Algerian Republic Democratic and Popular

Ministry of High Education and Scientific Research

University of Med Khider, Biskra

Faculty of Nature and life sciences and exact sciences

Department of Agricultural sciences

Polycopy courses support for L3 Level

Option Professional Poultry Production

Module

Genetic Improvement for Poultry Production

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Table des matières

1. Informations sur la matière (fr)

	VHS	VH hébdomadaire				Coef	Credit	Mode- Evaluation	
Unité d'enseignement	15 sem	C	TD	TP	Travail Pers.			Continus	Examen
UM1.6.2 Sélection génétique des volailles	37.5	1.5	0	1	37.5	2	3	40%	60%

Objectifs de la matière : faire apprendre les étudiants le démarche générale pour adopter un programme de sélection génétique chez l'espèce avifaune-cas de la poule.

Pre-requis : génétique mendélienne et de population

Contenu de la matière

I. Domestication

II. Standardisation des races

III. Evolution des performances en dernier 50 ans

IV. Diversité génétique chez la poule

V. Selection

1. Buts de la sélection: types et caractéristiques

2. Valeur économique

3. Etapes d'un programme de sélection

4. Collecte des données et pedigree
5. Modèle génétique
6. Utilisation du Coefficient d'héritabilité
7. Valeur génétique
8. Déterminer l'élite

2. About the Module

6 th semester

	HSV	Weekly HV				Coef	Credit	Evaluation manner	
Teaching Unit	**15 weeks**	**L**	**TD**	**TP**	**Pers. Work**			**Continuous**	**Exam**
UM1.6.2 Breeding Improvement for Poultry Production	**37.5**	**1.5**	**0**	**1**	**37.5**	**2**	**3**	**40%**	**60%**

Objectives of the MODULE

The main purpose of the module is to teach the students how to put a solid approach for adopting a genetic selection program in the avifauna species, essentially the broilers and layers hen's production.

Required Knowledge: Mendelian and population genetics.

Content of the teaching unit

I. Domestication

II. Breed standardization

III. Evolution of performances over the last 50 years

IV. Genetic diversity in chickens

V. Selection

1. Purposes of selection: types and characteristics
2. Economic value
3. Steps of a selection program
4. Data collection and pedigree
5. Genetic model
6. Use of the Heritability Coefficient
7. Genetic value
8. Determine the elite

Genetic for Poultry Breeding Improvement

3. Domestication

3.1 Introduction

In animal breeding we control which animals contribute to the next generation. In other words, we control the reproduction of animals. This level of control is only possible with domesticated animals.

Domestication is the process of conversion from wild animals to domestic use. Many animals have been domesticated and estimates of when this happened are very variable. Some of the best estimates are listed in the table 1 below.

Table 1. List of some domesticated animals in early times.

Specie	**Latin name**	**Date**	**Location**
Dog	*Canis lupus familiaris*	>30.OOO BC	Eurasia
Sheep	*Ovis orientallis aries*	11000-9000 BC	Souwth Asia
Goat	*Capra aegagrus hircus*	8000 BC	Iran
Cattle	*Bos primigenlus taurus*	8000BC	India, North Africa, Middle East
Cat	*Felis catus*	7500 BC	Cyprus and Near East
Chicken	***Gallus gallus domesticus***	**6000BC**	**India and South-East Asia**

4. Breeds standardization

4.1 Before 1900

Until roughly the 1700's animal breeding, as in selective breeding, did not really exist. People mated their animals with animals in the neighborhoods that they liked. But there was no systematic way of selecting animals for reproduction, based on predefined characteristics that did not change from mating to mating, but remained similar over time. In Europe, the origin of animal breeding lies in **England**. It was Sir **Robert Bakewell** (1725 – 1795) who introduced keeping accurate records of performance of animals so that objective selection became possible. With time, the number of people who were using the selective breeding approach introduced by Bakewell increased.

4.2 20th Century

Most of the animal breeding theory we still use today, was postulated in the first half of the 20th century. The statistician R. A. **Fisher** (1890 – 1962) showed that the diversity of expression of a trait could depend on the involvement of a large number of so-called **Mendelian** factors (genes). Together with Sewall **Wright** (1889 – 1988) Fisher showed how the results of biometricians, such as regression and correlation could be united with results of Mendelian genetics, such as frequencies of genotypes.

Jay L. Lush (1896 – 1982) is known as the modern **father of animal breeding.** He advocated that instead of subjective appearance, animal breeding should be based on a combination of quantitative statistics and genetic information. He developed methods to estimate **the breeding value** of an animal.

Lanoy Nelson Hazel (1911-1992), and his student **C. R. Henderson** (1911 – 1989), developed much of the statistical methods that have been applied for decades in modern animal breeding. The methods they developed in the 1950's allowed for the first computer evaluations in breeding of dairy cattle. Their methods were used for decades and allowed much genetic improvement in the cattle breeding industry.

4.3 21st century

Since the beginning of the 21st century, the use of DNA information has entered the field of animal breeding. Ways to incorporate large-scale DNA information into the statistical methods were developed by Theo **Meuwissen** and Mike **Goddard** and the application of this approach, called "**genomic selection**", has been taken up by many of the larger breeding programs.

Genomic selection has already had a major impact on breeding because it allows the prediction of breeding values for young animals without the need to measure phenotypes on the animal itself or on its close relatives. Thus, genomic selection may lead to the more accurate breeding values at very youngest ages of the animal, and accelerate the improvement tremendously.

5. Evolution of poultry performances in least 50 years

5.1 Growth of broilers

The researchers **Havenstein** and coworkers in 2003 grew chickens from two different strains. the first has been preserved at the genetic level of 1957, and the other strain has been selected for growth until 2001. In addition to measuring growth of chickens from the strains 1957 and 2001 they also used two different chicken diets, one with the composition of diets that were used in 1957 and the other diet with a composition used in 2001. Groups of chicken from both strains were fed the different diets to have 4 combinations of genetics and diet.

The figure 1 below shows results from these 4 groups of chickens. The chickens from 1957 grew to 809 grams in 8 weeks on the 1957 diet while the chickens from 2001 grew to 2,984 grams on that same diet and in the same period of time. The results show that breeding for growth has increased the growing speed more than threefold.

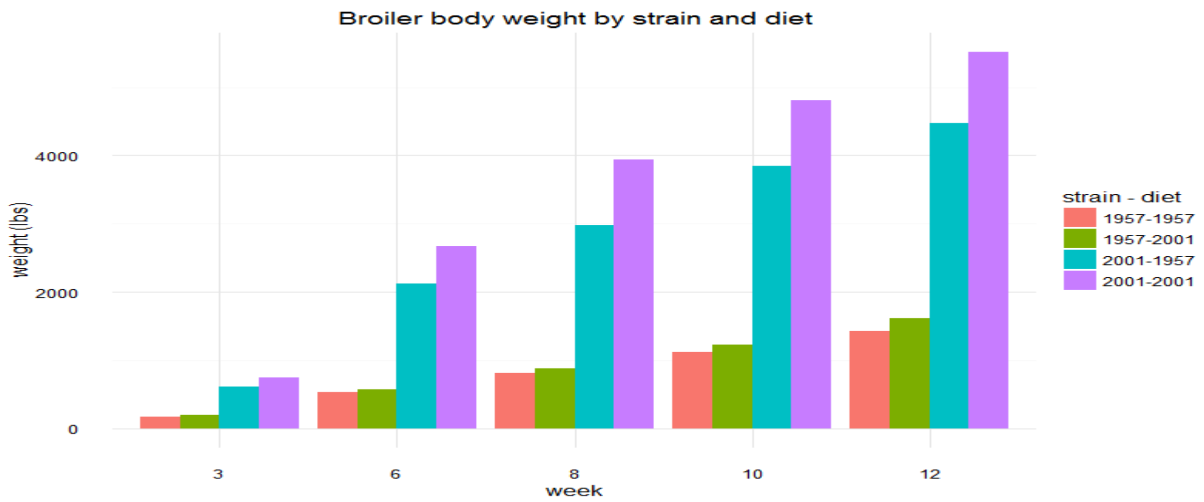


Figure 2. Variation of broiler body weight (1957 and 2001).

5.2 Dairy cattle

Dairy cattle breeds have long been selected for increased milk production. The council on dairy cattle breeding in Maryland, U.S.A. reports data on the genetic improvement of several cattle breeds. The figure below shows the average milk production of Holstein cows in the US from 1957 to 2015.

The amount of milk produced per cow per year has more than doubled in the time between 1957 and 2015. Part of this increase (54%) has been achieved with selective breeding. The other part of the increase is due to better management and feeding.

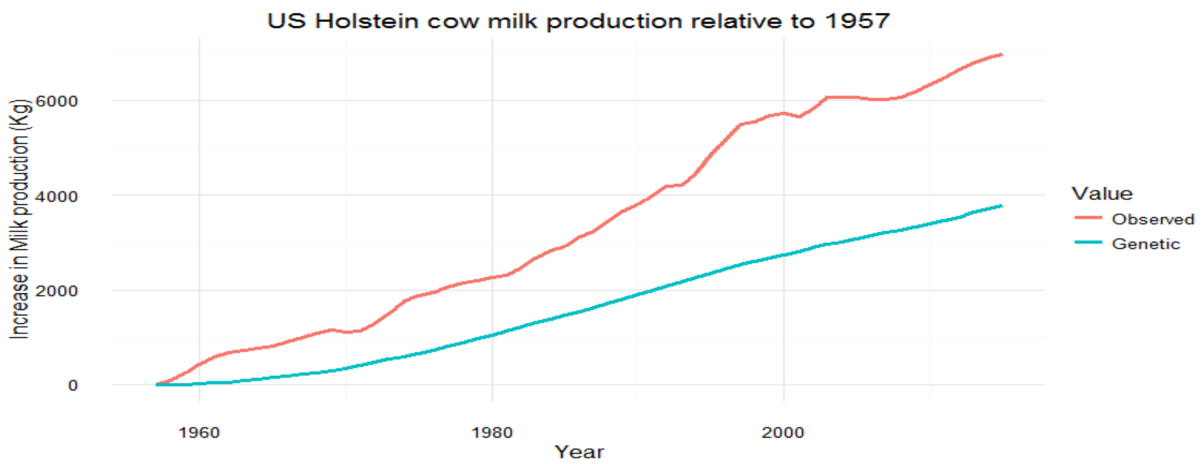


Figure 3. Variation of cattle milk production from 1960 to 2000.

These are two examples where selective breeding has made big changes in the performance of animals. We also saw that besides breeding, other improvements have also contributed to better performance. So, the aim of breeding is not always to **change a trait**. Sometimes we want things to stay constant, such as specific characteristics in the appearance of a breed like the colour of the hair or feathers.

6. Forms of breeding programs

Goals

At the end of the course the learner will be able to:

- ***Distinguish between the different forms of breeding programs in animal production;***
- ***Get the reasons and diverse purposes of them.***

6.1 Different forms of breeding programs

Breeding programs exist in many different forms. While the breeding of dogs and horses is usually done by individual owners or organized by herdbooks, the breeding of farm animals has developed into a professional industry with modern technologies, large-scale data collection, and data analysis. This has resulted in very efficient and effective breeding programs, producing many thousands of genetically improved animals for different parts of the world. However, for this large-scale animal breeding large infrastructure is required, combined with high-quality data collection, large computing capacity, and qualified people to run the breeding program.

6.1.1 Breeding programs for commercial farming

When we consider the commercial farming of terrestrial livestock species, breeding of those animals has concentrated in specialized companies. Globally, the number of breeding companies is decreasing, especially those related to poultry breeding. For broiler chickens, for example, there are currently only two major breeding companies. For cattle, there are more companies, but they all participate in international exchange of semen for many breeds. Especially for the main dairy and beef breeds, there is a lot of exchange and we can therefore consider each breed as a single global population.

In aquaculture, the situation is different. There are only a few breeding companies that run breeding programs for globally sold species like salmon, trout, tilapia or shrimp. For many other fish and shellfish species, there are no such breeding programs, simply because the production volume is too small. Instead, many companies develop their own breeding program, which is often fully integrated with their production.

In summary: ***farm animal breeding is an increasingly global industry.***

6.2 Diverse reasons of breeding programs

You may ask why we need to genetically improve animals. The demand for animal products is growing worldwide, and to produce enough eggs, meat, fish and milk for everyone can be addressed by animal breeding. Besides improving the efficiency of food production, more recent challenges are to produce these products with extra attention to the environment and the welfare of animals.

- It is very interesting and rapidly developing domain of science. The understanding of DNA helps us to better understand the role of natural selection and to design artificial selection programs to improve animals.
- Livestock production and aquaculture make an important contribution, not only for feeding the world but also to providing income for people working in the agrifood sectors.
- Meeting the needs of the growing world population and within the carrying capacity of our planet requires innovations in our food system.
- Feeding the growing population in a sustainable way is a big challenge. Animal breeding can help to meet this challenge.
- Animal breeding focuses on producing improve offspring. Improved offspring are produced by selecting animal with desirable qualities and using them as parents for the next generation.
- Animal breeding exploits the **natural genetic variations within** a population to create improvement generation after generation. The genetic changes made in one generation add to the genetic changes made in previous generations.
- The selection for improved food efficiency in poultry in the past 40 years has resulted in 50% reduction of the amount of feed deeded for the production of 1 kg of meat or a dozen eggs.

It has been recognized for a long time that there is far more than just efficiency to consider in animal breeding. That is why we talk about **Balanced breeding**: breeding that aimed to improving **efficiency**, **health** and **welfare** of the animals. The perfect balance in balanced breeding is not static, but changes over time.

There are differences between countries, the production system, the climate and types of feed differ from countries which means that best breed might also differ between countries. The breeding of the perfect chicken requires to be tailored to the local conditions. This starts with understanding the local production system and analyzing how animal breeding could contribute to an improvement of the system.

In selection improvement, breeders use genetic variation to generate a genetic progress. They also have the responsibility to protect genetic resources for the future:

- Activities today do not compromise the ability of future generations to meet their needs;
- Pay attention to safeguarding the genetic diversity

7. The breeding program

Objective

The learner will not only be capable to get the seven steps of any Breeding program, but to predict the future and the manner to establish a breeding program.

7.1 Introduction

The two main questions for setting up a breeding program are:

1. **Where to go?** → **Directions**
2. **How to get there?** → **Manner to get the determine direction.**

We aim to provide value at every stage of the **egg value** chain from breeding and genetics to delivering healthy, best quality eggs to the end consumer. We have always embraced the past to catch the future, and as a result of our strong history in poultry breeding.

7.2 The seven main steps of any breeding program

The design of breeding program typically follows 7 steps:

1. To choose the **traits** for which a genetic improvement is needed or desired;

- You need to consider the production environment and the markets. Production environments determine which traits are relevant for the animal. Markets determine the traits that are important for producers (income).

- Breeding program should always consider a balanced combination between production, animal health and welfare traits. Traits related to production and welfare are of main importance in well-controlled environments. Health and resilience traits are more important when animals are kept in less controlled environment

“**What are you producing? Milk, meat, egg…….**

2. To decide in which **direction** you want to change them

3. To indicate the importance of the chosen traits relatively to others by assigning weights. These weights can be used to rank animals to make the selection.

   The breeding goal summarizes the traits that animals are selected on, and their relative weights.

4. **Start selecting animals:** there are 2 types of information you need when selecting animals:

- **Phenotype:** the value of the trait of interest: Kg of live weight, number of eggs, dressing yield
- **Relationship between animals:** related animal share a proportion of their genes. Because they have at least one parent in common. Family relationships can be used to estimate the genetic potential of candidates for the traits of interest.

5. To estimate the breeding value of all selection candidates. The breeding values are estimates of the genetic potential of an animal for a given trait, relative to the mean of a population. To estimate the breeding values we need to use **genetic models**.
6. To determine the selection intensity. Determine the number of animals selected from the group of selection candidates (nb male & nb female/specie). Higher selection intensities means that only the very best candidates are used as parents for the next generation.
7. predict the **selection response** or **genetic gain** (difference between the mean of the parental generation and the mean of offspring generation)
8. **Dissemination and providing farmers with genetically improved stock.** Think of chickens: a typical chicken may produce up to 150 fertile eggs. Multiplication structures differ depending on the reproductive biology of species

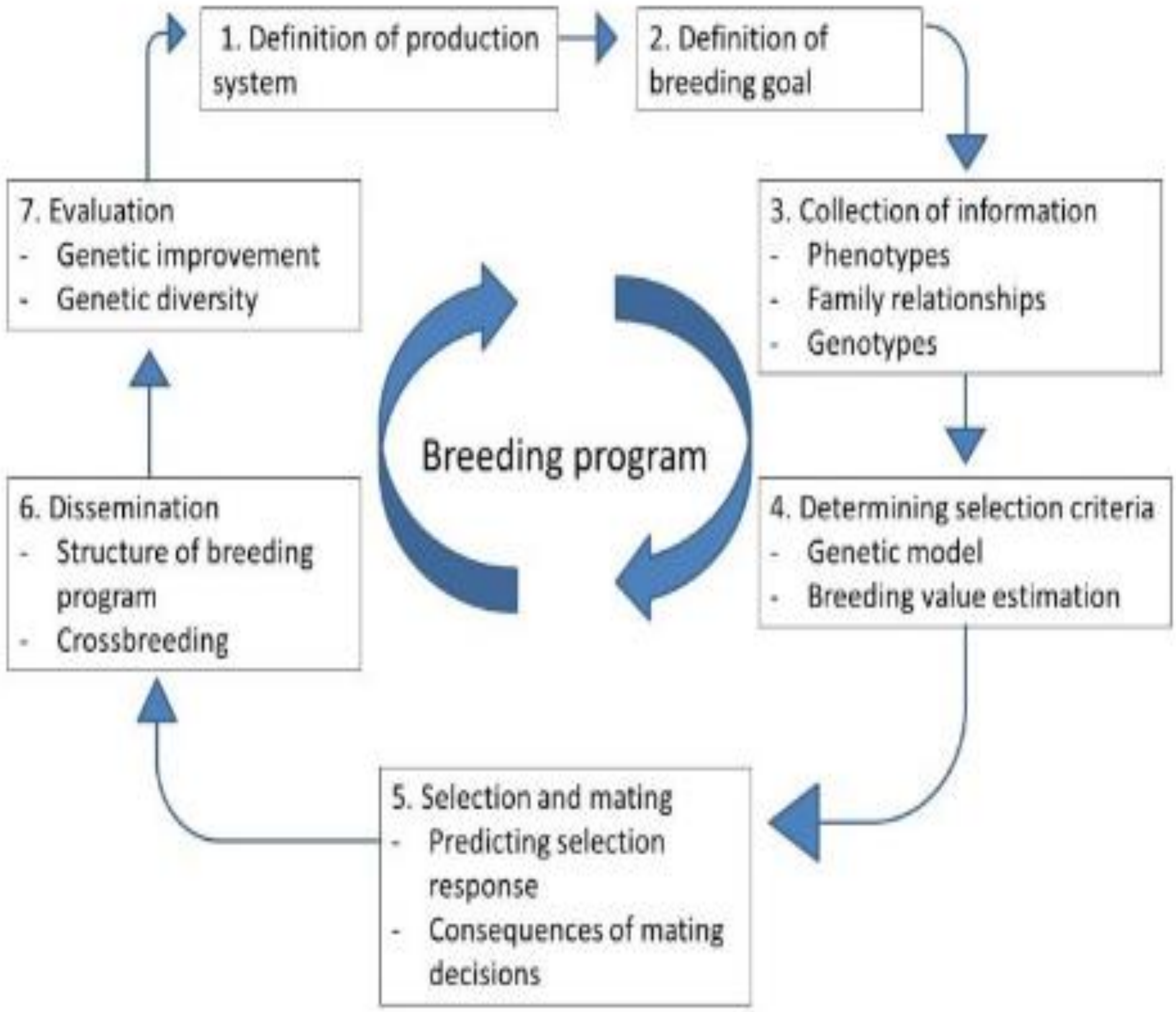


Figure 4. Breeding Program improvement Steps.

8. Analyse of the main steps of the breeding chicken program

8.1 Step 1_ Production system

Goals: At the end of the lecture the student will have the knowledge to:

- ***Define the production system***
- ***Analysis of production system***

8.1.1 Definition of the production system

8.1.1.1 The production system is the situation in which the animals are kept. It is a complex combination of factors that affect how animals perform. When defining the production system, a number of questions are asked. We may ask about:

- ✓ ***Location***

What the **location** of the animal production is. Is it in the tropics or in moderate climates? It makes a big difference whether animals are bred to be kept in Algeria or to be kept in the Netherlands. For example, the requirements for tolerance to specific parasites or susceptibility to heat stress vary a lot by country and region.

- ✓ ***Purpose***

In addition to the location, it is important to know the **purpose** of the animals. Are the animals kept for producing animal products, as a companion animal, or to be a working animal and/or as a means of savings. Production is the purpose of many populations of cattle, poultry or fish. When production is the purpose of the animals, we need to look at the **market** as well as legal and societal concerns. It might be that legislation puts certain constraints on animal production that may affect breeding.

Some animals are kept as companion animals (e.g. birds, dogs or horses). They can be kept just for fun and therefore need to have a friendly character, but they may also be used for sports such as dog racing or dressage in horses. Police horses, guide dogs or police dogs can be considered working animals, whereas other animals are used for land work or transportation. In some areas in the world, animals are kept as status symbols and/or as a source of **savings** instead of money.

- ✓ ***Breed***

When the production system is defined, a breeder can make a first choice. The first choice is which **breed** to use for breeding. Different breeds have different advantages. The growth potential of different breeds of chicken varies a lot. However, the fastest growing breed may not be the most suited for all production systems. Differences in susceptibility to disease or climatic conditions also play an important role.

9. Step 2_ The breeding goals

Objectives: At the end of this course, the student will be able to :

- ***Describe two types of breeding goals: genetic improvement and genetic diversity***
- ***Describe the six characteristics of a breeding goal***
- ***Derive economic values in a breeding goal aiming at genetic improvement***

Introduction

Breeding is based on finding the best animals and to use them as parents to make the next generation. So the goal is to make the next generation better, **on average**, than their parents. To make it better, we need first to decide for which traits we want to make them better.

Chickens can be selected for growth rate, egg production and many other traits. In order to determine the trait that we are going to select animals for, we need to analyse the **needs** of the farmers and the **restrictions** they face in production. For example, smallholder farmer in Algeria sell eggs and meat. So **egg production** and **growth rate** are important traits for them. After analyzing the system production, we found the animals have to survive during a period of food shortage.

Based on this information, the best animals should have:

- The highest egg production (in case for females)

- The highest growth rate

- The highest survival during dry periods

  So, we can say the goal of our breeding program is to **increase** egg production, growth rate and survival.

  H= $\uparrow$ egg production + $\uparrow$growth rate + $\uparrow$survival

So, to define the breeding goal, you need first to analyse the system production and the market for the species you are going to make the breeding program. In this way, you can decide on the trait that you want to improve. In the next step is to determine the desired direction of change by analyzing the effects of increasing traits on farms economics or farmers income.

- Higher egg production will lead to more sales of eggs

- Higher growth rate will lead to males can be sold for slaughter in early ages

- Higher survival increases the food security of the farm in periods of food shortage.

The breeding goal or breeding objective deals with the first question "**Where to go?".** For instance, do we want to improve production or appearance?. It is a list of traits we want to improve. Where each trait has a weight reflects its importance in the production system and the desired direction of change.

9.1 Types of breeding goal

- To make genetic improvements to the population

- To conserve the genetic diversity that is present in the population. This is often found in small population that are not kept for animal production in zoo population and small or local breeds.

  Even when the breeding goal is genetic improvement of the population, loss of genetic diversity is not completely ignored. In most breeding programs the purpose is to genetically improve a population, but conserving the genetic diversity can also be a breeding goal in itself. In breeding programs a **balance** needs to be found between maximizing **genetic improvement** and constraining the loss of **genetic diversity**.

9.2 Characteristics of breeding goal

The breeding goal can be described using its 6 characteristics. They are listed here and each characteristic is further explained below.

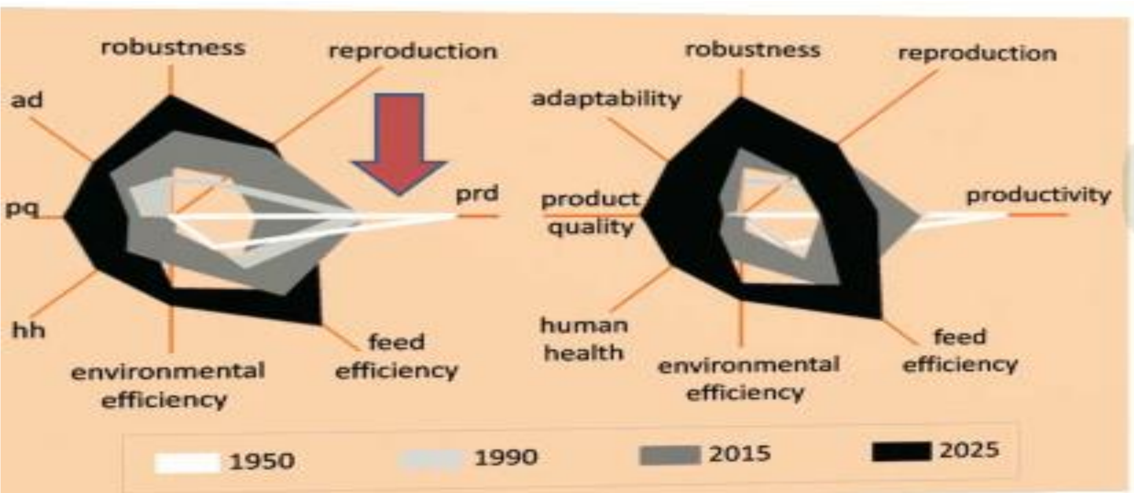
The six **characteristics** of breeding goals are :

9.2.1 The breeding goal aims at the future

Breeding is about changing the characteristics of populations of animals over generations of selection. The breeding goal summarizes which characteristics will change and in which direction. **This makes breeding a long-term activity.**

The breeding goal should be robust against changes that are likely to happen in the foreseeable future.

In this figure, you see how the breeding goal changed for chicken over time. In 1950, the emphasis was mostly on productivity traits. In 2025, it is expected that traits like adaptability and robustness of animals it also be important in breeding program.



In addition, it is expected that animals will have to be more efficient on alternative feed sources. Sustainable breeding goals are breeding goals that reflect these future trends.

9.2.2 <u>The breeding goals often consist of a combination of traits_ example of laying hen</u>

In principle, all traits of importance should be included in the breeding goal. This is irrespective of the heritability of a trait. Even trait with low heritability should be included if they are important. For example, if the interest in a system production is egg production and growth rate, there is a lot of feather pecking. Feather pecking causes cannibalism and is not desired for animal welfare reasons. Feather pecking in laying hens is a trait with low heritability. **However, given its importance it should be included in a breeding goal for laying hens. So, we can write:**

H= egg production + grow rate + feather pecking

Where h^2 of egg production = 0.22

h^2 Growth rate= 0.3

h^2 of feather pecking= 0.05

1. **The breeding goal can be used to rank animals**

In order to find the best animals, we need to know their **breeding values**. A breeding value is a measure of the genetic potential of an animal which can use to rank individual animals if we know their genetic potential.

Eg. The observation of two hens gives the data:

traits	Egg production	Growth rate	Feather pecking
Hen 1	+ 4	+ 5 g/day	1%
Hen 2	+6	+ 4 g/day	5 %

In order to make a choice, we need to know how important these traits are relative to each other. We can do this by assigning a weight to each trait. These weights are indicated by the letter "**V**". By describing each single animal as a sum of breeding values for all traits in the breeding goal, we can count the **aggregate phenotype for two chickens**.

Hen 1= V_1* (+ 4 eggs) + V_2 * (+5g/d) + V_3 * (+ 1% FP)

Hen 2= V_1* (+ 6 eggs) + V_2 * (+4g/d) + V_3 * (+ 5% FP)

9.2.3 <u>The breeding goals contains values to weight the trait</u>

Weights reflect the importance of a trait irrespective to the other traits in the breeding goal.

Let's assume that we have carried out an analysis of the farm economy, **and that we know how much extra profit a farmer can make from selling more eggs,** or selling cockerels for slaughter at an earlier age.

The weights are expressed in DZ. dinars per unit trait and show that egg production has a higher value compared to the other traits (25 dz/egg).

Weight of trait	Value on dz of extra profit
Weight for growth rate	+ 1 dz/g.day
Weight for egg production	+ 2 dz/egg
Weight for feather pecking	-0.2 dz/1% FP

The weight of feather pecking basically reflects the **economic loss** due to **cannibalism** and is **negative**. This means that the desired **direction of change is to decrease** feather pecking.

9.2.4 The breeding goal should ideally summarize all traits in a single criterion

In order to find the best animals, we need to rank them. That can be difficult if animals are compared on the basis of more than one trait. Ranking should ideally be done based on a single criterion (dz, euros, $....). For our example of laying hens, we can rank hens on the aggregate genotype if the breeding values for these traits are multiplied with the weights for these traits, expressed as extra profit in dz per unit of increase in a trait. The result is a single number.

Based on these numbers, it is clear that the hens N°2 has a higher value than hen N°1

Hen 1= V_1* (+ 4 eggs) + V_2 * (+5g/d) + V_3 * (+ 1% FP)

= 2* (+ 4)+ 1 (+5) - 0.2 (1%)

= 8 +5 - 0.2= 12.8dz

Hen 2= V_1* (+ 6 eggs) + V_2 * (+4g/d) + V_3 * (+ 5% FP)

= 2* (+6) + 1 *(+4) – 0.2 (5%)

= 12 + 4 – 1 = 15 dz

9.2.5 The values in the breeding goal can be economic and non-economic

6.1. The breeding goals contains (economic)values to weight the trait

Weights reflect the importance of a trait irrespective to the other traits in the breeding goal.

a. Economic value

To balance the emphasis given to different traits in the breeding programme, a weight, $\mathbf{V_x}$, is defined for each breeding value, $\mathbf{A_x}$. So

$$H= \sum A * V = A_1 * V_1 + A_2 * V_2 + A_3 * V_3 + A_4 * V_4 + \ldots\ldots + A_n * V_n$$

Often the values for the v_x are based on an **economic model** and are called economic values. There are two types of economic models used to derive economic values:

- A **profit equation** and
- A **bio-economic** model.

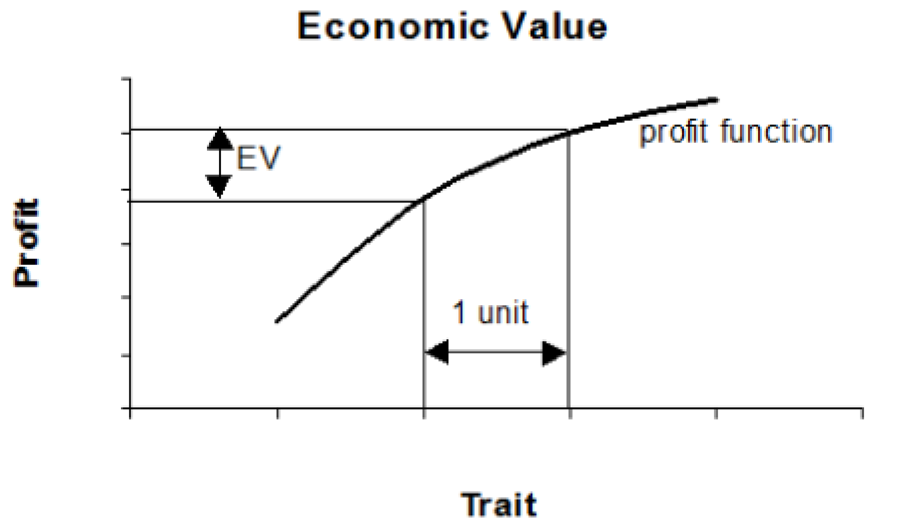
A profit equation relates the profit of an animal or farm to **phenotypic** levels (P) of the traits in the breeding goal in a single equation.

For laying hen farms for instance, if **P** is the phenotypic level of number of eggs produced, **R** and **C** are the marginal revenues and costs of producing that number of eggs. We can summarise the profit of this farm by the profit equation:

$$\text{Profit} = \sum (R_i - C_i) * P_i = (R_1 - C_1) * P_1 + (R_2 - C_2) * P_2 + (R_3 - C_3) * P_3 + \ldots + (R_n - C_n) * P_n$$

Where: the **R-C** represents the difference between the marginal revenues and marginal costs.

An **economic value** indicates how much money would be earned by genetic improvement of **1 unit** of the trait. For example, with number of eggs it is the value of 1 extra egg. You can imagine that genetic improvement with one unit is easier for one trait (e.g. extra egg) than for another trait.



We can obviously see that *the economic value (**EV**) of a trait is the increase in profit that results from a single unit increase of the trait value.*

When the production system is complex, a single equation may not be sufficient and in such cases, a system of multiple equations can be used, **called a bio-economic model.**

9.2.6 Non-economic value

Traits in the breeding goal can be weighted differently by using economic values. For example, **weighting factors** can be based on **biological efficiency** or on **carbon footprint** (the total amount of greenhouse gases; carbon dioxide and methane, that are generated by the action). Weighting factors can also be based on a measure of animal welfare. For instance, To To summarize, when the breeding goal aims to improve biological efficiency, weighting factors can be expressed as Net Energy in MJ per unit of the trait. Derivation of weighting factors based on biological efficiency can be done equivalent to profit equations or bio-economic models.

Welfare traits are difficult to express in economic terms as they reflect a societal desire rather than a market value. In developing countries, it can be difficult to derive economic values for traits that have other non-market values. The value of survival for example is more than just the economic loss of an animal when animals are also used for own consumption. In that case, the food security is far more important.

The breeding goal denoted by the capital H is a list of traits with the breeding value **A** that we want to improve, where each trait has a weight **V** that reflects its importance in the production system and the desired **direction** to change.

$$H= A_1*V_1+ A_2*V2+ A_3*V_3+ A_4*V_4+ \ldots\ldots\ldots\ldots+A_n*V_n.$$

10. Step 3_ Collection of Information and Family Relationships

Goals:

- ***to know more about the value of information in animal breeding***
- ***to learn about the importance of data recording and knowledge of the relationships between animals in breeding programme.***
- ***To learn how information about pedigree is used to quantify relationships***
- ***To understand the concept and consequences of inbreeding.***

Introduction

Collection of information on the animals in a population is of crucial importance in animal breeding! For example, if you want to breed chickens that lay more eggs, you need to know which animals are genetically the best ones for egg production. Only then, you will be able to select the right chickens to produce a next generation that performs better than the current generation. Thus, The key issue in breeding, is the ability to select the best animals as parents of the next generation. But what information can be used to determine which animals are the best ones?

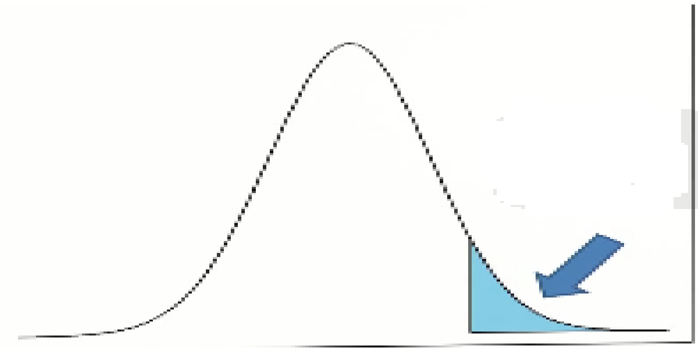
10.1 Several information sources used in selection

Several different information sources can be used for selection. The main sources are:

- **Phenotypes**
- **Family relationships "pedigree"**
- **DNA information**

10.1.1 Phenotypic selection

The simplest method for selection is so-called **phenotypic selection**



This strategy simply ranks animals and individuals based on their phenotypic performance and select the individuals with the highest performance. Common phenotypes used for selection are for instance Nb egg production, milk yield in dairy cattle (only in female, bulls are selected based on observed milk yield of their daughters) and body weight...

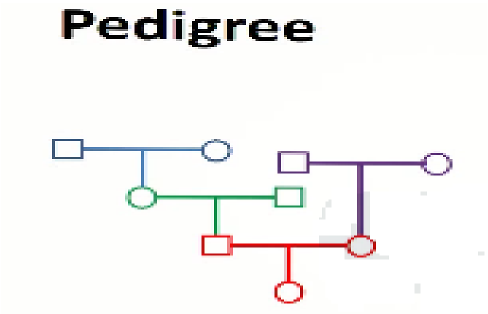
For several other traits, phenotypes are not measured on the selection candidates themselves but on their close relatives as **Carcass** trait for example which needs animals to be slaughtered.

Some traits re recorded repeatedly. Repeated records on the same individual may have different values. The extent to which repeated records on the same animal are similar, is measured by **repeatability (**ranges **from 0 to 1; 1** indicates that repeated records have identical values and therefore obtaining a single record per individual is sufficient. For traits with a low repeatability, however, multiple repeated records are required to obtain accurate phenotypes.

10.1.2 Pedigree selection

Recorded phenotypes are only partly affected by **genetics**, and actually mostly by the **environment**.

To get a better handle on which part of the phenotype is due to genetics, and can be transmitted to the next generation, requires that the **pedigree** of animals is known. Building a full pedigree for a population, requires that each animal its **Sir** and **Dam** are known. With this information, all the family links between individuals in a population can be traced.



Pedigree definition: A pedigree is the set of known parent-offspring relationships in a given population. Pedigrees are often displayed as a family tree diagram (for example, see the figure above).

In pedigrees, you can immediately see who is related to whom. This enables us to derive so called "**additive genetic relationships**". We will also use them when we start estimating the **genetic potential**, or **breeding values**, of an animal. They also provide information about **genetic diversity** and **inbreeding**.

Mistakes in a pedigree or mistakes in the connection between recorded phenotypes and the pedigree are disastrous for the predictive value of pedigrees. They may be caused by mixing up parents (or semen) at mating, by unnoticed matings, by mixing up young animals shortly after birth, or by administrative mistakes. This is especially important when animals are kept together in large numbers. You might imagine that in these cases, mistakes pop up quite easily.

10.1.3 Selection on basis of DNA information

Both phenotypes and pedigree records may contain some errors. Checking the pedigree for errors can be done by using DNA information (from blood, hair roots or mouth..). DNA information can be also used to replace pedigree data for selection. In this case, relationship between individuals are computed from DNA information.

11. Inbreeding

Inbreeding is the result of mating two related individuals. Related individuals are more alike genetically than non-related individuals because they share alleles. So an animal is **inbred if** :

- Its parents are **related (share alleles and have alleles in common)**
- Inbreeding increases **homozygosity** of individual**.**

Exapmle: ***inbreeding using C allele***

Small Human Pedigree

(**X**) (**Z**) (**Y**) :d**iploid**: 2n: they carry only 2 alleles at each locus (A/B/C)

AB CD EF

½ ½ 1/2

W AC Related CF **V**: W&V:carried alleles in common **C**

½ ½

β CC Inbred

β **CC: 2 identical alleles by descent (IBD), inbred:** his parents are related

Both alleles CC in β are a copy of a single allele in an **ancestor** (Z) of β.

Calculate probability of carrying two identical copies of C

The allele C must be passed on 4 times:

Once from Z via W to β and

Once from Z via V to β

Each transmission event has a probability a **half**. ***Prob (CC)=*** $\boldsymbol{(½)^4 = 6.25\%}$

We can repeat the same calculation for the other alleles of Z (D). the probability that β carries two copies od D from Z is also ***Prob (DD)=*** $\boldsymbol{(½)^4 = 6.25\%}$

Therefore, the total probability that β carries two IBD: to be CC or DD (β***: Homozygous***) is Prob(cc) + Prob (DD)= ***6.25% + 6.25%= 12.5%***

The probability to carry two **distinct alleles (β: heterozygous)**: **100- 12.5 = 87.5%**

12.5% is the so-called inbreeding coefficient of β and it usually denoted by **F: "F** $_{\beta}$ **= 12.5%".**

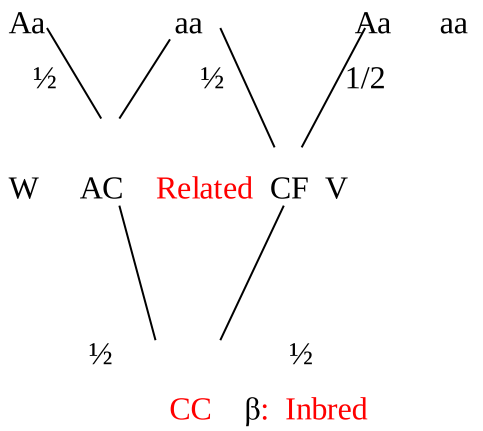
Inbreeding coefficient of an individual is the probability to have two IBD, that are a copy of an allele in its ancestors.

- $0 < F < 1$
- For a single locus, we can say 12.5 % of loci of β will be carry identical alleles that are a copy of a single allele from Z.

11.1 Inbreeding and homozygosity

Populations have ofyen a few distinct alleles codes A/a. Without inbreeding; homozygosity follow which so-called Hardy-weinberg equilibrium: H_w : P^2 : AA 2pq: Aa q^2:

(**X**) (**Z**) (**Y**) : Z: homozygous but not **inbred**



To be homozygous:

A. **Without inbreeding** or at HW equilibrium shows the proportions of homozygous individuals equal $P^2 + q^2$. **P(homozygous HW)=** $P^2 + q^2$.
   In the case **P= 0.33 and q= 0.67** **P (homozygous) = 0.55**
B. **with inbreeding** homozygosity has two components:

1. An individual can be homozygous because its alleles are identical by descent. This has probability equal to the inbreeding coefficient **F**
2. Or both alleles are not IBD with the probability : **1-F**
   P(homozygous inbreeding)= $F + (1-F)*(P^2 + q^2)$

The total homozygosity, therefore, is a combination of inbreeding and the HW equilibrium.

P(homozygous inbreeding)= F + (1-F)* (P^2 + q^2)

For β, (if p= 0.33, q= 0.67)

P (β homozygous)= 12.5 + (1- 12.5)* (0.55)= 0.61

Inbreeding increases homozygosity (0.61 > 0.55).

11.2 Consequences of inbreeding

Inbreeding is typically something we want to avoid in farm animal because it has negative effects on the performance of animals (**inbreeding depression**) and on the incidence of genetic diseases (increasing the prevalence of recessive diseases).

1. **Inbreeding depression** means that inbred animals **tend** to have **lower quality** (smaller, shorter lived, less intelligent and reduced health and fertility. These effects are often summarized as **reduced fitness.** Inbreeding depression is wide-spread in nature, not only in mammals and birds but also in smaller organisms and plants. In Holstein Friesian dairy cattle, for example, one per cent extra inbreeding reduces lifetime by 6.7 days and milk yield by 24 kg.

2. **Increasing the prevalence of recessive diseases also known as genetic defects**
   If A is the wild allele and a is the mutant allele which is recessive and causes the disease. With these two alleles, we can have three phenotypes:
   AA: Homozygote free of disease
   Aa: Heterozygote **healthy** but carrier of the allele disease"
   Aa: Homozygote suffers from the disease (unhealthy)
   The inbreeding increases homozygosity, so AA and aa will be increased. In others words, we get fewer carriers and more cases. This is the reason why the breeding increases the prevalence of recessive diseases.

On the population level, inbreeding is related to the loss of genetic diversity. Populations may lose the genetic diversity for several reasons:

- Small population size
- Population bottelnecks
- Strong selection

When population loses diversity the genetic differences among individuals become smaller. Thus, the individuals become more genetically similar and relatedness between individuals increases which increases inbreeding level in the population.

Small populations tend to suffer from reduced fitness or inbreeding depression and genetic defects. Moreover, in small population the genetic defects may spread over the entire population (mutant allele carriers).

As a conclusion:

- Mating related parents gives inbred offspring
- The inbreeding coefficient F is the probability that the two alleles in an individual are IBD
- Inbreeding increases homozygosity
- Loss of genetic diversity and genetic defects spread though entire population.

12. Step 4_ Determining Selection criteria

12.1 Genetic model

Learning outcomes

After completion of this lecture, you are expected to be able to:

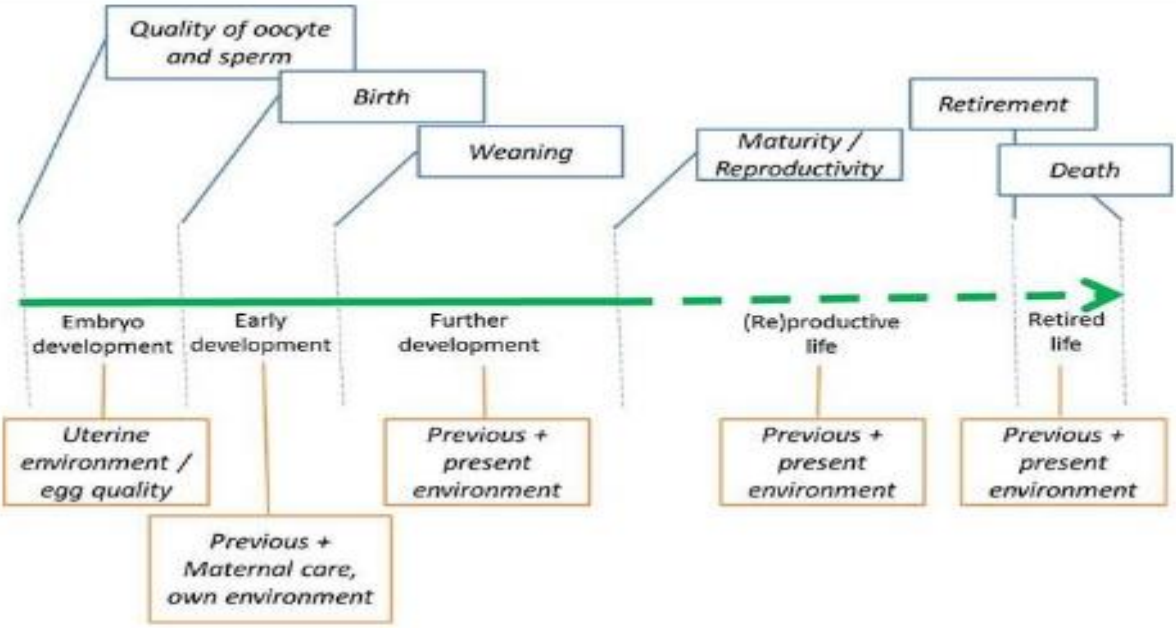
- understand why genetic models are used and describe the differences between models;
- apply the most suitable genetic model for different traits;
- Understand parameters such as heritability, repeatability and common environment ratio;
- Understand the transmission model and Mendelian sampling.

12.2 The Effect of the Environment

Environment: The environment can be defined as anything that influences the animal's performance that is not related to the genetic makeup of the animal, starting at the earliest possible moment in life**.**

Generally, not all variation in observed phenotypes is a result of differences in genetic makeup between animals. Part of it is determined by variation in what we call the **environment**. Often the environment has a very important influence on the animal's phenotype. Environments can have different influences on the life of an animal.

Note that environmental influences early in life may influence the phenotype later in life. However, not ALL early influences have a lasting effect. Some of the influences will be reversible or of insignificant influence.



12.3 Concept of genetic model

A key question for animal breeders is which animal is genetically the **best.** In other word, which animal would have the best offspring in the next generation? To answer this question we need to distinguish between the contribution of **genetic** and **environmental** effects on animal's performances.

Case_ With different type of feed they get**;** **Hen 1** produces 4 eggs per week and **hen 2** produces 3 eggs per week.

So hen 1 is superior due to better genes (**DNA**) or because of better feed (**Environment**)?

To predict which hen is genetically best, animal breeders use **genetic models** in order to separate the **genetic** and **environmental factors** contributing to the **phenotypes.**

Phenotypic value = genetic value + environmental effects or in symbols **P= G + E**

In terms of variation of phenotypes : **var (P) = var (G) + var(E)** this equation shows how much the phenotypic differences is due to the genetic differences.

In summary, the genetic models to separate genetic and environmental effects contributing to the phenotype. These models can be used to estimate the genetic merit of animals and to quantify the contribution of genetic effects to the observed phenotypic variation.

13. Decomposing the Genetic values "G" and Breeding value

The genotypic value of an animal is the **sum** of **effects** of **all alleles affecting the traits and the interactions between these alleles.**

G= Additive alleles effects denoted A + Alleles interactions

The interactions effects can be split up into:

A. **Dominance effects denoted D** : which are interactions between alleles at the same locus

B. **Epistatic effects denoted I:** which are interactions between alleles at different loci**.**

$$G = A + D + I$$

Because gametes are haploid, parents can only transmit the **additive genetic effects** to their offspring. The dominance and epistatic effects are not transmitted from parents to offspring.

The additive genetic effect is known as the **breeding value**. To improve the next generation by selection, animal breeders are therefore primarily interested in the breeding value of animals. Therefore, we can simplify the genetic model:

The phenotypic value is modelled as the breeding value and a residual effects. In symbols:

P = G + E

= A +[D+I +E]= breeding value + **residual effects** (includes: environmental effects, D , I)

= A + e

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