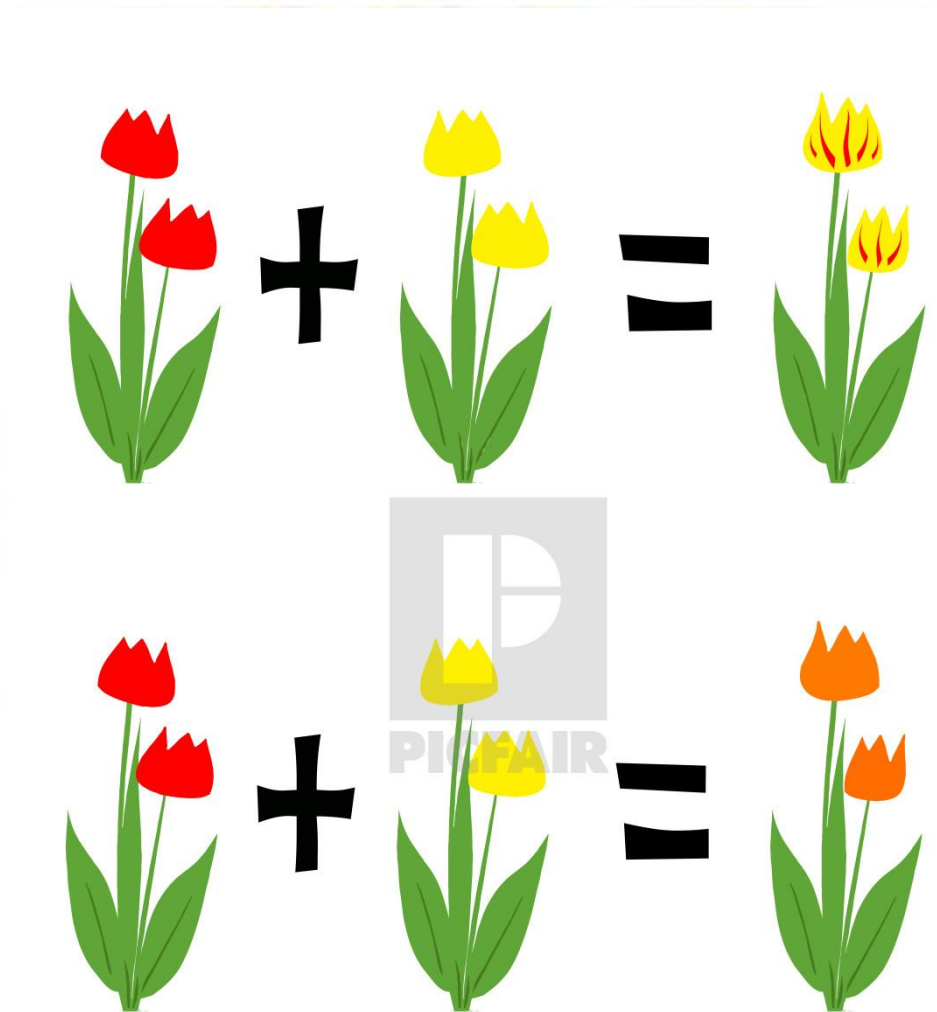


Unit 8: Plant Breeding

Dr. Pritam Chattopadhyay
Department of Botany
M.U.C. Women's College, Bardhaman

Plant breeding

Plant breeding can be define as a **science** as well as an **art** of improving the genetic make up of plant in relation to their economic use.



Plant Breeding:-

Plant breeding is the art, science and technology of changing the heredity of plants for human welfare.

Nature of Plant Breeding:-

1. Art

- In earlier days man depends on his skills and judgement in selecting better plants. He knew nothing about the inheritance of characters, role of environment in producing them and the basis of variation in various plant characters. His method of selection was designed without the understanding of principles of inheritance.
- Therefore during primitive time plant breeding was largely an art and very less science was involved in that. Even today success of selection depends upon ability of the person involved in the selection.

2. Science

- Plant breeding is considered as the current phase of crop evolution. As the knowledge of genetics and other related science progresses plant breeding become less art and more science.
- Especially, discovery of Mendel's work in 1900 added a lot to the knowledge of science.
- Selection of desirable plant even today is an art it depends on the skill of a person. But alone skill is not enough, modern plant breeding is a combined effort of art and understanding and use of genetic principles.

3. Technology

Product of all plant breeding activities, whether dependent on the art or science, is improved variety, hybrids, synthetics and composites. This product is utilized by farmers for commercial cultivation.

Therefore, plant breeding can be rightly viewed as a technology since it generates a useful product.

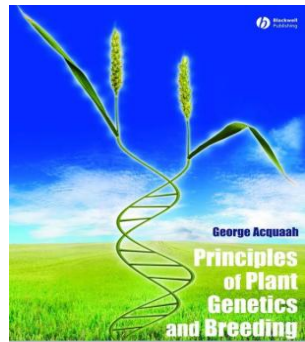
History of Plant Breeding:-

In broad sense history of plant breeding can be divided into 4 parts

- 1. Pre Mendelian era:-** before 1900
- 2. Mendelian era:-** 1900 to 1920.
- 3. Post Mendelian era:-** 1921 to 1950
- 4. Modern era:-** after 1950

Selected milestones in plant breeding

- 9000 BC First evidence of plant domestication in the hills above the Tigris river
- 1694 Camerarius first to demonstrate sex in (monoecious) plants and suggested crossing as a method to obtain new plant types
- 1714 Mather observed natural crossing in maize
- 1761-1766 Kohlreuter demonstrated that hybrid offspring received traits from both parents and were intermediate in most traits, first scientific hybrid in tobacco
- 1866 Mendel: Experiments in plant hybridization
- 1900 Mendel's laws of heredity rediscovered
- 1944 Avery, MacLeod, McCarty discovered DNA is hereditary
- 1953 Watson, Crick, Wilkins proposed a model for DNA structure
- 1970 Borlaug received Nobel Prize for the Green Revolution
Berg, Cohen, and Boyer introduced the recombinant DNA technology
- 1994 'FlavrSavr' tomato developed as first *GMO*
- 1995 Bt-corn developed



History of Plant Breeding in India

- 1871-** Government of India created the Department of Agriculture.
- 1905-** The Imperial Agricultural Research Institute was established in Pusa (Bihar), this was the first Agricultural Research Institute in the country.
- 1921-** The Indian Central cotton committee was established.
- 1929-** Imperial Council of Agricultural Research was established in New Delhi.
- 1936-** Imperial Agricultural Research Institute shifted to its present location in New Delhi.
- 1956-** Project for Intensification of Regional Research on Cotton, Oilseeds and Millets (PIRCOM) was initiated in order to intensify research on these crops.

- 1957-** All India Coordinated Maize Improvement Project was started with the objective of exploiting Heterosis.
- 1961-** First Maize hybrid was released (**Ganga1, Ganga101, Deccan and Ranjit**)
- 1964-** First Sorghum hybrid (**CSH-1**) was released.
- 1965-** First Bajra hybrid (**HB-1**) was released.
- 1991** – 1st pigeon pea hybrid (**ICPH-8**) was released from ICRISAT, Hyderabad

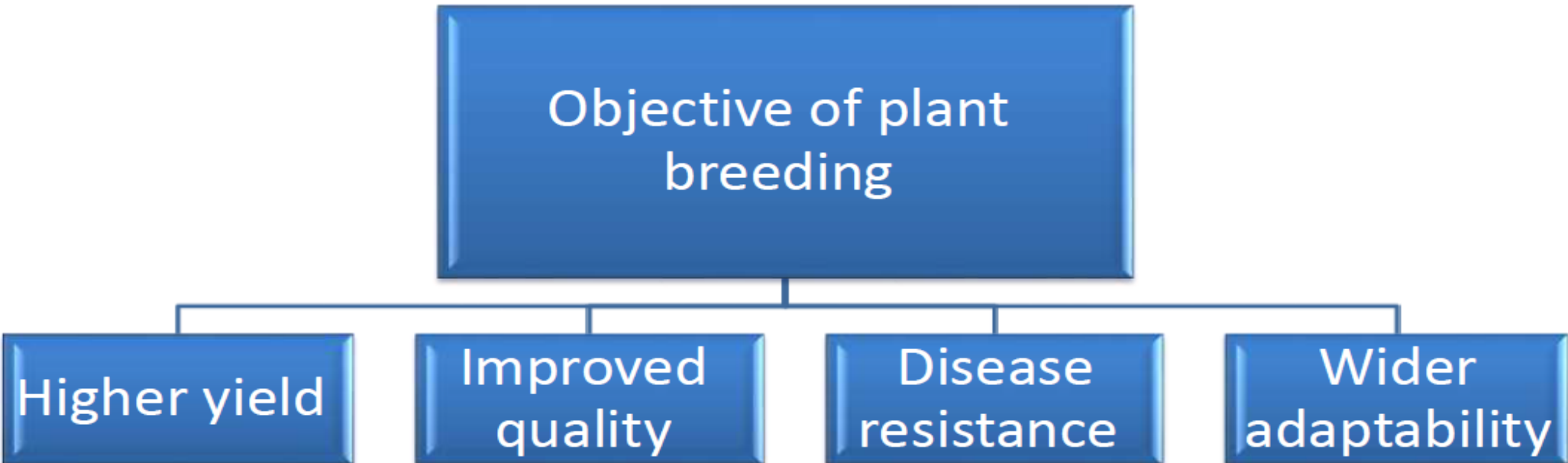
Some indian plant breeders:-

- **T. S. Venkatraman** - he transferred thick stem and high sugar contents from tropical cane (*Saccharum officinarum*) to indian cane (*Saccharum barberi*). this process is known as Noblisation of sugarcane.
- **B. P. PAL** – 1st director general of ICAR. He developed some superior disease resistance variety of Wheat.
- **M. S. Swaminathan** – father of green revolution in India. He developed the high yielding dwarf varieties of Wheat.
- **Puskarnath** – a famous potato breeder who developed several high yielding varieties of potato.
- **N. G. P. Rao** – he is an eminent sorghum breeder and developed the worlds 1st hybrid of sorghum (CSH-1).

Aim

- ▶ Plant breeding aims to improve the characteristics of plants so that they become more desirable agronomically and economically. The specific objectives may vary greatly depending on the crop under consideration.

Objective of plant breeding



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graph TD; A[Objective of plant breeding] --> B[Higher yield]; A --> C[Improved quality]; A --> D[Disease resistance]; A --> E[Wider adaptability];
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Higher yield

Improved
quality

Disease
resistance

Wider
adaptability

Objectives

The prime aim of plant breeding is to improve the characteristics of plants that they become more useful automatically and economically. Some of the objectives may be summarized as follows.

1. Higher Yield:

- ▶ Higher yield of grain, fodder, fibre, sugar, oil etc. developing hybrid varieties of Jawar, Maize, Bajara, etc.

2. Improved Quality:

- ▶ The quality characters may vary from one crop to another such as grain size, shape, colour, milling and backing quality of wheat, cooks quality in rice, malting in barley. Size shape and flavour in fruits and keeping quality of vegetables, protein contents in legumes, methionine and tryptophan contents in pulses etc.

3. Disease and Pest Resistance:

- ▶ Resistant varieties offer the cheapest and most convenient method of disease and pest control. They not only help to increase the production but also stabilize the productivity e.g. Rust resistance in wheat.

4. Maturity Duration:

- ▶ It permits new crop rotation and extends crop area. Thus breeding for early maturing varieties suitable for different dates of planting. This enables the farmer to take two-three crops in a year.

5. Agronomic Characters:

- ▶ This includes the characters such as dwarf, profuse tillering, branching erect resistance and fertilizer responsiveness.

6. Photo and Thermo Insensitivity:

- ▶ Development of photo and thermo insensitive varieties in rice and wheat will permit to extend their cultivation to new areas. E.g Cultivation of wheat in Kerala and West Bengal, Cultivation of rice in Punjab and Himachal Pradesh.

7. Synchronous Maturity:

- ▶ It is desirable in crops like mung (*Vigna radiata*) where several pickings are necessary.

8. Non-Shattering Characteristics:

- ▶ E.g. Mung, Black Gram, Horse Gram, etc.

9. Determinate Growth Habit:

- ▶ It is desirable in mung, pigeon pea and cotton, etc.

10. Dormancy:

- ▶ In some crops, seeds germinate even before harvesting if there are rains at the time of maturity. E.g Mung, barley, etc. A period of dormancy in such cases would check the loss due to germination while in other cases it may be removed it.

11. Varieties for a New Season:

- ▶ Breeding crops suitable for seasons. E.g Maize (Kharif) which is grown in Rabi and summer also.

12. Moisture Stress and Salt Tolerance:

- ▶ Development of varieties for a rainfed area and saline soils would help to increase crop production in India.

13. Elimination of Toxic Substance:

- ▶ It will help to make them safe for consumption E.g Khesari (*Lathyrus sativus*) seeds have a neurotoxin causing paralysis.

14. Wider Adaptability:

- ▶ It helps in stabilizing the crop production over region and seasons.

15. Useful for Mechanical Cultivation:

- ▶ The variety developed should give response to application of fertilizers, manures and irrigation, suitable for mechanical cultivation etc.

Challenges before Plant Breeder :-

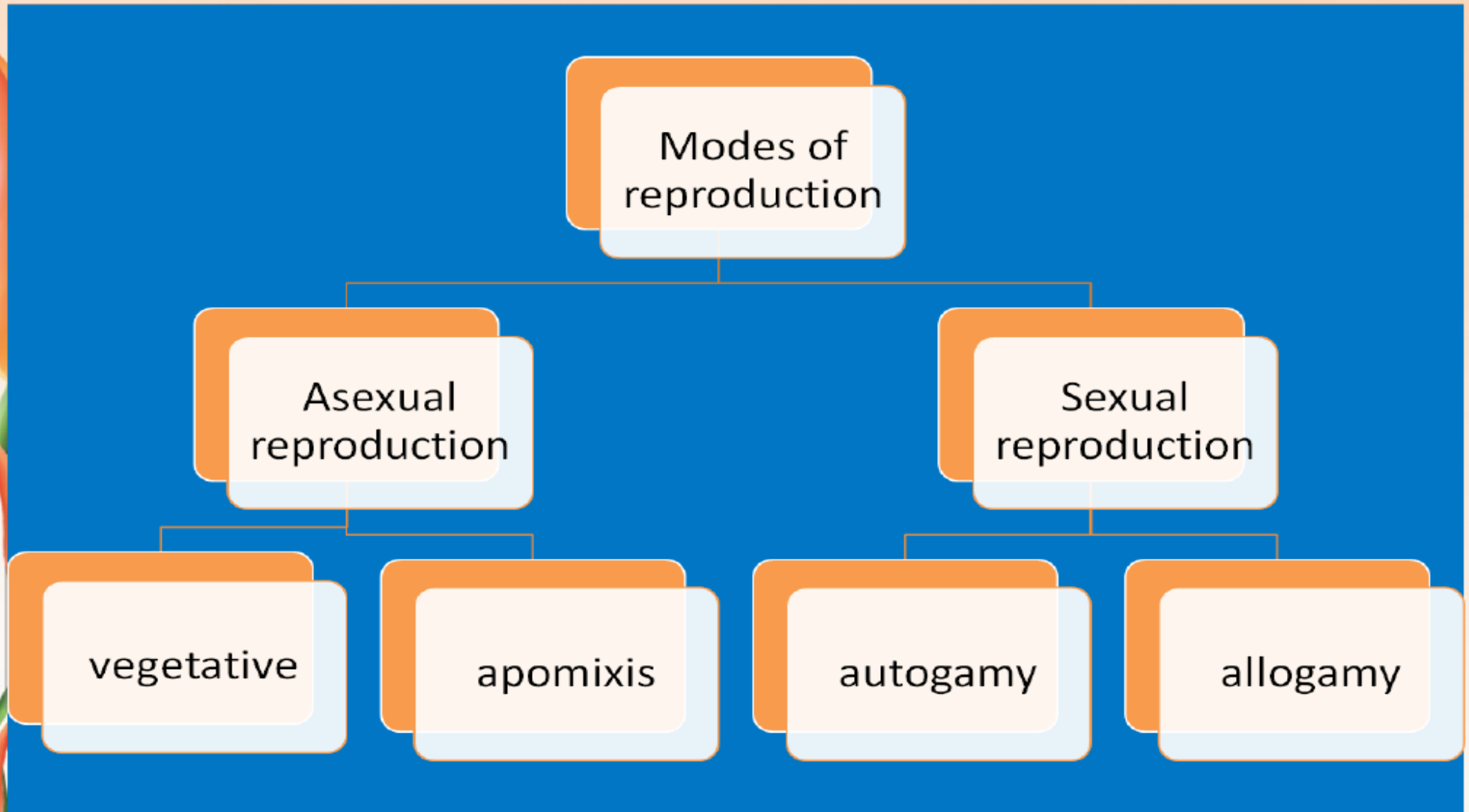
- 1. Increasing population:-** At present, the world population stand at 6.3 billion and will reach at 10-12 billion during the next 50-70 years. The main problem from breeding respect is that the population is growing faster than increases in food productivity, to reduce the use of harmful agrochemicals and to produce nutritious and healthful food is greater today.
- 2. Squeezing arable land :-** Day-by-day the total arable land for agriculture is decreasing due to urbanization and industrial development. Breeders have to tackle this problem by releasing improved varieties of major crops which gives better production per unit area.

3. Erratic rainfall :- In India, rainfall is erratic, unpredictable and unevenly distributed. Over 80% of the annual rainfall is received in the four rainy months of June to September. Therefore, varieties which can tolerate dry spells and perform better at low water availability are needed to be developed by Indian Breeders.

4. Mechanization:- The variety developed by plant breeders should give response to application of fertilizers, manures, irrigation and should be suitable for mechanical cultivation .

Breeding systems:

Modes of Reproduction in Crop Plants



Reproduction :-

- Reproduction :- is the production of new individuals from their parents.
- The **vegetative parts** of the plant are the roots, stem and leaves.
- The **reproductive parts** of the plant are the flowers.
- In plants there are two main types of reproduction. They are asexual reproduction and sexual reproduction.

A) Asexual reproduction :-

- In asexual reproduction new plants are produced without the help of seeds.

B) Sexual reproduction :-

- In sexual reproduction new plants are produced from seeds.

A) Asexual reproduction :-

In plants there are different types of asexual reproduction. They are vegetative propagation, budding, fragmentation, spore formation etc.

a) Vegetative propagation :-

In this method, new plants are produced from the vegetative parts like the root, stem or leaves.

Eg :- If the stem cutting of a rose plant or money plant is planted in the soil we can get a new plant.

Potato has small **buds** called **eyes**. If a part of the potato with an eye is cut and planted in the soil we can get a new plant.

If a part of ginger is planted in the soil we can get a new plant.

Bryophyllum leaf cutting develops into a new plant.

If a part of a cactus plant is planted in the soil we can get a new plant

Vegetative propagules

- Runners
- Suckers
- Stolons
- Bud
- Rhizomes
- bulbs



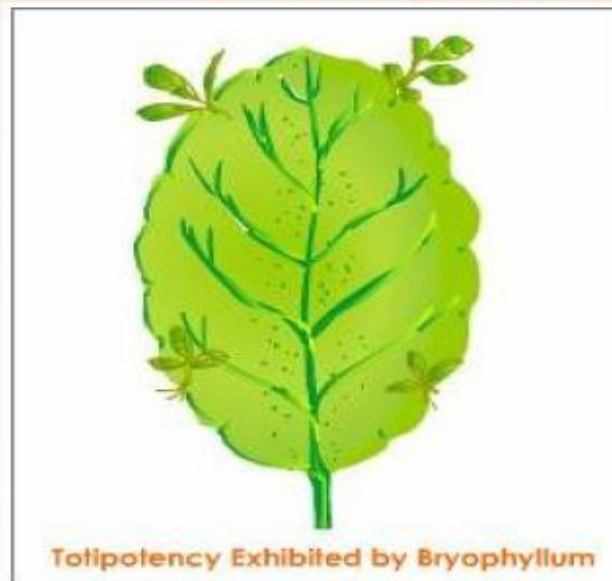
Money plant



Potato plants sprouting from eyes



Bryophyllum leaf with new plants



Cactus

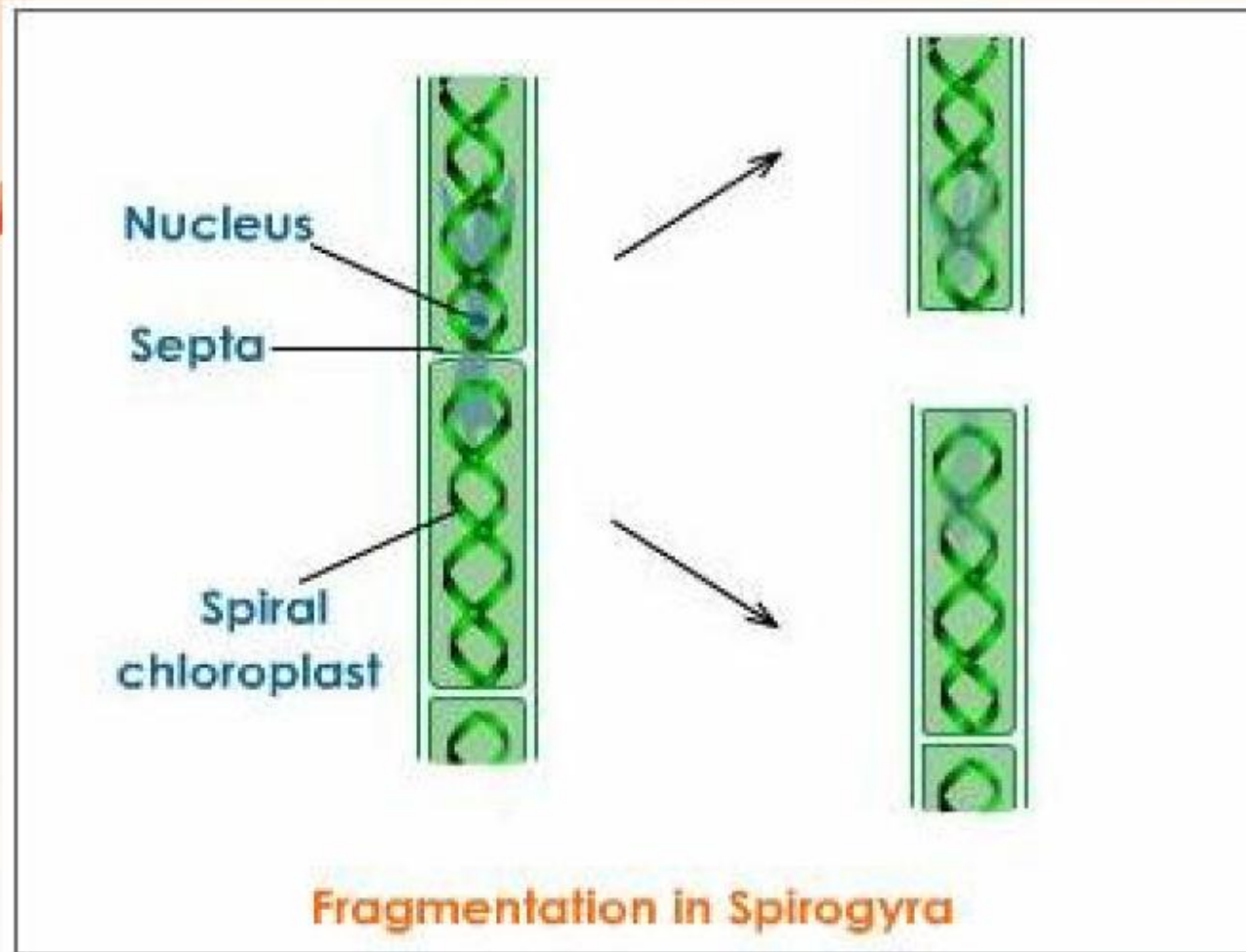


Ginger with new plants



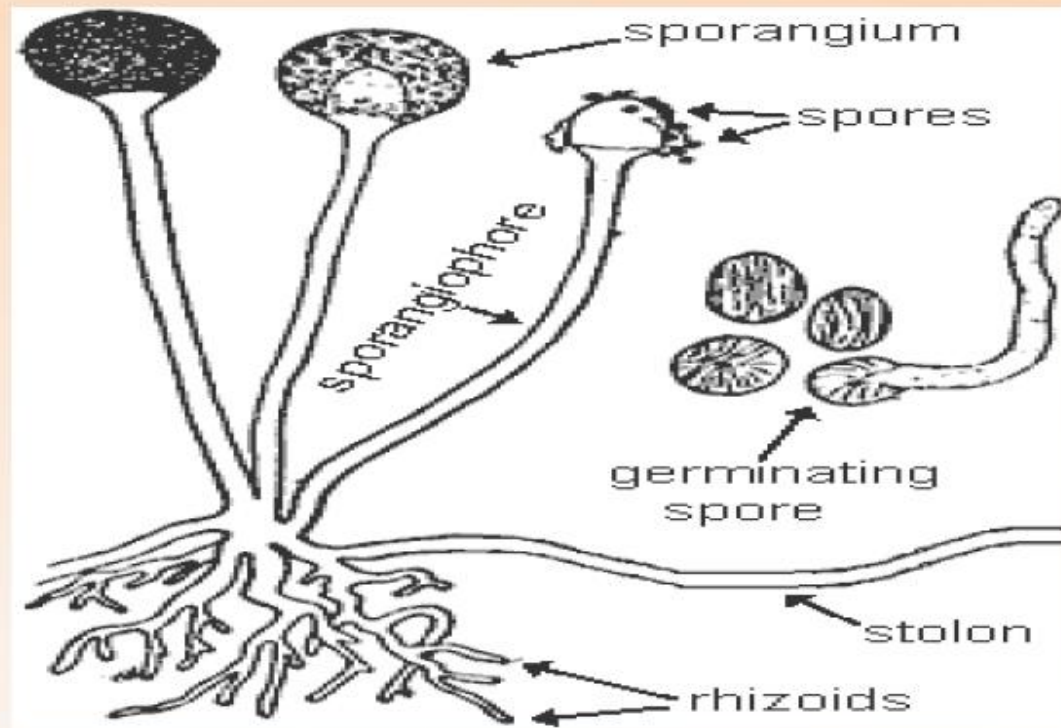
Fragmentation :- Eg :- Spirogyra

In this method the plant breaks up into two or more fragments and each fragment grow into new plants.



iv) Spore formation :- Eg :- Fungus, Fern etc.

In this method the fungus produces spores. The spores germinate and produces new plants.

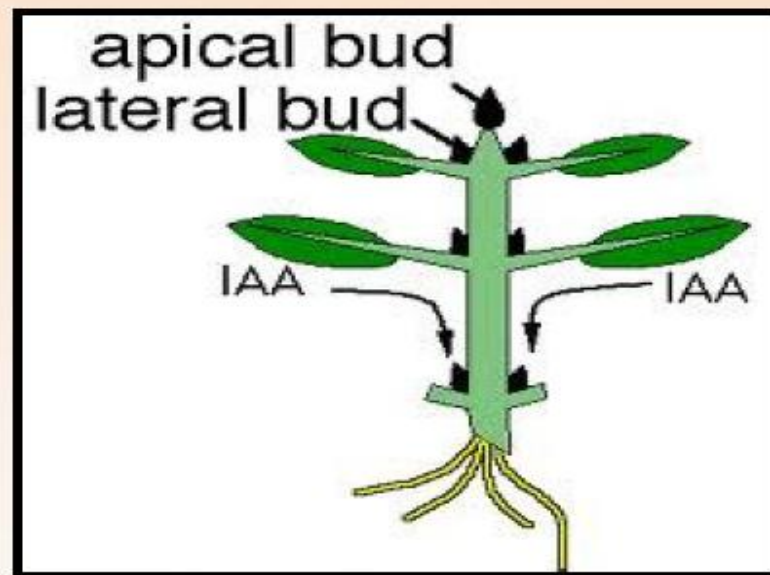
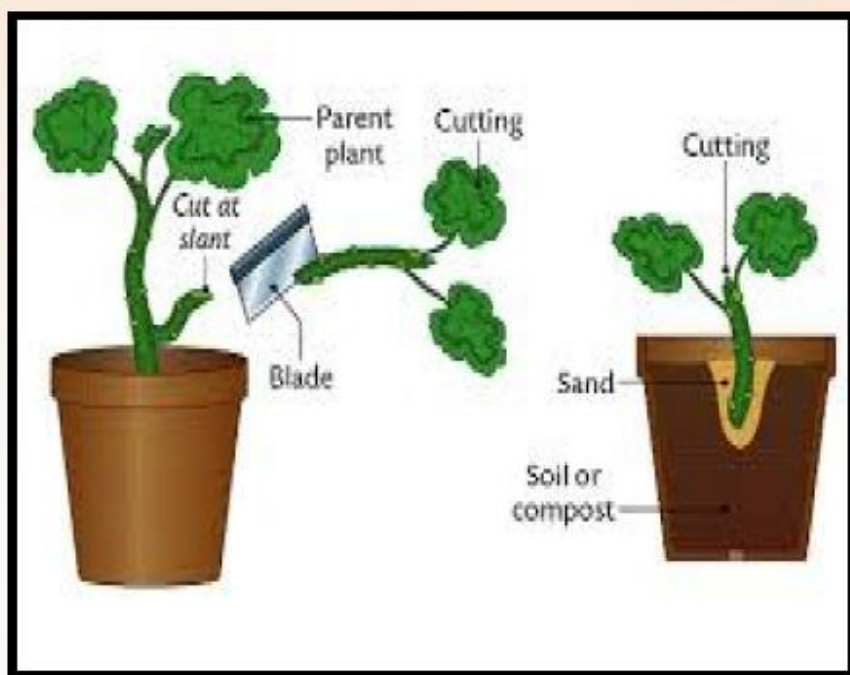
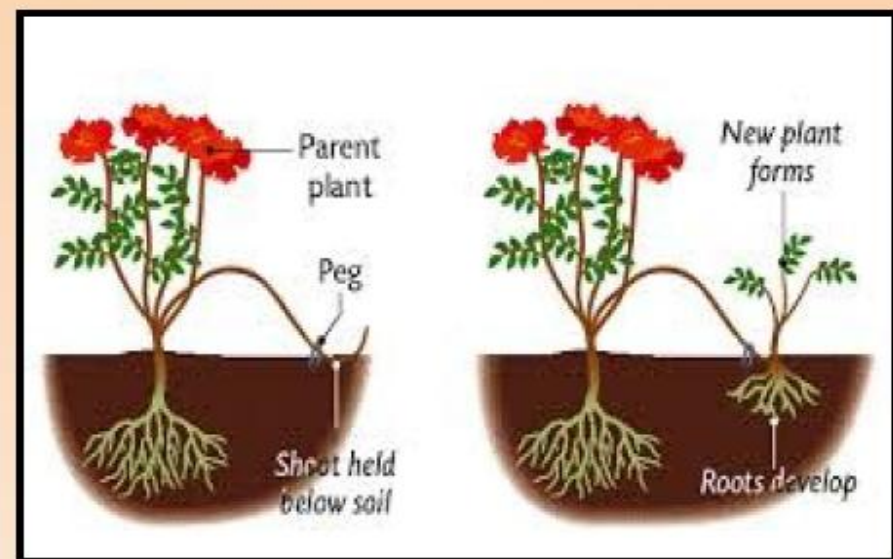


Spore formation in fungus



b) Artificial means

- Multiplication of plants by vegetative parts through artificial methods is known as artificial vegetative reproduction.
- Such reproduction occurs by cutting of shoots , roots, layering, grafting, budding etc..



Importance of vegetatively propagated crops

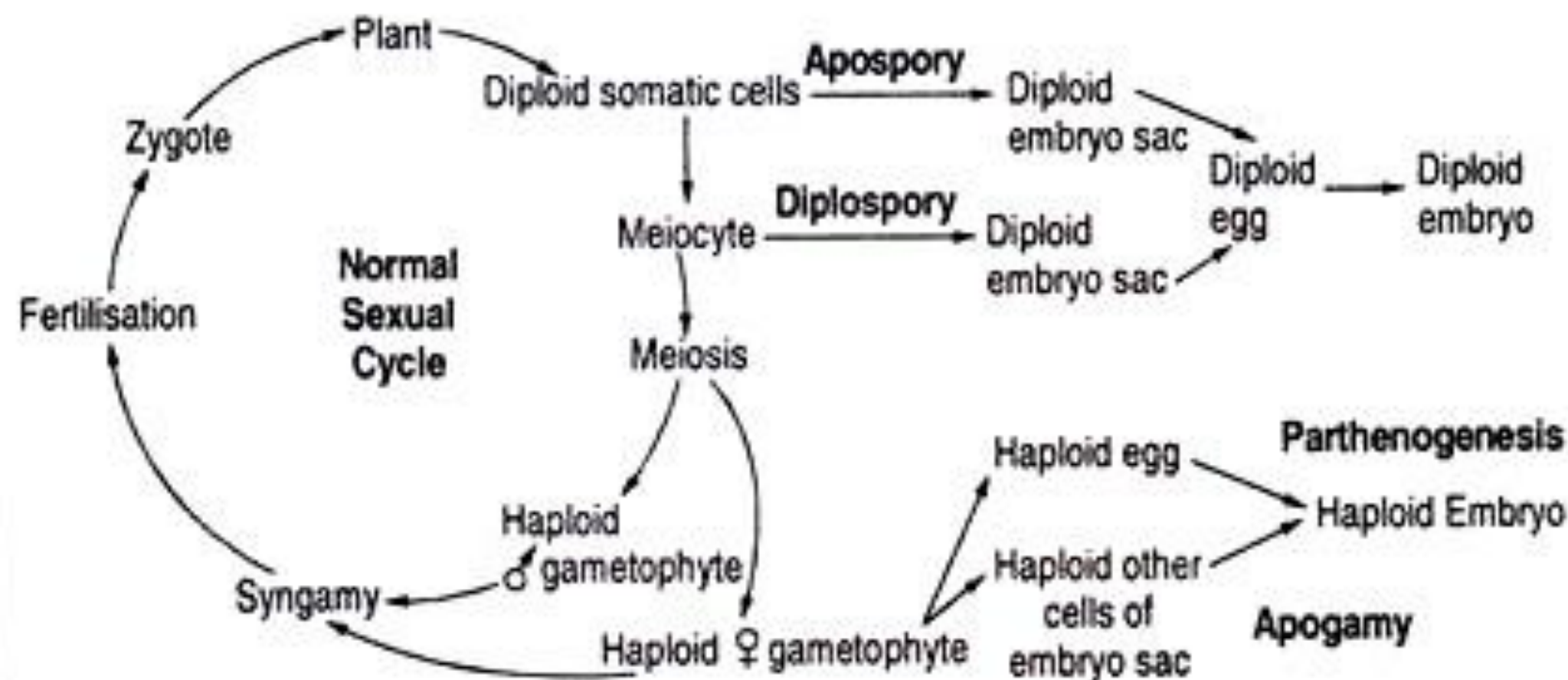
1. Most of these plants are perennial and annual. E.g Sugarcane, potato, sweet potato.
2. Many of them shows reduced flowering and seed set and many varieties do not flower at all.
3. They are invariably cross-pollinated.
4. They are highly heterozygous and show severe inbreeding depression.
5. Many species are interspecific hybrid. E.g Banana, sugarcane.
6. Many species shows wider adaptation.
7. These crop consist of a large number of clones. i. e. progeny derived from single plant through asexual reproduction.

Breeding Methods in Asexually Propagated Crop

- ▶ Crops which are propagated asexually or by vegetative means are known as asexually propagated or vegetatively propagated or clonal crops. There are some agricultural (Sugarcane, Potato, Sweet Potato, etc) and horticultural (Banana, mango, citrus, pears, peaches, litchi, etc) crops that propagates by asexual means. The main reasons of asexual reproduction are
 - ▶ 1) Reduced flowering and seed set,
 - ▶ 2) Non flowering in many cases.
 - ▶ 3) To avoid inbreeding depression in certain crops and
 - ▶ 4) Apomixis in some species.
- ▶ Asexual reproduction produces the progeny, which are exactly identical to their parent in genotype, because the progeny is derived from the vegetative cells through mitosis. Therefore, the main advantage of asexually reproduction is that it preserves the genotype of an individual indefinitely.

APOMIXIS

- *Apomixis refers to the development seed without sexual fusion.*
- Embryo develops without fertilization thus apomixis is an asexual means of reproduction.
- **Obligate apomixis:** reproduction in some species occurs only by apomixis
- **Facultative apomixis:** in some species sexual reproduction also occurs in addition to apomixis



Sexual and apomictic reproduction

Types of apomixis

i. Parthanogenesis

ii. Apogamy

iii. Apospory

iv. Advantive embryony



i. Parthanogenesis

- Parthanogenesis refers to development of embryo from the egg cell without fertilization.
- Two types: **a) haploid**
 - eg. *Solenum nigrum*
- **b) diploid**
 - eg. *taraxacum*

ii) Apogamy

- The origin of embryo from either synergids or antipodal cells of embryo sac is called apogamy.
- Types: a) Haploid
 - b) Diploid
- eg. *Allium*, iris and some other species

e.g. In *Lilium martagon*, *Erythraea centaurium* – two pro-embryos are formed; one is from fertilized egg (zygotic cell) and another from the synergid cell (haploid cell).

iii) Apospory

- In apospory, first diploid cell of ovule lying outside the embryo sac develops into another embryo sac without reduction. The embryo then develops directly from the diploid egg cell without fertilization.

- Types of apospory
- a) generative apospory
- b) somatic apospory

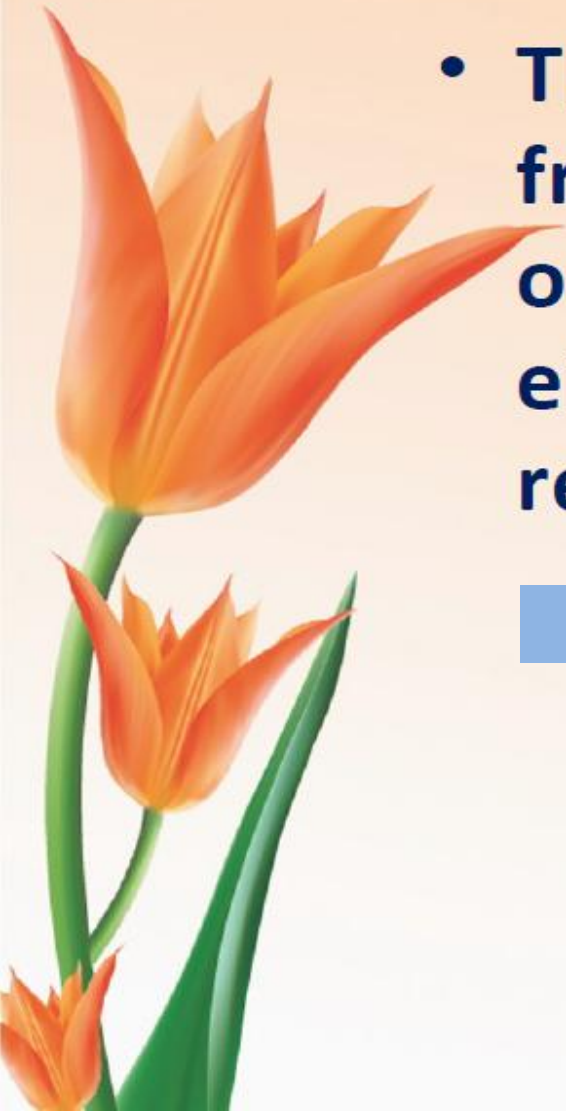
The diploid egg cell develops into embryo without fertilisation, one particular variety of *Parthenium argentatum* exhibits.

This phenomenon is found in *Allium*, *Meliss*, *Crepis* etc.

iv) Adventive embryony

- **The development of embryo directly from the diploid cell of ovule lying outside the embryo sac belonging to either nucellus or integuments is referred to as adventive embryony**

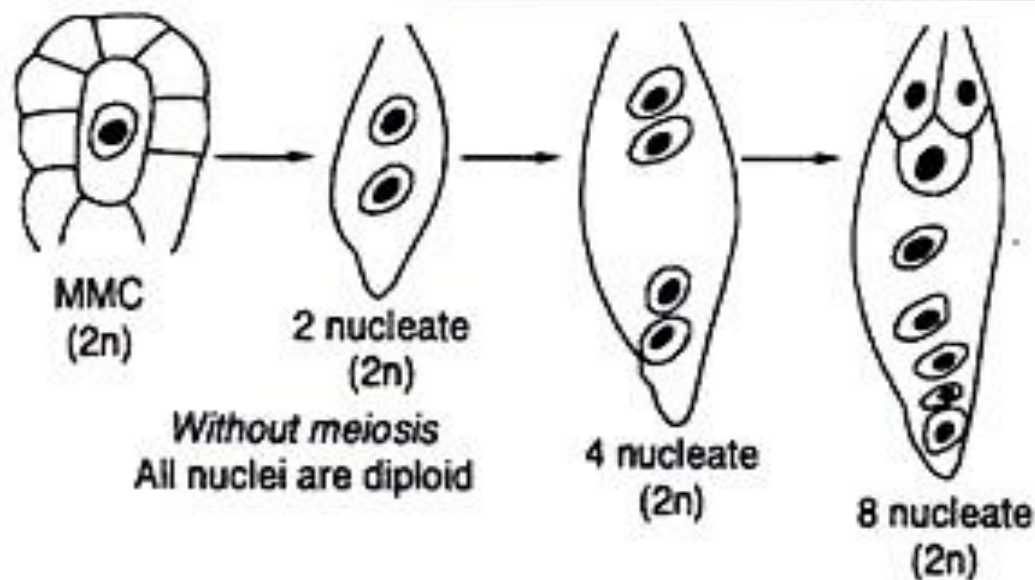
This kind of embryos is found in Citrus, mango, etc.



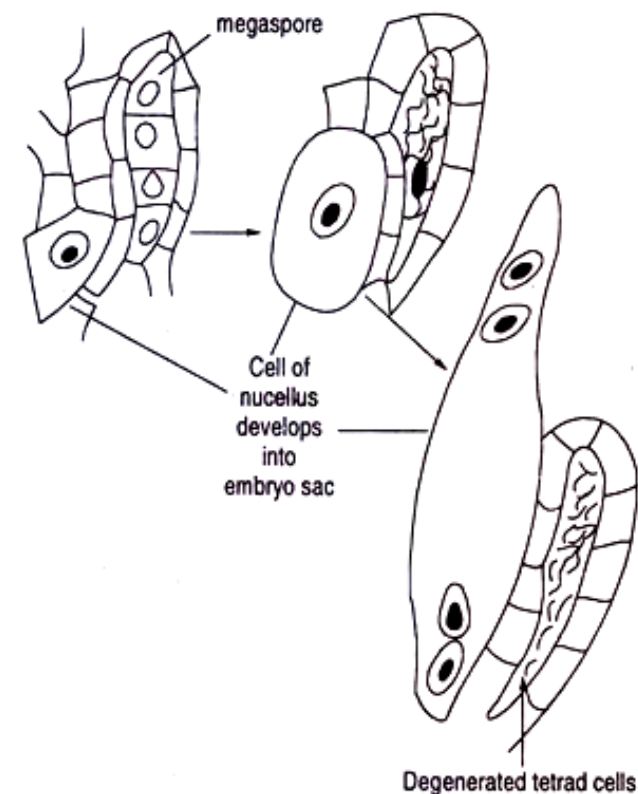
Apomixis also classified as

I. Recurrent (2n)

- embryo sac develops from diploid cells.
- no reduction of chromosomes and process repeated from generation to generation



Aposporous embryo sac in *Eupatorium*



Aposporous embryo sac in *Hieracium*



II. Non recurrent (n)

- Plants produced by this method having haploid set of chromosomes and they are usually sterile
- Process is not repeated.

The reasons may be:

- (i) Absence of pollen tube;
- (ii) Inability of the tube to discharge its contents;
- (iii) No attraction between male and female nuclei;
- (iv) Early degeneration of sperms;
- (v) Maturation of egg and sperm is not synchronized.

e.g., In *Orchis maculata*, *Platenthera chlorantha*, *Cephalanthera damasonium* – the pollen tube enters but fails to fertilize.

Role of apomixis in plant breeding

- 1. Rapid production of pure lines.**
- 2. Maintenance of superior genotypes.**
- 3. Conservation of heterosis.**



Sexual reproduction



Flowers are the reproductive parts of the plant. **Stamen** is the male reproductive part and **pistil** is the female reproductive part.

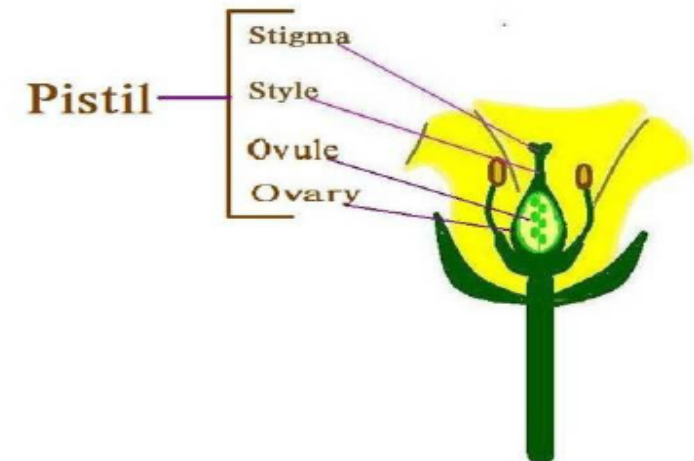
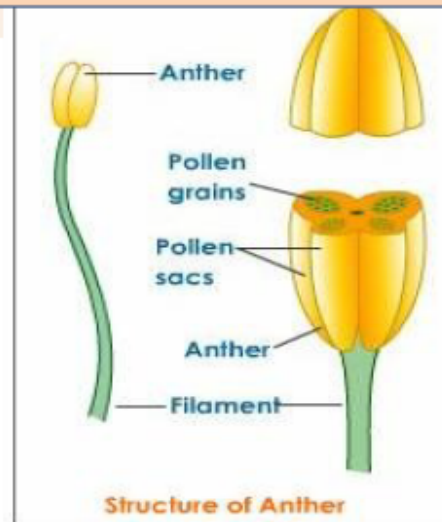
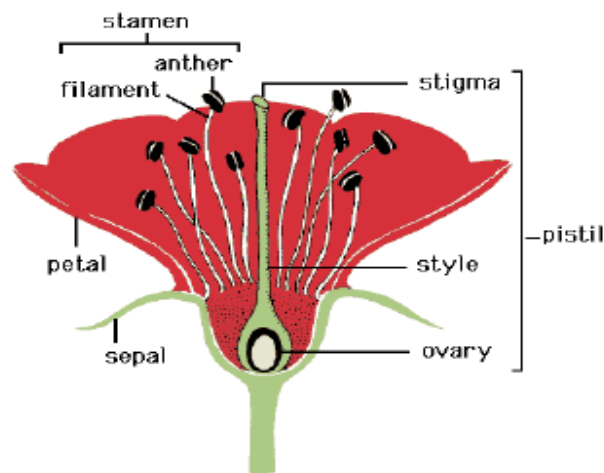
Flowers which have only the stamen or only the pistil are called **unisexual flowers**. Eg :- Maize, Papaya, Cucumber etc.

Flowers which have both the stamen and pistil are called **bisexual flowers**. Eg :- Rose, Mustard, Petunia etc.

The stamen has a filament and anther. The anther contains pollen grains which contain the **male gametes**.

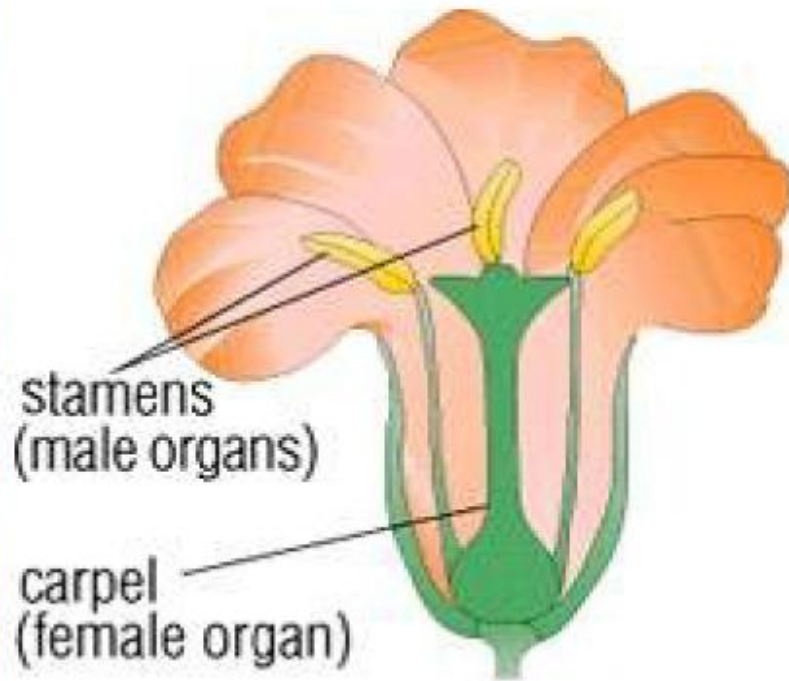
The pistil has stigma, style and ovary. The ovary contains ovules which contain the **female gamete or egg**.

In sexual reproduction the male and female gamete fuse together to form a **zygote**.

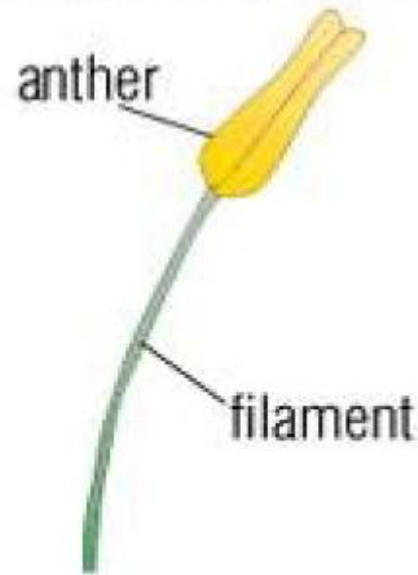


Reproductive parts of a flower

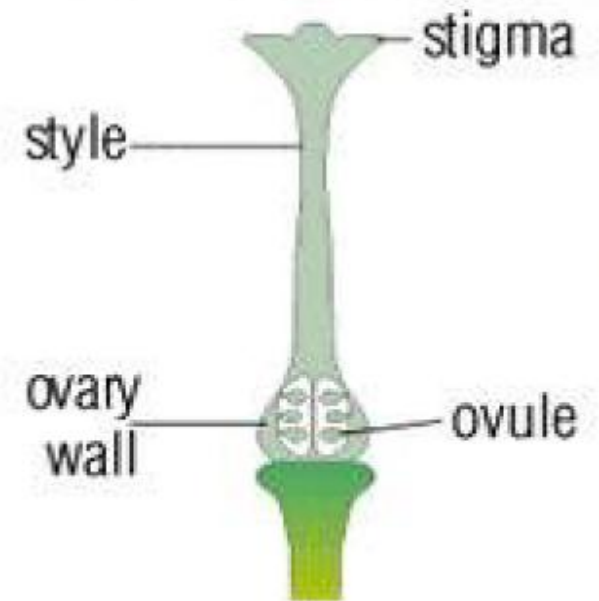
reproductive organs in flowering plants



structure of a stamen



structure of a carpel



1) Pollination

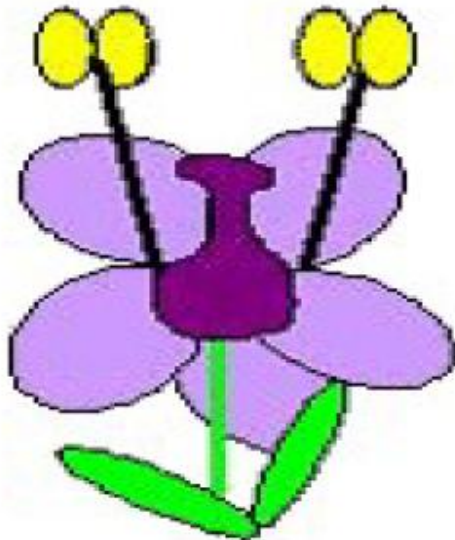
The transfer of pollen grains from the anther to the stigma of a flower is called pollination.

Pollen grains are transferred by wind, water or insects.

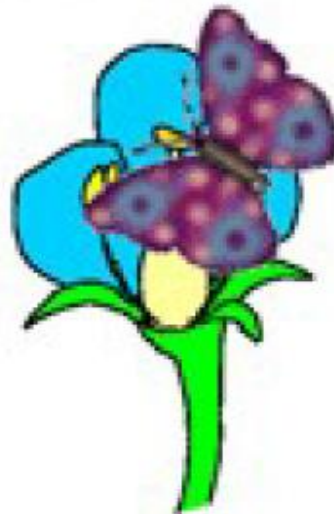
If pollen grains lands on the stigma of the same flower, it is called self pollination.

If pollen grains of one flower lands on the stigma of another flower it is called cross pollination.

POLLINATION



FLOWER 1



FLOWER 2

Mode of pollination

- 1) Autogamy

- Development of seed by self pollination.
- Several mechanism that promotes self pollination

I. Bisexuality

II. Homogamy

III. Cleistogamy

IV. chasmogamy



An illustration of three orange tulips with green leaves, positioned on the left side of the slide. The top tulip is in full bloom, while the two below it are in various stages of opening.

- **2) Allogamy**

- Development of seed by cross pollination
- Mechanisms which promotes autogamy

I. Dicliny

II. Dichogamy

III. Heterostyly

IV. Herkogamy

V. Self incompatibility

VI. Male sterility

Significance of pollination

The mode of pollination plays important role in plant breeding. It has impact on five important aspects : *viz.*

- gene action
- Genetic constitution
- Adaptability
- Genetic purity
- Transfer of gene



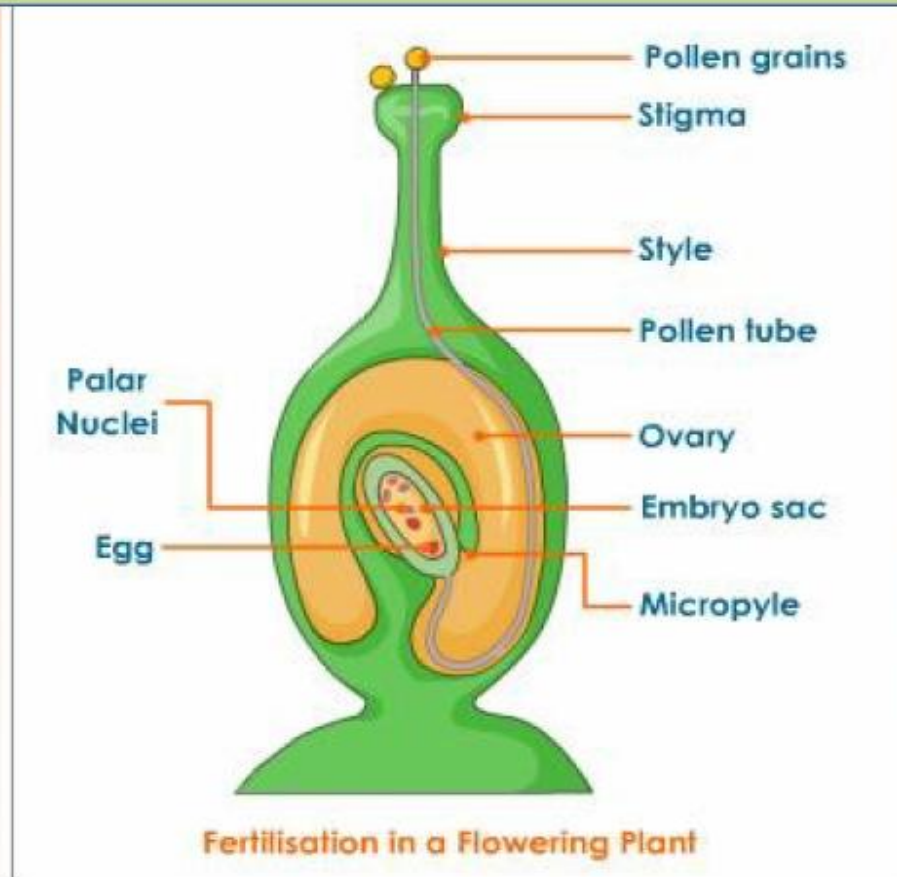
Classification of crops based on mode of pollination and mode of reproduction

Autogamous species	Allogamous species	Often allogamous species
Rice, wheat, barley, oat, cheakpea, pea cowpea, soybean, blackgram, common bean, mothbean, linseed, lentil, sesamum, khesri, sunnhemp, chilles. Tomatoes, brinjal, okra, peanut, potato etc..	Corn , pearlmillet, rye, alfalfa, raddish, cabbage ,sunflower, sugerbeet, castor, red clover, white clover, safflower, spinch, onion, garlic, turnip, squash, muskmelon, water melon, cucumber, pumpkin, kenaf, oilpalm, carrot, coconut, papaya , sugercane, coffee, cocoa, tea,apple, pears, peaches, cherries, grapes, almond, strawberries, pineapple, banana, irish, cassava, taro, rubber, sweet potato etc..	Sorghum, cotton, pigeonepea, tobacco, rai, tobacco, triticale etc..

2) Fertilisation :-

The process of fusion of the male and female gametes to form a **zygote** is called **fertilisation**.

After fertilisation the zygote develops into an **embryo**. The ovule then develops into the seed and the ovary develops into the fruit.



3) Seed dispersal :-

The carrying away of seeds from one place to another is called **dispersal of seeds**.

Seeds are dispersed by wind, water and animals.

Seeds dispersed by wind are light, have wings or hairs so that they are easily blown away by wind. Eg :- drumstick, maple, sunflower, aak etc.

Seeds dispersed by water have spongy or fibrous outer cover so that they can float on water. Eg :- coconut

Seeds dispersed by animals have spines with hooks so that they can attach to the bodies of animals. Eg :- xanthium



Which is Better?

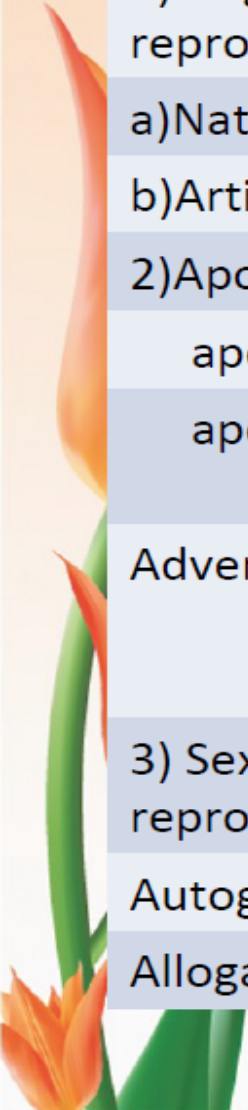
It depends!

Asexual Reproduction

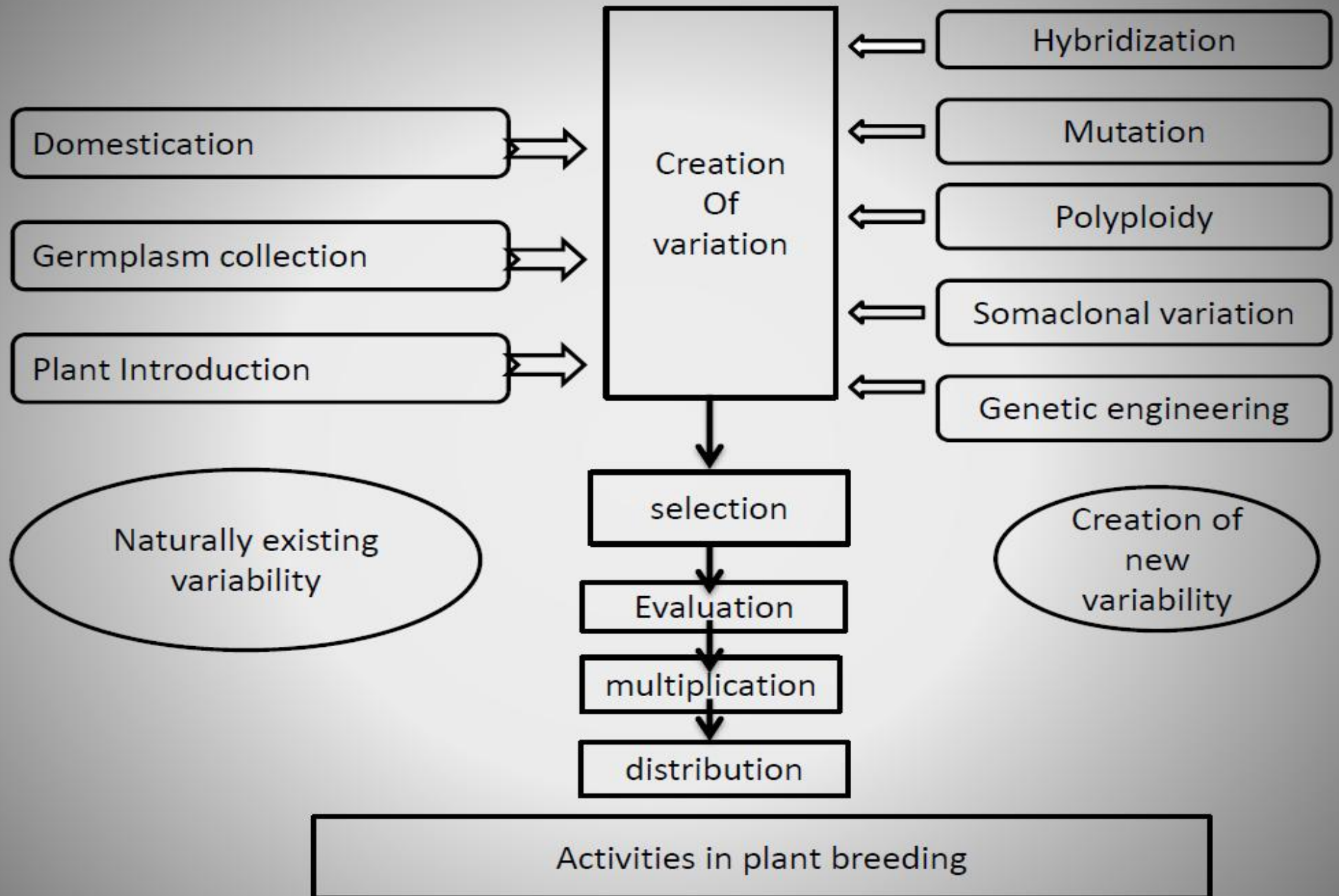
- advantages
 - does not require special cells or a lot of energy
 - can produce offspring quickly
 - in a stable environment creates large, thriving population
- disadvantages
 - limited ability to adapt
 - face massive die-off if environment changes

Sexual Reproduction

- advantages
 - lots of variation within a species
 - able to live in a variety of environmental settings
 - able to adapt to changes in the environment
- disadvantages
 - needs time & energy
 - produce small populations



Terms	Brief description / definition
Asexual reproduction	Multiplication of plants without fusion of male and female gametes.
1) Vegetative reproduction	Multiplication by vegetative plant parts
a) Natural	By rhizome, tubers, corm, bulb, runner, suckers etc...
b) Artificial	By stem and root cutting, grafting, budding, layering.
2) Apomixis	Development of embryo without sexual fusion.
apogamy	Embryo either from synergids or antipodal cells
apospory	Embryo originates from diploid egg cell of another embryo sac developed from other diploid tissue.
Adventive embryony	Embryosac originate directly from diploid cells belonging to either nucellus or integuments
3) Sexual reproduction	Multiplication of plants by fertilized embryos
Autogamy	Development of seed by self pollination
Allogamy	Development of seed by cross pollination



Important Concepts of Breeding of Cross pollinated Crops

1. Populations of cross-pollinated crops are highly heterozygous as well as heterogeneous.
2. Their genetic makeup is such that they show variable inbreeding depression.
3. which in some cases may be very severe. Consequently, breeding methods for cross-pollinated crops aim at preventing inbreeding.

BREEDING METHODS FOR CROSS POLLINATED CROP

A) Mass selection

B) Recurrent Selection

1. Simple Recurrent Selection
2. Recurrent Selection for General Combining Ability
3. Recurrent Selection for Specific Combining Ability
4. Reciprocal Recurrent Selection

Achievement of Plant Breeding

Today crop plants are different from the crop from which they are originated i.e. wild species. This change has been brought about by man through plant breeding. The important achievements of plant breeding are :

A) Production of Dwarf and Semi Dwarf Cereal Varieties:

Many dwarf and semi dwarf varieties are developed in crops like wheat and Rice. Dr. Borlaug used a Japanese variety NORIN-10 as a source of dwarfing gene, in wheat at CIMMYT (Mexico). In 1963 ICAR has introduced some dwarf selections from CIMMYT. Varieties Kalyansona and Sonalika were selected from these materials. In India majority of the wheat varieties grown are semi dwarf, and are resistant to water lodging, responsive to fertilizer doses etc.

Similarly the development of semi dwarf varieties of Rice has revolutionized rice cultivation. These varieties were developed by introducing the gene Dee-Geo-Woo-Gene. Ex TN. 1 developed at Taiwan and IR-8 at IRRI Philippines, both were introduced in India in 1966.

B) Nobilization of Sugarcane:

The Indian canes were of *Saccharum barberi*, largely grown in North India. They were hardy but poor in yield and sugar content, while tropical cane of *Saccharum officinarum* had thicker stem and higher sugar content but it performed badly in North India due to low winter temperature. C.A Barber and T.S Venkatraman at Sugarcane Breeding Institute, Coimbatore transferred thick stem higher sugar content and other desirable characters from the noble cane to Indian cane is commonly referred as nobilization on of Indian canes.

C) Development of Hybrid and Synthetic:

- a) Maize: Canga series of hybrid, Ganga safed-2, African Tall, Manjari, Deccan etc.
- b) Sorghum : CSH-1,2,3,4,5,6,7,8,9,10,12,14 and 15 R.
- c) Bajara: WCC-75, PHB-10, ICTP-8203, Shradha and Saburi.
- d) Cotton: H-4, Var.Laxmi, Savitri, NH-44, Jaylaxmi, etc.

Scope of Plant Breeding (Future Prospects)

- I) Genetic manipulation of population by increasing the frequency of desirable alleles in cross pollinated crops and introducing male sterile in self pollinated crops like wheat and Rice.
- II) Intensive breeding of pulses and oil seed crops as it was done in cereals and other crops.
- III) Proper breeding methods with improved crop management practises.
- IV) Use of heritability methods with improved crop management practises.
- V) Development of improved high yielding varieties of vegetable and seed crops.
- VI) Quality Improvement in Oil seed and Vegetables.
- VII) Use of transgenic plants as a medicine. E.g. Potato.
- VIII) Development of varieties which are desirable for mechanical threshing and cultivation.

Disadvantages of Plant Breeding

1. The varieties developed through plant breeding generally do not have wide adaptation and stability in production possessed by the local or desi varieties from which they are developed.
2. Plant breeding requires more time, space and is expensive.
3. The upper limit on improvement is set by the genetic variation present in the parent population.

Undesirable Consequences of Plant Breeding

1. It can lead to loss of species variety.
2. It does not have control over genetic mutations.
3. It brings about discomfort to animals.
4. It can create offspring with different traits.
5. It could create a genetic depression.
6. It poses some environmental risks.
7. It can change the evolution of species.

The background features a dark blue gradient on the left, transitioning into a series of overlapping, semi-transparent green and yellow-green geometric shapes on the right. These shapes are angular and layered, creating a sense of depth and movement. A thin white line runs diagonally across the lower right portion of the image.

Thank You