Damage of liver → cirrhosis

Science world HSIV

Date
Page

and unpleasant withdrawal syndrome if regular dose of drug / Alcohol is abruptly discontinued } This is characteristic by anxiety, shakiness, nausea and sweating, which may be relieved when used is resumed again. In some cases withdrawal syndrome can be severe and even life threatening and the person may need medical supervision.

- AIDS and Hepatitis B infections are chronic infections and ultimately fatal. Both can be transmitted through sexual contact or infected blood
- They (ois) use narcotic analgesics, anabolic steroids, diuretics and contain hormones in sports to the muscles strength and bulk and to promote aggressiveness and as a result the athletic performances
- The side effects of the use of anabolic steroids in females include masculinisation; Ted aggressiveness, mood swings, depression, abnormal or excessive hair growth on the face and body, enlargement of clitoris, deepening of voice.
- In males it include : acne, Ted aggressiveness, mood swings, depression, reduction the size of testis, Ted sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of the prostrate gland.

Molecular Genetics

Science world HSN

Date 24/9/018
Page

① - At the time of mendel, the nature of those 'factors' regulating the pattern of inheritance was not clear. Over the next hundred years, the nature of the putative genetic material was investigated culminating in the realisation that DNA is a genetic material, at least for the majority of organisms. In class XI you have learnt that nucleic acids are polymers of nucleotides.

- DNA and RNA are the two types of nucleic acids found in living systems.
- DNA act as the genetic material in most of the organisms. RNA though it also acts as a genetic material in some viruses, mostly function as a messenger. RNA has additional role as well. It function as adaptor, structural, and in some cases as a catalytic molecule.
- In class XI NCERT you have already learnt the st^{re} of N$_t$ and the way these monomers units are linked to form nucleic acid polymers.
- In this chapter we are going to discuss the st^{re} of DNA, its replication, the process of making RNA from DNA [transcription], the genetic code that determines the sequences of amino acids in proteins, the process of protein synthesis [translation] and elementary basis of their regulation.
- The determination of complete N$_t$ sequence of human genome during last decade has set in a new era of genomics. In the last section, the essentials of human genome sequencing and its consequences will also be discussed.
- Let us begin our discussion by first understanding the st^{re} of the most interesting molecule in the living system, that is, the DNA.
- In subsequent sections, we will understand that why it is the most abundant genetic material, and what its relationship is with RNA.
- The DNA: It is a long polymer of deoxyribonucleotide. The length of DNA usually defined as number of N$_t$. [or a pair of nucleotide referred to as Base pairs] present in it. This also is the characteristic of an organism.

Bic it is ssDNA (thus)

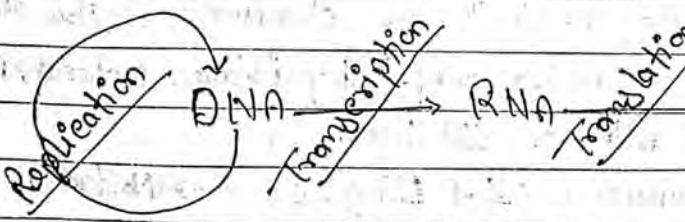
* for Example: A bacteriophage Klas ϕ X174 has 5386 (N+) } Bacteriophage Lamda has 48502 (B.P) } E.Coli has 4.6×10^6 (B.P) } Haploid content of human DNA is 3.3×10^9 (B.P)

- Str of polynucleotide chain:

N+ = N.B + Pentose sugar + Phosphate

- There are two types N.B — ① Purine [A & G] ② pyrimidine [C, U & T].
- Cytosine is common for both DNA and RNA and Thymine is present in DNA. } Uracil is present in RNA at the place of Thymine
- A Nitrogenous base is linked to the OH of 1'C pentose sugar through a N-glycosidic linkage to form a nucleoside.
- Nucleoside → adenosine or deoxyadenosine, guanosine or deoxyguanosine, cytidine or deoxycytidine and uridine or deoxythymidine.
- When a phosphate group is linked to OH of 5'C of a Nucleoside through phosphoester linkage, a corresponding ~~linkage~~ nucleotide [or deoxyribonucleotide depending upon the type of sugar present] is formed.
- Two N+ are linked through 3'-5' phosphodiester linkage to form a N+. } More N+ can be joined in such a manner to form a polynucleotide chain.
- A polymer thus formed has → At the end of free phosphate moiety at 5' end of sugar, which is referred to as 5' end of polynucleotide chain. } Similarly, at the other end of the polymer the sugar has a free OH of 3'C group which is referred to as 3' end of the polynucleotide chain.
- The backbone of polynucleotide chain is formed due to the sugar and phosphates } The N.B. linked to sugar moiety project from the backbone
- In RNA, every N+ residues has an additional -OH group present at 2'- position in the ribose } Also, in RNA the uracil is found at the place of thymine [5-methyl uracil, another chemical name for thymine]
- DNA as an acidic substance present in Nucleus was first

identified by friedrich meischer in 1869. He named it as Nuclein.
- However, due to technical limitation in isolating such a long polymer intact, the elucidation of str of DNA remained elusive for a very long period of time.
- It was only in 1953 that James watson and francis crick, based on the X-Ray diffraction data produced by maurice Wilkins and Roselind franklin, proposed a very simple but famous double helix model for the str of DNA.
- One of the hallmarks of their proposition was base pairing b/w the two strands of polynucleotide chains. However, this proposition was also based on the observation of Erwin chargaff that for the double stranded DNA, the ratios b/w A & T and G & C are constant and equal ones.
- the base pairing confers a very unique property of the polynucleotide chains. they are said to be complementary to each other, and therefore if the sequence of bases in one strand is known then the sequence in other strand can be predicted.
- Also, if each strand from a double [let us call it as a parental DNA] acts as a template for synthesis of a new strand, the two double stranded DNA [let us call them as daughter DNA]. thus, produced would be identical to the parental DNA molecule. Ble of this, the genetic implications of the str of DNA become very clear.
- The proposition of a double helix str for DNA and its simplicity in explaining the genetic implication became revolutionary.
- Very soon, francis crick proposed the central dogma in molecular biology. The genetic information flow is DNA → RNA → Protein



central dogma

② on the basis of following experiments, it is proved that, the nucleic acids are the bearer of hereditary characters :. ① Bacterial transformation Experiments ② Bacteriophage experiments ③ TMV experiments ④ DNA estimation test.

① Bacterial transformation experiments : this was the first experiments that showed that Nucleic acids are the hereditary character carriers } This experiments was first time conducted by Fredrick Griffith in 1928. } In this experiments he used bacteria Diplococcus pneumoni [Pneumococcus pneumoni | NCERT Mistake Streptococcus pneumoni.] } This bacteria produces disease pneumonia in mice } He used two strains of diplococcus bacteria.

① RII ⇝ Non pathogenic | Non virulent

② SIII ⇝ Have polysacch. coat } Pathogenic | virulent.

- RII is non pathogenic and not having polysacch. coat around it, so having rough surface } SIII is pathogenic and having a polysacch. coat around it which is antigenic in nature, so having smooth surface
- Griffith perform four experiments.

Exp. 1 — RII ⟶ Inject in mice ⟶ Disease not ⟶ mouse survive

Exp. 2 — SIII ⟶ Inject in mice ⟶ Disease produce ⟶ mouse dead

Exp. 3 — SIII heat killed ⟶ Inject in mice ⟶ Disease not ⟶ mouse survive

Exp. 4 — RII + SIII heat killed ⟶ Inject ⟶ Disease produce ⟶ mouse dead

- Living SIII strain recovered from the mouse body. } this experiment shows that some of the RII bacteria got transformed into the SIII bacteria. } This is also Bacterial transformation or Griffith effect.
- A/to Griffith, the transforming principle is ⟶ polysacch. (?)
- Later in 1944, Avery, MacLeod and MacCarthy reconducted Griffith's experiments and they found the same observations } Now they conducted the experiments in another way. } They isolated proteins, RNA, polysaccharides and DNA of SIII bact.

Experiments : protein of SIII + Living RII ⟶ No transformation

polysacch. of SIII + living RII ⟶ No transformation.

RNA of SIII + Living RII ——→ No transformation.

DNA of SIII + living RII ——→ Transformation of RII into SIII observed.

- Avery, MacLeod, MacCarthy proves that the transforming principle is DNA. {* Avery, MacLeod, MacCarthy first established biochemical nature of Gene.
- DNA is the molecule that is having information for the polysaccharide coat [RII → SIII] formation.
- when accidentally, living RII bacteria actively takes up the DNA fragment of dead SIII bact. ——→ the DNA inside cell expresses it self ——→ formation of polysacch. coat ——→ RII to SIII transformation ——→ Transforming principle is DNA.

(3) Bacteriophage Experiments: Conduct by* Hershey and chase in 1952.}

Bacteria is a virus that infects the bacteria. It is made up of DNA & protein.

- Hershey and chase chose the T_2 Bacteriophage [Coliphage i.e, attack on E.Coli] for their experiments. {In their experiment they radiolabelled protein with S^{35} and DNA with P^{32}. There is no sulphur in DNA and there is no phosphorus in protein. So both components DNA and protein are radiolabelled.
- Now these radiolabelled p Bacteriophage are allowed to infect the E.Coli bacteria. They found that the DNA of Bacteriophage enters inside bacterial cell and multiply itself and it passes into the next generation.
- while protein coat does not multiply itself. So the infective part of Bacteriophage is. DNA.
- for this Experiment Hershey got Nobel prize in ~~B~~ 1969.
- TMV Experiment: In 1957, Fraenkel and Conrat conducted and experiment with Tobacco mosaic virus [TMV]. {TMV is a ~~Rod~~ Rod shaped virus that infect the leaves of tobacco plants and produces mosaic disease {TMV → SSRNA virus
- In their exp. fraenkel and conrat isolated protein and RNA of TMV.
- protein of ~~tobacco~~ TMV → Applied on tobacco leaves ——→ No symptom.
- RNA of TMV ——→ Applied on tobacco leaves ——→ Symptom of mosaic disease occured

- This proves that RNA of TMV is infective.
- Later this exp. was extented by using Holmis Ribgrass virus [HRV]. HRV infects Plantago lanceolata plant and produces Ribgrass disease } By the use of TMV and HRV, Chimaric viruses are prepared. These are the hybrid viruses
- Protein of TMV + RNA of HRV ⇝ chimaric virus A → Cause Ribgrass dise
- Protein of HRV + RNA of TMV ⇝ Chimaric virus B → Cause TMV disease
- This experiment conforms that RNA is a genetic material of TMV virus
- *DNA is a genetic material of all the organism. } * RNA is genetic material of only some viruses
- DNA Estimation test: The total amount of DNA present in the Haploid genome of an organism ⇝ C value of DNA. } It is characteristic of a particular species
- During cell cycle amount of DNA: G_1 phase ⇝ 2C } S_2 phase ⇝ 2C → 4C } G_2 phase ⇝ 4C } M phase ⇝ 4C → 2C
- Mirsky and Ris analysed the amount of DNA in a cells. } In gametes → C } In somatic cell ⇝ 2C
- DNA is metabolically most stable molecule of the cell. It does not easially broken down in various metabolic pathways
- forms of double stranded DNA:

Form of DNA	B.P/turn	length of pitch	Axial Rise	Diameter
A-DNA	11	20.16 A°	2.56 A°	23 A°
B-DNA	10	34 A°	3.4 A°	20 A°
C-DNA	9.33	30.97 A°	3.32 A°	19 A°
D-DNA	8	24.24 A°	3.03 A°	Variable

- Normal DNA is the B. DNA, It is believed that when B-DNA undergoes dehydration, it converts into the A-DNA. } A-DNA is seen in excess Na^+ ion and in dehydration conditions.
- All the forms of DNA [A, B, C & D] are having right handed coiling
- Recently E. DNA has been discovered which has 7.5 bp./turn

Date
Page

- Z - DNA : Discovered Rich in 1979. } Having Left handed coiling } length of one pitch : 45.6 A. } 8 B.P. / turn ⇒ 12 } Axial rise ⇒ 3.8 A° } Diameter ⇒ 18 A°
- When Normal B- DNA is methylated or Brominated ⟶ It changes into Z-DNA. firstly observed in Drosophilla.
- Circular DNA : the double stranded molecule of DNA usually Linear. } But in Bacteria, chloroplast and mitochondria ⇒ DNA is circular. } In some Bacteriophage the DNA is linear when it is outside the host cell but when it is present inside host cell, it becomes circular. } These linear DNA of virus has sticky ends. it means at the free end of DNA unpaired Nt are present. } when the linear DNA converts into the circular DNA, these unpaired Nt shows base pairing. & the free ends of DNA behaves as sticky ends

④ The PD bonds of a polynucleotide can be cut enzymatically. Such enzyme are called Nucleases. These are of two type :-

Ⓐ Exonucleases : These breaks the terminal PD bonds of DNA. So, they are active only at the ends of the DNA.

Ⓑ Endonucleases : These can break the internal PD bonds of DNA., so they can cut DNA at any internal points } So popularly Kha Genetic Knife

- Those endonucleases which cut only specific nucleotide sequences of dsDNA are Kha Restriction endonuclease. These are called selective cutter Ex Eco-RI. } These enzymes identify Palindromic sequences of DNA. } These enzyme are naturally present in bacteria.
- Special : Bids by Si [SBS] model of DNA proposed by Radday and Seshachaaran which explains the unbinding of ~~nucleotide~~ DNA during replication. } Restriction endonuclease is most important enzyme used in genetic engineering } E.Coli is most commonly used bacteria in genetic engineering
- Single Stranded DNA : firstly discovered in Bacteriophage ϕ-174. } Discovered by Sinsheimer. } This virus has minimum no. of genes [5-9].

overlaping genes } Always circular DNA. } Not follow chargaff rule }
T > A > G > C = 1.33 > 1 > 0.98 > 0.75.

- DNA Replication :- It occurs before mitosis and meiosis I. } It occurs in the S-phase of Interphase. } There are three possibilities for the replication of DNA.

(A) Dispersive mechanism :- A/to this method, the original DNA molecule break up into small pieces. Each piece replicate itself and again rejoin to form two molecules of DNA. [No Evidence]

(B) Conservative mechanism :- A/to this method, the original DNA molecule is well conserved. Its copy / Replica is synthesized in the medium. [No Evidence]

(C) Semiconservative mechanism :- proposed by watson and Crick. } The evidence for semiconservative mechanism was provided by meselson and stahl in 1958. } for this they used bacteria E.coli as in experimental material. } they used the Isotops of Nitrogen [N^{14} and N^{15}].

(5) - In their experiments, they cultured bact. E.coli in a culture medium which contains Heavy Nitrogen [N^{15}]. } they grew in bacteria up to 17 generations in the culture medium. } After 17 generations, they found that now, in both the strand of DNA of bact. N^{15} is present. These DNA are Hes Heavy DNA } one of these bacteria was not cultured in a normal medium which contains normal Nitrogen [N^{14}]. } After one generation they found that the density of DNA of bact. is intermediate b/w heavy DNA and light DNA.

- This explains that ⇝ These DNA molecules have one parental strand and one new strand thats why these have intermediate density.

- Buoyant density centrifugation [also isopycnic centrifugation] uses the concept of buoyancy to separate molecules in solution. } * usually a CsCl [Caesium chloride] sol.^{n} is used. } This method very sharply separates molecules, and is so sharp that it can even separate different molecular Isotops from one another. } Buoyant density of majority of DNA is 1.7 gm/cm^3 which is equal to density to 6M CsCl solution.

Date
Page

- In intermediate or Hybrid DNA → one strand of DNA has N^{15} and the other complementary DNA strand has N^{14}. This experiments conforms that during replication of DNA, one parental strand of DNA is conserved which behaves like a template, on which the new DNA strand is synthesized.
So method of DNA replication is → semiconservative.

Q. If a heavy DNA is allowed to replicate in a normal medium [Having N^{14}] up to two generations, what % of DNA we get intermediate?
(a) 25% (b) 12.5% (c) 75% (d) 50%

Q. If an intermediate DNA is allowed to replicate in a normal medium [N^{14}] up to 3 generations, what %. of DNA will resemble with the parental DNA? (a) 25% (b) 12.5% (c) 75% (d) 50%

Q. If a DNA is having Radioactivity in both strands and is allowed to replicate in non radioactive medium for two generations, what %. of DNA will show radioactivity?
(a) 25% (b) 12.5% (c) 75% (d) 50%

Q. If a ds DNA is having radioactivity in one strand and is allowed to replicate in non radioactive medium for 3 generations, what % of DNA will not having non radioactivity?
(a) 37.5% (b) 12.5% (c) 87.5% (d) 50%

Q. If in a dsDNA the % of A is 21%. If this DNA segment has total 200 Nt, then how many of these having 'G'?
(a) 21 (b) 63 (c) 29 (d) 87

- Special: In eukaryotes, the semiconservative method of chromosome replication was proove by Taylor. By using Isotop of Hydrogen [H^3] in chromosome of vicia plant.

- A/to Benzer, the DNA has three parts:-
① Cistron: is also called house keeping gene. Have information of translation
② Recon: is the part of DNA which participate in recombination [Crossing over]
③ muton: Smallest part of DNA which may be 1 Nt long. It is that part of DNA which may undergo mutation.

Date
Page

⑥ They grew E. coli in a medium containing $^{15}NH_4Cl$ [N^{15} is the heavy isotop of nitrogen] as the only nitrogen source for many generations. The result was that N^{15} was incorporated into newly synthesized DNA. [as well as other nitrogen containing compounds]. This heavy DNA molecule could be distinguished from the normal DNA by centrifugation in a cesium chloride [CsCl] density gradient. [please note that N^{15} is not a radioactive isotop. and it can be separated from N^{14} only based on densities]

- Then they transferred the cells into a medium with normal $^{14}NH_4Cl$ and took samples at various definite time intervals as the cells multiplied, and extracted the DNA that remained as double stranded helices. The various samples were separated independtly on CsCl gradients to measure the densities of DNA.
- Very similar experiments involving use of radioactive thymidine to detect distribution of newly synthesized DNA in the chromosomes was performed on Vicia faba [faba beans] by Taylor and colleagues in 1958. This experiments proved that the DNA in chromosomes also replicate semiconservatively.
- If E. coli was allowed to grow for 80 minutes then what would be the proportions of light and hybrid densities DNA molecules?
- The machinery and Enzyme". In living cells, such as E. coli, the process of replication requires a set of catalysts [Enzymes]. The main enzyme is referred to as DNA dependent DNA polymerase, since it uses a DNA template to catalyse the polymerisation of deoxyribonucleotide. Those enzyme are highly efficient enzymes as they have to catalyse polymerisation of a large number of Nt in a very short time.
- E. coli that has only 4.6×10^6 bp. [Compare it with human whose diploid content is 6×10^9 bp.], completes the process of replication within 18 minutes; thats mean the average rate of polymerization has to be approximately ★ 2000 bp/sec. ? Not only do these polymerases

have to be fast, but they also have to catalyse the Rxn with high degree of accuracy. Any mistake during replication would result into mutations.

- Furthermore, energetically replication is a very expensive process. Deoxyribonucleotides triphosphate serve dual purpose.
- In addition to acting as substrates, they provide energy for polymerisation Rxn. [the two terminal phosphates in a deoxyribonucleotide triphosphates are high energy phosphates, same as in case of ATP.
- In addition to DNA dependent DNA polymerase many additional enzymes are required to complete the process of replication with high degree of accuracy.
- For long DNA molecules, since the two strands of DNA can't be separated in its entire length [due to very high energy requirment], the replication occur within a small opening of the DNA helix, referred to as replication fork.
- The DNA dependent DNA polymerase catalyse polymerisation only in one direction, that is 5' → 3'. This creates some additional complications at the replicating fork. Consequently, on one strand [the template with polarity 5' → 3', it is discontinuous. The discontinuously synthesized fragment are later join with the enzyme DNA ligase.
- The DNA polymerases on their own can not initiate the process of replication. Also the replication does not initiate randomly at any place in DNA. There is a definite region in E.coli where the replication originates. Such regions are termed as origin of replication. It is ble of the requirment of the origin of replication that a piece of DNA if needed to be propagated during recombinant DNA procedures, requires a vector. The vectors provide the origin of replication. Further, not every detail of replication is understood well.

- In Eukaryotes the replication of DNA takes place at S- phase of the cell cycle. } The replication of DNA and cell division cycle should be highly co-ordinated. } A failure in cell division after DNA replication results into polyploidy [a chromosomal anomaly]

⑦- DNA Helicase: unbind DNA helix. } utilize ATP for this purpose. } required in both replication and transcription.

- Topoisomerase: Break the H-bonds b/w two DNA strand. } Convert ds DNA into two ~~ss DNA~~ single stranded str. } Helps in the formation of replication fork. } Remove super coiling of DNA [Remove torgies.]

- There are two types of topoisomerase:-

- The type I topoisomerase first bind to a region of DNA where it begins its separation into single strand. } The type II topoisomerase is called DNA Gyrase. It helps in the function of DNA Helicases enzyme & play imp. role in the unbinding process.

- Special: Unbinding of DNA → Helicase and Gyrase } Topoisomerase inhibitors are used as chemotherapeutic agents. eg. Camptothecin → Topoisomerase I inhibitor and Doxorubicin → Topoisomerase II inhibitors. } Inhibitors of the bacterial specific topoisomerase. DNA Gyrase eg. Ciprofloxim.

- Single stand binding proteins [SSBPs]: These proteins tightly bind to the single strands of DNA. } prevent again the pairing b/w separated complementary DNA strands. } stabilized the replication fork. } very important proteins b/c they maintain the template activity of the DNA.

- primase: special type of RNA polymerase. } involve in the formation of a short fragment of RNA. } these short RNA fragment are called RNA primer. } These are essential for the activity of DNA polymerase enzyme during Replication.

- DNA polymerase: main enzyme of DNA replication. } involve in the formation of new DNA strands on the template of DNA. } It polymerises the N_t and form the polynucleotide chain of DNA.

- In prokaryotes, it is of three types:-

① DNA polymerase I ② DNA polymerase II ③ DNA polymerase III [main enzyme]

- Prokaryotic DNA polymerase I was first discovered DNA polymerase enzyme [discovered by Kornberg from E. coli]. So commonly K/as Kornberg enzyme.
- Crains discovered DNA polymerase II and DNA polymerase III from the mutant varieties of E. coli.
- DNA polymerase I was the first enzyme which was used in invitro DNA synthesis.

Property	DNA polymerase I	DNA polymerase II	DNA polymerase III
- m.wt.	1,09,000 D.	1,20,000 D.	>250000 D.
- Constitution.	monomer	unknown	multimer 7 polypeptide chains.
- Polymerisation	upto 1000	upto 50	upto 15000
Speed N_t/minute			
- molecules/cell	upto 400	upto 50	up to 15000
- 5'→3' activity	present	present	present
- 3'→5' activity ↓ Exonuclease	present	present	present
- 5'→3' activity ↓ Exonuclease	present	absent	absent.
- function.	DNA repairing and Proof reading	DNA repairing	main polymerizing Enzyme

- In Eukaryotes at least 4 types of DNA polymerase enzymes are present.

① DNA polymerase α : main enzyme ② DNA polymerase β : DNA repair ③ DNA polymerase γ : mt. DNA replication ④ DNA polymerase δ : 3'→5' Exonuclease activity.

- DNA ligase : Catalyse the formation of pD bonds b/w the DNA fragments.} Important Enzyme of DNA replication.} Also called Genetic gum.} used in Genetic Engineering.

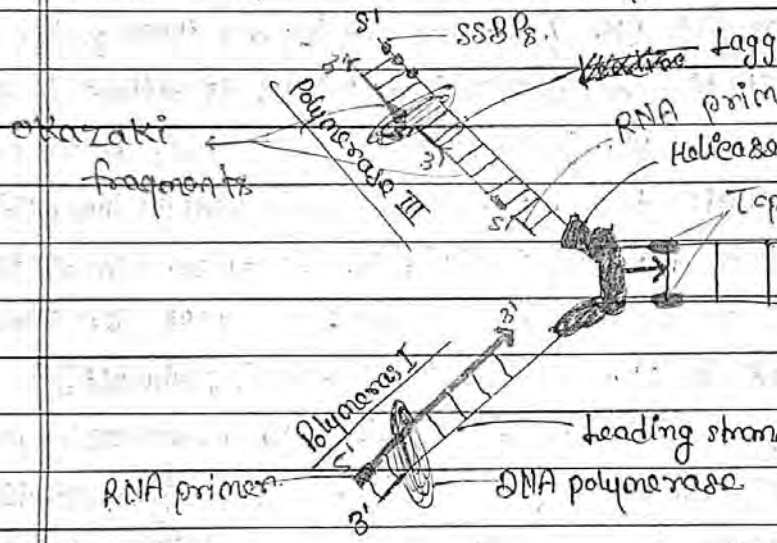
⑤ mechanism of replication : The replication starts with an incision or a cut of the DNA. this specific point is called Nick.} the incision enzyme

endonuclease participate in this process. As the result, the initiating point is identified for DNA replication, this initiating point is klas ori or origin. The closed circular DNA of prokaryotes usually only has one ori while linear eukaryotic DNA has multiple ori.

- The onzyme Helicase and Cyrase unbind the DNA helix. The enzyme topoisomerase breaks the H-bonds blw DNA strands and release the strands of DNA which are stabilized by SSBPs. As a result of this process, the ds DNA unbinds up to a point and gives a Y-shaped str. This str is klas Replication fork.
- The formation of replication fork and SSBPs bind to stabilized ss DNA.
- Both separated DNA strands act as a template for the synthesis of new strand DNA. The initiation of DNA synthesis requires an RNA primer which is a short sequence of RNA. It is formed by the primase enzyme. special type of RNA polymerase that synthesizes RNA primer. RNA primer always grow in 5'→3' direction.
- RNA primer behaves as a stepping stone or guide for DNA polymerase enzyme. It provides direction to the DNA polymerase [5'→3' for polymerization]. The DNA polymerase enzyme can polymerize the Nt only in 5'→3' direction.
- Both the strand of the replication fork are antiparallal to each other so new strands are synthesized in opposite directions. This is klas bidirectional DNA synthesis.
- In the replication fork on one of the DNA strand, the DNA polymerase enzyme gets the direction 5'→3'. So on this DNA template [having direction 3'→5'], there is continuous synthesis of DNA. This strand is said to be leading strand.
- On the other DNA template [having direction 5'→3'], the DNA polymerase get direction 3'→5' [from outside to inner side]. So on the DNA template, continuous DNA synthesis is not possible. The DNA is synthesized in the form of short fragments b/c the DNA

Date
Page

polymerase works inside to outside slowly with the help of RNA primer [to get 5' → 3' direction]. The results formation of short stretches of DNA. These DNA fragment are Was Okazaki fragments and this DNA template is Was lagging strand. These okazaki fragments are later joined with the help of enzyme DNA ligase. Now on the lagging ~~strand~~ strand complete DNA strand is synthesized.



- This indicate that → on leading strand DNA synthesized : continuous } on lagging strand DNA synthesized : discontinuous. } So replication of DNA is semidiscontinuous } semiconservative - semidiscontinuous } semiconservative - discontinuous

(9) Helicase vs. Topoisomerase : DNA helicase is the enzyme that unbind the DNA double helix. by acting on the H-bonds down the centre of the strands } for this function, the help of topoisomerase I is required to reduce supercoils } It begins at a site called the origin of replication, and it creates a replication fork by separating the two strs of the parental DNA.

Alms special : when replicating is studied with the help of electron microscope, the replicating areas appear at Eyes or Bubbles. These areas are Was Replicon. } Replicon is that part of DNA which is involve in replication. } main functional enzyme on : → Leading strand :

DNA polymerase III, tagging strand: DNA polymerase I. } The enzyme DNA ligase discovered by → Gilbert and Khorana } All enzymes which are involved in the replication of DNA are together Kha Replisome } DNA polymerases → Error rate $1/10^9$. } mutation rate in Base pair during replication is 10^{-9} to 10^{-10}. } mutation rate in a gene → 10^{-5} to 10^{-6}. } The easily unwound DNA is always a stretch of AT-rich DNA. } Initiator proteins are those proteins which activates the initiation of replication. } Primase is activated by interacting with the DNA helicase } Telomerase uses its reverse transcription activity to synthesize telomeric DNA on the RNA template } Rate of DNA synthesis / polymerization → In bacteria: 2000 bases per second., In mammals: 100 bases per second. } E. coli replicates its DNA with in 18 minutes [13 minutes J.

- protein complexes of the replication fork: DNA polymerase, primase, Helicase, SSBPs, sliding clamp., clamp loader, DNA ligase, Topoisomerase
- sliding DNA clamps Its processibility ÷ processibility means the ability of an enzyme to catalyze many Rxn before releasing its substrate
- RNA: polymer of ribonucleotides } It is of two types— ① Genetic/viral RNA ② Non genetic RNA.
- RNA world hypothesis: RNA is an information carrier [like DNA J } RNA molecules can act as catalysts [unlike DNA J.
- Alexander Rich first proposed the concept of the RNA world in 1962, and walter gilbert coined the term in 1986.
- Non genetic RNA: primarily involve in protein synthesis } Three types— ① rRNA ② mRNA ③ tRNA / Soluble RNA / Supernatant RNA
- Ribosomal RNA: found in ribosomes. } 67% of 70S ribosomes. } 50% of 80S ribosomes } most common type of RNA in cell } 70-80% of total cellular RNA. } 2nd most metabolically active molecule } formed by rDNA in prokaryotic genome } In E. coli

bacteria 3-2% DNA of genome is rRNA.} In eukaryotes rRNA is present in NOR region / pars chromosoma of Nucleolus.} In eukaryotes the rRNA formed in the nucleolus

(10) massenger RNA [mRNA] :- Term mRNA → Jacob and monad.} carries genetic information from DNA of nucleus to the cytoplasm where proteins are synthesize on the basis of these informations.} The mRNA synthesized inside the nucleus.} It is synthesized as a complementary strand on the DNA template.} Enz. RNA polymerase participates in this process.} These process of mRNA formation is klas ↪ Transcription.} It follows the rule of base pairing

- The DNA has genetic massage → these genetic massage are copied by the mRNA → the mRNA has these massages in the form of genetic code./ Codons.} Each genetic code is a base triplets.} It means it is made by three Nt.} A single mRNA has several genetic codes.} The genetic code determines the sequences of amino acids in a protein chain.} Each 'genetic code' codes an amino acid.} The average MWt of mRNA is 500000.} Its sedimentation coefficient is 9S.} 3-5% of total RNA of the cell.} short lived.
- The mRNA of Eukaryotes → have the information of one gene only → monogenic / monocistronic mRNA.
- The mRNA of prokaryotes → have the information of many genes → polygenic / polycistronic mRNA.
- Eukaryotic mRNA is more stable than prokaryotic mRNA.} Sometimes the eukaryotic mRNA is form m-RNA - protein complexes which are klas ↪ Informosome.} In informosome the mRNA : protein ↪ 1:4.
- An eukaryotic mRNA has several specific regions.} Cap region : 5' methylated region [m⁷G], 7-methyl guanosine at 5' end

figure NCERT

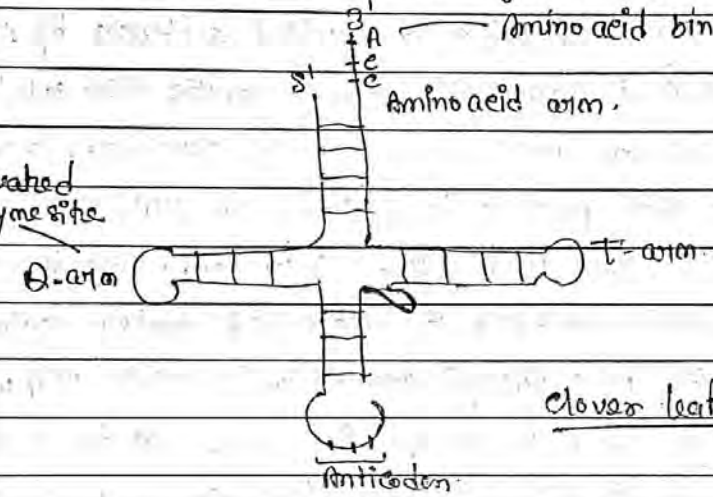
NCR-I Region/ UTR-I region: made up of 10-100 Nt., Rich in A & U N.B} Coding region: Generally it has 1500 Nt, always begins with codon AUG which is called chain initiating codon. At the end of coding region UAA/UAG/UGA codons are present. These are called chain terminating codons} The coding region has information for protein chain formation.} NCR-II Region: made up of 50-150 Nt.} Tail of mRNA/ poly 'A' region: It is poly adenylic acid sequences, it has 100-200 Nt. All are having adenine bases

-Special.: In 1993 sharp and Roberts discovered that the eukaryotic genes are not continuous. They have informations in segments. The segment which are having information for protein formation ↪ Exons while the segments which are not having information for protein formation ↪ Introns} Hence eukaryotic genes are made up of exons and introns. They are also split genes} In the eukaryotic cell, when mRNA copies the split genes, it has both exon and intron sequences. This mRNA is the precursor of actual mRNA ↪ Also Heterogenous nuclear RNA [hnRNA]. } It undergoes the process of RNA splicing during which, the intron sequences are removed and exon sequences are reunited} As a result, actual mRNA is formed ↪ which is shorter than the hnRNA} Enzyme ribozyme participate in the process of RNA splicing} The Shine-Dalgarno sequence [or Shine-Dalgarno box], proposed by Australian scientists John Shine and Lynn Dalgarno, it is a ribosomal binding site in the mRNA, generally located 16 Nt upstream of the start codon AUG.} The Shine-Dalgarno sequence exists only in prokaryotes [In E. Coli ↪ AGGAGGU]. This sequence help recruit the ribosome to the mRNA to initiate protein synthesis by aligning it with the start codon.} The complementary sequence [CCUCCU], is called the Anti-Shine Dalgarno sequence and is located at the 3' end of the 16S' rRNA in the ribosome} In eukaryotic equivalent to the Shine-Dalgarno sequence is called the Kozak sequence} mutations in the

Date
Page

Shine dalgarno sequence can reduce translation. This reduction is due to a reduced mRNA ribosome pairing efficiency.

(ii) Transfer RNA : Discovered by Crick. } presence in cell proved ↝ Hoagland } Also called supernatant / soluble RNA / Adaptor RNA. } 10-20% of total RNA of the cell. } Lighest macromolecules of the cell. } Sedimant coefficient ↝ 3.8'S' } made up of 73-93 Nt. [Rich and Rajbhandari].



Clover leaf model

* In 1965; Robert Holley proposed the str of yeast phenyl alanine tRNA. } He got Noble prize in 1968-[Shared with Nirenberg and Khorana]. } This macromolecular str of tRNA is Klas clover leaf model. } * It is 2D model made up of 78 Nt. } In clover leaf model of tRNA a specific site is present Klas Anticodon. } It is complementary to the codons of mRNA. }

- The Anticodon is also made up of 3 NB. [like codon of mRNA]. } The tRNA picks up a specific activated amino acid from the cytoplasm and carry it to the site of protein synthesis. } The 3' arm of tRNA behaves as an acceptor arm for amino acids } The tRNA is synthesized by the Nucleer DNA.
- It has unusual NB like Inosine, Pseudouracil, methylguanosine, Dihydrouridine, Ribothymidine. } In a tRNA, 10-15 NB are unusual } It assumes 2° or 3° str
- When it assumes 3° str / 3D str ↝ it becomes L-shaped; first time proposed by Kim in 1974. } tRNA shows abnormal base pairing. } Always at the 3'-arm, CCA sequence is present. } Always at 5' end arm 'G' Nt is present.

Genetic RNA : Genetic RNA is observed in few viruses [mostly in plant viruses] } Ex HIV : ssRNA , TMV : ssRNA.

Genetic code : Genetic massage are present on DNA. } These genetic massage copied by mRNA, the process is called Transcription. } on the mRNA the genetic massage of DNA are present in the coded form, these codes are called genetic code } Genetic code are Base triplet. } This was first time proposed by Gamow. } crick provided evidences by producing mutations in T_4 Bacteriophage. } Discovery of genetic code called cracking or Deciphering } It was first time done by Nirenburg and mathai in 1961. } for this they prepare homopolymer of RNA. } firstly they prepare poly U RNA. } used it as mRNA. } they found that this poly U mRNA when used in protein synthesis it synthesized protein chain only in that test tube which have phenyl alanine amino acid } poly phenyl alanine polypeptide chain is formed this proves that the code for phenyl alanine amino acid is UUU. } similarly they also prepare poly A, poly C and poly G RNA. } But poly G RNA assumes 2° str so can't be used in protein synthesis by Nirenburg and mathai. } poly A → poly lysine polypeptide chain. } poly C → poly proline polypeptide chain. } AAA → code for lysine Amino acid. } CCC → code for proline amino acid. } UUU → code for phenyl alanine amino acid ; first discovered genetic code

Main characters of genetic code : present on mRNA. } Are base triplet. } Have information of translation. } they are Degenerative } Non overlap and comma less. } Non ambiguous } universal

Special : The degeneracy of genetic code first time discovered by Burnfield and Nirenburg } some genetic codes are ambiguous. this character is Also Redundancy of genetic code. } Genetic code are universal in nature → due to this character Human protein can be synthesize in bact. by the techniques of genetic engineering } overlapping codons are present in Bacteriophage ϕ-174. } There are 64 genetic codes. } 61 codes for amino acids

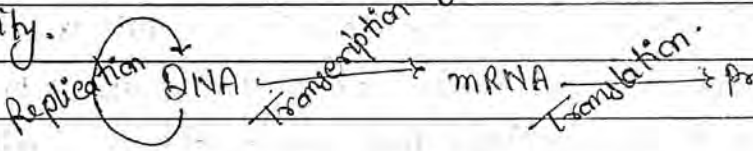
[Sense codon].} 3 are non-sense codons [UAA, UAG, UGA].} 5 are punctuat codons [AUG, GUG, UAA, UAG, UGA].} except methionine and tryptophan, all the amino acids are coded by more than one codon.} codons which specify the same amino acid are called synonyms.} Leucine, Serine and arginine have 6 different codons each.} The degeneracy of genetic code minimize the effect of mutations.} Variations b/co synonyms tend to occur at the third position of the codon, which is also wobble position.} when due to mutations in codon the amino acid get changed → mis-sense mutation.} when due to mutation in codon the protein chain get terminates [due to terminator codon] → Non-sense mutation.} when due to mutation in codon the amino acid not changed due to synonyms codon → silent mutation.} chain initiating codon: The first code in an mRNA is always AUG.} It always code for amino acid methionine in eukaryotes and formyl methionine in prokaryotes.} first amino acid of a polypeptide chain is always methionine.} AUG is chain initiating or start signal codon.} Rarely GUG acts as chain initiating codon.} In extreme rare condition → UUG acts as chain initiating codon.} GUG is the code for valine amino acid but when it behaves like chain initiating codon; it codes methionine amino acid.} stop signal codon: Also called non-sense or terminator codon.} when they read by ribosome the protein synthesis stop.} They do not code any amino acid.} these stop signal codon are: UAA [ochre] UAG [Amber], UGA [opal].} UGA firstly discovered non sense codon.} Non-sense codon never have 'C' NB.} Opal UGA → first discovered non-sense codon.} In yeast mitochondria UGA → code for tryptophan amino acid.} In ciliated protozoa UAA & UAG → codes for Glutamine amino acid.

- Contribution of H.G. Khorana: In 1979 H.G. Khorana synthesized an artificial gene in the laboratory.} This gene was 207 Base pair long.} Named as suppressor tRNA gene.} Khorana use copolymer for the discovery of genetic code: cystine | valine - UGUGUGUGUGUG, Leucine | serine - CUCUCUCUCUCU, Threonine | Histidine - ACACACACACAC.} He got

Noble prize in 1968.

- Wobble hypothesis: proposed by crick. } The third base of a codon is not very important, the specificity of a codon determined by first two bases } same tRNA can recognize more than one codons } wobbling allows economy of number of tRNA molecules.

(13) Central dogma of molecular biology: The path of flow of genetic information has been formed by crick as central dogma } It represents unidirectional flow of genetic information. } DNA performed two types of activity- Autocatalytic and heterocatalytic. } DNA acts as template for the synthesis of its own copy and mRNA. } Replication: Autocatalytic activity } Transcription: Heterocatalytic activity.



- Special: A gene express it self by the way → Transcription and translation. } Barry Commer proposed cyclic path for the flow of genetic activity. } the strand of DNA that directs synthesis of the mRNA via complementary base pairing is called → Template strand / Antisense strand. } The other DNA strand becoz the same sequence as the mRNA [except possessing T instead of U] is called → Non template / coding strand / sense strand.

- Teminism: In 1964 Teimin reported the reverse flow of genetic informations from RNA to DNA in retro viruses. } This is called reverse transcription. } In this process DNA is formed on RNA template. } for this teimin got Noble prize in 1975. } In this process enzyme Reverse transcriptase is used. } Reverse transcriptase enzyme is: * RNA dependent DNA polymerase } Discovered by Teimin and Baltimore in 1970. } * this enzyme also used in genetic engineering to synthesize copy DNA [cDNA].

- Mordern central dogma:-

Science world HSN

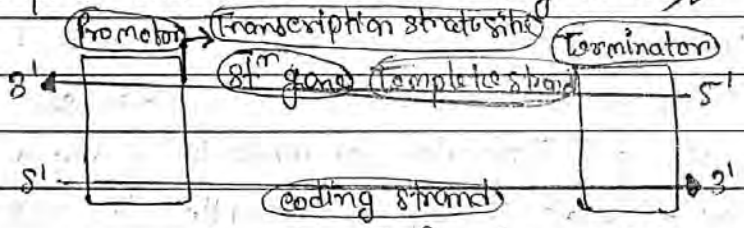
Date
Page

Replication

DNA ~~Replication~~ —Transcription / Reverse transcription→ mRNA —Translation→ protein.

- Special: As HIV uses reverse transcriptase to copy its genetic material and generate new viruses, specific drugs have been designed to disrupt the process and thereby suppress its growth. Collectively, these drugs are known as reverse transcriptase inhibitors → Zidovudine, lamivudine, tenofacir and nevirapine.
- The process of copying genetic information from one strand of the DNA into RNA is termed as Transcription. Here also, the principle of complementarity governs the process of transcription, except the adenosine complements now forms base pair with uracil instead of thymine. However, unlike in the process of replication; which once set in, the total DNA of an organism get duplicated, in transcription only a segment of DNA and only one strand is copied into RNA. The necessitates defining the boundries that would demarcate the region and the strand of DNA that would be transcribed.
- Why both the strands are not copied during transcription?
- first, if both strands act as a template, they would code for RNA molecule with different sequences [Remember complementarity does not mean identical], and in turn, if they code for proteins, the sequence of amino acids in the proteins would be different. Hence, one segment of the DNA would be coding for two different proteins, and this would complicate the genetic information transfer machinery. Second, the two RNA molecules if produced simultaneously would be complementary to each other, hence would form a double stranded RNA. This would prevent RNA from being translated into protein and the exercise to transcription would become a futile one.
- Transcription unit: A transcription unit → three regions in the DNA:
① A promoter ② The structural gene ③ A terminator.
- There is a convention in defining the two strands of the DNA in the

structural gene of a transcription unit. } since the two strands have opposite polarity and the DNA dependent RNA polymerase also catalyse the polymerisation in only one direction, i.e, 5'→3', the strand that has the polarity 3'→5' acts as a template, and is also referred to as template strand. } the other strand which has the polarity [5'→3'] and the sequence same as RNA [except thymine at the place of uracil], is displaced during transcription. } strangely, this strand [which does not code for anything] is referred as coding strand. } All the reference point while a transcription unit is made with coding strand.



Schematic str of a transcription unit

(14) the promoter and terminator flank the structural gene in a transcription unit. } The promoter is said to be located towards 5'- end [upstream] of the structural gene [the reference is made with respect to the polarity of coding strand]. } It is a DNA sequence that provides binding site for RNA polymerase, and it is the presence of a promoter in a transcription unit that also defines the template and coding strands. } By switching its position with terminator, the definition of coding and template strands could be reversed.

- The Terminator is located towards 3'-end [downstream] of the coding strand and it usually defines the end of the process of transcription. } There are additional regulatory sequences that may be present further upstream or downstream to the promoter. } some of the properties of these sequences shall be discussed while dealing with regulation of gene expression.

- Transcription unit and the Gene: * A gene is defined as the functional

Date
Page

unit of inheritance. Though there is no ambiguity that the genes are located on the DNA, it is difficult to literally define a gene in terms of DNA sequence. The DNA sequence coding for tRNA or rRNA molecule also define a gene.

- However by defining a cistron as a segment of DNA coding for a polypeptide, the structural gene in a transcriptional unit could be said as monocistronic [mostly in eukaryotes] or polycistronic [mostly in bacteria or prokaryotes.]
- In eukaryotes, the monocistronic structural genes have interrupted coding sequences — the genes in eukaryotes are split. The coding sequences or expressed sequences are defined as Exons. Exons are said to be those sequence that appear in mature or processed RNA. The exons are interrupted Introns. Introns or Intervening sequences do not appear in mature or processed RNA.
- The split gene arrangement further complicates the definition of a gene in terms of a DNA segment. Inheritance of a character is also affected by promoter and regulatory sequences of a structural gene. Hence, sometime the regulatory sequences are loosely defined as Regulatory genes, even though these sequences do not code for any RNA or protein.
- Types of RNA and the process of Transcription: In bacteria, there are three major types of RNAs: mRNA, tRNA and rRNA. All three RNA are needed to synthesize a protein in a cell. The mRNA provides the template, tRNA brings amino acids and reads the genetic code, and the rRNA play structural and catalytic role during translation. There is a single DNA dependent RNA polymerase that ~~catalytic role during translation~~ catalyses transcription of all types of RNA in bacteria
- RNA polymerase binds to promoter and initiates transcription [Initiation]. It uses nucleotide triphosphates as substrate and polymerises in a template depended fashion following the rule of

complementarity. It somehow also facilitates opening of the helix and continues elongation. Only a short stretch of RNA remains bound to the enzyme. Once the polymerases reaches the termination region, the nascent RNA falls off, so also the RNA polymerase. This result in termination of transcription.

- An intriguing question it that how is the RNA polymerases able to catalyse all the three steps, which are initiation, elongation and termination. The RNA polymerase is only capable of catalysing the process of elongation. It associates transiently with initiation-factor [σ] and termination-factor [ρ] to initiate and terminate the transcription, respectively. Association with these factors alter the specificity of the RNA polymerase to either initiate or terminate.

(15) In Bacteria, since the mRNA does not require any processing to become active, and also since transcription and translation take place in the same compartment [there is no separation of cytosol and nucleus in bacteria], many times the translation can begin much before the mRNA is fully transcribed. Consequently, the transcription and translation can be coupled in bacteria.

- In Eukaryotes, there are two additional complexities—

There are at least three RNA polymerases in the nucleus [in addition to the RNA polymerase found in the organelles]. There is a clear cut division of labour. The RNA polymerase I transcribes rRNAs [28S, 18S and 5.8 'S']. RNA polymerase III is responsible for transcription of tRNA, 5S rRNA and SnRNAs [Small nuclear RNAs]. RNA polymerase II transcribes precursor of mRNA, the heterogenous nuclear RNA [hnRNA].

- The second complexity is that the primary transcripts contain both exons and introns and are non-functional. Hence, it is subjected to a process called splicing where the introns are removed and exons are joined in a defined order.

Date
Page

- hnRNA undergoes additional processing called as capping and tailing.} In capping an unusual · Nt [methyl guanosine triphosphate] is added to the 5'-end of hnRNA.} In tailing, adenylate residues [200-300] are added at 3'-end in a template independent manner.} It is the fully processed hnRNA, now called mRNA, that is transported out of the nucleus for translation.
- The significance of such complexities is now begining to be understood. The split-gene arrangements represent probably an ancient feature of the genome.} The presence of introns reminiscent of antiquity, and the process of splicing represent the dominance of RNA-world.
- In recent times, the understanding of RNA and RNA-dependent processes in the living system have assumed more importance.
- A spliceosome is a large and complex molecular machine found primarily with in the nucleus of eukaryotic cells.} The spliceosome is assembled from snRNAs and approximately 80 proteins.} The spliceosome removes introns from a transcribed pre-mRNA, a type of primary transcript.} This process is generally referred to as splicing.
- In 1977, work by the Sharp and Roberts labs revealed that genes of higher organisms are 'split'.} The introns, are excised from the precursor mRNA in a process sharp named 'splicing'.} Sharp and Roberts got Noble prize in 1998.
- Each spliceosome is composed of five small nuclear RNA [snRNA] and a range of associated protein factors.} When these small RNA are combined with the protein factors, they make RNA protein complex called "snurps [small ribonucleoproteins] or snRNPs.} The snRNA that make up the major spliceosome are U1, U2, U4, U5 & U6 so-called ble they are rich in uridine, and participate in several RNA-RNA and RNA-protein interactions.
- New evidence suggests that the spliceosome is actually a ribozyme.} Zn metal is important in the splicing mechanism.} Triple small nuclear ribonucleoprotein [tri-snRNP] complex was reported in 2016.

- The presence of both RNA and protein at the core of the splicing machinary, suggest that the spliceosome is an RNP enzyme
- Special.: (2019) severo ochoa enzyme [polynucleotide phosphorylase] helpful in polymerising RNA with defined sequences in a template independent manner [enzymatic synthesis of RNA]. [George Gamow, a physicist, suggest that in order to code for all the 20 amino acids, that code should be made up of three Nt.] The genetic code is nearly universal: for example, from bacteria to human UUU would could for phenyl alanine So exception to this rule have been found in mitochondrial codons, and in some protozoans [AUG has dual function. It codes for methionine, and it also act as initiator codon.
- Mutation and Genetic code: The relation-ship b/w genes and DNA are best understood by mutation studied. [Effects of large deletions and rearrangements in a segment of DNA are easy to comprehend. It may result in loss or gain of a gene and so a function. The effect of point mutations will be explained here.
- A classical example of point mutation is a change of single base pair in the gene for β-globin chain that results in the change of amino acid residue glutamate to valine. It results into a diseased condition called as Sickle cell anemia.
- Effect of point mutations that inserts or deletes a base in structural gene can be better understood by following simple example. [Consider a statement that is made up of following words each having three letters like genetic code.
- The conclusion from the above exercise is very obvious [insertion or deletion of one or two bases changes the reading frame from the point of insertion or deletion. However, such mutations are referred to as frameshift insertion or deletion mutations.] Insertion or deletion of three or its multiple bases insert or delete in one or multiple codon hence one or multiple amino acid,

and reading frame remains unaltered from that point onwards

(16) Translation: It refers to the process of polymerisation of amino acids to form a polypeptide. The order and sequence of amino acids are defined by the sequence of bases in the mRNA.

- The amino acids are joined by a bond which is klay as a peptide bond. The formation of a peptide bond requires energy. Therefore, in the first phase itself amino acids are activated in the presence of ATP and linked to their cognate tRNA - a process commonly called as charging of tRNA or amino acylation of tRNA to be more specific. If too such charged tRNAs are brought close enough, the formation of peptide bond b/w them would be favoured energetically. The presence of catalyst would enhance the rate of peptide bond formation.
- The cellular factory responsible for synthesising proteins is the ribosome. The ribosome consists of structural RNAs and about 80 different proteins
- In its inactive state, it exists as two subunits, a large subunit and a small subunit. When the small subunit encounters an mRNA, the process of translation of the mRNA to protein begins
- There are two sites in the large subunit for subsequent amino acids to bind to and thus, be close enough to each other for the formation of a peptide bond.
- The ribosome also act as a catalyst [23S rRNA in bacteria is the enzyme - ribozyme] for the formation of peptide bond.
- A translational unit in mRNA is the sequence of RNA that is flanked by the start codon [AUG] and the stop codon and codes for a polypeptide. An mRNA also has some additional sequences that are not translated and are referred as untranslated regions [UTR]. The UTRs present at both 5'-end [before start codon] and at 3'-end [after stop codon]. They are required for efficient translation process.
- For initiation, the ribosomes binds to the mRNA at the start codon [AUG] that is recognised only by the initiator tRNA. The ribosome proceeds

to the elongation phase of protein synthesis. During this stage, complexes composed of an amino acid linked to tRNA, sequentially bind to the appropriate codon in mRNA by forming complementary base pairs with the tRNA anticodon.

- The ribosomes moves from codon to codon along the mRNA. Amino acid are added one by one, translated into polypeptide sequences dictated by DNA and represented by mRNA.
- At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome.
- Translation is a complicated process which involves several steps.

(A) Activation of Amino Acids: only L-isomer of amino acid are used in protein synthesis. In protein synthesis only activated amino acid are used. For the amino acid activation ATP and the enzyme amino acyl tRNA synthetase are required. Activated amino acid is a complex.

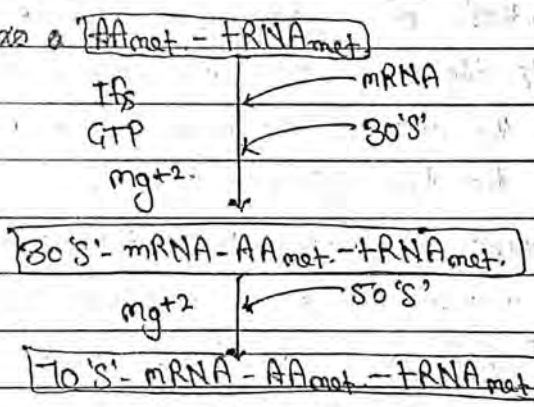
Amino acid methionine + ATP + E.
[Amino acyl tRNA synthetase] → 2 ip.
Amino acyl-AMP-Enzyme complex
[Activated amino acid]

(B) Transfer of Amino acid to tRNA: The tRNA takes only activated amino acids. The activated amino acid react with a particular tRNA and forms the Amino acyl tRNA complex. This process is called charging.

AAmet.-AMP-E. + tRNAmet. → E + AMP.
AAmet.-tRNAmet.

Date
Page

(C) Initiation of polypeptide synthesis : The initiation of polypeptide synthesis brought about by the amino acid methionine. The 1st code of mRNA is always AUG [rarely GUG] but both codes for amino acid methionine. During the formation of protein synthesizing unit, firstly the smaller subunit of ribosome combine with the mRNA and amino acid methionine - tRNA complex. After that, the larger subunit of ribosome combines and the complete ribosomal unit is formed. Now the protein machinery is ready for the synthesis of polypeptide chain. Some initiation factors [Ifs] participate in this process.



(A) Elongation of polypeptide chain : The elongation of polypeptide chain depends upon the codons of mRNA. The ribosome moves on mRNA from 5' to 3' end, and one by one, it reads the codons of mRNA and also that sequence it calls the tRNA which delivers the amino acids. The larger subunit of ribosome have enzyme peptidyl transferase which is responsible for the formation of peptide bonds b/w amino acids.

(E) Termination of peptide chain : It is brought about by the termination codons. These codons are : UAA, UAG, UGA. As the ribosome reads these codons → it stops protein synthesis. Some release factors [Rfs] release the newly form peptide chain. The ribosome get dissociated into subunits. The mRNA is destroyed by RNAase.

- End product: The end product of translation is a primary str of a protein. } A sequence of amino acid bonded together by peptide bonds.
- Special: Source of energy during translation is GTP. } The movement of ribosome on mRNA is called translocation. It requires enzyme translocase [EF-G]. } The F factor helps in the release of protein chain from ribosomes.

(17) Gene Regulation: The requirment of specific enzyme changes with the phase of the life cycle in which an organism is passing through. } Thus there ought to be some sort of genetic machinery to regulate the synthesis of certain proteins. } specific proteins are synthesized in those cells only where they are needed, although their genes are present in all the cells of the organism. } A particular protein is synthesized only at the time when it is needed by the organism. } only required amount of protein is synthesized.

- At a given time: At a particular time certain set sets of genes are in switched on condition and others are in switched off condition. } Switched on: gene active } switched off: gene inactive.
- Regulation of gene expression: Regulation of gene expression refers to a very broad term that may occur at various levels. } Considering that gene expression results in the formation of a polypeptide, it can be regulated at several levels.
- In (2019) Eukaryotes, the regulation could be exerted at: ① transcriptional level [formation of primary transcript] ② processing level [regulation of splicing] ③ transport of mRNA from nucleus to the cytoplasm, ④ translational level.
- The gene in a cell are expressed to perform a particular function or a set of functions.
- for example, if an enzyme beta-galactosidase is synthesized by E. coli, it is used to catalyse the hydrolysis of a disaccharide, lactose into galactose and glucose; the bacteria use them as a

source of energy. } Hence, if the bacteria do not have lactose around them to be utilised for energy source, they would no longer required the synthesis of the enzyme β-galactosidase. } Therefore, in simple term, it is the metabolic, physiological or environmental conditions that regulate the expression of genes

- The development and differentiation of embryo into adult organisms are also a result of the coordinated regulation of expression of several sets of genes
- In prokaryotes, control of the rate of transcriptional initiation is the predominent site for control of gene expression.
- In a transcriptional unit, the activity of RNA polymerase at a given promoter is in turn regulated by interaction with accessory proteins, which affect its ability to recognise start sites
- These regulatory proteins can act both positively [activators] and negatively [repressors]. } The accessibility of promoter regions of prokaryotic DNA is in many cases regulated by the interaction of proteins with sequences termed oprators. } The operator region is adjacent to the promoter elements in most operons and in most cases the sequences of the oprator bind a repressor protein.
- Each operon has its specific operator and specific repressor. } for example, lac operator is present only in the lac operon and it interacts specifically with lac repressor only.
- The operon model: } It is a scheme to explain the induction and repression of enzymes. } proposed to explain prokaryotic gene regulation. } The term 'operon' was first coined by French academy of ~~science~~ science in 1960. } Jacob and monad proposed operon model in 1961. } studied the organisation and control of lac operon in E. coli. } Got Noble prize in physiology 1965.
- Operon: } operon is a group of genes situated next to each other in the DNA that can be 'switched on' or 'off' in a

unified manner.} It is a unit of transcription.} Its function occurs at the level of transcription.

- There are two types of operon system:
  ① Inducible system ② Repressible system.

(10) Inducible system: In E.coli the utilization of lactose is brought about by three enzymes namely: β-galactosidase, Lac permease and Transacetylase

- When the lactose is added in the culture medium, the production of the enzymes is enhanced by 1000 times} such enzymes whose production is induced by adding the substrate are called Inducible enzymes} The genetic system which control their production is called Inducible system.} The substrate whose addition induces the synthesis of enzymes are called as Inducer.} Ex - Lac operon in E.coli.
- Repressible system: The synthesis of amino acid Tryptophan needs five enzymes in E.coli bacteria.} If tryptophan is added in the culture medium the synthesis of these enzymes is reduced, the phenomenon is called as Repression.} such enzymes whose production is checked by addition of the end products are called Repressible enzymes} The genetic system is Klas Repressible system.} The end product that ~~begins~~ brings repression is Klas* Co-repressor} Ex Tryp-operon in E.coli.
- Lac-operon in E.coli: Concerned with the synthesis of enzymes for lactose metabolism.} E.coli expresses genes for glucose metabolism continuously.} metabolism of other alternative types of sugars [eg lactose] are regulated specifically.} lactose → disacch., provides energy.}* lactose acts as an Inducer. [effector molecule]
- It stimulates expression of three enzymes: ① β-galactosidase [Lac Z]: synthesize by Z gene} Breaks lactose into glucose and galactose} Converts lactose to the allolactose, regulates lac operon.
  ② Lac permease [Lac Y]: synthesize by Y-gene} It helps in the transport

of lactose across cytoplasmic membrane.} It is a membrane bound transport protein.

(iii) Transacetylase [lac A]: synthesize by gene a.} function is not understood} perhaps it converts Galactose into glucose.

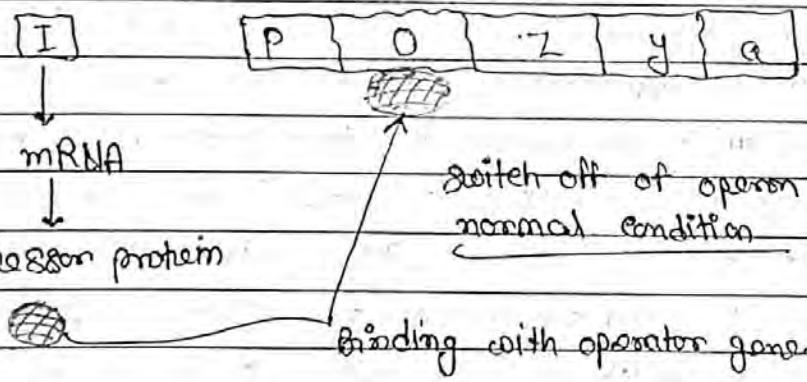
- Regulator gene: It is responsible for the synthesis of a protein called repressor.} In lac operon system the repressor is active} It has affinity for operator gene.} In lac operon the regulator gene is around 1200 BP long
- Repressor protein: product of regulator gene} tetramer} when bind with operator gene: switch off of the operon.
- promoter gene: It is the DNA segment at which RNA polymerase binds} The main site of promoter gene is CRP site.} CRP → cyclic AMP receptor protein site.} CRP is essential for binding RNA polymerase to the promoter site.} It is pribnow there are three essential elements in promoter region: Recognition sequence, Binding sequence, mRNA initiation site.} The promoter gene initiates the transcription of the structural genes.} It get massages from the operator gene and then control the mRNA synthesis.} It is in lac operon around 80BP long.} most recently discovered gene.} In E.coli around 1000 in number.} It is a segment of DNA which exercise a control over Transcription.} The repressor protein have affinity for operator gene.} If repressor protein bind with operator gene, operator can not pass its information to promoter gene so it prevent the activity of RNA polymerase, that results: switch off of the operon.} If repressor not bind with operator gene, operator pass its information to promoter gene: Switch on of the operon.} So we can say that the operator gene work as 'on' and 'off' switches in protein synthesis.} In lac operon the operator gene is around 85 BP long.
- Structural gene: These are those segments of the DNA which carry the massage for the synthesis of proteins.} In lac operon of E.coli there three structural gene.

(i) Gene 'Z': 3063 BP long, code for β-galactosidase.

Date
Page

② Gene 'y' ; 800BP. long, Code for lac permease
③ Gene 'a' ; 800 BP. long, code for transacetylase

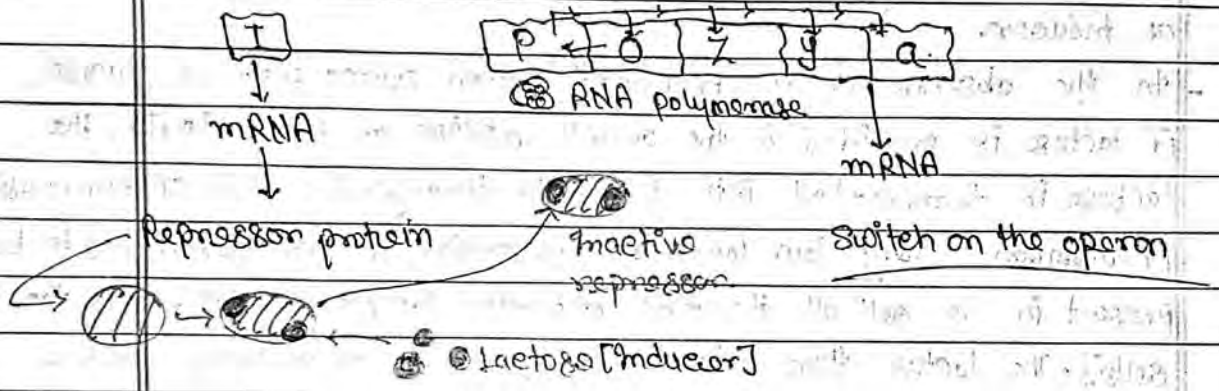
- Normal condition ; Glucose is present in medium, there is no need of lactose digesting enzymes so operon is switched off.
- Special condition ; Glucose is absent in the medium but lactose is present so this time there is need of lactose metabolizing enzymes so lac operon becomes switched on.
- The regulator gene codes for an active repressor protein. } The repressor protein then binds to the operator region of the operon. } when the active repressor protein bound to the operator region, RNA polymerase. [The enzyme responsible for the transcription of genes] is unable to bind to the promoter region of the operon.
- If RNA polymerase does not bind to the promoter region, the three enzyme genes [Z, y & a] are not transcribed into mRNA. } without the transcription of the three enzyme genes, the three enzymes needed for the utilization of the sugar lactose by the bacterium are not synthesized } In normal condition lac operon is in switch off condition.



- the regulator gene codes for an active repressor protein. } lactose, the inducer molecule binds to the active repressor protein. } The binding of the inducer alters the shape of the allosteric repressor causing it to become inactivated. } The inactivated repressor protein is then unable to bind to the operator region. } Since the inactive repressor protein is unable to bind to operator region, RNA polymerase

Date
Page

[The enzyme responsible for the transcription of genes] is now able to bind to the promoter region of the operon.
- RNA polymerase now able to transcribe the three enzymes ~~needed for the lact~~ genes [z, y & a] into mRNA. With the transcription of these genes, the three enzyme needed for the bacterium to utilize the sugar lactose are now synthesized.



(19) Lac operon: The elucidation of the lac operon was also a result of a close association b/w the geneticist, francois Jacob and a botanist, Jacque monod. They were the first to elucidate a transcriptionally regulated system. In lac operon [here lac refer to lactose], a polycistronic structural gene is regulated by a common promoter and regulatory gene.
- Such arrangement is very common in bact. and is referred to as operon. To name few such examples, lac operon, ara operon, his operon, val. operon, etc.
- The lac operon consist of one regulatory gene [the i gene - here the term i does not refer to inducer, rather it is derived from the word Inhibitor] and three structural gene [z, y, & a].
- The 'i' gene codes for the repressor of the lac operon. The 'z' gene codes for Beta-galactosidase [β-gal], which is primarily responsible for the hydrolysis of the disacch, lactose into its monomeric units, galactose and glucose. The 'y' gene codes for permease, which Is permeability of the cell to β-galactosidase. The 'a' gene

encodes a transacetylase } Hence, all the three gene products in lac operon are required for metabolism of lactose

- In most other operons as well, the genes present in the operon are needed together to function in the same or related metabolic pathway.
- lactose is the substrate for the enzyme β-galactosidase and it regulates switching on and off of the operon. Hence, it is termed as inducer.
- In the absence of a preferred carbon source such as glucose, if lactose is provided in the growth medium of the bacteria, the lactose is transported into the cells through the action of permease [Remember, a very low level of expression of lac operon has to be present in the cell all the time, otherwise lactose can not enter the cells]. The lactose then induces the operon in the following manner.
- The repressor of the operon is synthesized [all the - time - constitutively] from the 'i' gene } the repressor protein binds to the operator region of the operon and prevents RNA polymerase from transcribing the operon.
- In the presence of an inducer, such as lactose or allo lactose, the repressor is inactivated by interaction with the inducer } this allows the RNA polymerase access to the promoter and transcription proceeds
- Essentially, regulation of lac operon can also be ~~utilized~~ visualized as regulation of enzyme synthesis by its substrate.
- Remember, glucose or galactose can not act as inducers for lac operon. } Regulation of lac operon by repressor is referred to as negative regulation. } lac operon is under control of positive regulation as well, but it is beyond the scope of discussion at this level.
- Repressible system : Genes whose expression is turned off by the presence of some substances [co-repressor]. } Tryptophan represses the Tryp genes
- Biosynthetic pathway : co-repressor is typically the end product

of the pathway. } Tryptophan operon in E. coli is concerned with the synthesis of amino acid tryptophan; It is the best example of repressible & operon system.

- Tryptophan operon: Component of tryp-operon :- structural genes → E, D, C, B & A } Promoter gene } Regulatory gene: produces Apo-repressor. which is inactive } operator gene } Leader gene } Corepressor → Tryptophan.

- The trp operon of E. coli first characterized by charles Yanofsky
- Special: In E. coli bact., 4000 genes are present; out of these 1000 behaves as promotor. The promotor gene was not described by Jacob and monod; It is a new concept. } In promotor gene; a specific sequence of Nt TATAAT is present. This specific sequence is Kla Pribnow box. It is essential for transcription. It is located 10-15 Nt upstream from the site of transcription. } The pribnow box has a function similar to the TATA box that occurs in promotors in eukaryotes and ~~bacteria~~ archea :. It is recognized and bound by a subunit of RNA polymerase during

Date
Page

initiation of transcription. } The TATA box is also called Gold-berg Hogness box, it is a DNA sequence TATAAAAA [8 bp long] found in the promoter region of many genes in eukaryotes and archea. } It helps in aligning the RNA polymerase at the proper site. } The CAAT box [GGCCAATCT] is situated 70-80 bp upstream and avery important for the initiation of transcription. the CAAT regulate the effieiency of transcription. } The regular gene, promoter gene and operator gene are together Klas control region [control genes. } the Nt sequence of these genes in lac operon was studied by Gilbert, maxum, Dickson and maziels } In Eukaryotes basic mechanism of regulation of similar to prokaryotes. } Expression of genes is activated / inhibited through protein interactions with DNA. } majority of DNA is not expressed. } Gene are expressed in cells / tissue specific manner [pancreatic cells synthesized digestive enzyme, pancreatic islet - glucagons and insulin]

Allans special. The process of inhibition of RNA synthesis on a DNA template is called Repression. } RNA transcription inhibited by antibiotic Actinomycin D. } Tetracycelin inhibits binding of amino acyl tRNA to ribosome } streptomycin inhibits initiation of translation and causes misreading of mRNA. } chloramphenicol inhibits peptidyl transferase and so formation of peptide bonds } Erythromycin inhibits translation of mRNA along ribosome. } Neomycin inhibits interactions b/w tRNA and mRNA.

(20) Human Genome Project. Genetic makeup of an organism or an individual lies in the DNA sequences. } In two individual differ, then their DNA sequences should also be different, at least at some places. } These assumptions led to the quest of finding out the complete DNA sequence of Human genome.

With the establishment of genetic engineering techniques where it was possible to isolate and clone any piece of DNA and availability of simple and fast techniques for determinating DNA sequences.

Science world HSN

Date
Page

a very ambitious project of sequencing human genome was launched in the year 1990.

- Human genome project [HGP] was called a Mega project. } Human genome ~ 3×10^9 bp. } The total estimated cost of the project would be approx. 9 billion US dollars
- The enormous amount of data expected to be generated also necessitated the use of high speed computational devices for data storage and retrieval, and analysis. } HGP was closely associated with the rapid development of a new area in biology called Bioinformatics.
- Goals of HGP : Identify all the approx. 20,000 - 25,000 genes in human DNA. } Determination of sequences of the three billion base pairs of human DNA. } Store this information in databases., Improve tools for data analysis. } Transfer related technologies to other sectors, such as industries. } Address to ethical, and social issues [ELSI] that may arise from the project.
- Human genome project was a 13-year project coordinated by the U.S. Department of Energy and the National Institute of Health. } During the early years of the HGP, the Wellcome Trust [U.K] became a major partner, additional contributions came from Japan, France, Germany, China and others
- The project was completed in 2003.
- Knowledge about the effects of DNA variations among individuals can lead to revolutionary new ways of diagnose, treat and some day prevent the thousands of disorders that affect human beings
- Besides providing clues to understanding human biology, learning about non-human organisms DNA sequences can lead to an understanding of their natural capabilities that can be applied toward solving challenges in healthcare, Agriculture, energy production, Environmental remediation.
- Environmental remediation deals with the removal of pollution or contaminants media such as soil, ground water, sediment or surface water.
- many non-human organisms, such as Bacteria, Yeast, caenorhabditis

elegans [a free living non-pathogenic nematode], Drosophila [A fruit fly], plants [Rice and Arabidopsis], etc have also been sequenced.

- Methodologies: The methods involved two major approaches: } one approach focused on identifying all the genes that are expressed as RNA [referred to as Expressed Sequence Tags (ESTs)] } the other took the blind approach of simply sequencing of whole set of genome that contained all the coding and non-coding sequence, and later assigning different regions in the sequence with functions [a term referred to as Sequence Annotation].
- for sequencing, the total DNA from a cell is isolated and converted into random fragments of relatively smaller sizes and cot cloned in suitable host using specialised vectors
- The cloning resulted into amplification of each piece of DNA fragment so that the subsequently should be sequenced with ease. } The commonly used hosts were bacterium and yeast, and the vectors were called a BAC [Bacterial artificial chromosome] and YAC [yeast artificial chromosome].
- The fragments were sequenced using Automated DNA sequencers, that worked on the principal of a method developed by Frederick Sanger. [Remember, Sanger is also awarded for developing method for determination of amino acid sequences of proteins] } These sequences were then arranged based on some overlapping regions present in them } this required of developing fragments for sequencing.
- Alignment of these sequences was humanly not possible. } Therefore, specialised computer based programs were developed. } these sequence were subsequently annotated and were assigned to each chromosome.
- The sequence of chromosome 1 was completed only in May 2006 [this was the last of the 24 human chromosomes - 22 autosomes and X and Y - to be sequenced.]

Science world HSN

Date
Page

- Another challenging task was assigning the genetic and physical maps on the genome. This was generated using information ~~for~~ on polymorphism of restriction endonuclease recognition sites, and some repitative DNA sequences K(a) Microsatellites
- Salient features of Human genome: Human genome contains 3164.7 million bp. The average gene consists of 3000 bases; but size vary greatly, with the largest known human gene being dystrophin at 2.4 million bases. The total number of genes is estimated at 30,000- much lower than previous estimates of 80,000 to 1,40,000 genes. Almost all [99.9%] Nt bases are exactly the same in all people. The functions are unknown for over 50% of the discovered genes. Less than 2% of the genome codes for proteins. Repeated sequences make up very large portion of the human genome. Repetitive sequences are stretches of DNA sequences that are repeated many times, some times hundred to thousand times. They are thought to have no direct coding functions, but they shed light on chromosome str, dynamics and evolution. Chromosome 1 has most genes [2968], and the Y has the fewest [231].
- Scientists have identified about 1.4 million locations where single base DNA differences [SNPs - Single nucleotide polymorphism, pronounced as 'snips'] occur in human. This information promises to revolutionise the processes of finding chromosomal locations for disease-associated sequences and tracing human history.
- Applications and future challenges: Deriving meaningful knowledge from the DNA sequences will define research through the coming decades leading to our understanding of biological systems. This enormous task will require to expertise and creativity of tens of thousands of scientists from varied disciplines in both the public and private sectors worldwide. One of the greatest impacts of having the HG sequences may well be enabling and radially new approach

to biological research. They can study all the genes in a genome, for example, all the transcripts in a particular tissue or organ or tumor, or how ten of thousands of genes and proteins work together in interconnection networks to orchestrate the chemistry of life.

(21) DNA fingerprinting : 99.9% of bases sequence among humans is the same. Assuming human genome as 3×10^9 bp, in how many bases sequences would there be differences?

- It is these differences in sequence of DNA which make every individual unique in their phenotypic appearance.
- If one aims to find of genetic differences two individuals or among individuals of a population, sequencing the DNA every time would be a daunting and expensive task. Imagine trying to compare two sets of 3×10^6 bp.
- DNA fingerprinting is a very quick way to compair the DNA sequences of any two individuals.
- DNA fingerprinting involves identifying differences in some specific regions in DNA sequence called as repetive DNA, b/c in these sequences, a small stretch of DNA is repeated many times. These repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation. The bulk DNA forms a major peak and the other small peaks are referred to as satellite DNA.
- DNA fingerprinting is done in many steps. It would involve- Collection of biological sample. extraction of DNA. amplication of DNA in PCR machine. cutting the DNA in fragments. arranging the fragments on nitrocellulose membrane. Hybridising specific sequences by using radioactive probes. washing the membrane before developing on X-ray film.
- The X-ray plate will remain as a permanent genetic 'fingerprint'

Basis of DNA finger printing → RFLP.

Science world HSN

Date
Page

of the person.) such fingerprints are inherited : 50% from mother and 50% from father, hence a person could be easily identified when fingerprints are compared b/w parents / siblings.

- Depending on base composition [A:T rich or G:C rich], length of segment, and number of repetitive units, the satellite DNA is classified into many categories, such as micro-satellite, mini-satellite etc.) these sequences normally do not code for any proteins, but they form a large portion of human genome.) these sequence show high degree of polymorphism and form the basis of DNA fingerprinting [RFLP].
- SSR is also k/as microsatellite or short tandem repeat [STR].) segment of DNA consists of tandemly repeated unit, each b/w one and 10 bp. in length such as $[TG]_n$ or $[AAT]_n$.

$(TG)_6 = TGTGTGTGTGTG.$

- Single Nt polymorphism : it arise due to single Nt substitutions [transition / transversions] or single Nt insertions / deletions.) these point mutations give rise to different alleles with alternative bases at a particular Nt positions.) SNP are the most abundant polymorphisms in the genome [coding- and non-coding] of any organism.) these single Nt variants can be detected using PCR, microchip arrays or fluorescence technology.
- DNA probe :- They have a specific base sequence that is complementary to the base sequence of part of the target allele.
- Since DNA from every tissue [such as blood, hair-follicles, skin, bone, saliva, sperm, etc.] from an individuals show the same degree of polymorphism, they become very useful identification tool in forensic applications.
- further, as the polymorphisms are inheritable from parents to children, DNA fingerprinting is the basis of paternity testing, in case of disputes.
- A polymorphism in DNA sequence is the basis of genetic mapping of human genome as well as of DNA fingerprinting, it is essential

Date
Page

that we understand what DNA polymorphism means in simple terms.}
polymorphism [variation at genetic level] arises due to mutations.}
New mutations may arise in an individual either in somatic cells or in the germ cells [cells that generate gametes in sexually reproducing organisms.]
- If a germ cell mutation does not seriously impair individuals ability to have offspring who can transmit the ~~mutation~~ mutation, it can spread to the other members of populations [through sexual reproduction].
- Allelic sequence variation has traditionally been described as a DNA polymorphism if more than one variant [allele] at the locus occurs in human population with a frequency greater than 0.01.
- In simple terms, if an inheritable mutation is observed in a population at high frequency, it is referred to as DNA polymorphism.
- The probability of such variation to be observed in non-coding DNA sequence would be higher as mutations in these sequences may not having immediate effect/impact in an individual's reproductive ability.} these mutation keep on accumulating generation after generation, a form one of the basis of variability/polymorphism.
- There is a variety of different types of polymorphisms ranging from single Nt change to very large scale changes.} for evolution and speciation such polymorphisms play very important role.
- The techiques is of DNA fingerprinting was initially developed by Alec Jeffreys.} He used a satellite DNA as probe that show very high degree of polymorphism.} It was called as Variable number of Tandem Repeats [VNTR].} The techniques, as used earlier, involved Southern blot hybridization using radiolabelled VNTR as a probe.
- It induced ~~or~~ isolation of DNA.} Digestion of DNA by restriction endonuclease} separation of DNA fragments by electrophoresis.} Transferring [blotting] of separated DNA fragments to synthetic membranes, such as nitrocellulose or nylon.} Hybridisation using labelled VNTR probe}

Detection of hybridised DNA fragments by autoradiography

- The VNTR belongs to a class of satellite DNA referred to as minisatellite. {A small DNA sequence is arranged tandemly in many copy numbers.} The copy number varies from chromosome to chromosome in an individual.} The number of repeat show very high degree of polymorphism.} As, a result the size of VNTR varies in size from 0.1 to 20 kb.
- Consequently, after hybridisation with VNTR probe, the ~~exx~~ auto-radiogram gives many bands of differing size.} These bands give a characteristic pattern for an individual DNA.
- It differs from individual to individual in a population except in case of the monozygotic [identical] twins.} The sensitivity of the technique has be Ted by use of PCR.
- Consequently, DNA from a single cell is ~~i~~ enough to perform DNA fingerprinting analysis.} In addition of application in forensic science, it has much wider application, such as in determining population and genetic diversities
- Currently many different probes are used to generate DNA finger-prints
- Lalgi ~~Sha~~ Singh ~~is~~ father of indian DNA fingerprinting.

Plant Anatomy

Science world HSN

classmate
Date 24/09/018
Page

① The branch of botany dealing with the internal organisation of plants is called plant anatomy. } father of plant anatomy ↝ Grew

- Definition of tissue : A group of physically linked cells and associated intercellular substances having common origin and specialized for performing particular identical function.
- Specialization in tissue ↝ Increased efficiency } Physically linking ↝ Co-ordination. } Term tissue ↝ Grew.
- Plant tissue : Two types ① maristematic tissue ② permanent tissue.
- Study of internal st^re of plants is called Anatomy. } Plants have cells as the basic unit, cells are organised into tissues and in turn the tissues are organised into ~~organs~~ (wrong). } Different organs in a plant show differences in their internal st^re } within angiosperms, the monocots and dicots are also seen to be anatomically different. } Internal st^re also show Adoptations to diverse environments.
- A tissue of a group of cells having a common origin and usually performing a common function. } A plant is made up of different kinds of tissue } Tissue are classified into two main groups, namely; maristematic and permanent tissue } Based on whether the cells being formed are capable of dividing or not.
- Maristematic tissue : Growth in plants is largely restricted to specialised regions of active cell divisions called maristem. [Gk. maristos : divide]. } Plants have different kinds of maristems. } The maristem which occur at the tips of roots and shoots and produces primary tissues are called Apical maristems } Root apical maristems occupies the tip of a root while the shoot apical maristem occupies the distant most region of the stem axis. } During the formation of leaves and elongation of stem, some cells 'behind left' from shoot apical maristem, constitute the axillary bud. [marginal maristem]. Such buds are present in the axils of leaves and are capable of forming a branch or a flower.
- The maristem which occurs b/w mature tissues is Kles Intercalary maristem. } They occur in grasses and regenerate parts removed by the grazing herbivores.

- Both apical meristems and intercalary meristems are primary meristems b/c they appear early in life of a plant and contribute to the formation of the primary plant body.
- The meristem that occurs in the mature regions of roots and shoots of many plants, particularly those that produce woody axis and appear later than primary meristem is called secondry or lateral meristem. They are cylindrical meristem. ? fascicular vascular cambium, Interfascicular cambium and cork-cambium are example of lateral meristems. These are responsible for producing the secondry tissue.
- following divisions of cells in both primary as well as secondry meristems, the newly formed cells become structurally and functionally specialised and loose the ability to divide such cells are termed permanent or mature cells and constitute the permanent tissues.
- meristematic tissue: All the cells of the embryo of a plant are capable of division but with the growth of the plant this feature becomes restricted to only certain regions. ? A meristem [Gk. meristos: divisible] is a localised region in which actual cell division occurs.
- A/to their origin and development meristems are classified as promeristems, 1° meristem and 2° meristem. ? The meristem may also be classified according their position in the plant body as apical, intercalary and lateral.
- Unique features of meristem cells: spherical, polygonal, oval in shape? * Compactly arranged and lack intercellular space. ? Thin, homogenous and cellulosic cell wall. ? Dense cytoplasm and prominent nuclei. ? * Central vacuole not present. ? Plastid → proplastids. ? undifferentiated cells. ? Capacity of division.
- classification of meristem: ① on the basis of origin and development: ⇒ (A) promeristem → gives rise to 1° meristem. (B) 1° meristem → gives rise to primary permanent tissue. (C) 2° meristem → gives rise to 2° tissue.

Collenchyma absent in monocot.

science world HSN

② meristem on the basis of position :- ⇒ (A) Apical meristem ⇒ responsible for 1° growth. (B) Intercalary meristem ⇒ responsible for 1° growth. (C) Lateral meristem ⇒ Responsible 2° growth. } two types- (1) Vascular cambium (2) Cork cambium.

③ meristem on the basis of function :- ⇒ (A) protoderm ⇒ Produce epidermis (B) Procambium ⇒ produce vascular bundle (C) Ground meristem ⇒ Rest of the tissue

④ meristem on the basis of plane of division :- ⇒ (A) mass meristem ⇒ 3D plane growth volume Teg. (B) Plate meristem ⇒ 2D plane growth. Area Teg. (C) Rib/file meristem ⇒ 1D plane growth. Length Teg.

⑤ Theories related with shoot apex :- Apical cell theory : Nogeli, Hofmeister } * Histogen theory : Hanstein. } Tunica corpus theory : schmidt. } mantle core hypothesis : popham and cham. } Histogenic layer theory : Dermon. } * Annual initial and meristem d attord theory : Buvat.

- Apical cell theory : for Cryptogams [Bryophyte & pteridophyte]

* Histogen theory : developed by Hanstein } The main body of the plant arises from the histogens. } (A) Dermatogen : precursor of Epidermis (B) periblem : gives rise to cortex. (C) Plerome : constitutes the inner mass of the axis.

- Types of shoot apex — (A) monoplex type ⇒  (B) simplex type ⇒  (C) Duplex type ⇒

- Theory related with root apex :- (1) Apical cell theory } (2) Histogen theory :- Calyptrogen } (3) Kamper kappe theory :- Schuepp. } (4) T- body of root, Inverted T- root apex.

- Permanent tissues :- the permanent tissue comprises cell which have lost their capacity of division. } the permanent tissues may be classified two groups ⇒ (1) Simple permanent (2) Complex permanent.

- Secretary tissue are the third type of permanent tissue

(1) Simple permanent tissue :- these are homogeneous in nature and are composed of structurally and functionally similar cells. } three types — (1) Parenchyma (2) Collenchyma (3) Sclerenchyma

classmate
Date
Page

Parenchyma : It is the most common tissue } morphologically & physiologically unspecialised, forms the framework of all the plant organs and tissues like cortex, pith, mesophyll of leaf and floral parts. } Isodiametric cells but may be elongated or even lobed as in the mesophyll tissue of the leaves } These may be either be closely packed or show small intercellular spaces } The plasmodesmata [the thread like cytoplasmic strands, running from one cell to other.] are commonly present. } foundation tissue of the plant.
- when the parenchymatous cells are exposed to light, these develop chloroplast in them and such a tissue is/as chlorenchyma.
- The cells of parenchyma are involved in the various physiological activities like photosynthesis, assimilation, storage, secretion, excretion, etc.
- fruit pulp : parenchyma, having intercellular space.
- Endosperm of seed : parenchyma, not having intercellular space.
- 14 facet are present in closely packed parenchyma cell.
- Great variation in arrangement. } 1° cell wall, mainly cellulosic } component of xylem and phloem. } Helpful in healing } may regain the power of cell division, and gives rise to 2° meristem. } Cutinized parenchyma of leaf epidermis : protective in nature.
- In succulent plants : parenchyma cells store water in the form of mucilage.
- In aquatic plants the air is present in the intercellular space of parenchyma, such parenchyma is called : Aerenchyma.
- Prosenchyma : Elongated parenchyma.
- Stellate parenchyma : star shaped parenchyma.
- Idioblast : parenchyma with excretory material like tannin, oils, crystals of calcium oxalate.
- main tissue of pith or medulla : parenchyma.

(3)- Collenchyma : Composed of more or less elongated cells with primary, non lignified cell walls } Their cell wall is the most distinctive feature which is characteristically unevenly thickened. } The wall thickening is primary in nature and composed of cellulose, hemicellulose and pectic materials with a high percentage of water. } The thickenings may be primarily at the corners or angles of the cell. } Polygonal in shape

- These have vacuolated protoplasts [mature cell] and occur characteristically in the hypodermis [the layer lies below the epidermis] of herbaceous dicot, either as a homogeneous layer or in patches } These cell constitute an effective mechanical tissue and provide elasticity and support the growing organs
- Unique in distribution : present only in dicot } Present only in stem } Present only in cortex [hypodermis] } Never present in monocot } Never present in root } Never present in underground stem
- Also present in : Angles of young stem } mid rib of leaves } floral stalks
- On the basis of thickening on cell wall, there are three types of collenchyma.

Ⓐ Angular collenchyma : cell wall highly thicked at corners } Compact tissue

Ⓑ Lacunar / tubular collenchyma : the thickening are restricted to the wall regions bordering air spaces } These have large intercellular spaces

Ⓒ Plate / lamellar collenchyma : thickening at the tangential plane } Less on radial wall.

* Collenchyma is the living mechanical tissue of the plant } All mechanical tissue of plant : Stereome } Stereome = collenchyma + sclerenchyma.
- It provide tensile strength to plant } Provide mechanical support.
* Collenchyma : main supporting tissue in young plants and climbers } may protect VB of leaves
- Sclerenchyma : derived greek work : sclero = hard } thick walled and lignified tissue } have simple pits } Lignin deposite on the secondry wall.
- Two types — ① fibers ② sclereids / stone cells

① fibers : fibers are much elongated and have pointed needle like ends (tapering ends) } Always dead } * originated from : procambium of apical meristem and fusiform initial cells of cambium.
- classification of fibers : on the basis of their positions in the plant the fibers are classified into two large groups :-

Ⓐ Intraxylary / wood fiber : in xylem } two types
- Libriform fiber : simple pit and very thick wall.
- fiber tracheid : Bordered pit but comparatively thin wall } ~~Both type of fibers are septate~~ Both type of fiber are septate

Ⓑ Extraxylary / Bast fiber : in phloem } three type

- Cortical fiber: In cortex region
- Perivascular cambium: In the periphery of vascular bundles
- Phloic fiber: In the phloem.
- All are long spindle like } Having simple / Bordered pit
- function of fibers: provide mechanical support } maintaining elasticity and flexibility. } Economically important.

② Sclereids: These are Non-prosenchymatous cells. } without pointed ends } Dead cells of different shapes } originated from: In leaves from epidermal cells, In vascular bundle from cambium, In periderm from cork cambium, In seed coat from protoderm.

Types of sclereids / stone cells: (A) Brachy sclereids: Spherical and Iso-diametric. Ex* fruit pulp of pyrus

(B) macro sclereids: elongated and columnar Ex* seed coat of leguminosae [Pulse].

(C) Osteosclereids: Bone / Barrel shaped

(D) Astrosclereids: star shaped

(E) Trichosclerids: hairlike and branched / unbranched

- function of sclereids: provide stiffness and mechanical strength to the soft part of plants } produce hard texture for protection of fruit and seed

(A)- Complex permanent tissue: Heterogenous in nature } Composed of ~~different~~ type of cells } Xylem and phloem are complex tissue of plant } Both together form vascular bundles.

Xylem: It consists of four elements –

① Xylem trachids ② Xylem vessels ③ Xylem fibers ④ Xylem parenchyma.

① Xylem tracheids: originate from procambium or vascular cambium } very much elongated tube like cell } Thick lignified wall } large lumen than fibers } Dead, devoid of protoplast } fundamental and primitive type of xylem cell } present in all plant groups. } Ancient vascular plant have only tracheids in xylem.

- Pits are present in tracheids } Pits are unthicked circular areas in cell wall } These are of two types: (A) simple pits: - only primary wall without any secondary thickening. (B) Bordered pits: - dome shaped the pit is surrounding by a border of secondary thickening.

*Bordered pits are very common in the metaxylem of gymnosperm.

function of tracheids : well adopted to transport of water and dissolved solutes } main conducting elements of Gymnosperms and pteridophyta } Also provide mechanical support.

② Xylem vessels : Arises from procambium or cambium } In vessel cells the pattern of secondary wall deposition determines by microfibrils } long cylindrical tube like str. } formed from a row of cells placed end to end } partition wall dissappeared ⟶ resulting a elongated tube } Dead at maturity thick lignified wall with a broader lumen } Advanced type of conducting elements }

* Xylem vessels are characteristic of Angiosperms } * Some primitive families are vessel less → Winteraceae, Trochodendraceae and tetracentraceae } * Pteridophyta with vessels → Selaginella, Pteridium } * Gymnosperm with vessel → Gnetum, Welwitschia, afrida [Gnetaceae].

- function of vessel : more advanced than tracheids so more effient in water and mineral conduction } Provide mechanical conduction.

③ Xylem fibers : Do not conduct water } Dead, sclerenchymatous } Provide mechanical strength.

④ Xylem parenchyma : parenchyma associated with xylem } only living part of xylem } Two types : Axial / wood parenchyma → vertically arranged, may differentiated into new vessels or other parts. ② Ray parenchyma → horizontally arranged, helps in radial conduction of water.

- Xylem parenchyma is diffused → Apotracheal parenchyma.
- Xylem parenchyma surrounds the vessels → Paratracheal parenchyma.
- Special : Tern xylem → Hogeli } Transfer cell : helps in solute transport, these are modified parenchyma, having infoldings in cell wall to its surface area.

⑧ - 1° xylem is of two types - protoxylem and metaxylem } The first formed primary xylem elements are called protoxylem and the later formed primary xylem is called metaxylem. } In stems, the protoxylem lies towards the centre [pith] and the metaxylem lies towards the periphery of the organ } This type of primary xylem is called endarch } In roots, the protoxylem lies towards periphery and metaxylem lies toward the centre. Such arrangement of primary

xylem is called endarch.

Exarch xylem	Endarch xylem
protoxylem is towards the outer side of the organ.	Protoxylem is towards the centre of the organ.
Characteristic of roots.	Characteristic of stems

- phloem transports food materials, usually from leaves to other parts of the plant. } Phloem in angiosperms is composed of sieve tube elements, companion cells, phloem parenchyma and phloem fibres.
- Gymnosperms lack sieve tubes and companion cells.
- Sieve tube elements are also long, tube like st^r, arranged longitudinally and are associated with the companion cells. } their end walls are perforated in a sieve like manner to form the sieve plates.
- A mature sieve tube element possesses a peripheral cytoplasm and a large vacuole but lacks a nucleus. } The functions of sieve tubes are controlled by the nucleus of companion cells. } The companion cells are specialised parenchymatous cells, which are closely associated with sieve tube elements. } The sieve tube elements and companion cells are connected by pit fields present b/w their common longitudnal walls. } The companion cell helps in maintaining the pressure gradient in the seive tubes.
- phloem parenchyma is made up of elongated, tapering cylindrical cells which have dense cytoplasm and nucleus. } The cell wall composed of cellulose and has pits through which plasmodesmatal connection exist b/w the cells.
- The phloem parenchyma stores food material and other substances like resins, latex, and mucilage. } phloem parenchyma is absent in most of the monocot. }
- phloem fibres [bast fibres] are made up of sclerenchymatous cells. } These are generally absent in the primary phloem but are found in the secondary phloem. } These are much elongated, unbranched and have pointed, middle like apices. } The cell wall of phloem fibers is quite thick } At maturity, these fibers loose their protoplasm and become dead. } phloem fibres of Jute, flax and hemp are used commercially.
- The first form primary phloem consists a narrow sieve tube and is referred to as protophloem and the later formed phloem has bigger

classmate
Date
Page

sieve tubes and referred to a metaphloem.

- phloem: Another type of complex tissue. } also called Bast or leptome. } It is similar to xylem in that ~~progress~~ tubular structures. } involve in food translocation. } consist of four elements.

① sieve elements [sieve tube | sieve cells] ② Companion cells ③ phloem parenchyma ④ phloem fibres

- The different elements of phloem originate from the procambium or vascular cambium.

primary phloem: originate from procambium

secondary phloem: originate from vascular cambium.

① sieve elements: Two types {① less specialised → sieve cell ② more specialised → sieve tube. } sieve cell are narrow elongated cells without conspicuous sieve areas } sieve cells are found among members of lower vascular plants and Cycadophytes } sieve cells are analogous to tracheids

- sieve tube discovered by Hartig. } Long tube like cylindrical bodies } Arranged in longitudinal series. } The end wall are perforated in a sieve like manner and referred to as sieve plate. } The sieve plate is a more specialised area found usually in or near on end wall.

- If sieve plate have one sieve area → simple } If sieve plate have several sieve areas → compound.

- Sieve tube cell → having 1° walls. } Composed of cellulose. } Sieve tube cells are the living cells in plant kingdom that lack the nuclei at maturity but remain survived. This is unique feature of these cells.

- In mature sieve tube cell } Thin layer of parietal cytoplasm. } Large central vacuole } several trans cellular strands running longitudnally through the sieve area. } Trans cellular strands are made by P- protein [phloem protein] } maintain continuity b/w sieve tube cells and helps in conduction. } pores are present in transverse wall called sieve pores. } Each sieve pore has a single strand of cytoplasm extending through it and connect to the protoplast of adjoining sieve tube. } Border of sieve pore is surrounded by a layer of callose carbohydrate and thus the plasmodesmata or cytoplasmic strand with in the pore remain enclosed in a cylinder of callose.

- In mature sieve tube cell :- during maturation Nucleus, tonoplast and

vacuole disintegrate. { Ribosome and Golgi complex disappear. } mitochondria present [having few cristae]. } cytoplasm + cell sap → nyctoplasm. it is a homogenous sap.

- function of sieve elements : food translocation in both upward and down ward direction. } food translocated in the form of sucrose as organic solute.
- Atlas special : In phloem is inner to xylem → internal / intraxylary phloem. Ex Apocynaceae, asclepidiaceae, myrtaceae, solanaceae } of phloem patches are present in the secondry xylem → included / interxylary phloem. e.g. Amaranthaceae, chenopodiaceae, nyctaginaceae } A proteinaceous component p-protein makes it appearance in the cytoplasm as discrete slime bodies } slime plugs are dense funnel shaped str formed by the coagulation of slime bodies on sieve plate. } sieve tube → characteristic of Angiosperm.

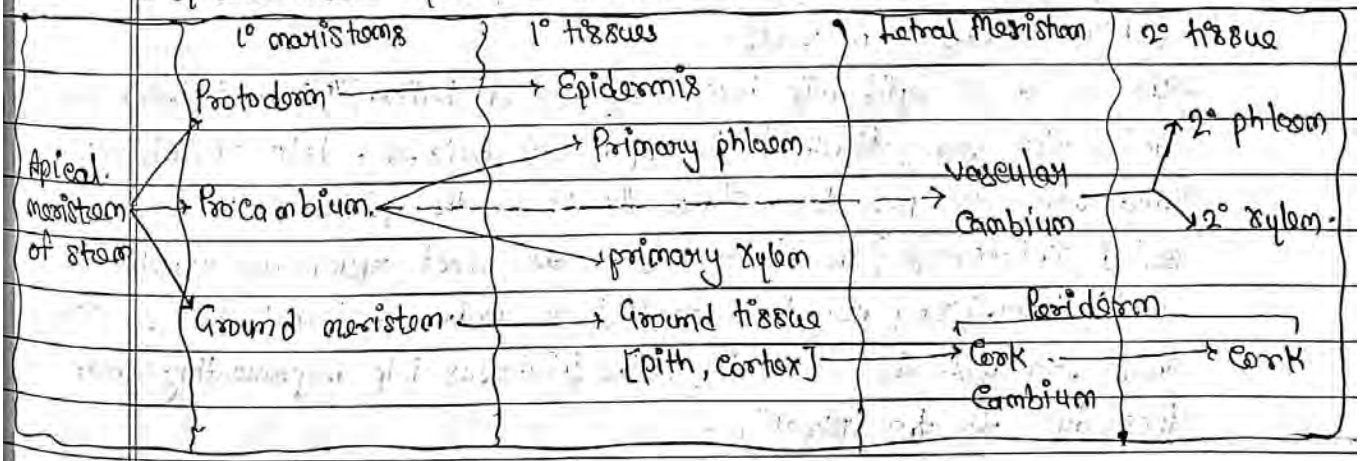
Xylem vessels	sieve tube
- open ends } wider	perforated and } Narrow
- Thick lignified cell wall	Thin cellulosic wall.
- Specialized thickening in wall.	No specialised thickening in wall.
- Dead but functional	living and functional
- freely permeable	Selective permeable
- low OP, Not having T.P.	High OP, having T.P.
- partially collaps when functional	partially distended when functional.
- Translocate both solvent & solute	Translocate only solute
- Translocation speed → 15 cm/min.	Translocation speed → 8 cm/min.

(B) Companion cells : Thin walled elongated cells } Associated with sieve tube cell } Both sieve tube and companion cell are sister cells } connected by simple pits } living cell with dense cytoplasm. } All functional cell organelle are present. } sharing common wall with sieve tube. } starch grain never present in these cells.

- The sieve tube cell not having nucleus so the nuclei of companion cell maintain the sieve tube cell and take care of it. } Essential for sieve tube cell so helps in food translocation. } maintain passer gradient in sieve tube and provide energy to it [for loading and unloading.]

- Companion cell are the characteristic of angiosperm only.
- Special: In pteridophyta & Gymnosperms some parenchyma cells remain associated with the sieve cells → Albuminous cells.} Albuminous cell are not sister cell with sieve cell, these are analogous to companion cell.
- ④ phloem parenchyma { parenchyma associated with phloem} Associated with storage of food and helps in radial conduction.} ~~Never~~ Never present normal.
- ⑤ phloem fibres: Also called Bast fibre} sclerenchymatous, extra xylary.} provide mechanical support.} phloem without fibre → Leptome} Term phloem. → Nogeli.
- ⑥ Special tissue [Secretory tissue]: Specialized for secretion} External secretory tissue → Digestive glands, Stinging hairs, Nectaries, Osmophores, Hydrathodes etc
- In many plants certain localized cells are only involved in producing the fragrant materials. The cells differ markedly from the other normal cells situated nearby and are termed as Osmophores. The osmophores secretes terpenes as the main fragrant materials.
- Epithem tissue present in hydathode.
- Internal secretory tissue → Secretory cells} ~~Oil~~ Oil glands: cavity → schizogenous, lysogenous} Lactiferous tissue → Latex cell; latex vessels
- Special: latex of papaya → papine enzyme.} latex of Banana → Tannin.
- Tissue system: structural tissue on the basis of physiological similarities and in reference to division of labor, are organised into tissue system.} A/to Sach there are three type of tissue system in plants.

① Epiderm tissue system ② Ground t.s ③ Vascular t.s



- Epidermal tissue system : outer most layer of the plant body. } originate from protoderm. } single layered epidermis ↔ uniseriate } multilayered epidermis ↔ multiseriate } * multiseriate epidermis characteristic of xerophytic habitate plants eg. ficus; Nerium, peperomia; cactus
structure of epidermal cell ↔ parenchymatous in nature } compactly arranged } intercellular space absent. } living cells } Have large central vacuole. } cutinized cell wall on outer surface. } cutin is a wax like material. } cuticle ↔ layer of cutin } cuticle never present in root } Epidermis of root without cuticle :↔ Epiblema. } Thick cuticle ↔ xerophytic plant } cuticle absent ↔ submerged hydrophytes. } cuticle thin ↔ exposed surface of hydrophyte } cuticle :↔ adoptation to xerophytic condition. } cuticle resistant to oxidation. } cuticle prevent loss of water.
- function of Epidermis : protective layer. } Reduce loss of water } store water in succulents } photosynthesis if green } modified str are present for various functions.

(1) Epidermal tissue system : The epidermal tissue system forms the outer most covering of the whole plant body and comprises epidermal cells, stomata and the epidermal appendages- the trichomes and hairs. } The epidermis is the outermost layer of the primary plant body. } It is made up of elongated, compactly arranged cells ; which forms a continuous layer. } Epidermis is usually single layered. } Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole } The outside of the epidermis is often covered with a waxy thick layer called cuticle which prevents the loss of water } cuticle is absent in roots.
- The cells of epidermis bear a number of hairs. } * The root hairs are unicellular elongations of the epidermal cells and help absorb water and minerals from the soil. } on the stem the epidermal hairs are called trichomes } the trichomes in the shoot system are usually multicellular. } They may be branched or unbranched and soft or stiff. } They may even be secretory. } The trichomes help in preventing water loss due to transpiration.

classmate
Date
Page

- Special epidermal str: (A) Lithocytes :→ Cystolith [Gr 'cavity' and 'stone'] is out growths of the epidermal cell wall, usually of $CaCO_3$, formed in special cells called lithocyte.] present in → Many genera of Acanthaceae] plant in the family Urticaceae, Cannabis and other plants in the family Cannabinaceae, and Ficus Elastica, the Indian rubber plant of the family Moraceae

(B) Myrosin cell : myrosinase is stored largely as myrosin grains in the vacuoles of particular idioblasts called myrosin cells.] Cells containing glucosinolates and myrosinases, enzymes hydrolysing the glucosinolates.] The myrosinase - glucosinolate system is a chemical defence system against herbivory in Brassicales.

(C) Bulliform cell : These are large, bubble-shaped epidermal cells.] occur in groups on the upper surface of the leaves of many monocots. [adaxial surface of the leaf.].] They are generally present near the mid vein.] These cells are large, empty and colourless.] Bulliform cells help in rolling of leaves to prevent loss of water through transpiration during stress conditions.

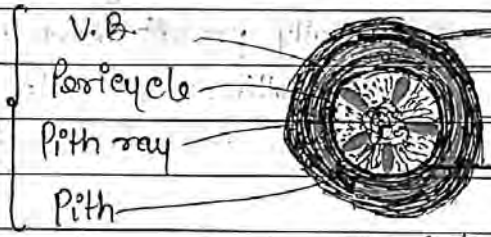
(D) Root hairs : Root hairs are tubular extensions of the epidermis that greatly Inc the surface area of the root.] The function of root hairs is to collect water and mineral ~~nutri~~ nutrients present in the soil and take this solution up through the roots to the rest of the plant.

(E) Stomata : stomata are tiny openings or pores in plant tissue that allow for gas exchange.] stomata are typically found in plant leaves but can also be found in some stems.] specialised cells Klas guard cells surround stomata and function to open and close stomatal pores.

- stomata are structures present in the epidermis of leaves.] stomata regulate the process of transpiration and gaseous exchange.] Each stoma is composed of two bean shaped cells Klas guard cells which enclose ~~sto~~ stomatal pore.
- In grasses, the guard cells are dumb-bell shaped.] The outer wall of guard cells [away from the stomatal pore] are thin and the inner walls [towards the stomatal pore] are highly thickened.] The guard cell possess chloroplasts and regulate the opening and closing of stomata.

- Sometimes, a few epidermal cells, in the vicinity of the ~~gua~~ guard cells become specialised in their shape and size and are ~~the~~ as subsidiary cells.
- The stomatal apparatus, guard cells and the surrounding subsidiary cells are together called stomatal apparatus.
- Ground tissue system : Bla epidermis and V.B. } Heterogenous in nature } major mass of plant body. } Diversified functions } Includes : Cortex ; Pericycle , pith and pith rays. } partially ~~origin~~ originate from pribiem and partly from plerome
- Cortex : Extra stelar zone } Bla epidermis and stele } Three zones — (a) Hypodermis (b) General cortex (c) Endodermis.

(a) (a) Hypodermis : just below epidermis. } Dicot stem → collenchymatous } monocot stem → sclerenchymatous } provide protection to the internal tissues.



T.S. of dicot

- provide mechanical support to peripheral regions. } Absent in roots. } In green stem of monocot it may be chlorenchymatous eg Ruscus and asparagus
(b) General cortex : Bla Hypodermis and endodermis. } parenchymatous } loosely arranged cells with inner cellular space } starch grains are present } chloroplast may / may not present } function → food storage, to participate in metabolic activities.

(c) Endodermis : Innermost layer of cortex. } Limiting layer of ~~cortex~~ stele } single layered } Compactly arranged modified parenchyma cells. } Intercellular space absent. } Vertically elongated cells. } Barrel shaped cells in cross section.
* The endodermal cells are characterized by the presence of waxy substance like suberin in the form of band or strips on their radial plane and transverse walls, these are commonly called Casparian strips.
- Casparian strips → discovered by ~~Casp~~ caspary. } Lignin may also found in casparian strips.

- function of endodermis : water tight jacket b/w xylem and cortex.} Act like air dam.} protective [accessory epidermis].} Regulate and maintain root pressure} Act like water dam.} synthesized water flow ↔ passage cells.} Starch sheath.
Special : In root cortex is homogenous, consists of only parenchyma.} When general cortex and hypodermis are not differentiated Ground tissue} passage cell lack casparian strips} Endodermis absent in ↔ woody stem of dicot and gymnosperm and in angiosperm leaves
- pericycle : B/w Endodermis and vascular bundles} one or several layered} outer most part of stele} Intrastellar tissue} In all roots ↔ Homogenous, parenchymatous} Dicot stem ↔ heterogenous, sclerenchymatous and parenchyma.} pteridophyta ↔ homogenous, parenchymatous
- function of pericycle : In roots it gives rise to lateral roots, it becomes meristematic to form lateral roots so called pericambium.} In stem cork cambium may arises from it.} In abnormal 2° growth it may give rise to 2° cambium.} In monocot it is sclerenchymatous ↔ mechanical support.} storage of food material
- Special : pericycle absents in ↔ Root and stem of aquatic plants, parasitic angiosperm.} In pteridophyta ↔ pericycle single layered.} In Gymnosperm ↔ pericycle multilayered.} In angiosperm ↔ pericycle 2-3 layered
- pith / medulla : main internal more or less cylindrical ground tissue} forms central cylindrical of the stem.} Externally remain bonded by the VB.} Consists of isodiametric and loosely arranged parenchymatous cells} large intercellular spaces.} In young delicate stem ↔ may have chloroplast.} mature pith cell ↔ leucoplast are present.} organ of food storage} In dicot stem ↔ large, well developed pith.} In dicot root ↔ reduced pith} In monocot stem ↔ pith absent} In monocot root ↔ well developed pith.} In cucurbita absent ↔ Hollow pith.} Herbaceous dicot ↔ Hollow pith.} outermost cells of pith in some plants are smaller than normal cells ↔ medullary sheath / pre medullary zone
- pith ray / medullary ray : The VB remain separated due to the presence of long strips of parenchymatous tissues passing through them.} such strips are called ↔ pith rays.} In roots ↔ not distinct} Helps in radial conduction of food and water from cortex to pith region in both directions.

(4) Vascular tissue system: consists of xylem and phloem, together called vascular bundles. } distributed in stellar region. } originate from procambium / vascular cambium. } phloic procambium → primary phloem. } Xyloic procambium → primary xylem. } phloem always differentiate centripetally - from periphery to centre.

- three pattern of xylem differentiation: * Exarch → centripetal [in root] } * Endarch → centrifugally [in stem] } * mesarch → Both centripetal as well as centrifugal [fern rhizome]

- Elements of vascular bundles: A typical primary VB. of the dicot stem consists of three types of elements —

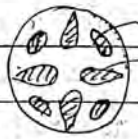
① primary xylem ② primary phloem. ③ fascicular / interfascicular cambium.

- fibres absent in protoxylem.

- fascicular cambium: present b/w xylem and phloem in VB. of stem of dicot and gymnosperm. } part of primary meristem. } tetral in position. } consists of two types of cells. ① fusiform initial ② Ray initial. } cambium cells are brick shaped. } one or two layered. } Have meristematic activity. } when present in VB. → they are called 'open type' } otherwise called 'close type' as in monocot stem and leaves.

- Types of vascular bundles: ① Radial VB. ② Conjoint VB. ③ concentric VB

① Radial vascular bundle: xylem and phloem are found as separate patches on alternate radii. } most primitive in nature. } * characteristic of Root.



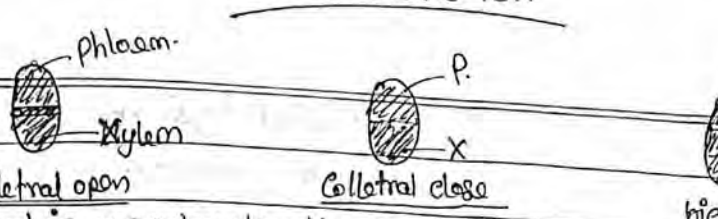
Radial VB

② Conjoint vascular bundle: xylem and phloem occurs side by side on the same radius. } Also the position of phloem these are recognized into two types.

ⓐ Collateral ⓑ bicollateral

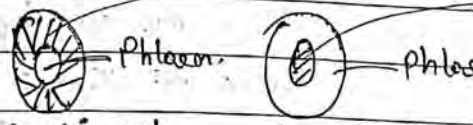
ⓐ Collateral conjoint VB.: xylem and phloem lie together on the same radius. } phloem external } xylem internal. } open type: - dicot stem. } close type: - monocot stem.

ⓑ Bicollateral conjoint VB: Two phloem patches one on outer side and other on inner side } * always open type. } * characteristic of family cucurbitaceae



Colletral open | Colletral close | bicolletral

② Concentric vascular bundles : one complex tissue remains completely surrounded by the other {always closed} Two types :- ① Amphivasal / leptocentric
② Amphicribal / hadrocentric



Amphivasal | Amphicribal

ⓐ Amphivasal :- xylem surrounds phloem. {present in Dracaena, yucca
ⓑ Amphicribal :- phloem surrounds xylem. {fern, lycopodium, selaginella,

Dicot stem V.B	monocot stem VB
- VB are uniform in size	VB are vary in size
- Each VB are conjoint, colletral or bi-colletral and open.	Each VB is conjoint, colletral and closed
- phloem parenchyma are present.	phloem parenchyma are absent.
- Bundle sheath is absent.	Bundle sheath is developed either partly or completely surrounding the VB
- No water containing cavity is present.	water containing cavity is present.
- VB are arranged in ring	VB are scattered in ground tissue

- Concept of stele : proposed by Von tieghem and douliot. {first time proposed for pteridophyta} use full in the comparative anatomical and phylogenetic studies

Root	Stem
- mistry in colour and irregular in shape	Usually green and straight.
- unicelled epidermal hairs	multicelled epidermal hairs
- cuticle layer and stomata absent	cuticle layer and stomata present.
- Epidermis takes the function of water absorption from soil.	Epidermis takes the function of protection.
- Hypodermis is not differentiated	Hypodermis is well differentiated
- Cortex is broad and well developed	Cortex is relatively less developed
- passage cell present	passage cell absent.
- pericycle single layer and parenchymatous	pericycle multilayered and usually sclerenchymatous

- Radial VB.	Colletral type VB.
- Xylem - Exarch.	Xylem - Endarch.
- Lateral roots - endogenous in origin.	Lateral ~~root~~ branch exogenous in origin.

Dicot stem	monocot stem.
- multicelled trichome generally ~~not~~.	trichome generally absent.
- Collenchymatous hypodermis.	Sclerenchymatous hypodermis.
- Cortex distinct	Cortex not distinct.
- Endodermis and pericycle are well distinct.	Endodermis and pericycle are not distinct
- VB arranged in a ring	VB are scattered in ground tissue
- Sclerenchymatous bundle sheath cell is not found	Sclerenchymatous bundle sheath cell is present.
- phloem parenchyma present	phloem parenchyma absent.
- Lysogenous cavity in VB is ~~present~~ absent.	Lysogenous cavity in VB is present, called protoxylem lacuna
- Both pith & pith rays are present.	Both pith and pith rays are absent.
- 2° growth present	2° growth absent.
- VB conjoint colletral open type	VB conjoint colletral close type.

Dicot root	monocot root.
- pericycle single layered	pericycle 2-3 layered.
- VB 2-6 i.e diarch to hexarch.	VB more than 6 i.e polyarch.
- pith reduced	well developed pith.
- 2° growth present	2° growth absent.

(10) Anatomy of leaf: single layered epidermis → cutinized outer wall of epidermal cells → in petiole, hypodermis → collenchymatous / sclerenchymatous → Ground tissue → parenchymatous → * VB → Conjoint colletral close type → Xylem → adaxial [facing upper surface] → phloem → abaxial [facing lower surface] → Xerophytes → multiple epidermis with sunken stomata and thick cuticle → Ground tissue of leaf b/w two epidermal layer → mesophyll.

- Dicot leaf → Dorsiventral → It means mesophyll differentiated into two zones - upper palisade parenchyma consists of columnar

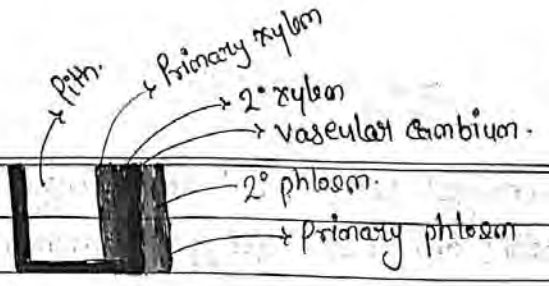
Compactly arranged cells; and lower spongy parenchyma consists of loosly arranged cells; and lower spongy parenchyma consist of loosly arranged parenchyma.

- monocot leaf → Isobilatral } It means uniform mesophyll.
- In leaf protoxylem face towards the adaxial / upper surface. } Bifacial leaf → dorsiventral leaf. } unifacial leaf → isobilatral leaf } Bulliform cells → seen in isobilatral leaves of some monocots. } Kidney shaped guard cell → Dicot } Dumbell shaped guard cell → monocot.

Secondary growth: The growth in main axis in length → due to 1° apical meristem : primary growth. } In most of the monocot, many annuals and herbaceous dicots have only primary growth.

- In majority of angiosperm and gymnosperm stem ↑es in girth due to 2° growth which is brought about by the activity of the lateral meristem } It occurs in the main stem and its branches

- **2° growth in intrastellar region:** The primary organization of a typical stem shows the presence of epidermis, cortex and stele } In stele the VB are conjoint, collateral and open type having fascicular / intrafascicular cambium. } The fascicular cambium is a type of lateral meristem which is found in stellar region and produces secondary xylem and secondary phloem. } In the presence of 2° growth the first step is the formation of cambium ring.
- **formation of cambium ring:** At the time of formation of cambium ring the fascicular [Intra fascicular] cambium of VBs becomes active and begin the meristematic activity } At the same time some cells b/w two VB [cells of pith rays] lying in the line with fascicular cambium also become meristematic and form interfascicular cambium. [Cambium b/w two VB.] } The inter fascicular cambium joins the strips of intrafascicular cambium from the sides to form a complete circular ring of cambium. } This is Klas cambium ring which gives rise to 2° tissue in the stellar region.
- The vascular cambium consists of two types of cells. ① fusiform initial → vertically oriented and produce different elements of 2° xylem and phloem. ② Ray initials → isodiametric cells which produce ray parenchyma in 2° xylem and phloem.



- 2° Vascular tissues: formed by the activity of cambium ring. The main difference b/w 1° and 2° xylem is that → 2° xylem has axial and radial [Horizontal] system while radial system is absent in primary xylem. 1° xylem has long tracheary elements in comparision to 2° xylem. There are no fundamental difference b/w primary and 2° phloem.
- All secondary xylem is inner side to cambium ring, produced more than the phloem. Youngest layer of 2° xylem just below the cambium ring. Oldest layer of xylem is far away from cambium ring [centrally].
- All the 2° phloem is outside the cambium ring and produce less than the 2° xylem. Youngest layer of 2° phloem is just outside the cambium ring. Also oldest layer of 2° phloem is at the periphery [far away from the cambium ring].
- Annual Rings: The activity of cambium is attached by the environmental fluctuations. Such fluctuations are more pronounced in temperate areas where all seasons are well marked. During different seasons the activity of cambium shows marked variations.
- most active cambium is spring season. Least active cambium is Autumn / summer season. Cambium almost inactive is winter season.
- The 2° wood [xylem] formed during spring is profuse and consists of large vessels with wider lumen, this part of wood [xylem] is called spring wood or Early wood.
- In summer or autumn the activity of cambium is highly reduced therefore 2° wood [xylem] formed is not profuse and consists of mainly fibers and narrow vessels, this part of wood [xylem] called summer wood / Autumn wood / late wood.
- In a transverse section of stem early and late wood appears in the form of distinct concentric rings which are commonly called Annual rings.
- The annual ring is consists of two parts, the spring ring and the autumn ring, which are formed in a span of year. [that's why called annual ring.]

- The successive annual rings year after year and likewise, these can be used in determining the age of tree } Determination of age by counting annual ring is called Dendrochronology.

(11) Special : In Linum and Tilia plant the VB are very close → intrafascicular cambium form the entire cambium ring } Activity of cambium ring is also affected by disease, drought, defoliation → multiple / false annual rings are observed in these situations } In tropics → Growth ~~rates~~ marks are observed in place of annual ring. ble of uniform climate, not correlate with age of the tree } In roots annual rings are not observed ble inside soil the temp. usually remain same throughout the year. } In root a salix plant well defined annual ring are present }

(12) In roots the arrangement of vascular bundles is Radial type, there is no fascicular cambium so when cambium ring formed. It is totally secondary in origin [In dicot and Gymnosperm].

- formation of cambium ring in root : In stem → vascular cambium ring is partly primary and partly secondary in origin. } In root → vascular cambium ring is secondary in origin.
- An deviated pattern of secondary growth → Abnormal secondary growth Eg Dracaena, Yucca, Aloe, Agave, Bignonia, Aristolochia, cucurbita
- Heart wood & sap wood : In the transverse section of the woody trunk, two regions, the outer light and central dark coloured regions are distinct. } The light colored region is called → sap wood while dark colored region is called Heart wood
- Sap wood : functional secondary xylem. } Involve in conduction. } Also called Alburnum.
- Heart wood : Dead } unsuitable for conduction } lumen block by Tyloses
- Tyloses are balloon like str that blocks the lumen of xylem vessels, these are parenchyma cells associated with vessel which are connected together pits } These parenchyma develop balloon like protrusions in the vessels and finally becomes dead and lignified that results the blockage of vessels. } Tylosoids are tyloses like str, observed in the tracheids of gymnosperm.
- Heart wood occupy most of the central part in oldest dicot tree and gymnosperm. } Removal of heart wood from a tree does not cause any damage to the plant.

- Heart wood commercially useful for manufacture of furniture.
- Gymnosperm wood lack vessels → Non porous / soft wood.
- Angiosperm wood have vessels → porous / Hard wood.
- Soft wood of pinus very hard. } Hard wood of bombax very soft.
- Extrastellar secondary growth: } B/c of continued 2° growth the stem gradually keeps on ↑ing in width and 2° tissues formed by vascular cambium exert more and more pressure on cortex and epidermis layer. } Due to pressure the epidermis get ruptured exposing the living cells to the external atmosphere. } At this stage epidermis is replaced by a group of 2° tissues [Periderm]. } These 2° tissues are called periderm, which are formed by the activity of a 2° lateral meristem called cork cambium or phellogen.
- Phellogen originate as a single layer of cells generally in the hypodermis region in many dicots, sometimes by epidermis [Malus], pericycle [Clematis] phloem [Vitis]. } Cork cambium or phellogen is generally an extrastellar lateral meristem. } phellogen have meristematic activity, it gives rise to cork [phellum] outside and 2° cortex [phelloderm] inside
- phellum + phellogen + phelloderm → periderm.
- phellum / cork is dead tissue having suberized cell wall and formed more than 2° cortex / phelloderm. } cork / phellum is impervious to water and air and having commercial value [Quercus suber = Commercial cork]
- 2° cortex / phelloderm is living, made up of thin wall living cells, store food; replaces the damaged cortex. } periderm includes phellum, phellogen and phelloderm. } periderm produced by phellogen. } In a old dicot tree the protective layers are: periderm and fragments of epidermis.
- Bark: All the tissues outside the vascular cambium are together called Bark. } It includes phloem, cortex, periderm and epidermis. } All the tissue outside the cork cambium → Rhytidom. } Rhitidom includes phellum and epidermis.
- Two types of bark—
  Ring bark → Ex vitis, betula, clematis
  Scale bark → Ex ficus, eucalyptus

- Removal of bark causes serious injury to plant b/c vital tissue phloem is removed. } In ringing experiments → Root died first.
- Lenticel : Lenticel are main air ~~exchange~~ exchange str. in a woody tree } Consists of loosely arranged thin walled cells occuring as small protrusions on the surface of stem, roots and fruits. } * lenticel never present on leaves. } These ~~they~~ are pore like openings which looks like lens shaped raised spots on the surface of stem. } loosely arranged cells of lenticel are called complementary cells. } Lenticel develops b/c cork layer is impervious to air so to maintain air exchange these str developed.
- The parenchymatous cells which lie b/w the xylem and phloem are called conjuctive tissue
- The cells of endodermis are rich in starch grain and the layer also ~~referred~~ referred to as starch sheath.

Reproduction in plant. Science world HSN

Date 25/08/2020
Page

① - smallest flower → Wolffia. } largest flower → Rafflesia arnoldi } Heaviest flower → Nelumbo nucifera. [Lotus] } Anthology → study of flower. }

- flower is highly condensed and modified shoot, having nodes and internodes.
- The flower is the reproductive unit in the angiosperms. it is meant the sexual reproduction. } A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicel, called thalamus or receptacle. } these are calyx, corolla, androecium and gynoecium. } calyx and corolla are the accessory organs, while androecium and gynoecium are reproductive organs.
- In some flowers like lily [monocot], the calyx and corolla are not distinct distinct and are termed as perianth. [tepals].
- when a flower has both androecium & gynoecium → bisexual. } And one then unisexual. }
- In symmetry, flower may be actinomorphic [Radial] or zygomorphic [Bilateral].
- when a flower can be divided into to equal radial halves in any radial plane passing through the centre, it is said to be actinomorphic. Ex mustard, dhatura and chilli.
- when it can be divided into two similar halves only in one particular vertical plane, it is zygomorphic. Ex pea, gulmohar, bean, cassia.
- A flower asymmetrical → Ex canna.
- A flower may be trimerous, tetramerous or pentamerous when the floral appendages are in multiple of 3, 4 or 5, respectively.
- flower with bracts - reduced leaf found at the base of the pedicel are called bracteate and those without bracts abracteate.
- Epicalyx : scaly appendages present on the pedicel - Bracteoles. } Bracteolated flower } Ring [whorl of bracteoles → Epicalyx. Ex- member of malvaceae family.
- Based on the position of calyx, corolla and androecium in respect of the ovary on thalamus, the flowers are described as hypogynous, perigynous and epigynous.

Date
Page

- In the hypogynous flower and gynoecium occupies the highest position while the other parts are situated below it. The ovary in such flowers is said to be superior, Ex mustard, china rose and brinjal.
- If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called perigynous. The ovary here is said to be half inferior. Ex Plum, rose, peach.
- The epigynous ovary, the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary. Hence, the ovary is said to be inferior Ex Guava, Cucumber, ray florets of sunflower.
- flower parts: flower axis → pedicel and thalamus, Calyx, Corolla, Androecium and Gynoecium.

(2) - Calyx: The calyx is the outermost whorl of the flower and the members are called sepals. Generally sepals are green, leaf like and protect the flower in the bud stage. The calyx may be gamosepalous [sepals united] or polysepalous [sepals free].

- Corolla: Corolla is composed of petals. Petals are usually brightly coloured to attract insect for pollination. Like Calyx, Corolla may be also united gamopetalous or polypetalous. The shape and colour of Corolla vary greatly in plants. Corolla may be tubular, bell shaped, funnel-shaped or wheel-shaped
- Aestivation: The mode of arrangement of sepals or petals in floral bud with respect to other members of the same whorl is known as aestivation. The main types of aestivation are valvate, twisted, imbricate and vexillary.
- When sepals or petals in a whorl just touch one another at the margin, without overlaping, as in Calotropis, it is said to be valvate
- If one margin of the appendage overlaps that of the next one and so on as in china rose, lady's finger and cotton, it is called twisted.

Date
Page

- If margins of sepals or petals overlap one another but not in any particular direction as in Cassia and gulmohur, it is called imbricate.
- In pea and bean flowers, there are five petals, the largest (standard) overlaps the two lateral petals (wings), which in turn overlap as two smallest anterior petals (keel), this type of aestivation is also vaxillary or papilionaceous.
- Quincuncial: when two petals are inner, two are outer and one is partly inner and partly outer. eg. Ranunculus
- Calyx modification: pappus - eg. Sunflower, Asteraceae} Leafy - eg. Mussaenda} spinous - eg. Trapa.
- Corolla - various forms: Cruciform - Cross shaped arranged four petals eg. Brassicaceae family.} Rosaceae - five or many petals spread regularly outwards eg. Rose.} Caryophyllaceous - five claw like petal eg. Dianthus plant.} ~~Tubular - Tube like petal - eg. Physalis~~} Campanulate - Bell shaped petal eg. physalis} Tubular - Tube like petals eg. Disc floret of sunflower.} Infundibuliform - funnel shaped petals eg. Dhatura.} Rotate - wheel shaped petal eg. Brinjal} Bilabiate - two lipped petal eg. Salvia.} Ligulate - tongue like. eg. Ray florets of sunflower.
- Androecium: It is composed of stamens} Each stamen which represent the male reproductive organ consist of a stalk or a filament and an anther} Each anther is usually bilobed and each lobe has two chambers, the pollen sacs.} The pollen grains are produced in pollen sacs.} The sterile stamen is called staminode.} stamens of flower may be united with other members such as petals or among themselves} when stamens are attached to the petals, they are epipetalous as in brinjal., or epiphyllous when attached to the perianth as in the flowers of lily.} The stamen of flower may either remain free (polyandrous) or may be united in varying degrees.}
- The stamens may be united - into one bunch or one bundle (monoadelphous) as in china rose.} two bundles (diadelphous) as in pea} into more than two bundles (Polyadelphous) as in citrus.

- There may be a variation in the length of filaments with in a flower, as in Salvia and mustard.
- Androecium: unit: stamen } stamen: Anther, connective, filament.}
Dithecous: two lobe.} Monthecous: one lobe.
- Cohesion of stamen: three types:- Adelphous → the stamen are fused by their filaments only. The anthers are free} fusion of filament may be produce a single group → monoadelphous Ex- Hibiscus, althaea, two group → Diadelphous eg: Pea and many group → Polyadelphous eg. citrus
- Syngenesious | synantherous: stamens are fused by anthers only, while filaments are free. The fused anther form a ring around gynoecium. e.g. Sunflower.
- Synandrous: stamens are fused both in the region of filaments and anthers. eg. Cucurbita.
- If the stamen shorter than corolla, they are called Inserted.
- If stamen produce protrude of the corolla, they are called Exserted.
- fixation of Anthers: The anther may be attached to the filament in any of the following manner. Basifixed / innate → filament attached to the base of the anther eg. pea. | Adnate → filament run throughout the length of the anther or become continuous with the connective eg. Magnolia, Ranunculus} Dorsifixed → filament is attached to the dorsal side of the anther. eg. Citrus} versatile → filament is attached in the middle of the connective, in such a way that the anther can swing freely eg. Grasses.
- when stamen are free [not fused with other parts of flower] → polyandrous} they may be equal or unequal in length.
- Two types of unequal stamens: Didynamous → 2 long and 2 short. eg. Ocimum [Labiatae] } Tetradynamous → 4 long two short. eg. Brassica [Cruciferae]
- Heterostemony → stamen different length. e.g. Citrus

Date
Page

- Homostamous ⇒ Stamen equal size.
- Number of stamen in flower : 1 ⇒ monandrous ; 2 ⇒ Diandrous ; 3 ⇒ triandrous ; 4 ⇒ polyandrous so on.
- Adhesion of stamen : Epipetalous ⇒ fused with petals eg. pitunia, solanum ; Epitepalous ⇒ fused with tepals eg. Asphodelus. ; Gynandrous ⇒ fused with Gynoecium
- Epiphyllus ⇒ stamen are found attached with perianth eg. liliaceae family.

(3) Gynoecium : It is the female reproductive part of the ~~ovary~~ flower and is made up of one or more carpels / pistil / megasporophyll. ; A carpel consists of three parts namely stigma, styl and ovary. ; ovary is the enlarged basal part, on which lies the elongated tube, the style. ; The style connects the ovary to the stigma. ; The stigma is usually at the tip of the styb and is the receptive surface for pollen grains. ; Each ovary bears one of more ovules attached to a flattened, cushion-like placenta. ; when more than one carpel is present, they may be free (as in lotus and rose) and are called apocarpus. ; they are termed syncarpus when carpel are fused, as in mustard and tomato. ; After fertilization the ovules develops into seeds and the ovary matures into fruits.

- Gynoecium : female part of ovary. ; unit ⇒ carpel / megasporophyll. ; consists of stigma, style and ovary. ; In ovary ⇒ ovules are present. ; the arrangement of ovule in on placenta with in the ovary is called placentation.
- Cohesion of carpel : Apocarpous ⇒ carpels free Eg Ranunculaceae. ; syncarpous ⇒ carpel more than two and fused. Eg most of the plant.
- Placentation : the arrangement of ovules with in the ovary is klas placentation. ; the placentation are of different type namely, marginal, axil, basal, central and free central
- In marginal placentation the placenta forms a ridge along the ventral suture of the ovary and the ovules are borne on this ridge forming two rows, as in pea.
- When the placenta is ~~with~~ axial and the ovules are attached to it in a

multilocular ovary, the placentation is said to be axile, as in china rose, lemon and tomato.

- In parietal placentation, the ovules develop on the inner wall of the ovary or on peripheral part. ovary is one-chambered but it becomes two chambered due to the formation of the false septum; mustard and Argemone.

- when the ovules are borne on the central axis and septa are absent, as in Dianthus and Primrose, the placentation is called free central.

- In basal placentation, the placenta develops at the base of the ovary and a single ovule is attached to it, as in sunflower, marigold.

- Placentation; marginal → Placenta developing along the junction of the two margins of the carpel in one chambered ovary. Ex Pea & Gram.

Axile; the ovary is two or many chambered and placenta bearing ovules develop from the central axis. Ex. Tomato, orange, cotton, china rose & lily.

Parietal; ovary is one chambered as in placenta bearing the ovules develop on the inner wall of the ovary. The number of placenta correspond to the number of carpels Ex. mustard, Radish, cucumber.

free central; ovary is one chambered and the placenta bearing ovules develop round the central axis. Ex Dianthus, stellaria.

Basal; ovary is unilocular and the placenta develops at the base of the ovary on thalamus and bears a single ovule Ex *wheat, *maize, Aster, Zinnia, sunflower.

Superficial; ovary is multicellular with numerous carpels as in axile type of placentation but placenta develop all around the inner surface of the partition wall. Ex water lily.

Are we not lucky that plants reproduce sexually? The myriads of flowers that we enjoy gazing at, the scents and the perfumes that we swoon over, the rich colours that attract us; are all there as an aid to sexual reproduction. flowers do not exist only for

Date
Page

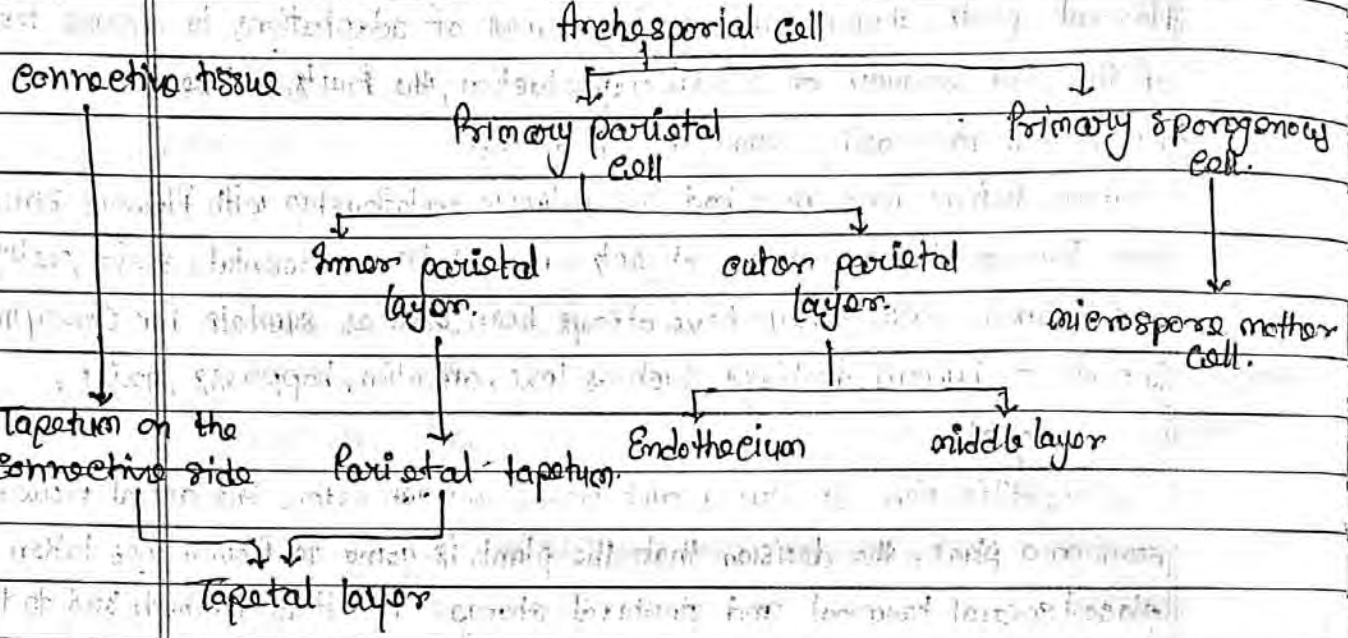
us to be used for our own selfishness. All flowering plants show sexual reproduction. A look at the diversity of st^{re} of the inflorescences, flower and floweral parts, shows an amazing range of adaptations to ensure formation of the end products of sexual reproduction, the fruits and seeds.

- flower ~ A fascinating organ of angiosperms.
- Human beings have ever had an intimate relationship with flowers since time immemorial. flowers are objects of aesthetic, ornamental, social, religious and cultural value ~ they have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning etc.
- Pre-fertilization: structures and events occur much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. Several hormonal and structural changes at initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bears the floral bud and then the flowers. In the flower the male and female reproductive st^{re}, and androecium and the gynoecium differentiate and develop. The androecium consists of a whorl of stamens representing the male reproductive organ and the gynoecium represents the female reproductive organ.

(21) Stamen, microsporangium and pollen grain: There are two parts of a typical stamen ~ the long and slender stalk called the filament, and the terminal generally bilobed st^{re} called the anther. The proximal end of the filament is attached to the thalamus or the petal of the flower. The number and length of stamens are variable in flowers of different species. A typical Angiosperm anther is bilobed with each lobe having theca, i.e they are dithecous. often a longitudinal groove runs longthwise separating the theca.

- In the transverse section of an anther: The bilobed nature of an anther is very distinct in the transverse section of the anther. The anther is a four sided [tetragonal] st^{re} consisting of 4 microsporangia located at the corners, two in each lobe. The microsporangia develop further and become pollen sacs.

extended longitudinally all through the length of an anther and are packed with pollen grains.



Str of microsporangium: In a transverse section, a typical microsporangium appears near circular in outline. It is generally surrounded by the four wall layers - the epidermis, endothecium, middle layers and the tapetum. The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen. The innermost wall layer is the tapetum. It nourishes the developing pollen grains. Cell of tapetum possess dense cytoplasm and generally has more than one nucleus.

- Can you think of how tapetal cells could become bi-nucleate?

When the anther is young, a group of compactly arranged homogeneous cells called the sporogenous tissue occupies the centre of each microsporangium.

Microsporogenesis: As the anther develops, the cells of sporogenous tissue undergo meiotic divisions to form microspore tetrads. What would be the ploidy level of the cells of the tetrad? (n)

- As each cell of the sporogenous tissue is capable of giving rise to a microspore tetrad. Each one is the partial pollen or mme. The

Date
Page

process of formation of microspores from a pollen mother cell [PMC] through meiosis is called microsporogenesis. The microspores, as the are formed, are arranged in a cluster of four cells ~ the microspore tetrad. As the anthers mature and dehydrated, the microspore dissociate from each other and develop into pollen grains. Inside each microsporangium several thousands of microspores or pollen grains are formed that are released with the dehiscence of anther.

pollen grain: The pollen grains represent the male gametophytes. They are generally sperical measuring about (25-50) microneters in diameter. It is a prominent two layered wall. The hard outer layer called the exine is made up of sporopollenin which is one of the most resistance organic material known. It can withstand high temp. and strong acids and alkali. No Enzyme that degrades sporopollenin is so far known.

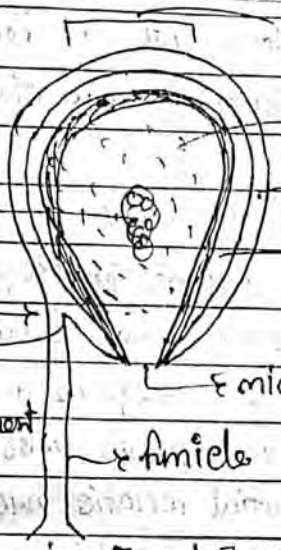
- pollen grain exine has prominent apperatures called germ pore. where sporopollenin is absent. Pollen grains are well preserved as fossils of the presense of sporopollenin. The exine exhibits a fascinating array of patterns and designs.
- why do you think the exine should be hard? what is the function of germ pore?
- The inner wall of the pollen grain is called the intine. It is a thin and continuous layer made up of cellulose and pectin. The cytoplasm of pollen grain is surrounded by a plasma membrane. When the pollen grain is mature it contains two cells, the vegetative and the generative cell. The vegetative cell is bigger, has abundent food reserve and a large irregularly shaped nucleus. The generative cell is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus.
- In over 60% of angiosperms, pollen grains are shed at this 2-celled stage. In the remaining species, the generative cell divide mitotically to give rise to the two male gametes before pollen grains are shed [3-celled stage]

- Pollen grains of many species cause allergies and bronchial afflictions in some people often leading to chronic respiratory disorder - asthma, bronchitis etc.) It may be mentioned that parthenium or carrot grass that came into India as a contaminant with imported wheat, has become ubiquitous in occurrence and causes pollen allergy.
- Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as food supplements. In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed the to the performance of athletes and race horses.
- When once they are shed, pollen grains have to land on the stigma before they lose viability if they have to bring about fertilization. How long do you think the pollen grains retain viability? The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temp. and humidity. In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminosae and Solanaceae, they remain viability for months. It is possible to store pollen grains of a large number of species for years in liquid nitrogen [-196°C] i.e. Cryopreservation.
- Such stored pollen can be used as pollen banks, similar to seed banks, in crop breeding programmes.

(5) The pistil, megasporangium [ovule] and Embryosac: The gynoecium represents the female reproductive part of the flower. The gynoecium may consist of a single pistil [monocarpellary] or may have more than one pistil [multicarpellary]. When there are more than one, the pistils may be fused together [syncarpus] or may be free apocarpous. Each pistil has three parts, the stigma, style & ovary.
- The stigma serves as a landing platform for pollen grains. The style is a elongated slender part beneath the stigma. The basal bulged

Date
Page

part of the pistil is the ovary. Inside the ovary is the ovarian cavity [locule]. The placenta located inside the ovarian cavity. Arising from the placenta are the megasporangia, commonly called ovules. The number of ovules in an ovary may be one [wheat, paddy, mango] to many [papaya, water melon, orchids]



The megasporangium [ovule]: The ovule is a small str attached to the placenta by means of a stalk called funicle. The body of the ovule fuses with funicle in the region called hilum. This, hilum represents the junction b/w ovule and funicle. Each ~~have~~ ovule has one or two protective envelops called integuments. Integuments encircle the nucellus except at the tip where a small opening called the micropyle is organised.

5(b) opposite the micropylar end, is the chalaza, represented the basal part of the ovule. Enclosed within the integuments is a mass of cells called the nucellus. Cells of the nucellus have abundant reserve food materials. located in the nucellus is the embryosac or female gametophyte. An ovule generally has a single embryosac formed from a megasporangium.

- megasporogenesis: The process of formation of megaspores from the megaspore mother cells is called megasporogenesis. Ovule generally differentiate a single megaspore mother cell in the micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a

prominent nucleus. The MMC undergoes meiotic divisions.
- What is the importance of the MMC undergoing meiosis?
meiosis results in the production of four megaspores.
- female gametophyte: In a majority of flowering plants, one of the megaspores is functional while the other three degenerate. Only the functional megaspores develops into the female gametophyte [Embryo sac]. This method of embryosac-formation from a single megaspore is termed monosporic development.
* - What will be the ploidy of the cells of nucellus, MMC, the functional megaspore and female gametophyte? Nucellus → 2n, MMC → 2n, functional megaspore → n and female gametophyte → n
- The nucleus of the functional megaspore divides mitotically to form two nuclei which moves the opposite poles, forming the 2-nucleate embryosac. To more sequential mitotic nuclear divisions results in the formation of 4 nucleate and later the 8 Nucleate stages of the embryosac. It is of interest to note that these mitotic division are strictly free nuclear, i.e, nuclear divisions are not followed immediately by cell wall formation. After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac. Observed the distribution of cells inside the embryosac; six of the eight nuclei are surrounded by cell walls and organised into cells; the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell. There is a characteristic distribution of the cells with in the embryo sac. Three cells are grouped together at the micropylar end and and constitute the egg apparatus. The egg apparatus, in turn, consists of two synergids and one egg cell. The synergids have special cellular thickening at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergids. Three cell are the chalazal end and are called antipodal cells. The

Date
Page

large central cell, has two polar nuclei (secondary nucleus (n+n)). Thus, a typical angiosperm embryosac, at maturity, though 8-nucleate is 7-celled.

⑥ Pollination: Transfer of pollen grains (shed from the anther) to the stigma of a pistil is termed pollination. Flowering plants have evolved an amazing array to arrangement of adaptations to achieve pollination. They make use to external agents to achieve pollination.

Kinds of pollination: Depending upon on the source of pollen, pollination can be divided into three types ~ ① Autogamy ② Geitonogamy ③ Xenogamy.

Pollination
- Self pollination
  - Autogamy
  - Geitonogamy
- Cross pollination
  - Based on plants
    - Allogamy / Xenogamy
    - Hybridism
  - Based on factors
    - Anemophily
    - Hydrophily
    - Zoophily

① Autogamy: In this type, pollination achieve within the same flower. Transfer of pollen grains from the anther to the stigma of same flower. In a normal flower which open and ~~express~~ exposes the anthers and the stigma, complete autogamy is rather than. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also, the anthers and the stigma should lie close to each other so that self pollination can occur. mirabilis jalapa

- Homogamy: It refers to the maturation of sex organs at same time Ex.
- Cleistogamy: It is a phenomena in which the flowers do not open at the time of fertilization. Ex Viola
- Herkogamy: In certain flowers, morphological barriers develop which makes self pollination impossible eg. calotropis ; Zeuxine

Geitonogamy or Ecologically cross pollination but genetically self pollination.

Date
Page

- Self-sterility: flowers in which pollens are incapable of causing fertilization. Ex: maize.
- Some plants such as Viola (common pansy), oxalis and Commelina produce two types of flower. ① chasmogamous flower which are similar to flowers of other species with exposed anthers and stigma. and ② cleistogamous flower which do not open at all.
- In such flowers, the anthers and stigma lie close to each other. When anther dehisces in the flower buds, pollen grains come in contact with the stigma to effect pollination.
- Thus, cleistogamous flowers are invariably autogamous as there is no chance of cross pollination pollen landing on the stigma. Cleistogamous flowers produce assured seed-set even in the absence of pollinators.
- Do you think that cleistogamous is advantageous or disadvantageous to the plant? Why?

② Geitonogamy: Transfer of pollen grains from the anther to the stigma of another flower of the same plant. Although Geitonogamy is functionally cross pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grains comes from the same plant.

③ Xenogamy: Transfer of pollen grains from anther to the stigma of a different plant. This is the only type of pollination which during pollination brings genetically different types of pollen grains to the stigma.

Chasmogamous flower	cleistogamous flowers.
- These open at maturity and expose there stigma and stamen.	- these are bisexual flowers which donot open at all even in maturity.
- They may be cross pollinated or self pollinated.	- self pollinated only.

Date
Page

- Agents of pollination

- Abiotic
  - Anemophilly [By wind e.g. Palm]
  - Hydrophilly [By water e.g. Vallisneria]
- Biotic
  - Entomophily → By insect Eg. Ficus, Salvia (bee)
  - Ornithophily → By birds e.g. Bombax, Bauhinia [By humming bird]
  - chiropterophily → By bats
  - malacophily → By insect & slugs e.g. aroids
  - myrmecophily → By ants e.g. Rubiaceae
  - ophiophily → By snakes.

(7) Advantage of self pollination: less energy required. } may occurs without pollinator. } Plant spread beyond the rang of suitable pollinators. } less chance of failure of pollination.

- Disadvantage of self pollination: No new species } No evolution. } less resistance to disease } No new characters } undesired characters.
- factors of pollination: weather } lack of pollinators } Domesticated pollinators } insecticides } light intensity or solar radiations. } floral display size. } flowering plant density. } Nectar-sugar concentration. } Humidity } wind velocity } Temprature.

wind pollinated flower	insect pollinated flower.
- Produce enormous amount of pollen grains.	produce small amount of pollen grains
- Pollen are small, light and smooth	Pollen are larger, heavier and with surface appendages like hooks, barbs etc
- flowers are dull, nectarless, scentless.	- flowers are bright, scented & with nectar.
- stigma long feathery or adhesive	stigma often small
- Stamen long & project above petals	stamens often within corolla tube.

Date
Page

Agents of pollination: Plants use two abiotic (wind and water) and one biotic (Animals) agents to achieve pollination. } majority of plants use biotic agents for pollination. } only a small proportion of plants use abiotic agents. } Pollen grains coming in contact with the stigma is a chance factor in both wind and water pollination. } To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen when compared to the number of ovules available for pollination. } Pollination of wind is more common amongst abiotic pollinations.

- Wind pollination also requires that the pollen grains are light and non-sticky so that they can be transported in wind currents } They often possesses well exposed stamens (so that the pollen grains are easily dispersed into wind currents) and large often-feathery stigma to easily trap air borne pollen grains.
- Wind pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence; a familiar example is the corn cob - the tassels you see are nothing but the stigma and style which wave in the wind to trap pollen grains } wind pollination is quite common in grasses.
- Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocots. } some example of water pollinated plants are Vallisneria and Hydrilla grow in fresh water and several marine sea-grasses such as Zostera.
- characteristic of water pollinated flowers: flowers are small and inconspicuous } Perianth and other floral parts are unwettable. } Nectar and odour are absent. } Pollen grains are light and unwettable due to presence of mucilage cover. } stigma is long, sticky and unwettable. It is of two types: ① Ephydrophily → pollination occuring on the water surface. Ex Elodes, Hydrilla. ② Hyphohydrophily → pollination occuring beneath the water surface. e.g. Najas, Ceratophyllum.

In flower fragrant oil release by osmophore glands

Science world HSN

Date
Page

- Not all aquatic plants use water for pollination. In a majority of aquatic plants such as water hyacinth and water lily, the flowers emerge above the level of water and are pollinated by insects or wind as in most of the land plants. In vallisneria, the female flower reach the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water. They are carried passively by water currents, some of them eventually reach the female flowers and the stigma.
- In another group of water pollinated plants such as seagrasses, female flower remains submerged in water and the pollen grains are released inside the water.
- pollen grains in many such species are long, ribbon like and they are carried passively inside the water; some of them reach the stigma and achieve pollination. In most of the water pollinated species, pollen grains are protected from wetting by a mucilagenous covering
- Both wind and water pollinated flowers are not very colourful and do not produce nectar what would be the reason for this?
- Coevolution is a term used to discribe the mutual changes in two or more species, usually one following the other, that affect their interactions. Flowering plants (Angiosperms) and their pollinators are often used as a classic example of this evolutionary phenomenon. The plant and the pollinators place evolutionary pressure on each other for changes in morphology, physiology, or habits that benifit both.

(8) Calotropis: In calotropis pollen grains occur in sacs called pollinia. To adjescent pollinia are attached to a common sticky corpuscelum to form a translator. These translator can be lifted by insect only.

- Coevolution and species interaction: Pollinators coevolve with the flowering plants they pollinate eg. yucca moths and yucca plants yucca flowers are a certain shape so only that tiny moth can pollinate them. The moths lay their eggs in the yucca flowers and the larvae

Date
Page

[caterpillars] lives in the developing ovary and eat yucca seeds
- yuccas are pollinated by special 'yucca moths', self pollination of yucca flowers of many species is impossible, although a few are self fertile. most yuccas are pollinated exclusively by small yucca moths with the plant and moth totally dependent on each other. Recent research has shown there are at least 16 different yucca moths [Tegeticula species] - all are specialized in pollinating their 'own' yucca species
- Each type of yucca plant can only be pollinated by a specific kind of yucca moth. That moth can only live on that kind of yucca.

Majority of flowing plants use a range of animals as pollinating agents. Bees, butterfly, flies, beetles, wasps, ants, moths, birds. [sunbirds and humming birds] and bats are the common pollinating agents

- Among the animals, insect, particularly bees are the dominant biotic pollinating agents. Even larger animals such as some primates [Lemurs], arboreal [tree-dwelling] rodents, or even reptiles [gecko lizard and garden lizard] have also been reported as pollinators in some species
- Often flowers of animals pb pollinated plants are specifically adapted for a particular species of animals
- majority of insect pollinated flowers are large, colourful, fragrant and rich in nectar.
- When the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous. Animals are attracted to flowers by colour and/or fragrance. The flowers pollinated by flies and beetles secrete foul odour to attract these animals
- To sustain animal visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are the usual floral rewards
- for harvesting the reward(s) from the flower the animal visitor comes in contact with the anthers and the stigma. The body of the animals gets a coating of pollen grains, which are generally sticky in

Date
Page

animal pollinated flowers } when the animal carrying pollen on its body comes in contact with the stigma, it brings about pollination.

- In some species floral rewards are in providing safe places to lay eggs; an example is that of the tallest flower of Amorphophallus [the flower itself is about 6 feet in hight.]
- A similar relationship exists b/w a species of moth and the yucca where both species- moth and the plant -cannot complete their life cycles without each other } The moth deposits its eggs in the locule of the ovary and the flower, in turn, gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing
- many insect may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred as to as pollen/nectar robbers.
- Some special example of pollination: Salvia: lever mechanism } ficus: Entomophily [fig wasp/ Blastagophaga insect] } yucca: Entomophily [Tragetiella yucca moth] } Ophrys: Entomophily by hairy wasp [Colpa] } Aristolochia: fly trap mechanism.

(9) Out breeding devices: majority of flowering plants produce hermaphrodite flowers and pollen grains are likely to come in contact with the stigma of the same flower. } Continued self-pollination result in interbreeding (2015) depression.

- Inbreeding depression is the reduced biological fitness in a given population as a result of inbreeding, or breeding of related individuals } Population biological fitness refers to an organism's ability to survive and perpetuate its genetical material.
- In some species, pollen release and stigma receptivity are not synchronised } Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.

Dichogamy

- Dichogamy: Here in a bisexual flower, anthers and stigmas matures at different times, so that self pollination is inhibited

e.g. Salvia, Sunflower, magnolia, Rose

Protandry – male first. | Protogyny – female first.

Heterostyly:
- In some other species, the anther and stigma are placed at different positions so that the pollen cannot come in contact with the stigma of the same flower.
- Both these devices prevent autogamy.
- Heterostyly: flower have different types of height of styles and stamens e.g. Jasmine, Primrose, Lythyrus, Oxalis

Self-incompatibility:
- The third device to prevent inbreeding is self-incompatibility. This is a genetic mechanism and prevents self pollen (from the same flower or other flowers of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.
- Self-incompatibility: Pollen will not germinate on genetically similar individuals

Dicliny:
- Another device to prevent self pollination is the production of unisexual flowers. If both male and female flowers are present on the same plant such as Castor and maize (monoecious), it prevents autogamy but not geitonogamy
- Unisexuality [Dicliny]: flower are unisexual or diclinous, Plants may be monoecious [e.g. maize, castor] or dioecious [mulberry, papaya, date palm]
- In several species such as papaya, male and female flowers are present on different plants, that is each plant is either male or female [dioecy]. This condition prevents both autogamy and geitonogamy
- Pollen-pistil Interaction: pollination does not guarantee the transfer of the right type of pollen [Compatible pollen of the same species as the stigma]. often, pollen of the wrong type, either from other species or from the same plant [if it is self-incompatible], also land on the stigma. The pistil has the ability to recognise the pollen, whether it is of the right type [Compatible] or the wrong type [Incompatible]
- If it is of the right type, the pistil accepts the pollen and promotes post-

when pollen tube enters through micropyle called porogamy
Chalaza and called chalazogamy Ex Casurrina.
other than chalaza and micropile called mesogamy.

Science world HSN

Date
Page

pollination events that leads to fertilisation.} If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.

- The ability of the pistil to recognise the pollen followed by its acceptance or rejection is the result of a continuous dialogue b/w pollen grain and the pistil.
- It is only in recent years that botanists have been able to identify some of the pollen and pistil components and the interactions leading to the recognition, followed by acceptance or rejection.
- As mentioned earlier, following compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through on of the germ pores } The contents of the pollen grain move into the pollen tube.} Pollen tube grows through the tissues of the stigma and style and reached the ovary.
- In some plants, pollen grains are shed at two-celled condition [a vegetative cell and a generative cell] } In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma.
- Pollen tube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus.
- Many recent studies have shown that filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.
- All these events - from pollen deposition on the stigma until pollen tubes enters the ovules - are together referred to as pollen pistil interaction.} pollen pistil interaction is a dynamic process involving pollen recognition followed by ~~pro~~ promotion or inhibition of the pollen.
- The knowledge gained in this area would help the plant breeder in manipulating pollen - pistil interaction, even in incompatible pollinations, to get desired hybrids.
- Artificial hybridization is one of the major approaches of crop improvement programme.} In such crossing experiments it is important to make sure that only the desired pollen grains are used for pollination and the stigma is protected from contamination [from unwanted pollen.].}

This is achieved by emasculation and bagging techniques
- If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps is necessary. This step is referred to as emasculation. Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of the stigma with unwanted pollen. This process is called bagging. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop.
- If female parent produces unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

(10) The fusion of two dissimilar sexual reproductive units (gametes) is called fertilization. This process was discovered by Strasburger (1884).
- Germination of pollen grain on stigma and growth of pollen tube: pollen grains reach the receptive stigma of the carpel by the act of pollination. Pollen grains, after getting attached to the stigma, absorb water & swell. Subsequent to mutual recognition and acceptance of pollen grains, the pollen grains germinate [in vivo] to produce a pollen tube which grows into stigma towards the ovarian cavity.
- G.B. Amici [1824] discovered the pollen tube in portulaca oleracea.
- Generally, only one pollentube is produced by a pollen grain [Monosiphonous]. But in some plants like members of cucurbitaceae produces many pollen tubes [Polysiphonous].
- The pollen tubes contains a vegetative nucleus or tube nucleus and two male gametes. Later, the vegetative cell degenerates. The pollen tube now reaches the ovule after passing through the style.
- Entry of pollen tube into ovule: After reaching ovary, the pollen

Date
Page

tube enters the ~~ovule~~ ovule. pollen tube may enter the ovule by any one of the following routes:

(A) Porogamy: when the pollen tube enters the ovule through micropyle, it is called porogamy. It is the most common type. e.g. lily.

(B) Chalazogamy: the entry of pollen tube into the ovule from chalazal region is ~~by~~ chalazogamy. It is less common. e.g. Casuring, Juglans, Betula { first observed by Treub (1891) in ~~Casuri~~ casuarina.

(C) Mesogamy: the pollen tube enters the ovule through its middle part. i.e, through integument [e.g. cucurbita, populus] or through funicle [e.g. Pistacia].

- Entry of pollen tube into embryo sac: The pollen tube enters the embryosac only from the micropylar end irrespective of its mode of entry into the ovule } the pollen tube either passes b/w a synergid and the egg cell or enters into one of the synergids through filiform apparatus. } The synergids direct the growth of pollen tube by secreting some chemical substances [chemotropic secretion]. } The tip of pollen tube enters into one synergids } The penetrated synergids start degenerating. } After penetration, the tip of pollen tube enlarge and ruptures releasing most of its contents including the two male gametes and the vegetative nucleus into the synergids

- Double fertilization: The nuclei of the both male gametes are released in the embryosac } one male gamete fuses with the egg to form the diploid zygote. The process is called syngamy or generative fertilization. } This syngamy was discovered by strasburger [1884] } The diploid zygote finally develops into embryo. } the other male gamete fuses with the two polar nuclei [or secondry nucleus] to form the triploid primary endosperm nucleus. This process is called triple fusion or vegetative fertilization. } These two acts of fertilization constitute the process of double fertilization. This process was discovered by S.G. Nawaschin [1898] and Guignard in Lilium and Fritillaria. }

Date
Page

Double fertilization occurs in angiosperms only.

Double fertilization: After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid. One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the syngamy. This results in the formation of a diploid cell, the zygote. The other male gamete moves towards the polar nuclei located in the central cell and fuses them to produce a triploid primary endosperm nucleus [PEN]. As this involves the fusion of three haploid nuclei it is termed triple fusion. Since two type of fusions, syngamy and triple fusion take place in an embryo sac, the phenomena is termed double fertilization, an event unique to flowering plants. The central cell after triple fusion becomes the primary endosperm cell [PEC] and develops into the endosperm while the zygote develops into an embryo.

- Embryology is the study of events, leading to the fertilization of egg and development of embryo. Father of plant embryology → C.F. Wolff. Father of plant embryo culture → Hanning. Father of Indian plant embryology → P. Maheshwari.
- Androgenic haploid plant: Develops only pollen grains by tissue culture. First time developed → Guha & Maheshwari.

(11) Post-fertilization events: following double fertilization, events of endosperm and embryo development, maturation of ovule into seed and ovary into fruit, are collectively termed post fertilization events.

- Endosperm: Endosperm development precedes embryo development. why?
- The primary endosperm cell divides repeatedly and forms a triploid endosperm tissue. The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo.
- In the most common type of endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei. This stage

Date
Page

of endosperm development is called free nuclear endosperm. Subsequently cell wall formation occurs and the endosperm becomes cellular. The no. of free nuclei formed before cellularization varies greatly.

- The number of free nuclei formed before cellularization varies greatly. The coconut water from tender coconut that you are familiar with, is nothing but free nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm.
- Endosperm may either be completely consumed by developing embryo [e.g. pea, groundnut, beans] before seed maturation or it may persist in the mature seed [e.g. castor and coconut] and be used up during seed germination.
- On the basis of development, endosperm are of three type:-

① Nuclear endosperm: In the nuclear type of endosperm development, the primary endosperm nucleus divides by repeated mitotic free nuclear divisions without the formation of walls. Finally cell wall formation takes place from the periphery of the embryosac towards the centre leading to the formation of cellular endosperm tissue. Nuclear endosperm is the most common type of endosperm and mostly found in polypetalae. e.g. Cotton, Zea mays, Capsella.

② Cellular endosperm: In the cellular type of endosperm development the first nuclear division of the primary endosperm nucleus is immediately followed by the wall formation. The first division results in the formation of two equal sized chamber: chalazal and micropylar chamber. The subsequent divisions are followed by regular cell wall formation. This type of endosperm formation is common in gamopetalae eg. Petunia, Datura.

③ Helobial endosperm: In the helobial endosperm type of endosperm, development, the endosperm is intermediate b/w cellular and nuclear types. The division of primary endosperm nucleus is followed by wall formation and as a result two chambers: micropylar and chalazal chambers, are formed. Generally the chalazal cell does not divide

Date
Page

further and function as haustorium. } Nucleus of the large micropylar cell divides by repeated free nuclear divisions and further development takes place in the same way as the nuclear endosperm. } Helobial type of endosperm development is prevalent in monocot.

- Some term related to endosperm: ① Ruminate endosperm :- mature endosperm with irregularity and unevenness in its surface is called ruminate endosperm. It is found in about 32 families of angiosperms, eg. Annonaceae, Palmae, Myristicaceae.

② Mosaic endosperm : In some cases, the tissue of endosperm is not homogenous but there are patches of different colours } such type of endosperm is called mosaic endosperm and was observed by Webber in Zea mays.

- Xenia : The effect of pollen on endosperm is called xenia. This term was given by focke. eg maize.

- Metaxenia : The effect of pollen on somatic tissue laying outside the endosperm is also metaxenia. Term given by swingle. eg Date palm.

Embryo : Embryo develops at the micropylar end of the embryo sac where the zygote is situated } most zygotes divide only after certain amount of endosperm is formed. this is an adaptation to provide assured nutrition to the developing embryo } though the seed differ greatly, the early stage of embryo development [Embryogony] are similar in both monocot and dicot. } The zygote gives rise to the proembryo and subsequently to the globular, heart shaped and mature embryo.

(12) Embryo : The zygote after a period of rest develops into embryo. The process of development of mature embryo from diploid zygote is called embryogenesis.

- In dicots : The normal type of dicot embryo development has been studied in shepherd's purse [Capsella bursapastoris] family cruciferae. } This is called as cruciferous or onagrad type of embryo development. } This development of embryo is endoscopic. i.e; apex is downward or towards inside.

Science World HON

Dev't of embryo — Typical

- The first division of zygote is transverse which produces a basal cell towards the micropyle and a terminal cell towards chalaza. The basal cell divides by transverse division and the terminal cell by a vertical division. So, a large T-shaped structure is produced. The two basal cells divide by transverse division and form a 6-celled suspensor. The uppermost cell of the suspensor is suspensor cell and lowest cell is called hypophysis which forms radicle and root cap. The two terminal cells first divide by vertical division (at right angle to first one), and then by transverse and periclinal division. So 8-celled globular embryo is produced. Due to differentiation of cotyledons globular embryo becomes heart shaped. Mature embryo in dicots consists of two lateral cotyledons, terminal plumule or shoot tip and radicle or root tip.
- ✓ A typical dicot embryo, consists of an embryonal axis and two cotyledons. The portion of embryonal axis above the level of cotyledons is the epicotyl which terminates with the plumule or stem tip. The cylindrical portion below the level of cotyledons is hypocotyl that terminates at its lower end in the radicle or root tip. The root tip is covered with a root cap.
- In monocots, the normal type of monocot embryo development has been studied in Sagittaria sagittifolia. The early development of dicot and monocot embryos is similar up to globular stage. Later on differentiation starts. Suspensor is single celled and vesicular. There is only one terminal cotyledon called scutellum (shield shaped).
- ✓ Embryos of monocots possess only one cotyledon. In the grass family the cotyledon is called scutellum that is situated towards one side (lateral) of the embryonal axis. At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorrhiza. The portion of embryonal axis above the level of attachment of scutellum is the epicotyl. Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.

Date
Page

Character	Dicot embryo	monocot embryo.
No. of cotyledon	two cotyledon attached to embryonal axis	one cotyledon attached to embryonal axis.
Position of plumule	occurs distally [terminal]	occur laterally.
Position of cotyledon	occurs laterally	single cotyledon occupies terminal.
Coleoptile.	absent.	The envelope of plumule called coleoptile
~~Coleorhiza~~	do	
Coleorrhiza	absent	This is a protective sheath of radicle.
Scutellum	Absent	A single cotyledon
Suspensor	large	Comparatively small.

Seed: * In angiosperm, the seed is the final product of sexual reproduction. It is often described as a fertilised ovule. Seed are formed inside fruit. A seed typically consist of seed coat, cotyledon and and embryo axis.

- The cotyledons of the embryo are simple. str, generally thick and swollen due to the storage of food reserves [as in legumes]. Mature seeds may be non-albuminous or albuminous
- Non-albuminous seeds have no residual endosperm as it is completely consumed during embryo development. eg. pea, ground nut.
- Albuminous seeds retain a part of endosperm as it is not completely used up during embryo development. eg wheat, maize, barley, castor.
- Occasionally, in some seeds such as black pepper and beet, remnants of nucellus are also persistent. This residual, persistent nucellus is the Perisperm.
- Integuments of ovules harden as tough protective seed coat. [outer- Testa and inner tegmen.]. The micropile remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination.
- As the seed matures, its water content is reduced and seeds become relatively dry [10-15% moisture by mass]

Date
Page

- The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called dormancy, or if favorable conditions are available [adequate moisture, oxygen and suitable temp.], they germinates.
- As ovules mature into seeds, the ovary develops into a fruit; i.e. the transformation of ovules into seeds and ovary into fruit proceeds simultaneously. The wall of the ovary develops into the wall of fruit called pericarp.
- The fruits may be fleshy as in Guava, orange, mango etc. or may be dry, as in groundnut and mushroom. Many fruits have evolve mechanism for dispersal of seeds.
- In most plants, by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as apple, strawberry, cashew, etc. the thalamus also contributes to fruit formation. Such fruit are called false fruit. Most fruits however develop only from the ovary and are called true fruits.

(b) Parthenocarpy: Although in most of the species, fruits are the results of fertilization, there are a few species in which fruits develop without fertilization. Such fruits are called parthenocarpic fruits. Banana is one such example. Parthenocarpy can be induced through the application of growth hormones and such fruits are seedless.

- Seeds offer several advantages to angiosperms. Firstly, since reproductive processes such as pollination and fertilization are independent of water, seed formation is more dependable. Also seed have better adaptive strategies for dispersal to new habitats and help the species to colonies in other areas. As they have sufficient food reserves, young seedlings are nurished until they are capable of photosynthesis on their own. The hard seed coat provides protection to the young embryo. Being products of sexual reproduction, they generate new genetic combinations leading to variations. Seed is the basis of agriculture. Dehydration

and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next season.

- How long do the seeds remain alive after they are dispersed?
- This period again varies greatly. In a few species the seeds lose viability within a few months. Seeds of the large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds.
- The oldest is that of a lupine, Lupinus arcticus excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy.
- A recent record of 2000 years old viable seed is of the date palm, Phoenix dactylifera discovered during the archeological excavation at King Herod's palace near the Dead sea.
- Can you think of some plants in which fruits contain very large number of seeds? Orchid fruits are one such category and each fruit contain thousands of tiny seeds. Similar is the case in fruits of some parasitic species such as Orobanche and Striga.
- Apomixis and polyembryony: Although seeds, in general are the products of fertilization, a few flowering plants such as some species of Asteraceae and grasses, have evolved a special mechanism, to produce seeds without fertilization, called Apomixis.
- What is fruit production without fertilization called? Parthenocarpy.
- Thus, apomixis is a form of asexual reproduction that mimics sexual reproduction. There are several ways of development of apomictic seeds. In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilization.

Date
Page

- More often, as in many citrus and mango varieties some of the nucellar cells surrounding the embryosac start dividing, protrude into the embryosac and develop into the embryos. } In such species each ovule contain many embryosac } occurrence of more than one embryo in a seed is referred to as polyembryony
- Hybrid varities of several of our food and vegetable crops are being extensively cultivated } cultivation of hybrids has tremendously increased productivity.
- One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters.
- Production of hybrid seeds is costly and hence the cost of hybrid seeds become to expensive for the farmers.
- If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny } then the farmer can keep on using the hybrid seeds to raises new crop year after year and he does not have to ~~buy~~ buy hybrid seeds every year.
- Ble of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties

Locomotion and movements

Science world HSN

Date 1/11/2018
Page

① - movement is one of the significant features of living beings. } Animals and plants exhibit a wide range of movements. } streaming of protoplasm in the unicellular organisms like Amoeba is a simple form of movement. } movement of cilia, flagella and tentacles as shown by many organism.
- Human beings can move limbs, jaws, eyelids, tongue etc. } some of the movements results in a change of place or locomotion. } such voluntary movements are called locomotion. } walking, running, climbing, flying swiming are all some forms of locomotory movements
- locomotory str need not be different from those affecting other types of movements. } for example, in paramoecium, cilia help in the movement of food through cytopharynx and in locomotion as well.
- Hydra can use its tentacles for capturing its prey and also use them for locomotion.
- We use limbs for changes in body postures and locomotion as well. }
The above observations suggest that movements and locomotion cannot be studied separately. } The too may be linked by starting that All locomotions are movements but all movements are not locomotions
- methods of locomotion performed by animals vary with their habitats and the demand of the situation. } However, locomotion is generally for search of food, shelter, mate, suitable breeding grounds, favourable climatic conditions or to escape from enemies / predators
- Types of movements. } Cells of the human body exhibit main types of movements, namely, amoeboid, ciliary and muscular.
- All WBC are capable of a crawling movements called amoeboid movement. } when WBC moves in blood from one place to another place the process is called diapedesis / migration.
- Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement. } It is effected by pseudopodia formed by the streaming of cytoplasm. } cytoskeletal elements like microfilaments are also involved in amoeboid movement.

- ciliary movement occurs in most of our internal tubular organs which are lined by ciliated epithelium.
- The co-ordinated movements of cilia in the trachea help us in removing dust particles and some of the foreign substances inhaled along with the atmospheric air. } Passage of ova through the female reproductive tract is also facilitated by the ciliary movements
- movements of our limbs, jaws, tongue, etc, requires muscular movement. } The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms. } locomotion requires a perfect co-ordinated activity of muscular, skeletal and neural systems

② - muscles: specialized tissue of mesodermal origin. } About 40-50 % of the body weight of a human adult. } specialized property is Excitability, contractility, extensibility and elasticity. } Muscles have been classified using different criteria, namely location, appearance and nature of regulation of their activities

- Based on their location, three types of muscles are identified:
① skeletal muscles ② Visceral muscles ③ Cardiac muscles.
- Skeletal muscles are closely associated with the skeletal components of the body. } They have a striped appearance under the microscope and hence are called striated muscles } As their activity are under the voluntary control of the nervous system, they are also voluntary muscles too. } They are primarily involved in locomotory actions and changes of body postures
- Visceral muscles are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc } They do not exhibit any striation and are smooth in appearance is smooth muscles (non-striated muscles). } Not under the voluntary control of the nervous system is involuntary muscles. } They assist, for example, in the transportation of food through the

multiple division of nucleus → syncitium.
fusion of multiple cells → coenocytic

Date
Page

digestive tract and gametes through the genital tract.

- Cardiac muscles are the muscles of heart. } many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle } Based on appearance, cardiac muscles are striated. } involuntary in nature as the nervous system does not control their activities directly.

- the str and mechanism of muscle contraction : Each organised skeletal muscle in our body is made of a number of muscle bundles or fascicles held together by a common collagenous connective tissue layer called fascia. } Each muscle bundles contains a number of muscle fibres } Each muscle fibre is lined by the plasma membrane called sarcolemma enclosing the sacroplasm.

- muscle fibre is a syncitium as the sarcoplasm contains many nuclei. } the ER, i.e., sarcoplasmic reticulum of the muscles fibres is the store house of calcium. } A characteristic features of the muscle fibre is the presence of a large number of parallelly arranged filaments in the sarcoplasm called myofilaments or myofibrils } Each myofibril has alternate dark and light bands on it.

- muscle → fascicles [muscles bundle] → muscle fibres [cells] → myofibrils → thick and thin filament

- A detailed study of the myofibril has established that the striated appearance is due to the distribution pattern of two important proteins → Actin and myosin.

- A light bands contain actin and is called I-band or Isotropic band, where as dark band called A-band or Anisotropic band contains myosin. } Both the proteins are arranged as rod like str, parallel to each other and also to the longitudinal axis of the myofibrils.

- Actin filaments are thinner as compared to the myosin filaments, hence are commonly called thin and thick filaments

Date
Page

respectively. In the centre of each 'I' band is an elastic fibre called 'Z' line which bisects it. The thin filaments are firmly attached to the Z-line. The thick filaments in the 'A' band are also held together in the middle of this band by a thin fibrous membrane called 'M' line.

- 'A' and 'I' bands are arranged alternately throughout the length of the myofibrils. The portion of the myofibril b/w two successive 'Z' lines is considered as the functional unit of contraction and is called a *sarcomere.

- In a resting state, the edges of thin filaments on either side of the thick filaments partially overlap the free ends of the thick filaments leaving the central part of the thick filaments. This central part of thick filament, not overlaped by thin filaments is called the 'H' zone.

- Str of contractile proteins: Each actin [thin] filaments is made up of two 'F' [filamentous] actin helically wound to each other. Each 'F' actin is a polymer of 'G' [globular] actins. Two filaments of another protein, tropomyosin also run close to the 'F' actins throughout its length. A complex protein Troponin is distributed at regular intervals on the tropomyosin. In the resting state a subunit of troponin masks the active binding sites for myosin on the actin filaments. Each myosin filaments is also a polymerized protein.

Date
Page

- many monomeric proteins called meromyosins constitute one thick filament. Each meromyosin has two important parts, a globular head with a short arm and a tail, the former being called the heavy meromyosin [HMM] and the latter, the light meromyosin [LMM]
- The HMM components, i.e. the head and short arm projects outwards at regular distance and angle from each other from the surface of a polymerized myosin filament and is known as cross arm. The globular head is an active ATPase enzymes and has binding site for ATP and active sites for actin.

(3) mechanism of muscle contraction: mechanism of muscle contraction is best explained by the sliding filament theory which states that contraction of a muscles fibre takes place by the sliding of the thin filaments of the thick filaments.

- muscle contraction is initiated by a signal sent by the CNS via a motor neuron. A motor neuron along with the muscle fibres connected to it constitute a motor unit. The junction b/w a motor neuron and the sarcolemma of the muscles fibres is called the neuromuscular junction / motor end plate. A neural signal reaching this junction release a neurotransmitter [Acetyl choline] which generate an action potential in the sarcolemma.
- Action potential spreads through the muscle fibre and caused the release of calcium ions into the sarcoplasm. The increased Ca^{2+} level leads to the binding of calcium with a subunit of troponin on actin filaments and thereby remove the masking of active sites for myosin.
- Utilizing the energy from ATP hydrolysis, the myosin head now binds to the exposed active sites on action to form a cross bridge. This pulls the attached action filaments towards the centre of 'A' band. The 'Z' line attached to these actins are also pulled inwards thereby causing a shortening of the sacromere, i.e., contraction.
- It is clear from the above steps, that during shortening of the muscles,

Date
Page

- ~~If it does~~ If i.e., contraction, the 'I' bands get reduced, where as the 'A' bands retain the length. } The myosin releasing the ADP and P_i goes back to its relaxed state. } A new ATP binds and the cross-bridge is broken.
- The ATP is again hydrolysed by the myosin head and the cycle of cross bridge formation and breakage is repeated causing further sliding. } The process continues till the Ca^{++} ions are pumped back to the sarcoplasmic cisternae resulting in the masking of actin filaments. } This cause the return of 'Z' lines back to their original position; i.e., relaxation. } The reaction of the fibres can vary in different muscles.
- Repeated activation of the muscles can lead to the accumulation of lactic acid due to anaerobic breakdown of glycogen in them, causing fatigue.
- muscles contains a red coloured oxygen storing pigment called myoglobin. } myoglobin content is high in some of the muscles which gives a reddish appearance ⇝ Red fibres. } Red fibres muscles contain plenty of mitochondria which can utilize the large amount of O_2 stored in them for ATP production ⇝ ~~Aerobic~~ muscles. } on the other hand, some of the muscles possess very less quantity of myoglobin and therefore, appear pale or whitish ⇝ white fibres.
- Number of mitochondria are also few in them, but the amount of sarcoplasmic reticulum is high ⇝ They depend on anaerobic process for energy.

(4) Skeletal system: It consist of a frame work of bones and a few cartilages. } This system has a significant role in movement shown by the body. } Bone and cartilage are specialised connective tissues. } The bone has a very hard matrix due to calcium salts in it and the cartilage has slightly pliable matrix due to chondroitin salts. } In human beings, this system is made up of 206 bones and a few cartilages.
- It is grouped into two principal divisions- the axial and the appendicular ~~skeleton~~ Skeleton.

Science world HSN

Date
Page

- Axial skeleton comprises 80 bones distributed along the main axis of the body. } The skull, vertebral column, sternum and ribs constitute axial skeleton. } The skull is composed of two sets of bones - cranial and facial, that totals to 22 bones. } cranial bones are 8 in number.} They form the hard protective outer covering, cranium of the brain.} The facial regions is made up of 14 skeletal elements which form the front part of the skull. } A single U-shaped bone called hyoid is present at the base of the buccal cavity and it is also included in the skull.
- Each middle ear contains three tiny bones - malleus, incus and stapes. collectively called ear ossicles. } The skull region articulates with the superior region of the vertebral column with the help of two occipital condyles [dicondylic skull].
- Our vertebral column is formed by 26 serially arranged units called vertebrae and is dorsally placed. } It extends from the base of the skull and constitutes the main frame work of the trunk. } Each vertebra has a central hollow portion [neural canal] through which the spinal cord passes. } first vertebra is the atlas and it articulates with the occipital condyles.
- The vertebral column is differentiated into cervical [7], thoracic [12], lumbar [5], sacral [1-fused] and coccygeal [1-fused] regions starting from the skull. } The number of cervical vertebrae are seven in almost all mammals including human beings. } The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back. } sternum is a flat bone on the ventral midline of thorax.
- There are 12 pairs of ribs. } Each ribs is a thin flat bone connected dorsally to the vertebral column and ventrally to the sternum. } It is ~~vertical~~ has two articulation surfaces on its dorsal end and is hence called bicephalic. } first seven pairs of ribs are called true ribs. } Dorsally

Date
Page

they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilage. The 8th, 9th and 10th pairs of ribs do not articulate directly with the sternum but join with seventh rib with the help of hyaline cartilage. These are called vertebro-chondral [false] ribs. Last two pairs [11th and 12th] of ribs are not connected ventrally and are therefore, called floating ribs.

- Thoracic vertebrae, ribs and sternum together form the rib cage.
- The bones of the limbs along with their girdles constitute the appendicular skeleton. Each limb is made of 30 bones. The bones of the hand [fore limb] are humerus, radius and ulna, carpals [wrist bone - 8 in number], metacarpals [palm bones - 5 in number] and phalanges [digits - 14 in number].
- Femur [thigh bone - the longest bone], tibia and fibula, tarsals [ankle bones - 7 in number], metatarsals [5 in number], and phalanges [digits - 14 in numbers] are the bones of the legs [hind limb]. A cup shaped bone called patella cover the knee ventrally [knee cap].
- The patella is a sesamoid bone roughly triangular in shape, with the apex of the patella facing downwards. The apex is the most inferior [lowest] part of the patella. It is pointed in shape, and gives attachment to the patellar ligaments.
- pectoral and pelvic girdle bones help in the articulation of the upper and the lower limbs respectively with the axial skeleton. Each girdle is formed of two halves. Each half of pectoral girdle consists of a clavicle and a scapula. Scapula is a large triangular flat bone situated in the dorsal part of the thorax b/w the second and the seventh ribs.
- The dorsal, flat, triangular body of scapula has a slightly elevated ridge called the spine which projects as a flat, expanded process called the acromion. The clavicle articulates with this.

- Below the acromion is a dipression called the glenoid cavity which articulates with the head of the humerus to form the shoulder joint. } Each clavicle is a long slender bone with two curvatures. This bone is commonly called the collar bone.
- pelvic girdle consists of two coxal bones. } Each coxal bone is formed by the fusion of three bones - ilium, ischium and pubis.
- At the point of fusion of the above bones is a cavity called acetabulum to which the thigh bone articulates. } The two halves of the pelvic gridle meet ventrally to form the pubic symphysis containing fibrous cartilage.

⑤ joints : Joints are essential for the all types of movements involving the bony parts of the body. } joints are points of contact b/w bones, or b/w bons and cartilages. } forces generated by the muscles is used to carry out movements through joints, where the joints acts as a fulcrum. } The movability of these joints very depending of different factors. } joints have been classified into three major structural forms, namely, fibrous, cartilaginous and synovial.

- fibrous joints do not allow any movements. } This type of joints is shown by the flat skull bone which fuse end-to-end with the help of dense fibrous connective tissues in the form of sutures, to form the cranium.
- In cartilagenous joints, the bones involved are joined together with the help of cartilages. } The joints b/w the adjacent vertebrae in the vertebral column is of this pattern and it permits limited movements.
- synovial joints are characterized by the presence of a fluid filled synovial cavity b/w the articulating surfaces of the two bones. such an arrangements allows considrable movements. } These joints help in locomotion and many other movements.
- Ball and socket joint [b/w humerus and pectoral girdle], hinge joints [knee joints], pivot joint [b/w atlas and axis], gliding joint [b/w

Date
Page

the carpals] and saddle joint [b/w carpal and metacarpal of thumb] are some example of synovial joints

- Disorder of muscular and skeletal system :- ① Myasthenia gravis :→ Autoimmune disorder affecting neuromuscular junction leading to fatigue, weaking and paralysis of skeletal muscles

② muscular dystrophy :→ progressive degeneration of skeletal muscle mostly due to genetic disorder

③ Tetany :→ Rapid spasms [wild contractions] in muscle due low Ca^{+2} in body fluid

④ Arthritis :→ inflamation of joints

⑤ Osteoporosis :→ Age-related disorder characterized by lod bone mass and lod chances of fractures, lod levels of estrogens is a common cause

⑥ Gout :→ inflamation of joints due to accumulation of uric acid crystals