Animal breeding types and their applications

Contents: Definition**;** A brief history**;** Breeding types**;** Genetic effects**;** Practical applications-Breeding plans for farm animals**;** Suggested reading.

Definition

Breeding refers to judicious selection and mating of individuals for desirable purposes, where selection is based on improved physical, physiological, genetic and reproductive features.

A brief history of animal breeding

A brief history of animal breeding is outlined below:

- 25,000-30,000 years ago: Social life of man began
- The first domesticated animal was dog, *Canis familaris*
- Then two species of cows, *Bos taurus* and *B. indicus*
- Next domesticated animal was pig, *Sus domesticus*
- Then sheep, *Ovis aries*
- Then goat, *Capra hircus*
- Chicken, *Gallus domesticus*
- Horse, *Equus caballus*
- 5^{th}–16^{th} century: Traditional breeding of domesticated animals continued.
- 17^{th}–19^{th} century: Improved varieties of cattle, chicken, sheep, pig, horse etc. in Europe.
- 20^{th} century:
  1930s: Selection + Hybridization + Artificial insemination (AI)
  1980s: Embryo splitting technique, transgenic animals
  1990s: Cloning introduced.
- 2000-recent: Modern animal breeding that includes
  Genetics and genetic engineering;
  Improved breeding techniques *e.g.* use of frozen sperm, biostatistics and reproductive physiology.

Types of animal breeding

Animal breeding is basically of two types:

1. Pure breeding: Breeding involving dam (♀) and sire (♂) from the same breed.

2. Crossbreeding (= hybridization): Breeding involving dam (♀) and sire (♂) from different breeds, races or even species.

Pure breeding is again of two types:

- **1. Inbreeding:** Mating between related individuals.
- **2. Outbreeding:** Mating between unrelated individuals of the same breed, race or species having no common ancestors within 4-5 generations.

Types of inbreeding

Inbreeding is of four types:

- **1. Self-fertilization:** The most extreme form of inbreeding, found only in hermaphroditic (bisexual) animals.
- **2. Sib-mating:** Mating between brothers and sisters, having one or both parents in common.
- **3. Cousin-mating:** Mating between cousin brothers and sisters, having one or both grandparents in common.
- **4. Line breeding:** Special type of inbreeding to maintain a high degree of genetic relationship to a desirable ancestor, usually a sire.

Full-sib and half-sib mating

Parents: ♂ × ♀
F_1 progenies: ♀/♂ × ♂/♀
Full-sib mating

Parents: ♂ × ♀ × ♂
F_1 progenies: ♀/♂ × ♂/♀
Half-sib mating

First-cousin mating

Grandparents: ♂ × ♀
Parents: ♂ × ♀
First cousins: ♀ × ♂
Paternal first cousin mating

Grandparents: ♀ × ♂
Parents: ♂ × ♀
First cousins: ♂ × ♀
Maternal first cousin mating

Line breeding

Line breeding is a special type of inbreeding to maintain a high degree of genetic relationship to a desirable ancestor, usually a sire. An example of line breeding is shown below:

Sire (♂)		Dam (♀)	Progenies
S	×	D	D_1 (50% of S's gene)
S	×	D_1	D_2 (75% of S's gene)
S	×	D_2	D_3 (87.5% of S's gene)
S	×	D_3	D_4 (93.75% of S's gene)

S= sire, D= dam; 1, 2, 3, 4 daughters from S × D crosses

Types of outbreeding

Outbreeding refers to mating between unrelated individuals of the same breed, race or species, having no common ancestors within 4-5 generations. An example of outbreeding is furnished below:

Parents:	P_1 (Inbred line-1) ♂	×	P_2 (Inbred line-2) ♀
Genotypes:	AABBCCDD		aabbccdd
F_1 progenies:	AaBbCcDd		
	(hybrid, heterozygote)		

If F_1 hybrid is greater than the mid-parental value [*i.e.* if $F_1 > ½(P_1+P_2)$], the outbreeding is known as **positive heterosis** or **hybrid vigour.**

But, if F_1 hybrid is less than the mid-parental value [*i.e.* if $F_1 < ½(P_1+P_2)$], the outbreeding is known as **negative heterosis.**

Types of crossbreeding

Crossbreeding refers to mating between individuals of different breeds, races or even species, which is clarified by the following examples:

1. Outbreeding between different breeds, *e.g.* Cattle, *Bos taurus*

P:	Red Danish cow ♀	×	White Jersey ox ♂
F_1:	Crossbred roan cattle		
	(hybrid fertile with higher % milkfat)		

2. Outbreeding between different races, *e.g.* Silkworm, *Bombyx mori*

P:	Bivoltine race	×	Multivoltine race
	(*e.g.* BV-1, Dong-34, Zing Su-12)		(*e.g.* BR-84, BSRI-801, Nistari)
F_1:	Crossbred silkwom		
	(hybrid fertile with improved silk quality and quantity)		

3. Outbreeding between different species (*e.g*. Horse *Equus equus* × Ass *E. hemionus*)

P:	Mare (♀ horse, 2n=64)	×	Jack (♂ ass, 2n=62)
F_1:	Mule (2n=63)		
	(hybrid sterile, but with improved fitness)		

Genetic effects of inbreeding

Beneficial effects

- Inbreeding increases homozygosity and decreases heterozygosity in the population.
- It improves a breed by the expression and elimination of deleterious or harmful genes.
- It contributes to the adaptation and evolution of a species.

Harmful effects

- Inbreeding sometimes result in 'inbreeding depression', a decrease in fitness in terms of fertility, viability, vigour, resistance to disease etc.
- It increases genetic load of a species by accumulating the lethal, sub-vital and deleterious genes in the population.

Genetic effects of outbreeding

Beneficial effects

- Outbreeding increases heterozygosity and decreases homozygosity in the population.
- It may restore the fitness lost due to 'inbreeding depression', resulting in hybrid vigour or positive heterosis.
- Some outbred lines are more adaptive than their corresponding inbred lines for many species of animals.

Harmful effects

- Outbreeding may result in the decrease in fitness by exhibiting negative heterosis.
- It is not suitable for many established inbred lines of animals. .

Genetic effects of crossbreeding

Beneficial effects

- Some crossbreedings may result in vigorous hybrids with increased productivity. For example, mule is larger, swifter and stronger than ass, more hardy, resistant to diseases and can do prolonged work than horse, and it is superior in intelligence to either parent.
- Crossbreds may perform better than the inbred and outbred lines. For example, Red Danish cow= average milk fat is 4.39%, inbred Danish cow has 4.04% milk fat, crossbred roan cow has 4.82% milk fat.
- It helps maintaining biodiversity in the population.

Harmful effects

- Most crossbreds reult in hybrid sterility *e.g.* Lion × Tiger= Liger;

  Horse × Jenny= Henny; Zebra × Horse= Zebroid.
- It is not suitable for many established inbred and outbred lines of animals.
- There ia chance of losing genetic identity through crossbreeding.

Practical applications: Breeding plans for farm animals

Animals provide us with the following:

- Meat, milk, egg, wool, leather, bones, feather, manure etc.
- They do much work for mankind; and
- They also entertain us.

Farm animals:

- Chickens (poultry)
- Cattle
- Goats
- Sheep
- Pigs
- Buffaloes
- Horses
- Camels etc.
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-

Captive breeding of animals:

- Deer
- Tiger
- Lion
- Giraffe
- Rhinoceros
- Panda
- Gorilla
- Turtle
- Elephants
- Snakes
- Crocodiles etc

Breeding of domestic chickens, *Gallus domesticus*

Inbreeding of chickens

Indigenous or *Desi* breeds: Aseel, Naked neck, Red Chittagong etc. Characteristics of the indigenous breeds:

(i) Meat favourite for flavour and taste;
(ii) Adaptive to our environment;
(iii) Disease resistant;
(iv) Late maturing and not so good layers.

Fig. 14.1 Indigenous or *Desi* chicken

Exotic breeds: Cobb 500 (broiler), RIR, Fayoumi, WLH, PMR, Wyandotte, Australorp, British Cornish etc.

Characteristics of the exotic breeds:

(i) Large size and early maturing;
(ii) Heavy layers;
(iii) Susceptible to diseases and environmental fluctuations.

Fig. 14.2 Some exotic breeds of chickens: from left to right Cobb 500 (broiler), Fayoumi, Rhode Island Red (RIR) and White Leghorn (WLH)

Outbreeding of chickens

P: Wyandotte Line 1 × Wyandotte Line 2
(Silver feathered) (Golden feathered)
F_1 hybrid: ♂ silver feathered; ♀ golden feathered

(i) Better meat and egg producers;
(ii) Resistant to diseases.

Fig. 14.3 Wyandotte's chickens

Crossbreeding of chickens

Hen (♀)		Cock (♂)	Hybrids
Fayoumi	×	WLH	*Rupali*
Fayoumi	×	RIR	*Sonali*
WLH	×	*Desi*	Vigorous hybrid

Fig. 14.4 Fayoumi and *Sonali* chickens

Note: *Sonali* is a popular and suitable hybrid for commercial poultry enterprise in Bangladesh.

Breeding of cattle, *Bos indicus* and *B. taurus*

Inbreeding

Indigenous cattle breeds: Pabna, Red Chittagong, White Munshigonj, Grey North Bengal etc.

Characteristics of indigenous cattle breeds

(i) High demand for meat, milk and hide;
(ii) Resistant to diseases and higher productivity;
(iii) Small size, not so suitable for dairy farming;
(iv) Well-adapted to our climate.

Fig. 14.5 Pabna breed of cattle in Bangladesh

Exotic beef cattle breeds include: Black Angus, Texas Longhorn, Hereford (USA), White Shorthorn (UK), Chianina (Italy) etc.

Characteristics of exotic cattle breeds

(i) Large size, higher milk producers;
(ii) Longer lactation period;
(iii) Susceptible to disease, not so adapted to our climate.

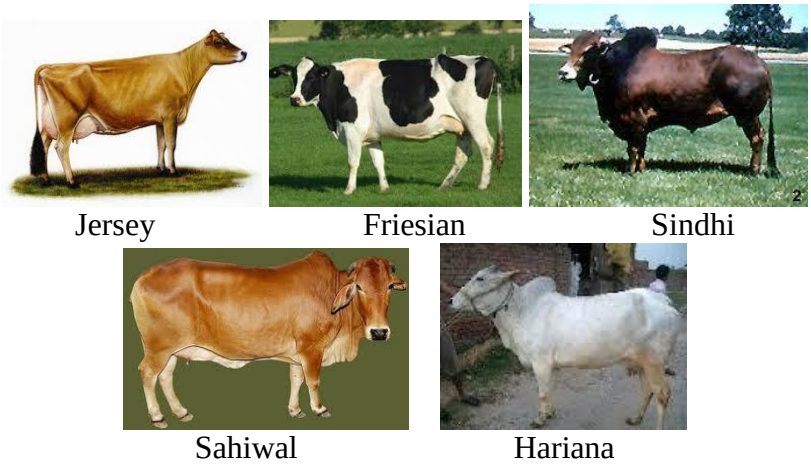

Fig. 14.6 Some exotic dairy cattle breeds: Jersey, Holstein-Friesian (Australia), Normandy (France) Sindhi, Shahiwal and Harianan (India)

Outbreeding of cattle

(a) Inbred bulls × unrelated cows= F_1 ~12% greater weight than ♀ parent.

(b) Dairy cattle × beef cattle= F_1 superior for commercial veal (calf meat) production.

Crossbreeding of cattle

(a) Pabna/RC cows × Friesian/Shahiwal bulls= F_1 ~14-24% enhanced lactation yield.

(b) White Shorthorn (UK) × Black Angus (USA) = F_1 Blue roan.

(i) Vigorous;

(ii) Rapid growth;

(iii) Consumes less ration;

(iv) High beef quality.

White Shorthorn ×  Black Angus

Blue roan

Fig. 14.7 Blue roan is an example of crossbreeding in exotic cattle

Breeding of goat *Capra hircus*

Inbreeding of goat

Indigenous breed: Black Bengal goat (BBG)

Characteristics of BBG

(i) Short size, but delicious mutton quality;

(ii) Early maturing, better fertility and litter size;

(iii) Disease resistant;

(iv) Higher hide demand.

Exotic breeds: Jamunapari, Barbari, Assam hill goat etc.

Characteristics of exotic goats

(i) Large size, rapid growth;

(ii) But mutton and hide quality are inferior to BBG.

Crossbreeding of goat

BBG ♀ × Jamunapari/Barbari ♂

Characteristics of crossbred goats:

(i) F_1 hybrids intermediate in size;

(ii) Increased productivity;

(iii) But mutton and hide qualities deteriorate.


Black Bengal goat (BBG)

Jamunapari


A crossbred goat

Fig. 14.8 Different breeds of goat

Breeding of sheep, *Ovis aries* and other species

Inbreeding of sheep

Indigenous sheep breeds: Dumari, Khorasani, Lohi, Hissardale, Kathiwari etc.

Characteristics of the indigenous sheep breeds:

(i) Mainly for cheap mutton production;

(ii) High fertility;

(iii)Not suitable for commercial wool production.

Exotic sheep breeds: Merino (Australia), Hampsire, Lincoln (USA); Shetland, Oxford, Dorst, Blackface (UK) etc.

These are mainly for commercial wool and mutton production.

Characteristics of the Merino sheep of Australia:

(i) It was originated in Spain during the 17^{th} century, then was imported to France in the 18^{th} century and finally was introduced to Australia in the 19^{th} century;

(ii) Merino sheep is the result of inbreeding and continued selection for more than 200 years;

(iii) It is world famous for its renowned wool quality.

Crossbreeding of sheep

Sometimes crossbreeding gives rise to better productivity. An example includes the Columbia hybrid. It came from gregarious Rambouillet, having short but fine wool, and solitary Lincoln, having long but coarse wool.

P:	Rambouillet	×	Lincoln
	(Gregarious)		(Solitary)
F_1:		Columbia hybrid	

Characteristics of the Columbia hybrid:
(i) Wide range;
(ii) Fine, intermediate-sized wool; and
(iii) Good and popular mutton quality.

A B C

D E

Fig. 14.9 Several breeds of indigenous and exotic breeds of sheep; (A) indigenous, (B) Merino, (C) Rambouillet, (D) Lincoln and (E) Columbia

Breeding of pig or swine, *Sus domesticus*

Inbreeding of pigs

Indigenous pigs and their characteristics
(i) These are non-descriptive, domesticated from wild-type pigs, smaller in size;
(ii) High productivity and disease resistant;
(iii) Not suitable for commercial pork production;
(iv) Reared and maintained by lower caste people like sweapers and saotals in the country.

Exotic pigs and their characteristics:
Yorkshire, Tamworth, Duroc, Jersey, Poland, China etc. are well-known and famous exotic breeds of pig reared in Europe and USA.
(i) They are larger in size and healthier;
(ii) Used for the production of pork, bacon (salted pork) and lard (pork fat);
(iii) Used in the production of ham (upper leg), processed with salt and/or smoke;
(iv) Also largely used in laboratory experiments.

Crossbreeding of pigs

Examples of crossbreeding between different breeds that are beneficial include:
(a) Duroc × Jersey: Bacon-producing hybrid;
(b) Poland × China: Lard-producing hybrid;
(c) Yorkshire or Tamworth × Duroc-Jersey or Poland-China (This is known as double-cross hybridiz ation)

Characteristics of the crossbred pigs:
(i) They produce vigorous F_1 hybrids;
(ii) They mature early;
(iii) They have superior market value;
(iv) Crossbered pigs are also used in the laboratory for research purposes.

A B C D

Fig. 14.10 Different breeds of pigs; (A) Indigenous, (C) Tamworth, (C) Duroc-Jersey, (D) Poland-China

Breeding of other animals

Apart from the farm animals described above, animals such as cats, dogs, horses, buffaloes, camels, llamas and elephants are used for domestic as well as commercial productions. In addition, captive breeding of some animals like deer, snakes, crocodiles, tigers and lions are also practised at home and abroad.

Recent advances in animal breeding

Apart from traditional breeding programmes, genetic engineering techniques are recently being utilized for animal breeding. Two main goals of such techniques are: (a) to produce transgenic animals by transferring 'foreign' gene(s); and (b) to improve the animals through introducing some desired traits.

Production of transgenic animals

This is done either by probing 'foreign' DNA into the fertilized eggs using micro-injections, or by transferring tetroviral vectors into the embryos. Success has been achieved in producing transgenic mice, sheep, pigs, rabbits, chickens, frogs and fishes. Merits of these transgenic animals include enhanced growth, less fat and cholesterol in their meats, increased feed conersion ratio and these are capable of reproducing under domestic conditions. However, there are demerits of the transgenics which include weakness, depression, weak musculature, arthritis and gastric ulcers.

Improvement of desired traits

A nice example includes the production of bird-flue resistant variety of chicken, which is now under laboraory trials. Other examples such as increased protein contents in the milk of transgenic cattle and sheep using genetic engineering are worth mentioning.

Suggested reading:

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