gene frequencies and small phenotypic effects and, moreover, is perceived as the driving force behind macroevolution. The latter term thus refers to large-scale changes in populations and species that result in speciation (i.e. the process by which a single species becomes two species, one of which may remain identical to the original single one). The term macroevolution often refers to the fragmentation and changes that occur at or beyond the species level (Plotkin 1994, 251).

According to the neo-Darwinian view of evolution, a gene pool (i.e. the totality of genes in a breeding population) changes over time, through the interaction of natural selection, and time and chance (Tudge 1993, 30).

This interaction of selection, time and chance will provide a starting point for this chapter, which will explore the impact of human social evolution on the development of other species. Keeping this neo-Darwinian view of evolution in mind, I will explore the idea that our own species, *Homo sapiens sapiens*, has in effect functioned as a 'chance' element in the evolution of particular species, such as sheep, goats, cattle, horses, camels, chickens, dogs, llamas, etc. What I thus wish to suggest is that the manner in which the human species itself has evolved in time, also through natural selection and chance has played a decisive role in the evolution of other animals. The following discussion will consider how human evolutionary success, cultural development and expansion into new environmental realms led to fundamental changes in the relationship between species. It will highlight the increasing differentiation between humans and other animals, focusing on the domestication process and how human beings have consistently exercised their influence on the genetic development of other species. The discussion will span a relatively 'short' period of time - which is brief at least in terms of both evolution and human history - extending from the earliest and most significant cultural innovations made by our ancestors to the present-day genetic manipulation of other species.

The Differentiation between Humans and Other Species

The emergence of humankind and its various exploits are, in terms of the history of the Earth as a whole, very recent developments. As Marvin Harris succinctly puts it, 'if the evolutionary clock from the origin of life to the present is reduced to the scale of 1 year, human beings make their appearance at about 8 p.m. on New Year's Eve' (Harris 1985, 42). The sheer recentness of the process of domestication can be put into even greater perspective when it is situated within the broader context of millions of years of hominid and human evolution. The first true hominids emerged some 5 million years ago; being followed a couple of million years later by *Homo sapiens*. Hominids and archaic humans, however, spent the best part of their existence as scavengers, foragers, hunters and gatherers. It was only a mere 10,000 years ago that some, but by no means all, of our ancestors took the first tentative steps towards domestication, animal husbandry and the cultivation of plants: these activities in fact account for less than one percent of hominid existence (Davis 1987, 126).

Domestication is generally taken to be the historical milestone that marks the most profound and definitive transformation in the relationship between humans and other species. Domestication is not only seen to sym-

bolise the critical transition from simply taking from nature to actively controlling it, but is also generally taken to represent the move which most clearly distinguished humans from other animals. Yet although food production through animal and plant husbandry is a development that very clearly separated human beings from other animals, the differentiation between humans and other species began to take shape long before humans switched from hunting animals to herding them. Domestication was far from an overnight occurrence. To the contrary, it was a gradual process which in fact continues to the present-day, subtly altering the behaviour, appearance, functioning and distribution of other species and, consequently, our relationship to them also. In the following, I shall briefly explore the development of humankind and its changing relationship with other species. It will become clear that as our own species developed into proficient formidable hunters and then agriculturalists, the balance of power between humans and other animals gradually shifted in favour of humans.

The gradual differentiation of behaviour and power between humans and other animals can be traced alongside the gradual biological and socio-cultural development of humankind. The biological evolution of humankind led to the emergence of distinctive physiological traits such as an erect posture, dextrous hands, a highly developed brain and the capacity to communicate through the use of symbols and facial expression. The latter two characteristics ultimately gave rise to the development of the complex patterns of cultural transmission and social organisation that are peculiar to humankind (Goudsblom 1990). The earliest cultural innovation made by our ancestors was probably the manufacture and use of tools. The most primitive stone tools unearthed by archaeologists date back some 2.5 million years ago. Although such tools offer us some material evidence of culture, they do not necessarily indicate the degree of cultural sophistication their manufacturers possessed (Ucko & Dumbleby 1969). Moreover, given the ability of other primates, most particularly chimpanzees, to use objects taken from their immediate surrounds as tools, we must be cautious as to the importance we place upon such developments in relation to how they distinguished our forebears from other species.

The innovation that fundamentally and decisively separated our hominid ancestors from other animal species was the mastery of fire. The domestication of fire provides the most tangible testimony to human cultural influence upon ecological processes. Archaeological evidence suggests that our predecessors *Homo erectus* were actively manipulating this natural phenomenon some 400,000 years ago. How efficient these hominids were at using this resource is here not the issue. Suffice it to say that over the course of time, these hominids and then their more successful successors -

archaic humans - developed the mental, physical and social skills necessary to keep fires burning and to actively use fire to protect themselves. As Goudsblom (1990 & 1992) argues, the ability to control and reproduce this natural force and use it to their advantage effectively allowed our ancestors to gain a degree of superiority over the other species with whom they were competing for food. Notwithstanding the complex cultural transmission, foresight and self-constraint necessary to achieve and maintain the control of fire, early humans - through their singular and eventually universal ability to manipulate this natural substance - ensured their own species' survival above that of their predatory competitors. Fire control enabled human populations to move north to explore new territories and to survive the cold glacial climates of the Ice Age. Furthermore, it extended the variety and availability of animal foods, since meat could not only be cooked, but could also be preserved through smoking or drying (Clutton-Brock 1987, 188). In short, by mastering fire, humans clearly distinguished themselves from other animals and improved their survival chances and predatory skill. Moreover, as a consequence of fire domestication, the fates of other species - both animal and plant - were to be inextricably linked with human evolution and socio-cultural development.

The gradual social and cultural evolution of humankind laid the foundations for the eventual domestication of animals, and plants also. Alongside the socio-cultural developments which accompanied tool and fire use, our progenitors also achieved a high degree of social organisation through their hunting activities. It has been suggested that the hunting of large ungulates during the Pleistocene period was probably 'one of the formative activities that led to the integration and coordination of all other behavioural patterns in the social evolution of humans' (Clutton-Brock 1994, 24). Human predatory success is most closely linked to our species' highly social nature. The need to provide food for the collective plausibly formed the basis for the exceptionally complex social behaviour of human beings. Although other social carnivores such as wolves were probably as effective group predators as humans, our ancestors were able to surpass them through both a high degree of cooperation between individuals and the development of increasingly innovative means of killing animals, such as the use of projectiles and setting fire to forests in order to drive animal herds to their deaths (Clutton-Brock 1994, 24). In addition to this, a detailed knowledge and understanding of the behaviour of other animals would have been imperative to the successful hunting of them. The recognition of changing seasons, the migration patterns of animal herds, seasonal appearance of various plants and flowers, and knowing which parts of animals and plants were good to eat, etc. facilitated human survival, for such environmental

appreciation - and the cultural transmission thereof - would have provided our forebears with constant and varying sources of nourishment.

Humans, in short, became highly efficient hunters and gatherers, capable of finding sustenance under whatever circumstances, both climatic and geographic, they found themselves. This manner of subsistence continued unabated for many thousands of years of human existence. Our ancestors lived an exclusively nomadic life, surviving by moving from place to place searching for, or following, potential prey and accumulating fresh stocks of plant food. However, around ten thousand years ago, a fundamental and irreversible change in human lifestyle was initiated. Some human groups began to settle, and the hunter-gatherer way of life was gradually supplanted by the tending of livestock and the tilling of land. Just why some of our forebears forsook the ways of old for an inherently more arduous and precarious existence is unclear. It is generally acknowledged that there must have been some kind of environmental pressure that forced them to tend their quarry rather than track it. Numerous hypotheses - often explicitly based upon Malthusian principals of causality - have been put forward to explain this transition.¹ In recent years, however, explanations of the origins of agriculture and domestication have tended to move away from theorising about human innovative response to environmental change or speculating about early human social relations. Instead these developments have been increasingly viewed as the product of evolutionary process (e.g. Rindos 1984; Budiansky 1992). This shift towards evolutionary explanations for animal domestication will be dealt with shortly below.

The Domestication of Animals

Domestication is most commonly portrayed as a fundamental change in the nature of the human-animal relationship. Some authors have envisaged domestication more as a continuation of existing human-animal relations; in other words, as an extension or elaboration of the hunter-prey relationship, rather than as a complete break from it. Domestication can in this way be viewed as the end product of a series of gradually intensifying relationships between humans and other animals (Higgs & Jarman 1969). With respect to this, Jarman and Wilkinson (1972) deem it inappropriate to focus merely upon the dichotomy between the wild and the domestic. They suggest that this represents only one aspect of a wide range of close relationships between humans and other animals. Marginal cases, such as the reindeer economies and game-cropping of the present-day, they argue, imply that this dichotomy may also not have been so clear cut in the

distant past (Jarman & Wilkinson 1972, 83). Similarly, Hecker has proposed a broad spectrum of human-animal interactions, ranging from the cooperative driving of animals to specialised hunting and culling to finally the selective breeding of domestic livestock (Hecker 1982, 220-223). Although this view of domestication highlights varying degrees of cultural manipulation and control which evolved over time to obtain animal protein, it fails to fully account for the radical changes in human social life and behaviour that animal domestication brought with it in its wake. As Bökönyi points out, although human activities have - in some way or another - always interfered with the lives of other animals, domestication is 'an interference of a quite different kind' (Bökönyi 1969, 219).

The profound social significance of the transition from hunting to herding has, however, been incorporated into several recent definitions of domestication. Meadow, for example, describes animal domestication as being a:

selective diachronic process of change in human-animal relationships involving, at the very least, a change in focus on the part of humans from the dead to the living animal and, more particularly, from the dead animal to the principal product of the living animal - its progeny (Meadow 1989, 81).

This process, he argues, manifests itself in two respects: firstly, in terms of the transformations in the social and economic structure of the human societies which associate with the animals; and secondly, in the behavioural, morphological and physiological changes which the animal undergoes as a consequence of domestication (Meadow 1989, 81). Similarly, Clutton-Brock defines a domesticated animal as:

one that has been bred in captivity for purposes of economic profit to a human community that maintains complete mastery over its breeding, organisation of territory, and food supply (Clutton-Brock 1987, 21).

She goes on to argue that domestication is both a cultural and biological process which 'can only take place when tamed animals are incorporated into the social structure of the human group and become objects of ownership'. The morphological transformation of the animal occurs subsequent to its initial integration into human society (Clutton-Brock 1989, 7).

The successful domestication of animals was most likely the product of a long-term process of trial and error. It has been suggested that early human efforts to tame other animals were a product of the highly social nature of humankind. Clutton-Brock, for instance, contends that the enfoldment of other species into human society was an extension of the practices

of 'sharing, nurturing and protecting weaker members of the human group' (Clutton-Brock 1994, 24). The assumption that our ancestors would have been prepared to tolerate or support weaker persons, other than perhaps infants and young children, let alone members of other species is somewhat suspect. Historical and anthropological accounts, however, confirm that in some societies, women suckle young mammals along with their human offspring (Serpell 1989, 1996; Clutton-Brock 1987, 1994). This suggests that within early hunting and gathering societies, juvenile animals were perhaps trapped, nurtured and raised alongside humans and were granted a certain level of protection by their human captors. The European explorers of the eighteenth and nineteenth centuries recorded many instances of pet-keeping and affection for small animals amongst the indigenous peoples they encountered. On the basis of their accounts, during the late nineteenth century, Francis Galton postulated that the 'savage' penchant for taming and caring for small animals as pets provided the basis for the development of livestock keeping (Serpell 1989, 10).

This notion has in fact provided a cornerstone for many explanations of the origins of domestication, most particularly with regard to the early assimilation of dogs into human society. Archaeological findings suggest that *Canis familiaris* was probably the first animal species to undergo domestication. Unlike later domesticates, dogs were not - as far as we are aware - much eaten. Instead, they were most likely used as an aid for obtaining meat. It is widely assumed that the domestic dog descends directly from wolves. Wolves exhibit complex social behavioural patterns similar to humans. They are efficient group predators with a social structure based on a dominance hierarchy. It is thought that our ancestors began to develop a close association with wolves by rearing young cubs that they had caught or found. The hypothesis follows that some of the more placid of these animals reached maturity and accepted human beings as pack members in their adulthood. These tamed animals began to breed in human captivity and, over several generations, eventually developed behavioural characteristics distinct from their wild relatives. This process ultimately culminated in the evolution of a separate kind of animal: the dog (Clutton-Brock 1987, 34-8). In this instance, one can clearly recognise the macroevolutionary occurrence of speciation, as one species has effectively become two separate ones over time, through (artificial) selection and chance. Humans and wolves were probably also close competitors for food. They shared the same prey and it is likely that they came into close contact, wolves possibly learning to scavenge on the leftovers from human game drives and the parts of animals which humans preferred not to eat in times of plenty (Hyams 1972, 7-8). Although one can speculate on a mutual interest in

proximity, it is perhaps more probable that humans saw a way of surpassing their lupine competitors in predation and securing food for themselves by using tamed adult wolves - and eventually dogs - to help in the hunt by detecting and tracking game, and later to help herd other animals rather than prey upon them (Clutton-Brock 1994, 25).

The dog is unique amongst early domesticates, given that it was probably not domesticated specifically for food. Most species that underwent domestication were probably intended as 'walking larders'. Sheep, goats and cattle, for example, were most likely exploited as transportable sources of meat and other animal by-products. At a later stage, species such as the horse, donkey and camel were domesticated to provide muscle power for transport and traction, although their meat and milk was also consumed long before they began to perform these roles in human society. Although humankind was effectively able to secure a constant supply of animal protein for itself through the enfoldment of animals into human society, the fact remains that only a handful of species were ever domesticated successfully. These include the following species: dog, sheep, goat, cattle, pig, donkey, horse, cat, ferret, guinea-pig, rabbit, chicken, turkey, camel, llama and alpaca.

It would thus appear that very few species have behavioural characteristics that have been amenable to domestication; the animal, therefore, plays a crucial role in the domestication process. As Bökönyi (1989) observes, domestication is a symbiotic process requiring at least two partners; it cannot simply be viewed from the side of one of those partners alone. Domestication, he argues, is:

a special kind of symbiosis in the sense that one of the partners, man, influences the other by isolating, taming, controlling, breeding, and taking animals into new habitats, etc., but the animal itself also plays an essential part in this process (Bökönyi 1989, 24).

Although Bökönyi here refers exclusively to the behavioural characteristics of animals and their potential for domestication, his plea to examine domestication from both sides of the fence can be extended much further. It has recently been suggested that by looking at animal domestication from the animal's point of view - rather than thinking about it purely in terms of how it benefited our own species - some of the intricacies of the domestication process might be unravelled. Rather than looking at domestication purely in terms of the human exploitation and subjugation of species, it has been proposed that we should instead seriously consider the extent to which domesticated animals have profited from their seemingly unholy do-

mestic alliance with humankind. Domestication should thus be regarded as a natural product of evolution, rather than the consequence of human innovation.

This alternative view of domestication has gained significant ground in recent years. David Rindos (1984), for example, an evolutionary theorist, has attempted to explain domestication and the origins of agriculture by highlighting the mechanisms of biological, rather than cultural, change. Although Rindos focuses chiefly upon the process of plant domestication, his ideas can be extended to encompass the domestication of animal species. To this end, Stephen Budiansky (1992) has drawn inspiration from Rindos' work and has attempted to shed new light upon the animal domestication process. Basing his analysis upon a wide variety of recent archaeological and animal behaviour studies, Budiansky endeavours to steer away from conventional analyses of domestication by arguing that domestication was an evolutionary strategy not only for humans, but also for particular species of animal. The crux of this argument revolves around the idea that domestication was the result of the cooperative evolution of species as a mutual strategy for survival. Budiansky advances the idea that the adaptability and sociability of these species provides the most important clue to solving the riddle of domestication. The earliest domesticated species - such as dogs, sheep and cattle - were highly opportunistic and did not restrict themselves to a highly specialised terrain or food source; like archaic humans, they too were not loathe to exploit new food sources or venture into new realms (Budiansky 1992, 15). The propensity to adapt was imperative for these species survival, particularly during the Pleistocene when vast environmental and climatic changes occurred, threatening many species with extinction. It was necessary for species to develop cooperative associations with others in order to ensure their own survival. In the long term, this entailed undergoing specific genetic and behavioural changes that would make cooperation easier.

Neoteny, the retention of juvenile traits into adulthood - a feature of all domesticated animals and humans also - was probably the most important of these adaptations. The curiosity and appearance of young animals, their willingness to freely associate with members of other species and care-soliciting behaviour are characteristics that domesticated animals continue to display during adulthood. Such traits probably made them far more malleable and willing to consort with humans than species that did not experience a perpetual youth (Budiansky 1992, 80). In addition to this, the majority of species that were domesticated, shared similar social and behavioural traits with humans. Wild dogs, sheep, cattle and horses, for example, live in groups, which have a social hierarchy similar to humans,

with a defined social rank and means of expressing dominance and submission recognisable to other species. Furthermore, ungulate species have a clear disposition to follow a dominant animal around. If a human is accepted as a dominant member of the animal group, then the rest of the herd or flock is instinctively inclined to cooperate with him. Finally, domesticated species have a tendency to groom one another and tend to solicit and tolerate the attentions of others who might scratch their backs or remove parasites (Budiansky 1992, 65-7). For the cat, the only domesticated species which did not naturally live within defined social groups or hierarchies, the close association with humans was simply one of social parasitism, although the species also underwent neoteny (Budiansky 1992, 98-100). In short, Budiansky contends that it was these traits and social affinities that naturally laid the foundations for the domestication process and made intra-species cooperation possible. Neotony, he argues, 'was the tie that bound evolution to domestication' (Budiansky 1992, 97).

Leaving aside the issue of exactly how and why domestication took place, it is reasonable to conclude that the incorporation of other species into human social organisation through the processes of domestication and selective breeding instigated a crucial and irreversible transformation in humankind's relationship with other creatures. By deliberately manipulating and interfering with the natural selection of other animals, humans gained a degree of control over the evolutionary destiny of other species. Once tamed and segregated from their wild conspecifics, domesticated species could only reproduce within the bounds of human desire and requirements; even their food supply and organisation of territory was determined by their human keepers (Bökönyi 1969; Clutton-Brock 1987; Hemmer 1990; Ucko & Dimbleby 1969).

Whilst 'freedom' was the price which animals had to pay for domestication, it could be argued that other species got a pretty good deal from their tacit covenant with their human 'oppressors': they were fed, sheltered, protected from predators, thus their proliferation and survival as species was ensured. Budiansky in particular lauds the success of this seemingly unholy domestic alliance by pointing out that domesticated animals today flourish, while their wild cousins are on the edge of extinction (Budiansky 1992:61). Others are more doubtful as to whether thriving numbers can be equated with success, given the loss of both genetic diversity and genetic autonomy which animals have suffered as a consequence of their enfoldment into human society (Clutton-Brock 1994).²

Extending the Gene Pool through Artificial Selection

As has thus far been suggested, the social evolution of humans provided them with the means by which they were able to gain control of and manipulate other species, largely enabling them to secure their own species survival. This is indeed a curious evolutionary development, for the behaviour of one specific species resulted in the gradual alteration of the gene pools of a variety of different species, not so much with respect to the interaction of natural, but instead *artificial* selection with the elements of time and chance. The animal species that have been domesticated, despite the significant variability between the individual breeds, still belong to the same genus. For instance, all domestic dogs, which may vary tremendously in size, shape and other characteristics - e.g. from the Chihuahua to the Great Dane - still belong to the same species, known as *Canis familiaris*. Two animals are considered to be of the same species if they are able to breed together sexually to produce fully viable offspring. Thus although different populations of the same basic species have existed in different geographical locations, which each apparently possess their own gene pool, these animals - if brought together - should still be able to viably breed and bear young, in spite of the various differences between them.³ This should become clearer shortly, with respect to the introduction of foreign breeds into native animal populations.

Artificial selection led to the creation of animal populations with a gene pool that was significantly different from the original wild one from which they derived. Such artificial selection was, of course, at first most likely the inadvertent consequence of the kind of decisions that our forbears were likely to have made with respect to which animals best suited their needs. It is, for example, entirely conceivable that the kinds of animals that were the easiest to handle were given preference to those that were more aggressive. The main consequence of this artificial selection in terms of genetics is that it leads to a reduction in the gene pool. The characteristics that are deemed desirable are given the opportunity to come to the fore, whereas undesirable ones - such as aggression - are eliminated. The gene pool of domesticated species may also initially have been further reduced by what is termed *genetic drift*, which is the loss of alleles (i.e. different versions of the same gene) through chance and time. In addition to this, the gene pool may have been added to through the processes of mutation and introgression (Tudge 1993, 160-3). The former process is, for example, clearly evident in some modern breeds of cats, such as the Sphinx and Rex, which have been deliberately bred for hairlessness following the occurrence of a mutant (recessive) gene (Tabor 1991, 169-70). The latter process is

a consequence of domestic species cross-breeding with related animals living in the wild. Husky dogs provide a clear example of this, given that they have at times been deliberately been cross-bred with wolves to make them 'tougher' (Tudge 1993, 163-4).

Eventually there came a time when our ancestors began to more deliberately select and breed the animals that they had enfolded within their societies. Upon the basis of empirical observation, the early livestock-keepers must have realised the consequences of deliberately mating animals with specific and desirable characteristics to beget progeny that would combine the best characteristics of both parents. It is certain that by the classical period, those engaged in animal husbandry, particularly horse-breeders, were well aware of successful strategies for selective breeding, *including the consequences of inbreeding* (Tudge 1993, 167-8). As human populations continued to expand - resulting in increased demand for food and other useful secondary animal products - an inevitable need to intensify livestock production also arose. From the earliest known societies, animal breeders had managed to selectively breed and refine livestock animals in order to obtain better quality wool, higher milk yields and greater muscle power. This trend continued throughout the centuries leading to the creation of bigger, better, fatter or faster domestic animals. By the Middle Ages, for example, the selective breeding of horses had led to the production of larger horses for warfare, eventually leading to the rise of huge varieties of draught animals such as the Shire (Langdon 1986, 17-9). By the seventeenth century, the average size of cattle, sheep, pigs and domestic fowl in Europe had greatly increased; meat, in particular, was in ever-greater demand (Davis 1987, 188).

It was, however, only to be during the eighteenth century that the improvement of livestock truly became an end in itself for the animal breeders of Europe. From this time onwards, we can speak of the concept of deliberate livestock 'improvement'. The most renowned pioneer of livestock improvement was Robert Bakewell. He was the first animal breeder to empirically demonstrate how new breeds of cattle could be produced through the practice of inbreeding and selection. In recognising the increased demand for high quality beef and tallow - a fat widely used for lighting - Bakewell set out to deliberately select stock that had a propensity for fattening and which matured quickly. His emphasis was upon increasing the animal's economic performance and productivity, rather than on its appearance which had been the chief goal of contemporary breeders (Dunlop & Williams 1996, 354-5). Indeed, Bakewell's methods received a great deal of criticism from his contemporaries. Having, for example, produced a breed of sheep - the New (or Dishley) Leicester - which would yield lar-

ger quantities of meat, he sacrificed other traits such as wool quality that were viewed by others as desirable and aesthetically pleasing. This 'disposition to produce fat on the most profitable parts', as one critic put it, went against the very notion of animal aestheticism (Thomas 1983, 285-286). Bakewell, however, was to set a trend for the future of livestock breeding and many - some taught by him - followed in his footsteps and went on to produce cattle with a higher milk yield and pigs that fattened more quickly.

Alongside these new breeding practices came also the importation and development of foreign breeds that were known for the quality and quantity of their produce. For instance, Spanish Merino sheep, prized for the quality of their wool, were imported into France during the mid-eighteenth century, partially in order that the French could produce their own wool supply and would no longer be dependent upon their Spanish neighbours to furnish them with the raw materials to produce quality cloth. Later Merinos were also imported to Britain and eventually ended up being exported to distant colonies (Ryder 1983, 427; Dunlop & Williams 1996, 356-61). Such sheep were to later become the economic mainstay of Australian and New Zealand; the latter country becoming a leading producer of sheep meat and the former a major world supplier of quality wool (Ryder 1983, 608-641). Imports from Asia also bore witness to changes in another species: the pig. Chinese pigs were cross-bred with the lean and slow-growing European breeds to produce animals that had a propensity to fatten. By the mid-nineteenth century, however, the consumer preference had changed from fat pork to leaner meat, requiring the development of an altogether different kind of pork that would produce the appropriate flesh in the kind of quantities that the consumer increasingly demanded (Wiseman 1986, 77-85).

In genetic terms, the importation of domestic animals from geographically distant locations had significant implications for the gene pools of the native populations to which they were introduced. Prior to such developments, the livestock populations - and thus the gene pool - with which the early animal breeders had worked had been rather limited. They could only really make their selection and crosses from the population of animals that lived within the near vicinity. As the means developed whereby people could travel over increasingly great distances, animal breeders were able to extend their search for animals from other populations with which they could also enhance their own livestock. The aforementioned example of the cross-breeding of Chinese pig breeds with established ones provides a prime example of this quest for the improvement of native livestock through the use of related animals that have also developed characteristics

through time, chance and selection in similarly limited conditions. Through such cross-breeding, the gene pool of existing populations could be successfully enhanced to meet human requirements (Tudge 1993, 168).

A further consequence of the increased opportunities for travel and contact with foreign populations of both humans and other animals was the introduction of new species to supplement the existing domestic animal population. For example, by the early sixteenth century, European farmers had acquired a new domesticated species that could be exploited for food: the turkey (Davis 1987, 194). This bird had been imported from the New World that had been 'discovered' following the Columbian voyage of 1492. The conquest of the Americas led not only to the dispersion of European civilisation, but also to the dispersion of animal populations across the great ocean (Crosby 1994). Alongside their human counterparts, European livestock species and horses thus came to colonise the American continent. The Spanish conquistadores also saw the Americas as providing a new solution to the stock-raising crisis back home. By the sixteenth century, the Iberian peninsula had become overgrazed and attempts to make room for new pastures upon which cattle could graze only led to deforestation. The ever-growing demand for beef and hide put great pressure upon Spanish soil, leading to substantial desertification. An opportunity was seized to transfer cattle production to the New World; the cattle imported from the home country also went on to flourish in their new environment (Rifkin 1992, 45).⁴

The Rise of Genetics

As the above discussion suggests, animal breeding practices have become increasingly sophisticated since animals were initially enfolded into the bounds of human society through the process of domestication. It was, however, only with the advent of Mendelian genetics that the traditional breeding process could accelerate and be refined far beyond anything that the earliest animal breeders could possibly have imagined. It was Gregor Mendel, a Moravian monk and a contemporary of Charles Darwin, who came up with the principle of heredity, through his experiments with edible garden peas. He discovered that the characteristics of organisms are controlled by single 'factors' contributed in sexually reproducing organisms by both parents. Mendel realised that these factors combine together to produce the characteristics of the offspring. However, he observed that these factors do not blend, but instead retain their integrity after fertilisation being passed on to the offspring, even if their effects are not actually

manifested in the individual. These factors that Mendel identified we now refer to as genes. Essentially, Mendel's experiments provided a mechanism that could have put the finishing touches to Darwin's theory of evolution; not that he was actually aware of Mendel's existence (Plotkin 1994, 34; Tudge 1993, 9-13). It was only at the turn of the twentieth century that Mendel's work was re-discovered and came to form the basis of the new science of genetics: a science that was to have a huge impact on human intervention in the evolution of domestic animal species.

Essentially, molecular genetics can be defined as a science that explores the mechanisms of heredity. Each individual, human or animal, possesses a unique genetic 'blueprint' that makes him or her different from any other living creature. Developments in the science of genetics have, however, led to the discovery that this genetic blueprint can in fact be modified. This can be achieved through a recombinant DNA technique that involves the injection of a foreign gene into an organism in order to produce specific new characteristics that in turn will also go on to be inherited by future offspring. Organisms that have been modified in such a fashion are commonly known as 'transgenic organisms'.

The science of molecular genetics has found an increasing number of applications with regard to food-producing animals (Blancou 1990). In recent years, the gene mapping of farm animals has become an important tool for breeding and has been employed to localise, isolate and characterise the genes that are responsible for specific traits important to both health and production (Horzinek & Van der Zijpp 1993, 84). With the development of new molecular genetic techniques that will help to isolate and identify the DNA markers that are linked to the genes responsible for economically important production traits and disease resistance, animal breeders will in the future be better equipped to single out the animals carrying the most desirable genes. Theoretically, once such genes are identified, animals may be genetically selected or engineered for disease resistance (Gogolin-Ewens et al. 1990).

Likewise, biotechnology - a term that may be generally applied to the manipulation of organisms for commercial purposes - has found important uses within animal reproduction. For many years, artificial insemination has provided the basis for the systematic genetic improvement of animals. A more recently developed reproductive technique, *in vitro* fertilisation (IVF), may possibly be employed within livestock production in the years to come. IVF involves the maturation of the egg outside of the body and its fertilisation in a test tube. The embryo is then implanted into the womb of a surrogate mother. Although IVF in cattle is still in its infancy, embryo transfer is a technique that is now widely employed in livestock species

and has various advantages with respect to genetic improvement, health protection and productivity (Blancou 1990, 650).

One of the most controversial applications of recombinant DNA technology has been the creation of transgenic animals. The first experiments with transgenesis in mammalian species took place with animals used for laboratory experimentation. For instance, during the mid 1980s, a transgenic mouse, christened the 'oncomouse', was developed by biomedical researchers at Harvard University in their bid to understand and find a cure for breast cancer. The 'inventors' of such transgenic creatures have even gone so far as to patent their creations, leading to heated debates upon the nature of intellectual property rights and their application to living organisms (Sagoff 1996). Not surprisingly, such genetic technology has also found its way into the realms of livestock production. Since the mid 1980s, fledgling experiments with transgenesis have taken place involving food-producing animals, such as sheep, goats, pigs and cattle (Postma et al. 1996, 39). In the first instance, the creation of transgenic farm animals has been seen as a possible means to increase and improve agricultural productivity, to meet increasing human demands for animal produce without incurring further detriment to the environment by requisitioning extra land for agricultural production (Ward et al. 1990, 847-8). However, some of these transgenic experiments with food-producing species have had quite different aims. One of the prime incentives to create transgenic farm animals has been to produce substances known as biopharmaceuticals in milk. Biopharmaceuticals are substances produced by human genes that are essential to fight off disease and keep healthy. When such genes are incorporated into the DNA of other organisms, e.g. bacteria or yeast, these organisms become able to produce biopharmaceuticals beneficial to human health upon a scale that is commercially viable (Postma et al. 1996, 39).

A prime example of such experimentation with transgenesis and the production of biopharmaceuticals can be provided by Herman, the world's very first transgenic bull. Born in 1990 - and the result of a unique collaboration between the biotechnological company Pharming BV and a Dutch governmental research institute - Herman was the product of a fertilised egg in which the DNA had been modified to include a synthetic gene identical to the human one that controls the production of lactoferrin: a milk protein that has strong anti-microbial properties and stimulates intestinal flora to provide protection against bacterial infections (Visser 1996; Trümpler et al. 1989). Apart from this single gene, Herman is essentially no different to any other bull with respect to his genetic make-up. Herman was created specifically in order to sire female offspring who would inherit this foreign gene and consequently produce human lactoferrin in their milk.

The first mature milk from Herman's transgenic progeny became available early in 1996 and was found to contain the appropriate lactoferrin (Postma et al. 1996, 42). The commercial implications of such successful biotechnological developments are potentially enormous, for they offer new possibilities for the production of pharmaceutical drugs to treat human conditions at a far lower cost. For example, Pharming the biotech company responsible for Herman and his daughters, is currently attempting to develop a range of human health care proteins in transgenic cattle. The human lactoferrin that they have developed is intended as a component in clinical nutrition that can be used in the treatment and prevention of bacterial gastrointestinal infections in patients who have been immuno-compromised. A further planned application is in the production of speciality medical formulas for new born and premature babies (Pharming 1995, 5). However, perhaps more importantly, the introduction of this new transgenic animal technology signifies a new role for domesticated animals within human society. It is likely that in the not too distant future, animals will not only continue to function as the providers of protein, but may also become living, breathing and walking 'pharmaceutical factories'.

Transgenic technology may also find other important human health applications in future years, particularly with respect to the use of animal organs for transplantation into human beings. Since organ transplant technology was first developed for the kidneys and liver and then first employed in human heart surgery by Christian Bernard in 1967, organ transplantation has become increasingly important in the treatment of life-threatening conditions. The continued success of surgical procedures such as kidney and heart transplantation has led to an ever-increasing demand for healthy human organs, yet - unfortunately for those awaiting such radical, though potentially life-saving, operations - there is a great shortage of suitable organs. As the population ages, it is inevitable that this demand will increase further still. In spite of numerous high profile campaigns to encourage people to carry donor codicils, the shortage of donor organs has remained critical, inspiring scientists to search for new alternatives to human organs for transplantation. Some have sought solutions in the form of artificial organs; others have begun to seriously investigate the possibilities of using animal organs for transplantation into humans (Hammer 1993).

Xenotransplantation, as such cross-species organ transplantation is known, has been heralded as a potential solution to the organ crisis, for it could provide a ready-made supply of healthy donor organs to the thousands of people who today, and in the future will, require transplant surgery. Because of the animals' genetic affinity to humans, scientists initially turned to primates - particularly baboons - in their attempts to transplant

organs to humans. The very first attempt at clinical xenotransplantation in fact occurred as early as 1910 when a German medical scientist transplanted a monkey kidney into a uraemic girl. More recently, in 1992, a baboon liver was transplanted into an HIV patient who was dying of hepatitis B in the USA (Hammer 1993, 361). Primates, however, pose particularly high risks to humans with regard to the transmission of zoonotic disease, raising serious questions as to their suitability for use in xenotransplantation. The recent emergence of new highly infectious diseases such as Ebola and Marburg have further emphasised the potential role of primates as the reservoirs of viral diseases deadly to humanity (Michaels & Simmons 1994). Further to this, the use of primates in medical experimentation has become increasingly controversial due to a growing sensitivity to the semblance between humans and primate species. In recent years, calls have even been made for the great apes to be accorded equal rights to humans (Cavaliere & Singer 1993).

In view of such developments, scientific attention has instead turned to the domestic pig in the bid to produce organs suitable for human transplantation. Although more distantly related to people, the pig has already proved to be the ideal provider of insulin to treat human (and pet animal) diabetes and valves to correct heart abnormalities. Porcine organs are also approximately the same size as human ones. Moreover, given that these animals breed most prolifically, they could potentially provide a regular and reliable supply of organs for transplantation. All this being said, there are major problems that would have to be overcome before pig organs could actually be transplanted into the human body. Organ rejection is probably the greatest obstacle. This commonly occurs in the transplantation of human donor organs and is generally counteracted by the life-long usage of anti-rejection drugs by the organ recipient; in xenotransplantation rejection is likely to be hyperacute (Sykes et al. 1994). One of the solutions to this problem that is currently being sought by scientists is to employ transgenesis in order to genetically modify the porcine donor's organ in a way that will trick the human recipient's body into accepting it. The hearts of transgenic pigs that have been bred by researchers have already been transplanted into monkeys with some degree of success, arguably giving some indication of future possibilities for human application. The question of disease transmission through such transplant technology is also here at issue. Some porcine pathogens may indeed pose risks to human health, though it is more than likely that pigs intended for xenotransplantation will be bred to be specific-pathogen free (Michaels & Simmons 1994, 4-5). In fact, some may even be inclined to argue that the option of transplanting animal organs carries *less* disease risk than the transplantation of human

donor ones. The animals used would necessarily have been genetically modified, bred and kept under strict clinical conditions; unlike the human donor who may carry all manner of diseases that may go on to infect the recipient once the organ has been transplanted.

Another recent development in the science and technology of genetics that may find its most ideal application with regard to producing transgenic animals for both transplantation and biopharmaceutical purposes is cloning. Once relegated to the realms of science fiction, cloning has today become very much a reality. In February 1996, the public and scientific world were stunned by the announcement that two genetically identical lambs, named Megan and Morag, had been born at the Roslin Institute in Scotland. These sheep had been cloned by the process of nuclear transfer from a cultured cell line, originating from different cells of the same embryo. Morag and Megan provided concrete proof of the possibility of creating animal life without the need for male sperm (Campbell et al. 1996). In February 1997, the even more astonishing news broke that a lamb had been cloned - by the very same scientific team - from the cells of an adult sheep. To create Dolly, as she was christened, DNA from a single cell had been taken from another sheep's udder, making her the very first mammal to have been created from the non-reproductive tissues of an adult animal (Wilmut et al. 1997). Dolly the sheep became a celebrity overnight and her very existence precipitated fervent debates about the ethics of cloning and its potential application to humans.⁵

The potential consequences of cloning are enormous. In the future it may well be possible to produce hundreds of copies of an adult animal. Such cloning would certainly assist the production of biopharmaceuticals in milk. Moreover, it could be feasibly used to create animals that grew faster for meat production and that were more resistant to disease; though one may imagine that a herd of identical animals may indeed be at a far greater risk of disease. Presumably, cloning could also play a role in protecting the biodiversity of species by ensuring that breeds would not die out through keeping the appropriate cells and embryos in cold storage; though at the same time it poses an enormous threat to the genetic diversity of animal species. From the point of view of both the consumer and livestock producer, cloning could theoretically ensure that meat and milk of a reliable and standard quality could be produced and sold at a standard price and would turn a standard profit. In this sense, cloning is an extremely attractive proposition for the livestock industry; as is transgenesis also - presumably these technologies will also be combined.

They are, however, scientific phenomena with which many already feel extremely uncomfortable. Such technology necessarily involves direct hu-

man interference in - what is often perceived to be - the natural order and raises serious questions about the ethics and morality of such scientific enterprise. At present, national governments and scientific regulatory bodies have chosen to err very much on the side of caution when it comes to biotechnological experimentation (Cantley 1990). Often only when it can be proved that genetic experiments with animals can provide important benefits to humankind - as has been successfully argued that the transgenic production of lactoferrin can - are they permitted under stringent controls. Legal prohibitions on the application of such genetic technology in human beings are already firmly in place, particularly with regard to the cloning of human embryos. It remains to be seen whether either animal cloning or the production of transgenic animals will gain widespread acceptance or become commonplace in the new millennium.

Clearly, the scientific developments of recent years and the impending future present a colossal moral quagmire through which scientists, law makers and ethicists alike will be forced to wade; undoubtedly, there are also likely to be significant implications for animal welfare. However, there are also a whole host of practical problems that would have to be overcome before such technology could be successfully and safely applied. The practice of genetic engineering, for instance, carries with it an inherent risk because of pleiotropy; that is a phenomenon which occurs when a gene that does one specific thing may have other, possibly unrelated, effects upon or could interfere with the behaviour of other genes (Tudge 1993, 243). One of the most major and commonly espoused objections to the genetic technology that has been developed in recent years is that it necessarily involves the deliberate and wholesale interference with 'nature's design'. Further to this, the idea of genetically modifying other life forms has also met with considerable hostility for it reeks of eugenics; the implications of which are still fresh in our collective memory from the darker events of the twentieth century. History has already taught us that the calculated 'improvement' of humans can be a highly dangerous business with the most sinister of consequences. Yet leaving the issue of the application of genetic technology to humans aside and focusing upon animals alone, it is pertinent to consider just how well grounded our objections to and fears of the genetic modification of animals actually are - most particularly in view of the above discussion on human intervention in animal evolution.

A Brave New Science?

Although the genetic technology of recent times has often been portrayed as an extremely new and outlandish development, the fact remains that there is - at least in principle - very little new about it; most certainly as far as animals are concerned. The genetic modification of animals can logically be viewed as an extension, or rather a continuation of the process of domestication and selective breeding that has already been going on for the past 10,000 or so years. As this chapter has sought to illustrate, for thousands of years, humankind has actively attempted - in ever-increasingly successful measures - to alter and improve the behaviour, physical appearance and productivity of animals in order to service its needs. Whether it be to produce a more tractable animal or one that will produce more milk or larger calves, animals have persistently been deliberately and selectively bred to achieve highly specific ends. In this sense, people have been practising the art of 'genetic engineering' since animals were first domesticated. Traditionally, new varieties of animal species have been produced by cross-breeding. Until very recently, breeders had no detailed knowledge of the genetic mechanisms involved in producing such new varieties. Animal husbandry was a purely empirically based occupation. Farmers gradually learned that if, for example, cattle that produced a high milk yield were bred with other high milk-yielding cattle, they would produce offspring that would go on to produce even more milk. This kind of genetic manipulation is, however, far from an exact science. Moreover, such selective breeding can take an extremely long time before it produces the desirable result. Recombinant DNA technology has expedited this process, for it has provided the means by which the genetic make-up of animals can be modified in order to produce specific traits that - by traditional means - would have taken many generations to introduce, or would never have occurred at all since they involve the insertion of DNA foreign to the recipient animal.

Likewise, although many tend to balk at the mention of it, there is little new about biotechnology. Biotechnology can essentially be defined as 'the application of scientific and engineering principles to the processing of materials by biological agents to produce goods and services' (Wray & Woodward 1990, 779). Whilst this may sound like a new-fangled idea, the fact remains that humankind has been using biotechnological techniques for many thousands of years in order to manufacture products such as beer, wine and bread. To produce such products, microorganisms have been routinely and deliberately manipulated for highly specific ends. The role of yeast in bread baking is perhaps the best example of this. Again, it has

been the development of recombinant DNA technology that has increased the capabilities of biotechnological production, rendering it an important and efficient technique for the future.

There are, however, good reasons why we should be cautious about the application of recombinant DNA technology to domesticated animals. Selective breeding, in the traditional fashion, has already proved to have had serious consequences for animal health and welfare. Take, for example, the current state of broiler chickens and turkeys that have been bred to grow so fast and produce such grossly enlarged breast muscle tissue that their legs become crippled; or the double-musled Belgian Blue calves that necessarily have to be born by caesarean section. Such breeding practices have been developed in the constant bid to increase productivity to meet consumer demands and to produce higher profits, generally at the expense of animal well-being. However, it is not only the food-producing species that have fallen foul to irresponsible breeding practices. The health and well-being of pet animals, such as cats and dogs, have also been compromised severely through breeders' continued attempts to produce new varieties and to emphasise specific animal characteristics. One could argue that the application of genetic technology could plausibly solve many of the problems created by both intensive farming practices and pet-keeping. For example, it may in the future be possible to create a race of hornless cattle, thus obviating the need for dehorning altogether. Likewise, transgenic chickens might be produced that lack nerves to their beaks and could thus be debeaked without causing them any pain. Whilst such developments may indeed be possible, they will nonetheless do nothing to improve the general conditions in which intensively farmed livestock live and are bred (Tudge 1993, 245). Similarly, transgenic cats could be produced without claws and dogs with modified vocal cords for the convenience of their human owners.

It remains to be seen whether the genetic modification of animals will create serious new problems with regard to animal welfare. The application of recombinant DNA technology to animals is so recent that it cannot yet be said with any great certainty whether, for example, the inclusion of a single human gene to cattle in order to produce biopharmaceuticals will endanger animal health and well-being in any fashion. Nor for that matter whether it may effect the health of humans who consume such genetically modified milk or its pharmaceutical derivatives. It is likely that such cattle will essentially continue to function just as and be treated like any other dairy animal. In that sense, transgenesis may change little with regard to how animals will live within human society. Creating transgenic pigs (and possibly other species also) for xenotransplantation, on the other hand, will

most likely entail that the animals be kept in extremely sterile, clinical environments that are a far cry from the conditions, for better or worse, that they now experience.

What is, however, clear is that with the introduction of genetic engineering, our manipulation and exploitation of animals has entered a brand new phase. The production of new animal varieties can now take place over the course of one single generation, rather than many. Moreover, and perhaps more importantly, recombinant DNA technology means that animals can be modified using genetic material that is completely alien to the recipient animal species. Needless to say, this signifies a crucial new development in the age-old practice of animal husbandry and an even greater human intervention into the evolution of other species. It remains to be seen to what extent the practice of genetic engineering will be continued and commercially employed, or whether this will be deemed ethically and biologically unacceptable.

Noten

* The content of this chapter derives largely from my recent publication *Animals, Disease and Human Society: Human-Animal Relations and the Rise of Veterinary Medicine* (Swabe 1999).

1. For an overview of these theories, see Swabe (1999, 27-31).
2. The fact that animal domestication also marks an important cultural turning-point for humankind must not be overlooked. The notion that other living animals could be the objects of human ownership not only altered the equilibrium between humans and other species, but also led to significant changes in relationships between humans themselves as the concept and issues of property emerged. Domestication thus resulted in the increasing differentiation, in terms of both behaviour and power, amongst and within human societies (Goudsblom 1992). Ultimately leading to specialisation of labour and the development of complex systems of social stratification based upon who owned and controlled

agricultural resources and who maintained them as underlings, in servitude or wage slavery.

3. Actual *speciation* will only occur when two populations have genetically diverged so far that they can no longer successfully interbreed (Dawkins 1984, 238).

4. In addition to the above, it is pertinent to mention - although it is largely beyond the bounds of this discussion on domesticated species - that human expansion and 'ecological imperialism', as Alfred Crosby terms it, has also been linked to the extinction of other species, through over-hunting and the introduction of domesticated species (particularly cats and dogs that have gone feral) (Crosby 1986). Moreover, it is likely that the appropriation of environments for agriculture, urbanisation and other human activities has placed the evolutionary success of other species into jeopardy by separating animal populations, consequently limiting the size of the genetic

pool of various species and reducing their genetic diversity.

5. For an overview of the current state

of the Dutch debate on cloning, I refer the reader to the recent report by Biesboer et al (November 1999).

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