1. Introduction to Animal Breeding Programs

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Learning objectives

On completion of this topic you should be able to:

- Understand the different aspects involved in animal breeding programs
- Analyse animal breeding programs as a logical order of decisions to be made

Put the different aspects of animal breeding in the right context, and understand the knowledge needed about making certain investments.

Key terms and concepts

Breeding Objectives, Breeding Strategies, Breeding Program Structures, Different factors determining rate of genetic improvement.

Introduction to the topic

The face of animal breeding has changed significantly over the past few decades. Animal breeding used to be in the hands of a few distinguished 'breeders', individuals who seemed to have specific arts and skills to 'breed good livestock'. Nowadays, animal breeding is dominated by science and technology. In some livestock species, animal breeding is in the hands of large companies, and the role of individual breeders seems to have decreased.

There are several reasons for this change. Firstly, a fair part of the breeding industry has taken up scientific principles (although the extent thereof varies between species, see later). Looking was replaced by measuring, and an intuition was partly replaced by calculations and scientific prediction. The rapid development of computer and information technology has greatly influenced data collection and genetic evaluation procedures in livestock populations, now allowing comparison of breeding values across flocks or herds, breeds or countries. Other major developments were caused by the introduction of biotechnology, including reproductive technologies, and molecular genetic technology. Not all of this is new. Artificial insemination (AI) was introduced in the 1950's in cattle. The AI technology has had a major impact on rates of genetic improvement in dairy cattle, and just as important, on the structure of animal breeding programs. New technologies like ovum pick up, in vitro fertilisation, embryo transfer, cloning of individuals, cloning of genes, and selection with the use of DNA markers are all on the ground, or close to application. The real question is when they should be applied, and how much they are worth investing in. To be able to answer such questions, a clear understanding of animal breeding programs is needed.

This introductory topic aims to show that all animal breeding activity forms a framework of logically ordered decisions. Understanding this framework will help you fit together the material in the rest of the unit. It is important to realise that this framework is applicable at all levels: individual farm, breed, industry, and nation, and that it forms a sensible basis for approaching research and extension/advisory activity.

With the introduction of breeding methods one typically needs to find the right balance between what is possible from a technological point of view and what is accepted by the decision makers and users within the socio-economic context of a production system. Ultimately it is the consumer who decides which technology is desirable or not. In most western societies, consumers are increasingly aware of health, environmental and animal welfare issues. Food safety and methods of food production are part of their buying behavior. However, price and production efficiency continue to be major contributors to sustainability of a livestock industry. Successful animal breeding programs need to find the right amount of technology that helps them to be competitive.

In the course of examining the important features of each industry, possible scope for improvement will be identified and in some cases where such improvements are not well adopted, reasons for this are suggested. An important message that will become clear through the course of this topic is that there are many similarities between different industries, and there is considerable scope to learn from experience in other animal industries when developing systems for applying genetic technology.

A few points to remember about animal breeding populations:

- They tend to be hierarchical (a pyramid structure), whether formally or informally. This means that the genetic improvement of the entire population depends on progress achieved in elite flocks/herds.

- For the commercial producer (and scientists) the important concept is that of moving the average genetic merit. This means we assume a (linear) relationship between genetic change (quantity/quality) and $$ (i.e. more kg weight = more $ profit).

1.1 Important factors in breeding programs

Which decisions need to be made?

Animal breeding can be summarised as the application of simple genetic principles to modifying animal performance. When geneticists work in animal breeding, they are usually concerned with changing the average performance of groups (or populations) of animals. The changes result from identifying with the best genes for some purpose, and breeding from them. Since these genes are inherited, the superior performance is passed on to future generations.

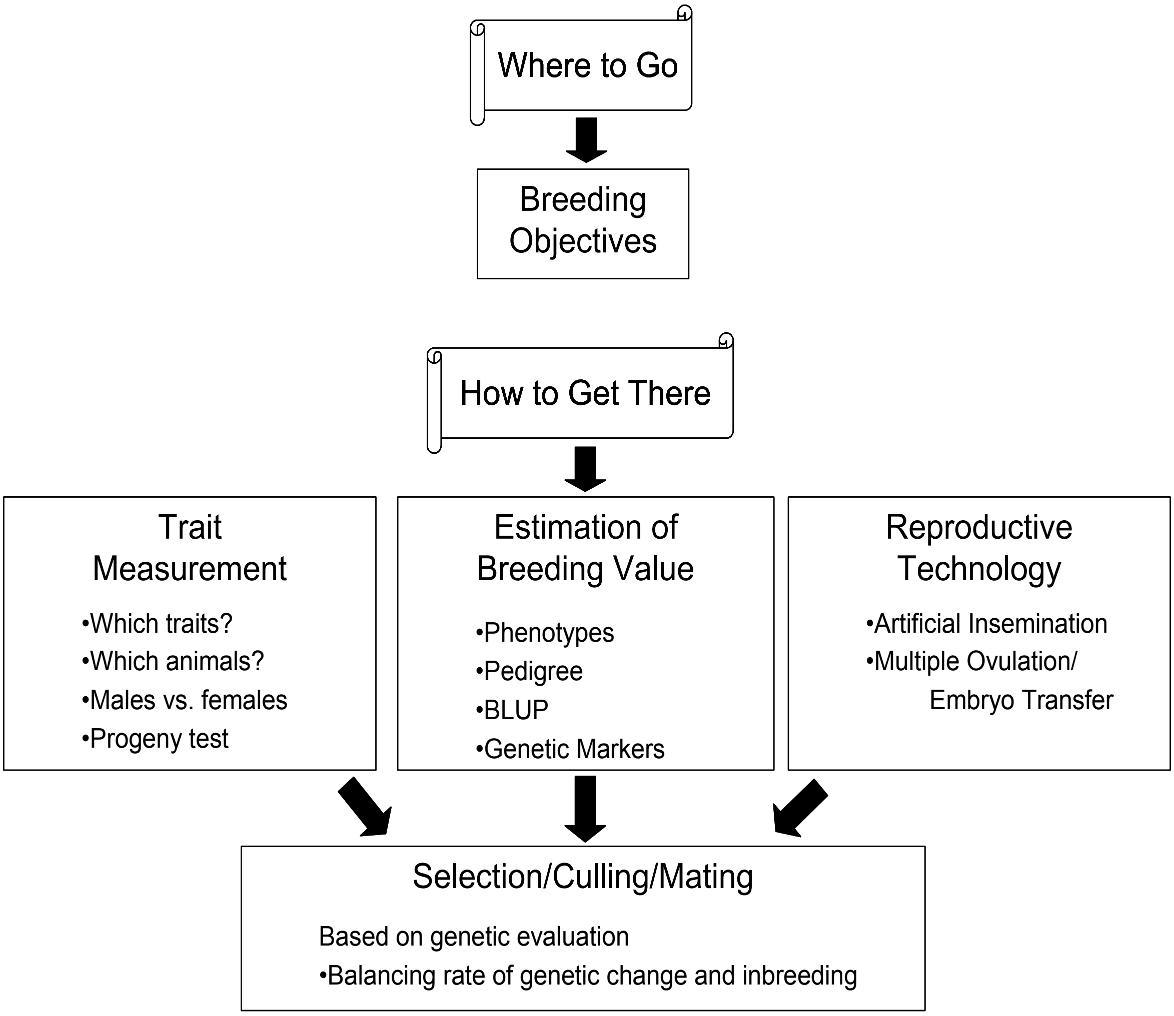
The skills of animal breeding lie in:

- knowing what changes will be worthwhile
- correctly and efficiently identifying the genetically superior animals
- identifying the most genetically and economically efficient way of mating the selected animals.

In essence, the two key questions in animal breeding are: *Where to go?* and *How to get there?* Running an animal breeding program involves the answer to these questions, which can be worked out in a bit more detail as:

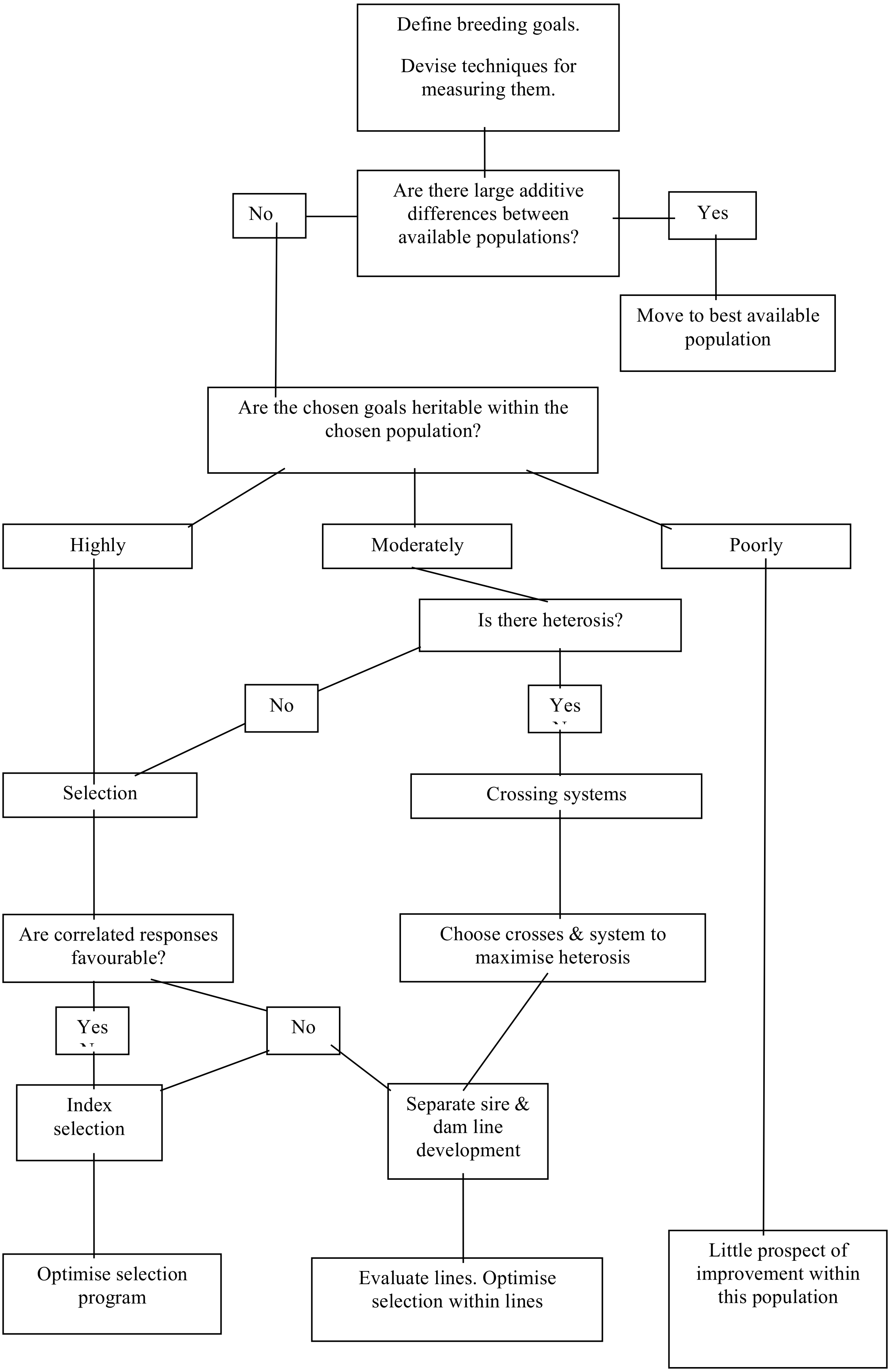
1. What is the breeding objective: which traits need to be improved and how important are different traits in relation to each other?
2. What and who do we measure? Which traits, which animals?
3. Do we need to use any reproductive technology (Artificial Insemination, Embryo Transfer)?
4. How many and which animals do we need to select as parents for the next generation?
5. How do we mate the selected males and females?

Figure 1.1 Decision issues in animal breeding. Source: van der Werf and Banks, (2006).



Another more general way of showing the decision making in animal breeding, that includes selection across breeds, is presented in Figure 1.2. This figure was developed by Cunningham (1979) and shows a sequence of questions to be answered in the process of designing a breeding program. You will find this framework useful for showing how different topics relate to the overall aims of animal breeding, and it will also be useful in organising your thinking.

Figure 1.2 General Strategy of Livestock Improvement. Source: Cunningham, (1979).



Breeding objective

Defining the *breeding objective* is the first and probably most important step to be taken. Improving the wrong traits could be equivalent or even worse than no improvement at all! If breeding animals are selected (or culled) for reasons *irrelevant to* the breeding objective*,* then the selected group will not be as good with regard to the breeding objective. It is important in the selection process that the selection criterion is clear, and whether the selection is efficient in relation to the breeding objective

Breeding objectives (or breeding goals) are simply a description of the changes we are aiming to make by selection and/or crossing. Geneticists usually make these descriptions in the form of equations with trait means related to profit. While it is often apparently simple to identify the changes that will make a population of animals more profitable, development of breeding objectives can be complicated by factors such as:

- poor market signals for some traits
- market signals that vary over time
- market signals that vary between different sectors of an industry

In recent years, more attention has been paid to proper development of breeding objectives, and examining ways of overcoming these problems. As this unit progresses, you will get more material that illustrates these problems. For now, the important thing to note is that the first step in considering applying genetic technology to animal production systems is to determine as clearly as possible exactly what changes are desirable. This should be as comprehensive as possible: giving consideration to all traits minimises the chance of accidentally allowing deleterious correlated responses, and also maximises the likely profitability of the genetic improvement program. It is important to realise that it is not just the easily measurable traits that should be part of the overall objective: all traits that affect income and cost must be considered.

Many practical breeding programs suffer from the fact that the objectives are not properly defined. Selection decisions are often influenced by attention to characteristics that are not formally defined in the objective. Furthermore, the outcome for a breeding program is noticed many years after selection decisions are made. Hence objectives have to be designed for future circumstance. It is quite difficult to predict such circumstances, and it is even harder to define objectives that are reasonably stable over time. Taylor (1997) has given examples in the beef industry where breed objectives (e.g. the size of the mature beef cow) have been fluctuating over the last decade, resulting in little change. However, other examples show consistent selection for clear breeding objectives (e.g. milk production in dairy cattle) with significant genetic progress.

Breeding strategies

Exploiting variation between breeds

Are there large additive differences between populations?

The basic question here is: are we starting with the best available population, and if not, why not import the genes of whichever population is the best? The extent to which this question is properly acted upon usually depends more on non-genetic factors than on real genetic merit:

- breeders may stick with an inferior breed/strain if that inferiority is not reflected in market prices. This may be because there is insufficient information, information has not been well extended, or market signals are poor.
- there may be costs associated with importation that effectively outweigh any genetic superiority. For example, Australia's meat sheep populations are effectively isolated by our quarantine regulations, so that to cover the cost of a 7-year importation, a potential new breed would have to be highly superior. An additional cost of importation is the time taken to up-grade the existing stock by crossing and backcrossing.

An example of an upgrading that has occurred world-wide is that of the "Friesianisation" of commercial dairy populations in response to superior milk yield of Friesians (and the Holsteinisation of Friesian populations). It is significant that this change was made entirely on the basis of commercial production value: breed interests were basically irrelevant.

Exploiting variation within populations

How much genetic variation exists within the population?

This question focuses on a basic requirement for an effective selection program: that there must be genetic differences between animals in order to make genetic improvement. Answering this question means determining whether the trait(s) of interest is heritable. This is a research task and has occupied a considerable amount of time in the past. You will cover this in more detail later on.

What is done next in designing the breeding program depends considerably on the answer to this question. The following situations are possible:

- if the goals are highly heritable (heritability 25% or greater), then selection will be effective in improving the genetic composition of the population. This is because if there are large genetic differences between animals, then it will be possible to make significant change by selecting those animals with the best genes as breeding stock.
- if the goals are moderately heritable (heritability 10-25%), then progress using selection is still possible but will be slower and/or harder to achieve.
- if the goals are lowly heritable (heritability < 10%), then progress from selection will be difficult, since there are only small genetic differences between animals.

As well as determining whether the goals are heritable (additive differences between animals), we need to be aware of the importance of heterosis, or hybrid vigour. Where there is heterosis for a trait(s), improvements in performance can be obtained by crossing breeds or strains. It is important to realise that these improvements are a "once-off": they are not passed on to progeny of the cross-bred animals, and for commercial "harvesting" continuous crossing is required.

Are correlated responses favourable or unfavourable?

Besides the variation that exists for the individual traits, it is also of critical importance how the different traits relate to each other. Breeding objectives will generally contain multiple traits. The correlations between traits can be positive or negative, but more importantly, they can be favourable or unfavourable (sometimes a positive correlation is unfavourable, like in wool production where we want more fleece but finer fibers, and these traits are positively correlated. There are many other examples of unfavourable correlations, such as productivity and fertility in many species, growth rate and mature weight, growth rate and feed intake, etc. When traits are favourably correlated, it is easy to improve them both in a desirable direction, but this is much harder when traits have an unfavourable correlation.

Where there are undesirable changes, two approaches are available. Firstly, we can develop a Selection Index that optimises the overall response in the two or more traits of interest. Using this Selection Index as the basis of selection, we can then proceed with selection in a single population. An alternative approach is to develop separate lines that excel in one or a few (compatible) traits, rather than in all. An example of this approach is the development of terminal sire lines and maternal lines in meat producing species: the terminal sire lines are selected for larger size and good carcase attributes while the maternal lines for reproductive rate and feed efficiency.

Optimise either the selection program or the program within each line.

The last question relates to ensuring that the selection program decided upon is as efficient as possible. Maximising efficiency will need to take account of:

- costs of measurement of each trait and of different types of relative,
- numbers of animals to be measured - effects on cost, selection intensity, and accuracy of selection,
- rate of dissemination of improved genes.

It is very often the case that selection programs begin at a very simple level and grow in sophistication as they demonstrate their effectiveness and generate returns. In this sense they may approach maximum efficiency gradually, rather than operating at maximum efficiency from the beginning. In this sense, questions of investment strategy for the enterprise (or breed or country) in the long term are important.

Little formal attention is paid to such questions in animal breeding theory, but experience suggests that one of the skills of animal breeding application is identifying sustainable levels of cost and sophistication, rather than attempting to implement "Rolls-Royce" programs immediately.

Measurement effort and genetic evaluation

The benefit of abundant and good measurement is that we may better be able to identify the genetically superior animals. This leads to more accurate selection and more genetic improvement.

Phenotypic measurements are turned into *Estimated Breeding Value's (EBV)*. Estimation of breeding value based on an animal's phenotype alone can be quite accurate for highly heritable traits. However, animals need to be compared across flocks, and genetic and environmental influences have to be disentangled. To achieve this, more sophisticated statistical methods are used, leading to *Best Linear Unbiased Prediction* (BLUP) of breeding values. Besides allowing across flock comparisons, BLUP also uses all available information about an animals' breeding value, including data on related animals.

Selection accuracy is strongly dependent on the degree of data recording, which requires a range of considerations related to cost and infrastructure. In data recording, individual performances need to be related to animal identification. If BLUP is used to generate EBV's, an animal's pedigree also needs to be known (in principle, for each animal only their sire and dam). If pedigree is not recorded, breeding value can be assessed on own performance only, and is limited to sexes, which express the traits of interest.

BLUP relies on good structure of data (use of breeding animals across flocks) and proper pedigree recording. If these prerequisites are in place, investment in BLUP methodology is usually highly cost efficient.

Molecular genetic technology has rapidly developed in the past 2 decades. Genes have been found coding for factorial traits (such as many diseases). Many production traits are *quantitative traits* and a likely genetic model is that genetic differences between animals are due to many genes. However, DNA technology has also provided genetic markers. Certain genetic markers can improve estimation of an animal's genetic potential as they are associated with regions that account for genetic variation. Genotyping animals for marker genotypes is therefore an investment with the aim to better assess true genetic merit of animals.

Reproductive technology

The most important limiting factors in a breeding program are related to the reproductive rate of breeding animals and uncertainty about their true genetic merit. How many and which animals should be selected is determined by these factors. Investments in breeding programs are therefore often related to trait measurement and genetic evaluation, and to technology used to increase reproductive rates.

Most of the main factors that determine genetic gain are directly influenced by the reproductive rate of the breeding animals. A higher reproductive rate leads to the need for a decreased number of breeding animals, therefore increasing the intensity of selection of these animals. If reproductive technology is possible, for example AI, the benefit could be expressed in terms of increased genetic rate of improvement, which in turn has a dollar component attached to it. More offspring per breeding animal also allows a more accurate estimation of breeding value.

Reproductive technology allows the intensive use of superior breeding stock. An obvious consequence is the possible overuse of the most popular breeding animals, and the population could encounter inbreeding problems. Typically, as new technologies in animal breeding allow faster genetic change, long term issues such as inbreeding and maintenance of genetic variation become important. For that reason, selection tools in animals breeding have become somewhat more sophisticated in recent years. The impact of reproductive technologies on rates of genetic improvement and inbreeding will be discussed in Topic 16.

Besides a direct effect on rate of genetic improvement, another important consequence from increasing reproductive rates is to disseminate superior genetic stock quickly. The influence of a superior breeding animal would be much higher if thousands of offspring could be born, rather than if the superiority is passed on through the production of sons via natural mating. Another example is that of cloning. Cloning is not extremely important for increasing rate of genetic progress, but it could have a large impact by allowing many copies of the best individual to perform in commercial herds. As reproductive rates are basically multiplying factors in a breeding structure, any improvement in reproduction will justify higher investment in improvement of the best breeding stock

Selection and mating

The decision about which animals should be selected as parents for the next generation is mainly based on *assessment of breeding value* of individual animals. *Genetic evaluation* is central to animal improvement schemes. Selecting animals based on estimated breeding value maximises the response to selection that can be achieved. However, there is one other criterion that is relevant when deciding which animals should have offspring. This criteria is *common ancestry* of all selected parents. The coancestry of selected parents should stay below certain limits, since it is directly related to the build up of inbreeding. Coancestry among selected parents is determined by the average relationship among the selected parents as well as the number of parents selected. In this unit we will more explicitly discuss selection strategies that maintain low levels of inbreeding.

Decisions about which animals need to be mated are often seen in relation to dominance effects. Utilising dominance variation is often not of primary importance for improvement of purebreds, but it can have more impact if breeding animals are selected from different breeds or lines, as heterotic effects between breeds can be utilised. When multiple traits are involved in the breeding objective, assortative mating could be useful, matching qualities in different parents for different traits.

There is a good possibility that in the near future, planned mating will gain in importance, when effects of specific genotypes will be better understood. One could envisage certain genotypes with high growing potential to be combined with specific genes that have a major effect on meat quality. Another argument for planned matings is to avoid inbreeding in direct offspring as well as the rate of inbreeding in the population. However, the rate of inbreeding depends mainly on population size and number of parents selected. Methodology to optimise selection and mating decisions related to inbreeding will be discussed.

Crossing systems: Choose crosses and systems

A crossbreeding system needs to be evaluated based on whole system efficiency. Producing a certain amount of crossbreed offspring also requires the maintenance of the appropriate numbers in the parental lines. The whole system performance is the sum of all inputs and outputs across the different crossbreds and parental lines in the system. These performances can be predicted from breed means, non-additive effects between breeds (mainly heterosis) and possibly within breed variation. Where exploitation of heterosis is important, there are choices to be made:

- among available breeds/strains usually on the basis of their level of performance, and
- among crosses on the basis of the performance of the progeny they produce.

Comments on this general strategy

A number of observations can be made about this series of decisions that help place them in context and clarify their use.

Firstly, decisions at a particular level imply that decisions have already been made at the earlier (or higher) levels. Obviously it makes little sense to think about development of a Selection Index without first having decided upon the goals of the program. Similarly it makes no sense to apply selection if there are no genetic differences to exploit. One problem that frequently arises in extending animal breeding theory is that one or more of the higher level decisions are treated as if they are common knowledge, when in fact they very rarely are. As an example particularly relevant to the grazing species, selection is often applied (or recommended) on the basis of incomplete or poorly understood breeding goals.

Therefore it is well worth while, particularly in extension work, to run through a mental checklist of these questions, even though the specific question at the time might relate to one small area of the technology. While it may make no difference to the outcome, it is valuable in reinforcing your own and clients' confidence in the overall program.

Secondly, while presented as a series for working through, there will often be a need to go back and reassess earlier decisions, particularly as costs of measurement and selection can be affected by choice of goal or by choosing lines or crossing systems. This need to optimise across levels is usually done intuitively, although some work has been done in the area of integrating crossing and selection.

Mention of the latter (which you will be covering later in the unit) raises the point that while these decisions are presented here as either/or, often the best approach will involve a series of "mixtures": for example of populations, or of selection and crossing simultaneously. Such "mixed" strategies are often the outcome in practice: the challenge for the researcher and advisor is to identify ways of maximising the efficiency of whatever strategy is chosen.

Finally, most animal breeding theory deals with the question of determining the level of heritability of the goals of the program, and with optimising a particular program of selection for a particular index or line. This highlights the importance of checking the "assumed" answers to higher level questions. There is very little point in maximising accuracy of selection for the wrong traits.

Balancing the different factors in genetic improvement

It is important that each decision to be taken in an animal improvement program should be taken in the context of the central dogma that determines rate of gain (see Introduction to Quantitative Genetics notes or Simm (2000): Chapter 4):

$$\text{Genetic gain} = \frac{\text{selection intensity} * \text{selection accuracy} * \text{genetic SD}}{\text{generation interval}}$$

To be cost effective, judge which of the factors is easiest to improve!

For example, accuracy of selection as well as intensity of selection are both directly related to genetic improvement, and increasing either of those by 5% will give a 5% improvement of the rate of genetic gain. Increased accuracy could be achieved for example by a more accurate measurement of correlated traits. However, this may be costly, and in the same breeding program it may be much easier to increase the selection intensity by 5% (e.g. by simply using less parents for breeding).

It is important to know in a breeding program where the big gains are.

Those are changes that are easy to implement and most cost effective. A good breeding program is not characterised by sophisticated reproductive technology and genetic evaluation software, but rather by cost effective decisions, giving the biggest part of the possible genetic gains for the limited resources available.

1.2 Structure of breeding programs

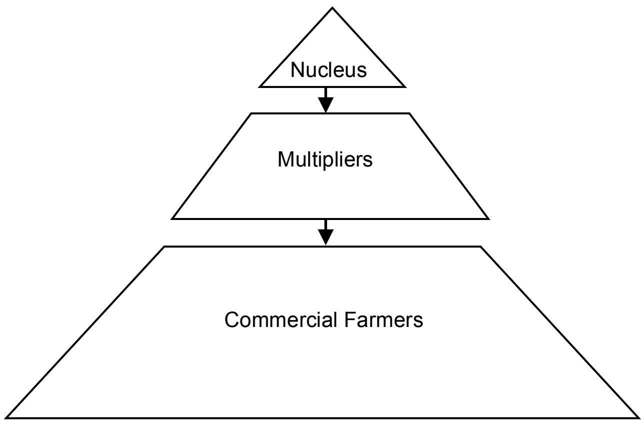
Most of the key decision factors mentioned earlier are related to the rate of genetic change that can be made. However, this could be genetic change in a small fraction of the national population (in nucleus or ‘elite breeders’). Genetic superiority should be transferred as soon as possible to most of the commercial farms.

The structure of a breeding program is therefore relevant for two aspects of an improvement scheme:

1) The genetic improvement aspect: how do we determine the genetically superior animals.
2) The dissemination aspect: how do we manage that those superior animals disseminate their genes quickly though the whole population of production animals

We often talk about the 'design of a breeding program', suggesting that breeding programs can be characterised by some kind of structure. The traditional model here is the pyramid with a small group of breeding animals that are actually improved (the 'elite breeders' in the nucleus) and the underlying levels of multiplier animals (possibly) and commercial animals (Figure 1.3). The latter groups may not be involved in selection, but merely, receive genes from the nucleus and are therefore improved over time. The genetic mean of lower tiers is somewhat lower than that of the nucleus, but the rate of improvement is, in principle, equal.

Figure 1.3 The traditional pyramid structure of animal breeding. Source: van der Werf and Banks, (2006).



1.3 Industry production systems

The following table (Table 1.1) identifies for each industry a number of aspects that affect the level and manner of investment in genetic improvement systems.

Several points need some explanation: they are discussed in the paragraphs following the table. Note also that the pig and poultry industries have been combined, mainly because they represent examples of "intensive" animal production.

Points of clarification for Table 1.1:

- amongst the component products, micron/FD refers to the fibre diameter of the wool. While Fibre Diameter is not a product itself, it clearly affects the value of each kg of wool.
- breaking the overall product into its components goes a long way towards developing the output side of a breeding objective.
- where there is reference to "Breeding" and "Production", these terms apply to sectors of the production system. The breeding sector comprises stud herds/flocks/companies, and provides the genetic raw materials to the production (or commercial) sector.
- where the degree of vertical integration via price signals is noted, this refers to the clarity with which price signals are transferred through the chain from breeder to consumer.
- biophysical environment refers to climate, soil, disease etc.
- degree of market influence refers to the extent to which the production end of the chain can influence consumers direct, through advertising, product development etc.

Table. 1.1 Industry Production Systems. Source: van der Werf and Banks, (2006).

	Beef	Dairy	Sheep Meat	Sheep Wool	Pigs/Poultry
Product:					
Primary	Meat	Milk	Meat	Wool	Meat/Eggs
Secondary	Hides	Meat	Skins	Meat	
Component Products:					
	N° Progeny	Yield/Litre	N° Progeny	Kg/Head	N° Progeny
	Wt/Progeny	Protein	Wt/Progeny	Micron (FD)	Wt/Head
	Lean/Wt	Fat	Lean/Wt	Weight	Lean/Wt
Number of Owners:					
Breeding	Large	Small	Large	Moderate	Small
Production	Large	Large	Large	Large	Moderate/Few
Degree of Vertical Integration:					
(i) Via Ownership					
Breeding & Production	Low	Low	Low	Low	Moderate/High
Whole Chain	Low	Low	Low	Low	Moderate/High
(ii) Via Price Signals					
Breeding & Production	Low/Moderate	High	Low	Low	High
Whole Chain	Low/Moderate	High	Low	Low/Moderate	High
Ability to Control the Environment:					
Feed	Low/Moderate	Moderate	Low/Moderate	Low/Moderate	High
Biophysical	Low	Low/Moderate	Low	Low	Moderate/High
Market Homogeneity:					
	Low/Moderate	Moderate/High	Low/Moderate	High (within FD)	High
Degree of Market Influence:					
	Low	Low	Low	Low	Moderate
Offspring/Female Lifetime:					
	5 to 10	5 to 10	5 to 10	5 to 10	10's to 100's

The main features to note from Table 1.1 are the differences between the intensive animal industries and the extensive ones. Intensive animal production is largely controlled at each stage of the chain by a few large operators, and these operations generally have greater control over all aspects of the industry.

Dairying fits between intensive and extensive animal production: some aspects such as the ownership and organisation of breeding are similar to that in intensive systems, while other aspects, particularly environmental control are more like the extensive. However, with the dairy industry now using intensive reproductive technologies, the breeding structure moves to a stronger pyramidal one, with fewer large companies providing most of the breeding bulls (at least in Holstein Friesian breeding).

The intensive industries have so far concentrated on species with very high reproductive rates per female. This allows high output per female housed/run, and allows small increments in efficiency or quality to be multiplied through very large output. By contrast, in all the other species proportionally larger improvements in individual animal performance are needed, since they are not multiplied so many times in the commercial sector.

In general, as the degree of vertical integration improves, the efficiency of application of genetic technology improves also. This is particularly so of the vertical integration that arises from clear flow of price signals. In this context, the wool industry is an exception: since the 1960's the wool industry has had clear price signals from consumer through to breeder, but adoption of genetic technology has been slow.

1.4 Breeding and industry objectives

This section summarises in simple terms some non-technical aspects of the breeding goals of each industry. These aspects are an important component of understanding why industries differ in their adoption of genetic technology. As with production systems, a table covering the different industries is used (Table 1.2).

Table 1.2 Breeding Objectives. Source: van der Werf and Banks, (2006).

	Beef	Dairy	Sheep		Pigs/
			Meat	Wool	Poultry
Consistency of objectives over time:					
"Real"	mod/high	mod/high	mod/high	high	High
"Perceived"	moderate	moderate	moderate	mod/high	high
Importance of type traits in the objective:					
	mod/high	mod/low	moderate	high	low
Number of traits in the objective:					
"Real"	small	small	small	small	small
"Perceived"	high	high/few	small	high	small
Acceptance of "scientific" objectives					
	low/mod	mod/high	mod/high	low	high
Uniformity of objective across industry:					
	low/mod	high	mod/high	moderate	high
Variation between stud and commercial objectives:					
	mod/high	mod/low	mod/low	mod/high	low/0
Inclusion of feed efficiency in objective:					
	low	low/mod	moderate	low/mod	high

NB: mod = moderate

Comments regarding Table 1.2:

- where there are excess traits in the breeding goal/objective (inclusion of traits which have low correlation with profit and/or efficiency measures), selection differentials are wasted.

- clear definition of objectives will be reduced by:
  - poor signals (consumer to producer to breeder)
  - heterogeneous markets
  - more decision-makers
  - lower degree of influence (real and attempted) over environment

- the major change over time (as consumers' standard of living increases) tends to be that product "quality" increases in importance. This probably reflects increasing disposable income, and the tendency to exercise more choice/discrimination that goes with this.
- more "industrial" production tends to improve definition of the production system and increase the value of product consistency; and this in turn highlights the cost of producing "non-optimal" product.
- costs of "wrong" objectives:
  - at stud level, possible reduced sales,
  - at commercial level, reduced production efficiency, and likely loss of market share, etc
  - for the nation, reduced rate of increase in standard of living
  - value of investment in any genetic improvement (and crossing) system is reduced.
- several aspects of breeding objectives vary between sectors of the meat sheep industry: the terminal sire breeders generally have a better understanding of the objective approach (and a clearer objective) than the maternal breeders,
- in the dairy industry, the dairy AI breeding companies are more "scientific" in their approach than the studs,
- feed efficiency may be included in the objective through a real or assumed correlation with "yield" traits. For example, in dairy cattle yield and efficiency have long been assumed to be the same thing, and there is some evidence in wool sheep that they are highly genetically correlated. In meat sheep, growth rate in the terminal sire breeds essentially is efficiency: lambs are grown usually under conditions of feed surplus.
- the distinction between "real" and "perceived" objectives is essentially between what would be the objective in the absence of things like showing, poor price signals, multiple owners etc (the real objective), and the objective(s) that is actually accepted and drives breeding programs. For these reasons, there is no difference between the real and perceived objectives in the intensive industries.

Given the comments made above, and the aspects identified in Table 1.2, there is a clear argument that the extensive animal industries may be wasting selection opportunities through a combination of excessively complicated objectives and mis-directed objectives. If any effective selection is being made in these industries, then it may well be in the "wrong" direction: this is a cost (or will be) to the respective industries.

Optimisation of programs

Beef Cattle:	Most breeders work independent from one another, although recently some change in Australia
Dairy Cattle:	highly structured populations, reflecting costs of AI and need to obtain value for investment; also sex-limited nature of traits.
Meat Sheep:	considerable attention in some countries since 1990's, e.g. Young Sire Programs in Australia.
Wool Sheep:	interest via group breeding schemes, multi-stage indices.
Pigs/Poultry:	rigorously organised and structured programs: both for commercial reasons, and for layers, because of sex-linked nature of traits in the case of egg production.

Investment perspectives

This area is not part of the decision-tree we have been working through, but has important consequences for the adoption of genetic technology. Smith (1978) compared the perspectives of the individual breeder or firm, with those of the "national interest".

Table 1.3 Issues affecting the adoption of genetic technologies from national and commercial perspectives. Source: Smith (1978).

	Breeding Perspective	
	National Improvement	**Commercial Firm or Breeder**
Investment	Improvement of national breeding stocks	Improvement of own breeding stock
Timescale of Investment (and Return)	Long	Short
Returns to Investor	Large	Small
Reasons for Investment		
1	Value of improvement in national commercial production	Returns from extra breeding stock sold
2	Permanent value of improvement over time	Temporary value of competitive advantage
3	Value of successive improvements accumulates	Successive improvement needed to maintain competitive position
4	Low risk of no returns	High risk of no returns
Investment Justified	Large	Small

Table 1.3 highlights some very important issues affecting adoption of genetic technology. It is worth noting that most animal breeding research and national evaluation programs reflect a national perspective. In extension of animal breeding, it is very important to understand that while a national evaluation system for example may be very valuable for the nation, for some breeders it will have deleterious effects and for the vast majority it is likely to have little clear effect on their economic circumstances.

This is a very important point to realise in animal breeding extension: geneticists often treat genetic technology as if it were obviously of benefit, and fail to realise or admit that the primary beneficiaries are consumers and geneticists. One of the main attractions of being a stud breeder is the social status that role confers. Effective implementation of genetic technology probably rationalises the stud sector and removes that status for many, usually for no apparent benefit to the breeder other than possibly staying in business. This makes extending animal breeding a challenge requiring integration of technical and social skills.

Readings

The following readings are available on CD:

1. Farquharson, R.J., G.R. Griffith, S.A. Barwick and R.G. Banks. 2002, ‘Estimating returns from investment into beef cattle genetic technologies in Australia’, *Proceedings 7th World Congress On Genetics Applied to Livestock Production*, Communic. N° 02-34.
2. Hoste, C.H. 2002, ‘Research and Development challenges for animal breeding programs in developing countries’, *Proceedings 7th World Congress On Genetics Applied to Livestock Production,* Communic. N° PS-02.
3. Lewis, R.M. and G. Simm. 2002, Small Ruminant breeding programs for meat: progress and prospects, *Proceedings 7th World Congress On Genetics Applied to Livestock Production*, Communic. N° 02-01.
4. Miller, S.P. 2002, ‘Beef cattle breeding programmes: progress and prospects’, *Proceedings 7th World Congress On Genetics Applied to Livestock Production,* Communic. N° 02-18.
5. Simm, G. 2000, 'What affects response to selection within breeds?', Chapter 4 in *Genetic improvement of cattle and sheep*, Farming Press, Miller Freeman, UK, pp. 107-146.

Further reading not provided on CD

1. Kinghorn, B.P. and van der Werf, J.H.J. 1999, *Quantitative Genetics, GENE 351 Lecture Notes*, University of New England, Armidale.

Activities

Available on WebCT

Multi-Choice Questions

Submit answers via WebCT

Useful Web Links

Available on WebCT

Assignment Questions

Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCt

Summary

I Animal breeding is a mix of technical and socio-economic issues that need to be optimised within the industry context. The first and most important decision to make is to set clear breeding objectives, i.e. define the traits to improve and their relative value. Selection and mating can be optimised between, as well as within, populations. Investments in new reproductive and molecular technologies need to be measured against the predicted benefit. Different industries have different breeding structures, largely related to the reproductive rate of the species. Decision making and investment can differ significantly between such structures.

References

Cunningham, E.P. 1979, *Quantitative genetic theory and livestock improvement*, Notes of a short course, AGBU, UNE, Armidale.

Simm, G. 2000, *Genetic improvement of cattle and sheep*, Farming Press, Miller Freeman, UK.

Smith, C.S. 1978, ‘The effect of inflation and form of investment on the estimated value of genetic improvement in farm livestock’, *Animal Production,* vol. 26, pp. 101-110.

Taylor, J. F. 1997, ‘Twenty first century challenges for genetic improvement in the livestock industries’, *Proceedings of the Association for the Advancement of Animal Breeding and Genetics,* Dubbo, vol. 12, pp. 1-19.

Glossary of terms

Additive difference[1]	Variance in a trait due to the combined effects of genes with additive action
Assortative mating	Mating can be assortative with respect to a certain genotype (e.g. individuals with genotype AA tend to mate with other individuals of genotype AA) or phenotype (e.g. tall individuals mate with other tall individuals).
BLUP[1]	Best Linear Unbiased Prediction – a statistical procedure for predicting animal breeding values
Breeding objective[1]	A description of the characteristic(s) which selection is intended to improve
Cloning – genes[1]	Multiplication of DNA by incorporation into DNA of a vector (such as a plasmid – a small self-replicating circle of double stranded DNA which exists independently in some bacterial cells)
Cloning – individuals[1]	Production of identical embryos by physically splitting embryos or by transferring cultured cells into eggs from which the nucleus has been removed
Correlation[1]	A measure of the direction and strength of the association between breeding values for two characters eg liveweight and fat depth
DNA or molecular markers[1]	Any identifiable segment of DNA in the genome
Embryo transfer[1]	Transfer of fresh or frozen embryos into recipient females
Factorial traits	Traits that result from a single gene action and are usually expressed in distinct classes (e.g. diseased/healthy)
Generation interval[1]	The weighted average age of parents when their offspring are born
Heritability[1]	The proportion of superiority of parents in a trait which is, on average, passed on to offspring
Heterosis[1]	Hybrid vigour – the advantage in performance of crossbred animals above the mid-parent mean
Inbreeding[1]	The practice of mating related animals. Also an inevitable consequence of long term selection in a closed population
In vitro fertilization	Fertilisation of eggs in the laboratory which are later transferred into the mother
Ovum pick up[1]	Collection of eggs from donors through an ultrasonically guided needle inserted into the ovary
Population	A group of individuals all exposed to the same environmental influences
Quantitative traits[1]	Traits that can be measured quantitatively eg. fleece weight or milk yield
Selection accuracy[1]	The correlation between the selection criterion (eg an index) and the breeding goal
Selection index[1]	An overall score of genetic merit which combines information on several measured traits, with an emphasis on strength of association with traits in the breeding objective and their relative economic value
Selection intensity[1]	The superiority of animals selected expressed in standard deviation units

[1] Glossary terms taken from Simm (2000).