Breeding
&
Reproductive Technologies

Anima(l) sana in corpore sano

RAAD VOOR DIERENAANGELEGENHEDEN

Letter of presentation

Excellence,

Breeding is not a new topic on the political and social agenda. Cases of abuse -- and particularly, disturbing images -- have led searching questions to be raised. But at the same time, much good has been done for humanity and for animals thanks to breeding and reproductive technologies.

Reading past reports on these issues, it is noticeable that many pertain mainly to the implementation level. In the current opinion, the Council on Animal Affairs has reached for a higher level of abstraction. By starting with the very essence of breeding – the use of selective reproduction to modify the characteristics of future generations of animals to suit the desires of humans – we bring into focus the underlying, ethical issues that breeding raises.

In scrutinizing practices in animal breeding, we have to address not only the interests of humans but also those of the animal. But human and animal interests do not always coincide – and that is where ethical issues arise. This, in itself, need not be problematic. But difficulties do emerge when the balance is skewed in weighing the respective interests of people and animals. When breeding by humans harms animal welfare and health, public sensibilities are quick to acknowledge that something is amiss.

Equipped with that knowledge, it may be possible for us to seek out a sustainable approach to breeding – one that is applicable to all animal species, that does justice to the interests of both the people and the animals concerned, and that, furthermore, makes apparent to everyone exactly what interests breeding serves.

With the current opinion, the Council on Animal Affairs hopes to make a constructive contribution to policy on breeding and the use of reproductive technologies on farm animals, hobby animals, horses and companion animals.

Sincerely,

Professor H. (Henk) Vaarkamp
Chairman, Council on Animal Affairs

The Hague, 6 December 2010

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Guide for readers

This opinion of the Council on Animal Affairs is addressed to the Minister of Economic Affairs, Agriculture & Innovation and the Minister for Agriculture and Foreign Trade. It was written at the request of former Minister of Agriculture, Nature and Food Quality, G. Verburg. Chapters II and III discuss the request that led to the drafting of this report and the background against which it was written. In formulating this opinion on breeding and reproductive technologies, the Council analysed the basic principles of breeding, which you will find, together with the definitions applied, in chapter IV and in appendix A. From the analyses it became clear that breeding indeed raises fundamental ethical concerns. These can be read in chapters V and VI. In order to address the ethical issues raised in a systematic manner, the Council presents an assessment model, also in chapter V. Finally, chapter VII provides a summary of the responsibilities attached to breeding and how the parties involved should act on their respective responsibilities. Appendix B (as yet available only in Dutch) provides a *quick scan* of breeding in the various animal husbandry sectors. Appendix C (also in Dutch) presents an overview of public laws and regulations pertaining to breeding and reproductive technologies in the Netherlands.

I Summary

Breeding is inherent in the keeping of animals, because it is the animal keeper who, to some extent, determines which animals will produce offspring. ‘Breeding’ is the selection and mating of animals for the purpose of changing the characteristics of the next generation to better correspond to a breeding goal formulated by humans. Breeding is therefore beneficial to people, but it is not always in the interest of the involved animals. Breeding, therefore, raises ethical concerns. It requires interests to be weighed: interests of human and animal welfare; interests of climate, biodiversity and food supply; and economic interests – in other words, sustainability.

Many examples can be mentioned of interests associated with breeding – and where interests might clash. For instance, the breeding done by agribusinesses to achieve higher productivity per animal can reduce the environmental impact of farming per kilogram of food output and raise economic returns to the farmer. But at the same time, it may lead to poorer animal welfare. In horses, hobby animals and companion animals, the environmental effects of breeding are probably less significant, though the economic impact can range from negligible to quite substantial. Breeding that aims to change the appearance of a companion animal can reach a point where harm is done to the welfare and health of the animal. On the other hand, breeding can be beneficially used to combat inherited defects.

Problems arise when the balance is skewed in weighing the interests of the people and animals concerned. Choices made in breeding can have considerable consequences: for the animal species concerned, but also for humanity, the environment, etc. That is why it is so important for the dilemmas associated with breeding to be fundamentally analysed and resolved.

It must also be said that in part due to breeding a category of ‘surplus’ animals is produced: animals that do not meet the breeding goal formulated. The fate of these animals too has to be brought into any ethical assessment of breeding practices.

Reproductive technologies are often used in breeding and the reproduction of animals. These technologies can have advantages for the animal. For example, use of artificial insemination (AI) has drastically reduced the spread of a number of sexually transmitted diseases, e.g. in pigs and cattle. But these technologies can also have harmful effects, on the parents as well as their offspring. Male catfish, for example, are killed to harvest their milt, and cloning can cause defects in the animals produced. So, the use of reproductive technologies, like breeding, requires a weighing of the interests involved. These interests are often closely linked to the interests underlying breeding programmes, because reproductive technologies typically play a key role in such programmes.

How are ethical issues addressed?
Addressing ethical issues in dealings with animals is not new, and there is no need here to retrace old ground. In this opinion, the Council has developed an *Assessment Model for Breeding and Reproductive Technologies* based on recognition of the intrinsic value of animals. This builds on the evaluation framework that has been in use for some time already to assess applications of biotechnology on animals. It also builds on the *Assessment Model for Policy on Animals* that the Council presented in its previous opinion, *Moral Issues and Public Policy on Animals*. The *Assessment Model for Breeding and Reproductive Technologies* structures the different interests in such a way that they can be transparently assessed against one another.

The starting point for the *Assessment Model for Breeding and Reproductive Technologies* is the following fundamental ethical question: *How far may we go in changing animals to suit our needs and interests?*

To assist practitioners in addressing this ethical question in real-life contexts, the assessment model presents a step-wise review procedure with a number of specific questions:

1. Based on an analysis of the current situation of the animal population of interest, and considering all social, economic and other arguments, why should a breeding programme be started?
2. What is the intended objective of the breeding programme or reproductive technology, and why is it important and necessary?
3. How feasible is the formulated breeding goal or reproductive output within ten years?
4. Are there realistic alternatives for achieving the intended objective?
5. Will the breeding programme or reproductive technology harm the health or welfare of the affected animals, including in addition to the parent animals any potential offspring? Or could it perhaps contribute to improve an existing adverse situation in the targeted area?
6. Will the breeding programme or reproductive technology violate the integrity of the affected animals? Or might it contribute to improve an existing adverse situation in the targeted area?
7. Does the breeding programme or reproductive technology pose any risks to public health? If so, how are these to be managed?
8. Does the breeding programme or reproductive technology pose any risks to biodiversity? If so, how are these to be managed?

A final assessment of all the issues that come up in answer to these specific questions should lead to an answer to the fundamental question: does the importance of the breeding programme or reproductive technology outweigh the (possible) harm?

It is not enough to provide *insight* into the deliberations involved. Ultimately, most important are the *choices* that follow from these deliberations. Not all of the questions in the assessment model will appear equally relevant in every case. The Council nonetheless believes that it is important to ask all of these questions, since posing the questions will clearly invoke the responsibilities of all of the parties directly concerned. The *Assessment Model* is not 'set in stone'; it can be adapted and/or expanded if necessary, based on practical experience.

Who does the assessment?

Breeding goals are formulated at the level of a population (a group of animals that can mate with one another). But to achieve the desired changes, choices are made at the level of individual animals: which animals will be selected as parents for the next generation, and which animals will be mated with one another? Decisions in breeding are made by breeders, the government and animal buyers:

- Breeders have primary responsibility for the welfare the animals under their influence and care. Only breeders who exchange no genetic material with other breeders will be able to establish a breeding programme entirely on their own. All other breeders are dependent to some extent on other breeders to achieve their breeding objectives. This means that assessments will have to be done at the level of breeding organizations and associations.
- The government sets minimum standards for the welfare and health of animals in the Netherlands.
- Buyers of animals have a very direct influence on breeding, because they determine the market demand for certain species, breeds and types of animals. Buyers – by virtue of their responsibility as future animal owners – should ensure that they are fully informed in advance of any welfare and health issues pertaining to the animal they wish to purchase. Breeders and (re)sellers in turn must make sufficient information easily available to potential buyers.

- Those who purchase animal products are much farther removed from the breeding stage. The actual breeding of, say, pigs takes place all the way at the start of the production chain, while a consumer of pork meat is all the way at the end of that chain. The choices open to the consumer are, moreover, strongly driven by retailers. Information provision occurs largely via retailers as well, though non-governmental organizations now also fulfil an increasing part of this role. Ideally, those who purchase animal products should be in a position to make a well-informed, conscious choice from a broad range of products on offer.

Voluntary or compulsory assessment?

Some of the interests at play go beyond the individual breeder. Examples of these are those related to the environment and biodiversity. Some interests, such as environmental conservation and animal welfare, might bring no direct economic benefits. This argues for a regulatory role for government.

On the other hand, farm animal breeding is often in the hands of multinationals operating on a global scale. The Netherlands' government has limited direct influence on such enterprises. Regarding companion animal breeding, these activities often take place in the private sphere, so their monitoring would require enforcement to extend 'beyond the front door'. The same is true for the breeding of hobby animals when this takes place outside of the official breeding organisations. That means the possibilities for direct government regulation and enforcement may be limited here as well.

The government's primary role lies in establishing regulatory frameworks (e.g. via the *Breeding Act*), creating enabling conditions (such as identification and registration schemes) and promoting transparency. The goal should be to allow market forces to work in breeding through quality assurance systems that enable consumers to differentiate between the products on offer. In such systems, a large role is reserved for private actors to regulate the various steps in production chains (in all animal husbandry sectors).

Recommendations

The recommendations of the Council aim to produce the following ideal image:

1. The *Assessment Model for Breeding and Reproductive Technologies* plays a central role in the formulation of breeding programmes and in assessing uses of reproductive technologies on animals.

2. Breeders weigh the different interests affected by breeding in a transparent manner along the lines set out in the *Assessment Model for Breeding and Reproductive Technologies*. Such assessments are done at the level of the breed clubs and breeding organizations, because breeding by definition is an issue pertaining to a population in its entirety.

3. All breeding organizations and breed clubs make use of a central contact point (for reporting performance, hereditary defects, etc.) in support of a central breeding programme and its monitoring. Before this can be instituted, however, an appropriate identification and registration system will be needed to track and record the animals bred.

4. A section on breeding and reproductive technologies, preferably substantiated by performance indicators, becomes a standard part of regularly published social reports on animal welfare and animal health (such reports were recommended in the Council opinion *Responsible Animal Keeping*).

5. Breeders communicate their breeding objectives to their buyers and indicate how they are working to achieve these.

6. Breeders have a socially acceptable solution for dealing with ‘surplus’ animals -- those animals that are not selected for further use in breeding -- as these are an inherent part of breeding.

7. The government establishes the necessary enabling conditions and legal prerequisites for identification and registration of animals and for effective private quality assurance schemes for breeding and the marketing of live animals.

8. In the framework of the *Breeding Act*, the government makes sufficiently effective demands of all breeding organizations and breed registries/studbooks. The *Breeding Act* is expanded to include poultry and companion animals, starting with dogs and cats.

9. The Council advises the government to ensure that guidelines on the breeding of all animal species are incorporated into a *European Law on Animal Welfare*. However, this most emphatically does *not* mean that law-making and regulation on breeding should take place exclusively at the European level.

10. Buyers can determine based on a label, certification, or (breed registry) records, that any animal – or animal product – they purchase comes from a responsible, quality-assured breeder. As such, a market emerges in which responsible breeding becomes an added value.

11. Because the chain produces what the buyer demands, buyers make considered choices in their purchases. This is as applicable to the purchase of a live animal as it is to the purchase of an animal product. Sellers at the consumer end of the retail chain provide buyers adequate and objective information and offer a broad enough range of selection.

12. Veterinarians and any other professional groups involved in animal breeding utilize their knowledge and expertise to contribute to responsible practices. They do this, first of all, at the level of their professional organizations, for example, by making proactive contributions to the political and social debate. In their individual capacity, they actively inform animal keepers, prospective buyers and government about relevant aspects of breeding and, obviously, they do not take part in breeding practices that harm animal welfare and health.

13. To test and optimize the practical usefulness and effectiveness of the *Assessment Model for Breeding and Reproductive Technologies*, the government, science, relevant professional and societal organizations, and breeders should together set up pilot applications of the assessment model, distributed over a number of animal husbandry sectors.

II. Advisory request

II.1 Main questions

On 12 November 2009, former Minister of Agriculture, Nature and Food Quality posed the following questions to the RDA (letter VDC 09.2219/LA): *What are the major developments in the breeding of farm livestock and companion animals? What influence will these developments have on the health and welfare of these animals? Are these developments in sync with societal expectations and the ambition to achieve a sustainable livestock industry by 2023?* [1]

II.2 Revised advisory request

The advisory request as originally formulated was discussed in a plenary brainstorming session of the RDA in January 2010. Subsequently, the RDA team conducted a literature review and carried out expert interviews with a number of council members (the sector experts). The information thus collected led to a meeting of the RDA chairperson and a senior official at the Ministry of Agriculture in late April 2010. Together with the Ministry, the advisory request was reviewed and revised and the delivery date for the report was extended to end 2010.

At the request of the Ministry of Agriculture, the advisory request was expanded to include a stock-taking of ethical issues in the use of reproductive technologies on animals.

The preliminary work indicated that many of the underlying practical questions on breeding (regarding the structure of breeding, pertinent regulation, and animal welfare and health issues linked to selection for inherited traits) had already been for the most part answered. Moreover, many recommendations had been put forward for improvements.

Where there were still ‘blank spaces’ in current knowledge, the RDA was to point these out and, if possible, fill them in. A comparison of the different animal husbandry sectors had never before been done in a structural way, and this was recognized as a potential value-added of the current work: why is it that one sector can tackle a problem successfully, and what needs to change in other sectors so that they can do so as well? In defining the different responsibilities and roles, the RDA’s previously published opinion *Responsible Animal Keeping* was to serve as a guideline.

II.3 Auxiliary questions

In the advisory request, the Minister of Agriculture formulated the following auxiliary questions:

1. How is the sector organized? Who are the major players? Who determines the current breeding directions?
2. What are the most important developments in breeding that affect the welfare and health of animals?
3. What are the pertinent national and international laws and regulations?
4. What concerns about breeding have been expressed within the political establishment and society?
5. What are the primary animal welfare and health problems?
6. What are the major ethical issues?

[1] The letter from the Minister of Agriculture to Parliament, dated 16 January 2008 (28 973, nr. 18), contains the following definition: In 15 years, livestock farming in the Netherlands is to have developed into a farming system that is sustainable in every respect and enjoys broad support in society. The Minister defines ‘sustainable livestock farming’ as farming that produces with respect for people, animals and the environment, wherever in the world.

7. How can these concerns be dealt with and by whom?
8. Who is responsible for what? Is there a role for the government? If so, what? If not, why not?

III. Background

This chapter sketches the background of the current advisory request, without professing to offer a full overview of everything that has been said and written about breeding in science, society and politics in recent decades. What is clear, in any case, is that this is an issue with many strands.

III.1 Advisory context

The remarks made by the Minister in putting forward this advisory request refer to societal concerns about animal welfare and health problems arising from breeding, such as piglets dying due to too-large litter sizes and physical disorders in inbred and 'over bred' animals. The Minister also makes reference to ethical questions such as: How far is it acceptable to go to increase productivity? For example, is it morally acceptable to breed double-muscled cattle even if that means they can only be born by caesarean section? Is it okay to breed hornless cattle? Such concerns about advances in animal breeding have been similarly expressed in an array of research and advisory reports published in past decades.

The current advisory request refers to farm animals as well as companion animals. For clarity's sake, in this report the Council groups animals into four categories, namely, farm animals (or farm livestock), hobby animals (backyard livestock), horses, and companion animals (pets). Though these animal categories differ distinctly from one another – and the differences may be large even within a category – this opinion of the Council is relevant across the whole breadth from farm animals to hobby animals, and horses and companion animals in the Netherlands. It does not pertain to laboratory animals however.

III.2 Society

In 2007, the research consultancy firm Bureau Ergo conducted a survey among residents of the Netherlands to seek insights into attitudes on animal welfare. The survey, commissioned by the Ministry of Agriculture, looked at what topics people considered most important in relation to animal welfare, as well as how well informed people were (content-wise) about the issues involved.

Bureau Ergo concluded that 68% of those surveyed were concerned about the breeding of dogs for their physical appearance, while just 39% indicated actually knowing about the issues involved. Regarding the selective breeding of broiler chickens for fast growth, 35% said they were aware of the issues involved, but 62% indicated being concerned about the practice. The killing of day-old hatchlings in the egg sector was described as 'worrying' by 50% of respondents, but only 35% said that they had known about this practice. The welfare problems surrounding the breeding of double-muscled cattle are even less well-known, with only 14% of respondents admitting having been aware of these. Yet when asked, 49% of the respondents said that it was a worrying situation.

III.3 Politics

Various politicians have expressed opinions about breeding-related dilemmas in animal keeping, with questions being posed to the Dutch Parliament, among other means. H.J. Ormel (a Christian-Democrat) submitted parliamentary questions in December 2008 about the use of sexed sperm in breeding Belgian Blue cattle. His questions related to the possible contribution of this reproductive technology to reducing the high rate of caesarean sections needed by this cattle breed and also about its potential impact on conservation and sustainable use of genetic diversity. Ormel further wanted to know whether an ethical assessment had been conducted in relation to this development. In a column written on the subject, he stated the general dilemma as follows: ‘How far should we take developments in breeding?’

In February 2009, in response to the airing on television of the British documentary *Pedigree Dogs Exposed,* M. Thieme (Party for the Animals) posed parliamentary questions about ‘cruelty to animals’ associated with the breeding of pedigree dogs in the Netherlands.

III.4 Research and advice

The January 2008 LNV/NWO research programme *The Value of Animal Welfare*[2] formulated the fundamental dilemma in more elaborate terms: '[D]o we take the animal as it is, or are we allowed to adapt the animal to a particular objective through breeding programmes? And, in the latter case, how do we assess the acceptability of specific adaptations?'

In 2004, the United Kingdom published an advisory report[3] on the breeding of farm animals. In 2006, this was followed by a report on the breeding of companion animals.[4]

The most recent research reports on breeding and animal welfare are those by Wageningen University on selection for personality traits in breeding and by the *European Food Safety Authority* (EFSA) on the influence of genetic selection on the welfare of broiler chicks. Very few scientific reports have been published about horse breeding.

To illustrate the range of subjects covered, the following are some of the reports published in recent decades offering conclusions and recommendations on breeding in the various animal husbandry sectors:

- *Breeding amiable animals*, Wageningen University and Research, 2010
- *Scientific opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers,* European Food Safety Authority, 2010
- *Independent inquiry into dog breeding*, Bateson, 2010
- *Considerations in the breeding of pedigree dogs in the Netherlands* (in Dutch), Van Hagen, Raad van Beheer (Dutch Kennel Club), 2008
- *Identification and registration of companion animals* (in Dutch), RDA, 2008
- *History and future of the Gelderlander horse* (in Dutch), Royal Warmblood Studbook of the Netherlands (KWPN), 2008
- *Plan of action for the welfare of horses* (in Dutch), Industry Council on Horses, 2008
- *Societal aspects of intensive livestock farming* (in Dutch), Aequator, Ecorys, Witteveen +Bos, 2008
- *A plea to implement robustness into a breeding goal: poultry as an example,* Star et al., 2007
- *Promotion of rare Dutch breeds among hobby animal keepers* (in Dutch), Ministry of Agriculture, Nature and Food Quality, 2007
- *Shared concern: action plan* (in Dutch), Forum on the Welfare of Companion Animals, 2006
- *Report on the trading and breeding of dogs and cats* (in Dutch), Forum on the Welfare of Companion Animals, 2006
- *High productivity dairy cattle: limits to growth?* (in Dutch) Council on Animal Affairs, 2006
- *Sustainable farm animal breeding and reproduction*, FABRE Technology Platform, 2006
- *The future of rare farm animal breeds* (in Dutch), Ministry of Agriculture, Nature and Food Quality, 2005
- *Breeding policy for purebred cats* (in Dutch), Gubbels, SIOK Magazine, 2005
- *Policy memorandum on horse-keeping* (in Dutch), Industry Council on Horses, 2004
- *Breeding recreation animals I and II* (in Dutch), Council on Animal Affairs, 2002

[2] Hopster, H. en H. Komen (eds), 2008. *The value of animal welfare: towards socially accepted and economically viable animal husbandry. LNV/NWO Research Programme*

[3] Farm Animal Welfare Council, 2004. *FAWC report on the welfare implications of animal breeding and breeding technologies in commercial agriculture*

[4] Companion Animal Welfare Council, 2006. *Breeding and welfare in companion animals*

III.5 In summary: dilemmas and opportunities

Advisory reports and social and political debates have put a number of breeding-related dilemmas on the public agenda in recent decades. These relate mainly to inherited defects, inbreeding, exaggerated strains, surplus animals, one-sided breeding goals, and objectionable trade-offs between animal welfare and other interests such as economics and aesthetics. Another frequently mentioned problem is the lack of guidelines and the absence of transparency in the breeding of a variety of animal species. Finally, it must be recognized that for many species breeding means that undesired offspring are also born (called 'surplus animals'), which have no useful purpose in the form of animal feed or human foodstuffs. These animals are destroyed.

Examples of breeding-related harm to animal welfare

Because of the long-term selection of dairy cattle for high productivity, these animals now have an increased risk of udder and locomotion disorders and calving difficulties as side effects of strong selection for milk production traits.

Selection of pigs for large litter size and lean meat has led to a higher risk of piglet mortality[5] and animals with an insufficient thermoregulation capacity.

In broiler chickens, strong selection for rapid growth has led to a number of detrimental effects, including a more frequent occurrence of leg problems.

The exaggerated crop size bred into a number of pigeon breeds (the so-called 'blowers') forces some birds to constantly strain to keep balanced and not fall over.

In certain dog and cat breeds, brachycephalia (short snouts) in combination with a wide skull causes breathing and birthing problems.

Bubble eye goldfish have reduced vitality and an abnormally short lifespan. They also have poor vision and the eyes are extremely vulnerable.

Examples of breeding-related violations of animal integrity

Virtually all harmful (breed) characteristics are associated to some extent with a violation of the integrity of the animal. A good example of this is the open fontanel seen in Chihuahuas and Yorkshire terriers.

Bent tails on dogs and taillessness and hairlessness in dogs and cats are likewise signs of a violation of animal integrity. It is not always obvious whether or to what extent the tailless and bald animals themselves perceive their nakedness as a problem. However, mating pairs of completely tailless cats has been shown to produce severely deformed, unviable kittens. This also occurs, for example, when mating lop-eared cats (Scottish folds).

An infringement of animal integrity that some might view as welfare-enhancing is the blindness bred into a certain strain of chickens. In crowded housing conditions, these birds exhibit significantly less pecking behaviour than their sighted counterparts.

[5] Now more than 10%, according to Agrovision

Nonetheless, breeding presents opportunities as well. For instance, many breeders (including those of companion animals and hobby animals) contribute to maintaining biodiversity by conserving rare pet breeds and endangered animal species.

Likewise, breeding can contribute to the more efficient production of animal products by healthy animals. To achieve that goal the importance of selection for multiple characteristics is generally recognized (so-called ‘multi-trait selection’). Along these lines, various breeding organizations have developed breeding values for ‘health’, ‘welfare’ and ‘sustainability’; and they are studying possibilities for breeding more robust animals – i.e. animals with a higher resistance to disease. Research has also shown that breeding can contribute to reduce problems such as boar taint in pork, which could potentially eliminate the need to castrate pigs in the near future.

Advances in knowledge about animal genomes imply new opportunities as well. These advances allow the mutations responsible for inherited single-gene defects to be traced more rapidly, enabling breeders to detect carriers of a genetic defect and exclude them from breeding. For traits that are determined by multiple genes (most traits in animals), genomic information (markers) can be used to improve breeding value estimations. Breeding value estimates of young animals can be considerably improved with the use of markers (called ‘marker-assisted selection’ or ‘genomic selection’, depending on the number of markers used).

Possibilities to apply gene technology (genetic modification) to solve ethical dilemmas such as the killing of day-old roosters are currently being carefully explored. Nonetheless, utilization of genetic modification in animals raises many concerns.

IV Definitions

When discussing the breeding of animals, the terminology used can easily cause confusion. For example, ‘breeding’ to one person might mean only the selection of animals with the goal of bringing about a genetic change, while someone else might also understand it to mean ‘production of offspring’.

IV.1 Breeding

In the current opinion, ‘breeding’ is defined as *the selection and mating of animals by humans with the purpose of changing the characteristics of the next generation in such a way that they better correspond to a predetermined breeding goal*.

More succinctly, breeding is a coordinated effort to produce a next generation of animals that meets a predefined goal. A ‘breeding programme’ -- including both the goal of breeding and the means of its implementation -- is formulated by a group of breeders (a breed registry/studbook or breed club) and is implemented by individual breeders. The goal of breeding is typically to maintain a population, possibly in combination with changing certain characteristics of that population through the selection and mating of animals.

The execution of a breeding programme is an interplay between, on one hand, individual breeders and, on the other hand, a breed registry/studbook, breed club or breeding organization. Besides these actors, other service suppliers may be involved, such as experts in reproductive technologies (e.g. artificial insemination and embryo transfer). The structure of the breeding sector, and with it the roles of the various stakeholders, varies widely from species to species. **Box 1** looks at some of these terms in more detail.

IV.2 Breeding programme

The goal of breeding is formulated at the level of a population. But to achieve the desired changes, choices are made at the level of individual animals: which animals are to be selected as parents for the next generation, and which animals are to be mated with one another? These choices have repercussions not only for the animals that are or are not selected as breeding stock, but also for the offspring. A breeding programme can be said to consist of five steps:

1. An <u>analysis</u> is carried out of the purposes for which the animals will be kept, husbandry conditions and the desires of users; i.e. what demands will be made of the animals, given any foreseeable changes in husbandry circumstances and conditions in future generations?
2. Based on that analysis, the <u>breeding goal</u> is defined.
3. Animals that are eligible as candidates for selection as parents are genetically evaluated; in other words, estimations are made of the breeding values of the animals in the population.
4. A <u>selection</u> is made of parent animals for the next generation, based on the breeding value estimates.
5. A breeding schedule is drawn up and <u>matings</u> are performed.

Appendix A looks at these steps in greater detail. **Box 2** presents an overview of the population structure of some key animal species in the Netherlands.

Reproductive technologies can make major contributions to a breeding programme. For example, artificial insemination (AI) has enabled progeny testing of bulls to be introduced for dairy cattle. This has meant that the breeding value of bulls can now be estimated with much improved accuracy. Application of embryo transfer can increase the chance of a bull calf being born out of a certain bull dam. Moreover, the use of AI enables genetic material to be rapidly disseminated throughout a population. Yet at the same time, AI may lead to an undesirable reduction of the number of sires used, which increases the risk of inbreeding.

Box 1: Breeders and their associations

A **breeder** is an individual animal keeper who selects animals and mates them for the purpose of producing offspring. Breeders are often private animal owners with just a few animals, as is typically the case in the breeding of dogs and horses. However, breeders may also be large, multinational enterprises, such as Aviagen and ISA in the poultry branch. In most cases the breeder owns the female animals, but not generally the male animals. The breeder selects from male animals belonging to others (when natural mating is used) or from sperm (when artificial insemination is used) derived from males owned by another breeder or breeding organization. Breeders seek to improve their own animals through selection and targeted mating of female animals.

To modify a population, breeders have to work together. Breeders are typically organized in associations, such as breed registries, studbooks, breeding organizations and breed clubs. These partnerships are essential for making and implementing breeding programme. Within these associations, members agree on the desired direction of population development, the role of individual breeders and the sharing of genetic material.

In **dairy cattle** breeding organizations play a major role in bull selection and therefore in determining the genetic make-up of the population. The breeding organization selects from the population bulls with a high breeding value (or genetic value) for the breeding goal. The breeding value is determined based on progeny testing. Only the very best animals are selected as breeding bulls. Livestock farmers (breeders) can utilize the semen of breeding bulls from various breeding organizations on their farm. In doing so, they can modify the genetic make-up of their own herd. In addition, a breeder can contribute to the improvement of the entire population by selling female animals, and even more so, by producing a breeding bull.

In laying hens the breeding organization owns both the female and the male animals in the purebred lines. These organizations' breeding programmes are aimed at genetic improvement of the purebred lines. In this case, the breeding organization is then also the breeder. The breeding organization sells crossbred hens and roosters to poultry farmers (multipliers). Poultry farmers mate these animals to produce offspring, which they then use for egg or meat production. According to the definition presented earlier, these poultry farmers are breeders too, since they produce offspring. But the animals produced by these breeders do not contribute to the genetic improvement of the population as a whole, because that is dependent on the selection done in the purebred lines.

Only breeders who exchange no genetic material with other breeders – such as the large poultry breeding companies – can implement a breeding programme entirely on their own. All other breeders are dependent to some extent on other breeders (often organised in breeding associations) to implement their breeding programme. Dairy farmers, for example, can decide for themselves which bulls to use to fertilize their cows, but their choice is limited by the assortment of bulls on offer by the AI organizations. Another example is that of dog breeders. While they can choose for themselves which male to mate with their females, they are nonetheless strongly dependent on which stud dogs are being offered by other breeders – and on the information that these breeders provide.

Box 2: Overview of population structures

	Use of crossings	Open breed registry/ studbook	Registration of descendants	Registration of performance	Number of breeders (4)	Reproductive technologies applied	Breeding goal (5)
Dairy cattle	+	++ (3)	+++	+++	4 (2)	AI (95%) ET (<1%)	+++
Beef cattle (8)	+	++	++	+	>100	AI	++
Laying hens	+++ (6)	+ (3)	++(1)	++	1	AI on breeding farm	+++
Broiler chickens/ turkeys	+++ (6)	+ (3)	++ (1)	++	1/0	AI on breeding farm	+++
Pigs	+++ (6)	+ (3)	++(1)	++	2	AI	+++
Hobby animals	+	+	+	+	>1000		++
Horses	+	+	+++	++	>100	AI	++
Dogs	0 (7)	+	+		>100		+
Cats	0 (7)	+	+		>100		+

0 = no
\+ = moderate/occasional
++ = regular/often
+++ = structural

(1) Registration of descendants and performance of animals in purebred line and to a lesser extent in crossbred animals
(2) Breeding organizations own bulls, from which sperm is made available to livestock farmers. Dairy cows are the property of farmers
(3) Farmers can also access material from organizations outside of the Netherlands
(4) Breeders based in and active in the Netherlands. For dairy cattle and pigs, this number refers to owners of male breeding stock. The number of owners of female breeding stock is much larger
(5) Is there a clearly defined and formulated breeding goal for the population? 0 = 'scarcely' +++ = 'yes, it is very much in evidence'
(6) In pigs and poultry, animals from different lines are systematically crossed to produce stock for farm operations. In other animal species, crossing is applied only occasionally
(7) This refers to breed clubs that do not sanction crossings with other breeds
(8) Most of the breeding material for beef cattle in the Netherlands originates from abroad (particularly through the import of sperm)

IV.4 Reproductive technologies

IV.4.1 Overview

A variety of reproductive technologies are being used in animal breeding and reproduction. Chapter VI outlines in more detail how the ethics of such applications can be assessed. This section introduces some of the techniques and the issues they raise. **Box 3** presents an overview of which reproductive technologies are being used on which animal species in the Netherlands.

Before an ethical assessment can be made of the use of a reproductive technology on an animal, it is first necessary to know how much discomfort the technology being considered would cause the animal, whether it would impair the animal's natural behaviour, and whether it would violate the animal's integrity. Of course, this applies mainly to the parent animal, but it is relevant to the offspring as well.

Box 3: Reproductive technologies in the Netherlands

	Technology	Cattle	Sheep/ goats	Pigs	Chickens/ turkey	Aqua-culture (1)	Horses	Dogs	Cats
REPRODUCTI ON	Artificial insemination	+++	+	+++	+++	+	++	+	—
	Embryo transfer + IVF	+	X	+	—		—	—	—
	Embryo transfer + super ovulation	++	X	+	—		+	—	—
SELECTION	Cloning	X	X	X	X	X	X	X	X
	Sperm sexing	+	+	-	—		?	+	—
	Marker-assisted selection	++	+	++	++		+	+	—
ASSISTANCE	Oestrus synchronization	+	+	+++	—?	+	+	—	—
	Parturition induction	+	+	+++	—		—	+	+
	Ovum pick-up (OPU)	+	?	+	—		+	—	—
	Semen collection	+++	+	+++	+++	+	++	+	—
	Electro-ejaculation	X	X	X	X	X	X	X	X

Use

+	occasional	? unknown
++	moderate	— not used
+++	routine	X prohibited in NL

(1): This overview is limited to the most common reproductive technologies that are applied on multiple animal species in the Netherlands. The Council is aware that in aquaculture, certain other reproductive technologies are used

IV.4.2 Additional remarks

In assessing the ethics of reproductive technologies, aspects must sometimes be considered that go beyond any possible violation of the animal's immediate welfare and integrity. It is useful here to mention some of the technologies used and the benefits and ethical concerns associated with them.

a. Artificial insemination (AI)

AI was developed in the middle of the 20th century as a technology to combat the spread of sexually transmitted diseases (STDs) in animals. In that regard, it has turned out to be extremely effective. The spread of other infectious diseases has been reduced as well, because AI has meant that much less movement of animals is required, both within farm operations and over long distances and internationally.

With the use of AI, a single male animal can have a much larger influence on a population than with the use of natural mating. Therefore, AI has had a very significant effect in terms of improving the genetic make-up of farm animal populations. At the same time, however, the large-scale use of a single sire increases the risk of inbreeding.

Both AI and natural mating are used in the breeding of broiler chickens. In turkey breeding, AI has become indispensable, because the toms are so large and heavy that they would cause serious harm to the hens in natural mating.

b. Semen collection

Semen can be obtained by means of pseudo-coitus (using a breeding mount with an artificial vagina for cattle, horses, pigs and rabbits, and by manually induced ejaculation in poultry and dogs). This technology is necessary for AI, in vitro fertilization (IVF) and sperm sexing.

To harvest sperm from catfish (milt) the male animal is sacrificed, which is to say: killed.

c. Sperm sexing

In mammals the sire determines the sex of the offspring. Using various sorting technologies it is now possible to select, with reasonable certainty, sperm that will conceive male or female offspring. The success rate can be up to 90%. However, sperm sexing causes a loss of 60-70% of the fertile sperm cells. Moreover, the fertility of the sexed sperm is slightly less than that of unsorted sperm.

Sperm sexing cannot be used on birds, because in these animals it is the mother that determines the sex of the offspring.

d. Cloning

A clone is a genetically identical copy of an individual. The technology is being applied on a limited scale abroad on sheep, horses, cattle and dogs. The best-known clone was the sheep named ‘Dolly’. A French laboratory cloned a male horse that excelled in sports but had been gelded. The benefits of cloning farm livestock appear limited as yet.

Cloning leads to a significantly higher incidence of foetal deformity and abortions. Further, if applied on a very large scale, cloning would produce a genetically uniform population. Under such circumstances, genetically determined susceptibility to, say, a certain pathogen could no longer be bred out.

Cloning may also lower the threshold for genetic modification of animals. At present, genetic modification is still at too experimental a stage to play a role in breeding, but the combination of genetic modification and cloning is nonetheless considered promising for the production of certain medicines in the future. For use in animal production, not only are the technical problems an issue, but the ethical objections associated with this technology are still much too great. In the Netherlands cloning is prohibited by law.

e. Induction of parturition

By administering certain hormones, parturition (birthing) can be brought on in animals. This is typically done in the final days of pregnancy when the foetus is fully mature. Induction of parturition earlier is called abortion. Abortion and inducement of parturition can be indicated for medical reasons, but are often employed for commercial purposes as well. For example, in the Netherlands the planning systems used by pig farmers routinely call for inducement of parturition. The necessary hormone injections may be administered by either a veterinarian or by the farmer (similar to distribution category POM-VPS).

IV.5 Genetic technologies

In recent years, there has been a dramatic increase in the use of marker-assisted selection (MAS) – also known as ‘genomic selection’ (GS). With this technology, a statistical link between certain ‘markers’ on the genome and genetic specific traits is exploited to more accurately predict the breeding value of animals. In only a very few cases (monogenetic traits), however, has a causal link been established between marker and trait. In most cases, the genes contributing to genetic variation are largely unknown and are being investigated using markers.

Use of MAS or GS could enable breeders to more accurately estimate the breeding value of animals at a younger age. Dairy cattle breeders used to have to wait for the evaluation of the performance of a young bull's descendants before the breeding value of the bull can be accurately estimate. Accurate breeding value is required before a bull is widely used as a breeding bull. That process took years. Now, thanks to GS, bulls can be evaluated at just one year of age. Estimations of breeding values based on markers (the GS breeding value) are less accurate than those e based on progeny testing. However, the time advantage easily outweighs this disadvantage – with GS the required information is available three years earlier. Targeted 'selection' using GS enables breeders to select in a more deliberate, and thus more efficient, manner than progeny testing.

Markers can also be used to trace carriers of (monogenetic) hereditary defects among animals that display no signs of the defect. These animals can then be excluded as parents, or mated only with non-carriers. In the latter case, they could at worst produce new carriers, not sufferers of the defect. A major benefit of their participation in the reproductive process is their contribution to reducing inbreeding.

V Ethical considerations

In breeding we do something to animals to serve the interests of people. We select animals to produce – with or without the use of certain technologies – a next generation that is better suited to a goal that we humans have defined.

V.1 Side effects

Genetically speaking, we select certain genes at the expense of others, by which the 'nature of the beast' is (sometimes drastically) altered over the course of generations. This is sometimes in the interest of the involved animals. But that is by no means always the case, as illustrated by the following examples of (undesirable) effects of breeding on animal behaviour and their physiological adaptation:

- Modern laying hens have fewer broody periods.
- Many highly productive Holstein cattle show few signs of oestrus.
- Strong selection for litter size in pigs has led to the birth of more weaker piglets and higher piglet mortality.
- Broiler chicken breeding stock suffers constant hunger because they cannot be fed to appetite.
- English bull dogs are conceived using AI and have to be born by caesarean section.
- Inbreeding rate increases of more than 1% per generation are common in some rare breeds due to breeding with small, closed populations.

These examples clearly demonstrate the ethical concerns associated with breeding, especially if we look closely at the affected animals. A related issue is what happens to the animals that do not meet the predefined breeding goal: the so-called 'surplus' animals.

A later section will examine a few concrete examples and reproductive technologies in more detail, but first the Council would like to offer a number of more general and principled considerations in the light of which concrete issues can be assessed.

V.2 Ethics

Animals have been used to serve the interests of people since time immemorial. This is a given in our culture, although it means that the interests of animals might clash with those of humans. Another given in our culture is that we place the interests of humans above those of the animal, at least when it comes to health and well-being.[6]

Therefore, in our cultural context this opinion addresses the question of when and for what purpose we may use animals, and at what cost. In other words, and with specific reference to breeding, the basic ethical question reads as follows: *How far may we go in adapting animals to suit our needs and interests?*

V.2.1 Intrinsic value

The justification for this question lies in the fact that we in our culture are increasingly aware that an animal has not only a utilitarian value, but also an 'intrinsic value', that is, a value in and of itself independent of any possible use to humans. This awareness has gained currency slowly but surely among wider and wider segments of society, especially since the 19th century, largely under the influence of animal-protection movements. Ultimately, many Western countries have translated this awareness into public policy. In the Netherlands, this process led to the issuance in 1981 of the *Memorandum on Animal Welfare*, which recognizes the intrinsic value of the animal as a cornerstone of policy on human-animal interactions. This viewpoint was further formalized in the *Experiments on Animals Act*, the *Animal Health and Welfare Act* and in the *Flora and Fauna Act*.

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[6] In its opinion *Moral Issues and Public Policy on Animals* (2010) the Council delves deeper into the three fundamental ethical questions raised by animal keeping in the Netherlands.

V.2.2 Sustainability

A second policy cornerstone that warrants mentioning is sustainability. The concept of sustainability was introduced in 1987 by the Brundtland Commission in the UN report *Our Common Future.* It has since come to play an increasingly important role in international and national debate. In very general terms, 'sustainability' states that meeting the needs of the present may not compromise the ability of future generations to meet their needs. This is usually operationalized in a pursuit of a balance between 'People', 'Planet' and 'Profit'. A key point of departure of national policy in the Netherlands is 'integral sustainability'. For example, one Dutch policy objective is that by 2023, livestock farming in its entirety should be 'integrally sustainable'. Sustainability is defined here as 'producing with respect for people, animals and the environment' (so including animal welfare).

V.2.3 Biodiversity

Sustainability goes hand in hand with the concept of 'biodiversity conservation', which is the third policy cornerstone and includes both the diversity of plant and animal species and the diversity of ecosystems, alongside their protection and preservation. Biodiversity's close link to sustainability is demonstrated by the Convention on Biological Diversity, which was formulated in Rio de Janeiro in 1992. Obviously, these concepts are much more widely applicable than just human-animal interactions, but they are certainly relevant in this regard.

Biodiversity is usually understood to mean the Earth's species richness, though it also covers genetic variation within a species, as reflected in different breeds, and the genetic variation found within breeds. Indeed, natural selection and domestication have produced a wide range of animal species, and breeds within these species, each adapted to specific environmental conditions. In natural selection, species that are insufficiently adapted die out. Yet because conditions can change, it is vital to preserve a range of species – and thus a variety of genetic traits – at the global level, so that animal species can continue to adapt to their surroundings through natural selection.

'Inbreeding', that is, the production of offspring by mating animals that are closely related to one another, reduces the genetic variation within the offspring – and ultimately also within the breed. For breeding – which is to say, artificial selection – it is vital that there is genetic variation within a breed. After all, without genetic variation there is nothing left to select, nothing left to change. Inbreeding is also deliberately employed by some breeders to 'fix' certain genetic traits in the genome. Usually, however, breeding programmes aim to limit any increase in inbreeding, by excluding matings of animals that are close kin to one another.

V.2.4 Moral responsibility

A final policy cornerstone is that breeders, reproduction experts, administrators, chain actors, buyers and other actors can be called on to act to fulfil their (moral) responsibilities. The Council's 2009 opinion *Responsible Animal Keeping* examines the division of roles and responsibilities among animal keepers, government and other parties involved in protecting the health and welfare of captive animals. Among the Council's recommendations in that opinion is that those who have responsibilities associated with animal welfare should be able to justify their actions and activities to society.

The division of responsibilities sketched in *Responsible Animal Keeping* also forms the basis of the recommendations presented in chapter VII of the current opinion.

V.2.5 *Bioethical principles*

Alongside these four cornerstones, several other bioethical principles are important in relation to breeding and reproductive technologies. They are derived from human bioethics,[7] but can be similarly applied *mutatis mutandis* in other contexts involving living organisms.[8] These are (1) the age-old principle of no-harm (*primum non nocere*), (2) beneficence (i.e. provide good care) and (3) respect for species-specific behaviour (the identity of the animal).

The ideal of animal ethics can be defined, again *mutatis mutandis,* by employing the classical formulation of the ideal image of humanity: *anima sana in corpore sano* (a healthy mind in a healthy body).

V.3 Assessment model

Assuming recognition of the intrinsic value of the animal and the importance of sustainability and biodiversity, in light of the abovementioned bioethical principles and keeping in mind the responsibilities of e.g. breeders, consumers and the government, it is obvious that in breeding ethical assessments have to be made. This is also clearly demonstrated in the dilemmas and opportunities described in chapter III. The question then is how such a process of assessment can be implemented in practice.

Now, assessing ethical concerns in human-animal interactions is not new, so there is no need here to start from scratch. As early as 1992, a provisional ethical review committee was established on the genetic modification of animals in the context of the *Animal Health and Welfare Act*. That committee mainly examined questions related to Herman the bull.[9] In 1997, it was followed by the Committee on Animal Biotechnology. One of that committee's tasks was to advise the Minister of Agriculture on requests for permits to conduct biotechnological procedures on animals. The committee was to determine whether proposed procedures could have unacceptable consequences for the health and welfare of the affected animals and whether other ethical objections could be raised against the procedures.

To further the committee's work, several ethicists wrote *Assessing Biotechnological Procedures on Animals* in 1996, which proposed a five-step evaluation framework for animal biotechnology. After some revision and refinement, the Committee on Animal Biotechnology adopted the framework for use in evaluating requests for permits in the field of animal biotechnology.

In part in the interest of policy consistency, the Council investigated the extent to which that evaluation framework could be used in designing a model for assessing the ethical and societal concerns raised by breeding. In this regard, it is worthwhile to state clearly from the start that breeding does not fall under the precautionary 'no, unless…' rule (prohibiting a procedure unless permission for it is explicitly granted); rather for breeding the 'yes, if…' principle applies (allowing procedures as long as certain minimum conditions are met) – except when it comes to biotechnology.

[7] Beauchamp, T.L. & Childress, J.F., *Principles of Biomedical Ethics.* Oxford (Oxford University Press), 2001

[8] See e.g. Mepham, B., 'Ethical Analysis of Food Biotechnologies: An Evaluative Framework'. In: B. Mepham (ed.), *Food Ethics*. London (Routledge) 1996, pp. 101-119

[9] Officially this concerned the research proposal 'Tissue-specific expression of genes in the mammary glands of genetically modified cows' which was part of a research project implemented in a cooperative effort by Gene Pharming Europe, B.V. and the Institute for Cattle Production Research of the Dutch Agricultural Research Service (IVO-DLO).

The backbone of the ethical review procedure used by the Committee on Animal Biotechnology to assess a (research) proposal in which modern biotechnology is to be used is made up of five steps:

1. What is the importance of the proposed research? Is that importance considerable or minor? Though the end cannot justify the means, it is a crucial aspect of any ethical evaluation.
2. Are there real alternatives to the biotechnological procedure to achieve the goal? This question is certainly relevant in the framework of the 'no, unless...' rule that applies to genetic modification, but it is also of interest in considering the so-called 'three Rs' in animal use: replacement, refinement and reduction.
3. What harm is expected to the health and welfare of the affected animals? This question stems directly from the passage in the *Animal Health and Welfare Act* that states that no permit may be granted if unacceptable harm is inflicted on the health and welfare of the animals concerned. Moreover, in relation to the bioethical considerations set out earlier, it follows from the principles of 'no harm' and 'beneficence'.
4. To what extent is the integrity of the affected animals violated? The meaning and applicability of this criterion has been the subject of frequent probing discussions within the Committee on Animal Biotechnology. These have led to its operationalization in terms of the effects of the biotechnological procedures on the appearance, behaviour, independence and susceptibility to diseases and disorders of the affected animals.
5. Final assessment: After answering the first four questions, does the importance of the research weigh up against the harm inflicted on the animals affected?

If this evaluation framework were 'translated' into an assessment model for breeding, it would look something like the following:

1. What is the goal of the proposed breeding programme,[10] and what is its importance? The question of the need for the programme also has to be considered here.
2. Are there real alternatives for breeding to achieve the goals defined?
3. Will the breeding programme harm the health and welfare of the affected animals, including in addition to the parent animals, any potential offspring?
4. Will the breeding programme lead to a violation of the integrity of animals, and if so, to what degree?
5. Final assessment: After answering the first four questions, does the importance of the research weigh up against the harm inflicted on the animals affected?

To evaluate the desirability and acceptability of the use of (certain) reproductive technologies on animals, a similar assessment model could be envisioned.

1. What is the importance of the proposed reproductive technology and of the result sought with its application? Here again, the need for the procedure must be considered.
2. Are there real alternatives to achieve the same reproductive output?
3. Will the use of this reproductive technology harm the health and welfare of the affected animals, including in addition to the parent animals, any potential offspring?
4. Will the use of this reproductive technology lead to a violation of the integrity of animals?
5. Final assessment: After answering the first four questions, does the importance of the use of this reproductive technology weigh up against the harm inflicted on the animals affected?

[10] This would also be translatable as 'the breeding goal and the way in which one hopes to achieve this goal'.

Because the use of artificial reproductive technologies is an inextricable part of animal breeding, both assessment models can be integrated into a single *Assessment Model for Breeding and Reproductive Technologies.* The Council, moreover, speaks of an 'assessment model', because the goal is to design a model for use in the assessments that e.g. breeders themselves make, whereas the 'evaluation framework' of the Committee on Animal Biotechnology was expressly designed as a tool for reviews done by a third party (the committee).

After this translation it is important to examine whether assessment criteria are missing and whether the use of such a model is even feasible in assessing breeding programmes and goals and particular applications of reproductive technologies. In actuality, the question of workability can be answered only through practice, but the experiences of the Committee on Animal Biotechnology suggest that an affirmative answer is likely. Given current developments in breeding and in reproductive technologies, the questions contained in this assessment framework can certainly be viewed as relevant.

Regarding assessment criteria that may be missing, the Council suggests four elements that need to be added.

First, in its preliminary form, the model contains no question about the achievability of the envisaged breeding goal or reproductive technology, particularly in relation to the time factor and possible alternatives. These considerations can be integrated into the assessment model as steps 2 and 3 with the following questions:

2. How achievable is the proposed breeding goal or reproductive output, within a reasonable time frame of, say, ten years?
3. Are there real alternatives for achieving the breeding goal or reproductive output?

Second, public health considerations have a rightful place in the assessment framework, though evaluating these might be left to the Food and Consumer Product Safety Authority. The Council adds this step to the assessment model for the time being, though recognizing that it will by no means be applicable to all cases.

Third, the effect on biodiversity has to be incorporated as a separate consideration. This is not limited to biodiversity at the level of the animal population, which is to say, the conservation of sufficient genetic variation within a population, but it also extends to the ecological level, meaning the conservation of adequate species variety.

Finally, every assessment in breeding has to start with a study of the current situation. This analysis will be important for answering the question of whether a breeding programme may or may not be commenced. In other words, does the *status quo* within a certain animal population provide cause for establishing a breeding programme? The socio-economic context must also be brought in here. After all, an ethical assessment like the one outlined here cannot take place in a vacuum. Substantial interests are often at stake. It is essential to be transparent about these.

In the opinion *Moral Issues and Public Policy on Animals,* the Council sketched an assessment model for transparently and consistently weighing the interests involved in policy formulation related to animals. If we apply that model to issues raised by breeding and the use of reproductive technologies on animals, we arrive at an ***integrated assessment model for animal breeding and reproductive technologies on animals*** such as that presented on page 25.

The questions in the assessment model will not all appear equally relevant to each and every case. Nonetheless, the Council believes that it is important to consider each of the questions in every assessment carried out, as this will ensure that each assessment draws out complete and consistent insights on the responsibilities of all the actors concerned.

Obviously, it is not enough to just assess the issues at stake. Assessments must always be seen in light of their underlying objectives. In chapter VII the Council identifies what those objectives should be. Moreover, assessments must lead to action – and not be confined to a rote exercise.

With the assessment model, the Council seeks to activate a transformation in culture and behaviour. To achieve such a transformation it is essential that the assessment model be consistent with practice. A final challenge will be for the actors involved to start to work with the assessment model *con amore* – that is, proactively and enthusiastically. Only then can the model's workability be tested and, based on experience, adapted and expanded where needed. The Council advises starting this process by setting up pilot applications involving all relevant parties and distributed over a number of animal husbandry sectors.

‘Ethical assessment’
Breeding and reproductive technologies

Based on:

Public morals

Broadly supported and based on:

- Intuition (e.g. animal welfare concerns)
- Principles (e.g. animal welfare is morally important)
- Facts (e.g. on inherited defects)

and

Scientific knowledge
(current and relevant)

- *Animal welfare, including animal health*
- *heritability*
- *reproduction*
- *breeding programmes*
- *human-animal relations*
- *animal vs. environment*
- *ethics (intrinsic value, integrity)*

interests are weighed.

Basic moral question

Specific questions:

1. Based on an analysis of the *status quo* of the animal population of interest, and considering all social, economic and other arguments, why should a breeding programme be started?
2. What is the intended objective of the breeding programme or reproductive technology, and why is it important and necessary?
3. How feasible is the formulated breeding goal or reproductive output within ten years?
4. Are there realistic alternatives for achieving the intended objective?
5. Will the breeding programme or reproductive technology harm the health or welfare of the affected animals, including besides the parent animals any potential offspring? Or could it perhaps contribute to improve an existing adverse situation in the targeted area?
6. Will the breeding programme or reproductive technology violate the integrity of the affected animals? Or could it contribute to improve an existing adverse situation in the targeted area?
7. Does the breeding programme or reproductive technology pose any risks to public health? If so, how are these to be managed?
8. Does the breeding programme or reproductive technology pose any risks to biodiversity? If so, how are these to be managed?

A final assessment of all issues that come up in answer to these specific questions should lead to an answer to the underlying question: does the importance of the breeding programme or reproductive technology outweigh the (possible) harm?

VI Elements of the Assessment Model

In the assessment model, the welfare, health and integrity of the animal are weighed against other interests. Before putting these issues on the balance, however, the terminology used has to be defined with a degree of precision.

VI.1 Measurement of animal welfare

An animal is in a good state of welfare if it is capable of adapting to its living environment and achieving a state of being that it perceives as positive.[11]

Regulations that narrowly prescribe minimum standards for an animal's living environment (required square metres per animal, mesh size on cages, lighting regimes, feed, etc.) cannot guarantee that an animal perceives its condition as positive. After all, animals with different inherited traits, fostered and raised in a wide variety of conditions, are unlikely to experience the same well-being even when living in the exact same setting. Likewise, individuals, breeds and strains can differ markedly in the demands they make of their environment and in the way they adapt to their surroundings. For example, a Siberian Husky will be significantly less comfortable in very hot weather than a Rhodesian Ridgeback.

For that reason, any claims made about the welfare of animals have to be based on signals, characteristics and behaviours of the animal itself (the 'output' of the animal) and not be derived only from aspects of the husbandry conditions (the 'input'). Researchers and policymakers have become aware of this and are now focusing less on input or design variables, in favour of output or performance indicators. The aim of the European *Welfare Quality* project is to stimulate a significant step in this direction.

An additional concern in defining performance indicators is that performance not be measured exclusively in terms of the *absence* of violations of welfare, but that the repertoire also includes the positive element of species-specific behaviour that contributes to a good state of well-being for the animal.

VI.2 Breeding and animal welfare

Breeding-related performance indicators of animal well-being can be grouped in the following categories based on differences in uncertainty/reliability:

1) Harmful morphological and functional hereditary defects;
2) Risks of welfare loss due to exaggerated inbred traits and/or one-sided selection;
3) Risks of welfare loss due to differences between the selection environment and the use environment;
4) Violation of the integrity of the animal.

Performance indicators for animal welfare can be broadly divided into three categories:

1) Indicators of physical health and vitality;
2) Indicators of behavioural and mental health;
3) Indicators of integrity.

VI.2.1 Indicators of physical health and vitality

Without resorting to abstractions, it is impossible to establish generic indicators of health, pain and functional disorders for the world's vast and richly varied range of animal species, breeds and breeding lines. This is easier to do per animal species, breed or crossing, though the emphasis will then usually be on *disorders* as a corollary of health. Due to the multiplicity of different disorders (for examples see chapter III, section III.5), a mosaic of tailored indicators is needed, targeted to the distinct characteristics of each of the many, very different products of breeding.

VI.2.2 Indicators of species-specific behaviour and mental health

Through natural selection, animals have evolved over millions of years into organisms equipped with behaviour that, given their natural living environment, best enables them

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[11] *"Dierenwelzijn" – De diergeneeskundige positie*, F. Ohl and L.J. Hellebrekers, *Tijdschrift voor Diergeneeskunde*, 134 (18), 15 September 2009

to pass on hereditary traits to future generations. In that respect, the time scale of domestication can be likened to just the blink of an eye. While modern breeding techniques have turned out to be highly effective in improving the characteristics targeted in breeding goals, the chance that basic (species-specific) behavioural needs have changed is nonetheless considered to be very small.[12] Where behavioural changes have been observed these have tended to be limited to differences in expression.

Any typology of behaviour into categories is arbitrary. Nevertheless, a typology that has proven useful for evaluating the behaviour and mental health of animals is that of Tembrock,[13] with four categories of behavioural needs:

1) Basic needs, necessary for survival;
2) Specific needs driven by morphology and physiology;
3) Needs originating in individual characteristics;
4) Learned needs, acquired from other individuals.

In discussing these needs, Tembrock introduced the so-called ‘functional cycles’ (from earlier work by Von Üxküll, 1926). The cycle begins when an animal reacts to an external or internal stimulus with a certain behaviour, thereby influencing its environment or internal processes and thus exerting an impact on the stimulus. With this, the cycle is completed. If functional cycles are disturbed or frustrated, abnormal behaviours arise (under-expression or over-expression, stereotypic behaviour, damaging actions) targeted towards the animal itself, its environment or species counterparts. Such abnormal behaviour can be viewed as a performance indicator for (a lack of) mental health[14] -- here again, it is easier to put the emphasis on reducing the negative rather than promoting the positive.

Examples of performance indicators for the welfare of broiler chicks

On the farm: mortality, feed conversion, rate of growth, food and water absorption, panting and spreading wings, shivering, lameness and gait score, spatial distribution of the birds, fear (avoidance, reactions to new objects), sand-bathing, qualitative behavioural evaluation

In the slaughter house: death at arrival, pre-stun shock and fluttering on the slaughter line, clinical diseases such as ascites, emaciation, dehydration, hepatitis, pericarditis, abscesses, sepsis, wing injuries and bruises, broken limbs, dislocation of the hip and other joints, carcass quality

On the farm and in the slaughter house: contact dermatitis (footpad burns, burning soles, breast blisters or burns), condition and cleanliness of feathers, skin damage and injuries, condition of eyes

Captive animals tend to be social animals that benefit from being kept in groups. Community living brings out certain social behaviours, towards both people and species counterparts, such as exploration and playfulness, caring behaviour, and maternal and sexual behaviour. For these behaviours too, defining performance indicators requires an individualized tailored approach, suited to each animal species examined.

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[12] See e.g. *The behaviour of pigs in a semi-natural environment*, Stolba A, Wood-Gush D.G.M. Animal Production 48, 419-425, 1989 and The Laboratory Rat: A Natural History, www.ratlife.org

[13] *Grundriß der Verhaltenswissenschaften. Eine Einfuhrung in die allgemeine Biologie des Verhaltens*, Tembrock, G. , 1980. Fischer Verlag, Jena.

[14] *Towards a general psychobiological theory of emotions*, Panksepp, J., 1982. Behavioral and Brain Sciences, 5, pp 407-422

VI.2.3 Indicators of integrity

When essential species traits have disappeared in an animal, the integrity of that animal is said to have been violated.[15] Virtually all harmful (breed) characteristics are to some extent associated with a violation of integrity. However, violations of integrity are also conceivable that do not lead to an immediate loss of well-being for the animal itself, such as blindness bred into a particular strain of chickens because these animals exhibit less feather-pecking behaviour.

VI.2.4 Calculations

Welfare losses can be calculated as the product of prevalence, incidence, severity and duration. This is the approach chosen in the analyses of animal suffering published by the Ministry of Agriculture.[16]

The RDA opinion *Breeding of Recreational Animals* (in Dutch, RDA 2002/03) and its underlying model for describing, characterizing and weighing welfare risks[17] adhere to similar basic principles and provide a useful baseline for characterizing and calculating harmful hereditary traits as follows:

1) Genetic background (is the trait recessive, dominant, familial, polygenic?);
2) Life expectancy (does the trait cause death at birth or in birthing, is it life-threatening in the short term, does it cause a chronic disorder with fatal consequences, does it require death by euthanasia, or is it non-life-threatening but cause a loss of vitality?);
3) Observable (is the trait directly and reliably observable, demonstrable with diagnostic instruments, or gradual and not-clearly defined?);
4) Prevalence (high>10%, medium 5-10%, limited 1-5%, low 0.1-1%, very low <0.1%);
5) Pain and/or impairment (is the trait very painful, very impairing/difficult, painful, impairing/difficult?);
6) Integrity (is the animal's integrity violated or not?);
7) Time of onset (does the trait emerge before birth, immediately after birth or during life?).

In the prioritization procedure developed, boundary values are established for the impairment scores for welfare, health and integrity with an estimation of the scale on which they occur. Based on the combined scores, a degree of urgency can be calculated for instituting ameliorative (breeding) measures. The RDA opinion *Breeding Recreation Animals* contains overviews of these scores per animal species and per breed.

The European Welfare Quality programme has developed, next to parameters for physical health, vitality and integrity, indicators for behavioural aspects as well – and with them indicators for mental well-being.

Similar considerations are being applied in systematic assessments of welfare risks such as those that the EFSA is carrying out with increasing regularity.[18] 'Risk assessment' is a systematic, scientifically based process to determine the probability of exposure to a threat and estimate the magnitude of the effects of that exposure. A 'threat to animal welfare' can be defined as a factor that could potentially adversely impact the well-being of animals. 'Risk' is a function of the likelihood that a threat will become a reality and the intensity and duration of any consequences.

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[15] *Ethics of farm animal breeding*, Sandøe et al., 2006. *Journal of Agricultural and Environmental Ethics*, 19:37–46.

[16] *Ongerief bij rundvee, varkens, pluimvee, nertsen en paarden: inventarisatie en prioritering en mogelijke oplossingsrichtingen,* Leenstra et al., Animal Sciences Group van Wageningen UR, Lelystad, 2007.

[17] *Fokken met recreatiedieren*, Netto, W.J., 1998.

[18] *Scientific Opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers*, EFSA, 2010.

VII Conclusions & Recommendations

In chapter III, the Council observed that the breeding of animals raises serious questions -- questions about the potential of breeding to achieve sustainability objectives and questions about the animal welfare dilemmas associated with breeding and reproductive technologies. In chapter V the Council observed that these questions are ethical ones. It also presented the *Assessment Model for Breeding and Reproductive Technologies* as a tool to structurally address the concerns surrounding breeding and the use of reproductive technologies.

In this chapter, the Council first sets out the framework within which breeding should be done. It then describes how the different parties are involved in breeding, before identifying areas where improvements can be made. To arrive at solutions, *best practices* are formulated and tools are offered for working towards them. The chapter closes with the recommendations: how should the actors involved work to solve the bottlenecks observed?

VII.1 Framework

The Council believes that breeding should be done within the following framework:

- Maintenance of vitality and physical health;
- Maintenance of species-specific behaviour and mental health;
- Maintenance of integrity;
- Maintenance of genetic diversity.

VII.2 Actors

Who has what influence on the breeding of animals?[19] First of all, obviously, are the breeders themselves. As animal keepers, breeders have primary responsibility for the welfare and health of the animals under their influence and care. Breeders who are members of a breed club or breed registry/studbook are obliged to abide by the current regulations of their respective organizations. Because the breed clubs and breed registries/studbooks influence the ‘room for manoeuvre’ that breeders have, they too share in the responsibility for the welfare of the animals bred under their auspices. The same is true for chain parties:[13] virtually all (products) of farm animals, as well as a large proportion of companion animals/pets, are purchased via a dealer, a re-seller or a retailer and not directly from the breeder. The government too is an important party, because it has final responsibility for the quality of life of animals in the Netherlands. Because production chains, in principle, produce what the buyer demands, consumers – those who purchase an animal or animal product – play a crucial, guiding role. However, the extent to which consumers are able and willing to fulfil this role is an open question.

VII.2.1 Breeders

The Council notes that breeders play distinctly different roles in the different animal husbandry sectors. For example, in livestock production, especially pig and poultry farming, breeding organizations are large, internationally operating enterprises that have a very important role; the part played by individual animal keepers is limited in these sectors. Breeders of companion animals, however, tend to be private animal keepers. Dairy cattle husbandry can be characterized as a hybrid form, with a few large breeding organizations owning the bulls and individual dairy farmers, each of whom establishes their own breeding policy for their farm operation. In horse and hobby animal husbandry, a broader range of degrees of organization and professionalism are found, depending on the animal species and breed.

The influence of breed registries and studbooks also differs markedly. For example, the Friesian horse studbook (KFPS) and the Dutch warm blood studbook (KWPN) both have a great deal of influence on the way animals are bred within their registry. But the governing board of the Dutch Kennel Club has repeatedly and unsuccessfully tried to

[19] In its opinion *Responsible Animal Keeping* (2009), the Council extensively discusses roles and responsibilities with respect to the welfare of captive animals.

establish a central policy for dog breeding. In cat breeding and in some hobby animal sectors there is very little central direction, much less central programmes being compulsory in nature.

VII.2.2 Government

There is also a considerable range in the influence of the government on breeding in the different animal husbandry sectors. It is doubtful whether the Netherlands government could exert any direct influence on the internationally operating breeding companies in the livestock industry.

Regarding national laws and regulations, we see that these pertain almost exclusively to farm animals (both commercial livestock and hobby animals) and to horses. With respect to companion animals, the Dutch *Dog and Cat Act* pertains exclusively to commercial breeders. The *European Convention for the Protection of Pet Animals* (1988), while containing a few sections on the breeding of companion animals, has not yet been ratified by the Netherlands (though it was signed).

VII.2.3 Consumers

Finally there is the consumer. Those who buy animals have a very direct influence on breeding, because they are the ones who set the market demand for particular species, breeds and types of animals.

Buyers of companion animals generally say they consider the health of an animal to be an important concern. The question, however, is whether buyers are sufficiently aware of the hereditary disorders that may occur in the species they are considering purchasing. The Dutch Pet Information Centre (LICG) recently began publishing such facts, among others, in ‘pet information leaflets’ which it produces on a large number of species.

We also have to ask ourselves whether buyers have sufficient knowledge to understand that certain (physical) characteristics can impair the welfare of an animal. And, even if they do have this awareness, will potential buyers be inclined to ask themselves whether their enjoyment weighs up against the harm done to the welfare of the animal concerned.

Buyers of animal products are much farther removed from the breeder: the actual breeding of, for example, pigs takes place all the way at the start of the production chain, while a shopper buying pork meat is all the way at the end of that chain. The choices open to the consumer are, moreover, strongly driven by retailers. Information provision also occurs largely via retailers, though non-governmental organizations are taking on a growing part of this role. In this regard, breeding-related issues can be seen as one aspect of the sustainability policies of retailers and food producers, in the context of the demands being placed on suppliers.

VII.3 Best practices

Past successes, while offering no guarantee for the future, can nonetheless point to ‘best practices’. Examples of these are the successful way the Royal Dutch Sport Horse studbook (KWPN) has combated certain hereditary defects and the way the Friesian horse studbook (KFPS) is working to restrict inbreeding. These successes appear to be partly attributable to the following conditions:

- The breeders, the studbook and buyers are aware of and have adequate knowledge about the problems caused by hereditary defects and inbreeding.
- Most breeders and the studbook association are prepared to tackle the problem in a structural way.
- For buyers, there is a clear added value of buying an animal with a studbook-registered pedigree.
- Malevolent breeders cannot produce recognized pedigree animals outside of the studbook, nor is it possible for them to start their own (parallel) studbook.

So there is awareness, knowledge and the determination to improve, in addition to market demand and adequate regulation for an independent approach.

VII.4 Areas for improvement

Chapter III provided a sketch of the ethical concerns that arise in animal breeding. Chapter IV described how a breeding programme is established and the key organizational features underlying the breeding of a variety of animal species. Chapters V and VI demonstrated that assessments are made – and how these can be carried out in a systematic and comprehensive way. Without the intention of ignoring the things that are already working well in breeding, the Council nonetheless would like to devote the next sections primarily to points on which improvements can be made in the breeding of different types of animals. Its subsequent recommendations will be based on these points.

VII.4.1 Horses

Much good can be said about current developments in horse breeding, but this does not mean that breeding programme in the horse sector is already managed as well as it possibly could be. The Council observes a number of points for improvement. First, identification and registration (I&R) for horses in the Netherlands is incomplete. I&R is complete – yet not up to date – for all animals listed in the studbook registry, but it is not fully applied for animals outside of the registries. This means an invisible shadow population is created for which there are no known records.

Selection against known hereditary defects in horse breeding is good, but the reporting of hereditary defects is not always ensured (e.g. reporting of bowed legs in Shetland ponies is patchy). Records of hereditary defects could also be made more transparent.

Finally, the Council commends the sector's transparency on its breeding goals. Nonetheless, it suggests that the arguments underlying the setting of these goals be made more systematic and transparent, preferably based on the proposed *Assessment Model for Breeding and Reproductive Technologies*.

VII.4.2 Farm animals

Information provision is generally very good within the various chains in the commercial livestock industry. However, there is room for improvement in the area of health and welfare indicators. Also, transparency to the outside world is quite varied. Yet the activities of breeders and livestock farmers can be rightly judged only if there is sufficient information and clarity on how animal welfare, economics and sustainability aspects are being weighed and what progress is being made towards advances in each of these areas.

Consumers are often barely aware of what happens in the breeding of commercial livestock. There is, moreover, a question of how aware consumers are of the role they could play in influencing the livestock industry, and the extent to which they are willing to take on this role. Non-governmental organizations, as representatives of citizens and consumers, have taken some steps towards fulfilling a larger part of this role.

Wholesalers and retailers play important roles as well: they determine the selection from which consumers make their purchasing decisions. For wholesalers and retailers, animal welfare is a theme that reputations could be built upon, for instance, a business might develop an advertising campaign around the sedated castration of piglets or responding to public outrage about cheap, industrially produced meat.

In the poultry and pig industries, and to a lesser extent in dairy farming, breeding is in the hands of large, internationally operating organizations (usually companies). Limited influence can be exerted on these enterprises from the Netherlands. There is a voluntary, international code of good practice for farm animal breeding (the EFABAR code), but not all breeding organizations have as yet implemented this. Moreover, Sandøe et al. assert in a 2005 ethics report on the EFABAR code that 'non-economic values' such as animal welfare, integrity and biodiversity cannot be entrusted to regulation by voluntary means.

VII.4.3 Hobby animals

Looking at the breeding of hobby animals, we find large differences in awareness and attitudes among breeders and in their level of organization via breed registries and studbooks. Here the art will be to stimulate the good and to fight the excesses. Some hobby animal breeders have made laudable contributions, for example, to conserving rare animal species and breeds – and with them biodiversity. Such efforts deserve support and emulation.

Identification and registration (I&R) of hobby animals is far from complete. This means that the monitoring of hereditary defects and inbreeding is limited to populations that are registered through clubs, breed registries and studbooks. If a registered population is too small, serious consideration should be given to whether breeding within that population is still responsible, in relation to the risk of a too-large increase in inbreeding per generation. Another problem in hobby animal breeding is that of 'surplus animals': (young) animals that do not have the desired appearance are killed.

VII.4.4 Companion animals

In companion animal breeding, buyers have a very direct influence: they determine the market demand for certain species, breeds and types of animals. Buyers of companion animals say that it is important for the purchased animal to be (and remain) healthy. Yet few buyers have the expertise to judge whether this is in fact the case in a particular animal. Besides, there is a growing market for animals with unusual characteristics, even when it is unclear the extent to which these impair the animal's well-being — and sometimes these obviously do harm welfare.

Information provision on inherited defects and welfare-diminishing characteristics in companion animals is fragmented and voluntary. The Dutch Pet Information Centre (LICG) recently began publishing such details in their 'pet information leaflets'. Nonetheless, there is no legal obligation compelling breeders and (re)sellers to provide information to potential buyers. Many consumers perceive no obvious, objective added value in an animal with a pedigree (in other words, an animal bred and documented within a formal breed registry). Therefore, a (large) market exists for companion animals bred under unknown, unregulated conditions.

Documentaries like *Pedigree Dogs Exposed* (BBC, 2008) demonstrate that some breeders view physical characteristics as more important than the welfare and integrity of their animals. Moreover, when animals with extreme (overstated) breed characteristics win at shows, the mind-set of their breeders is confirmed. This is applicable beyond dog breeding as well. Documentaries like this one have contributed to the awareness-raising process, helping to trigger attitude changes both among buyers and among breeders of companion animals.

An important issue in companion animal breeding is the absence of government guidelines and regulations, such as those that apply to horses and farm animals in the form of the *Breeding Act*. This means that anyone is free to set up a breed registry, without needing to provide any assurances whatsoever about animal health and welfare – and without any form of monitoring as well. Central control of breeding programme would therefore seem doomed from the start: those with malevolent intentions can easily side step guidelines by starting their own registry, beyond the reach of the central breeding programme.

Finally, it must be noted that a significant proportion of companion animals sold in the Netherlands (with the exception of dogs and cats) are bred abroad. The breeders of these animals therefore fall outside of the remit of the Netherlands government.

VII.5 Tools

There are a number of ways that the parties involved can fulfil their responsibility to work towards improvements in the areas mentioned. The 'best practices' observed in section VII.3 serve as a guide in this respect, as does the allocation of roles and responsibilities sketched by the Council in its opinion *Responsible Animal Keeping* (2009). The sections below look at some of the tools available.

VII.5.1 Assessment model

While not all of the steps of the proposed assessment model will be equally relevant to breeding in each and every animal husbandry sector, the model does pave the way for structured and comprehensive assessments that, moreover, build on the four cornerstones that underlie current policy on animals in the Netherlands. The explicit analysis and weighing of the current situation of a breed/species, the explication of the envisioned breeding programme, and the examination of available reproductive technologies, furthermore, should contribute to raise awareness and change attitudes among breeders, breeding organizations and consumers.

VII.5.2 Codes of conduct

Breeders and breeding organizations have primary responsibility for the health and welfare of the animals under their influence and care. It is up to them to demonstrate how they have fulfilled these responsibilities. This could be achieved by formalizing codes of conduct for endorsement – voluntary or otherwise – by individual breeders or breeders' organizations.

An example of such a code is the – voluntary – EFABAR code for farm animal breeders. The Netherlands' *Code on Farm Animals Kept as a Hobby and Not for Profit*, as well as the *Code of Good Sheep and Goat Husbandry*, also contain sections (albeit brief) on breeding.

A central breeding programme, like the one the Dutch Kennel Club is trying to establish for dog breeding, is another means of establishing a code of conduct at the branch level. If such a code were to guarantee responsible breeding, which is to say, healthy animals with good welfare produced by breeding, it could constitute an added value for buyers, who would then be stimulated to purchase an animal bred under the code of conduct.

Certification of professionalism in the companion animal industry should also include standards related to breeding. Private certification with flanking government policy has been envisioned to replace the *Dog and Cat Act*, providing an effective tool for ensuring professionalism among breeders and dealers of companion animals. Yet for the time being, collaboration on this between government and private parties appears to be floundering.

VII.5.3 Transparency

Those who bear responsibilities towards animals, must also account for and justify their execution of these. In the opinion *Responsible Animal Keeping* the Council recommended that animal keepers – initially at the sector level – regularly produce a social report on animal welfare and health. These reports could also contain a section about breeding.

Transparency to society would stimulate desired behaviour and make it more difficult to carry out undesired activities. Transparency within sectors -- for example, with compulsory reporting and registration of hereditary defects – would enable breeding programmes to be better designed and more effective. Transparency to consumers is necessary to put buyers in a position where they can make a conscious choice, by which they can live up to their role in guiding production chains.

VII.5.4 Laws and regulations

The government has final responsibility for the quality of life of animals in the Netherlands. That means, among other things, that the government must establish minimum standards for animal welfare and health, and it must erect a framework within which animal keepers (in this case, breeders) can fulfil their primary responsibility.

Laws and regulations are only as effective as their enforcement. So for areas where it is obvious from the start that enforcement is not feasible, other tools will have to be employed. One such tool is private certification, by which government supervision can be restricted to the monitoring of the certification system and carrying out individual supervision (preferably remunerated) of non-participants.

Government has a regulatory framework already in place, in the form of the *Breeding Act*. Remarkably, the *Breeding Act* is limited to farm livestock and horses; neither companion animals nor hobby poultry fall under its remit.

The government similarly has regulations in place for identification and registration (I&R) of farm livestock and horses. While I&R already covers virtually all animals in livestock farming, coverage is less complete for horses and hobby animals. Regarding companion animals, measures are under discussion for compulsory I&R of dogs. As it now stands, however, I&R will be effective only for new-born dogs as of 2011 or 2012.

I&R is, nonetheless, a key resource in the fight against hereditary defects in breeding.[20] An identification and registration system that is as complete as possible provides insights into a population, which can be used in implementing a breeding programme (e.g. to estimate breeding value and limit inbreeding) and for any management measure undertaken by a breed registry, studbook or chapter.

VII.6 Recommendations

First of all the Council has found that much has already been done. For example, at the international level a voluntary code of conduct has been established for farm animal breeding (the EFABAR code). In the Netherlands, a range of horse, sheep and goat breed registries and studbooks are very active in reducing inherited defects and inbreeding. In dog breeding, multiple efforts have been made to establish a central breeding programme.

At the same time, the Council observes that much remains to be improved. The concerns raised by breeding are not new, and even in areas where things are going relatively well, they could be better. To this end, the Council makes thirteen recommendations for breeders, government and consumers and for other involved parties.

VII.6.1 General

Breeding in a responsible, sustainable manner and using reproductive technologies responsibly calls for a clearer, more transparent means of weighing interests.

1. *The Assessment Model for Breeding and Reproductive Technologies should play a central role in the formulation of breeding programmes and in assessing uses of reproductive technologies on animals.*

But voluntary use of the assessment model is not enough. In part because animal welfare (in many cases) has no direct economic value, it is doubtful that market forces can be relied upon to guarantee animal welfare in breeding. This will certainly be the case as long as consumers lack a reliable way of ascertaining whether a breeder in fact breeds responsibly, in accordance with the assessment model.

VII.6.2 Breeders

Only breeders who exchange no genetic material with other breeders can establish and implement a breeding programme entirely on their own. All other breeders are dependent to some extent on other breeders (in fact, breeding associations) to achieve their breeding goals. Therefore, partnerships are required to make and implement breeding programme. Within these associations, agreements are made about the desired direction of population development, the role of the breeders and the sharing of genetic material.

[20] See the RDA opinion on the identification and registration of companion animals (In Dutch -- *Identificatie en Registratie van gezelschapsdieren,* 2008)

2. *Breeders must weigh the different interests affected by breeding in a transparent manner along the lines set out in the Assessment Model for Breeding and Reproductive Technologies. Such assessments are done at the level of the breed clubs and breeding organizations, because breeding by definition is an issue pertaining to a population in its entirety.*

Sharing information about a population is an essential part of implementing a comprehensive and responsible breeding programme. This information should be traceable to the level of the individual animal, so that inherited traits can be charted at the population level.

3. *All breeding organizations and breed clubs should make use of a central contact point (for reporting performance, inherited defects, etc.) in support of a central breeding programme and the monitoring, for example, of inbreeding and inherited disorders. Identification and registration of animals is a prerequisite for this.*

Breeders, breeding associations, registries and studbooks, as well as chain parties, must transparently demonstrate how they arrive at their decisions, how they are working towards the four priority areas – maintenance of vitality and physical health, maintenance of species-specific behaviour and mental health, maintenance of integrity, and maintenance of genetic diversity – and progress towards achieving these objectives.

4. *A section about breeding and reproductive technologies, preferably substantiated by performance indicators for animal welfare, health and integrity, should become a required part of the regular social reports on animal welfare and health produced by the different animal husbandry sectors.* [21]

Moreover, breed clubs and breeding associations should be required to proactively communicate their objectives to potential buyers. Breeding goals should preferably incorporate the four priority areas. A pedigree or studbook predicate would then constitute a guarantee of a healthy animal bred under good welfare conditions, giving buyers an opportunity to make a conscious purchasing decision. This way, animal welfare would become a market value.

Today, livestock farming in the Netherlands operates under a magnifying glass. The industry would therefore do well to safeguard its sustainability by incorporating the *Assessment Model for Breeding and Reproductive Technologies* into private certification systems and into the EFABAR code, which is now already being used in farm animal breeding.

5. *Breeders should make their breeding objectives known to their buyers and indicate how they are working to achieve these.*

In breeding, animals are also born that do not meet the established breeding target. These animals are selected out of the population: they are not bred further.

6. *Breeders should have a socially acceptable solution for dealing with these 'surplus' animals. After all, they are inherent to breeding.*

VII.6.3 Government

The government is the only party capable of creating the enabling conditions required for breeding programme to be successful in the various animal husbandry sectors. Among the conditions needed are compulsory identification and registration (I&R) of animals (at least for those species for which this is technically feasible and affordable), framework regulations for breed registries, studbooks and other breeding organizations (via the *Breeding Act*), and enactment of the legal prerequisites needed for private certification systems (with government supervision of the monitoring system for participants and individual remunerated monitoring of non-participants).

[21] See the RDA opinion *Responsible Animal Keeping* (2009), recommendation nr 27

7. *The government should establish the necessary regulatory framework and legal prerequisites for identification and registration of animals and for effective private quality assurance schemes in breeding and in the marketing of live animals.*

In the *Breeding Act*, the government has a good instrument in place to make the appropriate demands of breeding organizations and breed registries/studbooks. Most such demands will be general in nature, but these can nonetheless have an immediate positive impact on the quality of breeding. For example, standards can be set for minimum population sizes (to restrict inbreeding) and norms can be established for breeding programmes. A system by which breed clubs could be recognized only by an authority designated by the *Breeding Act* would ensure that malevolent breeders could no longer side step a central breeding programme by establishing a parallel breed registry.

The government should also promote transparency in the various animal husbandry sectors, for instance, by requiring regular submission of social reports on animal welfare and animal health. The Council recommended this in its previous opinion *Responsible Animal Keeping* as well. This transparency could be made mandatory via the *Breeding Act*.

8. *In the framework of the Breeding Act, the government must make sufficiently effective demands of all breeding organizations and breed registries/studbooks. In this regard, the purview of the Breeding Act should be expanded to include poultry and companion animals, starting with dogs and cats.*

In the European context, regulations exist or are in the make on the breeding of farm animals, including horses. The Dutch *Breeding Act* stems in part from those regulations. Yet European guidelines and ordinances deal mainly with animal health. The Council considers it desirable for the European rules to be expanded to encompass animal welfare and to include companion animals.

9. *The Council advises the government to ensure that guidelines on the breeding of all animal species are incorporated into a European Law on Animal Welfare. With this, however, the Council emphatically does not mean that law-making and regulation on breeding should take place exclusively at the European level.*

VII.6.4 Buyer and seller

Buyers of animals have a very direct influence on breeding because they determine the market demand for certain species, breeds and types of animals. People who are considering buying an animal should – by virtue of their responsibility as future animal keepers – acquaint themselves in advance of any welfare and health concerns related to the animal that they want to purchase.

Buyers of animal products are much farther removed from breeding: the actual breeding of, for example, pigs takes place all the way at the start of the production chain, while a shopper buying pork meat is all the way at the end of that chain. The choices open to the consumer are, moreover, strongly driven by retailers. Information provision similarly occurs largely via retailers, though non-governmental organizations also fulfil a growing part of this role. Ideally, a buyer of an animal product would make a well-informed, well-considered choice from a broad selection of products.

Transparency to consumers is necessary to ensure that buyers can make a conscious choice, by which they can live up to their role in guiding production chains.

10. *The buyer should be able to ascertain, via a quality or grade label or certification by a breed registry or studbook, that the animals – or animal products – they purchase come from a responsible, quality-assured breeder. As such, an added value is created in the market for responsible breeding.*

11. *Because the chain produces what the buyer demands, buyers make considered choices in their purchases. This is as applicable to the purchase of a live animal as it is to the purchase of an animal product. Sellers at the consumer end of the retail*

chain should provide buyers adequate and objective information and offer a broad enough range of selection.

VII.6.5 Other parties

Veterinarians and breeding support organizations have a role at two levels. The first is at the level of their professional organizations. These should take a proactive stand against abuses in breeding. Moreover, they should contribute their knowledge and expertise – whether solicited or not – to the improvement of breeding programme in the various animal husbandry sectors.

Individual veterinarian practitioners, along with inseminators, breeding advisers and pet shop managers have an awareness-raising task towards breeders as well as towards animal keepers (buyers). Society, moreover, expects professionals to refrain from taking part in breeding practices and using reproductive technologies that they recognize as unacceptably harming the welfare and health of animals. To evaluate these in a professional way, the *Assessment Model for Breeding and Reproductive Technologies* should be used as a guideline.

In light of the veterinarian's role in serving the public interest[22] and in view of the transparency required in animal keeping,[23] veterinarians, moreover, must make available to the government all relevant information on animal welfare and animal health -- for example, on prevention of genetic defects and routine caesarean births.

12. *Veterinarians and the other professional groups involved should utilize their knowledge and expertise to advance responsible breeding. They do this at the level of their professional organizations, among others, by actively contributing to political and societal debates. In their individual capacity, they inform animal keepers, (potential) buyers and government of relevant aspects of breeding and, obviously, they refrain from taking part in breeding practices that harm animal welfare and health.*

VII.6.6 From theory to practice

A final challenge will be for the actors involved to set to work with the assessment model *con amore* – that is, proactively and enthusiastically. Only then can the workability of the assessment model be tested and, based on experience, adapted and expanded where needed. The Council advises starting this process by setting up pilot applications involving all relevant parties and distributed over a number of animal husbandry sectors.

13. *To test and optimize the practical usefulness and effectiveness of the Assessment Model for Breeding and Reproductive Technologies, the government, science, relevant professional and societal organizations, and breeders should together set up pilot applications, distributed over a number of animal husbandry sectors.*

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[22] See the RDA opinion *Visibly Better* (2009)

[23] See the RDA opinion *Responsible Animal Keeping* (2009)

Appendix A Breeding

When discussing the breeding of animals, the terminology used can easily cause confusion. For example, 'breeding' to one person might mean simply the selection of animals with the goal of bringing about genetic improvement, while to someone else it may also mean 'the production of offspring' – the multiplication of animals.

Chapter IV of this opinion briefly summarized what the Council means by the various terms used in this report. This appendix elaborates further on some of the definitions to provide a more comprehensive overview of the essential science on which the breeding of animals is based.

The key terms are defined briefly in the box below.

Terminology, in summary

The **breeding goal** is a description of the objective being pursued by breeding. To operationalize breeding, the breeding goal has to be described in detail, specifying the traits for which change is being pursued and the relative importance (weightings) of a change in each of these areas.

The **breeding value estimate** is an estimation of the genetic value of the animals in a population. Breeding value estimates combine information on characteristics measured in an animal and in its relatives. For breeding value estimates, it is essential that information be systematically recorded on the performances of animals and on kinship between animals. Breeding value estimates for separate characteristics can be combined according to their relative weights in the breeding goal to arrive at a total index estimate.

Inbreeding refers to the mating of related animals. Inbreeding diminishes the genetic variation in a population. The rate of inbreeding can be determined based on the kinship of animals in a population. The increase in inbreeding is a function of the number of parent animals in use. A smaller number of breeding animals leads to a stronger increase in inbreeding, and therefore, to a greater loss of genetic variation.

Genetic defects refer to disorders that are caused by a single gene. In most genetic defects, the abnormal phenotype occurs only in animals that are homozygous for the mutation (receiving the mutant gene from both father and mother). Animals that are heterozygous (receiving the mutant gene only from the father or the mother) are called **carriers.**

The **quantitative traits,** such as growth and milk production, are determined not by one or a few genes, but by interactions between a large number of genes. In addition, these traits are influenced by factors in the environment (such as feed, climate and care).

Genetic correlation measures the association between genetic values for two characteristics. For example, a negative genetic correlation between milk production and fertility means that one-sided selection for milk production will lead to a diminishment in genetic value for fertility. Such an undesirable reduction in fertility is termed a **side effect or trade-off.**

Multiple trait selection is aimed at simultaneous genetic improvement of several characteristics. By applying multiple trait selection it is possible, for example, to achieve genetic improvement in both milk production and fertility. But the improvement in milk production is in this case less than in the case of one-sided selection for milk production.

A.1 Natural and artificial selection

Natural selection is aimed at increasing the survival chances of a species. In natural selection, animals with favourable traits (those best suited to the environment) make the largest contribution to the next generation.

Natural selection enhances the ability of a species to adapt and it contributes to genetic diversity. Species that are incapable or insufficiently capable of responding to changes in the environment (habitat, climate) die out.

Artificial selection is the human selection and mating of animals with the goal of changing the characteristics of the next generation. Artificial selection is also referred to as 'breeding'.

A.2 Breeding

Breeding is a process aimed at maintaining a population and, if desired, changing the traits of that population through the deliberate selection and mating of certain animals.

In farm animals, breeding generally targets maintenance of genetic diversity (limiting inbreeding) and improvement of the genetic value for productivity, health and well-being (the breeding goal). In companion animals and hobby animals, the emphasis of breeding lies more on appearance and less on performance. Thus, the emphasis placed on different types of traits will differ from livestock farmers, to pet owners and hobbyists. The emphasis might differ between breeding within the same breed but also between breeds.

Breeding aims at changing a population (a group of animals). The purpose of breeding can be summarized as 'through selection of parent stock, to produce a next generation[24] of animals that is better suited[25] to the expected conditions'.[26] To achieve change within the population, choices are made at the level of individual animals: which animals will be selected as parents for the next generation, and which animals will be mated with one another? These decisions have repercussions for the offspring that are born. Nonetheless, a breeding programme targets the traits (genetic value) of the group.

A.3 Breeding value and environment

The performance of animals (productivity, behaviour, health, athletic ability) is determined by genetic value, environmental factors (rearing conditions, care, feed, climate), and for farm animals the livestock holding conditions. Modern hybrid breeds are the result of decades of intensive selection for productivity under optimal husbandry conditions, feed and care. Under no circumstances would market parties want to risk losing the qualities so carefully built up in these animals. But they are increasingly asking for animals that can achieve this high productivity under more extensive and less controlled husbandry conditions. At the same time, breeding organizations are paying increasing attention to – and demanding – traits that can be used to select for animal well-being and robustness. This shifting demand has come primarily from Western Europe, where 'free range' and 'organic' husbandry systems are growing more and more popular as a practical embodiment of the social drive towards more sustainable production and socially responsible business. The current demand is for robust animals that are healthy and without defects and which can function well in a wide variety of

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[24] Breeding is aimed not at the current generation but at the next one. Parent animals transmit their genetic predisposition to the next generation. This means that selection of breeding stock must be aimed at producing animals with the desired genetic value.

[25] A generation that, more than the current generation, meets the desires of owners. Which traits are used to decide which animals are better depends on the goal, husbandry conditions and the particular point in time.

[26] Of importance here are not the current conditions but the conditions under which the future generation of animals will be kept. For example, in the near future, beak treatments will no longer be allowed on laying hens. That means the parent animals have to be evaluated on their behaviour and performance with intact beaks.

production systems, and that are capable (if given the opportunity) of easily adapting to changing farm conditions.[27]

Research in this field investigates the limits to productivity. Selection for increased productivity characteristics has increasingly come at the expense of reproduction, overall health and natural behaviour. Knowledge is still limited about how these characteristics are biologically related to productivity. Breeding organizations are therefore in urgent need of new insights and methods that could lead to more balanced selection methods and the production of robust animals, without sacrificing animal welfare.

A.4 Designing and implementing a breeding programme

The design and implementation of a breeding programme consists of five steps. The **breeding goals** are derived from an initial **analysis** of desires and husbandry conditions. Then follows an estimation of the **breeding value** of animals, on which the **selection** of parent animals is based. Finally, the selected animals are mated according to a predetermined scheme.

Analysis

The performance of animals is an additive measure of a range of characteristics varying from the ability to survive, produce and resist infections, to capacity to metabolize food and reproduce. The conditions under which animals are kept are influential in determining which characteristics a breeding programme has to consider. In farm animals, the importance of a particular characteristic depends on the livestock holding conditions and on the expected market. Future conditions also have to be accurately mapped not only to identify the relevant characteristics but also to determine their relative importance (step 2).

Breeding goal

Based on the results of step 1, a decision is made on what characteristics of an animal should be included in the selection process. In addition, the relative importance of characteristics in the breeding goal is determined.

Until recently, profitability was the basis for deriving the relative importance of dairy cattle characteristics. For all characteristics the effect on profit was calculated of one unit of change. This method can be applied when there are known relationships between the target characteristics and profitability and improved profitability is the goal. However, application of this approach resulted in an undesired deterioration of cow fertility. This prompted a switch, in 2008, to an alternative method for weighing the importance of particular traits in a breeding goal: ‘desired gains’. Here the importance (weight) is derived from the gain that is desired in various traits. This method is now being applied in the breeding of other animal species as well.

Box 1 presents the average genetic gain of the top 100 bulls for three types of breeding goals. This example demonstrates that using a balanced breeding goal, it is possible to achieve improvement on functional characteristics as well as on production, while one-sided selection for milk production can result in a worsening of functional characteristics.

[27] Source: *The Value of Animal Welfare*

Box 1: Effects of the use of different breeding goals on the average breeding value of the top 100 bulls in relation to all bulls born between 1996 and 2000. For 'longevity', 'udder health' and 'fertility' higher values are better. The following breeding goals were employed:
PROD = one-sided breeding goal targeting production traits (milk, fat and protein)
FUNC = one-sided breeding goal targeting functional traits (longevity, udder health and fertility)
COMB = balanced breeding goal targeting progress in production traits and improvement or maintenance of functional traits (NVO22 in the original notation).

Trait	PROD	FUNC	COMB
Kg milk	559	-215	322
Kg fat	36	-16	21
Kg protein	27	-9	18
Longevity	-1.0	7.4	3.7
Udder health	-0.2	3.4	2.0
Fertility	-2.4	3.0	0.0

Source: Van Pelt, M. and J.A.M. van Arendonk, 2006. Onderzoek naar effecten van verschillende totaalindexen voor melkvee. Research Report (June). Wageningen University.

Breeding value estimation

A few animal characteristics are governed by a single gene. Examples include halothane sensitivity in pigs, red factor in Holsteins, scrapie susceptibility in sheep, and inherited copper toxicosis (ICT) in the Bedlington terrier. Many of the disorders caused by a single gene are referred to as 'genetic defects'. In most genetic defects, the abnormal phenotype occurs only in animals that are homozygous for the mutation (receiving the mutant gene from both father and mother). Animals that are heterozygous (receiving the mutant gene only from the father or the mother) exhibit a normal phenotype and are termed 'carriers'. To be able to select effectively against a genetic defect, it is important to detect carriers and exclude these animals from the section or use them only in a very deliberate manner. Using molecular technologies, a test can be developed to detect carriers for most genetic defects. In pig breeding, in the late 1990s a halothane test was successfully applied to eliminate a genetic defect that led to increased sensitivity to stress and reduced quality of meat. However, many inherited disorders are caused by multiple genes.

Most characteristics, such as growth and milk production, are determined not by one or a few genes, but rather by interactions among a large number of genes. In addition, the phenotype (the outward expression) of these so-called 'quantitative traits' is influenced by environmental factors as well. Quantitative traits can be described by the mean and the variation found within a population. An important question is what part of the variation within a population is caused by genetic factors and what part by environmental factors. From the perspective of evolution, or that of a breeding programme, the magnitude of genetic variation is of major significance, because it determines the degree to which a characteristic will respond to selection. To facilitate comparisons between characteristics and populations, genetic variation is often expressed as a fraction of the phenotypic variation, a parameter referred to as 'heritability'. For illustrative purposes, a few examples of heritabilities are: litter size in pigs - 10%; protein production in dairy cows - 35%; meat quality in pigs - 30%.

Besides the extent of genetic variation (heritability) it is important to have some insight into side-effects (trade-offs) that may occur. This is further explained in Box 2, which also indicates that genetic correlations between characteristics reflect the extent of side effects.

Box 2: Side effects
One-sided selection for productivity adversely affects reproduction, health and natural behaviour. To prevent these disadvantages, it is essential to have good insight into the biological and genetic associations underlying these characteristics, and into mechanisms that can explain the effects of (selection for) high productivity on health and behaviour. Side effects and threshold values play an important role in health and natural behaviour. Because of these, the genetic relation between productivity on one hand and reproduction, health and natural behaviour on the other, could depend in part on the holding conditions.

Genetic correlation, is a common means to quantify the relation between two characteristics. For example, the genetic correlation between milk production and fertility (calving interval) is unfavorable in dairy cows. That means that one-sided selection of cows for milk production will result in an undesired decline of fertility (i.e. longer calving interval). However, by selecting for a combination of milk production and fertility (multiple trait selection), cows can be selected for both increased milk production and improved fertility.

In choosing parent animals, their true genetic value is not available for use by breeders, so they must make due with an estimate of it, called the ‘breeding value’. The accuracy with which the breeding value can be estimated has a bearing on the genetic progress made within a population.

Today most breeding value estimates in farm livestock are made using the so-called ‘animal model’. In the animal model the performance is measured of all animals in a population and combined with ancestry data to produce an estimation of the genetic value of the animals. Information on different traits can also be combined in the breeding value estimate. Approximate genetic correlations are used for this. Advances in statistical methods and computers have enabled these to be applied on a large scale.

Selection
Selection is aimed at improving the genetic structure of a population for the breeding goal and to maintain genetic diversity. Selection of parent animals based on estimated breeding values produces the best possible genetic structure in the subsequent generation (the descendants). The response over the longer term depends on the extent to which genetic variation is preserved.

Inbreeding (diminishment of genetic variation) is a function of the number of parent animals used. A smaller number of breeding animals produces a greater increase in inbreeding and a greater loss of variation. In the long term, conflicting effects emerge that require careful consideration by breeders. Within a given population size, the selection intensity can be raised only by reducing the number of parent animals, with increased inbreeding as a result. The use of family information to improve the accuracy of selection also raises the chance of selecting family members within and across generations, again leading to a higher rate of inbreeding. It recently became possible to accurately predict the increase in inbreeding in a population under selection. One key element of this approach is a prediction of the long-term contribution of an individual to the population. Optimization of breeding programmes can be significantly improved by applying this method. A higher long-term response can be achieved by putting less emphasis on family data in the selection criteria, focusing instead on information about the animal itself or its descendants.

The increase in inbreeding in a population under selection can be limited by using procedures to prevent too many related animals from becoming parents of the next generation, e.g. by setting a maximum number of full brothers and sisters that can be used for breeding or a maximum number of inseminations or matings that may be done by a particular animal. One of the more advanced approaches is use of genetic contribution methods. These are aimed at minimizing the kinship between the selected parents and with it the rise in expected inbreeding in the offspring. Genetic contribution methods are being employed in breeding programmes for dairy cattle, pigs and poultry.

A.5 The genetic consequences of breeding

The genetic consequences of a breeding programme for a population can be assessed based on two criteria: the genetic change of traits and the maintenance of genetic diversity.

Genetic change
The genetic progress can be determined by analysing data on a population over time. However, not all changes observed from year to year can be attributed to changes in the genetic structure of the population. Changes in the environment (climate, feed quality) contribute to these changes as well. Using ancestry data, changes in both the genetic structure and in the environment can be quantified. Where ancestry data are missing, the magnitude of the genetic change becomes difficult to quantify. The genetic change can be quantified for the breeding goal as a whole, or separately for each underlying characteristic.

Genetic diversity
The number of parent animals – and their degree of kinship to one another – affects the genetic diversity of the next generation. The use of a small number of parent animals leads to a decrease of genetic diversity, also referred to as an increase in inbreeding. The rise in inbreeding can be quantified based on an analysis of ancestry (over multiple generations). Typically, a rise in inbreeding by 1% per generation is considered acceptable. Where ancestry data is lacking, DNA analysis can be used to get an idea of the genetic diversity within a breed. This information can also be employed to select parent animals in populations with missing or incomplete ancestry records.

The discussion above deals with inbreeding at the population level. The average 'coefficient of inbreeding' provides an assessment of the extent of inbreeding in a population. The average coefficient of inbreeding is determined by breeding programme as well as by the quality of the ancestry records. As such, the coefficient of inbreeding of the current generation rises with an increase in the number of generations over which ancestry can be traced. So the coefficient increases where ancestry records for the current and previous generations are more complete. This is important to keep in mind when comparing populations. Some of the problems associated with the measure can be avoided by looking only at the *increase* in inbreeding rather than at the absolute figure for the average coefficient of inbreeding.

Inbreeding results from the mating of related animals. For example, a father-daughter mating produces offspring with an inbreeding coefficient of at least 25%. These offspring have a considerably higher risk of developing genetic defects. Limiting inbreeding in a population should therefore also aim at reducing the increase of inbreeding in the entire population, and at preventing the mating of animals that are close kin.

A.6 Evaluation of breeding programmes

Genetic models can be used to predict the level of genetic progress and the increase in inbreeding in a population. These are therefore an important tool for the design and evaluation of breeding programmes.

The level of genetic progress in a population per year is dependent on:

- The **selected fraction**;
- The **accuracy** of the breeding value estimate;
- The **genetic variation** in the breeding goal, which is dependent on the relative importance of traits and is a characteristic of the population under the given conditions;
- The **generation interval**, which is the age of the parents when their offspring are born.

A breeding organization has influence on three of these parameters, that is, the selected fraction, the accuracy of the breeding value estimate and the generation interval.

By considering more animals as candidates for selection as parents for the next generation, the selection intensity can be raised. Selection intensity can also be increased by using reproductive technologies, with which fewer animals are required to produce the next generation.

The accuracy of the breeding value is dependent on the amount of information available for making the estimation (by measurement of traits). Progeny testing enables the breeding value to be estimated with greater accuracy and is widely used in dairy cattle breeding. In this industry, a limited number of offspring is produced from a young bull. Information is then gathered about these offspring, based on which the breeding value of the father is determined (the sire is then about six years old). Only the best bulls are selected for large-scale use as sires.

With the use of progeny testing, offspring of progeny tested animals are produced at a higher age which means that the generation interval becomes longer. Yet a longer generation interval reduces the genetic progress that can be made annually. This illustrates the interrelated nature of the parameters determining genetic progress.

Optimization of a breeding programme means seeking out the combination of parameters (breeding intensity, breeding value accuracy and generation interval) that results in maximum progress towards the breeding goal with a given increase of inbreeding.

The parameters of the breeding program can be translated into characteristics of the population, such as the number of selection candidates (animals eligible to be chosen as parents), the number of parents and the frequency with which they are used, and the age at which the parent animals are used.

With regard to the breeding goal, it is important to measure how many animals (with known ancestry) are produced with certain traits. The animals for which performance is measured do not necessarily have to be the same animals that are eligible for selection.

The rise of inbreeding in a population can be predicted based on the number of parents (sires and dams) in a population and the kinship between these animals. In the absence of selection, the inbreeding rate can be determined based on the effective population size, which is a function of the number of sires and dams. However, in a population under selection – i.e. in most populations – the expected inbreeding rate is actually much higher than that calculated based on the effective population size. In predicting rates of inbreeding in a population under selection, inheritance of selective advantage also has to be taken into account – as better parents have a greater chance of producing good offspring and therefore are more likely to supply the parents of the subsequent generation. There are methods available that take into account the inheritability of selective advantage in predicting inbreeding rates.

The increase in inbreeding in a population under selection can be limited by procedures that prevent too many related animals from becoming parents of the next generation, for example, by establishing a maximum of number of full brothers and sisters that can be used for breeding (in poultry) or a maximum number of inseminations using AI (in horses). Genetic contribution methods are among the more advanced approaches to minimizing kinship between selected parents. These are being applied in breeding programmes for dairy cattle, pigs and poultry.

A.7 Structure of a population

The structure of a population has a major influence on the breeding programme. Structural differences explain a large part of the differences observed between the breeding programmes for different animal species. The following elements determine the structure of a population:

1. Purebred or cross
2. Closed or open population
3. Registration system for recording ancestry and performance
4. Ownership of breeding animals
5. Biological characteristics of the animal species
6. Application of reproductive technologies

Purebred or cross

In breeding purebreds, only animals belonging to a single line (or breed) are eligible to be parents of the next generation. In a crossbred population, parents are selected from two different lines (or breeds) and mated to produce the next generation. Most pig and poultry breeding programmes make systematic use of cross breeding. Farm animals are typically produced by combining animals from three different lines (or breeds). Cross breeding is used to combine traits of different breeds (for example, taking a breed with good fertility traits as the maternal line and one with good growth traits as the paternal line) and to take advantage of outbreeding enhancement (heterosis). Genetic improvement of pigs and poultry is achieved by selection from the different purebred lines. Crossbred animals are not eligible for selection as parents for improvement of the purebred line.

In some cases, crossing may also be used to improve or, in extreme cases, to replace a population (displacement crossing). For example, at the end of the 20th century, Holstein-Friesian dairy cattle from North America were frequently used for breeding in the Netherlands – to such an extent that over a number of years the Dutch dairy cattle population came to consist almost entirely of Holstein-Friesian animals. The genes of the native black-and-white Friesian cattle and the red-and-white Meuse-Rhine-Issel breeds disappeared almost entirely.

Closed or open population

In a closed population only animals from that population are used as parents for the next generation. Animals from other populations are excluded as parents. In an open population, animals of the same breed from other populations (usually from another country) can be used as parents. In a closed population the genetic change in a population is determined solely by the breeding programme implemented in that population. In an open population the genetic change is partly – or in some cases even entirely – dependent on the breeding programme in use in the other population (the population from which those animals originated).

Using animals of the same breed but from other countries (populations) can reduce the inbreeding rate in a population. This benefits the genetic diversity of the population. However, if animals from another population are used systematically, the genes originally present in the native population might disappear completely, as happened due to the use of Holstein animals in the Dutch dairy cattle population.

Registration systems for ancestry and performance

To estimate breeding values, it is essential to have records of ancestry and performances in a population. Moreover, ancestry is important for evaluating the degree of kinship between animals and therefore also for assessing the risk of inbreeding. Breeding programmes for farm livestock use only animals with a known ancestry. To estimate the breeding value of animals, information on the performance of all animals whose ancestry is known can be used. However, not all animals with a known ancestry are eligible for selection as parents in a breeding programme. For example, in poultry, information collected from crossbred animals is used in estimating the breeding value of animals in the purebred line. But these crossbred animals are not eligible for selection as parents in the purebred line.

Ownership of breeding animals

The aim of a breeding programme is to improve a population. Therefore, to achieve the goals of a breeding programme, it is important to have the cooperation of all owners of animals. The number of owners involved in a breeding programme varies considerably from species to species. In poultry, all purebred animals are the property of the breeding organization. In dairy cattle and pigs, the breeding organization owns the bulls/boars while the cows/sows belong to farmers. Companion animals are usually owned by private individuals. The interests of the breeding organization and owner might differ at times, which could hamper the overall implementation of the breeding programme. For example, an owner might be able to earn more if a popular stallion is allowed more matings, while a breeding organization would want to set a maximum for the number of matings to reduce inbreeding in the population.

Biological characteristics

The reproductive capacity of animals is of influence on the breeding programme. The number of offspring that can be produced per year is of interest, as well as the age at which the animals can begin to reproduce. This is because the number of offspring that can be produced determines what fraction of animals will be selected as breeding stock: if more offspring can be produced in a year, fewer animals are needed to produce the next generation. The reproductive age affects the generation interval as well.

Application of reproductive technologies

Use of reproductive technologies increases the number of offspring that an animal can produce. They therefore increase the chance that a selected animal will in fact contribute to the next generation. Three reproductive technologies that are commonly applied today are artificial insemination, embryo transfer and sperm sorting.

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