1. Animate or biotic causes: Pathogens of living nature are categorized into the following groups.

(i) Fungi
(ii) Bacteria
(iii) Phytoplasma
(iv) Rickettsia-like organisms
(v) Algae
(vi) Phanerogams
(vii) Protozoa
(viii) Nematodes

2. Mesobiotic causes : These disease incitants are neither living or non-living, e.g.

(i) Viruses
(ii) Viroides

3. Inanimate or abiotic causes: In true sense these factors cause damages (any reduction in the quality or quantity of yield or loss of revenue) to the plants rather than causing disease. The causes are:

(i)Deficiencies or excess of nutrients (e.g. 'Khaira' disease of rice due to Zn deficiency)
(ii) Light
(iii) Moisture
(iv) Temperature
(v) Air pollutants (e.g. black tip of mango)
(vi) Lack of oxygen (e.g. hollow and black heart of potato)
(vii) Toxicity of pesticides
(viii) Improper cultural practices
(ix) Abnormality in soil conditions (acidity, alkalinity)

On the Basis of Extent of Occurrence and Geographic Distribution:

1. Sporadic Diseases:

- When a disease occurs at very irregular intervals and locations and in relatively few instances, it is referred to as sporadic disease. Ex: Fusarium wilt of cotton and loose smut of wheat.

2. Endemic Diseases

- When a disease is present constantly in a location (area, district, state, country or part of the earth) in a moderate or severe form, it is called endemic disease. Ex: Wart disease of potato in Darjeeling, citrus canker endemic in Asia and sorghum rust by *Puccinia purpurea* is endemic in India.

3. Epidemic (or Epiphytotic) Diseases

- Epidemic means among the people. That diseases of human beings (also animals such as cattle and poultry) and plants which appear severely or virulently among the large section of population periodically is known as epidemic. Examples: black or stem rust of wheat, late blight of potato, red rot of sugarcane and blast of rice.
- The epiphytotics which become destructive on a continental scale is called as pandemic. Late blight of potato and Black or stem rust of wheat are examples.

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On the Basis of the Types of Infection:

1. Localized Diseases:

- When the effect of infection induces disease development remaining restricted in or around the area surrounding the infection site, the disease is called localized. Examples: leaf spot and anthracnoses caused by different fungi.

2. Systemic Diseases:

- When the effect of infection induces disease development appearing throughout the entire plant or most of its parts or any of its parts after an interval of time during which the pathogen spreads in the host body remaining externally invisible, the disease is called systemic.
- All infections caused by fastidious vascular bacteria, mollicutes (phytoplasmas and spiroplasmas), protozoa, all-natural infections caused by viruses and viroids, and downy mildews caused by fungi are systemic.

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On the Basis of Method of Perpetuation and Mode of Primary Infection:

1. Soil-borne Diseases:

- When the pathogen of a disease perennates in the soil or on infected plant debris lying in the soil and, then primary infection on host plants commences from within the soil in the next season, such a disease is called soil borne.

TABLE: Some important soil-borne diseases, their pathogen, and the host(s)

Disease	Pathogen	Host(s)
Root rots	*Phytophthora* spp.	Tobacco, soybean, ornamentals,
Damping off	*Pythium* spp.	Many crops
Root and steam rots	*Fusarium* spp.	Many crops
Southern blight	*Selerotium rolfsii*	Vegetable crops peanut, soybean, forage crops,
Root rots, leaf blight, and damping off	*Rhizoctonia solani*	Tomato, beans, cereal grains, turf grasses, and others
Black rot	*Cylindrocladium crotalariae*	Peanut, soybean, other legumes
Crown and stem rots, watery soft rot	*Selerotinia* spp.	Vegetable crops, forage legumes, peanut, soybean, etc.

2. Seed-borne Diseases:

- When the pathogen of a disease perennates in or on the seeds or other similar structures and infest plants from them in the next season, such a disease is called seed borne.

TABLE: Some seed-borne diseases, their pathogen, and the host

Disease	Pathogen	Host(s)
Covered smut	*Ustilago hordei*	Barley
Loose smut	*Ustilago tritici*	Wheat
Seedling rot	*Cephalosporium acremonium*	Maize
Blight	*Ascochyta rabie*	Gram
Wart	*Synchytirum endobioticum*	Potato

Red rot	*Colletotrichum falcatum*	Sugarcane
Angular leaf spot	*Xanthomonas malvacearum*	Cotton
Green ear	*Sclerospora graminicola*	Bajra

3. Air-Borne Diseases:

- When the pathogen of a disease is disseminated by air bringing about primary as well as secondary infections in plants, such a disease is called air borne.

On the Basis of Parts of Host Affected:

(1) foliage diseases
(2) stem diseases
(3) root diseases
(4) vascular diseases

On the Basis of the kind of Symptoms Produced:

(1) root rots
(2) fruit rots
(3) powdery mildews
(4) downy mildews
(5) rusts
(6) smuts
(7) wilts
(8) leaf blights
(9) leaf spots
(10) cankers
(11) damping-off
(12) hyperplasic
(13) hypertrophic
(14) hypoplasic
(15) mosaic

TABLE: Some air-borne diseases, their pathogen, and the host

Disease	**Pathogen**	**Host(s)**
Stem rust	*Puccinia graminis f. sp. tritici*	Wheat/barbery
Leaf rust	*Puccinia recondite*	Wheat
Loose smut	*Ustilago tritici*	Wheat, barley, oats
Late blight	*Phytophthora infestans*	Potato, tomato
Leaf blight	*Bipolaris (Helminthosporium) maydis*	Corn
Leaf spot	*Alternaria* spp.	Many crops
Downy mildew	*Plasmopara viticola*	Grape
Powdery mildew	*Erysiphe spp., Sphaerotheca spp.*	Many plants
Blast	*Magnaporthe grisea (=Pyricularia oryzae)*	Rice
Anthracnose	*Colletotrichum* spp.	Mange, many crops
Scab	*Venturia inaequalis*	Apple

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On the Basis of Inoculum Multiplication:

1. Simple Interest Diseases (or Monocyclic Diseases):

- In these diseases the seedlings are first infected in soil, the pathogen then systemically moves throughout the plant and subsequently produces spores in the inflorescence on maturity of the crop provided that the pathogen does not spread (i.e., secondary infection lacks) from the smuted heads. The spores, the propagules of the disease, overcome the dormant period and serve as source of primary inoculum in the next growing season of the host plant.

2. Compound Interest Diseases (or Polycyclic Diseases):

- This happens as the primary inoculum infects host plant, the propagules produced are disseminated to other healthy plants where they quickly produce another crop of propagules. The latter are again disseminated, and the cycle is repeated.
- With each secondary cycle the amount of inoculum is multiplied many folds. However, the pathogen causing a compound interest (polycyclic) disease is called polycyclic pathogen.
- Examples: late blight of potato caused by *Phytophthora infestans*, rust of cereals, powdery mildews, downy mildews, leaf spots, blights, aphid-borne viruses and root-knot nematodes.

Some common Plant diseases:

MYCOPLASMA DISEASE: -			
1.	Sandal spike	Mycoplasma like Bodies **(MLB)**	Reduction in leaf size and shortening of internodes.
2.	Citrus Greening	MLB	Discoloration of leaving sun blotching on fruits
3.	Sesamum phyllody	MLB	Vein clearing of leaves, phylloid flowers
4.	Grassy shoot disease of Sugarcane	MLB	Production of thin tillers from the base of the affected plants.
5.	Little Brinjal	MLB	Reduction in size of leaves and nodes.
FUNGAL DISEASE: -			
1.	Apple Scab	*Venturia inaequalis*	Light brown or olive-green spots on lower surface of leaf. Scabs on fruit.
2.	Tikka disease of ground nut or Leaf Spot of ground nut	*Cercosporidium personatum, Cercosporidium Arachidicola*	Pale areas on upper surface of leaf dark brown of black lessons are smaller. Circular reddish-brown lesions
3.	Wilt of cotton	*Fusarium oxyspoum*	Vein clearing→ interveinal tissue necrosis
4.	Downy mildew of Grapes	*Plasmopara viticola*	On upper surface of leaf → light spots opposite surface → downy growth
5.	Powdery mildew of Grapes	*Uncinula necator*	White patches on both surfaces C later becomes floury berries turn black.
6.	Early blight of potato	*Alternaria solani*	Small pale brown patches on leaf - later covered greenish blue growth of fingers.
7.	Late Blight of Potato	*Botrytis infestans*	Faded green patches → brown black lesions.
8.	Red Rot of Sugarcane	*Glomerella*	Loss of color → drooping of leaves rind shrinks →

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		tucumanensis→ perfect stage Conidial Stage→ Collets trichum falcatum	longitudinally wrinkled pith→ grayish white mycelium
9.	Smut of Sugarcane	*Ustilago seitaminae*	Whip like black shoot covered - silvery membrane.
10.	Green Ear disease of Bajra or Downy mildew	*Scleospora geaminicola*	Affected plant → sunted pale yellow in color chlorosis on upper surface and hairy outgrowth on lower floral organs→ leafy structures.
11.	Smut of Bajra	*Tolypospoium penicillariae*	Ear→ bright green to choc late brown grains replaced by smut sore.
12.	Ergot of Bajra	*Cleviceps microcephale*	Honeydew stage→ small droplet of pink color excludes out from spikelet sclerotia projects out b/w glumes.
13.	Flag smut of wheat	*Urocystis tritici*	leaf→ twisted culins – sterile no grains grayish black sori on leaf sheath
14.	Loose smut of wheat	*Ustilago tritici*	In place of ears → mass of blackish powder → smut spores
15.	Hill Bunt or stinking smut of wheat	*Tilletia carries* *Tiletia oetidal*	Infected culms shorter than normal Infected culms 10 times longer.
16.	Karnal bunt of Wheat	*Neovossia indica*	All the grains are not infected smutted grains → irregularly distributed.
17.	Black stem Rust of wheat	*Puccinia graminicola*	Uredia → Culms → leaf → sheath Telia → on all green parts Barberis & Mahonia →alternate host (pycnial and aerial cups)
18.	Brown Rust of Wheat	*Puccinia recondite*	Uredopustules on leaves C- bursts C- points of bright orange colour.
19.	Yellow Rust of Wheat	*Puccinia striiformis*	Green leaves-fades in long streaks
20.	Blast disease of Rice	*Pyricularia oryzae*	Brownish lesions & spots on leaves
21.	Brown leaf spot of Rice	*Helminthosporium oryzae*	Rectangular brown spot C- dark centre on coleoptile, leaf blades 90% loss in yield in Bengal in 1942.

Disease		**Causal Organism**	**Symptom**
VIRAL DISEASES: -			
1.	Yellow vein Mosaic of Bhindi	*Hibiscus virus*	Vein clearing and vein chlorosis
2.	Tobacco & Tomato Mosaic	*Nicotiana virus* *Lycopersicon*	Light & dark mottles on leaf. Deformed fruit brown inside.
3.	Leaf Roll of Potato	*Solanum* virus 14	Leaf roll up along the margins.
4.	Crinkle of Potato	*Solanum* virus 3	Yellow patches on foliage.
5.	Bunchy disease of Banana	*Musa* Virus I	Leaves become bunched together to form rosette or bunchy top.

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PHOTOSYNTHESIS- Pigments, photophosphorylation, Mechanism of photosynthesis, photorespiration, photosynthesis in C4 plants, CAM.

In plants

Most plants are photoautotrophs, which means that they are able to synthesize food directly from inorganic compounds using light energy - for example from the sun, instead of eating other organisms or relying on nutrients derived from them. This is distinct from chemoautotrophs that do not depend on light energy, but use energy from inorganic compounds.

$6\ CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_20$

The energy for photosynthesis ultimately comes from absorbed photons and involves a reducing agent, which is water in the case of plants, releasing oxygen as a waste product. The light energy is converted to chemical energy (known as light-dependent reactions), in the form of ATP and NADPH, which are used for synthetic reactions in photoautotrophs. The overall equation for the light-dependent reactions under the conditions of non-cyclic electron flow in green plants is:

$2\ H_2O + 2\ NADP+ + 2\ ADP + 2\ Pi + light \rightarrow 2\ NADPH + 2\ H+ + 2\ ATP + O_2$

Most notably, plants use the chemical energy to fix carbon dioxide into carbohydrates and other organic compounds through light-independent reactions. The overall equation for carbon fixation (sometimes referred to as carbon reduction) in green plants is:

$3\ CO_2 + 9\ ATP + 6\ NADPH + 6\ H+ \rightarrow C_3H_6O_3$-phosphate + 9 ADP + 8 Pi + 6 NADP+ + 3 H_2O

More specifically, carbon fixation produces an intermediate product, which is then converted to the final carbohydrate products. The carbon skeletons produced by photosynthesis are then variously used to form other organic compounds, such as the building material cellulose, as precursors for lipid and amino acid biosynthesis or as a fuel in cellular respiration. The latter not only occurs in plants, but also in animals when the energy from plants get passed through a food chain. Organisms dependent on photosynthetic and chemosynthetic organisms are called heterotrophs. In general outline, cellular respiration is the opposite of photosynthesis: glucose and other compounds are oxidised to produce carbon dioxide, water, and chemical energy. However, both processes take place through a different sequence of chemical reactions and in different cellular compartments.

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In algae and bacteria

Algae comes in multiple forms from multicellular organisms like kelp, to microscopic, single-celled organisms. Although they are not as complex as land plants, photosynthesis takes place biochemically the same way. Very much like plants, algae have chloroplasts and chlorophyll, but various accessory pigments are present in some algae such as phycocyanin, carotenes and xanthophylls in green algae and phycoerythrin in red algae (rhodophytes), resulting in a wide variety of colors. All algae produce oxygen, and many are autotrophic. However, some are heterotrophic, relying on materials produced by other organisms.

For example, in coral reefs, there is a symbiotic relationship between zooxanthellae and the coral polyps.

Photosynthetic bacteria do not have chloroplasts (or any membrane-bound organelles). Instead, photosynthesis takes place directly within the cell. Cyanobacteria contain thylakoid membranes very similar to those in chloroplasts and

are the only prokaryotes that perform oxygen-generating photosynthesis. In fact chloroplasts are now considered to have evolved from an endosymbiotic bacterium, which was also an ancestor of and later gave rise to cyanobacterium. The other photosynthetic bacteria have a variety of different pigments, called bacteriochlorophylls, and do not produce oxygen. Some bacteria, such as Chromatium, oxidize hydrogen sulfide instead of water for photosynthesis, producing sulfur as waste.

►The evolution of photosynthesis

Plant cells with visible chloroplasts.The ability to convert light energy to chemical energy confers a significant evolutionary advantage to living organisms. Early photosynthetic systems, such as those from green and purple sulfur and green and purple non-sulfur bacteria, are thought to have been anoxygenic, using various molecules as electron donors.

Green and purple sulfur bacteria are thought to have used hydrogen and sulfur as an electron donor. Green nonsulfur bacteria used various amino and other organic acids. Purple nonsulfur bacteria used a variety of non-specific organic molecules. The use of these molecules is consistent with the geological evidence that the atmosphere was highly reduced at that time.

Fossils of what are thought to be filamentous photosynthetic organisms have been dated at 3.4 billion years old

Oxygen in the atmosphere exists due to the evolution of oxygenic photosynthesis, sometimes referred to as the oxygen catastrophe. Geological evidence suggests that oxygenic photosynthesis, such as that in cyanobacteria, became important during the Paleoproterozoic era around 2 billion years ago. Modern photosynthesis in plants and most photosynthetic prokaryotes is oxygenic. Oxygenic photosynthesis uses water as an electron donor which is oxidized into molecular oxygen by the absorption of a photon by the photosynthetic reaction centre.

►Origin of chloroplasts

In plants the process of photosynthesis occurs in organelles called chloroplasts. Chloroplasts have many similarities with photosynthetic bacteria including a circular chromosome, prokaryotic-type ribosomes, and similar proteins in the photosynthetic reaction centre.

The endosymbiotic theory suggests that photosynthetic bacteria were acquired (by endocytosis or gene fusion) by early eukaryotic cells to form the first plant cells. In other words, chloroplasts may simply be primitive photosynthetic bacteria adapted to life inside plant cells, while plants themselves have not actually evolved photosynthetic processes on their own. Another example of this can be found in complex animals, including humans, whose cells depend upon mitochondria as their energy source; mitochondria are thought to have evolved from endosymbiotic bacteria, related to modern Rickettsia bacteria. Both chloroplasts and mitochondria actually have their own DNA, separate from the nuclear DNA of their animal or plant host cells.

This contention is supported by the finding that the marine molluscs *Elysia viridis* and *Elysia chlorotica* seem to maintain a symbiotic relationship with chloroplasts from algae with similar RDA structures that they encounter. However, they do not transfer these chloroplasts to the next generations.

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Chlorophyll:-

	Chlorophyll *a*	**Chlorophyll *b***	**Chlorophyll *c1***	**Chlorophyll *c2***	**Chlorophyll *d***
Molecular formula	$C_{55}H_{72}O_5N_4Mg$	$C_{55}H_{70}O_6N_4Mg$	$C_{35}H_{30}O_5N_4Mg$	$C_{35}H_{28}O_5N_4Mg$	$C_{54}H_{70}O_6N_4Mg$
Occurrence	Universal	Mostly plants	Various algae	Various algae	cyanobacteria

►In diethylether, chlorophyll a has approximate absorbance maxima of 430 nm and 662 nm, while chlorophyll b has approximate maxima of 453 nm and 642 nm.

►The absorption peaks of Chlorophyll a are at 665 nm and 465 nm. Chlorophyll a fluoresces at 673 nm. The peak molar absorption coefficient of chlorophyll a exceeds 105 M^{-1} $cm^{-1,}$ which is among the highest for organic compounds

CONCEPT 1:-

Light absorption and emission by chlorophyll.

* **Chlorophyll appears green because it absorb light in Red & Blue region**

⇨chlorophyll (Chl) in its lowest-energy, or ground, state absorbs a photon (represented by *hn*) and makes a transition to a higher-energy, or excited, state (Chl*):

$$Chl. + h\upsilon \rightarrow Chl^*$$

⇨Absorption of Blue light excites the chlorophyll to a higher energy state than absorption of red light because of their high energy photon.

Upon returning to lower excited or back to ground state from higher excited state (which is extremely unstable) chlorophyll dispose its energy in several possible pathway.

1. **Fluorescence** :- Excited chlorophyll can re-emit a photon and thereby return to its ground state

   Reemission of photons → (higher wave length then absorbed) (Chlorophyll Fluoresce in Red region)

2. **Heat** - The excited chlorophyll can return to its ground state by directly converting its excitation energy into heat, with no emission of a photon

3. **Energy transfer** = during which an excited chlorophyll transfers its energy to another chlorophyll molecule.

4. **Photochemistry** = energy of excited state causes chemical Reaction to occur.

CONCEPT 2:

Quantum yield (Q.Y) = **yield of Photochemical product**

Total number of quanta absorbed

- Sum of Q. Y. of all possible processes is 1.0
- In functional chloroplast the quantum yield of photochemistry is approximate .95 the quantum yield of fluorescence .05.
- For O_2 production the measured maximum quantum yield is approximate 0.1

- Quantum requirement = 10 quanta absorbed for $1O_2$ mole.

CONCEPT 3: Action Spectra of Photosynthetic Activity

An **action spectrum** depicts the magnitude of a response of a biological system to light, as a function of wavelength. For example, an action spectrum for photosynthesis can be constructed from measurements of oxygen evolution at different wavelengths

⇨ Engelmann used a prism to disperse sunlight into a rainbow that was allowed to fall on an aquatic algal filament. A population of O2-seeking bacteria was introduced into the system. The bacteria congregated in the regions of the filaments that evolved the most O2. These were the regions illuminated by blue light and red light, which are strongly absorbed by chlorophyll.

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⇨A portion of the light energy absorbed by chlorophyll and other pigments is eventually stored as chemical energy via the formation of chemical bonds. **This conversion of energy from one form to another is a complex process that depends on cooperation between many pigment molecules and a group of electron transfer protein.**

The majority of pigments serves as an antenna collecting light and transferring the energy to long term energy storage, takes place.

⇨ **R. Emerson & Arnold** :- Provided first experimental evidence for the cooperation of many chlorophyll molecules in energy conversion during photosynthesis.

⇨ only one molecule of oxygen was produced for each 2500 chlorophyll molecules in the sample.

►**Jan Ingenhouz** :- Documented essential role of light in photosynthesis. In 1779, Jan Ingenhousz carried out more than 500 experiments spread out over 4 months in an attempt to understand what was really going on. He wrote up his discoveries in a book entitled 'Experiments upon Vegetables'. Ingenhousz took green plants and immersed them in water inside a transparent tank. He observed many bubbles rising from the surface of the leaves whenever the plants were exposed to light. Ingenhousz collected the gas which was given off by the plants and performed several different tests in attempt to determine what the gas was. The test which finally revealed the identity of the gas was placing a smoldering taper into the gas sample and having it relight

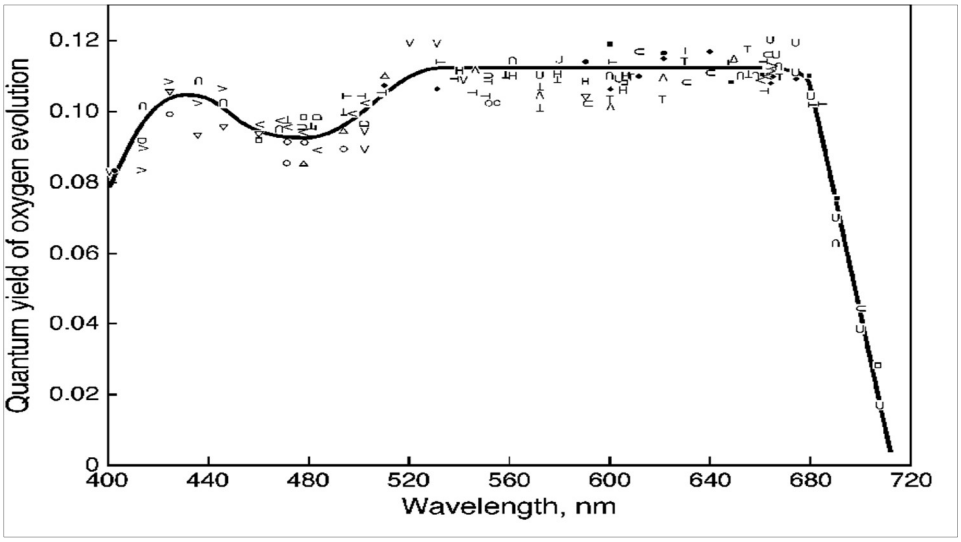
►**Quantum efficiency:- is a measure of the percentage of absorbed Photons that give rise to Photo chemistry.**

►**Energy efficiency:- is a measure of the percentage of absorbed photons that give rise to photo chemistry,**

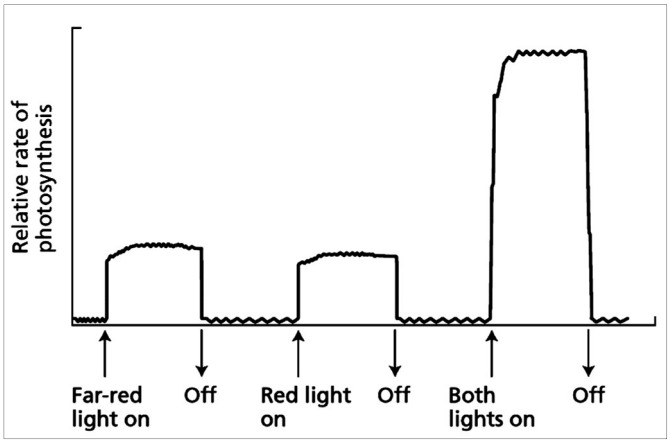
►**Red drop** :- Emerson, measured the quantum yield of photosynthesis as a function of wavelength and revealed an effect known as the red drop

Experimental observation that the photosynthetic efficiency of monochromatic light is greatly reduced above 680 nm, even though chlorophyll absorbs well up to 700 nm,

⇨**Quantum Yeild drops.** This yield drop simply says that absorption is falling off, Because the Quantum yield measure only light that has actually been absorbed.

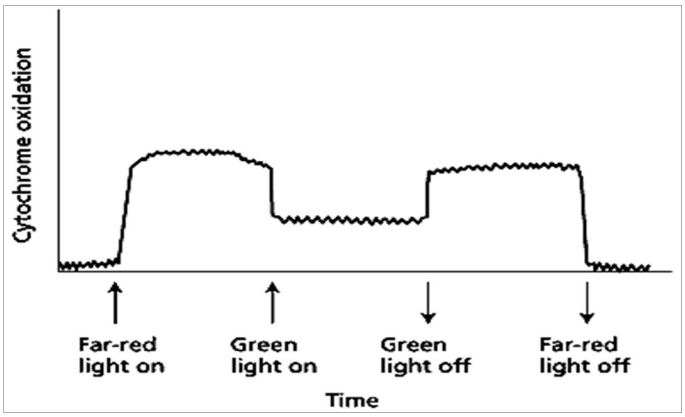


Enhancement effect (discovered by Emerson): -⇨ rate of photosynthesis separately with light of two different wavelengths and then used the two beams simultaneously . When red and far-red light were given together, the rate of photosynthesis was greater than the sum of the individual rates.



. * Enhancement effect was explained by **Duysen. (**This Led to the discovery of the two light reactions of photosynthesis) He actually tested cytochrome with **Far red and green light** when **FR** was given cytochrome was in **oxidized condition** when green light is also given some cytochrome mole are in **reduced condition**, saying occurrence of two photochemical events one tended to oxidize cytochrome and one that tended to reduce it.

This experiment was done in Red algae in which PSII is driven best by green light and PSI is driven best by FR light.

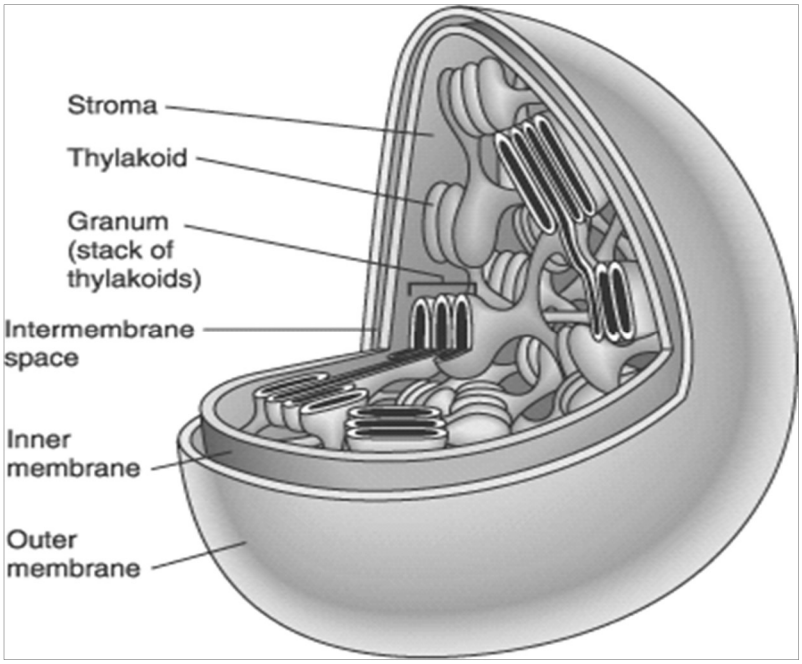


Photosystem I preferentially absorbs far-red light of wavelengths greater than 680 nm; photosystem II preferentially absorbs red light of 680 nm and is driven very poorly by far-red light. This wavelength dependence explains the enhancement effect and the red drop effect.

Another difference between the photosystems is that

- Photosystem I produces a strong reductant, capable of reducing NADP+, and a weak oxidant.
- Photosystem II produces a very strong oxidant, capable of oxidizing water, and a weaker reductant than the one produced by photosystem I.

CHOLOROPLAST STRUCTURE AND PHOTOSYNTHETIC COMPLEXES



Thyllakoid: These membranes containes integral membrane proteins that contains a large proportion of hydrophobic Aminoacid. The Reaction - centre, the antenna-protein complex, and most electron transport enzymes are all integral membrane protein and are inserted in the lipid bilayer of the membrane.

⇨ Many thyllakoid membrane proteins have one region pointing toward the stromal side of the membrane and other oriented toward the interior portion of thyllakoid (lumen)

⇨This vectorial arrangement of membrane is a universal feature of energy conserving membrane.

Antenna System: Many pigments together serve as an antenna, collecting light and transferring its energy to the reaction center, where chemical reactions store some of the energy by transferring electrons from a chlorophyll pigment to an electron acceptor molecule. An electron donor then reduces the chlorophyll again. The transfer of energy in the antenna is a purely physical phenomenon and involves no chemical changes.

⇨ The antenna system varied in different class of photosynthesis organism. Its main function is to deliver energy efficiently to the reaction centre with which they are associated. It size varies according to organism. In prokaryotes 20-30 Bacteriochlorophyll per reaction centre.

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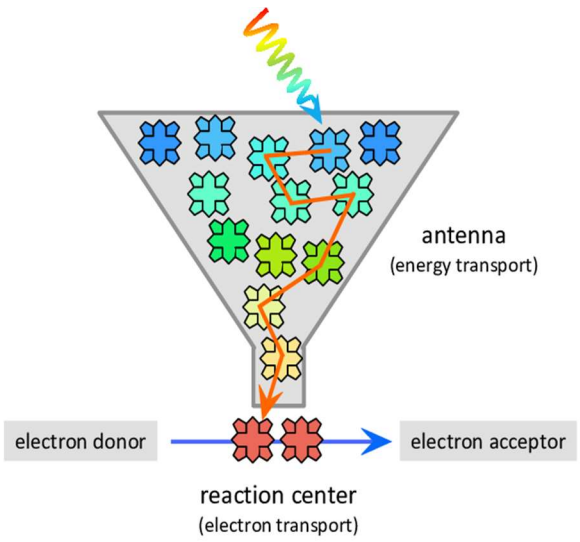

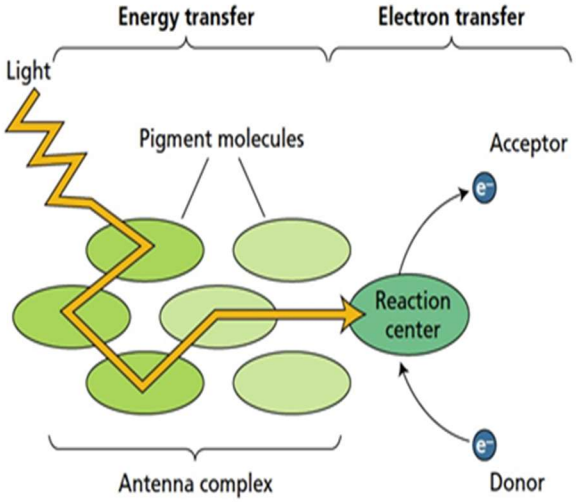

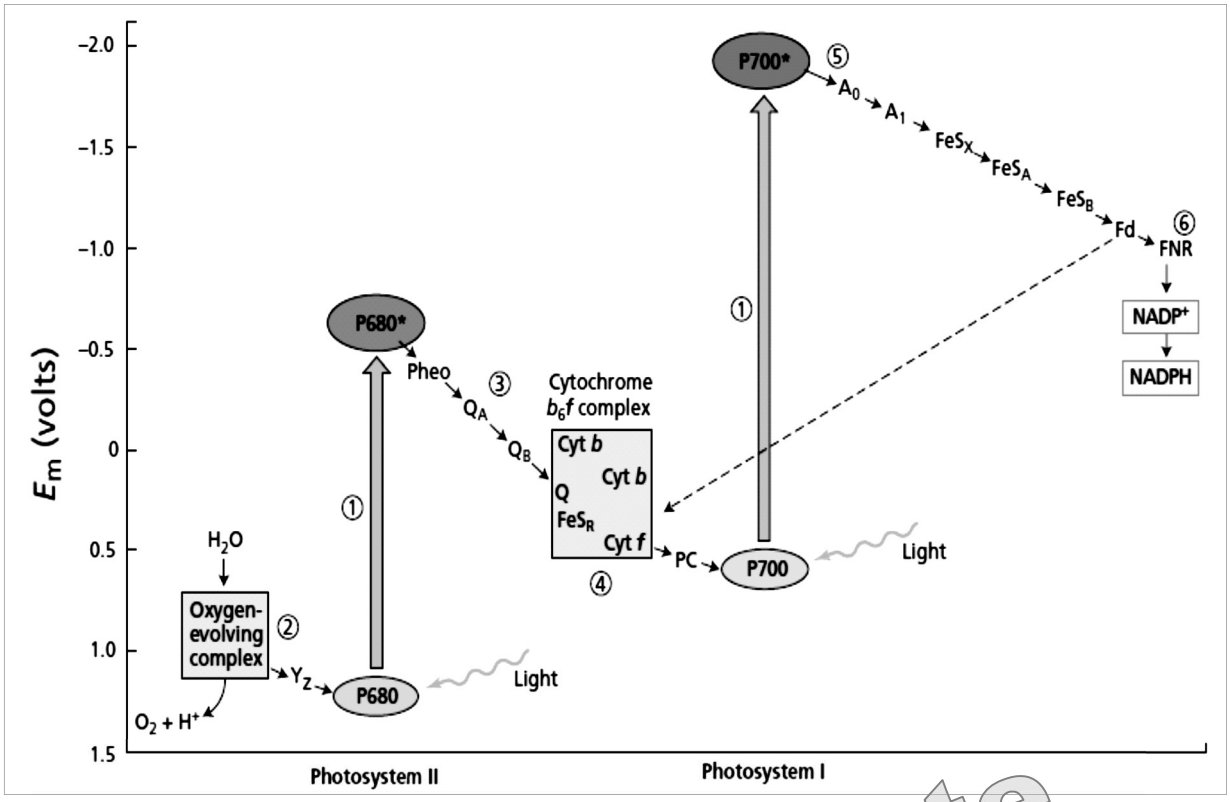

The mechanism by which excitation energy is conveyed from chlorophyll that absorbs the light to the reaction center is Resonance transfer (forster transfer) this is a non radioactive process. The energy absorbed in antenna pigment is funneled toward the Reaction center by a sequence of pigment with absorption maxima that are progressively shifted toward longer red wavelengths. This shift means that the energy of the excited state is some what lower nearer the Reaction center than in the more peripheral portion of the antenna system.

This effect gives the energy trapping process a degree of directionality or irreversibility and makes the delivery of excitation to Reaction center more efficient.

POINT(1) The vertical arrows represent photon absorption by the reaction center chlorophylls: P680 for photosystem II (PSII) and P700 for photosystem I (PSI). The excited PSII reaction center chlorophyll,P680*, transfers an electron to pheophytin (Pheo).

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POINT (2) On the oxidizing side of PSII (to the left of the arrow joining P680 with P680*), P680 oxidized by light is re-reduced by Yz , that has received electrons from oxidation of water.

POINT (3) On the reducing side of PSII (to the right of the arrow joining P680 with P680*), pheophytin transfers electrons to the acceptors QA and QB, which are plastoquinones.

POINT (4) The cytochrome *b*6 *f* complex transfers electrons to plastocyanin (PC), a soluble protein, which in turn reduces P700+ (oxidized P700).

POINT (5) The acceptor of electrons from P700* (A0) is thought to be a chlorophyll, and the next acceptor (A1) is a quinone. A series of membrane-bound iron–sulfur proteins (FeSX, FeSA, and FeSB) transfers electrons to soluble ferredoxin (Fd).

POINT (6) The soluble flavoprotein ferredoxin–NADP reductase (FNR) reduces $NADP^+$ to NADPH, which is used in the Calvin cycle to reduce CO2. The dashed line indicates cyclic electron flow around PSI.

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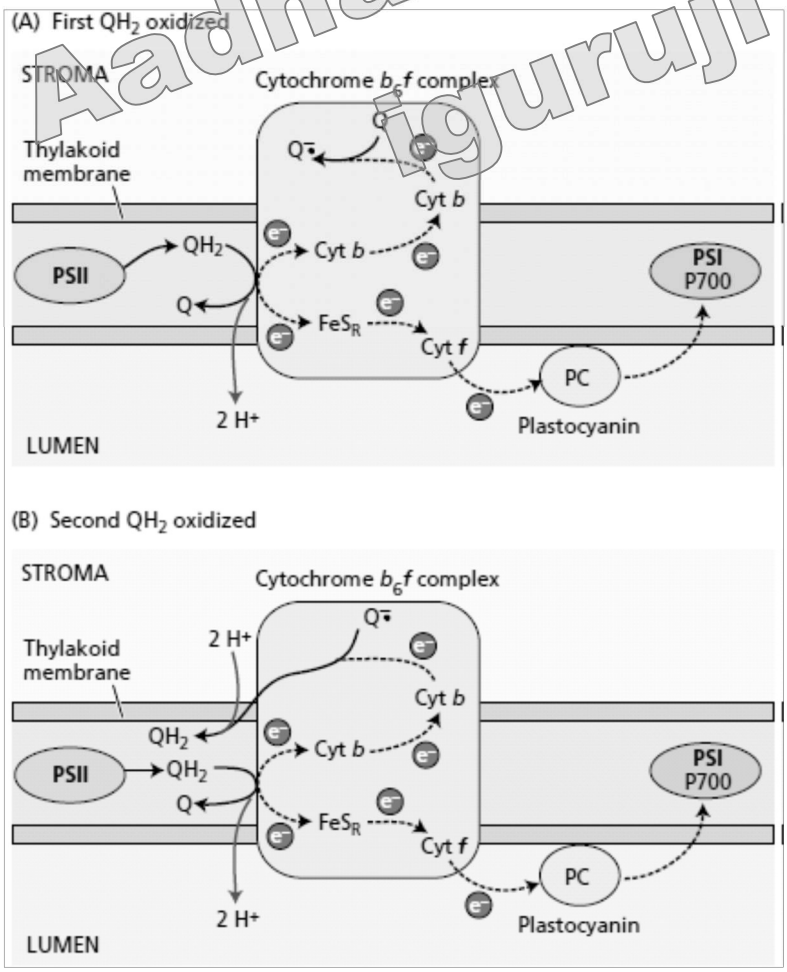
Q Cycle:- Plastohydroquinon (QH_2) get oxidized, with one of the 2e- passed along a linear electron transport chain toward PsI, while the other electron goes through a cyclic process that increase the number of Protons pumped across them membrane. Actually in cyclic part of the process, the **Plastoquinone** transfers its other electron to one of the b-type heme releasing both its proton to terminal side of the membrane. The b type heme transfer its electron through the second b type heme to an oxidized quinine molecule, reducing it to the semiquinone form near the stromal surface of the complex. Another similar sequence of electron flow fully reduces the plastoquinone, which picks up H+ from the stromal side of the membrane and is released from the cyt b_6f complex as **Plastohydroquinone**.



plastocyanin is a small (10.5 KDa), water soluble, copper contain protein that transfers electron between the cyt b_6f complex and P_{700}. This Protein is found in the lumenal space.

* **Cyclic electron flow**:- It occur under certain condition flow of electron from reducing side of PsI through cyt b_6f and back to P_{700} is known to occur.

⇨This cyclic electron flow is coupled to proton pumping into the lumen which can be utilized from ATP synthesis but does not oxidized water or reduce $NADP^+$.

With a sample size of 1448, this would amount to 12 (0.0084 X 1448)double recombinants but We actually only detected 8 DCO.

To measure interference, we first calculate the coefficient of coincidence (c.o.c.) which is the ratio of observed to expected double recombinants. Interference is then calculated as 1 - c.o.c. The formula is as follows:

$$I = 1 - c.o.c. = 1 - \left[\frac{\text{Observed \# of double recombinants}}{\text{Expected \# of double recombinants}}\right]$$

For the *v ct cv* data, the interference value is
1/3 from above formula (1-8/12)].

Most often, interference values fall between 0 and 1. Values less than 1 indicate that interference is occurring in this region of the chromosome.

⇨⇨⇨⇨**TRY ONE MORE EXAMPLE :-** An individual heterozygous at three genes *Aa, Nn* and *Rr* is crossed with the homozygous recessive parent *aa, nn,* and *rr.* The frequency of progeny with different phenotypes is given in

Table .

Phenotypes of progeny	Frequency	Class
Parental		
A N R	**347**	**(1)**
a n r	**357**	**(2)**
Recombinant		
A N r	**52**	**(3)**
a n R	**49**	**(4)**
A n r	**90**	**(5)**
a N R	**92**	**(6)**
A n R	**6**	**(7)**
a N r	**7**	**(8)**
Total	**1000**	

If there were no linkage between these genes each of the eight classes of progeny should have arisen with equal frequency. **This is clearly not the case:**

- **classes (1) and (2**) represent progeny from gametes where no recombination had taken place between the three genes. These are parental gametes because they retain the parental combination of alleles of the three genes;
- **classes (3) and (4)** represent progeny from gametes where recombination has occurred between the genes N and *R;* classes (5) and (6) represent recombination between the genes *A* and *N;*
- **classes (7) and (8)** are the most important because they represent gametes where recombination has taken place both in the interval between *A* and *N* and also between *N* and R, These are referred to as double cross-overs; they are less frequent than any of the other classes because they require two independent events to take place. The two least frequent classes progeny in a test cross of this nature can be used to identify which gene lies between the other two. In this case the central gene is *N.*

To determine the map distance between the genes it is necessary to quantify all the recombination events that have occurred.

(i) To determine the map distance between *A* and *N:*

add progeny in classes (5) and (6) (recombination between *A* and N)
and progeny in classes (7) and (8) (double cross-over, one of which is between *A* and *N)*
Express the total as a percentage of all progeny.
(90 + 92 + 6 + 7) x 100 / 1000 = 19.5% recombination, or 19.5 cM

(ii) To determine the map distance between *N* and *R:*

By the same logic as used for the map distance between *A* and *N* the distance between genes *N* and *R* is;

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(52 + 49 + 6 + 7) x 100 / 1000 = 11.4% recombination, or 11.4 cm

(iii) To determine the map distance between *A* and *R:*

This requires a summation of all recombinants.

(52 + 49 + 90 + 92+7 + 6 + 7) x 100 / 1000 = 30.9% recombination or 30.9 cm

Note that the distances are additive.

***A* <----------30.9 cM----------->R**

***A* < ---------- 19.5cM ----------> *N* <---------11.4 cM------- ---> R**

that would go undetected in two-factor crosses. Because more recombination events are detected the calculated recombination frequencies are greater. This is not a problem as recombination frequencies merely reflect the frequency of cross-overs detected rather than act as a physical measurement of actual distance between genes.

*******For simplicity, in this example alleles denoted by capital letters are completely dominant over the lower case alleles, and the three genes are simply named after their dominant alleles.**

Interference

Crossing-over takes place at chiasmata. These are physical structures involving two chromatids. Not surprisingly the presence of one chiasmata in a particular chromosome region can reduce the frequency of others forming close to it. This can result in a reduction in the number of double cross-overs observed.

INTERFERENCE

⇒ This occur when one region of chromosome inhibit a second in nearby region

This will tend to affect DCO

I = 1 – C

Positive interference = when c < 1

Negative interference = when C > 1 C= Coincidence

- **In the previous example the observed frequency of double cross-overs is 13 / 1000 (0.013).**
- By using the data for the observed single cross-over between *A* and *N* and between *N* and *R* we can predict the expected number of double crossovers.

Single cross-overs between *A* and *N* - 195

Single cross-overs between *N* and *R* = 114

- **Predicted number of double cross-overs**

(195/1000) x (114/1000) x 1000 = 22.3

This is greater than the observed number, 13, suggesting that positive chromosome interference is observed in this region. The extent of interference is calculated as the coefficient of coincidence (C), the observed number of double cross-overs divided by the expected number of double cross-overs. In this case it would be:

C = 13 / 22.3 = 0.58

Recombination frequency and physical distance

We have assumed that recombination frequency is a measure of the actual distance between genes.

This is only true in a semi-quantitative sense. It is now known that the frequency of cross-overs varies in different regions of the genome. It tends to be lower near centromeres and higher near telomeres.

It can also differ between males and females. However gene maps based on linkage data give a reasonably accurate indication of distance between genes and they are most useful in determining the order of genes along the chromosome.

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Plant Breeding and Crop Improvement

Classical Breeding Release/production of variation Conventionally this is achieved through sexual crossing, particularly of cultivated lines, in other words following Mendel's principles. Two parents who have expression of the desirable characters between them are intercrossed and the subsequent generations examined for plants with the desired characters in new combinations, i.e. we look for recombinants. This process therefore basically relies on the segregation of alleles at all the relevant genetic loci, during the normal process of meiosis (the reduction divisions that are undertaken to form the egg and pollen cells that fuse at fertilization). At fertilization there is a random fusion of gametes (pollen from the one plant and egg from the other) to give the embryo which develops into the seed. So by the natural process of sexual reproduction, but between plants that the breeder has deliberately chosen, we get offspring that contain novel combinations of the alleles that were originally dispersed between the two parents. Clearly the choice of parents is critical.

Sources of variation The breeder generally uses the natural variation that already exists within the species. For virtually all characters we only need to look or measure any character to observe variation in their expression, and often this reflects not just variation produced by differences in the environment in which the plant happens to be growing, but also genetic variation – variation that is heritable.

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This naturally occurring source of heritable variation accounts for most of the responses that have been made in plant breeding. However, reliance on this one source of variation does limit the potential for long-term progress, particularly in relation to improving specific characters. So the use of intraspecific variation of existing crop cultivars is supplemented by one of the following:.

Wild ancestral relatives of the crop itself: these may or may not still be able to cross sexually with the crop species and may be indigenous in another country. . inducing the variation that is required: the genetic variation that we see around us actually comes from the occasional and rare mistakes that occur in the otherwise faithful replication of the DNA in all organisms.

These occasional mistakes are called mutations and what we see as variation in any character today is the accumulation of such mistakes over a long period of time. The frequency with which mutations occur can be increased and the subsequent variants exploited. . Developments in the areas of molecular biology and biotechnology: these have extended the possibilities for introducing additional variation in the breeding process

Select amongst the variation The first difficulty is to decide which characters to select. This may seem straightforward but in practice it means trying to put in order of priority what will be needed in the new cultivar not only in relation to improving characters but also in relation to the ones whose expression is already satisfactory in the parents (as the characters will not normally remain unchanged without positive selection). If this did not present sufficient problems, the breeder is also faced with practical difficulties.

First, it is not possible to measure every character that might be relevant because there are simply too many for this to be practical. In addition, some characters take a great deal of time and effort to measure, and so may demand more resources than are available..

A major problem in a breeding programme is that there is a need to handle large numbers of different genotypes but only small quantities of planting material of each is available.

How does the breeder grow the plants such that they display their characters under conditions that resemble those under which they will actually be grown in agriculture?

So it is important for the breeder to check the feasibility and relevance of the characters being measured in the context of the reality of how and where the cultivar will be grown. Connected with the above is the efficiency with which selection

can be practised. We note that what the breeder observes is the phenotype but what he needs to select is the genotype (i.e. the heritable part of the variation that is observed). The relation between phenotype and genotype can be written as:

Phenotype = **Genotype + Environment** + **(Genotype x Environment)**

Breeding objectives and important traits The general objectives of virtually all breeders of crop plants are to increase the usable yield, increase its stability, ensure the quality and nutritive value, and produce types that suit the particular growing conditions and farming needs.

1. Usable yield. This means that it is not crude yield that is important but the part that can actually be used, eaten, processed, etc. This therefore brings in factors such as the storage life, waste produced and consumer acceptance. Also it means that the use that the crop will be put to is of major importance, i.e. for direct human consumption, animal foodstuff, processing etc., and this must be considered at the outset of the breeding programme.

2. Stability of yield. The fact that some lines/cultivars/ varieties do very well in some years or under some particular conditions may be useful but can lead to disaster when they fail because of changes in the growing conditions, a poor year for rain, no fertilizer available, too wet a period at harvest etc. Thus breeding for resistance/tolerance to all biotic and abiotic stresses is a major aim.

3. Quality of the product. This includes nutritional quality and taste and is related to the awareness of usable yield but is concerned with the nutritive value, calorific value, protein content, fat level, vitamin concentration etc.

4. Environmental impact. Agriculture affects any area where it is practised and so generates considerable debate in many parts of the world – and quite rightly so. There are many aspects to this issue and all affect the plant breeder's aims and objectives. There are therefore much clearer calls for more ecologically sympathetic methods to achieve these aims. The production of varieties with disease and pest resistance is an obvious route to follow. Taking this further, if, for example, low-nitrogen input is required then clearly specific varieties will need to be produced that grow best under these conditions.

5. Better adapted. The need to produce varieties that have been selected to grow under prevailing conditions is clear but easily overlooked. This may be the climate of a particular geographical location, the narrow conditions of a local area, the type of agricultural practices used, the needs of the farmer/village/country etc.

6. Prediction. Every breeder knows that it takes a number of years from starting to breed a cultivar until its release to the grower (often 10 years or more). This means that a breeder requires an ability to forecast the future, i.e. be a crystal ball gazer.

So, for example, a breeder might need to assess/guess:

(i) What will growers be requiring in the future?
(ii) What will happen in terms of the emphasis for growers, e.g. what subsidies will there be and what will the political situation be in the future?
(iii) How will climate change have affected growing patterns?
(iv) How will farming systems have changed?
(v) What will be the spectrum of diseases and pests?
(vi) What will the end-users require in the future?

Stabilizing and multiplying the desired types One of the most important determinants that introduces differences in the details of this part of the breeding strategy is the natural breeding system of the plant. The main natural breeding systems can roughly be classified into inbreeders, outbreeders (outcrossers) and clonally reproduced (i.e. clonal or vegetative propagation). These three main differences in the natural breeding system lead to what are commonly considered the main categories of classical breeding programmes identified and are briefly reviewed here. Inbreeders Examples of crops that are inbreeders are wheat, barley, rice, soybean, peas, tobacco, tomato, millet, lentil, flaxand chickpea. These are

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species that naturally self-pollinate and in commercial practice are grown as true breeding, homozygous lines. So all the individuals of a particular cultivar are genetically identical. Each generation is produced by allowing the plants to self-pollinate in each cycle of the breeding programme so that while the trialling and selection process is proceeding the plants are becoming more inbred. When the finished cultivars are selected they will breed true from seed (they are genetically homozygous). So the genotype is now fixed and the cultivar can be multiplied simply by letting it set seed (isolated from any other genotypes of this crop – as some pollen is likely to pass between them). There are two main methods by which selection is achieved during this inbreeding process: bulk method and pedigree method.

Bulk method The bulk method (Figure 2) starts with the creation of genetic variation by the hybridization between two parents (P1 X P2). The F1 and several subsequent generations, often up to and including the F5 generations, are grown as bulk populations. No conscious selection is imposed on these generations and it is assumed that the genotypes most suited to the environment in which the bulk populations are grown will leave more offspring and hence predominate in future generations. It is therefore very important that the bulks are grown in an environment that will be similar to that needed for the resulting cultivars. At the next stage, individual plants showing desirable characteristics are selected. From each selected plant, a plant (or head) row is grown and the produce from the best lines/rows are selected, bulk harvested, for initial yield trials, and resown for multiplication. This method is one of the least expensive methods of producing populations of inbred lines. The disadvantage of this scheme is the length of time from initial crossing until yield trials are grown. In addition, it has often been found that the natural selection that is relied on in the early, bulked generations is not always that which favours characters thought desirable for growth in agricultural practice.

Pedigree method In a pedigree breeding scheme single plant selection is carried out at the F2 through to the F6 generations. Again, the scheme begins by hybridization between chosen homozygous parental lines (P1 XP2), and F2 populations are obtained by selfing the heterozygous F1 plants. Single plants are selected from amongst the segregating F2 population. The produce from these selected plants are grown in plant/head rows at the F3 generation. The most desirable single plants are selected from the 'better' plant rows and these are grown in plant rows again at the F4 stage. This process is repeated, but with an increasing shift from individual plant to row performance, until plants are near homozygous (e.g. F5). At this stage the most productive rows are bulk harvested and used as seed source for initial yield trials at F6. In addition to being laborious (as a considerable amount of record keeping is required) and relatively expensive, the reliance on individual plant selection is inefficient and leads to the loss of valuable genotypes before they are fully tested. However, the greater control over the selection and the defined pedigrees make this a preferred method in many crops.

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Cross-pollinated (or outbreeding) crops Some examples of cross-pollinated crops are alfalfa, rye, herbage grasses, forage legumes, red clover, some maizes, perennial ryegrass, sugar beet and oil palm. The selection of new cultivars of cross-pollinated crop species is a process that changes the gene frequency of desirable alleles within a population of mixed genotypes while trying to retain a high degree of heterozygosity. So it is really the properties of the population that are vital, not individual genotypes (as in self-pollinating crops). Instead of resulting in a cultivar for release that is a uniform genotype, the population will be a complexmixture of genotypes, which together give the desired performance. There are basically two different types of outbreeding cultivars, which are determined by the methods of their maintenance and multiplication: open-pollinating populations and synthetic cultivars

Open-pollinating population cultivars In open-pollinating populations, selection of desirable cultivars is usually carried out by mass selection, recurrent phenotypic selection or selection with progeny testing. The maintenance of these cultivars is through open-pollinated populations with uncontrolled (random) mating.

Mass selection Mass selection is based on the same underlying philosophy and assumptions as the bulk method for inbreeding species. It is a very simple breeding scheme, which uses natural environmental conditions to alter the genotypic frequency of an open-pollinating population. A new population is created by cross-pollinating two different existing open-pollinating populations. In this case a representative set (any single plant will not, of course, be fully representative of the populations) of individuals from each population will be taken to be crossed. The seed that results from such a set of crosses is grown under field conditions over a number of seasons. It is assumed that crossing will be at random and so result in a population quickly moving towards equilibrium which can be maintained, as a population, for

Seed Dormancy And Germination, Hormonal Regulation Of Growth And development. Physiological Effects And Mechanism Of Action Of Auxins,Gibberellins, Cytokinins, Ethylene, Abscisic Acid And Jasmonic Acid, Plant rythms And Biological Clock, Secondary Metabolites, Plant Responses Tobiotic And Abiotic Stresses. Physiology Of Flowering- Photoperiodism And vernalization.

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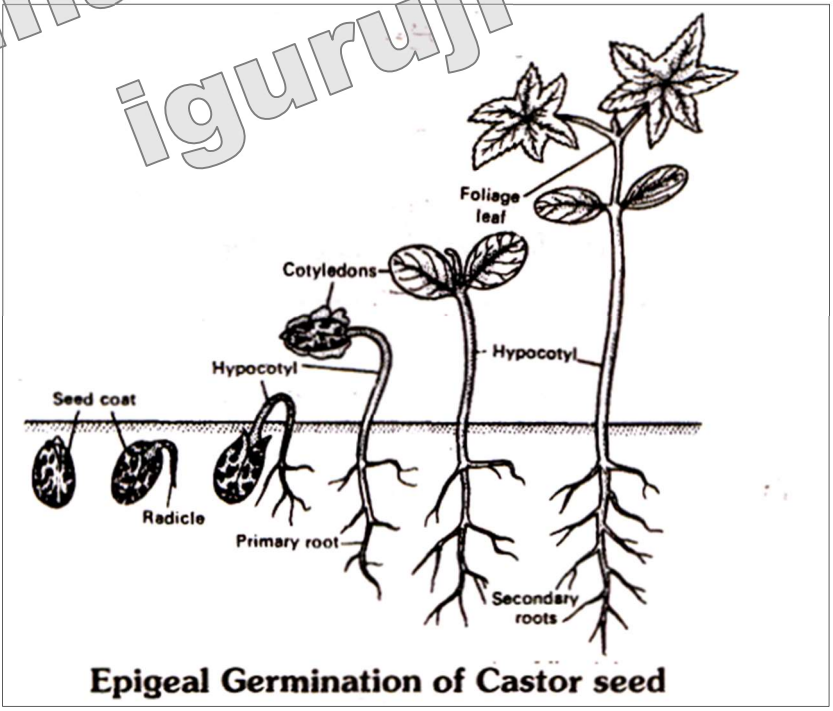
Germination of seed

- The embryo of seed grows in to a sporophyte plant. The radicle produces primary root. The plumule develops short and latter on cotyledons degenerates.
- In some of the plants cotyledon comes above the surface of the soil during the germination of seed. Such type of germination is called epigeal germination, e.g. Capsella. This is due to higher growth take place in hypocotyle region of embryo in seed, so that cotyledon pushed above the soil surface [capscella, castor, French bean etc.]
- In some of plants the epicotyle region grow faster during the germination results cotyledon remains under the soil. It is known as hypogeal germination, e,g. In most of angiosperms [pea. Gram, Rice, Maize etc]



Epigeal Germination of Castor seed

Factors Affecting Seed germination

The process by which the dormant embryo wakes up [becomes active] and begins to grow is known as germination of seed. The seed germination take place in the presence of favorable condition such such as temperature, moisture, and air. This is a very delicate stage in the life of the plant. Any minute change in the environment has harmful effect on growing embryo. So that favorable environment should be essential for germination. The following factors are essential for germination of seed.

1. Moisture: The moisture or water is the most important factor for germination of seed. Generally, the cells of embryo contain about 10-15% water in the dormancy period. The vital activities like growth and development is unable to continue in this less amount of water. For active life processes, water must be present about 75-90%. The seed absorbs water and swell up to increase in size before the germination. Water absorb through seed coat and micropyle.

The following effects have been observed in seed due to absorption of water:

a. The seed coat becomes soft and absorbed water reaches to the cells of embryo. When the ratio of water increases in the cells, the protoplasmic contents becomes more active.

b. The size of embryo increased due water absorption results, seed coat breakes up and radicle and plumule easily comes out. Seed coat absorbs water, it becomes soft and increase its permeability. Resulting it increases rate of exchange of oxygen and CO_2. The rate of respiration increases in active cells of embryo. Thus it require more oxygen.

c. The enzymes are present in the cells or endosperm or cotyledons, which are only active in the presence of water. The stored food changed in to dissolved form by the activity of enzymes and it is reaches to the active embryo.

2. Oxygen [O_2]: The process like cell division, cell elengation etc. of the embryo require energy. This energy release by the oxidation of carbonic substances. Oxygen is essential for oxidation process. The upper surface of soil contains sufficient amount of O_2. The healthy germination does not take place in the absence or scarcity of oxygen in deep soil. So that crop seed sown in the in soil by the farmers in the field is only up to 5-7 c.m. deep.

3. Temperature: The suitable temperature is essential for germination of seed. The protoplasm of the cell remains active at certain range of temperature. Most of seed do not germinate in between the range of 0°C to 5°C and above the 45°C, The favourable range of temperature is 20-25°C for germination of seed in the majority of seeds.

4. Food or Nutrition: The growing embryo requires [needs] nutrition during germination. The embryo depends upon stored food materials in cotyledons or endosperm in the germination period up to the formation of primal} root from the radicle and first leaf from the plumule.

5. Light: Light produces different effect in different variety of seeds. The most of the plants do not require light up to the formation of first leaf. Adversely, the rate of germination very fast in the absence of light But for some plants light is very essential for germination.

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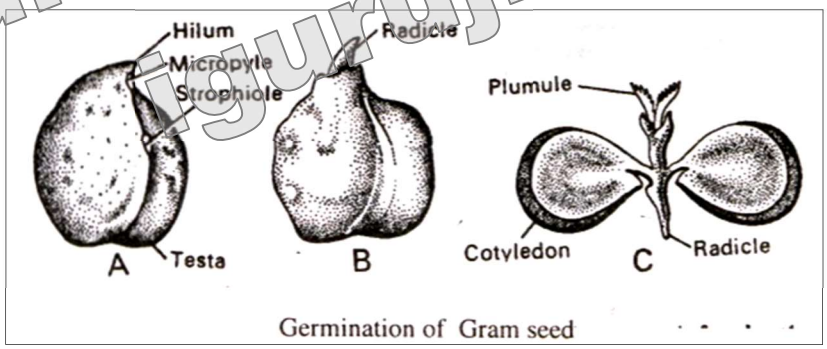
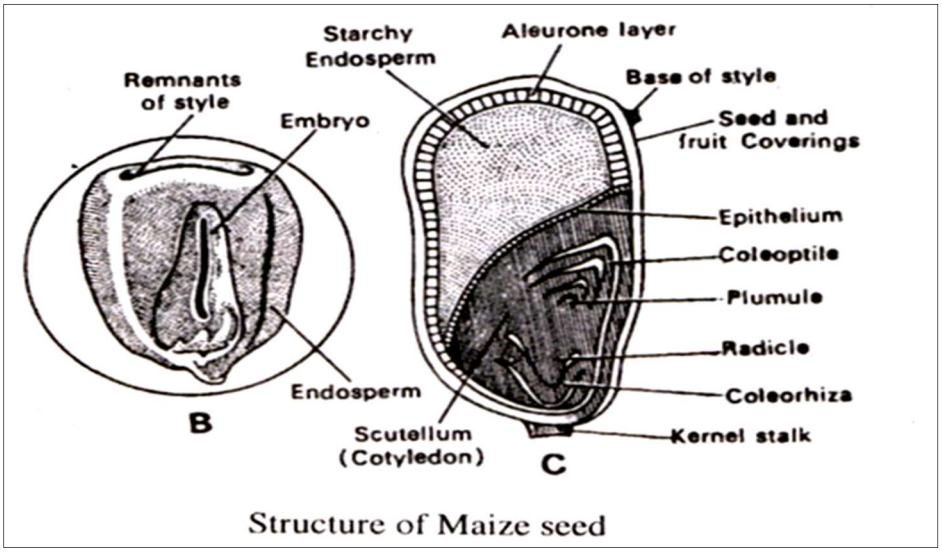
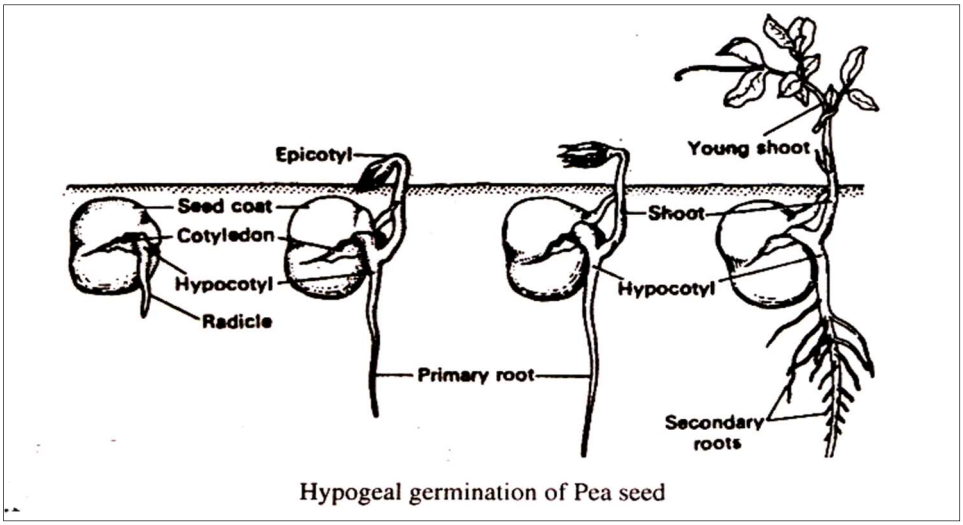


Germination of Gram seed



Structure of Maize seed



Hypogeal germination of Pea seed

They will not germinate in the dark. For example seed of ephiphytes, orchids, tobacco, mistletoe etc. After the development of newly leaves on shoot then light is very essential factor. The chlorophyll is not formed in the absence "of light and this newly formed plant [juvenile] will die in the absence of photosynthesis and deficiency of food.

SPECIAL POINTS

(1) Highest amount of **fat** is found in endosperm of **Coconut.**
(2) Kinetin hormone is present in **endosperm.**
(3) The immediate effect of pollen grains on endosperm is called **xenia.**
(4) Embryonic development of capasella is **endosporic** because it is developed from chalazal region of embryo.
(5) Single celled suspensor is found in **Triticum** [wheat] and **Caryophyllum.** Their seeds are **caryopsis** fruit.
(6) Suspenser is absent in **Sunflower** and **Marigold.**
(7) 125 meiotic divisions are essential for development of 100 grains of wheat.
(8) Two generation and three genotypic cells are present in Angiospermic seed.
(9) Haeviest 6 k.g. weight of seed is found in **Lodoshia** & 1 meter in length and wt. of fruit is 18 kg.
(10) Edible part of Betalnut is endosperm.
(11) Abscissic acid is the natural germination inhibitor of seed.
(12} The germinatism of seed take place inside the fruit while it is attached with plant is called **vivipary.**
(13) Light inducess germination in Lettuce/Lactuca **sativa**
(14) Anatomical transition from root to stem occurs in hypocotyle region,
(15} Seed of the **Ruella** dispersed by jaculator technique.
(16) Smallest or minute seeds are found in **Orchids** which are lightest in plant kingdom and are called **''Dust seeds"** [wt. 20.33 μg].
(17)Longest leaf in Angiosperm is **Raphia vinifera** [10-15 m]and broadest in diameter in V**ictoria regia-1-1.5 m.**

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Molecular Biology Of Seed Development

- All mature seeds contain an embryo and a protective covering called a seed coat (testa). In early development all angiosperm seeds also contain an endosperm, but in many seeds the endosperm is completely absorbed by the developing embryo. The embryo and endosperm are products of fertilization while the seed coat develops from the integuments of the ovule.
- The seed coat contains a variety of adaptations related to protection and dispersal mechanisms. The seed coat usually forms a dry tissue. It may contain waxes for water impermeability, mucilage to make seeds sticky, compounds resistant to digestion by animals, etc. In pomegranate, the seed coat forms the fleshy tissue that is consumed by humans. The seed coat often contains multiple layers with different characteristics.
- Maternal tissues appear to have an important influence on seed development. An arabidopsis mutant called ***aberrant testa shape (ats)*** that lacks one of the 2 integuments also lacks several cell layers in the testa

(3 layers vs. 5 normally). The seed are abnormally shaped in this mutant and seed shape shows maternal effect (ie. the genotype of the maternal parent determines the shape of the seed). Therefore, the seed coat and not the embryo determines the shape of the seed, and the embryo just grows to fill in the shape determined by the testa.

- Another maternal gene called *FBP7* is specifically expressed in the ovule and seed coat and is required for normal ovule development. Downregulation of this gene in transgenic plants resulted in degeneration of the endosperm that was dependent on maternal genotype. This demonstrates the interaction between maternal tissues and those produced by fertilization.

The importance of global gene regulation

- Several genes have been identified that negatively regulate seed development until fertilization has occurred. A mutant screen on a sterile line identified 3 genes that regulate seed development. Seeds develop on these mutants in the absence of fertilization. They are called *fis* for *fertilization independent seeds*. The genes appear important for control of seed development by fertilization. Several similar genes have been identified and cloned. They include:
  - ***FIE*** = *fertilization independent endosperm*, encodes a WD type POLYCOMB protein
  - ***MEDEA*** encodes a SET domain type POLYCOMB protein
  - ***FIS2*** = *fertilization independent seed2*, encodes a zinc finger protein
- **POLYCOMB** proteins are involved in chromatin structure and regulate (repress) the expression of genes in big portions of the genome. Therefore, the repression of large groups of genes is necessary to inhibit seed development until fertilization has occurred.
- All three genes show parent-of-origin effects (imprinting). The maternally inherited gene is expressed and required but the paternally inherited gene is not expressed or required for seed development. (I.e. heterozygous mutants show 50% seed abortion, even when fertilized by wild type pollen .
- **MEDEA and FIE proteins have been shown to interact by yeast 2-hybrid**

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Preparation for developmental arrest (seed/embryo maturation).

- Most cell division is complete by the beginning of the maturation phase of embryo development, but the embryo can increase in size up to 100 fold. This is by cell expansion and accompanies a massive accumulation of storage compounds. The major storage compounds are proteins, starch and lipids. These storage compounds are what give nutritional value to important crops such as cereals and beans. They are also valuable for other uses such as production of vegetable oil and starch which are used in a wide variety of ways ranging from cooking to industrial lubricants and plastics. Therefore there is a huge economic interest in seed storage compounds.

Accumulation of storage products

- Storage proteins represent an important source of amino acids, nitrogen and carbon for the germinating seedling. Storage protein mRNAs represent up to 20% of the total mRNA found in a maturation phase embryo. They are synthesized on the RER and accumulate in the vacuole or as membrane bound vesicles called protein bodies. The storage proteins are encoded by several multigene families with up to 55 different genes coding for a given storage protein. Synthesis is controlled at the transcriptional level, with a few regulatory genes each controlling particular classes of storage proteins. An example is the *opaque2* gene of maize which codes for a transcription factor.
- The regulation of starch and lipid accumulation, although no less important, is less well understood. These compounds are produced by complex enzymatic pathways. Each class of compound is a mixture of molecules with different chain lengths, chain branching characteristics, levels of saturation and other chemical modifications. Thus the synthesis of these compounds is much less straight forward than storage proteins.

Acquisition of dessication tolerance

- At the end of embryonic development, most seeds dehydrate to about 5% moisture content. Such severe dehydration is lethal to most plant tissues and embryos express a developmental program that allows them to survive. Acquisition of dessication tolerance is part of the seed maturation program. Two problems faced by desiccated cells are high ionic concentrations and membrane stresses. At such low moisture levels, solutes would

Jasmonic Acid is a Plant Stress Hormone that Activates many Defense Responses

Jasmonic acid levels rise steeply in response to damage caused by a variety of different herbivores and trigger the formation of many different kinds of plant defenses besides proteinase inhibitors, including terpenes and alkaloids.

- Another defensive response to infection is the formation of hydrolytic enzymes that attack the cell wall of the pathogen. An assortment of glucanases, chitinases, and other hydrolases are induced by fungal invasion.
- Chitin, a polymer of N-acetylglucosamine residues, is a principal component of fungal cell walls. These hydrolytic enzymes belong to a group of proteins that are closely associated with pathogen infection and so are known as **pathogenesis-related (PR) proteins.**

Phytoalexins: Perhaps the best-studied response of plants to bacterial or fungal invasion is the synthesis of phytoalexins. Phytoalexins are generally undetectable in the plant before infection, but they are synthesized very rapidly after microbial attack because of the activation of new biosynthetic pathways.

- **HORMONE ACTION IN RESPONSES TO BIOTIC STRESS**

- As sessile organisms, plants seem to be easy targets for herbivores and pathogenic microorganisms. Not surprisingly, plants produce numerous physical and chemical defenses, such thorns and toxic or foul-tasting compounds. Some defenses are constitutive (produced all the time), whereas others are induced by the presence of a pathogen through pathways that include hormonal signaling. The hormonal response depends on the type of pathogen or herbivore attacking the plant.
- Biotrophic pathogens live within living tissues and don't immediately kill the plant cells; Pseudomonas is a bacterium that is widely studied as a model for plant responses to biotrophic pathogens.
- Plant defenses against biotrophic pathogens are mediated in part through SA signaling pathways.
- Necrotrophic pathogens, such as many fungi, kill their plant hosts directly through the production of toxins or hydrolytic enzymes. Responses to necrotrophic pathogens and many herbivores are mediated in part by jasmonates and synergistic effects of ethylene.
- **The salicylate and jasmonate/ethylene pathways are sometimes antagonistic; one response dampens the other. Activation of either pathway interferes with GA or auxin-induced growth pathways, and both defense pathways are reduced by elevated ABA levels** (suggesting that a stressed plant puts its resources into combating the abiotic challenge before the biotic challenge).
- Other hormone signaling pathways also affect stress responses; for example, reducing the auxin response increases resistance to some pathogens. These interactions are sometimes exploited by pathogens that produce phytohormones or affect hormone signaling in other ways.

- **Jasmonates**

- **Jasmonates are derivatives of jasmonic acid (JA), which is derived from membrane lipids linolenic acid in a series of steps occurring in the chloroplast and peroxisome**.
- Herbivore damage (wounding and/ or herbivore oral secretions) induces JA accumulation within 30 min.
- In the cytoplasm, JA is conjugated to isoleucine to form the **active compound JA-Ile.**
- Jasmonate accumulation leads to an induction of the expression of genes that have an antiherbivory function, including several that interfere with insect digestive capabilities, as well as defensin proteins with broad antimicrobial functions.
- Mutant plants that don't produce or respond to jasmonates are far more susceptible to insect or necrotrophic pathogen attack.
- Jasmonates can also induce systemic defense responses and the production of herbivore-induced plant volatiles that attract carnivorous or parasitoid arthropods, to eat or lay their eggs on or in the herbivore. Other volatile signals are perceived by nearby plants or other branches of the same plant, priming them to produce defensive compounds in case of an attack.

- The signaling pathway for jasmonate response is very similar to that of auxin. Like TIR1, the JA-Ile coreceptor COI1 is an F-box protein; binding of JA-Ile to COI1 causes the complex to bind to and ubiquitinate JAZ coreceptor repressor proteins, **thereby promoting transcription via MYC2 TFs.**
- Besides their role in defense**, jasmonates participate in reproductive and vegetative developmental functions.**

- **Salicylates**

- Salicylates include salicylic acid (SA) and its derivatives. SA is named for willow trees in the genus Salix; willow bark has long been known for its pain-relieving properties.
- **In the 19th century, the active ingredient was purified, and in 1899, a derivative of SA, acetylsalicylic acid, was given the trade name aspirin. In the 20th century, aspirin and SA were recognized as promoting disease resistance in plants.**
- SA synthesis is induced by pathogen infection, and mutants affected in SA synthesis are less resistant to pathogens. SA can be methylated to produce a mobile signal, methyl salicylate, which is thought to move through phloem to uninfected cells and, after demethylation to SA, prime them to a heightened resistance, a phenomenon called systemic acquired resistance.
- Although SA's role in mediating plant defense responses, including systemic acquired resistance, has been recognized for 20 years, its receptor has not yet been identified, and many gaps remain in our understanding of its signal transduction pathway. It is clear, however, that SA is has a central role in the plant response to many pathogenic microorganisms.
- Plant cells perceive molecules that are commonly found on microbial pathogens, referred to as pathogenesis-associated molecular patterns (PAMPs). The cellular response to PAMPs is referred to as PAMP-triggered immunity. Recognition of a pathogen initiates the production of SA, which leads to the induction of several genes that contribute to pathogen defenses; some of these are pathogenesis-related proteins.
- Pathogenesis-related proteins include enzymes that directly attack bacteria or fungi, such as chitinases or proteases, as well as those that synthesize compounds with antimicrobial activities.

Some pathogens produce effectors that induce a more vigorous defense response called effector-triggered immunity. These stronger responses are conferred by plant resistance genes, which have a very narrow specificity.

The effector-triggered immunity response is more vigorous than the PAMP-triggered immunity response and ensures that the recognized pathogen is quickly killed off. This response, called a hypersensitive response, includes the production of sticky cell wall materials called lignin to seal off the infected cell and a burst of reactive oxygen species to kill the infected cell and the pathogen.

Bacteria

- Metabolomic and transcriptomic analysis of rice in response to bacterial blight pathogen Xanthomonas oryzae pv. oryzae revealed global metabolic and transcriptomic changes in leaf tissues . Ethylene response element binding protein (EREBP) transcription factor gets significantly expressed together with ROS scavenging system and lower expression of alcohol dehydrogenase gene.
- These factors lead to hypersensitive cell death in the resistant cultivar upon bacterial infection.
- Stimulation of glutathione-mediated detoxification and flavonoid biosynthetic pathways in combination with up-regulation of defense genes during infection inhibits pathogen from further spreading in the host tissues.
- Transcripts encoding disease resistance proteins via JA/ET signaling as well as osmotic regulation via proline synthesis genes were found differentially expressed when microarray analysis was performed in cotton associated with Bacillus subtilis induced tolerance .
- The major protein of bacterial flagella is flagellin which is a well characterized PAMP.

Fungi

- On the basis of their lifestyles, plant pathogenic fungi have been divided into two classes: the biotrophs and the necrotrophs. Biotrophs feed on living host tissue, whereas necrotrophs first kill the host tissue and then

feed on the dead tissues. However, there are many plant pathogenic fungi which behave both as biotrophs and necrotrophs, depending on the conditions in which they find themselves or the stages of their life cycles.

- Such pathogens are called hemi-biotrophs. Earlier, many fungi were commonly considered as necrotrophs whereas they had a biotrophic stage early in the infection process and hence were basically hemi-biotrophs.
- In general, SA signaling is involved for resistance against biotrophic and hemibiotrophic pathogens whereas the JA and ET signaling is important for immnity towards necrotrophs .
- Biotrophic Fungi For resistance against biotrophs, gene-for-gene mechanism is important. According to gene-for-gene hypothesis, given by Flor, for every gene in the plant that confers resistance, there is a corresponding gene in the pathogen that confers avirulence. It leads to activation of SA-dependent signaling and SAR.
- In Arabidopsis, overexpression of ADR1 (NBS-LRR resistance gene) provides resistance against Erysiphe cichoracearum . Another example is of barley and Blumeria graminis where gene-for-gene resis- tance response is evident. Various studies show that SA signaling has important role in resistance whereas JA- and ET- signaling may not be involved.
- Therefore, during biotrophic pathogen attack, SA-dependent defense responses are effective together with gene-for-gene resistance. There is no induction in JA-dependent responses, but if they are artificially induced, then they are quite effective .
- Transcriptome data from microarray experiments suggest that during defense responses the photosynthesis-related genes are highly down-regulated which is required to support the induction of a defence response.
- The nitrogen invested in photosynthetic proteins, primarily Rubisco, is lowered or even withdrawn to provide nitrogen for the induction of defensive compounds.

Necrotrophic Fungi

- Transcript profiling of various plant-pathogen systems suggest differential regulation of a large number of transcripts in response to pathogen attack.
- These transcripts included those which are associated with JA biosynthesis and signaling, ROS metabolism, and cell wall structure and function.
- Isolation of early responsive genes of chickpea infected with blight fungus Ascochyta rabiei was carried out using PCR based suppression subtractive hybridization (SSH) strategy and ~250 unique genes were identified.
- These genes belonged to eleven different categories viz. stress, signaling, gene regulation, cellular metabolism and genes of unknown functions.
- Chitin, which is a major component of fungal cell wall, serves AU2 as a PAMP. Therefore, chitosan (the deacetylated form of chitin) plays important role in inducing defense responses against pathogens in many plant species.
- GeneChip microarrays and quantitative RT-PCR of Botrytis cinerea infected Arabidopsis leaves revealed that chitosan has inductive role on several genes involved in defense responses and camalexin biosynthesis

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ALGAE

The term Algae (L. alga- sea weed) is collectively used for all the Chlorophyll bearing nonvascular thalloid organisms.

- Linnaeus (1754) first coined the term algae, which he placed along with Liverworts & lichen under class Cryptogamia of Conventional Plant-Kingdom.
- But, in Whittaker's classification, all members of algae are redistributed in three kingdoms i.e. Monera (Blue Green Algae), Protista (Diatoms, Dinoflagellates, Euglenoids) & Plantae (Greenlagae, Brown algae & Red algae).
- The study of algae is called Phycology or Algology..
- F.E. Fritsch is known as 'Father of algology' and, his student M.O.P. Iyenger from Madras University is known as the 'father of Modern Algology of India'. His important contribution is discovery of heterotrichous terrestrial alga (Fritschiellatuberosa).

Nature :- MAIN CHARATERS

Algae are aquatic plants. They are both freshwater *and* marine. Freshwater includes ponds, streams, moist rocks and bark of trees. Marine forms are present from sea shore to depth upto 100meter. Algae may be:

(a) Epiphytes: These algae grow on the surface of other plants.
(b) Endophytes: These algae live inside the other plants.
(c) Phytoplankton: The free floating algae are phytoplankton.
(d) Sessile: Some algae are attached to the substratum by holdfast.

- Body is a relatively simple simple unicellular or multicellular thallus, not differentiated into roots, stems and leaves.
- Unicellular thallus may be non motile, rhizopodial or coccoid.
- Multicellular thallus may be colonial, palmelloid, dendroid, filametous siphonous and so on.
- Algae cells exhibit three levels of organization, namely prokaryotic (eg: Myxophyceae), mesokaryotic (eg: Dinophyceae) and eukaryotic (other groups).
- Cells are covered by a rigid cellulose cell wall.
- Cells contain plastids and three classes of pigments, namely chlrophyll(a, b, c,d, and e), caroteneoids (alpha, beta, gamma and the theta carotenes, lycopene, leutin, flvicine, fucoxanthin, violaxanthin, astaxanthin, zeaxanthin, myxoxanthin), and phycobilins or biliproteins(phycocyanin, phycoerythrin, allophycocyanin).
- The reserve food includes mostly starch and oils (in C*hlorophyceae* starch; in *Xanthophyceae* and *Bacillariophyceae* chrysolaminarin and oils; in *Phaeophyceae* laminarin, mannitol and oils, in *Rhodophyceae* floridean starch and galactan; in C*yanophyceae* cyanophycean satarch)
- Absence of conducting (vascular) and mechanical tissues; the entire thallus is formed of only parenchyma cells.
- Presence of holdfast, stipe and lamina. Holdfast is for attachment, stipe forms the axis, and lamina serves as the leaf like photosynthetic part.
- Algae flagella have typical 9+2 pattern of arrangement of microtubules.
- Reproduction occurs by vegetative, asexual and sexual methods
- Vegetative reproduction is by fragmentation, hormogonia, akinetes etc.
- Asexual reproduction is by motile zoospores, or by non motile apalnospores, autospores, hypnospores, exospores, endospores, carpsospores etc. Spores are produced in sporangia.
- Sexual reproduction may be isogamous, anisogamous or oogamous. Oogamous species possess antheridia and oogonia.
- Sex organs are usually unicellular and non jacketed; multicellular sex organs are rare and in them each cell is fertile without a jacket of sterile cells.
- Embryo is not formed after gametic fusionwhich is a characteristic feature of thallophyta.
- In most genera the only diploid stage in the life cycle is the zygote, which immediately undergoes meiosis.
- Sporophytic and gametophytic genetations, which present in the life cycle, are independent. So, there is no alga with a sporophyte parasitic on gametophyte.

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Algae are commonly presumed to be occurring in water and moist places but algae are found in a variety of habitats.
The common places of occurrence of algae are as follows:

(i) Aquatic Algae:
Aquatic algae can be:
(a) Fresh water forms
(b) Marine forms.

(a) Fresh water forms:
Fresh water forms are found in water of low salinity such as in ponds, lakes, rivers, ditches etc. Cladophora, Vaucheria, Chara and some algae found in slow running water while Spirogyra, Chlamydomonas, Hydrodictyon and Volvox are found in stagnant water.

(b) Marine forms:
The algae found in sea water are called marine algae. Such algae grow in water of high salinity. Marine algae can be macroscopic and very large in size e.g., Macrocystis (70 meters) and Nereocystis (100 meters).
Some other examples of marine algae are: Viva, Enteromorpha, Sargassum, Fucus, Polysiplionia, Gelidium and Gracilaria etc.

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(ii) Terrestrial Algae:
Algae growing on moist soil surface, stones and rocks are terrestrial algae. The algae growing on surface of soil are called saprophytes and the algae growing under the surface of soil are called cryptophytes. Some terrestrial algae grow on moist walls and barks of trees. These algae absorb CO_2 and water from atmosphere.
Some common terrestrial algae are: Fritschiella, Vaucheria, Chlorella, and Oscillatoria.

(iii) Lithophytic Algae:
Algae growing on surface of rocks and stones are lithophytic e.g., Nostoc, Gloeocapsa.

(iv) Halophytic Algae:
Algae growing in water of high concentration of salts as in salt lakes are halophytic algae e.g., Chlamydomonas ehrenbergii and Dunaliella.

(v) Thermophytic Algae:
The thermophytic algae grow in water of high temperature where other plant forms cannot grow. Some blue green algae are capable of growing at very high temperature because of unorganized nucleus. The thermal algae found in hot water springs are Oscillatoria terebriformis, Heterohormogonium, Synechococcus, Scytonema etc.

(vi) Cryophytic Algae:
Algae occurring in snow and ice are cryophytic algae. These algae impart special colours to snow due to their pigments. Red snow is caused by Haematococcus nivalis and Chlamydomonas nivalis. Green snow is caused by Chlamydomonas yellowstonensis. Purple brown snow is caused by Ancyclonema nordenskliоldii. Black snow is caused by Raphidonema.

(vii) Epiphytic Algae:
Algae growing on other algae and plants are called epiphytic algae e.g., Polysiphonia, Oedogonium are found growing on other algae, bryophytes and aquatic angiosperms.

(viii) Epizoic Algae:
Algae growing on other animals are called epizoic algae e.g., Cladophora crisposa grows on snails, Stigeoclonium grows on gills of fishes.

(ix) Endophytic Algae:
Algae growing inside other plants are called endophytic algae e.g., Nostoc is found in thallus of Anthoceros, Anabaena cycadearum is found in coralloid root of Cycas, Anabaena azollae is found in Azolla.

(x) Endozoic Algae:

Algae found inside the body of animals are endozoic algae e.g., Zoo chlorella is found in Hydra and sponges. Some blue green algae are found in respiratory and digestive tracts of animals.

(xi) Parasitic Algae:

Some algae can be found as parasites on plants and animals e.g., Cephaleuros is found on leaves of tea, coffee and mango plants and causes red rust. Polysiphonia fastigiate is semi-parasitic on algae Ascophyllum.

(xii) Symbiotic Algae:

Some algae of Chlorophyceae and Cyanophyceae are found in symbiotic association with other plants. Nostoc and Anabaena make symbiotic association with Anthoceros and coralloid roots of Cycas. Lichens are symbiotic association of algae and fungi.

(xiii) Planktons:

Algae growing on surface of water and found as free floating on surface of water are called planktons. Planktonic algae are mainly members of Chlorophyceae, Cyanophyceae and Bacillariophyceae. When planktonic algae grow fast and increase enormously in number, these algae form water blooms.

Structure of Algae

- The plant body in algae is always a thallus. It is not differentiated in root, stem and leaves. Algae range in size from minute unicellular plants (less than 1 μ in diameter in some planktons) to very large highly differentiated multicellular forms e.g., some sea-weeds.
- Their forms may be colonial (loose or integrated by inter-connections of protoplasmic strands), filamentous (branched or un-branched), septate (branched or un-branched), non-septate or branched, multinucleate siphonaceous tube where the nuclear divisions occur without usual septa formation.
- Structural and cellular organizations are important characters in the classification of algae and in establishing the inter-relationship among them. Similarities of some morphological structures are seen among various classes of algae. The unicellular types which are seen in all groups of algae except the brown algae are considered to be the basic type from which, through evolution, other types of thalli developed.
- **The range of thallus organization in algae may be classified as follows:**
    1. Unicellular: - Motile and non-motile
    2. Aggregates:- Palmelloid and Dendroid
    3. Colonial
        (a) Colony motile
        (b) Colony non-motile
    4. Filamentous
        (a) Un-branched
        (b) Branched
            (i) Simple
            (ii) Heterotrichous
            (iii) Pseudoparenchymatous.
    5. Siphonaceous.
    6. Parenchymatous.

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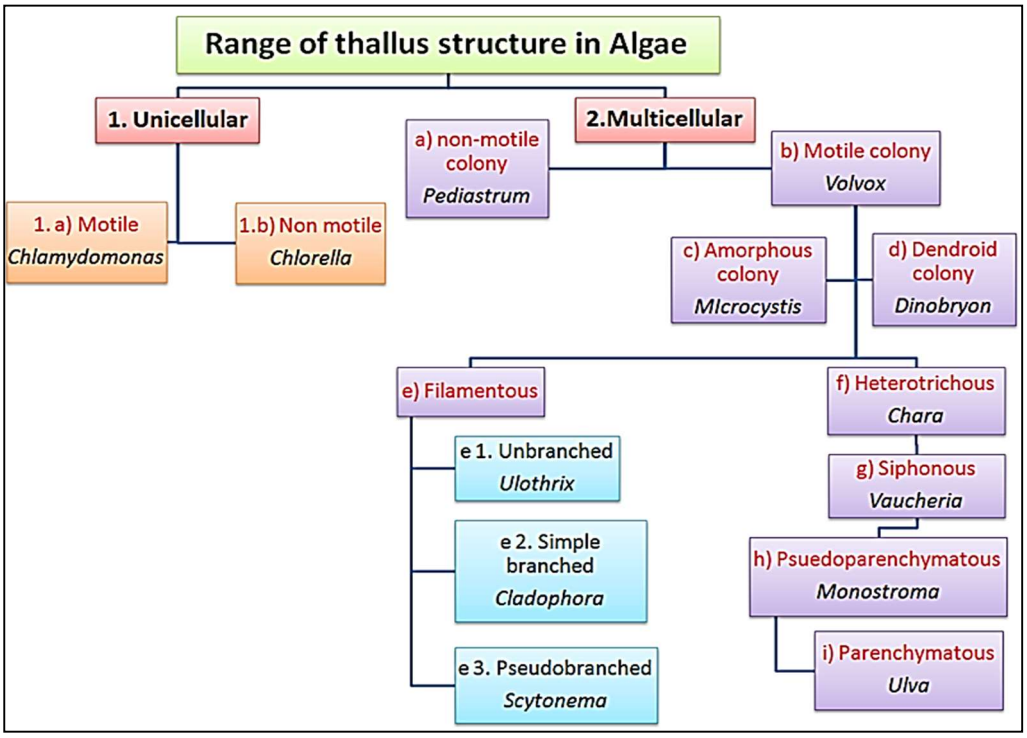

1. Unicellular Type:

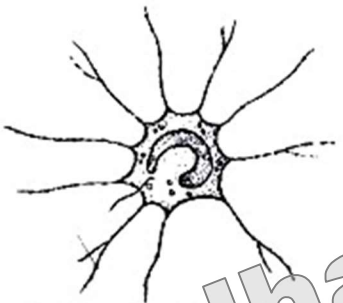

Fig. 1. Thallus organization. Unicellular amoeboid form

- The unicellular types are seen in all groups of algae with the exception of the class Phaeophyceae. The unicellular types may be amoeboid motile or non-motile, the motility being due to the movement of the flagella attached at the anterior end.
- The number of flagella may be one or more, usually two or in multiples of two. The cells may have a rigid cell-wall or the outer layer of the protoplast forms do the '**periplast**' giving a definite shape to the cell or may allow changes in shape (rhizopodial or amoeboid type).

(a) Unicellular Amoeboid Forms or Rhizopodial Forms:

- These algae lack flagella, the organs of motion, but are able to perform amoeboid movement by means of cytoplasmic growth e.g., Chrysamoeba (Fig. 1).

(b) Unicellular Motile (Flagelloid) Forms:

- The unicellular motile forms are the simplest type of thallus in algae. The flagellated unicellular forms are seen in various classes of algae. The flagellated unicelled structures are distinctive of certain classes e.g., Euglenineae, Cryptophyceae, Chrysophyceae and Dinophyceae. Flagellated vegetative cells are absent in Cyanophyceae, Phaeophyceae, Rhodophyceae, Bacillariophyceae.
- Nature of flagellation, type and number of flagella and the attachment of flagella, is an important character in classification. In most of the Chlorophyceae members, the flagella are usually two or in multiples of two in number, equal in size, of whiplash type and anteriorly attached (Fig. 2).

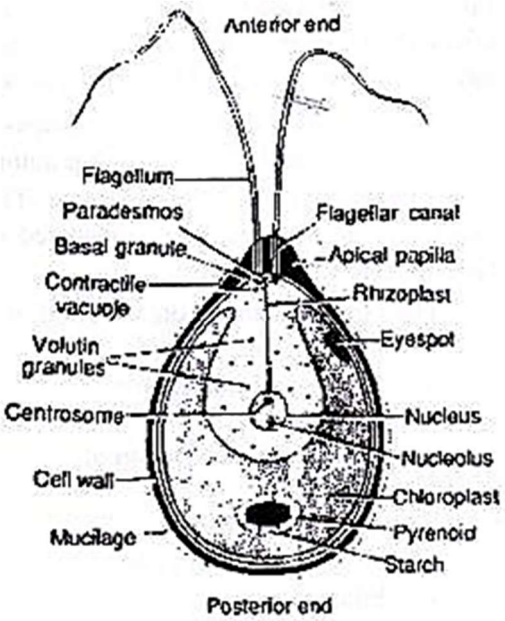

Fig. 2. Thallus organization. Unicellular Flagellated forms

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- The unicellular plant body may be spherical, oblong or pear-shaped and sometimes elongated (Fig. 2); and approximately circular in cross section. In some cases, the plain body proper and peripheral layer is separated by a space. This envelope is spherical, rigid, variously shaped and is provided with apertures for the protrusion of the flagella.
- Such types are termed **'en-capsuled'** e.g., Haematococcus etc. The common examples of unicellular flagellated forms are Chlamydomonas, Chlorogonium, (Chlorophyceae), Ochromonas, Chromulina (Chrysophyceae) etc.
- The unicellular flagellated forms can be **'naked'** and **'en-capsuled'** e.g., Crypto-monas. Euglena (naked) and Chrysococcus (encapsuled). A feature common with the motile of flagellated forms is the presence of eye-spot (stigma).

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(c) Unicellular Non-motile (Protococcoidal) Forms:

- Unicellular non-flagellated cells show many morphological variations e.g., Bacillariophyceae (Diatoms), in many Chlorophyceae (Chlorellti, Cosmarium) Cyanophyceae (Synechococcus), and in some forms of Xanthophyceae, Dinophyceae and Rhodophyceae (Porpliyridium).
- They are simple spherical or elongated cells e.g., Microcystis, Cylindrocystis, Pinnularia (Bacillariophyceae); triangular as in Tetragonidium (Cryptophyceae) and Triceratium (Bacillariophyceae). The epiphytic or attached forms have a basal disc (Fig. 3).
- Cell-wall ornamentations of various types may occur e.g., in the Desmids (Conjugates), they are in the form of ribs, spines or warts and more complex among the Diatoms (Bacillariophyceae) due to the poroid nature of their siliceous wall.

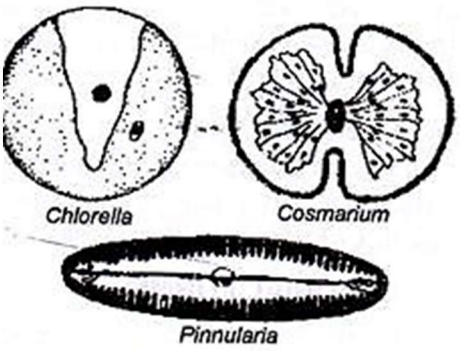

Fig. 3. Thallus organization. Non-motile Unicellular forms

- Though non-flagellated, many diatoms may be motile by the extrusion of mucilage through the pores, some Desmids and Cyanophycean members also show slight motility. In a very large number of cases the motile flagellated types, at times, lose their flagella and become non-motile.
- This is a period of rest in the changeover from vegetative phase to reproductive phase. This feature gets further elaborated in many forms where the vegetative phase is completely non-motile. They are motile in the re-productive phase only. Such developments ultimately lead to palmelloid, dendroid and coccoid habits.

2. Aggregates:

- Aggregates are formed by the collection of single cells to make thallus. Unlike the coenobium the aggregation of cells does not have fixed number of cells shape or size.
- The cells are aggregated into more or less irregular colony like mass. When the cells divide, the daughter cells remain in same gelatinous mass. Thus there is increase in the number of cells after division. The aggregates can be palmelloid, dendroid and rhizopodial in form.

(a) Palmelloid Habit:

- In a large number of genera this habit is a permanent one e.g., Tetraspora (Chlorophyceae), Phaeocystis (Chrysophyceae) or is a temporary phase, in the life-cycle e.g., Chlamydomonas (Chlorophyceae) Chromulina, (Chrysophyceae). The habit is named after the genus Palmella (Palmeflaceae, Chlorophyceae) (Fig. 4).

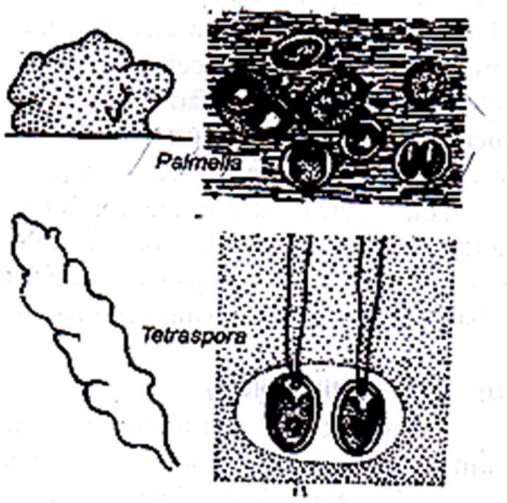

fig. 4. Thallus organization Palmelloid forms

Here the individual lion-flagellated cells have mucilaginous sheaths around them and are enveloped in a common gelatinous matrix of indefinite shape which may be microscopic or macroscopic in size.

Such **'colony'** like or **'filamentous'** structures (e.g., Hydrorus) in which the individual cells are loosely aggregated in a common gelatinous matrix and behave independently are termed Palmelloid. (**'Palmelloid-stage'** means Temporary phase and **'palmelloid-habit'** or **'palmelloid-form'** denotes permanent habit).

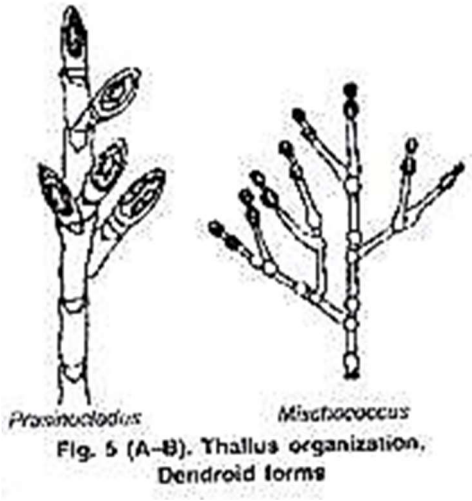

Fig. 5 (A–B). Thallus organization. Dendroid forms

(b) Dendroid Forms:

- A variation of the palmelloid condition is seen in dendroid colonies. Here the mucilage is produced locally, generally at the base of the cell. This polarity differentiates the two habits. Dendroid forms are seen e.g. Prasinocladus (Chlorophyceae), Mischococcus (Xanthophyccae) and in Chrysophyceae and Euglenineac (Fig. 5 A, B).

(c) Rhizopodial Forms:

- Variable number of amoeboid cells formed together by cytoplasmic projections give the shape of roots or rhizoids e.g., in Chrysidiostum (Chrysophyceae).

3. Colonial Forms:

- A further evolution of the unicellular types from occasional and indefinite type of colony like structures—with independent individual cells inside it to a well-defined colony prasinocladus with interlinks among the cells results in a true colonial habit.
- Here varying numbers of unicells aggregate together in different ways, often within a mucous envelope. Colonial forms are seen among Chlorophyceae. Chrysophyceae, Bacillariophyceae, Dinophyceae, Xanthophyceae etc. The colony may be (a) motile or (b) non-motile.

(a) Motile Colonial Forms:

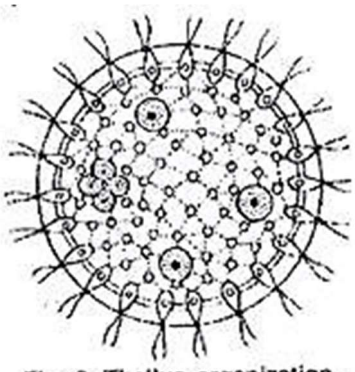
Fig. 6. Thallus organization. Motile colonies

- Motile flagellated cells aggregate together to form motile colonies. Colonies vary in shape and size and in the number of cells.
- The movement of the colony is effected by the conjoint and uniform flagellar action by all the cells. In Chlorophyceae, the colony is made up of Chlamydomonas like cells and the cells arc arranged just below the mucilaginous surface. The colonies are either **"plate-like"** (e.g., Gonium) or spherical (e.g., Volvox).
- The cells may be connected by cytoplasmic strands, (e.g.. Volvox). Though in the majority of cases all the individual cells are alike, a few forms have some larger cells for reproductive functions; the rest of the cells being purely vegetative (e.g., Volvox) (Fig. 6). Mostly they are coenobia (sing, coenobium) i.e., colonics composed of definite number of cells arranged in a defined manner.
- Thus, a clear advancement in the organization of the thallus is seen in the sequence gradually from unicellular motile types to aggregates in a colony with a regular pattern, where the cells are inter-connected and behave as a single unit (multicellular organism).

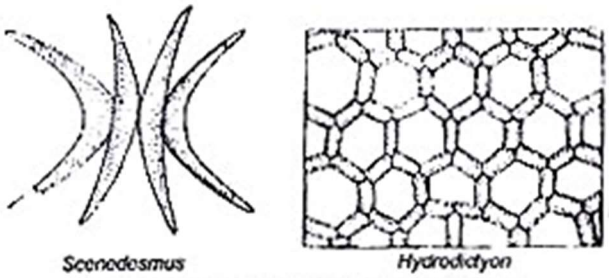

Fig. 7. Thallus organization. Non-motile colony

PLANT SUCCESSION IN VARIOUS HABITATS, CONCEPT OF CLIMAX

ECOLOGICAL SUCCESSION IN A COMMUNITY

***Hult** (1885), when studying communities of Southern Sweden, is said to have used for the first time the term 'Succession.'

***Definition:** An orderly sequence of different communities over a period of time in some particular area.

***SERE** Particular example of plant succession. Seres originating in water are referred to as **Hydroseres**; those arising under dry condition as **Xeroseres**, of which those developing upon exposed rock surfaces are known as **Lithoseres**. The term sere is often used to describe the sequence of plant communities.

Important General Principles Associated with Ecological Succession

1. The physical environment determines which communities can exist in a particular place.
2. **Succession is community controlled**, i.e., succession is caused by modification of the surrounding physical environment by the existing community, i.e., a successional community will alter the environment so that the environment is then more favorable for a different community than the existing one.
3. **Ecological succession is directional - and therefore predictable.**
4. Succession ends in a stabilized community and ecosystem called the ecological climax. It is in equilibrium with the physical environment of that particular area and perpetuates itself.

*** Usually an external disturbance to the area, e.g., fire, puts the area back into an earlier successional stage. This tendency for the ecosystem to reach a stage where it stays in equilibrium is an example of Homeostasis – developing and maintaining stability**.

5. High diversity produces stability.

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Types of Ecological Succession

1. **Primary Succession** begins on an area that has not been previously occupied by a community, e.g., newly exposed rock. There is no soil. Soil is a combination of broken down rock plus organic matter (humus and small, living organisms). Primary succession takes place very slowly with a low rate of production of biological material.
2. **Secondary Succession** begins on an area where a community has previously existed. Secondary succession usually begins on an already established soil.Secondary succession has a higher level of production of biological material at a faster rate than primary succession.

➡**The progressive development in an ecological succession can be enumerated as below—**

(a) There is usually progressive development of the soil with increasing depth, increasing organic content and increasing differentiations of layers towards mature soil of the final community.

(b) The origin, height, massiveness and differentiation into strata of the plant communities increases.

(c) As density of above ground plants increases, the microclimate within the community is increasingly determined by characteristics of community itself.

(d) Species diversity increases from simple to complex communities of early succession to the richer communities of mature or of late succession.

(e) Population and density of pioneer stages rise and fall, replace one another with the time gradient due to interspecific and intraspecific competition for space. The rate of this replacement slows through the course of succession as smaller and ephimeral (short-lived) pioneer species are replaced by larger and longer-lived ones.

(f) As a result, the relative stability of the communities increases and the final community which is usually stable called 'Climax' stage is termed.

Frederick Clements defined succession as "a sequence of plant communities marked by the change from lower to higher life forms"

5 Key points:

1. Replacement of species by other species over time
2. Early species change the environment, making it more suitable for species that follow

3. Only one uni-directional succession trajectory
4. Succession is deterministic (predictable)
5. Succession leads to a single terminal steady-state called “climax”

6 stages of succession, according to Clements (“Facilitation model”):

1. Nudation: creation of a bare substrate
2. Migration: arrival of propagules
3. Ecsesis: germination, establishment and reproduction
4. Competition: leads to species replacement
5. Reaction: vegetation modifies the environment making it suitable for new colonists
6. Stabilization: attainment of climax

Characteristics of early-seral environments(Pioneers):

- Low soil moisture
- Low soil organic matter
- Poor soil structure
- Low vegetation cover
- Temperature extremes

Therefore unstable and unpredictable environment:

• weakly functioning or inoperative primary processes (water cycle; nutrient cycle)

• succession driven mostly by abiotic factors

Characteristics of early-seral plants:

- Tolerant of unstable/unpredictable environments
- Fast growth
- Short-lived
- Many seeds
- Widely-dispersed seeds
- Resources put into reproduction
- Small size

Characteristics of late-seral environments(Climax):

- Well-developed soil
- Maximum soil organic matter
- Soil water available
- Increased vegetation cover
- Modulated temperatures
- Therefore stable and predictable environment: • functioning primary processes driven by biotic factors

Characteristics of late-seral plants:

- Intolerant of environmental disturbance
- Slow growth
- Long-lived
- Large size
- Infrequent reproduction
- Resources put into permanent tissues

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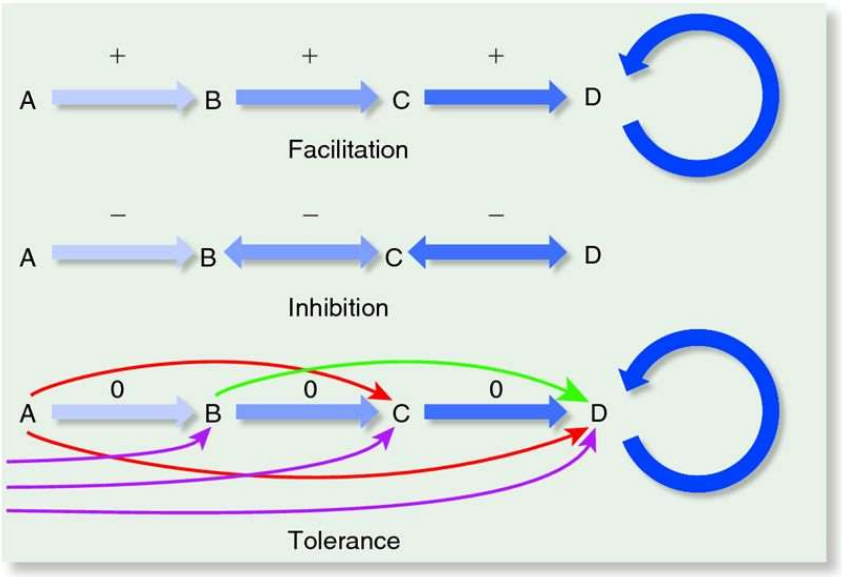

3 alternative mechanisms producing the sequence of species change during plant succession

1. Facilitation Model:

Disturbed area exploited by pioneer species that modify the site making it suitable for other species.

Once established, the later-successional species eliminate the pioneers through competition.

Possible modes of facilitation are:

- amelioration of environmental stress
- increase in resource availability
- enhanced invasion

2. Tolerance Model:

Species enter the community in an order determined by their dispersal capabilities as the community ages, resources are shifted from the environment into the biomass of the community and so the environment becomes more nutrient poor as time goes on species invade if they can Tolerate the lower levels of nutrients available species are lost if they require the higher levels of nutrients available in disturbed areas

Competitive exclusion drives the succession sequence through scramble competition

- **Possible modes of tolerance are:**
  - passive tolerance (differences in life history traits such as growth rate and longevity)
  - active tolerance (ability to endure low resource levels)

3. Inhibition Model:

Like the tolerance model, both early- and late seral species can establish after disturbance. But, some species make the site less suitable for other species.

Inhibition is the **competitive** exclusion of a species from a community by the activity of another Species

- can occur through the production of a secondary chemical
- can occur through the unequal effects of pathogens on two species, as one species may be excluded by a disease tolerated by another (so that the winning species acts as a reservoir for the disease)
- inhibition is the opposite of facilitation - it explains the loss of species as the community changes
- Inhibition can lead to communities that become resistant to invasion

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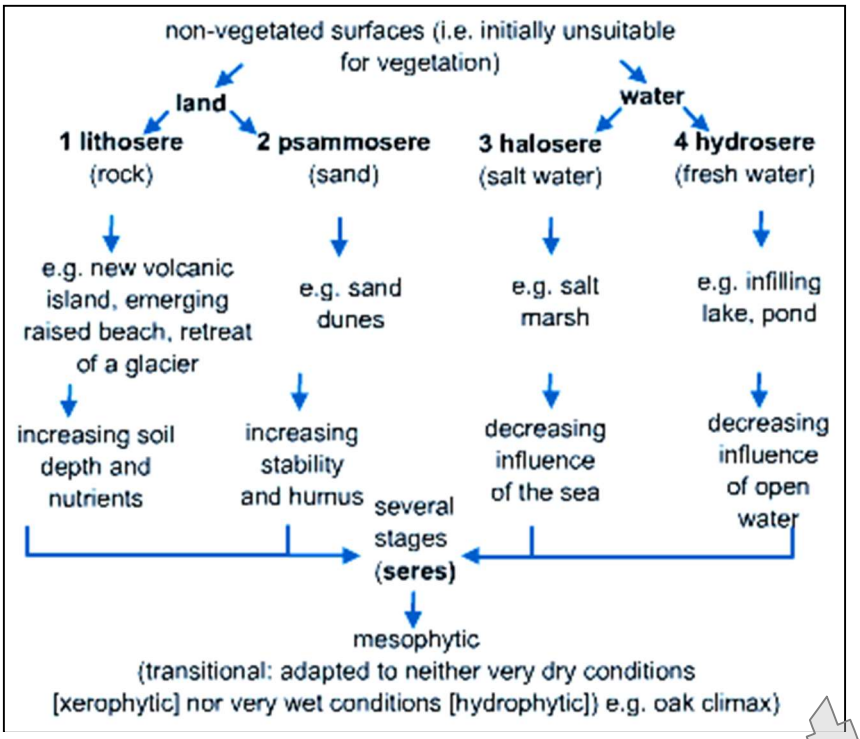
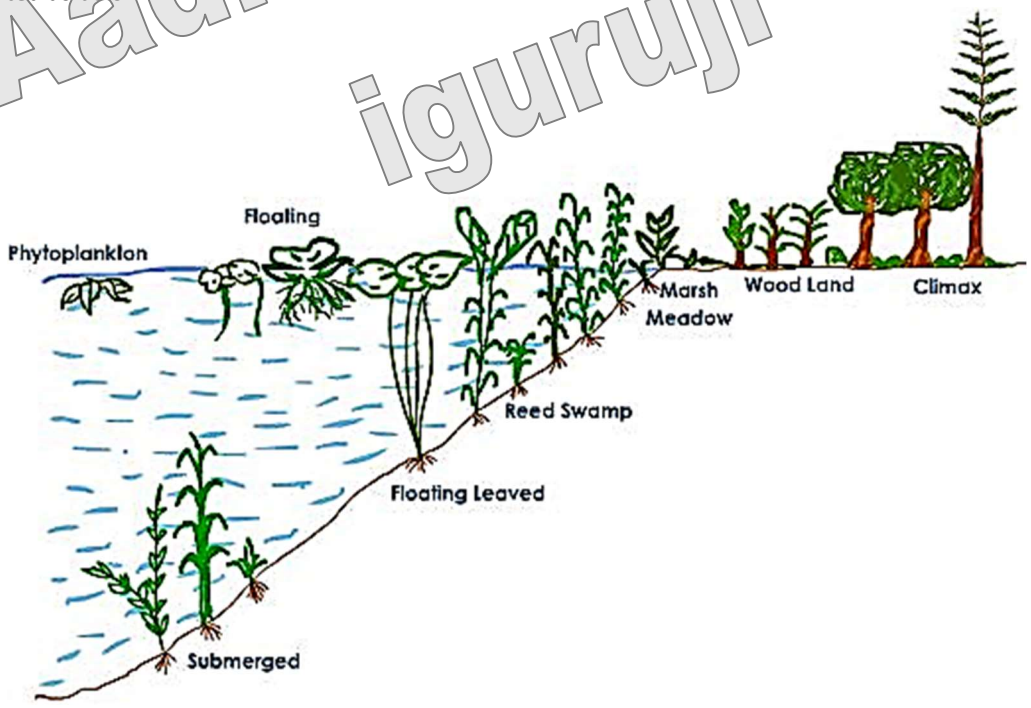
PATTERNS OF SUCCESSION



Depending upon the types of habitant and varing amount of moisture, the successions are designated as below—

HYDROSERE

Hydrosere, originating in a pond, starts with colonisation of some phytoplanktons which ferns are the pioneer community and finally terminates into a forest or climax community. The various stages of hydrosere can be enumerated as below—



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Trend of succession in a Hydrosere

Pioneer Community	Seral Communities					Climax Community
1	2	3	4	5	6	7
Phytoplankton stage e.g Diatoms, Bacteria, Cyanobacteria, Green algae	Rooted-submerged stage e.g Elodae, Hydrilla, Vallisneria, Ultricularia, Potamogeton	Rooted-floating stage e.g Nymphaea, Trapa, Azolla, Lemna, Wolffia, pistia	Read-swamp stage e.g Sagittaria, Phragmites, Typha, Scirpus	Sedge-meadow stage e.g Juncus, Cyperus, Eleocharis, Carex	Woodland stage e.g Salix, Poplus, Almus, Cornus	Forest stage e.g Temperate mixed Tropical rain tropical Deciduous

General trend of succession →

LITHOSERE

Bare uncolonised rock exposed

↓

Colonisation by lichens, weathering of rock and build up of dead organic material

↓

Growth of moss, further weathering; soil begins to form

↓

Growth of small plant such as grasses, leading to further improvement of soil

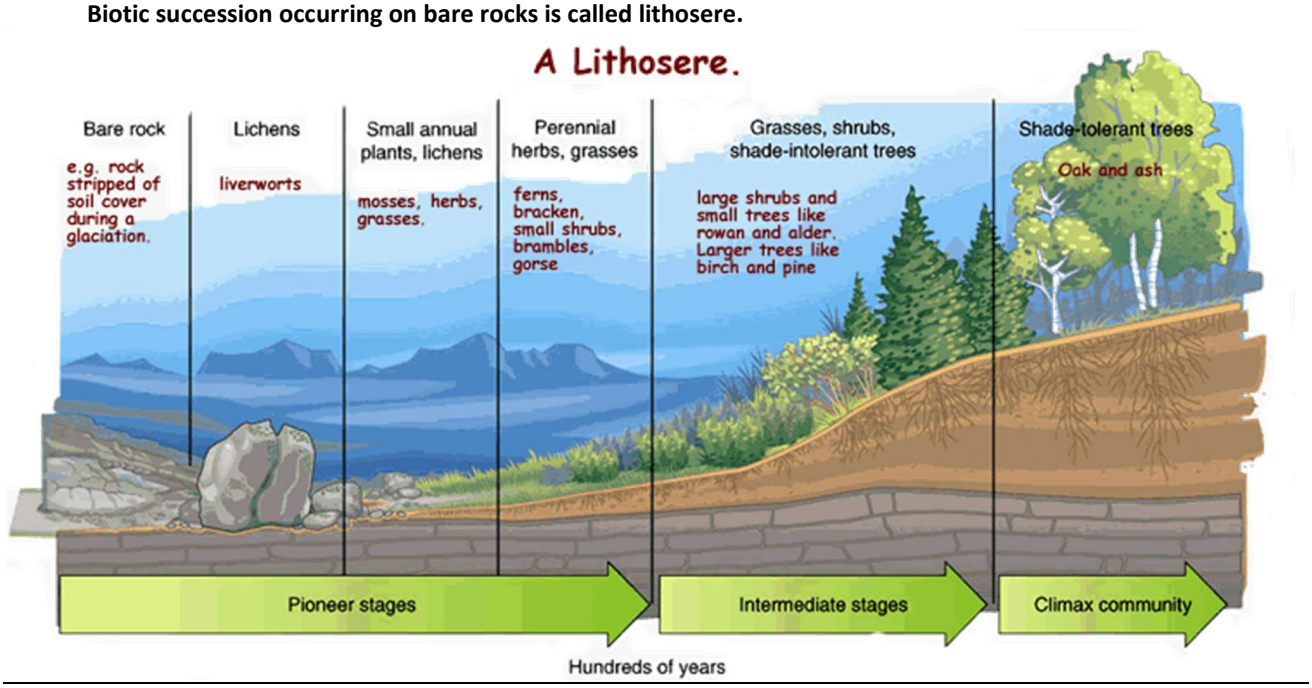
↓

Larger plants can grow in the deeper and more nutrient rich soil

↓

Climax Community of shrubs and trees

Biotic succession occurring on bare rocks is called lithosere.



1. First organisms to establish on bare rocks are lichens which produce acids which corrode the rock surface. Timely addition of organic remains etc. brings about chemical and physical changes in structure of the substratum. **Pioneer lichens are crustose lichens (Graphis, Rhizocarphon). Crustose lichens are replaced by foliose lichen (Parmelia) which cause greater erosion of the rock.**

2. Moss stage. Foliose lichen give way to hardy mosses (large sized, gregarious plant bodies which bear rhizoids to penetrate more into the rocks) which accumulate more soil and organic matter.

As a result substratum remains moist for a long time and finally weathering of rock starts. The spot now becomes ready for next invasion.

3. Grass stage. During rainy season the mat of mosses formed over the fragmented rock becomes sufficiently moist wherein thereafter the seeds of grass germinate **(Poa, Heteropogon, Dristida etc**.). Their roots penetrate deeper in soil causing further fragmentation. More moisture and soil increases and sets stage for next succession.

4. Shrub stage. No sooner seeds and rhizomes of xerophytic shrubs invade the area occupied by grasses (**Zizyphus, Rhus, Rubus etc.)** shrub penetrate deeper causing greater fragmentation.
They shade the area, making it more moist inviting trees and other organisms.

5. Climax stage. Several hardy and light demanding trees grow in area occupied by shrubs. Slowly and gradually environment becomes more moist and shadier and the climax community spreads in the area.

Psammosere

This is a sand sere - an environment of sand substratum on which ecological succession occurs. Most common psammoseres are **sand dune systems.**

►In a typical succession on a sea-coast psammosere, the organisms closest to the sea will be salt tolerant species such as littoral algae and glasswort.

►Progressing inland the succession is likely to include meadow grass, sea purslane, and sea lavender eventually grading into a typical non-maritime terrestrial eco-system.

►Psammoseres graduate until they reach a climatic climax which ultimately leads to the growth of oak trees. As you move away from the high water mark there are many characteristic features that change and help you determine the natural succession of the dunes. For instance, the saturation rate slows down as you move inland from the HWM as the land is more compact and has better soils rather than sand which is seen at the start of the dune formation.

►The land is less acidic with closeness to the climatic climax as there are fewer shell pieces in the soil. The shell pieces are slightly acidic, and prevent any substantial vegetation growth. As the quality of the soil improves and it has a more neutral pH it provides the foundation for increased growth and instead of basic marram grasses and heather there are ample conditions for such trees as birch and ash to survive.

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The origin and domestication of different pulses are given below:

Pigeon Pea अरहर

Botanical Name: *Cajun's cajan* **L. Common Name: Pigeon pea, red gram, Congo pea**



The plant is probably a native of Africa where it is often found naturalized. It was cultivated in Egypt as early as 2,000 B.C. (Purseglove, 1974). It was probably brought to India at an early date and diversified into many types.

Chickpea काबुली चना

Botanical Name: *Cicer arietinum* **L. Common Name: Chickpea, gram, Bengal Gram, Chana**

This is one of the oldest pulse crops known to be cultivated in Asia and Europe since ancient times. Helbeak (1966) has reported the occurrence of archaeological remains of chickpea dated 5,450 B.C at Hacilar in Turkey and 4,000 B.C. from Palestine.

Gram, like other important pulses, is not known in a wild state and has been recorded only in cultivation. It is believed to have originated in Western and South Western Asia – in the area lying between the Caucasus and the Himalayan Mountain. From here it spread to Southern Europe, Iran, Egypt and India. The plant has also been introduced into tropical America, Africa and Australia but is of little importance in these areas.

Cluster Bean

Botanical Name: *Cyamopsis tetragonoloba(* L.) **Taub Common Name: Cluster bean, guar**



The plant is native of Southeast Asia and is now distributed throughout the tropics, especially India, Malaysia, Mauritius, Sierra Leone, Transvaal and the West Indies.

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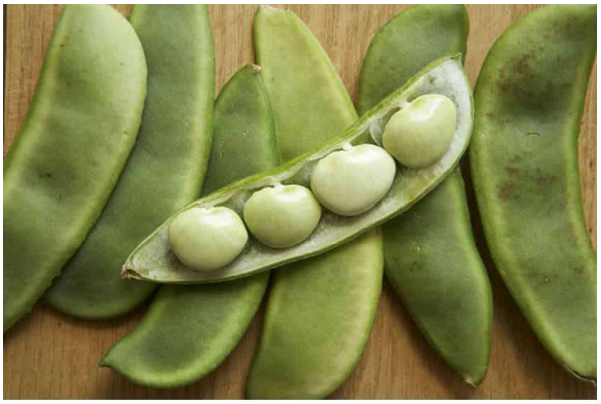
Hyacinth Bean सेम

Botanical Name: *Lablab purpureus(* L.) Sweet
Syn. *Dolichos lablab* L.
Syn. *Dolichos purpureus* L.

Common Name: Hyacinth bean, bonavist bean, Lubia bean, Sein bean Indian bean

Hyacinth bean is native to India, where it grows in wild. It is now cultivated extensively in India, South and Central America, the East and West India, China and Africa, especially in Egypt and Sudan.



Grass Pea

Botanical Name: *Lathyrus sativus* L.

Common Name: Grass pea, Chickling vetch or pea, lathyrus pea, Khesari dal



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The grass pea, known in India as the khesari dal, is of very ancient cultivation, and probably originated in Southern Europe and Western Asia. Its archaeological remains have been found at Jarmo, dating as for back as 6,000 B.C. Similar findings have also been recorded from Neolithic sites in Hungary and Switzerland.

It is grown as a winter crop in India, Iran, Southern Europe and parts of Africa and South America.

Lentil

Botanical Name: Lens esculenta

Common Name: Lentil मसूर की दाल

Syn. Lens culinaris Medik

This is one of the oldest leguminous crops, believed to be indigenous to South Western Asia and the Mediterranean region. From these areas it spread northward to Europe, eastward to India and China, and southward to Ethiopia. Lentils have been esteemed as a food since biblical times and formed a common food of the ancient Greeks, Jews, Egyptians and Romans. Lentils are found with field pea and horse bean in the earliest agricultural sites in the Near East. The occurrence of archaeological remains of lentils, dated back to 7,500 to 6,500 B.C, has been reported from Hacilar, Beidha and Jarmo (Helbaek, 1966). Likewise, seeds of *Lens* have been reported from Neolithic deposits in Greece.

Common Bean (French bean)

Botanical Name: *Phaseolus vulgaris* **L. Common Name: Common bean, French bean, Kidney bean, haricot bean, Runner bean, Snap bean, Salad bean.**

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Figure: 3.2. *Phaseolus vulgaris* (Common Bean)

- It is of New World origin and is cultivated in many parts of the tropics and subtropics, and in temperate regions. It has been cultivated throughout North, Central and South America. Remains of common beans, dated to 4,975 B.C. have been found in the caves of the Tehuacan valley in Mexico.
- Vessels containing bean have been recovered from the Pre-Inca tombs in Peru.
- The remnants of common beans and lima beans have been recorded from archaeological deposits in the inter-montane Peruvian valley, and dated to about 6,000 B.C.
- The common bean was introduced into Europe in the sixteenth century by the Spaniards and Portuguese and was later carried to Africa and other parts of the world.
- The crop is grown extensively in Brazil, the United States of America, Mexico, Italy, and Turkey. Beans are grown in India in the hilly regions.

Black Gram उड़द

Botanical Name: *Phaseolus mungo* **Common Name: Black gram, wooly pyrol, Urd**

- The legume has been under cultivation in India since ancient times. According to Vavilov (1926), this pulse originated in India, and central Asia which is recognized as a secondary centre for its spread.
- It is suggested that the *Phaseolus mungo* probably originated from the wild species *Phaseolus trinervius* or *Phaseolus sublobatus*commonly grown in India. It has been introduced in many tropical and subtropical regions by Indian immigrants.
- Carbonized grains of black gram have been recovered from the Chalcolithic site, Navdatoli-Maheshwar (India), dated to 1,660-1,440 B.C.

- It is grown in many tropical and subtropical countries, mainly in India, Iran, Malaysia, East Africa and the Southern parts of Europe. It is also grown to a limited extent in South and Central America and the West Indies.

Green Gram मूँग

Botanical Name: *Phaseolus aureus* **Common Name: Green gram, mung, golden gram, Penara**

Like *Phaseolus mungo*, *Phaseolus aureus* too is of ancient cultivation in India and has not been found in the wild states. It is supposed to be a native of India and Central Asia.

Besides India, this pulse is cultivated in South-East Asia, some parts of Africa, the West Indies and the United States of America.

Moth Bean मोठ की दाल

Botanical Name: *Phaseolus aconitifolius* **Common name: Mat or moth bean**

The moth bean is probably a native of India, Pakistan and Myanmar where it grows wild and appears to have been recently domesticated.

At present it is largely grown in India, Sri Lanka, China, Pakistan and the South Western United States, particularly in Texas and California.



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Pea

Botanical Name: *Pisum sativum* L. **Common Name: Pea, garden pea, Field pea, Matar**



Figure: 3.3. *Pisum sativum* (Pea)

- As in the case of many other widely cultivated plants, *Pisum sativum* has not been found as a wild plant. It has been known in cultivation since ancient times. Excavations of Neolithic sites dating as far back as 7,500-6,500

B.C. have shown carbonized pea seeds. They were first discovered in the Near East in Jarmo and other sites. Later similar findings were made from other Neolithic sites in Europe.

- The Russian Botanist, Vavilov (1951) suggested that the garden pea may have originated in Ethiopia, or the Mediterranean and Central Asia with a centre of diversity in the Near East.

- On the other hand the French Botanist De Candolle was of the view that "this species seems to have existed in Western Asia from the South of Caucasus to Persia before it was cultivated".

- Interestingly, a wild plant of *Pisum arvense* which is closely related to *Pisum sativum* occurs in Russia. An important observation about *Pisum* is that all the species are self pollinating diploids and they intercross freely. Thus the actual origin of the cultivated garden pea has not been established.

- The plant has been cultivated since the Greek and Roman times. It was probably domesticated in Central or Western Asia and it later spread to other parts of the world.
- The crop is cultivated extensively in countries having a cool climate especially in the Northern Hemisphere. Europe, United States of America, Canada, China, Ethiopia, India and Japan are the major producers of pea.

Cow Pea **लोबिया**

Botanical Name: *Vigna unguiculata* **L. Common Name: Cowpea, Catjang Cowpea Lubia**

Cow pea is an important pulse crop cultivated since ancient times in Africa and Asia. There are references to this pulse crop in ancient Sanskrit literature also. In Africa this legume is widespread both in the wild state as well as in cultivation. On the basis of all the evidence, it is now believed that the cultivated cowpea originated in Central Africa from where it spread in early times through Egypt or Arabia to Asia and the Mediterranean.

It was brought to the West Indies in the sixteenth century by the Spaniards and was introduced to America in about 1700 A.D. Cowpeas are now widely distributed throughout the tropics and subtropics.

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OIL SEED CROPS

- Oils, fats and waxes have been in use since prehistoric times. Probably the fats initially used by man were of animal origin such as tallow, obtained from cattle and sheep and grease from pigs, and were separated from the other tissues by 'rendering', a process involving heating either in the presence (wet rendering) or absence of water (dry rendering). Ancient Chinese and Hindus developed the art of recovering vegetable oils from the oil-bearing materials with the help of primitive mills much earlier than in any other parts of the world.

- The old Chinese oil presses were driven by man, in contrast the primitive Indian extractor (known as the ghani, kolhu) were driven by bullocks. Even today, the ghani is still being used in remote rural areas of India and operates on the principle of a pestle rotating in a mortar, generally made of wood.

- Vegetable oils were used for food and for anointing by the ancient Egyptians and Phoenicians. As early as 1400 B.C., Egyptian lubricated chariot wheels with greases consisting of fats and lime.

- From the Egyptians and Phoenicians, the knowledge of the use of fats and oils spread to the Hebrews and to the Greeks. Pliny wrote about the use of vegetable fats in soap making. Today oils and fats are used in a variety of ways.

Vegetable oils and fats are triglycerides of complex organic fatty acids. Naturally occurring fats are usually mixtures of triglycerides of various fatty acids with general formula:

CH2—COOR1
CH— COOR2
CH2—COOR3
R1, R2 and R3 represent the carbon chains of the different fatty acids.

Most commonly, each fatty acid radical is different. Fats in which all the fatty acid molecules are identical are common. The fatty acids are of two principal kinds- saturated and unsaturated. The common saturated fatty acids in fats are palmitic and stearic, the former being the most abundant in vegetable fats. The common unsaturated fatty acids are oleic (one double bond), linoleic (two double bonds) and linolenic acids (three double bonds).
The most important fatty acids are given in Table along with their empirical formulae.

Table.1: Important fatty acids with empirical formulae

Saturated acids		Unsaturated acids	
Acids	Empirical formula	Acid	Empirical formula
Capric	$C_{10}H_{20}O_2$	Oleic	$C_{18}H_{34}O_2$
Laturic	$C_{12}H_{24}O_2$	Linoleic	$C_{18}H_{32}O$
Myristic	$C_{14}H_{28}O_2$	Linolenic	$C_{18}H_{30}O_2$
Palmitic	$C_{16}H_{32}O_2$	Ricinoleic	$C_{18}H_{54}O_5$
Stearic	$C_{16}H_{36}O_2$	Erucic	$C_{22}H_{42}O_2$

- Oils, fats and waxes are very similar in their composition, Oils are liquid at ordinary room temperature whereas fats are solid or nearly solid. In general, at ordinary temperatures the triglycerides of unsaturated fatty acids are liquid whereas glycerides of saturated fatty acids with 12 or more carbons atoms are solid. Coconut oils, palm oil, palm kernel oils, cocoa butter and shear butter are examples of fats.

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- Vegetable oils differ from volatile or essential oils in a number of important respects. (1). They do not volatilize at ordinary room temperatures, (2). They cannot be distilled without being decomposed; (3). They leave a permanent greasy stain on p glycerides, they form soaps with alkali; (5). They lack strong taste and odour of essential oils and cid on long exposure to air.

The important oilseed crops grown in this country in order of importance are groundnut, rapeseed, mustard, sesame, linseed, safflower, castor, sunflower, coconut and niger.

1. Groundnut (Arachis hypogaea L.)

Botanical Name: ***Arachis hypogaea*** **Common Name: Peanut, Monkeynut Moongphali** Family: Fabaceae

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Figure: 3.4. *Arachis hypogaea* (Pea Nut)

- Groundnut is a native of Brazil and it became widely distributed throughout South America at an early date.
- **According to Vavilov (1951), this plant was first domesticated in the Brazilian – Paraguayan region.**
- The area of the valleys of Paraguay and Parana rivers is the most likely centre of origin of this legume. No wild plant of this important crop has been found. But several other species grow in the wild and all of them produce geocarpic fruits.
- Excavation in coastal Peru dating back to 800 B. C. shows the cultivation of groundnut. From South America, this legume spread to other parts of the world.
- It was commonly found in the West Indies but not in the United States in Pre-Columbian times. Groundnut was introduced to the old World in the 16th century when the Portuguese took the seeds from America to Africa.
- The Spaniards introduced it into the Philippines. It then spread to China, India, Japan, Malaysia and other parts of the world.

- Usually, the application of only N and P is resorted to, since most of the Indian soils are rich in K. The application of N in two equal split doses, one before sowing and the other 30 days after sowing, is found to increase the yield. In virgin lands, when groundnut is newly introduced, the application of a culture of *Rhizobium* as seed treatment is beneficial in increasing nodulation and nitrogen fixation. The application of gypsum at 500 kg per ha at the peggingstage will enhance pod formation.