(4) Examples of transgenic plant varieties include transgenic papaya that is resistant to ring spot virus, “golden rice,”
(5) With genetic engineering, however, such gene transfers can be done more quickly, more specifically, and with intermediate species

12. Which of the following is not an undesirable effect of artificial breeding.
(1) Artificial breeding is geared towards producing a uniform set of plants or animals with traits desirable to humans.
(2) Reduction of genetic diversity will have adverse consequences on the evolutionary fitness of the species leading to low resistance to infections
(3) Limited opportunities for the natural selection act upon the population is likely to drive them towards  a lower fitnessplateau
(4) Increase in heterozygosis which would in turn increase the expression of recessive deleterious mutations .
(5)Artificial breeding improves certain characters in the population, simultaneously and unintendedly it could lead towards deterioration of other characters that are not under direct observation.

13. Which one of the following statements is correct?
(1) Gene frequencies in a population normally fluctuate with time.
(2) In an isolated population, homozygotes decrease whereas heterozygotes increase.
(3) Heterosis increases in inbreeding population.
(4) Hardy Weinberg equilibrium is a common state in natural populations.
(5) Fertile offspring could never be obtained in interspecific breeding. (Olympiad 2020)

14. Which of the following could be the reason/reasons for cystic fibrosis?
(A) Y—linked inheritance (B) X-linked recessive inheritance (C) Pleiotropy
(D) Autosomal recessive inheritance (E) Autosomal dominant inheritance 2022 AL/46

**Essay / 2019 AL**

**1. (a) Briefly describe the significance of polyploids in agriculture.**

1. Polyploidy is the presence of more than two (complete) sets of homologous chromosomes per nucleus.
2. This is widely used in plant breeding.
3. Used for increasing size of plant organs/gigas effect.
4. Caused due to increased number of gene copies.
5. Results in reduced fertility
6. due to meiotic errors.
7. Allows the production of seedless varieties.
8. eg. triploid watermelon
9. Used as a bridge for gene transferring
10. between two species having different ploidy levels.
11. Restoration of fertility
12. by genome doubling.
13. Promotes buffering effect
14. by masking deleterious alleles by extra copies of wild type alleles.
15. Allows functional diversification of redundant gene copies in which
16. one member of duplicated gene pair mutates and
17. acquires a new function without compromising essential functions.
18. It increases heterozygocity
19. which enhances vigour.
20. eg. Maize/ potato/ alfalfa
21. It improves the quality of the product and
22. increases the tolerance to (biotic and abiotic) stresses.

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# Biology 4

NEW SYLLABUS

## English Medium

UNIT 06

## Genetics

Plant and Animal Breeding

SAMPATH LANKADHEERA

5. Which one of the following statements regarding plant and animal breeding is incorrect?
   (1) The breeding among genetically similar individuals are known as inbreeding.
   (2) When plants or animals of different breeds (races) are mated with each other, it is known as out-breeding.
   (3) When genetically unrelated pure-bred plants or animals in the same species are mated with each other it is known as cross-breeding
   (4) Inter-specific hybridization, male and female organisms of two different species are mated.
   (5) In artificial selection plants or animals with specific traits were selected to breed so that their desired traits could be passed to the next generations to produce a high performing new variety.

6. What is meant by genomic redundancy.
   (1) expose of harmful recessive genes (2) Removal of undesirable traits
   (3) Quality improvement (4) Having additional gene copies
   (5) increase in such characteristics over those of parents

7. Which of the following is incorrect regarding hybrid crossing
   (1) It is crossing of genetically unrelated pure-bred plants or animals in the same species
   (2) this is carried out with plants and animals who do not share common ancestors on either side of their pedigree up to four to six generations
   (3) vigour may decrease, however, if the hybrids are mated together
   (4) rice hybrids, has more than tripled yields over the past 50 years from an average of 35 bushels per acre in the 1930s to 115 bushels per acre in the 1990s
   (5) Hybrids have extended growing season and often mature up to 15 days earlier than local true breeding varieties

8. Find correct statement regarding interspecies crosses
   (1) The progeny obtained from iner-species crossing are usually different from both the parental species and always sterile
   (2) Animals hybridize much more frequently and successfully than plants do
   (3) Intermediate form of a animal hybrid is more likely to be physiologically successful.
   (4) Bread wheats that humans use today are a result of two hybridizations each followed by chromosome doubling to produce fertile hexaploids
   (5) (Rubus ursinus x idaeus) were developed crosses between blackberries (*Rubus fruticosus*), European rasp berries (*Rubus idaeus*)

9. What is meant by gigas effect
   (1) Having additional gene copies (2) Reduced fertility due to meiotic errors
   (3) Larger organs compared to their diploid counterparts
   (4) Extra copies of wild-type alleles. (5) Higher levels of heterozygosity

10. Find the correct relationship
    (A) Sodium azide - Antimitotic agent
    (B) Ethylene oxide - Chemical mutagen used for mutation breeding
    (C) Ethyl methanesulphonate - Reduce microbial populations
    (D) Colchicines - Chemical mutagen used for mutation breeding
    (1) A and B correct (2) A and B correct (3) A, B, C correct (4) All correct (5) All incorrect

11. Which of the statement incorrect regarding genetic engineering in plant.
    (1) Genetic material is obtained from one organism showing a desired trait and will be inserted to another second organism
    (2) In traditional plant breeding techniques transfer of genes is limited to the closely related species or genera
    (3) Genetic engineering of crop plants is the key to overcoming some of the most pressing problems of the 21st century

2. Find correct organism for the given breeding technique

| | | |
|---|---|---|
| (a) Out Breeding | | Boysen berries, Winter harden apples, |
| (b) Hybrid Breeding | | Seedless 3n watermelon. |
| (c) Interspecific breeding of plants | | Cross Indian Zebu and nondescript cows with Holstein Fersian, Brown swiss Jersey bulls or their semen. |
| (d) Polyploidy | | Male donkey and female horse. |
| (e) Mutation breeding | | Papaya resistant to ringspot virus. |
| (f) Interspecific breeding of animals | | Firm flesh of wax gourd, Crispy taste watermel-on |
| (g) Genetic modification | | Wheat, barley, rice potatoes and onion. |

**MCQ**

1. Which of the following statements is incorrect regarding polyploidy in plants?
(1) This is condition brought about by having more than two pairs of homologous chromosomes in a cell.
(2) Self fertilization in plants causes polyploidy. (3) Some polyploidy plants are sterile.
(4) Polyploidy occurs due to abnormal cell division.
(5) Polyploidy can be induced in plants and tissue cultures by some chemicals.
(2011Old/26)

2. Select the incorrect statement regarding uses of plant and animal breeding
(1) Plant and animal breeding helps to enhance the value of food by improving their nutritional quality.
(2) Plant breeding is useful in reducing these toxic components and making them safer to eat
(3) super wheat which boost the harvest by 20-40% of normal wheat and several high yielding corn, maize and soya bean varieties.
(4) develop new plant types that can resist various biotic and other abiotic stresses.
(5) Polyploid plants also have fast growth rates, and tend to flower faster, which is a desirable feature for ornamental breeding.

3. Hybrid vigor is
(1) Increased by breeding among genetically similar individuals
(2) Higher in parents than n the F1 generation (3) Achieved by increasing heterozygosity
(4) Maintain by breeding among hybrids (5) Result inter-specific hybridization
(2020/31)

4. Find the correct relationship between give technique application
(1) Artificial selection - Negatively affected once are removed
(2) Inbreeding - Domestication of plants
(3) Out breeding - Crispy taste of watermelon
(4) Out crossing - Cross Zebu and Holstein Frisian
(5) Interspecies cross - Boysen berries

**Plant and Animal Breeding**

People have intervened in the reproduction and genetic make up of plants and animals since the dawn of agriculture, eight to ten thousand years ago. Early farmers selected the best looking plants and seeds and saved them to plant for the next season. Likewise, the best farm animals were allowed to mate with each other to preserve and improve their desirable traits.

This phenomenon wherein human beings interfere in the process of reproduction to allow only selective mating to occur, so that off spring with improved characters are produced is called breeding (as against natural reproduction).

With the science of genetics became better understood, plant and animal breeders used what they knew about the genes of a plant or an animal to select for specific desirable traits to develop improved plant varieties or animal breeds. The selection for features such as faster growth, higher yields, pest and disease resistance, larger seeds or sweeter fruits in crop plants, color and pattern of the skin, hair or feathers in animals have now dramatically changed domesticated species compared to their wild relatives.

**Importance of plant and animal breeding**

In breeding programmers, the attributes, structure and composition of plant and animals are manipulated in such a way to make them more useful to humans. Accordingly, plant and animal breeding has a significant impact of world's agro-economy as discussed below;

**1. Addressing world food and feed quality needs**

An estimated 800 million people in the world, including 200 million children, suffer from malnutrition and associated health issues. Plant and animal breeding helps to enhance the value of food by improving their nutritional quality. For example, rice which is the most widely eaten staple food, lacks many essential vitamins.

Another problem encountered in major food crops is the presence of toxic substances within them such as alkaloids in yam, cynogenic glucosides in cassava (manioc), trypsin inhibitors in pulses, and steroidal alkaloids in potatoes. Plant breeding is useful in reducing these toxic components and making them safer to eat. Plant breeding is also useful in making some plant products more digestible. For example, a high lignin content of the plant material reduces its value for animal feed which can be overcome with the use of breeding techniques.



Although there are negative impacts artificial breeding is still preferred over natural breeding for the numerous advantages it could bestow upon overall animal and plant productivity as discussed earlier.

**Structured Essay**

1. (i) State the traditional breeding techniques which caused significant improvement in agriculture.

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(ii) What is inbreeding.

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(iii) State why it is said that continued inbreeding reduces genetic fitness of the population.

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(iv) What is polyploidy.

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(v) (a) What is meant by Gigas effect and what is the advantage of it.

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(b) What are agents to induce mutation breeding.

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higher prevalence of congenital anomalies and reduced fertility. For example when a population of animals or plants with the same genetic traits are attacked by a pathogen to which they are susceptible, the entire population is likely suffer due to the absence of the resistant trait within the gene pool. This limited opportunities for the natural selection to act upon the population is likely to drive them towards a lower fitness plateau.

On the other hand, natural breeding can rule out weaknesses and disabilities which affect survival by allowing natural selection to act upon the species. This will produce fitter and stronger individuals in the long run. However, the natural selection would not guarantee a productivity increase in the consumer perspective, despite the increase in genetic fitness. As discussed earlier, sometimes inbreeding is practiced as an artificial breeding technique. This would result in an increase in homozygosis which would in turn increase the expression of recessive deleterious mutations that would otherwise stay masked within heterozygotes. This can cause the population to undergo inbreeding depression with adverse effects on the overall fitness.

Sometimes artificial breeding can exhibit negative correlated responses. This refers to the fact that while artificial breeding is improving certain characters in the population, simultaneously and un-intendedly it could lead towards deterioration of other characters that are not under direct observation. For example the shape of the skull in some dog breeds has made it difficult for them to eat normal food because of the upper jaw being much shorter than the lower jaw, such as in the case of Boxer or the Bulldog. Likewise selection for large off spring has resulted in a high fraction of difficult births, sometimes requiring caesarean sections in the Texel sheep, and even almost as a standard way of delivering in the beef cattle breeds Belgian White-and-Blue cattle and the Dutch Improved Red-and-White. This kind of negative responses are difficult to predict in advance and usually only visible after the new breed is established.



**2. Addressing food supply needs for a growing world population**

It is anticipated that an additional three billion people will be added to the world population within the next three decades. Aligned with this population growth, an expansion in world food supply should be required to meet the projected needs. Unfortunately, land for farming is scarce and therefore more food will have to be produced on less land. This calls for improved and high yielding animal and plant varieties to be developed. In response plant breeding has produced super rice which has 50% more yield compared to the normal rice, super wheat which boost the harvest by 20-40% of normal wheat and several high yielding corn, maize and soya bean varieties. The total production of meat and milk has also increased considerably over the years due to careful use of selective breeding techniques.

**3. Need to adapt to environmental stresses**

Weather and soil conditions can have a major impact crop yield. Climate changes and global warming are partly responsible for modifying the crop production environment (Eg. Some regions of the world are getting drier and others saltier**).** To meet the increasing demand for food new cultivars need to be bred which can sustain these adverse conditions. For example, it is necessary to develop new plant types that can resist various biotic (diseases and insect pests) and other abiotic (Eg: Salt, drought, heat, cold) stresses in the production environment. In response, genetically modified, pest resistant cotton, maize, and potatoes which carry Bt toxin, salinity tolerant rice varieties, cold tolerant tobacco, potato and strawberry varieties etc. are now available in agricultural industry. Likewise, both crop plants and farm animals (cattle, pig sheep goat etc.) with increased immunity to pathogens have also been produced through various breeding techniques.

**4. Satisfying industrial and other end-use requirements**

Consumers are having different requirements based on the texture, colour and composition of a particular food item irrespective of its taste or nutritional value. These diverse demands for the same food can be now successfully met through breeding procedures. For example, potato is a versatile crop used for food and industrial products. Different varieties are being developed by breeders for baking, cooking, fries (frozen), chipping, and for starch. These cultivars differ in size, specific gravity, and sugar content, among other properties. High sugar content is undesirable for frying or chipping because the sugar caramelizes under high heat to produce undesirable browning of fries and chips. Likewise, there is a high demand for seedless fruits such as grapes, melon and strawberries and also for leaner meat.

Depending on these end-user requirements, it is possible to develop quality added products using animal and plant breeding techniques.

**5. Developing animal and plant varieties with aesthetic values**

Aesthetics is of major importance in horticulture as well as in the industry of ornamental and pet animals. The ornamental plant industry depends to a large extent on the development of new varieties that exhibit new flower/leaf colours, varying sizes and attractive shapes etc. using plant breeding. The pursuit of novelty has spurred a similar explosion of types in pet animals as well.

Today selective breeding for numerous morphological features and functional abilities have given rise to nearly 400 dog breeds making them one of the most diversified species on earth. Likewise, there are close to 50 rabbit breeds, vast number of bird varieties and an extensive range of ornamental fish.

## Breeding techniques

Plant and animal breeders use numerous techniques to create new varieties with enhanced features. Many of these techniques have been successfully practiced over centuries even without the knowledge of the underlying genetics. Following section summarizes some of these traditional breeding techniques which has caused significant improvements in agriculture and farming.

**1. Artificial selection**

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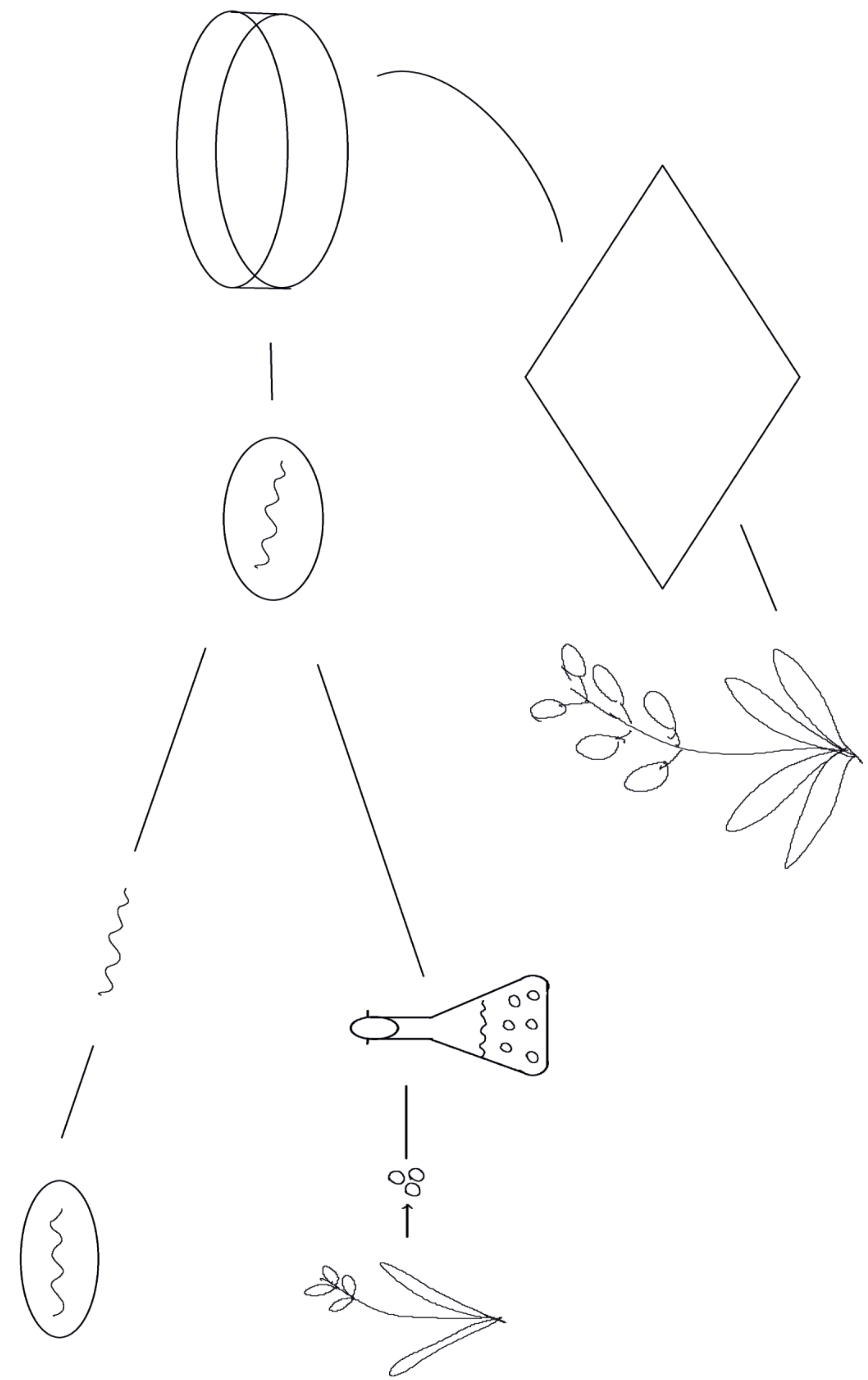
The method has made a huge impact on agriculture by way of improving plant and animal products b**efore** the discovery of more sophisticated technologies like genetic engineering.





### 3. Genetic modification

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Thus, by transferring genes within and across species, improved or novel organisms are produced. In traditional plant breeding techniques transfer of genes is limited to the closely related species or genera. For example, traditional breeding techniques could not be used to insert a desired gene from daffodil into rice because the many intermediate species between rice and daffodil and their common ancestor is extinct. With genetic engineering, however, such gene transfers can be done more quickly, more specifically, and without the need for intermediate species. The **term transgenic or genetically modified organism (GMO)** is used to describe organisms that have been engineered to express a gene from another species. Advocates for plant biotechnology believe that the genetic engineering of crop plants is the key to overcoming some of the most pressing problems of the 21st century, including world hunger and fossil fuel dependency. Examples of transgenic plant varieties include transgenic papaya that is resistant to ring spot virus, "golden rice," with increased levels of beta-carotene and salinity resistant rice varieties among others.

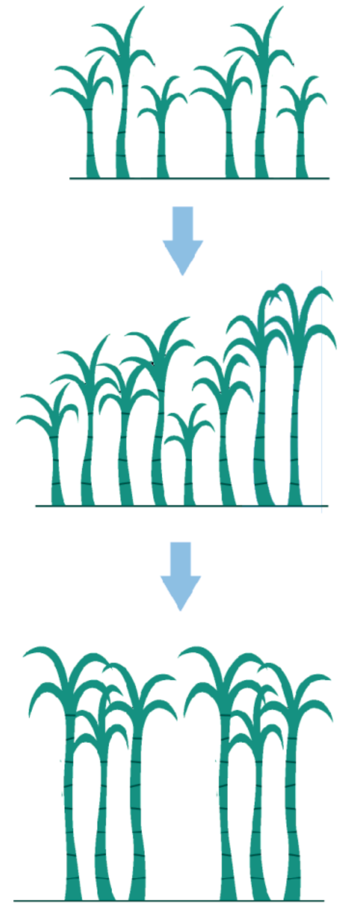
**Natural or artificial breeding: Advantages and disadvantages**

Although artificial breeding is extensively practiced today with remarkable economic gains, there are serval drawbacks in the method in comparison to the natural breeding.

The artificial breeding is geared towards producing a uniform set of plants or animals with traits desirable to humans. The development of this uniformity needs compromising the variability within the species. This reduction of genetic diversity will have adverse consequences on the evolutionary fitness of the species leading to low resistance to infections,



The first prerequisite of artificial selection is the availability of variation with respect to the desirable characters. Once a population with a desirable variation is recognized, the best performing individuals for the desired feature are selected. For example, when selecting for fruit size in plants, only those giving the biggest fruits are chosen for the breeding programme and the rest of the population is discarded or rejected. The progeny of the selected individuals is grown further and again screened for the desired feature. This process is repeated sometimes for many generations, until a uniform plant population is attained which has the best-desired characters. Eventually, a new uniform crop variety with the desired characteristic is produced by this successive selection, followed by multiplication of the selected individuals.



The advantage of selective breeding is that it uses the processes of natural selection, but under direct supervision from carefully selected animals or plants with the desired traits. There are no genetic modifications or other forms of tampering that could potentially harm people and the risk to the plant or animal is often minimum. Crops like corn and wheat are commonly selectively bred in order to obtain the highest yielding plants. Breeding animals with higher protein and lower fat percentages, as well as plants that have higher nutritional values, had been used to create food sources with a higher quality of nutrition. In addition, selective breeding has, effectively removed undesirable traits such as low resistance to disease, in some animals and plants. However, selective breeding among animals can take a long time for the process to work.

In horse breeding, for example, the given standard to establish a new breed is to have off spring with the desired traits to be produced over the course of 7 generations. This means it may take 25-50 years for the desired traits to become a foundational component of an animal.

**2. Inbreeding and out breeding**

**I. Inbreeding**

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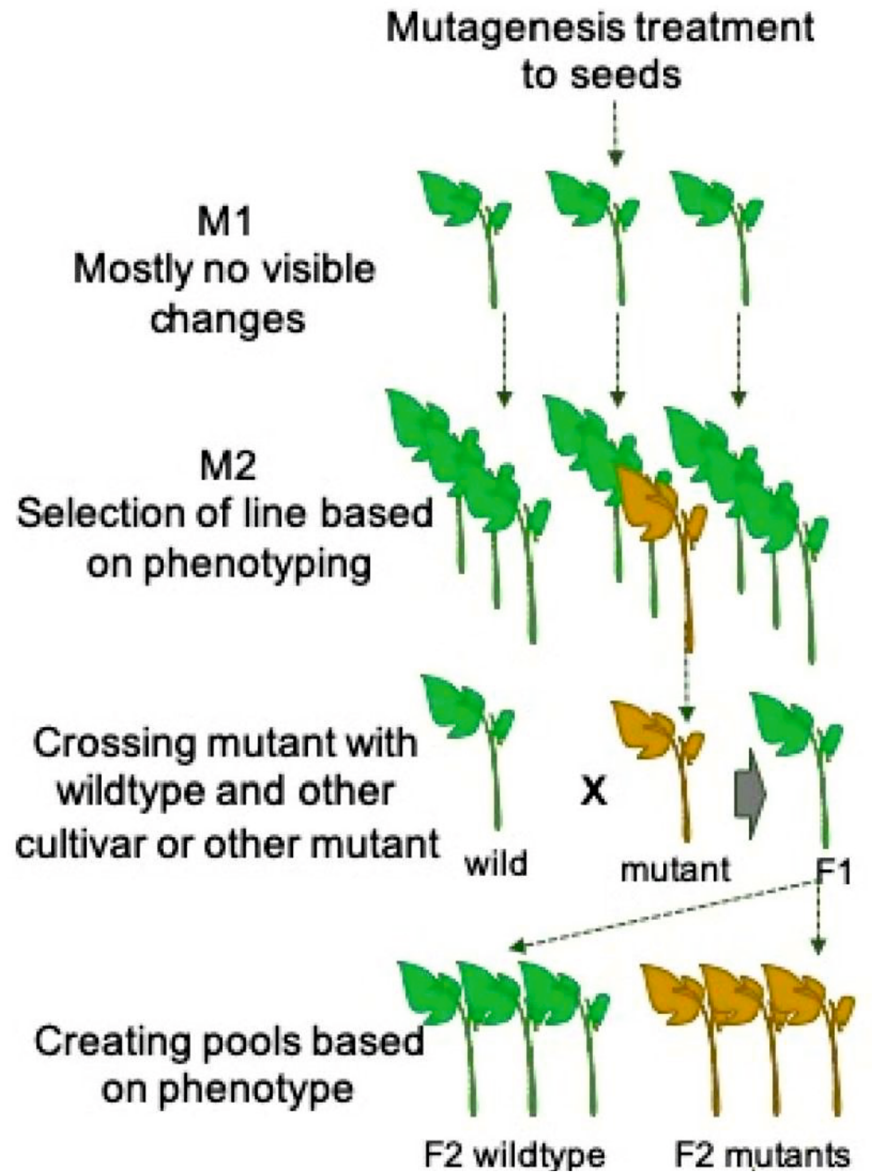
Among plant breeders the term "inbreeding" is commonly used to mean self-fertilization, Eg. The fertilization of a flower with its own pollen or with pollen from a different flower on the same plant. This is done to produce an inbred variety, which is exactly the same generation after generation. Many important crops, such as wheat, oats, barley, and tobacco, are produced from seeds which are habitually self-fertilized.

However, in animal breeding the term " inbreeding " is used to refer to the mating of closely related individuals, as, for instance, the mating of father and daughter, brother and sister, or cousins. In both crop plants and farm animals, inbreeding brings uniformity of the required type while preserving the desired characters. Inbreeding is used for developing pure lines in agriculture as well as for research.

As a rule, inbreeding increases homozygosis and thus exposes harmful recessive genes which would have otherwise stay hidden among heterozygotes. Continued inbreeding, therefore, reduces genetic fitness of the population. As a result, the growth and fertility of the inbred population would go down with adverse effect on their productivity. Prevalence of genetic disorders might also increase among the inbred population. This phenomenon of having a reduced genetic fitness in a given population as a result of inbreeding is called inbreeding depression.





## 2. Mutation Breeding

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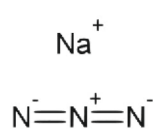
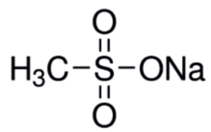
This method of inducing desirable mutations in crop plants using either chemical or physical agents was termed mutation breeding.

Several agents can be used to cause mutations. This include ionizing radiation such as gamma rays, protons, neutrons, alpha and beta particles and chemicals such as sodium azide and ethyl methanesulphonate.



**Sodium azide**



**Ethyl methane-sulphonate.**

Since the desirable mutations induced by these treatments are found at a very low frequency (0.1% of total mutations), breeders have to screen a large population to select a desirable mutation. In addition, most mutations act in a recessive fashion and are likely to be masked by their dominant allelic counterparts making the screening procedure even harder.

The effectiveness of using induced mutation depends on the breeding system of the plant. Its use in self-pollinated plants is likely to be more successful than in cross pollinated ones. Populations of cross-pollinated plants usually possess stores of genetic variability in the recessive condition and it would not be likely that induced mutation would produce significant amounts of new variability. Further, induced mutation is potentially useful in the improvement of asexually propagated crop plants.

Despite these limitations, mutation breeding efforts continue around the world today. It has improved both morphological and physiological characteristic of both crop and ornamental plants such as flower colors, seed size, crop yield, disease resistance and salinity tolerance, drought tolerance and early maturity. Examples of plants that have been produced via mutation breeding include wheat, barley, rice, potatoes, soybeans, and onions.



However, in agriculture and animal husbandry, positive effects of inbreeding will be harnessed as much as possible. To ensure this, only those off spring that are exhibiting the desired trait, without other negative ones, will be used for future breeding. The negatively affected individuals in the progeny are removed or are not be allowed to be bred. Thus, inbreeding is used in agriculture to help accumulation of superior genes.

### II. Out-breeding

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This allows the desirable characters of the exotic parent, which the indigenous parent does not have, to be transmitted to the progeny. Eg: Cross breeding is carried out by animal breeders to enhance milk and meat production. In India zebu breeds of cows and nondescript cows are crossed with exotic breeds like Holstein Fresian, Brown Swiss and Jersey bulls or their semen, to enhance the milk production potential of the progeny. Likewise crop plants like corn and hemp, are normally cross-fertilized.

**Zebu Breed**

**Holstein Fresian**

### 3. Hybrid breeding/Out crossing

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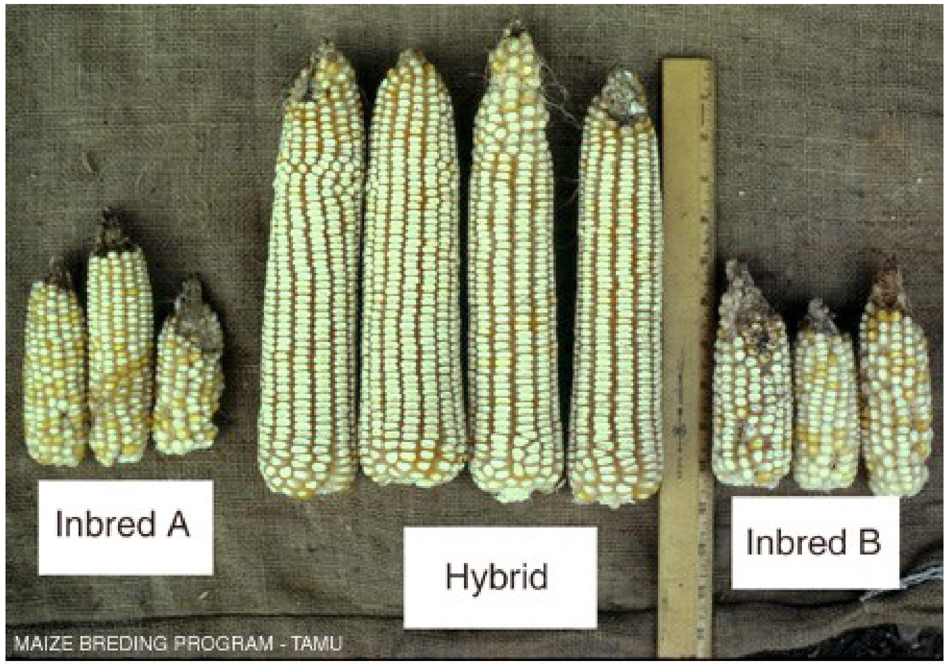
The offspring of such a mating is known as the out cross and will possess stable characteristics and hybrid vigour. **Hybrid vigour,** also called heterosis, is the increase in such characteristics as size, growth rate, fertility, and yield in the hybrid organism over those of its parents.

Plant and animal breeders exploit heterosis by mating two different pure-bred lines that have certain desirable traits. The first-generation off spring generally show, in greater measure, the desired characteristics of both parents. This vigour may decrease, however, if the hybrids are mated together; so the parental lines must be maintained and crossed for each new crop or group desired.




In plant breeding, because creating hybrids involves many years of preparation to create pure lines that have to be constantly maintained so that F1 hybrid seeds can be harvested each year, the seeds then become more expensive. Nevertheless, hybrid seeds have had a tremendous impact on agricultural productivity. Today, nearly all corn and 50% of all rice are hybrids. In the US, the widespread use of corn hybrids, coupled with improved cultural practices by farmers, has more than tripled corn grain yields over the past 50 years from an



**1. Polyploidy**

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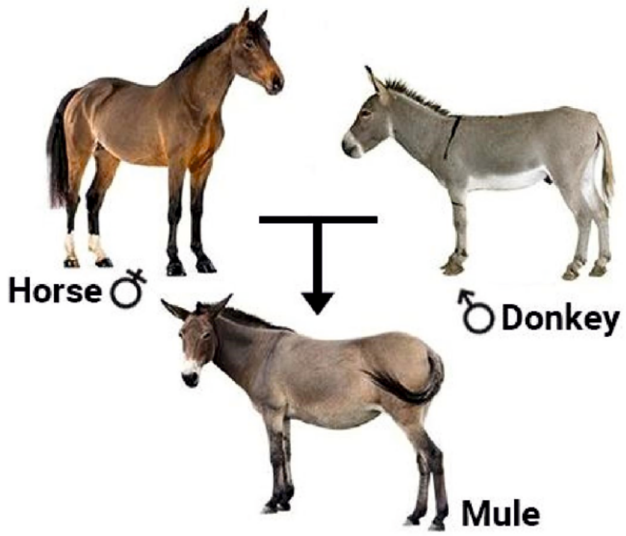
One of the most important consequences of polyploidy for plant breeding are the increment in plant organs ("gigas" effect) caused by the larger number of gene copies. Polyploid individuals may thus exhibit larger organs compared to their diploid counterparts, such as roots, leaves, tubercles, fruits, flowers and seeds. Polyploid plants also have lower growth rates, and tend to flower later or over a longer period of time than related diploids, which is a desirable feature for ornamental breeding.

In addition, polyploidy often results in reduced fertility due to meiotic errors, allowing the production of seedless varieties such as the triploid watermelon. On the other hand, when the crossing between two species is not possible because of differences in ploidy level, polyploids can be used as a bridge for gene transferring between them. Similarly, the genome doubling in a newly formed sterile hybrid allows the restoration of its fertility.

Genome redundancy (having additional gene copies due to increase ploidy) have other benefits as well. It promotes a "buffering" effect in which the deleterious alleles are masked by the extra copies of wild-type alleles. At the same time, it allows functional diversification of redundant gene copies, in which one member of a duplicated gene pair mutates and acquires a novel function, without compromising essential functions.
The increment in heterozygosity is another feature that accompanies polyploidy. Higher levels of heterozygosity have been positively related to vigor increment in maize, potato and alfalfa improving the product quality and increasing the tolerance to both biotic and abiotic stresses.




Zonky

Zorse

Liger

**Genetic principles of breeding techniques**

From the beginning of plant and animal breeding, farmers made use of principles of genetics, with or without awareness of these concepts. Following section explains, three most widely used genetic principles applied in animal and plant breeding at present.



average of 35 bushels per acre in the 1930s to 115 bushels per acre in the 1990s. (one bushel = 36.37 liters) No other major crop anywhere in the world even comes close to equaling that sort of success story.

Many cultivars of popular vegetables or ornamental plants are hybrids. In terms of improved plant characteristics, tropical vegetable breeders can point to some rather clear achievements over the last two decades:

- **Yield improvement.**

Hybrids often out yield traditional true breeding varieties (inbred varieties) by 50-100% due to its improved vigor, improved genetic disease resistance, improved fruit setting under stress, and higher female/male flower ratios.

- **Extended growing season.**

Hybrids often mature up to 15 days earlier than local true breeding varieties. For many crops, the hybrid's relative advantage over the true breeding is most pronounced under stress conditions.

- **Quality improvement.**

Hybrids have helped stabilize product quality at a higher, and more uniform level – this implies improved consumption quality (e.g. firm flesh of wax gourd, crispy taste of watermelon).

**Inter-specific breeding**

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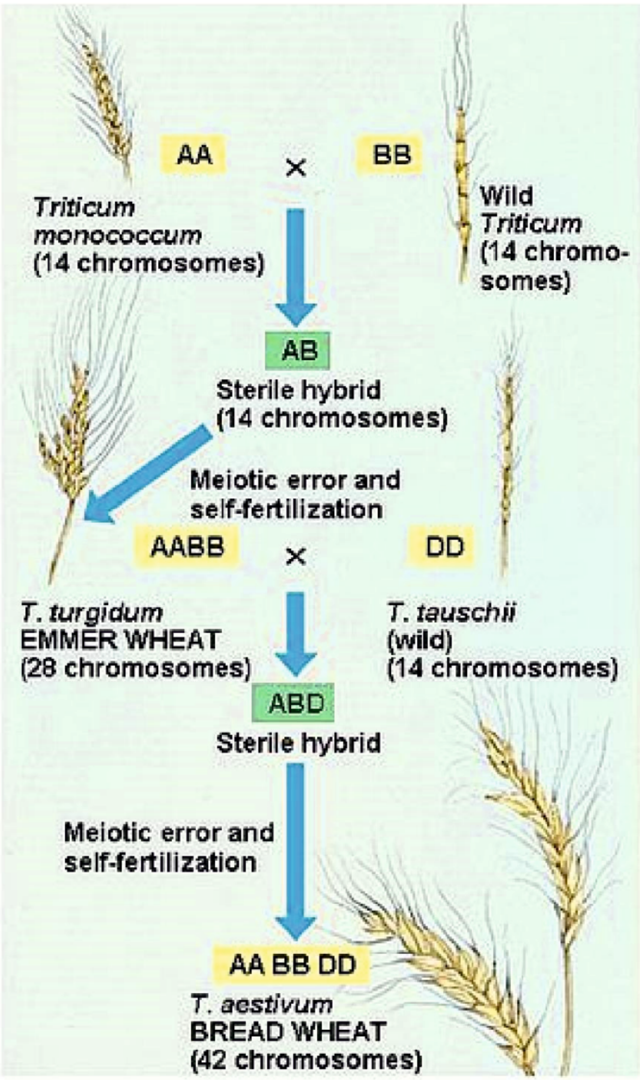
Plants hybridize much more frequently and successfully than animals do. Pollen from flowering plants disperses widely and may land on flowers of other species allowing natural inter-specific breeding to take place. Plant forms are less stringently controlled than animal forms, and so the intermediate form of a plant hybrid is more likely to be physiologically successful.

Often inter-specific hybrids are sterile or for some other reason cannot interbreed with the parental species. Occasionally sterile inter-specific hybrids can undergo a doubling of their chromosome set and become fertile tetra-ploids (four sets of chromosomes). For example, the bread wheats that humans use today are a result of two hybridizations each followed by chromosome doubling to produce fertile hexa-ploids (six sets of chromosomes). In such instances, the hybrids can become new species with characteristics different from either of the parents.






Crop yields increase dramatically when hybridization is used to exceed one or more of the parents in size and reproductive potential. For example, boysenberries (*Rubus ursinus* x *Rubus idaeus*) were developed at Knott's Berry Farm in California. They are a result of a set of crosses between black-berries (*Rubus fruticosus*), European raspberries (*Rubus idaeus*) and loganberries (*Rubus* × *loganobaccus*).


**Black-berries (*Rubus fruticosus*)** **European raspberries (*Rubus idaeus*)**

**Loganberries (*Rubus* × *loganobaccus*)**

For many fruit crop species, the use of inter-specific breeding is increasing, in order to utilize naturally occurring sources of pest and disease resistance, fruit-quality components, etc. within the available germ plasm. For example, winter hardiness of apple was improved by making a hybrid species *Malus* × *domestica* from *Malus* × *asiatica* and *Malus pumilifolia.*

However, among animals inter-specific breeding is restricted to few species. Common examples include Mule (male donkey x female horse), Hinny (male horse x female donkey) and Liger (male lion x female tiger).

Note that in mules and hinnies, the common genus the parents belong to is Equus and in liger, its Panthera. Other examples are zebra/donkey cross resulting in an off spring called zonkey, zebra/horse cross resulting in zorse. The off spring from this cross could develop into adults, but may not develop functional gametes. Sterility is often attributed to the different number of chromosomes the two species have, for example, donkeys have 62 chromosomes, horses have 64 chromosomes.