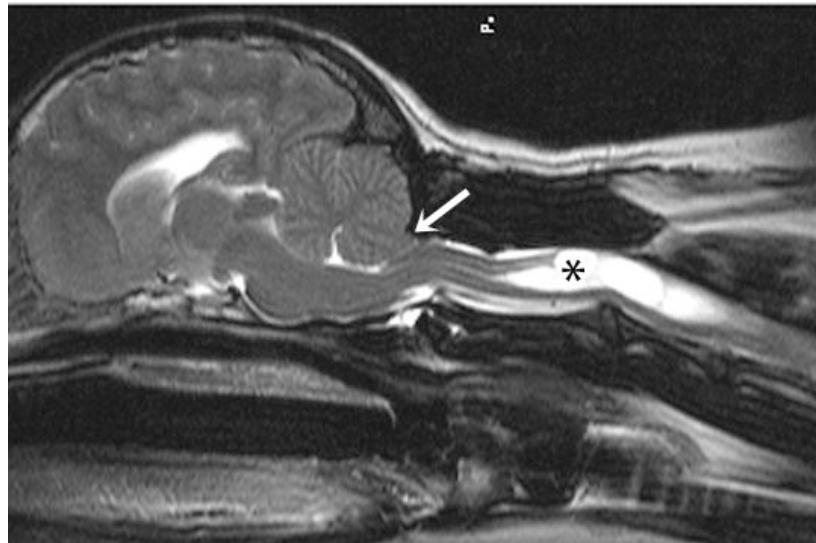# Breeding and Welfare in Companion Animals

The Companion Animal Welfare Council's Report on Welfare Aspects of Modifications, through Selective Breeding or Biotechnological Methods, to the Form, Function, or Behaviour of Companion Animals

Syringomyelia in Cavalier King Charles Spaniel

This cover illustration is a magnetic resonance image[1] of the head and neck region of a 16-month, female Cavalier King Charles spaniel (which had a 3 month history of yelping and tendency to scratch at the right shoulder). The arrow shows where the back part of the brain (cerebellum and medulla) is pushed into the canal into which, normally, only the spinal cord passes. Resulting abnormal cerebrospinal fluid pressure in the spinal cord has caused syringomyelia - the formation of fluid-filled cavities (the pale distensions marked with the asterisk) in the spinal cord.

This disease which is due to a hereditary mismatch of brain and skull design, resulting in inadequate skull capacity, occurs commonly in Cavalier King Charles spaniels and is associated with signs of chronic, and in some cases severe, neck pain in a proportion of affected dogs.

This condition illustrates how selection for particular traits can have unforeseen serious side effects on welfare. Although the particular aspect of appearance or behaviour the then breeders were wittingly or unwittingly selecting for, that led to this disease, is unknown, the Cavalier King Charles Spaniel breed was developed in the 1920s in response to a reward offered for recreating a toy spaniel with a longer nose as depicted in portrait paintings of King Charles II. The modern breed is descended from about six animals.

Breeding and Welfare in Companion Animals

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Preface

'*When we look to the hereditary varieties or races of our domestic animals and plants, and compare them with species closely allied together, we generally perceive in each domestic race, less uniformity of character than in true species. Domestic races of the same species, also, often have a somewhat monstrous character; by which I mean, that, although differing from each other, and from the other species of the same genus, in several trifling respects, they often differ in an extreme degree in some one part, both when compared one with another, and more especially when compared with all the species in nature to which they are nearest allied.*'

Charles Darwin (1859) The Origin of Species.

Executive Summary

There has been rapid growth in the number of species of vertebrates and invertebrates kept as companion animals and, in the UK, this exceeds 1000 vertebrates species alone. Many hundreds of these species are bred for this purpose. A considerable number of species have been selected for specific traits, or suites of traits, for countless generations (eg dog, cat, rabbit, pigeon, goldfish) and include breeds that differ markedly in appearance from their wild ancestors. There has been a great drive for novelty amongst companion animal breeders.

Historically at least, most companion animal breeding has been undertaken in pursuit of specific aspects of performance, appearance and temperament (eg speed, size, colour, shape, behaviour) with little or no specific regard to the possible welfare consequences.

The 'creation' of new strains, characterised by colour, shape, size, behaviour or whatever other features, is, with few exceptions driven, not by a process of actively generating new forms – it is nature that does this – but by actively selecting and breeding from 'new' mutant forms that arise spontaneously or from those individuals that most nearly approach the ideal being selected for (eg the largest, the whitest, etc). The process works largely by preventing the breeding of those animals that do not meet the ideal being selected for, rather than by accelerating the breeding of those that do.

Protected from the rigours of natural selection, under human stewardship, individuals can survive and breed that would not do so in the wild. The very strong constraints to colour, shape, size, behaviour and other aspects of biology imposed by survival of the fittest in the wild are relaxed through captivity/domestication, and this has opened the way for the extraordinary diversification of forms that has occurred.

The methods that have been used in the development of companion animal breeds – breeding from small numbers of animals in the selection of particular traits and the use of sibling or parent matings in the 'fixing' of these traits in 'true-breeding' lines – tend all too often to lead to significant inbreeding and the accumulation of potentially harmful alleles.

Many problems with clear welfare consequences are known to have arisen in association with selection for specific traits or suites of traits. These include, to give a few examples here (there are many others in the report): osteosarcoma (bone tumours) in giant breeds of dogs, predisposition to intervertebral disc disease in dachshunds, glaucoma in Siamese cats, predisposition to vitamin A deficiency in white canaries, and complications to health associated with long fur in rabbits. These and many other problems that have a genetic basis can seriously compromise welfare.

Welfare problems associated with genetic changes to the phenotypes of animals can be particularly serious in that:

(i)   they can affect large numbers of animals,
(ii)   they have the potential to continue to do so generation after generation into the future,

(iii)   they can have a severe adverse impact on animals' feelings (eg through pain or increased fearfulness) and,

(iv)   these effects can be of long duration – potentially affecting the animal for a large part of, or throughout, its life.

Increasingly, efforts are now being made to address some of the problems that have occurred in some species. These involve screening to identify affected and carrier animals and programmes to control breeding within populations in order to eliminate or reduce the incidence of harmful genetic effects.

In the case of recessive monogenic inheritance, homozygotes may be relatively easily picked out and prevented from breeding (providing the trait is apparent prior to breeding age). Detecting carriers (heterozygotes) of genetic diseases is often more difficult. Increasingly, modern genetic tests are being developed and used to detect carriers (but the number of such tests available remains small at present).

Historically, 'improving' a breed has often been about pursuit of arbitrary standards of appearance or performance that reflect human aesthetic preferences rather than improving welfare. As McGreevy and Nicholas (1999) have suggested, *'replacing the concept of quality with the concept of welfare'* may be beneficial for the animals and less ambiguous for both breeders and the general public.

In contrast to society's apparent concern for the welfare of animals and for strict animal welfare regulation in some circumstances, for example in the use of animals in scientific procedures, it seems that an almost unquestioning acceptance continues to prevail regarding the selection and breeding of companion animals for arbitrary traits, despite the great potential for very serious welfare consequences.

To help promote awareness of the potential risks and to promote awareness of the responsibility for welfare that rests on all those who breed companion animals of whatever species, CAWC proposes the following brief code, based on the wording of the Council of Europe Convention (Council of Europe, 1987):

'The selection and breeding of companion animals can result in, or perpetuate, characteristics or inherited conditions that seriously affect the quality of animals' lives. No one should breed companion animals without careful regard to characteristics (anatomical, physiological and behavioural) that may put at risk the health and welfare of the offspring or the female parent.'

We believe, for the reasons set out above, that the subject deserves greater attention and that there should be more public debate about it. We hope that this Report and its recommendations may play a role in this.

Responsibilities for contributing to the tackling of the problems fall to many groups including those involved in developing and overseeing breed standards, companion animal breeders, judges, veterinarians, geneticists, animal welfare scientists, regulators and the companion animal owning public.

Conclusions and recommendations

Conclusions

Conclusion 1. (See Section 2.8) The shaping of breed characteristics by human selection has a history as long as that of the domestication of animals. Selection has been for aspects of utility and, often to a considerable extent, in pursuit of aesthetic interests (eg particular aspects of appearance, including novelty). Recently some concerted efforts have begun to emerge to select specifically for good health and welfare.

Conclusion 2. (See Section 2.8) In the breeding of companion animals there has been, and continues to be, selection for a wide range of often arbitrary features according to the tastes, preferences and whims of individuals or breed societies. These features include aspects of, for example: body size (larger or smaller); conformation of body, head, limbs or tail; colour; fur or feather type; and behaviour.

Conclusion 3. (See Section 3.6) The methods that have been used in the development of companion animal breeds – breeding from small numbers of animals in the selection of particular traits and the use of sibling or parent matings in the 'fixing' of these traits in 'true-breeding' lines – tend to lead to significant inbreeding and the accumulation of potentially harmful alleles.

Conclusion 4. (See Section 3.6) To date, the (extensive) genetic manipulation of companion animals has been almost entirely through traditional breeding methods. However, already two transgenic ornamental fish species (whose colours are the result of inserted sea anemone genes) are commercially available. There are moves to produce, and make commercially available within a few years, a genetically-modified hypoallergenic cat. The welfare consequences of these modifications are unknown and should be assessed before made commercially available.

Conclusion 5. (See Section 3.6) Modern biotechnological methods may become useful in tackling some genetic diseases of welfare significance through deleting or replacing potentially harmful alleles.

Conclusion 6. (See Section 3.6) Although to date no companion animals have been cloned in the UK, commercial pet cloning services are emerging in other parts of the world. It seems likely that this technology will be taken up in the production of companion animals but it is hard to foresee the extent of this. Cats, horses and (reportedly) dogs have already been experimentally cloned.

Conclusion 7. (See Section 4.3) Some of the heritable diseases or characteristics of companion animals that have adverse welfare impacts affect large numbers of animals and have the potential to cause, depending in their nature, severe pain, discomfort, anxiety or other unpleasant feelings for prolonged periods or significant proportions of the animals' lives.

Conclusion 8. (See Section 5.7) Unless it is specifically aimed at better adapting an animal to its domesticated/captive environment, any breeding away from the wild

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type is much more likely to have adverse impacts on fitness and welfare than beneficial ones.

Conclusion 9. (See Section 5.7) Selective breeding for particular traits may lead to adverse welfare consequences in several ways: (i) because the trait itself has some adverse impact on welfare, (ii) because selecting for the trait has accompanying phenotypic effects that affect welfare, and (iii) through inbreeding effects including the accumulation of harmful recessive alleles.

Conclusion 10. (See Section 5.7) It is not easy to foresee the welfare impact of selection for various traits but adverse impacts have already occurred in various species through selection for a diverse range of traits, including aspects of colour, fur and feather type, size, conformation and behaviour.

Conclusion 11. (See Section 7.7) There are methods for selection and breeding that can greatly lessen the chances of there being an increased risk of genetic diseases with concomittant welfare impacts in future generations.

Conclusion 12. (See Section 8.1) In the breeding and artificial selection of companion animals, great care should be taken to avoid welfare problems arising or being perpetuated. It seems that there have been many cases in which the welfare consequences of breeding have been given little or no consideration.

Conclusion 13. (See Section 8.1) In contrast to the considerable attention given to, and concern expressed about, the welfare of farmed animals and about animals used in scientific procedures, society's tolerance of the scale and severity of the welfare risks inherent in selection for arbitrary traits in companion animals seems rather surprising. It appears that the subject has been, to a large extent, overlooked.

Conclusion 14. (See Section 8.6) Breeders, show judges (for strains which are shown and judged), and veterinarians involved in diagnosis of problems, all have key responsibilities and roles in preventing both the perpetuation of existing problems and the emergence of novel ones.

Recommendations

Recommendation 1. (See Section 5.7) Research should be undertaken to elucidate the welfare impacts of morphological and behavioural changes brought about through selective breeding for particular traits in a wide range of taxa.

Recommendation 2. (See Section 7.7) In view of its importance to welfare and the dramatic recent advances in knowledge of the genome, we recommend that, where possible, all those with interests in this field, including veterinary research funding bodies, help promote, and make funds available for, work aimed at elucidating the causes of genetic diseases, developing diagnostic tests and developing strategies for their elimination or control.

Recommendation 3. (See Section 8.1) All those responsible for the breeding of companion animals should take steps to avoid inbreeding. More than this, we suggest that selection for particular traits should be generally avoided unless there is a clear and duly justifiable need for it (eg for health or welfare benefits for future

generations). In breeding companion animals, the strategy should generally be to prevent loss of genetic diversity rather than, in selecting for arbitrary traits, acting to promote it.

Recommendation 4. (See Section 8.6) In the past, health and welfare have not been the major priorities of many breed societies. It seems clear that in future the promotion of health and welfare should be one of the major roles of breed societies and they should show leadership in this through developing codes of practice with regard to health and welfare and in encouraging their uptake and enforcement.

Recommendation 5. (See Section 8.6) Bodies that take responsibility for administration of breeding registers, pedigree registration etc, should also take responsibility for, and show leadership regarding, health and welfare aspects.

Recommendation 6. (See Section 8.6) Breed clubs should have in place systems for identifying health and welfare problems in their early stages and for addressing them as effectively as possible. This may often require advice from geneticists.

Recommendation 7. (See Section 8.6) Systems for accreditation of breeders should be such that accreditation depends upon maintenance of high health and welfare standards in breeding.

Recommendation 8. (See Section 8.6) The governing boards of breed societies should include a veterinarian and at least one person from outside the breeding community for that species to represent pet owners.

Recommendation 9. (See Section 8.6) Breed societies should exercise a leadership role in taking steps to maintain genetic diversity in breed gene pools and minimise the risks of inbreeding.

Recommendation 10. (See Section 8.6) Links between national umbrella bodies and regional clubs should be such that problems can be tackled in a prompt and coordinated way.

Recommendation 11. (See Section 8.6) The control of inbreeding or of any potentially harmful traits depends on reliable breeding records/registered pedigrees and it is therefore important that all those involved in breeding companion animals should maintain breeding records.

Recommendation 12. (See Section 8.6) For all species, there should be a bar to entry in breed shows of animals with known welfare problems of genetic origin or from parents that have tested positive for hereditary disease (unless, on the advice of a geneticist, there is a strong case not to do so, eg if, although positive for one deleterious trait, the animal is genetically valuable to the population as regards breeding out other harmful traits).

Recommendation 13. (See Section 8.6) There should be a system for the collection of data on causes of disease and death in pedigree animals and for regular review and analysis of these data, to aid in the detection of diseases whose causes have a genetic component. We suggest that primary responsibility for this falls to breeders and breed

organisations and that they should liaise with veterinary authorities about how such surveillance could be achieved.

Recommendation 14.   (See Section 8.7) Companion animal breeders should familiarise themselves with and respect the following code: '*The selection and breeding of companion animals can result in, or perpetuate, characteristics or inherited conditions that seriously affect the quality of animals' lives. No one should breed companion animals without careful regard to characteristics (anatomical, physiological and behavioural) that may put at risk the health and welfare of the offspring or the female parent.*'

Recommendation 15. (See Section 8.7) Whilst every effort should be made to alleviate suffering in animals resulting from defects arising through their breeding history, in the long run it will be a better use of resources for welfare improvements to develop ways to prevent the breeding of animals likely to be at welfare risk through genetic diseases, than to develop husbandry/therapeutic methods aimed at alleviation of the problems caused by these diseases.

Recommendation 16. (See Section 8.7) Since many of the issues relating to welfare and breeding in companion animals are similar to those in animals kept for other purposes, the Government's various animal welfare advisory bodies (the Farm Animal Welfare Council, the Animal Procedures Committee, the Zoos Forum and CAWC) should consider ways of working together to keep the subject, and new developments in the field, under review.

Recommendation 17. (See Section 8.8) The relevant professional bodies, breed societies, clubs and others in a position to do so, should promote education about the risks of selective breeding and the steps necessary to deal with these risks.

1. Introduction and Aims

1.1 Background

There has been rapid growth in the number of species of vertebrates and invertebrates kept as companion animals and, in the UK, this exceeds 1000 vertebrates species alone. Many hundreds of these species are bred for this purpose (CAWC, 2003). A considerable number of species have been selected for specific traits, or suites of traits, for countless generations (eg dog, cat, rabbit, pigeon, goldfish) and include breeds that differ markedly in appearance from their wild ancestors. There seems to be a great drive for novelty amongst companion animal breeders and it is often not long after species first start breeding in captivity that particular colour morphs, or strains that differ from the wild form in other ways, start to be selected.

Historically at least, most companion animal breeding has been undertaken in pursuit of specific aspects of performance, appearance and temperament (eg speed, size, colour, shape, behaviour) with little or no specific regard to the possible welfare consequences.

Many problems with clear welfare consequences are known to have arisen in association with selection for specific traits or suites of traits. These include, to give a few examples here (there are many others in the report): osteosarcoma (bone tumours) in giant breeds of dogs, predisposition to intervertebral disc disease in dachshunds, glaucoma in Siamese cats, predisposition to vitamin A deficiency in white canaries, and complications to health associated with long fur in rabbits. These and many other problems that have a genetic basis can seriously compromise welfare.

Welfare problems associated with genetic changes to the phenotypes of animals can be particularly serious in that:

(i)   they can affect large numbers of animals,

(ii)   they have the potential to continue to do so for many generations into the future,

(iii)   they can have a severe adverse impact on animals' feelings (eg through pain or increased fearfulness) and,

(iv)   these effects can be of long duration – potentially affecting the animal throughout its life (and they may also affect lifespan).

In view of these risks, there has been considerable attention to the impact of breeding on the welfare of farmed (eg AEBC, 2002; FAWC, 2004) and laboratory animals (eg Royal Society, 2001; APC, 2001), but there has been surprisingly little public interest in the subject as it relates to companion animals (but see Council of Europe, 1987; 1995). It is interesting to note, for example, in this context that the subject is not addressed at all in the Breeding of Dogs Acts 1973 and 1991 or in the Sale and Breeding of Dogs (Welfare) Act 1999: these Acts dealt with selected areas of concern which were limited to husbandry standards for breeding animals (see also BVA, BSAVA, CIEH & LGA, 2000).

However, increasingly, efforts are now being made to address some of the problems that have occurred in some species. These involve screening to identify affected and carrier animals and programmes to control breeding within populations in order to eliminate or reduce the incidence of harmful genetic effects.

In view of the apparent importance of the subject to welfare, the Companion Animal Welfare Council decided, in 2003, to undertake this Inquiry.

1.2   Aim

The aim of the Inquiry was to conduct a wide-ranging review of the subject in order to form objective views on the welfare aspects, identify areas in which research is needed, and make recommendations about tackling problems.

2.   The history of selective breeding in companion animals and the range of characters selected for intentionally

2.1   Introduction

Before beginning to address how selective breeding may have consequences to the welfare of the individuals produced, we outline below some examples of selective breeding of various vertebrate species to provide an overview of the history and extraordinary range of these activities.

As noted in the CAWC report on the keeping of non-domesticated species (CAWC, 2003), selection away from the wild type starts, intentionally or not, as soon as animals are bred in captivity. We can expect that minor changes to phenotype will occur even without any deliberate selection (as those that survive to breed in captivity are the subset that can survive to breed in captivity). However, the extraordinary variety of strains with atypical (as judged in relation to the wild type) colour, size, conformation, or behaviour seen in most, if not all, species that have become established favourites in the companion animal industry, is a reflection of a great deal of deliberate selection for a wide range of characters, some related to aspects of the animal's use in the past and some relating to the human fascination with, and drive for, novelty. The welfare consequences of this phenomenon have received little attention (but see Council of Europe 1987, 1995; FVE, 1999; McGreevy & Nicholas, 1999; Steiger, 2005; Mäki et al, 2005).

The 'creation' of new strains, characterised by colour, shape, size, behaviour or whatever other features, is, with few exceptions (see Section 3.5 on genetic engineering) driven not by a process of actively generating new forms - it is nature that does this – but of actively selecting and breeding from 'new' mutant forms that arise spontaneously or of actively selecting and breeding from those individuals that most nearly approach the ideal being selected for (eg the largest, the whitest, etc). The 'creation' is thus brought about through actively discarding animals from the breeding population. That is, the process works very largely by putting the brakes on the breeding of animals that do not meet the ideal being selected for rather than by accelerating the breeding of those that do (although artificial insemination and embryo transfer have certainly resulted in such acceleration in the breeding of farm animals). The process is the same as that which drives evolution in nature except that nature's criterion for 'selection' is not based on preferences or judgements about ideal forms (colours, shapes, sizes, behaviours, etc) but only on evolutionary fitness: those that breed are simply those that have been able to survive and breed. (We put 'selection' in quotation marks in this context because the process is, of course, a blind and passive mechanism: in evolution nothing actually does any selecting.)

Protected from the rigours of natural selection under human stewardship, individuals can survive and breed that would not do so in the wild. The very strong constraints to colour, shape, size, behaviour and other aspects of biology, imposed by survival of the fittest in the wild, are relaxed through captivity/domestication, and this has opened the way for the extraordinary diversification of forms that has occurred. Whilst much of this diversification (some of it with related welfare implications) has been actively driven by human interests, some (again, in some cases with related welfare implications) is likely to have arisen passively as a result of the relaxed or different

evolutionary constraints under human stewardship. Within the boundaries of modern human ecology there are niches, which do not exist otherwise, for all manner of animal types from achondroplastic dogs to red canaries, bubble-eyed goldfish and albino corn snakes. In one sense, what we see is that the process of evolution, being constantly 'on the look out' to fill all possible niches, has begun to 'explore' these new ones; and with its inherent disregard of whether or not they are pleasant 'places' to be.

Many breeds of the species kept as companion animals today are the descendents of breeds that were originally selected for characteristics that made them useful to our ancestors. For example, in dogs: speed and agility for hunting, shepherding behaviour, and size and aggression for guarding property; and in rabbits: rapid growth to large size for meat production. Whilst some such selection for utility has continued, a good example being selection for ideal guide dogs for the blind (see Box 3.1), selection has more recently been for characters thought to enhance the animals' value in sport (eg greater homing speed in racing pigeons, better retrieving efficiency in gun dogs) or for aesthetic reasons. The last appears to be a major driver these days: selection for colours, shapes, sizes and behaviours which best conform to an individual's or a breed club's notion of what is attractive, novel or best. The variety that we see today reflects the diversity of human aesthetic tastes.

These kinds of selection have been going on for a very long time. Darwin, himself, chose to keep a wide variety of breeds of pigeons in order to study the variation that had been achieved, noting (Darwin, 1859) that, '*The diversity of the breeds is something astonishing*'.

Characteristically, Darwin's observations were extraordinarily detailed and perceptive. He outlined features of carriers, tumblers, pouters, Jacobins, trumpeters, laughers and fantails and others and commented, '*Altogether at least a score of pigeons might be chosen, which if shown to an ornithologist, and he were told that they were wild birds, would certainly, I think, be ranked by him as well-defined species. Moreover, I do not believe that any ornithologist would place the English carrier, the short-faced tumbler, the runt, the barb, pouter and fantail in the same genus…*'. He observed that the fantail has 30 to 40 tail feathers instead of twelve or fourteen (the normal number in the pigeon family Columbidae) and that the preen gland has been lost in this breed; that among breeds there are striking differences in shape and development of some bones, the number of caudal and sacral vertebrae (the bones of the hip and tail), the relative size of parts of the upper digestive tract, and number of primary wing feathers.

He was interested in the effects of selection on behaviour in animals also, observing, in another section relating to pigeons, and relevant to this report: '*No one would ever have thought of teaching, or probably could have taught, the tumbler-pigeon to tumble, - an action which, as I have witnessed, is performed by young birds that have never seen a pigeon tumble. We may believe that some one pigeon showed a slight tendency to this strange habit, and that long-continued selection of the best individuals in successive generations made tumblers what they now are; and near Glasgow there are house-tumblers, as I hear from Mr Brent, which cannot fly eighteen inches high without going head over heels.*'

In the following sections, brief reviews of the history and scope of selective breeding are provided for various vertebrate taxa kept as companion animals.

It should be noted that, as documented in CAWC's Report on the Keeping of Non-Domesticated Animals for Companionship (CAWC, 2003), a very wide range of species are kept by private owners and for a wide range of purposes. Some are motivated by a concern to help maintain stocks (and genetic diversity) of threatened species and, in these cases (as generally in zoos), efforts may be made to deliberately avoid any artificial selection pressures in order to preserve the wild genotype as far as possible. Others are motivated to avoid further deliberate selection for changes to existing artificial breeds or strains in order to preserve or conserve particular strains in their present state. In order to try to maintain into the future the genetic constitution of a founder population, whether that be a group taken from the wild (for conservation or other purposes) or a group of individuals of a certain breed, selective breeding is likely to be necessary to avoid chance over- and under-representation of the genes of certain founder individuals in descendant populations. The welfare consequences of selective breeding will depend upon whether the selection is for a change that may be beneficial, or harmful, or if it is being used to perpetuate a phenotype with sub-optimal welfare resulting from previous selection for harmful traits. In recent years and in some circles, interest in selecting for good health and welfare has begun to gain momentum.

2.2   Fish

Ornamental fish have been bred and kept for thousands of years (Walster, 2001): fish with red scales (believed to be the earliest coloured goldfish) are mentioned in the literature of the Chinese Tsin dynasty period (AD 265-420). Chinese literature from the 17th century describes fish with double, triple or enlarged tails and with shortened bodies. Goldfish lacking dorsal fins and with telescope eyes were well known in China by the 18th century. Goldfish keeping was established in Japan by the 16th century, was recorded in London by Samuel Pepys in 1665 and was common in the UK by the late eighteenth century. There are estimated to be over 125 varieties of fancy goldfish including the common goldfish, the comet, fantail, shubunkin or calico, oranda, lionhead, black moor, celestial and water bubble eye goldfish (Ostrow, 1995).

The ornamental species commonly kept in outdoor ponds are koi, orfe, common carp, mirror carp, leather carp, tench and rudd (Prince-Iles, 2001). Unlike goldfish, which seem to be bred for unusual shapes and attributes, Koi breeding has focused on colour and scale patterns (James, 2000). Koi were developed from the common carp *Cyprinus carpio*, first bred in Japan in the 1820s. By 1870 the kohaku (red on white) variety was perfected, with many other forms recognised by the 1930s (James, 2000).

2.3   Reptiles and Amphibians

There has been a great increase in the popularity of reptiles and amphibians as pets in recent years and wide ranges of species of both are now bred in captivity (CAWC, 2003).

The cornsnake, *Elaphe guttata*, has been captive-bred for over 50 years. Many colour and pattern morphs of this species have been produced. Other reptile species being selected for particular traits for aesthetic appeal, including reticulated, Burmese, royal and blood pythons and leopard geckoes (Federation of British Herpetologists, 2004). In addition, a number of interspecies hybrid reptiles and amphibians are being produced (Federation of British Herpetologists, 2004).

2.4   Birds

Birds have been kept as companions for thousands of years. Parrots were highly prized by the Ancient Greeks, and parrots, ravens and bullfinches were among the species kept by Romans. Christopher Columbus brought back a pair of parrots from Cuba for Queen Isabella of Spain, and Henry VIII had an African Grey parrot at Hampton Court (Alderton, 1992).

Canaries, derived from wild serins *Serinus serinus* from the Canary Islands, have been kept as companion animals from at least the fifteenth century. Wild budgerigars were imported into the UK from Australia in tens of thousands during the middle of the nineteenth century and soon came to be bred widely in Europe (David, 1987b). Budgerigars are now the world's most popular pet bird (Alderton, 1995).

Many species, including pigeons, budgerigars, and finches, have been selected to produce strains with particular characteristics. A few examples are outlined below.

2.4.1   Canaries, *Serinus canaria*

Canaries have been bred for a variety of types of characteristics and, in particular, for aspects of behaviour, most notably song type, colour, feather structure and posture. For example, the roller has been bred to sing with its beak closed so as to produce a "softer mellifluous" sound (David, 1987a) and this and other breeds continue to be selected for particular aspects of song quality (as judged by the human ear).

Colour is also a popular focus for canary breeders. Wild serins are a greenish colour, but there are now over fifty colour types of canary. The oldest breed is thought to be the lizard whose plumage pattern has been recognised since 1709 and has changed relatively little since then (Alderton, 1995; David, 1987a). The popular red factor canary (denoted *Serinus domestica*: Alderton, 1992) was derived from a hybrid of the canary and the black-hooded red siskin (*Carduelis cucullata*) in the 1920s.

Among the breeds developed by selection for abnormal feathers are the frilled and crested canaries whose feathers curl as they grow such as the parisian, paduan, dutch and italian humpback (David, 1987a). These breeds are distinguished by the nature and position of the abnormal feathering on the head or body.

Other breeds have been selected for particular body conformations and postures. These include the belgian fancy, scotch fancy, japanese hoso, *Gibber italicus* and *Giboso espanol*. The belgian fancy has a '*small head, a long neck and body ... unusually high shoulders ... legs ... particularly long and upright ... shoulders and tail in straight line ... neck should be extended with head pointing downward during*

judging' (David, 1987a). The *Giboso espanol* was first exhibited in 1982 and its long neck is due, partly, to the presence of an extra cervical vertebra (David, 1987a).

2.4.2   Budgerigars

Wild budgerigars *Melopsittacus undulatus* are light green with black and yellow markings on the head, back and wings, a blue-tipped tail, violet cheek patches and a black 'mask' or necklace of throat spots. There has been selection for a large variety of colour morphs. There are also feather mutations such as tufted, half circular and circular crests and forms with long flight feathers (David, 1987b), and there are size differences between strains.

2.4.4   Other birds

In the breeding of birds for falconry, various hybrids have been produced including peregrine x merlin (*Falco peregrinus* x *Falco columbarius*) and peregrine x saker (*F. peregrinus* x *F. cherrug*).

Another example was provided by one of the respondents to the CAWC Inquiry who wrote: '*In addition, the long established branch of aviculture which specializes in the creation of hybrids of British native finches (Goldfinches, Greenfinches, Bullfinches, and so on) along with the 'mules' produced with the domesticated Canary, should not be denigrated. Breeders of these birds are proud of their traditional knowledge and skills, and – provided pure stocks of the contributing species are maintained – no harm to the birds seems to result. Such birds appear to be no less healthy or prone to disease than the pure species, and - as far as is known - these particular hybrids and 'mules' are sterile.*'

2.5   Mammals

2.5.1   Dogs

The domestic dog, *Canis familiaris*, is thought to have been the first species to be domesticated. Evidence from mitochondrial DNA sequence analysis indicates that the more than 500 dog breeds (Jackson, 1994) are descendents of the wolf (*Canis lupus*) and are derived from a small number of domestication events that occurred in the Middle East some 30 to 50 thousand years ago. The recent sequencing of the dog genome has confirmed that dogs are most closely related to the grey wolf and has opened new roads for exploration of the derivation and relatedness of the many breeds (Lindblad-Toh et al, 2005). Egyptian illustrations from about 1900 BC show distinctly different forms of dogs, some of which resemble greyhounds and Pharaoh hounds and others of which are short-legged types akin to Dachshunds (see Clutton-Brock 1999). Until relatively recently, the majority of breeds were of hunting, guard or herding types. However, archaeological remains suggest that the Romans had a much smaller breed also that could well have been a general housedog and companion. The differentiation into the many different breeds that occur today is thought to have gathered pace around the 14th or 15th century, with a huge acceleration in the development of new breeds occurring from the 18th century. Dog competitions and organisations overseeing such events have been in existence for at least 400 years (Jackson 1994) and the first official dog show was held in 1859 (Kennel Club, 1998).

The variation in body size, shape and other characters between breeds of dogs is greater than that in any other species (Asdell, 1966). The adult body weights of the smallest breeds are some 70 times less than those of the largest breeds. Skull length varies between 7 cm and 28 cm (McGreevy et al, 2004).

Dogs have been selected for a very wide range of characters including size, and aspects of shape, colour, and temperament. See Box 2.1 for an example of current selection for temperament.

Lindblad-Toh et al (2005), commenting on the diversity produced through selection for various traits during the history of dogdom, noted '*As a consequence of these stringent breeding programmes and periodic population bottlenecks (for example during the World Wars), many of the ~400 modern dog breeds also show a high prevalence of specific diseases, including cancers, blindness, heart disease, cataracts, epilepsy, hip dysplasia and deafness.*'

Box 2.1 Guide Dogs for the Blind Breeding Programme

The text in this box was provided by Guide Dogs for the Blind to whom CAWC is grateful.

' *.... The success rate of our training programme and the supply of qualified dogs to clients was therefore inconsistent which, over time, was proving costly to the Association in terms of both time and money. As a result, Guide Dogs established its breeding programme and today, we manage breeding stock of around 240 dogs and breed over 1,000 puppies per year. Through selective breeding, we have been able to attain a success rate of 75% and we can continue to breed dogs that meet the changing needs of our clients.*

Guide Dogs will intentionally select for specific characteristics as part of the breeding programme. Physically, the breed should have a middle of the road bodyweight and size, mature relatively quickly (by the age of two years) while the coat should be short and easy to maintain. Temperamentally, the dog needs to be stable, not easily distracted or frightened, with low aggressive tendencies and reasonable initiative. In addition, the breed needs to be as free as possible from hereditary defects or other health problems that may affect its work or lifestyle.

This observational assessment is undertaken by the dog's trainer and aims to identify and monitor the suitability of the dog's temperament to guide dog work. This is done by scoring the dogs display of certain characteristics including willingness, confidence, stress resilience, attentiveness, distraction, suspicion, aggression and sensitivity at different stages of its training.

Guide Dogs also undertakes regular health assessments of every dog and all prospective breeding stock are routinely screened for eye defects and orthopaedic conditions. Any dog found to be affected by a serious health problem or hereditary condition will not be accepted onto the breeding programme.

Artificial Insemination (A.I) is occasionally used within the breeding programme in order to ensure that as many matings as possible are successful. A.I has also been used on occasion during the exchange of semen between Guide Dog Schools internationally. This has increased the genetic pool available to our breeding programme and has reduced the need for dogs to travel from one country to another. Semen evaluation may also be undertaken at intervals to monitor fertility levels and provide an early warning system of potential problems.

The success rate of the Guide Dogs breeding programme currently stands at 75 %. Of those rejected, approximately 80% are for temperament problems, primarily distraction and suspicion, while 20% are as a result of health problems.'

2.5.2   Cats

It is thought that cats were first domesticated about 5000 years ago in the Middle East and that this was related to their ability to control pests, specifically rodents, in grain stores (Bradshaw, 1992). The dissemination of domesticated cats through Europe was facilitated by the Romans, who introduced them to England in the first century AD (Hart-Davis, 2000).

There was probably some selection over the centuries through keeping better mousers and by keeping more attractive colours as pets, but deliberate selection for aspects of appearance (including head and body shape, and fur colour and quality) began more recently. The first modern cat show in the UK was held in 1871 and Harrison Weir then devised 'The Standard of Points of Excellence and Beauty' for the breeds that existed at the time. The deliberate breeding of pedigree cats began in the second half of the nineteenth century (Steiger, 2005). More breeds of domestic cat were developed during the twentieth century than in the whole of the cat's previous domesticated history (Fogle, 1997). However, the pure-bred population amounts to only 6-7% of the total cat population in the UK and the USA (Bradshaw, 1992).

In addition to aspects of head and body shape and colour, there has been selection for various other features including size, aspects of temperament, and taillessness

2.5.3   Horses

The domestication of the horse (*Equus caballus*) may have begun 5,000 to 6,000 years ago. There is evidence of horse breeding in Persia in 3,000 BC (Jones & Bogart 1971). Horses may have been used initially as a food source before domestication ensued for agricultural work and transport.

There are approximately 400 breeds (Hendricks, 1995). The oldest breeds are thought to be those originally developed in the Fertile Crescent, today represented by the Arab, Barb and Turkoman breeds. These breeds have contributed to the development of 'warm-blooded' domestic horse breeds, whilst the heavy draught horse breeds are

thought to have been developed separately and later from ancestors that lived in the tundra and steppes.

The 'Arab' breed has contributed extensively to the formation of many other breeds, probably most famously in the case of the Thoroughbred horse. All Thoroughbreds can be traced back in the male line to one of three imported founding stallions, the Godolphin Arabian, The Byerly Turk and the Darley Arabian. The foundation mares for the Thoroughbred breed also included many imported Eastern horses.

Many Arab horses have one less lumbar vertebra than is present in horses of most other breeds, though this is not a unique feature of the breed as it occurs in small numbers of horses of many other breeds. It is thought to be responsible for the short-backed appearance of the Arab horse.

Horses have been bred for conformation (eg Arabs), colour (eg Pinto or paint horses - piebald, skewbald, and Appaloosa), behaviour (eg quarter horses for herding cattle and ranching duties, trotters and paso finos for their unique gaits) and size (eg from Shetland ponies to shire horses).

Falabella miniature horses are thought to be descendents of a group of small horses found in 1845 (Hendricks, 1995) and/or a small stallion whose genes for this condition appeared to be dominant (Kidd, 1995). By 1893 the breed type and conformation had been established (Porter, 2002). These horses appear to have fewer lumbar vertebrae and ribs than their wild ancestors (Hendricks, 1995). The motive for producing the Falabella appears to have been as novel companion animals.

2.5.4   Rabbits

Rabbits (*Oryctolagus cunniculus*) were domesticated by the Romans for food. Selective breeding later resulted in larger breeds that also developed a different skull shape during this time (Clutton-Brock, 1999). Selection for aesthetic criteria had begun at least by the 16th Century (Sandford, 1996). In 1850 there were 10 recognised and standardized breeds of rabbit. By 1995 there were 61 breeds and 531 colour varieties (Sandford, 1996). Features selected for include: colour, size, ear length and shape, fur texture and length. Adult body weight varies from about 1kg in the Netherland dwarf to 6kg in British giants (Sandford, 1996).

2.5.5   Hamsters

Three species of hamsters are kept as pets: the Syrian (previously known as Golden), the Chinese and the Dwarf Russian (Logsdail et al, 2002). It is alleged that the captive Syrian hamster population is descended from a single female and her twelve offspring (Clutton-Brock, 1999). The longevity of hamsters appears to be increasing and it has been suggested that this may be an effect of selective breeding (Logsdail et al, 2002). Hamsters have been selected for fur length and colour.

2.5.6   Guinea Pigs

Guinea pigs are decended from South American wild cavies and it is believed that they were domesticated and farmed for food by the Incas (they still are reared for food

in South America). There has been selection for hair colour, type and arrangement (Elward, 1987). Peruvian cavies have long hair that must cover the body and (according to the breed rules) include a fringe that obscures the face (Elward, 1987). In contrast, shelties (or silkies in the USA) must have a face free from the long hair that covers the body. Abyssinians are chacterised by a harsh coat that is rough, erect and wiry and has distinct rosettes of fur. Any area of coat that lies flat to the skin constitutes a fault (as judged by the guinea pig cognoscenti) in this breed (Elward, 1987).

2.5.7   Rats

Associated with their role as laboratory animals, over 300 inbred strains of rats have been produced (Abbott, 2004). Domestic rats are usually albino-white or parti-coloured (Clutton-Brock, 1999). The UK National Fancy Rat Society was established in 1976 and publishes standards for varieties of pet and exhibition rats (National Fancy Rat Society, 2005).

2.6   Farmed animals as pets

There is growing interest in keeping farm animals in small numbers not for production but as companion animals. Many farm animal breeds have been selected for production traits such as rapid rates of growth or high levels of milk or egg production, or to adapt them to particular environments, and have special husbandry requirements associated with this.

2.7   Overview of the range of characters selected for

Summaries showing some of the wide range of characters that have been and/or are selected for in the breeding of companion animals are given in Tables 2.1 and 2.2. Examples of health and welfare related traits now being selected for to control inherited diseases in some breeds, especially of dogs and cats, are given in later sections (eg see Section 7).

Table 2.1 Some examples of the range of traits that have been or are selected for in some companion animals: traits relevant to function

Trait	Breed	Function
Body size	St Bernard dog	Guarding, draught
	Chihuahua	Lap dog
	Shire horse	Draught
Shape	Newfoundland dog (webbed toes)	Improved swimming ability for rescue work (American Kennel Club, 1992)
	Dachshund	Hunting in tunnels
Speed	Lurcher and Greyhound dogs	Coursing and hunting
	Racing pigeons	Rapid homing
Behaviour	Various gundog breeds	Retrieving game
	Pointer and Setter dogs	Indicating presence of game
	Various falcon crosses	Flight quality
Voice	Basenji dog	Silent hunting
Allergenicity	Hypoallergenic cat	Lack of an allergenic protein

Table 2.2 Examples of the range of traits that have been or are selected for in some companion animals: novelty or aesthetics of appearance.

Trait	Species/Breed	Purpose
Colour	Dalmatian dog	Spotted coat
	Chow Chow dog	Black tongue
	Siamese cat	Colour pattern
	Appaloosa horse	Spotted coat
	Red Factor canary	Orange-red colouration
	Corn snake	Various colour morphs
Size	Chihuahua dog	Small size
	Falabella miniature horse	Small size
	British Giant Rabbit	Large size
Shape	Scottish fold cat	Tips of ears bent backwards
	Dachshund dog	Elongated back
	Bull Terrier	Facial conformation
	Pug	Facial conformation
	Kathiawari horse	Ears curve to touch or overlap at tips.
	Lop-eared rabbit breeds	Extremely long ears
Behaviour	Ragdoll cat	Temperament
	Peruvian Paso horse	Gait
	Tennessee Walking Horse	Gait (Hope & Jackson, 1973; Hendricks, 1995).
	Tumbler pigeons	Tumbling in flight
	Canary and hybrids	Song type
Integument	Angora rabbit	Long fur
	Sphynx cat	Very little fur
	Various cage birds	Abnormal feather shapes

2.8   Conclusions

Conclusion 1. The shaping of breed characteristics by human selection has a history as long as that of the domestication of animals. Selection has been for aspects of utility and, often to a considerable extent, in pursuit of aesthetic interests (eg particular aspects of appearance, including novelty). Recently some concerted efforts have begun to emerge to select specifically for good health and welfare.

Conclusion 2. In the breeding of companion animals there has been, and continues to be, selection for a wide range of often arbitrary features according to the tastes, preferences and whims of individuals or breed societies. These features include, for example: body size (larger or smaller); conformation of body, head, limbs or tail; colour; fur or feather type; and behaviour.

3.   Past and present methods used for selection and genetic modification: and some observations on their potential welfare impact

3.1   Introduction

Controlled breeding is used both for the perpetuation of existing breeds to established breed standards and for the development of novel forms. There are several ways in which new types are produced. These approaches (which overlap to some extent) are:

(i)   Selection for a particular characteristic within a breed, subspecies or species. (eg breeding for large size by breeding from large sires and dams).

(ii)   Cross-breeding – to combine traits from two or more breeds (subspecies or even species) in the production of a new strain.

(iii)   Capturing 'new' mutations as and when they arise or reappear, by breeding from the animals in which these new mutations appear in order to spread the trait to all descendents in the new breed. The trait for curled ear tips was 'captured' in this way in the selection of American curl cats (Fogle, 1997).

Further detail about the way in which these approaches are applied is provided below. As will become apparent, there are various ways in which welfare problems can arise and be perpetuated during the processes of developing and maintaining breeds. A brief outline of some key principles of genetics and selective breeding is provided in **Appendix 4** which we hope may be helpful for those not familiar with the subject. Readers may also find the glossary of technical terms given in **Appendix 5** to be helpful.

Where a new breed is developed, there is a high risk that it will inherit any genetic predispositions to disease that are present in the parent breed. For example, Exotic Shorthair cats are prone to polycystic kidney disease as are the Persian pedigrees from which they were derived (Vella et al, 2002). Avoiding the propagation of genetic diseases requires careful selection of founder stock and avoidance of extensive inbreeding.

3.2   Cross-breeding to combine traits from different breeds or strains

Cross-breeding is used with the aim of combining characteristics, that are believed to be desirable, from two or more existing breeds (or subspecies). For example, Arab horses have been cross-bred with many other breeds (Jones and Bogart, 1971) with the aim of gaining some of their respected characteristics. The Sealyham terrier was produced by cross-breeding among several terrier breeds including the wire fox terrier, Dandie Dinmont and corgi (Parsons, 2004).

After crossing-breeding to combine characters, breeders may then attempt to fix the new combination so that future descendents will breed true (ie the offspring will consistently resemble their parents rather than one or other of the ancestral types). This process involves some degree of inbreeding.

Although cross-breeding can have beneficial effects for welfare, there are also potential risks. An obvious example is when there is a significant difference in body size between the sire's and the dam's strains creating a risk of birth difficulties due to disproportion between size of the neonate and the pelvic outlet of the dam.

An interesting potential problem has been drawn to our attention by the Federation of British Herpetologists. Where animals from different genera with widely varying habits are hybridised (gopher snakes x cornsnakes, for example) their behavioural requirements (such as burrowing habits etc.) may differ from one or other of their parent stock and, if not catered for correctly, may lead to welfare problems. If the offspring from such crosses are bred back with one of the original parent species, the second generation offspring may appear identical to one of the parent species and be passed on as a pure or normal type animal of that species. However its behaviour, and the behaviour of its offspring, may not be typical for that species.

Interspecies hybrids have been created from interspecies crosses in birds (see Section 2). The impact on behaviour and the effects of this on welfare have not been investigated as far as we are aware.

Traditionally, companion animal breeding has involved selection for observable characteristics such as size, conformation and colour. However, increasingly, predisposition or resistance to various genetic diseases, as indicated through various biochemical or genetic tests, are also being taken into account.

3.3   Selection for traits or suites of traits

Breeders may focus on selecting for just one trait – eg larger size, a particular colour, or an aspect of temperament. In which case the approach is to consistently pair individuals (or to breed from families) that show this trait to an exceptional degree. Many breeds may have arisen through focused selection of this sort in the past. This kind of selection could have adverse welfare consequences (i) if change to the character selected for has a direct impact on welfare because of the nature of the character itself (eg selection for white coat colour imposes a welfare risk through susceptibility to sun damage to the skin including burning and squamous cell carcinoma in cats, and through deafness in dalmation and boxer dogs), and (ii) if, selecting for the trait, has the consequence of concentrating potentially harmful alleles of other genes linked (on the same chromosome as) the gene that regulates the expression of the trait selected for.

Today, when the focus may have switched, in some cases, from developing a novel type or breed to trying to produce offspring that approach ever more closely a set of (arbitrary) breed standards, the aim of selection is often not just to alter one trait but a suite of them. There are several approaches to this (tandem selection, selection based on minimum standards, and selection based on scoring systems) as outlined below.

Tandem selection involves focusing on one character at a time and only moving on to address the next after satisfactory progress has been made with the previous one. Alternatively, sometimes a variety of characters are selected for simultaneously (in parallel). In one form of this, a minimum standard is set for each character and individuals that do not meet these standards are not used for breeding (Hope &

Jackson, 1973). In another form of parallel selection, characters are scored numerically and weighted according to their relative importance to the breeder (Robinson, 1990). Individuals are then selected for breeding on the basis of their total weighted scores.

McGreevy and Nicholas (1999) commented that '*after breeders have taken into account the many traits incorporated into breed standards, there is very little selection pressure remaining to be devoted to traits that are directly related to welfare and adaptability to modern (mainly urban) environments*'. However, it appears that, at least for some taxa, priority is increasingly being given to health and welfare in the selection of animals for breeding.

3.4   Breeding to fix traits or new mutations

Following selection for animals that show the trait or combinations of traits desired by the breeder, efforts may then be made to 'fix' the relevant genes in the descendent population so that all in future will breed true for these characters. Fixing mutations (especially recessive forms) generally requires a degree of inbreeding (the mating of related individuals). There are a number of methods of inbreeding used to fix characters as outlined below.

- Sib Mating. The mating together of full brothers and sisters is one of the quickest ways to reduce heterozygosis (Robinson, 1991b) and thus increase homozygosity (the proportion of individuals homozygous for particular genes).

- Parent-Offspring Mating or Backcrossing. Back-crossing - mating the offspring with its parent - results in the same level of inbreeding and the same rate of loss of heterozygosity as in sib mating.

- Half-sibling matings. In half-sibling matings the rate of decline of heterozygosis is lower.

As noted above, there is a risk that, in selecting for particular wanted features in this way, potentially harmful genes may also be concentrated in the population. The inbreeding associated with the use of these methods can also lead to a general loss of vigour (see Section 5.2).

The use of such methods in the past has resulted in a degree of background inbreeding in many breeds of companion animals, through:

(i)   sib mating, back-crossing or other inbreeding practices during the development and establishment of a breed;

(ii)   as a result of the small size of the founding populations when animals of a particular breed were first imported;

(iii) or because of a time in which the population of the breed was very small (for whatever reason).

Once background inbreeding has risen to 6% it can be difficult to control the dissemination of undesirable genetic anomalies (Jackson, 1994).

3.5 Genetic engineering

Genetic engineering is the use of artificial means to manipulate gene combinations in organisms. A transgenic animal is one whose DNA includes genetic material (one or more genes) from another species. The use of genetic engineering is currently largely confined to the farm and laboratory animal industries. However, some have predicted that it may not be long before this technology is more widely applied in companion animals (eg Long et al, 2003).

It is possible that, in the future, genetic engineering techniques could be used to benefit the welfare of companion animals through the replacement of harmful alleles with healthy ones. This methodology may offer an approach to tackling some of the genetic problems that have been created through selection for particular breed traits. Because the high prevalence of specific diseases within certain breeds suggests that a limited number of loci underlie some of these diseases, it has been suggested that determination of the genetic basis of these problems may be more tractable in dogs than in humans (Lindblad-Toh et al, 2005). Modern genetic methods have been used for genetic manipulations in farm animals aimed at health improvements such as increased resistance to infections and infestations. For example, genetically engineered sheep with the enzyme chitinase expressed in their skin have a better chance of escaping blowfly infestations (Ward, 1995). Such approaches may come to be applied in companion animals also in the future. However, the technology is not without potential welfare costs (see Section 3.6) and these would need to be carefully taken into account in considering any proposal to use the technology for such purposes.

3.5.1 Transgenic ornamental fish

Transgenic ornamental fish have been produced for sale in Taiwan and the USA. Genes from jellyfish and sea anemones that confer bright colours have been inserted into rice medaka (*Oryzias latipes)* and zebra danios (*Brachydanio rerio)*. These transgenic fish have been marketed under descriptors such as 'Glofish'. The motivation for the research that led to the development of these transgenic fish was, it seems, related to the production of fish that could help in the detection of pollution events rather than in production of varieties for sale in the ornamental fish industry.

3.5.2 Hypoallergenic cats

The chemical, present in the skin and saliva of cats, that commonly induces allergies in humans has been found to be a glycoprotein (labelled Fel d1). An American company is planning to produce cats that lack Fel d1 so that they can be kept by people who are allergic to normal cats (Allerca, 2004). The company aims to use gene silencing to disrupt and reduce the ability of the relevant gene to produce Fel d1. Allerca have scheduled their first hypoallergenic kittens to be created in 2007 and are taking orders now for hypoallergenic British shorthairs for $3500 (Allerca, 2004). Hypoallergenic cats of other breeds are planned for the future. The function of this glycoprotein is not fully known so the effects of removing it (from the cat's point of

view) are unclear at the moment. Allerca hopes to sell 200,000 cats annually in the United States (CNN, 2004). The intention is that they will be neutered to prevent any breeding with non-genetically modified cats. However, it may be hard to prevent this in the long run. Escape of genetically modified cats to breed with feral or wild counterparts might result in the modification occuring in free-living populations.

3.6   Cloning

Despite initial doubts that cloning was ever likely to be applied in the companion animal field, it now appears that it could come to be applied more extensively in this context than for farm and laboratory animals. Cats, horses and, reportedly, dogs have already been cloned. Genetic Savings and Clone (GSC) of Sausalito, California has recently produced cloned kittens that are genetic duplicates of 'Tahini' a Bengal cat that was itself derived from crossing Asian Leopard cats with domestic cats. GSC runs 'PetBank Express' a gene banking service. Clients pay $295 for storage of genetic samples from their pets from which it may be possible to produce clones in the future (at an estimated cost of $50 000 (CNN, 2004). Some market surveys have found that a quarter of people interviewed would be interested in cloning their pet (Long et al, 2003). GSC launched its cat cloning service in February 2004 and expects to begin cloning dogs soon (Kirk, 2004). There are a number of other companies that are also already collecting and preserving cell and tissue samples of pets for clients (Long et al, 2003).

Recently, a cloned foal was derived from a cell taken from an Arab gelding who won world champion endurance events in 1994 and 1996. The new foal is the first horse clone produced for the purpose of making a breeding animal out of a sterile one. Competition horses are frequently gelded before they compete, which previously has created a barrier to breeding from the best competition horses. Cloning could preserve the genes of exceptional horses whose genetic material is presently lost because of castration. The genetic bank at Cryozootech is reported to contain cells from 30 different horses, including champions from the endurance, show jumping, dressage and eventing worlds (from a report in the Racing Post).

The first cloned dog, an Afghan hound named Snuppy (for Seoul National University Puppy), was reportedly born in South Korea in June 2005 (Lee et al, 2005). The scientists involved in this work suggested that the ability to clone dogs by somatic-cell nuclear transfer should help to determine genetic and environmental contributions to the diverse biological and behavioural traits associated with the many different canine breeds (Lee et al, 2005). In the work that resulted in the live birth of the two cloned dogs, a total of 1095 embryos were implanted in 123 surrogate mothers, so it seems unlikely that the technique will be taken up imminently for commercial cloning of pets.

Various authorities (eg APC, 2001; AEBC, 2002; FAWC, 2004) have reviewed the potential welfare impacts of cloning: there are risks to the animals involved in producing the clone and potential risks also to the clones produced. In view of this, the Animal Procedures Committee (the body that advises the Government on the Animals (Scientific Procedures) Act 1986), in its Report on Biotechnology published in 2001, recommended that licences should not be given under the Animals (Scientific

Procedures) Act 1986 for research in this field for trivial objectives such as the creation or duplication of favourite pets.

3.6   Conclusions

Conclusion 3. (See Section 3.6) The methods that have been used in the development of companion animal breeds – breeding from small numbers of animals in the selection of particular traits and the use of sibling or parent matings in the 'fixing' of these traits in 'true-breeding' lines – tend to lead to significant inbreeding and the accumulation of potentially harmful alleles.

Conclusion 4. (See Section 3.6) To date, the (extensive) genetic manipulation of companion animals has been almost entirely through traditional breeding methods. However, already two transgenic ornamental fish species (whose colours are the result of inserted sea anemone genes) are commercially available. There are moves to produce, and make commercially available within a few years, a genetically-modified hypoallergenic cat. The welfare consequences of these modifications are unknown and should be assessed before made commercially available.

Conclusion 5. (See Section 3.6) Modern biotechnological methods may become useful in tackling some genetic diseases of welfare significance through deleting or replacing potentially harmful alleles.

Conclusion 6. (See Section 3.6) Although to date no companion animals have been cloned in the UK, commercial pet cloning services are emerging in other parts of the world. It seems likely that this technology will be taken up in the production of companion animals but it is hard to foresee the extent of this. Cats, horses and (reportedly) dogs have already been experimentally cloned.

4. Assessment of the welfare impact of changes to form or function caused by selective breeding or other genetic changes

4.1   What is welfare?

The term 'welfare' is often used to encompass two different concepts. One relates to the physical health and evolutionary fitness of animals, the other to the quality of their subjective feelings. There is much to be said for distinguishing clearly between these by employing the terms 'health', 'viability' and 'evolutionary fitness' where these meanings are intended, and referring to 'welfare' only where the quality of consciously, subjectively, experienced feelings (eg pain, fear, warmth, pleasure) is at issue. This is our approach here. That is most definitely not to say that health is irrelevant to welfare; injuries and illness very often result in very unpleasant feelings and are typically very major threats to good welfare – but not all diseases cause welfare problems. There are some that seriously compromise health and evolutionary fitness (for example, by causing infertility) but which are not associated with pain, fear or other unpleasant feelings. Such diseases are certainly serious from the point of view of health and evolutionary fitness, but they are not welfare problems.

Assessment of the welfare status of animals is difficult because feelings cannot be measured directly but can only be inferred based on our knowledge of the biology of the animal, its physical state and behaviour, and in the light of our own experiences of pleasant and unpleasant feelings.

We make inferences about how other humans feel all the time but, in this case, whilst we cannot be certain that sensory stimuli and emotive thoughts feel the same to us as they do to other people, the fact that we share the same brain design and that their verbal reports are often consistent with our own experiences, makes this a very reasonable assumption. Piscine, amphibian, reptilian, avian and mammalian brains have evolved along separate paths for a very long time (our last common ancestor with birds, for example, was a primitive reptile that lived over 300 million years ago) and there is great variation in brain size and structure among the vertebrates. There have been remarkable advances in knowledge of the specific brain regions, and the circuitry, involved in the generation of feelings in humans, and also regarding the capacities for feelings that may be lost when specific brain regions areas are damaged (eg Damasio, 1999; 2003). However, although this knowledge offers a basis for inferences about feelings in closely related animals; speculation about the nature of feelings in more and more distantly related species becomes increasingly tenuous.

In short, we cannot know how other animals feel - how it feels to be a dog, a cat, a canary or a corn snake - we can only make inferences about this based on our assessment of their physical state and behaviour, taking into account our knowledge of their neural capacities and in the light of our own experiences. In view of these obvious difficulties, it is appropriate to be cautious in making such inferences.

4.2   Approaches to welfare assessment

Making inferences about how animals feel (which is what an assessment of welfare ultimately seeks to address), involves two distinct steps. The first involves making a comprehensive scientific description of the factors that may impact upon the animal's

welfare: its state of biology, health and behaviour. The second stage involves making a judgement about the possible impact of these measurable parameters on how the animal feels (Kirkwood et al, 1994). The first step deals with objectively measurable parameters; the second involves making a subjective judgment. The subjectivity cannot be avoided but the problems associated with this can be minimised by making the bases for the judgements as explicit as possible (see Table 4.1).

This process involves detailed knowledge of the clinical and pathological effects of the feature under scrutiny and an assessment of its impact on the animal's feelings based on observations and knowledge of their impact on its behaviour, the likelihood that its nervous system can sustain conscious aware states relating to the challenges observed (there may be differences between taxa in this: Kirkwood, 2006), and in the light of how similar conditions feel to humans.

There has been considerable recent interest in the assessment of welfare of genetically altered laboratory animals (those altered by either biotechnological or traditional selective breeding methods). Reports on this subject have been produced by the Animal Procedures Committee (2001) and by the NC3RS GM Mouse Welfare Assessment Working Group (2004).

4.3   Conclusions

Conclusion 7. Some of the heritable diseases or characteristics of companion animals that have adverse welfare impacts affect large numbers of animals and have the potential to cause, depending in their nature, severe pain, discomfort, anxiety or other unpleasant feelings for prolonged periods or significant proportions of the animals' lives.

Table 4.1. Breed traits or defects, their physical consequences and their inferred impact on welfare. These examples are provided to illustrate how inferences about welfare impact may be made.

Feature	Effects	Inferred impact on welfare
Foetal/pelvic size disproportion in dogs	Dystocia – narrowness of the birth canal slows or prevents birth.	Pain, exhaustion and complications at parturition.
Hip dysplasia in dogs	Joint instability, degenerative joint disease, arthritis.	Chronic pain which may be severe, possible frustration due to compromised locomotion
Giant size in dogs	Predisposition to osteosarcoma	Severe bone pain over weeks to months.
Lip folds in St Bernard dogs	Lip fold pyoderma (Gough & Thomas, 2004)	Chronic skin irritation, discomfort, and pain.
Brachycephalic Airway Obstruction Syndrome (BAOS) eg Bulldogs and Cavalier King Charles Spaniels	Respiratory problems including laboured breathing and snoring (Lorinson et al, 1997; Panckeri et al, 1996).	Discomfort due to frequent, persistent, difficulty in breathing.
Syringomyelia in Cavalier King Charles Spaniels	Disruption to normal flow of cerebro-spinal fluid with associated formation of fluid filled cavities within the spinal cord (Rusbridge and Knowler, 2005; Appendix 7)	Chronic and severe head and neck pain, loss of mobility
Polydactyly in Maine Coons	Additional digits on paws.	No apparent effects on physical health or behaviour.
Eye shape in Siamese cats	Glaucoma (Gough & Thomas, 2004)	Pain, progressive loss of vision with associated risk of trauma.
Manx cats	May lack coccygeal vertebrae (Vella et al, 2002) and associated rump fold intertrigo, megacolon, constipation and rectal prolapse (Gough & Thomas, 2004). Abnormal gait (Robinson, 1991b).	Discomfort and pain associated with these complications

Oranda goldfish 'Hood' – fleshy growth on top and sides of head	Debris, bacteria and fungi may settle in the folds of the growth and cause infection (Ostrow, 1995)	Potential for chronic irritation and pain
Baldness in Sphynx cat or Chinese Crested (Hairless) dog	Increased likelihood of skin trauma (GCCF, 2002).	Increased likelihood of skin inflammation and/or infection, sunburn (pain), carcinomas, and climatic discomfort in cold weather.
White coat colour in cats	Predisposition to squamous cell carcinoma	Associated pain and malaise.
Blue plumage in budgerigars	No apparent effects on physical state or behaviour	None detected yet.
Lethal white overo syndrome from breeding two overo paints (colour breeds of horses)	Atresia coli (closure of lumen of the colon)	Gut blockage, leads to pain, weakness and death (Jones & Bogart, 1971)
Abnormal fearfulness and anxiety in Burmese cats	Tendency to fear at greater intensity and/or triggered at a lower threshold of stimulation than normal.	Frequent intense fear (an unpleasant aversive experience)
Tumbling in pigeons	Tumbling in flight	If extreme (as in Darwin's house-tumblers) would be likely to interfere with normal foraging and lead to welfare problems associated with this

5. The impact of selection/genetic modification on physical health, behaviour and welfare

5.1 Introduction

All aspects of the biology of wild animals are the result of the constant intense scrutiny of natural selection throughout their evolution. Their design and behaviour is that which has conferred maximum fitness for the environments in which they have evolved. Deviations from this design, in any aspect, are far more likely to render them less fit than more so (although, of course, evolution operates by 'seizing' changes that increase fitness).

In the domestic/captive environment, in which animals are not subject to the full rigours of natural selection but are cared for by their owners, individuals can survive and thrive even when they have been changed dramatically through artificial selection away from their original (natural) form. Genetic changes that might compromise their welfare in the wild may have no adverse effect in captivity. For example, although a very pale coloured corn snake may be less likely to thrive in the wild than one of a typical wild colour (because, of the greater likelihood it would be seen and attacked by a predator) its welfare may not necessarily be compromised in captivity where it is protected from predation. Nevertheless, it is difficult to know, when selecting for particular features, what the welfare consequences might be. Selecting for white plumage in canaries, has, for example, resulted in physiological changes (see Section 5.3.1) that go far beyond this particular characteristic, and which do undoubtedly put the welfare of the birds at risk (Wolf et al, 2000).

There is a general risk that, in this way, breeding away from the wild type can de-couple evolutionary fitness (ability to reproduce successfully) from welfare, such that, whilst the strains produced may be entirely viable, their quality of life may be poor (see Box 5.1). Accordingly, it would seem to be appropriate for much greater caution to be exercised when undertaking selective breeding than currently seems to be the case.

Box 5.1 Coupling of fitness and welfare in natural and artificial selection (Kirkwood, 2005)

In the wild, selection for evolutionary fitness and good welfare tend to go hand-in-hand. It is plausible that pleasant and unpleasant feelings are carrots and sticks that arose to help prompt the behaviours found by evolution to be successful in this or that circumstance. We feel bad when our evolutionary fitness is under threat and, conversely, actions that improve fitness from the evolutionary perspective, feel good. We suppose this system guides other animals too. Thus, as argued by Duncan & Petherick (1991), an animal's welfare is largely about its wants and if these - its cognitive needs - are met, physical health will generally be safeguarded. (However, we should note in passing that the system easily breaks down when animals are in an environment other than that in which they evolved and in which there are harms they have no sensory equipment to detect or which have not become labelled to them, through natural selection, as aversive.)

In contrast, in our domesticated animals or any of the other animals that we manage, there is very much less evolutionary pressure for good welfare and evolutionary fitness (the production of viable offspring) to remain coupled. The survival and breeding of these animals have been under human control and characters have often been selected for without any awareness or regard for their possible impact on welfare – on how the animals feel. Welfare problems can arise in two ways in these circumstances: (i) by resulting in predisposition to, for example, painful conditions such as lameness or infectious diseases, or (ii) through altering the sensitivity of the affect systems (the mechanisms that generate reward/pleasant and punishment/unpleasant feelings) such that, for example, animals experience aversive feelings (such as fear) more intensely or more frequently than appropriate. Controlled breeding has, in these ways, huge potential to affect welfare positively or negatively. Although this is independent of the technology involved – whether traditional selection for particular traits or use of modern biotechnology – it is concerns about the latter that have especially prompted some recent reviews (eg APC, 2001; AEBC, 2002; FAWC, 2004).

The following sections highlight some of the potential problems associated with artificial selection and breeding. However, before moving on to this, a few general comments are relevant here. Hybridisation, back-crossing and inbreeding may all occur at times under natural selection and may have played parts in the adaptation of populations to their environments. They do not necessarily have harmful effects, indeed they can be beneficial under some circumstances, but, as mentioned above, their welfare consequences may often be more likely to be adverse than beneficial.

It has been suggested to us that selection for particular colour morphs of birds may have an indirect welfare benefit, as such morphs '… *are highly valued which ensures the ultimate care*'. However, there may be an implicit danger in this view in that those that do not fall within current breed optima may be less valued. It has also been suggested to us (by another respondent) that the breeding of colour morphs may, through helping to stimulate and maintain interest in aviculture, prove to be beneficial for species conservation in the long run, if the wild populations should come to be lost in the future through anthropogenic changes to the environment.

5.2   Inbreeding

The development of breeds typically involves a degree of inbreeding because it is initially based upon breeding from a relatively small subset of animals from the ancestral population and may then involve back-crossing or sib-matings to fix the desired characters in the development of a true-breeding line (see Section 3).

As the degree of inbreeding increases so to does the effect of inbreeding depression. Inbreeding depression is the collective term for a suite of effects that can be deleterious to biological fitness including loss of fertility, reduced birth weight and litter size, reduced neonate size, and increased risk and severity of various diseases (Vella et al, 2002). This loss of vigour is due to the cumulative effects of increasing homozygosity for a large number of genes. Although some of these effects do not

impact upon welfare (animals will not, for example, suffer through impaired fertility), others do. Anything that increases susceptibility to clinically apparent infectious disease, for example, presents a threat to welfare as infectious diseases can cause malaise, discomfort and pain.

5.3   Selection for characters that may have a direct impact on welfare

Selection for some characters may have a direct impact on welfare. It seems unlikely that anyone would deliberately select for features *because* they cause pain or other unpleasant feelings, but there seem to be many examples of selection of features that increase the likelihood of such problems. A variety of examples are listed below (see also Table 4.1)

5.3.1   Morphology and colour (selection for morphological or colour traits which may have an impact on welfare)

Where the design of structures, such as tails and ears, used for communication are altered through artificial slection, as with taillessness in cats and pendulous ears in dogs and lop-eared rabbits, capacities for normal social interactions with conspecifics may be compromised with deleterious welfare consequences.

Veiltail goldfish are considered by some goldfish fanciers to be 'one of the most beautiful strains, … also one of the weakest', the latter because the fins are delicate and at risk of injury and infection (Ostrow, 1995). In this case, it would seem that it is the feature that is selected for – the delicateness of the tail - that results in the welfare risk.

The Water-Bubble Eye goldfish has been selected for upturned eyes surrounded by very large fluid-distended periorbital skin sacs, which at maturity obscure vision and hamper swimming (Ostrow, 1995; Whitaker, 2001). This variety may also lack a dorsal fin and have a double tail fin. Because the eye sacs can rupture easily, leading to pain and infection, it is recommended by aquaculturalists that there should be no sharp objects in their aquaria (Ostrow, 1995).

The telescope form of the eyes of the telescope goldfish are inherited as a recessive trait and begin to protrude from the head at six months of age until they extend as much as 2cm from the head in adults (Ostrow, 1995; Yanong, 2001). These protruding eyes may be at greater risk of damage through trauma.

Many species have been selected for long-haired forms, for example, Lhasa Apso dogs, Persian cats, and Peruvian guinea pigs. The hair of Angora rabbits can be up to 15 cm long (Sandford, 1996) and, without regular and meticulous grooming these animals are at risk of bacterial infections and fly strike. Long-hair can also directly affect welfare by compromising sight and mobility or through knock-on effects on their behaviour and ability to communicate (eg by raising hackles) with conspecifics (McGreevy and Nicholas, 1999).

Selection for hairlessness, on the other hand, puts animals at risk of cold stress and, particularly if they have pale skin, sunburn.

In many cases there is no evidence that selection for particular colour morphs has had an impact on welfare. However, examples are known in which selection for colour can have direct welfare consequences. For example, white cats are predisposed to squamous cell carcinoma of the ears (because the absence of pigmentation puts skin at greater risk of damage by solar radiation), and it has been shown that white canaries are unable to utilise β carotene and are therefore predisposed to vitamin A deficiency (which may lead to disease) unless high levels of dietary supplementation with retinol are given (Wolf et al. 2000).

Crested and other fancy canaries selected for unnatural feather forms are predisposed, as a direct result, to the development of feather cysts (Alderton, 1992; David, 1987a). CAWC has noted previously (CAWC, 2003) that it seems quite possible that bizarre feather types such as those of the Parisian frilled canary have the effect of compromising normal feather function in both flight and thermoregulation.

5.3.2   Behaviour

Animals selected for tameness (decreased responsiveness to fearful stimuli, decreased flight distance, etc) may be less likely to have aversive feelings in a captive environment. In this case, their welfare may be improved compared with their more nervous ancestors. However, care needs to be taken not to misattribute the basis of decreased responsiveness; there is the danger that it could be the result not of increased tameness, but of factors that have adverse welfare consequences such as, for example, deafness, poor sight, or reluctance to move because of pain or malaise.

The Boyd Group (a discussion group in the UK that addresses ethical issues relating to the use of animals in scientific procedures) highlighted the '*insidious*' nature of selective breeding, noting that '*the gradual nature of these changes can also lead society to accept features – in some breeds of pet, for instance – which would generally be considered unacceptable if introduced by genetic modification*' (Boyd Group, 1999).

For example, animals that have been selected for docility may be easy to control, and make convenient pets, because their thresholds for activity have been raised (which may possibly be beneficial for their welfare) or because they are chronically depressed (which is by definition bad for welfare). Such diametrically opposed mechanisms may not be easily distinguished either by behavioural or physiological approaches. Artificial selection for behaviour appears to result in the disruption of previously adaptive 'suites' of behaviour, such that the animals affected can no longer function without constant intervention from man.

A guard dog might (hypothetically) be completely effective as far as its owner was concerned, even if its aggression was motivated entirely by fear and therefore associated with episodes of acutely diminished welfare. Barnard & Hurst (1996) have concluded that 'the use of artificial selection to manipulate traits, especially behaviour, thus has alarming possibilities for the invisible subjective experiences of the organisms in question'.

Evidence is accumulating that, despite the best intentions of the majority of owners, many pets experience diminished welfare for a significant amount of their lives

(Appleby et al, 2002; Bradshaw et al, 2002; Casey, 2001), largely stemming from fear or anxiety. It is not possible to estimate the precise contribution of selective breeding towards such an apparent epidemic, but dissociations between behaviour and its original functions, as described above, must logically play a large part.

There are behavioural differences between breeds of dogs. These differences must, therefore, have a genetic basis. Bradshaw et al (1996), in a study of 49 breeds, assigned each of these to one of 8 categories based on measures of aggressiveness, reactivity and immaturity, as shown below (Table 5.1).

Table 5.1   Categorisation of 49 breeds of dogs on the basis of assessment of their aggressivity, reactivity and behavioural immaturity (from Bradshaw et al, 1996).

Group	Characteristics	Breeds
A	High aggressivity, average reactivity, low immaturity	Rottweiler, German shepherd, bull terrier
B	High aggressivity, average reactivity, high immaturity	Jack Russell, corgi, cocker spaniel, West Highland terrier, Cairn terrier, fox terrier, border collie
C	Average aggressivity, low reactivity, low immaturity	British bulldog, chow, great Dane, Airedale
D	Average aggressivity, high reactivity, low immaturity	Toy poodle, Yorkshire terrier, Chihuahua, miniature poodle, Papillion, miniature dachshund, Pekingese, lhasa apso, Pomeranian, shih tzu, standard dachshund,
E	Low aggressivity, average reactivity, high immaturity	English setter, Irish setter, springer spaniel, golden retriever, Dalmatian, Labrador, boxer
F	Low aggressivity, low reactivity, low immaturity	Greyhound, bassett hound, whippet, English pointer
G	Low aggressivity, high reactivity, low immaturity	King Charles spaniel, Cavalier King Charles spaniel, Shetland sheepdog
H	Average aggressivity, average reactivity, average immaturity	Samoyed, standard poodle, rough collie, Old English sheepdog, miniature schnauzer, border terrier, beagle, Staffordshire bull terrier, Scottish terrier

The extent to which these behavioural differences may have a direct effect on the quality of the lives of the animals is unclear, but they can certainly have indirect effects because of the impact they may have on the way the animal is kept (through mismanagement or lack of provision for psychological needs).

There are also genetic predispositions to fear or confidence (Willis, 1995; McCune, 1995) and there is an inherited component to the rage syndrome/episodic dyscontrol of cocker spaniels (Podberscek and Serpell, 1998).

Border collie dogs having been bred for working are said to have 'an inborn instinct to work…not content to sit at home by the hearth all day' (The Kennel Club, 1998). Their welfare may be compromised if they are unable to meet their behavioural need for high levels of activity.

Ragdoll cats are reported to have a very relaxed, unreactive demeanour and it has been suggested that this could have adverse welfare consequences if it reduces the ability of the cats to avoid dangers such as traffic.

5.4   Selection of features that can lead indirectly to adverse welfare consequences

Selection for one trait often leads to correlated changes in a suite of other characters and there is the possibility, therefore, that welfare problems may arise through these correlated changes.

5.4.1   Increased or decreased body size

For example, many other aspects of the biology of the dog have been altered in association with body size differences brought about through selection for larger and smaller size (Kirkwood, 1985). For example, as adult bodyweight increases between breeds of dogs:

- brain size becomes relatively smaller
- litter size tends to increase
- resting heart rate tends to decrease
- pup size becomes relatively smaller (whilst there is a 35-fold weight range in mean adult weight across dog breeds, there is only a 7-fold weight range in pups)
- incidence of osteosarcoma increases.

Among breeds of dogs, as adult size decreases, the dimensions of both the pelvic outlet of the adult female and of full-term pups' heads decrease, but the latter decrease less (as the pups of small breeds stay relatively longer, for their size, in the womb and are therefore relatively bigger at birth) than the dimensions of the pelvic outlet such that dystocia due to foetal oversize would seem increasingly unavoidable in pursuit of further adult size reductions (Kirkwood, 1985).

On the other hand, some features that show a correlated increase with bodyweight between species do not show a corresponding correlation with increasing size among breeds of dogs. The most notable example of this is gestation period, which is close to 63 days for all breeds. This is a comparatively long period for mammals equal in size to the smallest breeds and a comparatively short period for mammals equal in size to the largest. This, and the variation in litter size, may partly explain why the puppies of smaller breeds are relatively larger at birth (because their metabolic rates are higher, they effectively have more metabolic time in which to grow prior to birth), and why they are more predisposed to birth difficulties.

5.4.2   Selection for specific face shapes

Selection for specific face shapes in dogs has lead to associated welfare problems. For example, resulting facial skin folds in Shar Pei, St Bernard, Pug, and Pekingese, predispose to bacterial dermatitis (Gough & Thomas, 2004). Some of the breeds with head shapes characterised by short faces and wide muzzles can have laboured breathing or suffer prolapsed soft palates (Robinson, 1990). Similarly short-nosed White and short-nosed Cream guinea pigs may have such distorted bone structure that 'they will be heard wheezing and gurgling from the nose and the throat' (Elward, 1987). Many dog breeds suffer from ocular problems as a result of selection for particular eye and eyelid shapes (Robinson, 1990). The high incidence of syringomyelia in Cavalier King Charles spaniels is thought to be related to skull morphology (Rusbridge & Knowler, 2005).

5.5   Welfare problems attributable to the inadvertent concentration of harmful alleles during selection and breed development.

There are over 400 canine diseases that are either known to be inherited or in which inheritance is thought to play a part (AHT, 2004; see also the Online Mendelian Inheritance in Animals website – http://www.angis.org.au/Databasess/BIRX/omia/). Many of these diseases have an adverse effect on the welfare of the affected animals. (At least 10 times as many heritable diseases have been described in humans.) The majority are the result of recessive mutations in particular genes. Fewer are known in cats but there is still a considerable list (Gough and Thomas, 2004) and Steiger (2005) have provided recent overviews of welfare problems associated with some of these.

Some specific examples, mainly involving dogs and cats, are given below.

Although hip dysplasia (in which the head of the femur does not correctly fit with the socket of the hip bone) can occur in any dog, it is most often observed in the large-sized breeds (Robinson, 1990). In this condition, the hips become unstable and progressively degenerate, causing arthritis and pain (Gough and Thomas, 2004). The condition may be inherited in different ways in different breeds but is generally regarded to be polygenic (Jackson, 1994). Environmental factors also have a very important role to play in the development and severity of the disease.

Selection to breed standards in the development of some English Cocker Spaniels has resulted in genetic predisposition to higher levels of aggression. Selection resulting in aggression can have an adverse impact on the welfare of affected animals because of the way they have to be housed, restrained and handled.

Collie eye anomaly is a recessive disorder that has been shown in the past to affect 80% to 90% of dogs classified as collie breeds in surveys (Jackson, 1994; Robinson, 1990). In the only survey undertaken in this country it was found that the incidences in the Sheltie and the Rough Collie were 72% and 64% respectively, although only 5-6% of the affected animals have resulting sight difficulties or blindness (Peter Bedford, personal communication). The disease affects the development of the back of the eye and varies in its severity and effects (Robinson, 1990). It has been hypothesised that selection for the long narrow skull shape (body structure) or the

merle colouration gene (attribute) may have led to the development of the problem (Robinson, 1990).

Golden Retriever dogs are predisposed to sex-linked muscular dystrophy, the gene for which is carried on the X chromosome (Gough and Thomas, 2004).

Bassett Hounds are particularly susceptible to canine distemper (caused by a morbillivirus infection) because of a sex-linked characteristic that resists the immunity provided by a vaccine, causing many male puppies to suffer and be at increased risk of dying from the virus (Jackson, 1994).

Rabbits are increasingly susceptible to malocclusion of the teeth, most commonly of the incisors. Whilst many cases are due to nutritional mismanagement, there also appears to be an inherited aspect due to a recessive gene (Sandford, 1996).

5.6   Selection for features that appear to have no impact on welfare

Many characters, such as atypical pelage colours, may have no impact on how the animals' feel and on whether or not they suffer. However, because in many cases, a change in one character leads to correlated changes in others also, and the results of these may not be readily apparent, caution needs to be exercised in assuming that there are no adverse welfare consequences. It is important to remain vigilant for these possibilities.

5.7   Conclusions

Conclusion 8. Unless it is specifically aimed at better adapting an animal to its domesticated/captive environment, any breeding away from the wild type is much more likely to have adverse impacts on fitness and welfare than beneficial ones.

Conclusion 9. (See Section 5.7) Selective breeding for particular traits may lead to adverse welfare consequences in several ways: (i) because the trait itself has some adverse impact on welfare, (ii) because selecting for the trait has accompanying phenotypic effects that affect welfare, and (iii) through inbreeding effects including the accumulation of harmful recessive alleles.

Conclusion 10. It is not easy to foresee the welfare impact of selection for various traits but adverse impacts have already occurred in various species through selection for a diverse range of traits, including aspects of colour, fur and feather type, size, conformation and behaviour.

Recommendation 1. Research should be undertaken to elucidate the welfare impacts of morphological and behavioural changes brought about through selective breeding for particular traits in a wide range of taxa.

Such studies would be likely to present considerable scientific challenges and we do not propose to suggest detailed approaches here. However, it would seem likely that assessment of welfare impacts of phenotypic changes could be explored through comparisons of behaviour, disease incidence, aspects of physiology such as food intake, reproductive rate and lifespan, and immunological indices. For example, do

birds of breeds selected for abnormal plumage spend more time preening, shiver more or consume more food, have shorter lifespans or higher prevalence of infectious diseases than relatives whose plumage more closely resembles the ancestral state?

6.   The scale of the problem

There are many animal welfare problems in the world and it makes sense to direct the resources available for tackling these, towards the most important ones first. In developing a strategic approach to dealing with animal welfare problems it is therefore helpful to make assessments about their relative importance and, of course, also to take into account the likelihood or not that practical solutions can be found (there is no point wasting efforts where there is no realistic prospect of success).

In judging the relative importance of animal welfare problems it is logical to consider:

- the severity of the impact on affected animals, ie the intensity of pain, fear or other unpleasant feelings caused (see Section 4),

- the duration of the period in which the animal is likely to be exposed to these unpleasant feelings, and

- the number of animals affected

Difficult judgements remain to be made when using this approach. For example: should a condition causing mild but prolonged discomfort to a very large number of animals be ranked as more important than one that causes brief but more intense pain to a few? Nevertheless, it does offer a useful method for helping to reach judgements about relative importance.

It is way beyond the scope of this Report to undertake a detailed review of the relative welfare impact of the very many known genetic diseases of dogs, cats and other companion animals (and we suggest, later, that this is an area in which research is needed). However, we can offer some points that may be helpful in providing a context for judging the scale of the welfare importance of genetic diseases in companion animals.

As we have seen, very many genetic diseases have been recognised in companion animals. Some of these that are known to cause severe pain occur commonly in breeds that are kept in large numbers. For example, syringomyelia (which causes chronic head and neck pain which can be severe in a proportion of affected animals – see Table 4.1) is thought to occur in over 50% of Cavalier King Charles Spaniels and this is the most popular of the toy breeds kept in the UK. Likewise, hip dysplasia (which can lead to arthritis and chronic joint pain) occurs commonly in dogs of breeds that are kept in large numbers in the UK and elsewhere in the world.

Judged in terms of the intensity of unpleasant feelings caused, the durations of the periods for which animals are affected, and the number of animals affected, it is likely that the anthropogenic welfare problems of companion animals stemming from their breeding histories would be likely to be found to be of a very much greater scale than many other animal welfare *causes celèbres*.

Procedures that may cause distress, pain or lasting harm to animals that are undertaken for scientific purposes cannot be undertaken except under licence and under strict control within the Animals (Scientific Procedures) Act 1986 (many other

countries have comparable legislation). Although the selection and breeding of companion animals is not for scientific purposes, there is something inherently experimental about it, in that the physical and behavioural characters of the offspring cannot be predicted exactly. Furthermore, it can, as we have seen, lead to distress, pain and lasting harm.

However, in contrast to society's concern for strict welfare regulation of animals in scientific procedures, it seems, by comparison, that an almost unquestioning acceptance has prevailed regarding the selection and breeding of companion animals for arbitrary traits. Although it is clear that efforts are increasingly being made to address some existing problems and that scientific research in this area is providing new tools that are likely to assist greatly in tackling some problems in the future, there still seems rather little evidence of general awareness of the welfare risks and of the need for caution in pursuit of novel forms or of forms that approach ever more closely to arbitrary human ideals.

7. Efforts to prevent welfare problems arising through selective breeding and to tackle existing problems through breeding programmes / genetic modification

7.1   Introduction

A growing number of programmes have been initiated to tackle genetic problems that affect the health and/or welfare of companion animals. Amongst the earliest were schemes to reduce the incidence of hip dysplasia in dogs.

7.2   Prevention and amelioration of inbreeding

As outlined in Section 5, the development of breeds often involves the mating of closely-related animals and inbreeding effects can occur. Inbreeding depression can be prevented by avoiding inbreeding and can be corrected by breeding with more distantly related animals (within or without the breed). Various methods for doing this whilst trying to preserve the characteristics as defined by the breed standard have been developed (Vella et al, 2002; Robinson, 1991b). These include outbreeding and cross-breeding as outlined below

7.2.1   Outbreeding

Outbreeding (or outcrossing) is the pairing of very distantly related individuals. If a breed is numerically large and the levels of background inbreeding and current inbreeding are low, mating between distantly-related individuals within the breed may result in heterosis (the opposite effect of inbreeding depression) and improved vigour (Vella et al, 2002). However, because most breeds are developed from few founder individuals, there is often little genetic variation between even distantly related individuals within the breed and thus relatively little prospect for marked increase in vigour. The breeding strategy to develop or preserve certain breed characteristics is often in conflict with the optimum strategy for fitness.

7.2.2   Cross-breeding

Cross-breeding, the mating of individuals of different breeds can result in 'hybrid vigour' or heterosis in the offspring and alleviate inherited defects or inbreeding depression. Backcrossing the offspring with healthy individuals of the original breed is a way of improving the health of the breed which preserving characteristic traits as far as possible (McGreevy & Nicholas, 1999).

For example, it was suggested that unregistered Jack Russell terriers could be crossbred with white working Lakeland terriers to help combat hereditary problems due to stumpy legs in the Jack Russells. Breed rules prevented such crossbreeding of recognised Parson Jack Russell terriers (Jackson, 1994). Most recognised breeds of dog and cat have closed stud books and breeding with unregistered animals of the same breed, registered animals of a different breed or animals of unknown heritage or mongrels is not permitted.

Some breeds however are permitted a little more freedom. For example, interbreeding among long and short-haired chihuahuas and among bull terriers and miniature bull

terriers is permitted by the Kennel Club (Jackson, 1994). The Malinois, Tervueren, Groenendael and Laekenois dog breeds were combined as 'Belgian shepherd dogs' by The Kennel Club, apparently to promote cross-breeding among these four variants although there was some opposition by breeders (Jackson, 1994; The Kennel Club, 1998).

In some cases there are differences of opinion between registries about the permissibility of cross-breeding. Some cat registries permit cross breeding in certain breeds while others do not. Where crosses are approved there may be limits as to which breeds can be crossed, limits on which colour morphs or hair lengths of the chosen breed are deemed suitable for crossing, and a specified time frame within which such a cross must be made (Vella et al, 2002). For example, the Cat Fanciers Association (CFA) does not permit the crossing of Manx cats with any other breeds, but the Fédération Internationale Féline d'Europe (FIFé) does allow crosses between manx and others (Vella et al, 2002). The International Cat Association (TICA) does not permit the crossing of munchkin cats with any other breeds (although this may be designed to protect other breeds rather than to protect the munchkin itself (Fogle, 1997). Ragdoll, Turkish Van, and Maine Coon cats are not permitted by either CFA or FIFé to be crossed with any other breed (Vella et al, 2002).

Modern genetic technology permits analyses of breed genomes so that their history and relatedness can be unscrambled (see Parker et al, 2004). This will be advantageous in moves to improve health through cross-breeding without compromising breed features (Sampson, 2004).

Among horse breeds, some stud books are closed (eg Arab) so that cross-breeding is not permitted whilst others are open (Edwards, 1993). The Icelandic horse has not been crossbred for 1000 years (Edwards, 1993).

7.3   Weeding out harmful alleles

Tackling genetic diseases requires the identification of affected and carrier animals and either their exclusion, or their careful use only, in breeding programmes.

Breeders may use hard or soft selection when deciding which animals should continue breeding. In hard selection any individual with the problematic trait, regardless of the degree of severity, is completely rejected from the breeding program. In soft selection, the decision whether or not to reject takes into account the degree of severity and takes into account also other indicators of the quality of the animal (Vella et al, 2002). The decisions become difficult when individuals exhibit both highly desirable and highly undesirable features.

It is often not simple or easy to breed out inherited diseases. Rapid selection against a particular inherited disease can lead to other serious consequences. For example in the United States, an attempt to eradicate retinal dysplasia led to a greatly enhanced incidence of the potentially fatal inherited disease of liver copper toxicosis (seen in Bedlington and West Highland White Terriers (Robinson, 1991a)). The Guide Dogs for the Blind also found that focusing their breeding programme to reduce the incidence of hip dysplasia tended to have an adverse effect on temperament.

The initial selection of individuals for the founding population of a breed should be scrupulously investigated and checked to minimise the risk of perpetuation or concentration of harmful genes. However, in some cases, it may be many generations before a problem becomes apparent, at which point there may be greater difficulties in trying to overcome the problem (Vella et al, 2002).

Once an anomaly is detected it is important to try to determine its mode of inheritance so that appropriate control measures can be put in place. Some inherited diseases are caused by one gene (monogenic) that may be dominant or recessive, and some are the result of the effects of several genes (polygenic). In the latter cases, the trait may vary in severity between individuals because of interactive effects of the genes.

With dominant monogenic inheritance, it is theoretically relatively easy to eliminate individuals carrying one or both of these alleles from the breeding population, as both heterozygotes and homozygotes will express the diseased phenotype. However age of onset is clearly an important factor. Diseases that emerge later in life after breeding age has been reached, are harder to deal with than those that are apparent from a very early age.

Another factor confounding the elimination of simple dominant diseases is the occurrence of incomplete penetrance. This is the phenomenon whereby an individual with a copy of the dominant mutated gene does not display disease signs and is apparently normal. It is thought that the lack of penetrance of the disease may be caused by other genes that modify the phenotype, or by the absence of environmental triggers. These individuals can have offspring which do display the disease phenotype if they inherit the disease mutation.

In the case of recessive monogenic inheritance, homozygotes may be relatively easily picked out and prevented from breeding (providing the trait is apparent prior to breeding age). Detecting carriers (heterozygotes) of the disease is more difficult. In the past, the only way to identify heterozygotes was by test mating suspected carriers with affected animals (homozygous for the condition). In these circumstances, if any offspring show the trait, the test animal must therefore have been heterozygous. Increasingly, modern genetic methods can be used to detect carriers of deleterious genes (Vella et al, 2002).

Dealing with polygenic diseases is more difficult. It may not be reasonable or possible to aim to eliminate all the genes involved as some of them may have important roles for health and welfare. Various cardiovascular defects in dogs: patent ductus arteriosus, persistent right aortic arch, pulmonic stenosis, and subaortic stenosis have a polygenic aetiology (Robinson, 1991a).

7.4   Detecting carriers

Endeavours to tackle diseases associated with mutant alleles can be greatly facilitated if tests are available to identify carriers. The development of such tests depends upon identifying the mutant allele. In some cases it may be possible to test for the presence of the mutant allele itself, in other cases, it is more feasible to test for DNA 'markers' (genes for which there are exisiting identification tests) that are known to reside close on the same chromosome as the mutant allele. In such circumstances, the DNA

marker will usually be inherited with the mutant allele so that detection of the marker is very good evidence that the mutant allele will be present also.

One of the first commercially available DNA screening tests was for canine leucocyte adhesion deficiency (CLAD) in Irish setters. CLAD is an inherited disease in which neutrophil abnormalities result in severe and recurrent bacterial infections. Direct tests for the presence of mutant genes are available for various other diseases including narcolepsy in dobermans and dachshunds (Kennel Club, 2004b). DNA Marker tests are available for narcolepsy, haemophilia B, muscular dystrophy (Duchenne and Becker types) and Wilson disease (copper toxicosis) in dogs (McGreevy & Nicholas, 1999).

Worldwide there are around 40 different DNA tests for breed specific-inherited diseases of dogs. However, due largely to restrictions imposed by patenting issues in the USA, only about 10 of these are available to the dog breeding community in the UK. These tests are very valuable because they allow precise genotyping of an individual dog for a particular inherited condition. The cost of these tests is typically about £30-£100 per sample. Because they detect the offending DNA itself they can be used to screen young animals that may not show clinical signs until much later in life. Small blood samples are required.

Increasingly rapid progress is being made in the detection of the genes responsible for various defects because, in many cases, advances in understanding the roles and locations of genes in one species (and there is a great deal of work of this kind being undertaken in laboratory animals and humans) can help greatly in searches for the location of comparable genes in other species. For example, determination of the location of the gene for progressive retinal atrophy (PRA) in the Irish Setter breed of dog was facilitated by knowledge of its location in other species (The Kennel Club, 2004a). New DNA tests are emerging rapidly and almost certainly there will be a much greater range available in the future. This will enable breeders to select parent stock taking into account the results of breed-specific DNA tests for various mutant alleles that cause breed-specific inherited diseases.

Increasingly rapid progress is being made in the detection of the gene mutations responsible for various defects because, in many cases advances in understanding the roles and locations of genes in one species informs searches for comparable genes in other species. Rapid progress in whole genome sequencing of the human and mouse genomes were important in the identification of many canine and feline disease mutations, and increasingly genome sequences are being derived for the most popular companion animal species. The dog genome has been sequenced recently (Lindblad-Toh et al, 2005) and plans are in place to derive extensive cat genome sequence in the near future. These developments are expected to accelerate the identification of disease mutations in these species.

7.5   Screening schemes and how they are used

Some examples of screening and breed improvement programmes for pedigree cats and dogs are outlined below.

7.5.1   Screening programmes for dogs

The British Veterinary Association, the Kennel Club and the International Sheep Dog Society (BVA/KC/ISDS) run a number of schemes aimed at eliminating or reducing the prevalence of a variety of diseases in pedigree dogs. Some examples are outlined below.

(i)   Eye disease

The BVA/KC/ISDS Eye Scheme was set up to reduce the frequency of inherited eye disease (excluding eyelid and lacrimal abnormalities) by screening dogs for these conditions prior to breeding. The scheme presently tackles ten types of ocular disease in the UK. There are comparable schemes in other countries, for example, the Canine Eye Registration Foundation (CERF) in the USA (Gough & Thomas, 2004).

(ii)   Hip dysplasia

Hip dysplasia (see Section 5.5) is inherited polygenically with heritability ranging between 0.17 and 0.6 (Leppänen & Saloniemi, 1999). It can be detected by examination of radiographs (AHT, 2004) or by manipulation to assess joint laxity, and many countries have screening programmes based on radiography. Despite the use of screening to inform breeding programmes, progress in reducing the prevalence has not been consistent. In one study, evidence was found that the prevalence had significantly increased in boxers, Dobermans, German Shepherd dogs and rough collies between 1988 and 1995 and that the prevalence in other breeds had not changed (Leppänen & Saloniemi, 1999). There are several difficulties. These include consistency of detection and lack of enforcement but also that the disease is simply difficult to tackle because of its polygenic nature and because environmental factors influence the degree to which the dysplasia occurs. Some have expressed caution that an overly aggressive approach to breed the problem out could, through leading to the emergence of other problems, have a net detrimental effect (Bouw, 1982 in Leppänen & Saloniemi, 1999).

(iii)   Elbow dysplasia

There are similar voluntary certification schemes in the UK and other countries (like those for hip dysplasia) for elbow dysplasia.

7.5.2   Screening programmes for cats

Polycystic kidney disease (PKD) is an autosomal dominant condition of cats. The characteristic kidney lesions can be identified easily using ultrasound examination. The prevalence of the disease is about 40% in the UK. Affected animals should not be used for breeding because 50% of their offspring will be affected. Genetic tests are available for polycystic kidney disease (PKD) and for gangliosidosis GM1 and GM2 in cats, and these tests are in use for screening Persians and Korats respectively (Felis Britannica, 2004). We understand that the incidence of PKD has been dramatically reduced in screened populations.

Glycogen storage disease type IV occurs in Norwegian forest cats in the USA and in Europe. It is an autosomal recessive disease caused by a deletion in the glycogen branching enzyme gene that leads to unstable mRNA and an accumulation of abnormal glycogen in the tissues, including the skeletal muscle (Gaschen et al, 2004). All affected cats die of the disease either as stillbirths, a few days after parturition or at about 10-14 months of age, following the onset of the disease at between 5 and 7 months of age (Gaschen et al, 2004). A DNA test is available from the University of Pennsylvania for the detection of carriers*.

*(www.vet.upenn.edu/research/centers/penngen/ services/deublerlab/gsd4.html).

7.5.3 Screening programmes for horses

Genetic tests are available for hyperkalemic periodic paralysis (HYPP), severe combined immunodeficiency (SCID), lethal white overo syndrome (LWS) and glycogen branching enzyme deficiency (GBED). Whilst HYPP is a dominant condition initially common in Quarter horses and related breeds, the other three diseases are all inherited as recessive diseases. There is some evidence that the HYPP mutation was positively selected for because it produced an increase in muscling, which is regarded as a positive trait in Quarter horses that are shown rather than raced. The other three conditions are lethal, with foals generally not surviving beyond three months of age. The genetic tests provide the ability to rapidly identify carrier individuals, which in turn offers a realistic opportunity for the diseases to be eliminated from the relevant population through selectively breeding to reduce the frequency of the disease allele. Testing for HYPP, LWS and GBED is undertaken at the Veterinary Genetics laboratory at the University of California, Davis (http://www.vgl.ucdavis.edu/service/horse/index.html), whilst SCID testing is undertaken by Vetgen (http://www.vetgen.com/).

7.6 Research into the diagnosis and control of genetic diseases

Knowledge of genetic diseases of companion animals has derived from studies undertaken in many centres of veterinary expertise around the world. Research in these fields has been supported by charities that fund research, government research councils and from other sources.

In the UK, for example, the Kennel Club supports research aimed at tackling hereditary diseases in dogs through the following approaches:
  (i)   contributions to breed society funded research
  (ii)   support for university/institution based research (PhD studies, supported by the British Small Animal Veterinary Association's Clinical Studies Trust Fund, the Guide Dogs for the Blind Association, and others)
  (iii)   breed society based research (involves a clinician/geneticist, eg RPED in the briard, collie eye anomaly in the rough collie, glaucoma in the Dandie Dinmont)

The Kennel Club Health Foundation Fund of the Kennel Club Charitable Trust has awarded funds to Cambridge University, the Animal Health Trust, the Royal Veterinary College and the University of Uppsala in Sweden respectively for investigation of the molecular genetics of diseases such as portosystemic shunts in

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Irish Wolfhounds, lens luxation in Lancashire Heelers and the development of genetic screening tests for von Willebrand's disease in various breeds (Anon, 2004).

7.7   Conclusions

Conclusion 11. There are methods for selection and breeding, that can greatly lessen the chances of there being an increased risk of genetic diseases with concomittant welfare impacts in future generations.

Recommendation 2. In view of its importance to welfare and the dramatic recent advances in knowledge of the genome, we recommend that, where possible, all those with interests in this field, including veterinary research funding bodies, help promote, and make funds available for, work aimed at elucidating the causes of genetic diseases, developing diagnostic tests and developing strategies for their elimination or control.

8.   What needs to be done?

'*Shouldn't there be a body which oversees the breed clubs to ensure that breeding practises and procedures place the priority on the health and welfare of the breed?'*

'*Breed clubs draw up their own codes of ethics, and my understanding is that they vary from breed to breed. It would seem sensible to standardise these, so that health and welfare are the priorities of all breed clubs. Perhaps the composition of breed club committees needs to be looked at, to ensure that they are not just made up of breeders, who will protect their own interests. There should be genetic advisers attached to each breed club to help educate breeders how to breed for diversity and keep the breed healthy'*

Excerpts from replies received in response to CAWC's Inquiry.

8.1   Introduction

In the preceding sections we have reviewed the remarkable extent of the past breeding of companion animals for particular traits in pursuit of the breeders' preferences, tastes or whims regarding various aspects of appearance and behaviour. It is clear that this continues at the present time although, for some taxa, health and welfare aspects are now being given greater priority in selection for breeding. We have discussed how, although in many cases selection for morphological or behavioural characteristics has no apparent welfare consequences, it can sometimes have adverse welfare effects either because the feature selected for directly compromises welfare or because of the occurrence of adverse side-effects arising as a result of selection (some effects of inbreeding for example). We have suggested that in some cases the welfare impact can be severe in that: (i) some genetic changes lead to severely unpleasant feelings (pain or fear), that (ii) tend not to be brief and transient but may be prolonged and chronic and affect animals for much of their lives, which (iii) can affect large numbers of animals, and which (iv) have the potential to be perpetuated through generations far into the future.

Conclusion 12. In view of these points, it is the Council's view that, in the breeding and artificial selection of companion animals, great care should be taken to avoid welfare problems arising or being perpetuated. It seems that there have been many cases in which the welfare consequences of breeding have been given little or no consideration.

Recommendation 3. All those responsible for the breeding of companion animals should take steps to avoid inbreeding. More than this, we suggest that selection for particular traits should be generally avoided unless there is a clear and duly justifiable need for it (eg for health or welfare benefits for future generations). In breeding companion animals, the strategy should generally be to prevent loss of genetic diversity rather than, in selecting for arbitrary traits, acting to promote it.

Conclusion 13. In contrast to the considerable attention given to, and concern expressed about, the welfare of farmed animals and about animals used in scientific procedures, society's tolerance of the scale and severity of the welfare risks inherent

in selection for arbitrary traits in companion animals seems rather surprising. It appears that the subject has been, to a large extent, overlooked.

In this chapter, we briefly review existing regulations and codes and then discuss what could be done in future to minimise genetic risks to the welfare of companion animals.

8.2   Existing regulations and codes of practice

Although there is legislation which aims to protect farm animals from risks to welfare associated with breeding - the Welfare of Farmed Animals (England) Regulations 2000 provide that: *'It shall be the duty of any person who selects an animal for the purpose of breeding from it to have due regard to any anatomical, physiological or behavioural characteristic apparent in the individual or the breeding line which is likely to put at risk the health or welfare of the offspring or the female parent'* – there is at present no corresponding legislation in the UK to protect companion animals. A corresponding clause exists in the Council of Europe Convention for the Protection of Pet Animals but this Convention has not been ratified by the UK (see Section 8.2.1 below).

In its report on the welfare of non-domesticated species kept as companion animals, CAWC (2003) recommended that if breeding to select for particular characteristics is undertaken at all, it should be carried out with extreme caution. In its response to DEFRA's consultation letter on an animal welfare Bill (CAWC, 2002), the Council urged that consideration be given to extending more widely the provisions relating to the breeding of farm animals contained in the Welfare of Farmed Animals (England) Regulations.

As regards the genetic modification of animals - the deletion or changing of genes, or the insertion of genes from one species to another using biotechnological methods (as with the 'Glofish' see Section 3.5.1) – this is controlled at present under the Animals (Scientific Procedures) Act 1986.

In the UK, genetically modified (GM) laboratory animals produced for scientific purposes are controlled under the Animals (Scientific Procedures) Act 1986 regardless of whether they are known to have welfare problems. GM animals can be considered for release from the controls of the Act only when bred to homozygosity for two generations without showing any signs of harm. It is possible that GM animals (eg rats or mice) could enter the pet animal population in this way although we are not aware that this has happened.

The pet trade is international and import of GM animals developed elsewhere, such as the Glofish, is possible. Populations of GM companion animals could become established in the UK from imported individuals.

8.2.1   Council of Europe Convention for the Protection of Pet Animals

The Council of Europe's European Convention (ETS 125) for the Protection of Pet Animals (Council of Europe, 1987) includes an article on breeding as follows:

'*Article 5 – Breeding*

Any person who selects a pet animal for breeding shall be responsible for having regard to the anatomical, physiological and behavioural characteristics which are likely to put at risk the health and welfare of the offspring or the female parent.'

A further article in this Convention - Article 8 - covers commercial breeding. Paragraph 3 of this Article requires that commercial breeding (it specifies various other practices also, eg trading and boarding) '*may be carried out only: (a) if the person responsible has the knowledge and abilities required for the activity either as a result of training or of sufficient experience with pet animals and (b) if the premises and the equipment used ... comply with the requirements...*'. Paragraph 4 of this Article requires that, if these conditions are not adequately met, the competent authority 'shall recommend measures and, if necessary for the welfare of the animals, it shall prohibit the commencement or continuation of the activity.'

This Convention has been ratified by, and has entered into force in, 18 European countries but has not been ratified by the UK. The countries in which the convention has entered into force are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Lithuania, Luxemburg, Norway, Portugal, Romania, Sweden, Switzerland and Turkey.

8.2.2   Council of Europe Resolution on the Breeding of Pet Animals

A multilateral consultation of parties to the European Convention for the Protection of Pet Animals led to the adoption on 10th March 1995 of a resolution on the breeding of pet animals (Council of Europe, 1995). The parties to this resolution, '*convinced that these problems are related for a large part to the way breeding standards are formulated and interpreted*' and '*Considering therefore that a revision of these breeding standards is necessary in order to fulfil the requirements of Article 5 of the Convention*' agreed to:

(i) encourage breeding associations, in particular dog and cat breeding associations, to:
  • reconsider breeding standards;
  • take behavioural characteristics into account in selection;
  • take steps, through information and education of breeders and judges, to ensure that breed standards are interpreted in such a way as to avoid extreme characteristics which can cause welfare problems;
  • raise public awareness of the problems; and

(ii) if the above measures are not sufficient, '*to consider the possibility of prohibiting the breeding and for phasing out the exhibition and selling of certain types or breeds when characteristics of these animals correspond to harmful defects ...*'

With regards the harmful defects mentioned in the last line above, in an Appendix to the Resolution guidelines were provided about measures to tackle a variety of problems. These guidelines included for example that maximum and minimum sizes should be set to avoid skeletal and joint disorders, that limits be set to the shortness of

the skull to avoid breathing difficulties (in eg Persian cats and bulldogs), and that the occurrence of various other features should be prevented including: abnormal size of eyes or eyelids, very long ears, and markedly folded skin.

CAWC's view is generally in line with the thrust of this resolution. However, the main focus of the Resolution is on dogs and cats and clearly the problems involve a very wide range of species and, in tackling the problem, this cannot be ignored.

8.3   Codes of practice

Some organisations involved in the regulation of companion animal breed standards and breeding have recently developed codes of practice that address aspects of health and welfare.

The Kennel Club's Code of Ethics is given to all breed societies and it contains advisory comments on both breeding and disease control. The code is issued as guidance and breed societies are left to institute their own degree of application.

The Governing Council of the Cat Fancy's 'General Code of Ethics for Breeding and Owners' requires that: 'Registered owners of all GCCF registered cats/kittens accept the jurisdiction of the GCCF and undertake to abide by this general code of ethics' and, although not mentioning welfare specifically, specifies that: '*Owners should not breed cats in a way that is deleterious to the health of the cat or the breed*'.

8.4   Breed standards

Clearly a great deal depends upon the breed standards. The setting, and breeding to meet, these can have a great significance to welfare. How have breed standards been set?

8.4.1   Breed standards for dogs

The British Kennel Club (hereafter the Kennel Club), founded in 1873, was the first such organisation in the world (Kennel Club, 1998) and there are few countries that do not now have comparable clubs (Jackson, 1994). Although the Club registers over 260,000 dogs each year (Kennel Club, 1998), it has been estimated that less than one third of the dogs in the UK are registered. The American Kennel Club registers more than 1.5 million dogs each year (Jackson, 1994).

The Kennel Club produces and publishes breed standards that define the ideal for each breed. These standards are used by the show judges and in breed society assessments. Significant changes have been recently proposed and accepted for the Bulldog and Pekingese Breed Standards to minimise the perceived health issues resulting from these standards. Other breed clubs are, we gather, presently discussing their current breed standards with a view to coming back to the Kennel Club with their proposed changes. In addition, a clause specifically addressing welfare has recently been added to every breed standard which states: '*Any departure from the foregoing points should be considered a fault and the seriousness with which the fault should be regarded should be in exact proportion to its degree and its effect upon the health and welfare of the dog*'.

To register a new breed of dog in the UK, owners and breeders form a Breed Club or Council and agree the characteristics and criteria for classification under the breed name. This is then discussed with the Breed Standards Sub-Committee of The Kennel Club before being viewed (and if successful, endorsed and eventually published) by its General Committee (The Kennel Club, 1998). New breeds may be accepted from within the UK or from overseas. Over 90 breeds have been admitted to The Kennel Club's registers since the middle of the twentieth century (The Kennel Club, 1998), and a total of 204 breeds are currently registered.

In most cases, the official breed standards are changed periodically. Few breeds listed in the American Kennel Club's 'Complete Dog Book' (1992) have remained the same since its first publication in 1926. As selection for the particular features that characterise the breed progresses with time, in some cases, the standards are altered to reflect this and then act to drive selection for these features still further. In this way, the process can seemingly come to be driven through positive feedback.

8.4.2   Breed standards for cats

There are a number of organisations that set and oversee breed standards (Fogle, 1997) including the following:

- the Governing Council of the Cat Fancy (GCCF) founded in 1910. This organisation registers breeds in the UK but its influence extends to many other countries;
- Britannica (FB) is the British Federal Member of The Fédération Internationale Féline d'Europe (FIFé). (FIFé) was founded in 1949 and most countries have at least one cat registry linked to this association (see http://www.felisbrittanica.co.uk for the objectives of Felis Brittanica). The GCCF and FB register and regulate pedigree cat breeding in the UK;
- the Cat Fanciers' Association (CFA), founded 1906, is the world's largest pedigree cat registry and has clubs on most continents. It recognises over 30 pedigree breeds and sponsors 400 annual international shows (Little, 2001);
- the International Cat Association (TICA), which was founded in 1979.

There is variation among registries in the recognition of breeds and, in some cases, in breed nomenclature (Fogle, 1997; Vella et al, 2002).

The Governing Council of the Cat Fancy (GCCF) and the Fédération Internationale Féline d'Europe (FIFé) discourage breeding for types associated with defects. For example, discouraging breeding for blue-eyed white cats since these are commonly deaf because the gene that prevents the expression of pigment also causes damage to the organ of Corti in the cochlea (Fogle, 1997).

In contrast, the International Cat Association (TICA), which is based in the USA, permits registration of munchkin and Scottish fold cats, which the GCCF and FIFé do not because of the welfare problems they face (Fogle, 1997; GCCF, 2002).

The Cat Fanciers Association (CFA) sets a general standard for all breeds of cat that they be free from discomfort and poor health and has regard to their well-being,

which is in addition to and takes priority over individual breed standards (Vella et al, 2002).

8.4.2   Breed standards for rabbits

Standards for all rabbit breeds have to be approved by the British Rabbit Council's Breed Standards Committee.

8.4.3   Breed standards for other companion animals

We have not been able to conduct a review of breed standards for the full range of species kept as companion animals. There appear to be very many such standards which define the ideal (from the breed standard viewpoint) characteristics of many strains of fish, reptiles, 'cage' birds, and mammals.

8.5   Breeding to arbitrary standards of appearance or for welfare?

As we have discussed above, in the breeding of companion animals the emphasis has traditionally been on selection for various arbitrary features chosen by humans according to their own preferences and with no attempt to formally address the issue of welfare. One illustration of this is, for example, the scoring system advocated for hamsters in the UK (Logsdail at al, 2002). This system, used in the selection of animals for breeding, gives higher weighting to colour and markings than to 'condition' (see Fig 8.1).

Fig 8.1   Example of a scoring system used in the selection of hamsters for breeding (Logsdail et al, 2002).

Category	**Potential Maximum**
Colour and markings	30
Type	25
Fur	20
Size	10
Condition	10
Ears and eyes	5

As McGreevy and Nicholas (1999), among others, have pointed out, the notion of many breed and kennel clubs of 'improving the quality' of a breed does not necessarily result in the improvement of the animal's health or welfare. Historically, 'improving' has often been more about breeding strains that more closely approach an arbitrary standard of appearance that reflects human aesthetic preference rather than improving welfare. Thus, as McGreevy and Nicholas (1999) suggested, '*replacing the concept of quality with the concept of welfare*' may be beneficial for the animals and less ambiguous for both breeders and the general public.   Maki et al (2005) concluded, from their study into the potential for progress in reducing incidence of hip and elbow dysplasias in the Finnish Rotweiler population, that emphasis on selection for against these dysplasias needs to be increased at the expense of traits regarding appearance if good progress is to be made.

8.6   How can breeders, breed societies, registration authorities, show judges and others work together to prevent or tackle welfare problems?

The roles of breeders, breed societies, registration authorities and others in working together to prevent and tackle welfare problems are outlined below.

8.6.1   Tackling welfare problems in dogs within the conventions, as we understand them, regarding dog breeding in the UK.

(i)   Setting breed standards

Although breed standards for dogs are owned in the UK by the Kennel Club, changes in these standards, in pursuit of improved health and welfare goals, cannot be effected unless the breed society agrees to it also. The first step towards such a change is the realisation that a welfare problem exists. In an effort to awaken vigilance and concern about this, we understand that the Kennel Club requests information about health issues through annual returns from each breed society.

Through this process, changes to breed standards can be made and recent examples are the change to the breed standards for pekingese and bulldogs that are aimed at reducing the incidence of conformation-related problems. The Kennel Club has no mandatory power in these matters and can help facilitate change only where the breed society and all breeders are motivated and fully cooperative.

In the USA the existence of not one, but more than twenty, registration bodies for dogs (each operating to its own protocols and conventions) makes strategic approaches to tackling genetic problems even more complex. Having one registration body in the UK should be advantageous for the development and promotion of national programmes for health and welfare improvements of dogs. The Kennel Club currently reviews all breed standards, taking into account health and welfare aspects, on a 5 to 10 year cycle.

Recommendation 4. In the past, health and welfare have not been the major priorities of many breed societies. It seems clear that in future the promotion of health and welfare should be one of the major roles of breed societies and they should show leadership in this through developing codes of practice with regard to health and welfare and in encouraging their uptake and enforcement.

Recommendation 5. Bodies that take responsibility for administration of breeding registers, pedigree registration etc, should also take responsibility for, and show leadership regarding, health and welfare aspects.

Recommendation 6. Breed clubs should have in place systems for identifying health and welfare problems in their early stages and for addressing them as effectively as possible. This may often require advice from geneticists.

Recommendation 7. Systems for accreditation of breeders should be such that accreditation depends upon maintenance of high health and welfare standards in breeding.

Recommendation 8. The governing boards of breed societies should include a veterinarian and at least one person from outside the breeding community for that species to represent pet owners.

Recommendation 9. Breed societies should exercise a leadership role in taking steps to maintain genetic diversity in breed gene pools and minimise the risks of inbreeding.

Recommendation 10. Links between national umbrella bodies and regional clubs should be such that problems can be tackled in a prompt and coordinated way.

Recommendation 11. The control of inbreeding or of any potentially harmful traits depends on reliable breeding records/registered pedigrees and it is therefore important that all those involved in breeding companion animals should maintain breeding records.

(ii)   Judges

Dog show judges are appointed by breed societies, but the appointments require endorsement by the Kennel Club. Judges are obliged to support any changes to the breed standards that the Club records. Judges can have a significant influence on the future of breeds and the Kennel Club has instituted judging development seminars to promote knowledge and concern for health and welfare matters in judging. Both the Kennel Club and registered breed societies require that: '*In assessing dogs, judges should penalise any features or exagerrations which they consider would be detrimental to the soundness, health and well being of the dog*'. We suggest that this principles covered by this clause for judging dogs should be applied in the judging of companion animals of all other species also.

Recommendation 12. For all species, there should be a bar to entry in breed shows of animals with known welfare problems of genetic origin or from parents that have tested positive for hereditary disease (unless, on the advice of a geneticist, there is a strong case not to do so, eg if, although positive for one deleterious trait, the animal is genetically valuable to the population as regards breeding out other harmful traits).

(iii)   Taking disease records into account

Through the Kennel Club/British Veterinary Association/International Sheepdog Society schemes for diagnosis of inherited ocular disease, hip dysplasia and elbow dysplasia, some 20,000 dogs are screened each year. The results are listed on the Kennel Club dog registration details that are published regularly. However they are listed for information only and positive results are not a bar to registration.

With the emergence of DNA tests for inherited diseases, consideration is being given, in the UK, Sweden and Holland, to the introduction of scheme for making registration dependent on DNA screening results. (Since tests based on the presence of markers are not 100% reliable this would not be extended to the results of marker tests.) It is envisaged that this will be introduced in two stages. The first phase involves the testing of all dogs prior to breeding but carrier and affected animals can be mated to homozygous normals but all the progeny have to be tested. The results would be published in the registration databases (and available on the web). The duration of the

first phase will be determined in discussion with the breed societies. In the second phase it will not be possible to register carrier or affected animals.

The conditions that will be covered by this scheme are: canine leucocyte adherence deficiency (CLAD) in Irish setters, von Willebrand's disease in the doberman, congenital stationary night blindness in the briard, fucosidosis in the English springer spaniel, and progressive retinal atrophy in the cardigan corgi and Irish setter. The scheme for CLAD is already in the second phase, all the others listed above are in the first phase. Others (including for choroidal hypoplasia – the cause of collie eye anomaly), for which there are new tests, will probably join the first phase shortly.

Conclusion 14.   Breeders, show judges (for strains which are shown and judged), and veterinarians involved in diagnosis of problems, all have key responsibilities and roles in preventing both the perpetuation of existing problems and the emergence of novel ones.

Recommendation 13. There should be a system for the collection of data on causes of disease and death in pedigree animals and for regular review and analysis of these data, to aid in the detection of diseases whose causes have a genetic component. We suggest that primary responsibility for this falls to breeders and breed organisations and that they should liaise with veterinary authorities about how such surveillance could be achieved.

8.6.2   Tackling welfare problems in other species

Similar approaches to that outlined above for dogs are pursued for other species. For example, before white epistatic cats can be shown or bred, FIFé members must produce a certificate of evidence that they are not deaf.

8.6.2.1 Limitations of this approach

Whilst the approach outlined above has undoubted merits and must be encouraged, it is unlikely that it can be 'rolled-out' to deal with all the challenges in dogs or other species. One problem is that whilst breed clubs are able to encourage members to avoid inbreeding to counter health problems they 'cannot reach those breeding apparently purely for profit' (The Kennel Club, 2005). That is, the system is voluntary and those who choose to operate outside it are free to do so without constraint.

Many breed societies run their own voluntary schemes, the success of which depends on the vigour of the club officials and the willingness of the club members to participate. For example, we understand that both CLAD and the rod-cone dysplasia type of progressive retinal atrophy are subject to excellent control in the Irish Setter whilst Collie Eye Anomaly (CEA) runs riot in the Shetland Sheepdog and the Rough Collie breeds. We understand also, however, that a new specific DNA test for CEA is likely to become available in the very near future which, if used widely, could have a great impact on the incidence of the disease.

For some species, notably dog and cat, there are, as we have seen, voluntary schemes that allow for the inclusion of welfare parameters in the breeding of registered breeds. For many other species there are no breed clubs, breed standards, or corresponding

regulatory mechanisms. In these cases, selection and breeding are under the sole control of individual breeders and responsibility for avoiding or tackling welfare problems therefore lies entirely with them.

8.7   Welfare code for the breeding of companion animals

To help promote awareness of the potential risks and to promote awareness of the responsibility for welfare that rests on all those who breed companion animals of whatever species, the Council proposes the following brief code, based on the wording of the Council of Europe Convention (Council of Europe, 1987):

'*The selection and breeding of companion animals can result in, or perpetuate, characteristics or inherited conditions that seriously affect the quality of animals' lives. No one should breed companion animals without careful regard to characteristics (anatomical, physiological and behavioural) that may put at risk the health and welfare of the offspring or the female parent.*'

Recommendation 14. Companion animal breeders should familiarise themselves with and respect the above code

Recommendation 15. Whilst every effort should be made to alleviate suffering in animals resulting from defects arising through their breeding history, in the long run it will be a better use of resources for welfare improvements to develop ways to prevent the breeding of animals likely to be at welfare risk through genetic diseases, than to develop husbandry/therapeutic methods aimed at alleviation of the problems caused by these diseases.

Recommendation 16. Since many of the issues relating to welfare and breeding in companion animals are similar to those in animals kept for other purposes, the Government's various animal welfare advisory bodies (the Farm Animal Welfare Council, the Animal Procedures Committee, the Zoos Forum and CAWC) should consider ways of working together to keep the subject, and new developments in the field, under review.

8.8   Education

We noted in Sections 6 and 8.1 that the subject of the risks to the welfare of companion animals associated with their selective breeding appears to have been, to a large extent, overlooked. Although there have been notable expressions of concern and recommendations for improvements (eg Council of Europe, 1995), the issue still seems to have a paradoxically low public profile.

We believe, for the reasons set out above, that the subject deserves greater attention and that there should be more public debate about it. We hope that this Report and its recommendations may play a role in this.

Because of the importance of the subject to welfare it is essential that it is properly addressed during the education of veterinary students and also through the continuing professional development of veterinarians after graduation. We hope that this report will be helpful in this context.

As illustrated in Section 8.6.1, breeders, show judges (for those strains which are shown and judged), veterinarians and others involved all have important roles to play in tackling existing problems and in preventing new ones from arising. Success in this will depend upon knowledge of the problems and how they can be addressed (many examples of which are given in this report), and on commitment to addressing these problems.

Recommendation 17. The relevant professional bodies, breed societies, clubs and others in a position to do so, should promote education about the risks of selective breeding and the steps necessary to deal with these risks.

8.9   Research

8.9.1   Welfare assessment

As we have seen, selective breeding has resulted in remarkable changes in many species of animals kept as companion animals. Although many genetic diseases have been documented, especially in traditional pets (dogs and cats), as far as we are aware there have been rather few studies that have investigated methodically the welfare impact of selective breeding in companion animals. It has not been easy, in undertaking this review, to find studies or reviews that attempt to quantify the welfare impact of specific conditions.

We suggest that there is a need for studies that assess the welfare impact of inherited problems in terms of:

- the nature of the problem and its welfare consequences (pain, fear, etc)
- the number of animals affected
- the severity of the problem, and
- the duration of the problem.

The results of such studies would be helpful both in focusing preventive efforts to where they are most needed and helping to raise awareness of the risks of selective breeding.

8.9.2   Diagnostic methods

Tackling inherited diseases that adversely affect welfare depend upon being able to detect carriers. There is a need for further research to develop genetic (or other) tests to identify carriers of harmful genes.

8.10   Is there a need for legislation?

As noted above, in its response to DEFRA's consultation letter on an Animal Welfare Bill (CAWC, 2002), the Council urged that consideration be given to extending more widely the provisions relating to the breeding of farm animals contained in the Welfare of Farmed Animals (England) Regulations. These Regulations provide that: *'It shall be the duty of any person who selects an animal for the purpose of breeding from it to have due regard to any anatomical, physiological or behavioural*

characteristic apparent in the individual or the breeding line which is likely to put at risk the health or welfare of the offspring or the female parent'.

Not all agree that legislation is part of the way forward. For example, one of the cat breeding regulatory organisations, in its response to CAWC's enquiry, argued that there was no need for compulsory registration or licencing of cat breeders in the UK on the grounds that this has been impossible to enforce in other countries and that attempts to do so have been detrimental to cat welfare. They suggested that self-regulation was effective because cat breeders are good at reporting poor breeding practices and/or welfare problems of other breeders to regulating bodies. The problem is, however, that there are not breed societies for each and all of the very large numbers of species bred and, even where such breed societies exist, not all breeders chose to be involved with them or to be bound by their rules.

There is therefore a good case for consideration to be given to inclusion of a duty of care of the sort specified in the Welfare of Farmed Animals (England) Regulations (see above). Whilst difficulties with enforcement can be envisaged, for example: (i) regarding whether, or to what extent, certain anatomical, physiological or behavioural characteristics in some cases, put health or welfare at risk; and (ii) in undertaking inspections to determine whether individuals with compromised welfare had been bred; legislating for this principle would at least provide control against clear cut disregard for welfare in breeding.

In view of the complexity of the subject, CAWC is planning to give further thought to the subject of regulation in this area.

9. References

Abbott, A. (2004). Laboratory Animals: The Renaissance Rat. **Nature** 428, 464-466.

AEBC (2002). **Animals and biotechnology**. Agriculture and Environment Biotechnology Commission. AEBC, Bay 479, 1 Victoria Street, London SW1H 0ET.

Alderton, D. (2002). **Cichlids: Understanding Your Fish's Natural Behaviour and Biology**. Dorking: Interpet Publishing. 144 pp.

Alderton, D. (1995). **Looking After Cage Birds**. London: Blandford. 128 pp.

Alderton, D. (1992). **You and Your Pet Bird** - The Complete Owners Guide to Cage and Aviary Birds: Their Care, Health and Behaviour. London: Dorling Kindersley. 224 pp.

Allerca. (2004). **Lifestyle Pets**. Web Address: http://www.allerca.com/. Accessed: 1st January 2005.

American Kennel Club. (1992). **The Complete Dog Book: The photograph, history and official standard of every breed admitted to American Kennel Club registration, and the selection, training, breeding, care and feeding of pure-bred dogs**. 18th Edition. New York: Howell Book House. 724 pp.

Andersen, J. (2002). **The Latchkey Dog: How the Way you Live Shapes the Behaviour of the Dog you Love**. USA: First HarperResource Quill. 214 pp.

Animal Health Trust (2004). Animal Health Trust. http://www.aht.org.uk/. Accessed: 24th January 2005.

Animal Procedures Committee (2001) **Report on Biotechnology**. Available at the APC website: www.apc.gov.uk.

Anon. (2004). Canine research grants: every dog has its data. **Veterinary Times** 34, 3.

Appleby, D.L., Bradshaw, J.W.S. & Casey, R.A. (2002) The relationship between problematic canine aggression and avoidance behaviour, and experience in the first six months of life. **Veterinary Record** 150, 434-438.

ARC (2004). Call for Evidence: Snub-nosed Dogs and Air Transport. Animal Reception Centre, Heathrow Airport, London. 1 pp.

Asdell, S. A.(1966). **Dog Breeding: Reproduction and Genetics**. London: J & A Churchill Limited. 194 pp

Barnard, C.J. & Hurst, J.L. (1996). Welfare by design: the natural selection of welfare criteria. **Animal Welfare** 5, 405-433.

Boussarie, D. (2005). Carte D'Identite Chinchilla. 27 WSAVA Congress. Web Address:
http://www.vin.com/proceedings/Proceedings.plx?CID=WSAVA2002&PID=2570.
Accessed: 20th January 2005.

Bradshaw, J.W.S. (1992). **The Behaviour of the Domestic Cat**. Wallingford: CAB International. 219 pp.

Bradshaw, J.W.S., Goodwin, D., Lea, A.M. & Whitehead, S.L. (1996). A survey of the behavioural characteristics of pure-bred dogs in the U.K. **Veterinary Record** 138, 465-468

Bradshaw, J.W.S., McPherson, J.A., Casey, R.A. & Larter, I.S. (2002). Aetiology of separation-related behaviour in domestic dogs. **Veterinary Record** 151, 43-46.

Brinicombe, D. (1997).. Awful Warnings – Diseases and Genetics. Keoka Maine Coons. Web Address: http://dspace.dial.pipex.com/brini/awful.htm. Accessed: 17th March 2004.

BVA, BSAVA, CIEH & LGA (2000). **Breeding of Dogs Acts 1973 and 1991 and the Breeding and Sale Dogs (Welfare) Act 1999: guidance and model conditions for local authorities and their authorised officers and veterinary inspectors for the licensing of dog breeding establishments.** British Veterinary Association, British Small Animal Veterinary Association, Chartered Institute of Environmental Health and Local Government Association. Available from the British Veterinary Association, 7 Mansfield Street, London W1M 0AT.

Campbell, N. A., Reece, J. B. & Mitchell, L. G. (1999). **Biology**. Fifth Edition. Harlow: Addison-Wesley Longman, Inc. 1175 pp.

Cat World.com. (2004). Are some breeds of cat hypoallergenic? Web Address: http://www.cat-world.com.au/Hypoallergenic.htm. Accessed: 1st January 2005

Casey, R.A. (2001). Pathological consequences of environmentally induced stress in the domestic cat. In: **Proceedings of the Third International Congress on Veterinary Behavioural Medicine**, Vancouver, Canada, Overall, K.L., Mills, D.S., Heath, S.E. & Horwitz, D (Eds). Wheathampstead: Universities Federation for Animal Welfare. pp. 30-36.

CAWC (2002). **Response of the Companion Animal Welfare Council to Defra's consultation letter on an Animal Welfare Bill**. Companion Animal Welfare Council. www.cawc.org.uk.

CAWC (2003). **The welfare of non-domesticated animals kept for companionship**. Companion Animal Welfare Council. www.cawc.org.uk.

Clutton-Brock, J. (1999). **A Natural History of Domesticated Mammals**. Second Edition. Cambridge: Cambridge University Press. 238 pp.

CNN (2004). Technology Explorers: Genetically modified cats for sale. Web Address: http://www.cnn.com/2004/TECH/10/27/biotechnology.cats/. Accessed: 1st January 2005.

Council of Europe (1987). European Convention for the Protection of Pet Animals. European Treaty Series No. 125. http://conventions.coe.int/treaty/Commun/.

Council of Europe (1995). Multilateral Consultation to Parties of the European Convention for the Protection of Pet Animals (ETS 125): Resolution on the Breeding of Pet Animals. http://www.coe.int/T/E/Legal_affairs/Legal_co-operation/Biological_safety%2C_use_of_animals/Pet/A_texts_documents.asp

Cowen, S. (2004). Winter warmers for small furries. **Pet Business World** 6, 22.

Damasio, A. (1999). **The feeling of what happens**. London: William Heinemann.

Damasio, A. (2003). **Looking for Spinoza: joy, sorrow and the feeling brain**. London: William Heinemann.

Darwin C (1859). **On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life**. London: John Murray.

Davenport, K. (2001). Ornamental Fish Trade. In: **BSAVA Manual of Ornamental Fish**. Second Edition. Wildgoose, W.H. (Ed). Gloucester: British Small Animal Veterinary Association. Pp 9 – 12.

David, T. (1987a). **A Complete Introduction to Canaries**. New Jersey: T.F.H. Publications Inc. 125 pp.

David, T. (1987b). **A Complete Introduction to Budgerigars**. New Jersey: T.F.H. Publications Inc. 93 pp.

Deaton, H. & Pond, T.W. (1968). **The Hamster Handbook**. Fourth Edition. London: Pond Press.

Duncan, I.J.H. & Petherick, J.C. (1991). The implications of cognitive processes for animal welfare. **Journal of Animal Science** 69, 5017-5022.

Edwards, E. H. (1993). **Horses: The Visual Guide to over 100 horse breeds from around the world**. London: Dorling Kindersley Limited. 256 pp.

Elward, M. (1987). **Guinea Pigs: A Complete Introduction**. New Jersey: T.F.H. Publications Inc. 125 pp.

Evatt, C. (2004). Industry Profile: Rodents on the Rise. **Pet Business World** 6,12-13.

FAWC (2004). **FAWC Report on the welfare implications of animal breeding and breeding technologies in commercial agriculture**. Farm Animal Welfare Council, London. www.fawc.org.uk.

Federation of Veterinarians of Europe (FVE) (1999). **Breeding and animal welfare: resolution.** FVE/99/010.
Available at www.fve.org/papers/pdf/aw/position_papers/fve_99_010.pdf.

Fogle, B. (1997). **The Encyclopaedia of the Cat**. London: Dorling Kindersley. 240 pp.

Governing Council of the Cat Fancy (2002). *GCCF says "health comes first".* The Governing Council of the Cat Fancy. 4 pp.

Gough, A. & Thomas, A. (2004) **Breed dispositions to disease in dogs and cats**, Oxford: Blackwell Publishing. 235 pp

Hart-Davis, D. (2002) **Fauna Brittanica**. London: Weidenfield and Nicolson.

Hendricks, B. L. (1995). **International Encyclopaedia of Horse Breeds**. Norman: University of Oklahoma Press. 486 pp.

Hope, C. E. G. & Jackson, G. N. (Eds). (1973) **The Encyclopaedia of the Horse**. London: Peerage Books. 336 pp.

ICSGNM, International Committee on Standardised Genetic Nomenclature for Mice. (2004). *Rules for Nomenclature of Mouse and Rat Strains*. Web Address: http://www.informatics.jax.org/mgihome/nomen/strains.shtml#mice. Accessed: 20th January 2005.

University of Iowa. (2002). **Biomethodology of the Guinea Pig**. *Animal Research: Institutional Animal Care and Use Committee*. Web Address: http://research.uiowa.edu/animal/?get=g_pig. Accessed: 20th January 2005.

Jackson, F. (1994). **Dog Breeding: The Theory and the Practice**. Marlborough: The Crowood Press Limited. 208 pp.

James, B. (2000). **An Interpet Guide to Koi**. Dorking: Interpet Publishing. 117 pp.

Jones, W. E. & Bogart, R. (1971) **Genetics of the Horse**. Michigan: Caballus Publishers. 356 pp.

Keevil, P. (2004). A Breed in Crisis. In: **Vulnerable Native Breeds: A Kennel Gazette Special Feature**. The Kennel Club.   Redditch: CWW Corporate Communications. Pp 12 – 15.

Kennel Club. (2005). Viewpoint: Considering people's motivation for breeding and canine competition. **Kennel Gazette** 1490, 7.

Kennel Club. (2004a). Dog Genetic Health – Frequently Asked Questions. Web Address: http://www.doggenetichealth.org/faq.php. Accessed: 20th January 2005.

Kennel Club. (2004b). Current Breed Specific Health Checks – March 2004. Web Address: http://www.the-kennel-club.org.uk/registration/breedtable.pdf. Accessed: 20th January 2005.

Kennel Club. (1998). **The Kennel Club's Illustrated Breed Standards: The Official Guide to Registered Breeds**. London: Ebury Press. 400 pp.

Kidd, J. (1995). **The Horse: The Complete Guide to Horse Breeds and Breeding**. London: Tiger Books International. 208 pp.

Kirk, D. (2004) US cloning chief arrives in UK. **Veterinary Times** 34, 8.

Kirkwood, J.K. (1985) The influence of size on the biology of the dog. **Journal of Small Animal Practice** 26, 97-110.

Kirkwood, J.K., Sainsbury, A.W. & Bennett, P.M. (1994) The welfare of free-living wild animals: methods of assessment. **Animal Welfare** 3, 257-273.

Kirkwood, J.K. (2004) The importance of animal welfare. In G.C. Perry (Ed) **The welfare of the laying hen**. Proceedings of the World Poultry Science Association Symposium on welfare of the laying hen, Bristol, July 03. Oxford: CAB International. Pp 1-7.

Kirkwood, J.K. (2005) Welfare implications of breeding and breeding technologies in commercial agriculture: Report and Comment. **Animal Welfare** 14, 83.

Kirkwood, J.K. (2006) The distribution of sentience in the animal kingdom. **Proceedings of the CIWF Trust Conference**, London, March 2005. London: Earthscan.

Lee, B.C., Kim, M.K., Jang, G., Oh, H.J., Yuda, F., Kim, H.J., Shamin, M.H., Kim, J.J., Kang, S.K., Schatten, G. & Hwang, W.S. Dogs cloned from adult somatic cells. **Nature** 436, 641.

Leppänen, M. and Saloniemi, H. (1999). Controlling canine hip dysplasia in Finland. **Preventive Veterinary Medicine** 42, 121 – 131.

Lindblad-Toh, K., Wade, C.M., Mikkelsen, T.S. et al (2005) Genome sequence, comparative analysis and haplotype structure of the domestic dog. **Nature** 438, 803-819.

Little, S. (2001). Feline Breeding and Infertility. **Veterinary Medicine** 96, 548.

Logsdail, C., Logsdail, P. & Hovers, K. (2002). **Hamsterlopaedia: A Complete Guide to Hamster Care**. Dorking: Ringpress Books. 174 pp.

Long, C.R., Walker, S.C., Tang, R.T. & Westhusin, M.E. (2003). New commercial opportunities for advanced reproductive technologies in horses, wildlife, and companion animals. **Theriogenology** 59, 139-149.

Lorinson, D., Bright, R.M. & White, R.A.S. (1997). Brachycephalic Airway Obstruction Syndrome – a review of 118 cases. **Canine Practice** 22, 18-21.

Mäki, K., Liinamo, A-E., Groen, A.F., Bijma, P. & Ojala, M. (2005) The effect of breeding schemes on the genetic response of canine hip dysplasia, elbow dysplasia, behaviour traits and appearance. **Animal Welfare** 14, 117-124.

McCune, S. (1995) The impact of paternity and early socialisation on the development of cats' behaviour to people and novel objects **Applied Animal Behaviour Science** 45, 109-124.

McGreevy, P., Grassi, T.D. & Harman, A.M. (2004). A strong correlation exists between the distribution of retinal ganglion cells and nose length in the dog. **Brain Behaviour and Evolution** 63,13-22.

McGreevy, P.D. & Nicholas, F.W. (1999). Some practical solutions to welfare problems in dog breeding. **Animal Welfare** 8, 329-341.

National Fancy Rat Society (2005). Varieties of Fancy Rat taken from NFRS Standards of Excellence. Web Address: http://www.nfrs.org/varieties.html. Accessed: 20th January 2005.

NC3RS GM Mouse Welfare Assessment Working Group (2004) Assessing the welfare of genetically altered mice. NC3RS website. www.nc3rs.org

Ostrow, M. (1995). **Goldfish: A Complete Pet Owner's Manual**. Second Edition. New York: Barron's Educational Series, Inc. 94 pp.

Panckeri, K.A., Schotland, H.M., Pack, A.I. & Hendricks, J.C. (1996). Modafinil decreases hypersomnolence in the English Bulldog, a natural animal model of sleep-disordered breathing. **Sleep** 19, 626-631.

Parker, H.G., Kim, L.V., Sutter, N.B., Carlson, S., Lorentzen, T.D., Malek, T.B., Johnson, G.S., DeFrance, H.B., Ostrander, E.A. & Kruglyak, L. (2004) Genetic structure of the purebred domestic dog. **Science** 304, 1160-1164.

Parsons, S. (2004). What determines popularity? In: **Vulnerable Native Breeds: A Kennel Gazette Special Feature**. The Kennel Club. Redditch: CWW Corporate Communications. Pp 6-11.

Podberscek, A.L. & Serpell, J.A. (1996). The English Cocker Spaniel: preliminary findings on aggressive behaviour. **Applied Animal Behaviour Science** 47, 75-89.

Porter,V. (2002). **Mason's World Dictionary of Livestock Breeds, Types and Varieties**. Fifth Edition. Wallingford: CABI Publishing. 380 pp.

Prince-Iles, F. (2001). Pond Fish Keeping. In: **BSAVA Manual of Ornamental Fish**. Second Edition. Wildgoose, W.H. (Ed). Gloucester: British Small Animal Veterinary Association. Pp 25 – 36.

Robinson, R. (1991a). Genetic Anomalies in Dogs. **Canine Practice** 16, 29-34.

Robinson, R. (1991b). **Genetics for Cat Breeders**. Third Edition. Oxford: Butterworth-Heinemann. 234 pp.
Robinson, R. (1990). **Genetics for Dog Breeders**. Second Edition. Oxford: Butterworth-Heinemann. 280 pp.

Royal Society (2001) **The use of genetically modified animals.** The Royal Society, London. www.royalsoc.ac.uk.

Rusbridge, C. & Knowler, P (2005) Research update. **Syringomyelia News**, Summer 2005. http://www.cavaliers.co.uk/articles/Syringomelia%20Summer05.pdf. Accessed 3 January 2006.

Ryder, R. (1995). Animal Genetic Engineering and Human Progress: An Overview. In: **Animal Genetic Engineering: of Pigs, Oncomice and Men**. Wheale, P and McNally, R. (Eds). London: Pluto Press. Pp 1 – 16.

Sampson, J. (2004). Extending the Gene Pool. In: **Vulnerable Native Breeds: A Kennel Gazette Special Feature**. The Kennel Club. Redditch: CWW Corporate Communications. Pp 34 – 37.

Sampson, J. & Nicolson, D. (2000) **From dog to DNA**. Kennel Club.

Sandford, J.C. (1996). **The Domestic Rabbit**. Fifth Edition. Oxford: Blackwell Science. 278 pp.

Siberian Cats.com. (2004). How is it that the Siberian is non-allergic? Information on Hypoallergenic Fur. Web Address: http://www.siberiancats.com/allergy.htm. Accessed: 1st January 2005.

Steiger, A. (2005) Breeding and welfare. In I. Rochlitz (Ed) **The Welfare of Cats**. Springer, Dordrecht. Pp 259-276.

Vella, C.M., Shelton, L.M., McGonagle, J.J. & Stanglein, T.W. (2002). **Robinson's Genetics for Cat Breeders and Veterinarians**. Oxford: Butterworth-Heinemann.

Walster, C. (2001). Ornamental Fish Farming. In: **BSAVA Manual of Ornamental Fish**. Second Edition. Wildgoose, W.H. (Ed). Gloucester: British Small Animal Veterinary Association. Pp 13-18.

Ward, K. (1995). Transgenic Farm Animals and Enhanced Productivity. In: **Animal Genetic Engineering: of Pigs, Oncomice and Men.** Wheale, P and McNally, R. (Eds). London: Pluto Press. Pp 39-48.

Welberg, L.A.M. & Seckl, J.R. (2001). Pre-natal stress, glucocorticoids and the programming of the brain. **Journal of Neuroendocrinology** 13, 113-128.

Whitaker, B.R. (2001). Ocular Disorders. In: **BSAVA Manual of Ornamental Fish**. Second Edition. Wildgoose, W.H. (Ed). Gloucester: British Small Animal Veterinary Association. Pp 147-154.

Willis, M.B. (1995) Genetic aspects of dog behaviour with particular reference to working ability. In Serpell, J. (ed) **The Domestic Dog**. Cambridge University Press, Cambridge.

Winter, P.C., Hickey, G.I. & Fletcher, H.L. (1998). **Instant Notes in Genetics**. Oxford: Bios Scientific Publishers Limited. 342 pp.

Wolf, P., Bartels, T., Sallman, H-P., Heisler, K. & Kamphues, J. (2000) Vitamin A metabolism in recessive white canaries. **Animal Welfare** 9, 153-165.

Yanong, R.P.E. (2001). Reproductive and Genetic Disorders. In: **BSAVA Manual of Ornamental Fish**. Second Edition. Wildgoose, W.H. (Ed). Gloucester: British Small Animal Veterinary Association. Pp 231 – 236.

10.   Appendices

Appendix 1   Members of the CAWC Working Party on breeding and welfare in companion animals

Dr James Kirkwood   Chairman
Lord Soulsby of Swaffham Prior   CAWC Chairman
Professor Sir Colin Spedding   Advisor to CAWC
Mr Mike Radford
Mr Michael Herrtage
Dr Anne McBride
The Reverend Professor Michael Reiss
Professor Peter Bedford
Professor Matthew Binns

Mrs Cynthia Baldock   Secretary (to November 2005)
Mr Alan Waldron   Secretary (from November 2005)

Appendix 2   Organisations and individuals who submitted evidence to the inquiry

1.   Animal Health Trust (Mr E A Chandler)
2.   Ark Groups (Mr G Glasson)
3.   Sir James Armour
4.   Ms J Balmer
5.   Miss J Beeson
6.   Dr J W S Bradshaw, Bristol University
7.   British Bird Council (R Caton)
8.   British Rabbit Council (Mr A Gibbs)
9.   BSAVA (Dr Freda Scott-Park, Dr Mark Holmes)
10.   Dr P Burgess
11.   BVA (Clare Lynch, Chris Collins)
12.   Dr R Cook, Tufts University
13.   Mr K Davenport, OATA
14.   Dogs Trust (Mr C Laurence)
15.   Ms A E Fearn, Veterinary Surgeon
16.   Federation of British Herpetologists (Chris Newman, Chairman)
17.   Felis Britannica (Mr D Brinicombe)
18.   Ms Carol Fowler
19.   Governing Council of the Cat Fancy
20.   Guide Dogs for the Blind Association (H Perryman)
21.   Ms B Hargreaves
22.   Mr Jim Hayward
23.   Mr E Hutchings, British Rabbit Council
24.   Kennel Club (J Sampson)
25.   Karat Breed Advisory Committee (Jen Lacey)
26.   Alyson Lockwood
27.   OATA (K Davenport)
28.   PDSA (M Rydstrom)
29.   Pet Care Trust (Mr David Cavill, Acting CEO)
30.   RSPCA (T Miles, Chief Vet Advisor)
31.   Dr B Svendsen, Donkey Sanctuary
32.   Thames & Chiltern Herpetological Group (Mr C Clark)
33.   Mr B Wingate, Animal Health Inspector/Deputy Manager, Heathrow

Appendix 3   Acronyms used in the Report

AEBC   Agriculture and Engineering Research Council
AHT   Animal Health Trust
APC   Animal Procedures Committee
BSAVA   Bristish Small Animal Veterinary Association
BVA   British Veterinary Association
CAWC   Companion Animal Welfare Council
CEA   Collie eye anomaly
CERF   Canine Eye Registration Foundation
CFA   Cat Fanciers Association
CLAD   Canine leucocyte adhesion deficiency
CNN   Cable News Network
DNA   Deoxyribose nucleic acid
FAWC   Farm Animal Welfare Council
FB   Felis Brittanica
FiFé   Fédération Internationale Féline d'Europe
FVE   Federation of Veterinarians of Europe
GBED   Glycogen branching enzyme deficiency
GCCF   Governing Council of the Cat Fancy
GM   Genetically-modified
GSC   Genetics Savings and Clone, Sausalito, California
HYPP   Hyperkalaemic periodic paralysis
KC   Kennel Club
ISDS   International Sheepdog Society
LWS   Lethal white syndrome
MRNA   Messenger RNA (ribose nucleic acid)
NC3RS   National Centre for the Replacement, Refinement and Reduction in Animals used in Research
OATA   Ornamental and Aquatic Trade Association
PDSA   Peoples Dispensary for Sick Animals
PKD   Polycystic kidney disease
RSPCA   Royal Society for the Prevention of Cruelty to Animals
RPED   Retinal pigment epithelial dystrophy
SCID   Severe combined immunodeficiency disease
TICA   The International Cat Association
UFAW   Universities Federation for Animal Welfare

Appendix 4.   Some principles of genetics and selective breeding

It is outside the scope of this report to provide a detailed review of the genetic basis of inheritance but it is hoped that the following brief outline may be a helpful introduction to some of the principles of genetics and selective breeding for those not familiar with the subject.

A4.1   Chromosomes, genes and alleles

Genes are specific sequences of base pairs in the deoxyribonucleic acid (DNA) helices (chromosomes) that code for particular proteins. The production of these proteins at specific times during development results in the construction of the organism and variations in the nature and timing of the proteins produced underlie variations in all aspects of morphology and behaviour. The design and all aspects of the biology of an individual (its phenotype) is a reflection of its genetic constitution (its genotype) and the interaction of environmental effects.

Inheritable variations are due to variations in genes. Variants of genes are called alleles and most genes have multiple alleles. For example, slight differences in the sequence of bases (nucleotides) in a gene for fur colour may result in different coat colours. Such variant forms of the gene are called alleles. New alleles arise by mutation – a change in the base pair sequence. These may occur through base-pair substitution, in which one nucleotide replaces another; insertions, in which nucleotides not normally present in the gene are added; and deletions, in which nucleotides are lost (Campbell *et al*. 1999).

In a genetically healthy individual, each nucleated somatic (non-sex) cell contains a number of chromosomes specific to that species. For example, the domestic dog has 78 chromosomes arranged as 39 pairs. Half of the 78 chromosomes originate from the individual's mother and half from its father (ie 39 from each parent). The nuclei of sex cells (sperm and ova) contain half the number of chromosomes of somatic cells because they have not yet been paired with those from another individual (as occurs at fertilisation).

A4.2   Factors affecting the patterns of inheritance of various characters

Following fertilisation, the conjugation of the sperm and ova, the resulting somatic cells contains pairs of chromosomes – one set of chromosomes is inherited from the mother and the other from the father. To stick with the example used above, of a gene for fur colour, each cell would have this gene, in one of its allelic forms, on each of the two chromosomes that carry it.

In general, where the alleles are identical (homozygous genotype), it is only possible for the offspring to show traits produced by that allele type, but where the two alleles differ (heterozygous genotype), the resulting trait (in our example coat colour) depends on which of the alleles is dominant and which is recessive. The dominant

allele is the one that is expressed and the recessive allele has no effect on the individual (the phenotype). However, the interaction between the alleles is not always of a straightforward dominance/recessive kind. There can be other forms of interaction including:

- co-dominance, in which, in a heterozygote, the alleles do not differ in dominance and an intermediate phenotype is expressed (not to be confused with incomplete dominance – see Winter *et al,* 1998);
- epistasis, in which the epistatic gene masks the effects of certain other independently inherited genes that are present. For example, in dogs the e allele removes all agouti pigment from the hair resulting in a yellow colouration (Robinson, 1990);
- sex-linked inheritance in which the gene for the trait is on one of the sex chromosomes (the X or Y) only, so that females (XX) may have two copies but males (XY) only one (NB in birds males are XX and females are XY). For example, tortoiseshell cats are usually females because they can inherit two copies of the O gene (which is on the X chromosome) in different alleles, orange and black. The male cat has only one X chromosome and so can only inherit one allele and have black or orange colour, not both.

If an individual is homozygous for a particular gene (ie both alleles are identical), it is considered to be 'true-breeding' because, if it is mated with another animal that is homozygous for the same allele, all their offspring will also be homozygous for that allele and will display the same phenotypic character for which that gene is responsible: the young will be like their parents for this trait. However if the same individual is mated with an individual that is homozygous for a *different* allele, the offspring will all be heterozygotes and their appearance will depend upon which of the alleles is dominant (unless the alleles show incomplete dominance).

If an individual is heterozygous (having two different alleles) for a particular gene then the individual will not be true breeding as its offspring may inherit one allele or the other. The appearance of the offspring will however depend also on whether the other parent is heterozygous and on the relative dominance/recessiveness of the alleles.

Test mating can be used to detect carrier individuals for recessive mutations. Individuals with one copy of the mutation are clinically normal and look identical to individuals that carry two normal alleles. By mating the test individual to a homozygous affected individual it is possible to identify whether the test individual is a carrier of the mutation. If the individual is a carrier, there is a one in two chance that the mutation will be transmitted to any individual offspring. The other parent can only provide mutated copies of the gene, such that any individual receiving a mutation from the test parent will become affected. If a litter of six puppies is healthy there is only a one in $2 \times 2 \times 2 \times 2 \times 2 \times 2 = 64$ chance that it could be carrying a mutation. This procedure was used by Irish setter breeders to test for progressive retinal atrophy before the availability of a DNA test. The test mating procedure takes time and money and can produce unwanted affected individuals as part of the process. In comparison, DNA tests are rapid and cheap and do not involve the generation of any unwanted animals.

It is rare for characters (colour, size, etc) to be dependent on a single gene. More usually, particular characters or traits, are dependent upon the action of many genes. Also, in the population, there are often many alleles of each gene. For example, multiple alleles of one gene are responsible for various coat colour phenotypes in rabbits (Winter *et al,* 1998). There are four members of this allelic series and these dictate whether colour pattern will be agouti, chinchilla, Himalayan or albino. When homozygous, each produces its distinct coat pattern but when heterzoygous the colour depends on the dominance of the alleles. Agouti is dominant over all the other alleles, chinchilla is dominant over Himalayan and albino, Himalayan is dominant over albino, and albino is recessive to all the others (Winter *et al,* 1998).

Appendix 5   Glossary

Allele: a form of gene that codes for a specific format of a specific gene, eg blue eyes for the eye colour gene

Autosome: Any of the non-sex chromosomes

Breed   *'A group of animals that has been selected by humans to possess a uniform appearance that is inheritable and distinguishes it from other groups of animals within the same species'* (Clutton-Brock, 1999)

Cull: definition differs between authors but usually taken to mean the removal of animals from a population by killing. However some authors refer to 'culling' as the removal of animals from the breeding population; for example, for selling on as pets or neutering.

Dam: breeding female and mother of offspring

Dominant allele: A variety of allele that is more 'powerful' than one or more other types of allele for the same gene, and is therefore preferentially expressed over the other types.

Dystocia: Difficulty or inability to give birth, commonly seen in brachycephalic breeds where the females have narrow pelvises and the young have large heads and shoulders.

Gene: a specific section of a chromosome that codes for or contributes to a particular trait such as eye colour

Gene silencing: Repression of a gene to prevent its expression

Genotype: an individual's genetic composition

Heterozygosis: the proportion of individuals heterozygous for particular genes in an inter-breeding group

Heterozygote: An individual with two different alleles of a particular gene

Homozygosis: the proportion of individuals homozygous for particular genes in an inter-breeding group

Homozygote: An individual with the same two allelic forms of a particular gene

Inbreeding: The mating together of closely related individuals.

Locus: Area on a chromosome that corresponds to a specific gene

Monogenic: Due to one gene

Phenotype: the observable characteristics of an organism

Polygenic: Due to more than one gene

Polyploidy: A chromosomal alteration, where an organism possesses more than two complete sets of chromosomes

Recessive allele: A variety of allele that is subordinate in terms of expression to one or more other types of allele of the same gene.

Sex-linked: A gene found on one of the sex chromosomes. Usually present on only one of the sex chromosomes.

Sire: breeding male and father of offspring

Appendix 6.   The Kennel Club's bulldog breed standard

The following is the text of a press release from the Kennel Club dated 10th September 2003 it is included as an example of a breed standard.

The Kennel Club's work in seeking to obviate the need for the adoption of the European Convention for the Protection of Pet Animals has been well documented in recent months.   The efforts in this respect are ongoing at Clarges Street, but the Kennel Club wishes to highlight the way in which joint meetings with representatives of breeds named in the convention are contributing to this.   Following a meeting with representatives from the Bulldog Breed Council in November 2002, a number of clarifications in the wording of the Breed Standard were put forward to the Kennel Club by the Bulldog Breed Council, all of which aim to ensure the breeding of healthy dogs.

These have now been passed by the General Committee, and in so doing, the Committee commended the Breed Council for its approach in reviewing the standard in order to amplify health and welfare issues in this way.

The revisions to the General Appearance, Head and Skull, Eyes, Neck and Gait/Movement clauses are given below, having become effective on 1 September 2003.

General Appearance: Smooth-coated, thick set, rather low in stature, broad, powerful and compact.   Head (*) fairly large in proportion to size but no point so much in excess of others as to destroy the general symmetry, or make the dog appear deformed, or interfere with its powers of motion.   Face short, muzzle broad, blunt and inclined upwards. <u>Dogs showing respiratory distress highly undesirable</u>.   Body short, well knit, limbs stout, well muscled and in hard condition <u>with no tendency towards obesity</u>.   Hindquarters high and strong but somewhat lighter in comparison with heavy foreparts.   Bitches not so grand or well developed as dogs.

Head and Skull: Skull large in circumference.   Viewed from front appears very high from corner of lower jaw to apex of skull; also very broad and square.   Cheeks well rounded and extended sideways beyond eyes.   Viewed from side, head appears very high and short from back to point of nose.   Forehead flat with skin upon and about head, loose and <u>finely</u> wrinkled, neither prominent nor overhanging face.   Projections of frontal bones prominent, broad, square and high; deep, wide indentation between eyes.   From stop, a furrow, both broad and deep extending to middle of skull being traceable to apex.   Face from front of cheek bone to nose short, skin wrinkled.   Muzzle short, broad, turned upwards and very deep from corner of eye to mouth.   Nose and nostrils large, broad and black, under no circumstances liver colour, red or brown; top set back towards eyes.   Distance from inner corner of eye (or from center of stop between eyes) to extreme tip of nose not exceeding length from tip of nose to edge of underlip.   Nostrils large, wide <u>and open</u>, with defined vertical straight line between.   Flews (chops) thick, broad, pendent and very deep, hanging completely

over lower jaws at sides, not in front, joining underlip in front and quite covering teeth. Jaws broad, massive and square, lower jaw projecting (**) in front of upper and turning up. <u>Nose roll must not interfere with the line of layback</u>. Viewed from front, the various properties of the face must be equally balanced on either side of an imaginary line down center.

Eyes: Seen from front, situated low down in skull, well away from ears. Eyes and stop in same line, at right angles to furrow. Wide apart, but outer corners within the outline of cheeks. Round in shape, of moderate size, neither sunken nor prominent, in colour very dark – almost black – showing no white when looking directly forward. <u>Free from obvious eye problems.</u>

Neck: Moderate in length, (***) very thick, deep and strong. Well arched at back, with much loose, thick and wrinkled skin about throat, forming dewlap on each side, from lower jaw to chest.

Gait/Movement: Peculiarly heavy and constrained, appearing to walk with short, quick steps on tips of toes, hind feet not lifted high, appearing to skim ground, running with one or other shoulder rather advanced. <u>Soundness of movement of the utmost importance</u>.

(*) - removed 'massive). (**) – removed 'considerably'.
(***) – removed 'rather short than long'.

Appendix 7

Syringomelia and mitral valve disease in Cavalier King Charles Spaniels

There were, we understand, around 700 litters of King Charles Spaniels registered in 2004 in the Breed Supplement for this breed from breeders who were members of the breed Club and about 1800 litters from breeders who were outwith the breed club (comprising a total of 10,733 puppies). This breed is the most popular of the toy breeds (only 3,877 puppies of the next most popular toy breed, the Yorkshire Terrier, were registered that year). It has been predicted that about 50% of King Charles Spaniels could have heart murmurs as a result of mitral valve disease by 5 years of age. It has been suggested to us that it is perhaps now time to ensure that only litters from dams and sires that are certified to have had no heart murmurs at the time of mating are registered.

Syringomelia, a painful and progressive neurological condition caused by obstruction of the flow of cerebrospinal fluid (CSF) has also been found to affect over 50% of Cavalier King Charles Spaniels. In affected dogs, the CSF flow is compromised by pressure from the cerebellum at the foramen magnum which is caused by the shape of the skull and, in particular, of the occipital bone in this (and sometimes other) small breeds. The symptoms include signs of head and neck pain, which can be very severe, fore and hind limb weakness and ataxia. There is a method available for screening (by magnetic resonance imaging) prior to using dogs for breeding (see Rusbridge & Knowler, 2005).