Government College Autonomous (Rajahmundry)-Department of Microbiology

II B.Sc Microbiology Honours -III Semester

Course-8 (CELL BIOLOGY AND GENETICS)

Question Bank-2024-25

Essay type questions (Select any Two from each Unit for Internal Choice)

Unit -I

Q.No	Questions	Marks	BL	CO	PO
1.	State Cell theory. Explain detailed structure of Chloroplast	2+6	1&2	1	
2.	Discuss detailed structure and functions of Mitochondria	8	2	1	
3.	Illastrate cell cycle and it s regulation	8	3	1	

Unit -II

Q.No	Questions	Marks	BL	CO	PO
1.	Review structure and functions of Cell membrane	8	6	2	
2.	Discuss about structure and functions of nuclear membrane	8	3	2	
3.	Define and describe about Oncogenes and suppressor genes.	8	1	2	

Unit -III

Q.No	Questions	Marks	BL	CO	PO
1.	Generalise different Intracellular signal transduction pathways.	8	3	3	
2.	Explain about Programmed cell death	8	2	3	
3.	State structure and importance of Lampbrash and polytene chromosomes	8	2	3	

Unit -IV

Q.No	Questions	Marks	BL	CO	PO
1.	Compare and evaluate Mendal's Law of segregation and independent assortment	8	4&5	4	
2.	Define and distinguish between Incomplete dominance and co-dominance.	8	1&5	4	
3.	Define Multiple alleles, Lethal alleles, Epistasis and Pleiotropy.	4x2=8	1	4	

Unit -V

Q.No	Questions	Marks	BL	CO	PO
1.	Define crossing over. Interpret molecular mechanism of Crossing over	8	1&3	5	

2.	Evaluate the role of Natural selection and its role in Genetic drift and genetic shift	8	4		
3.	Write a short note on A. Sex linked inheritance B. extra chromosomal Inheritance	4+4	2	5	

Review structure and functions of Cell membrane

Plasma Membrane: Structure, Composition, Functions

Membranes are lipid structures that separate the contents of the compartment they surround from its environment.

Plasma membranes separate the cell from its environment while other membranes define the boundaries of organelles and provide a matrix upon which complex chemical reactions can occur.

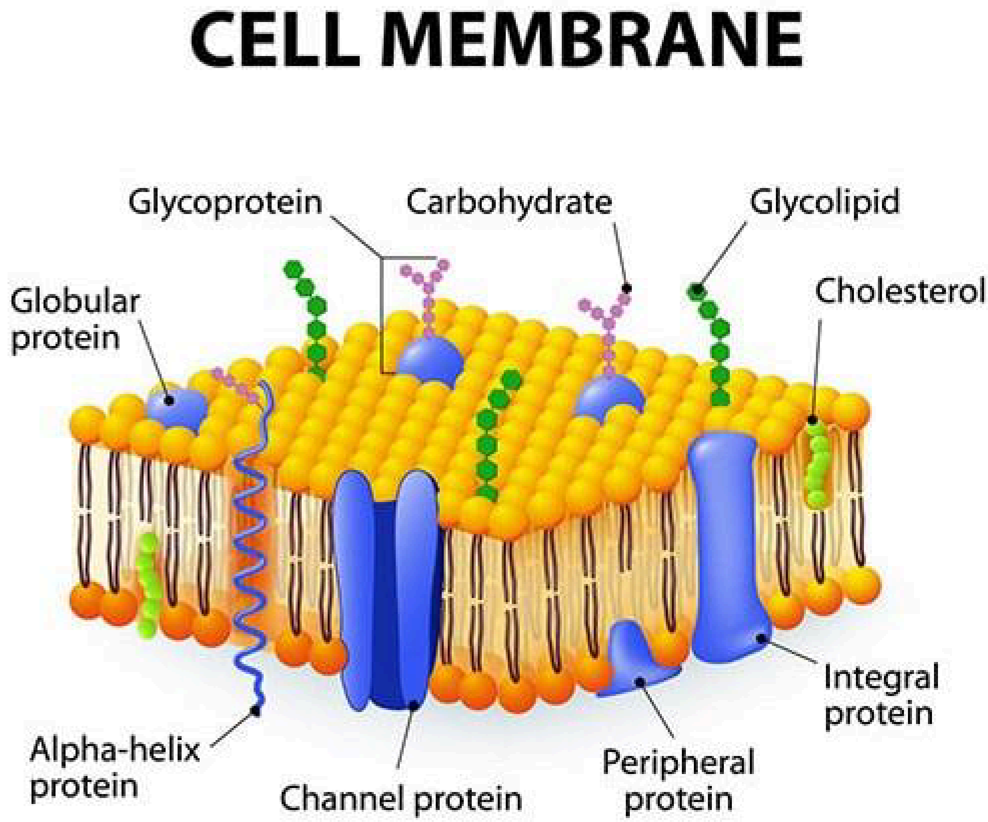
The plasma membrane, also known as the cell surface membrane or plasmalemma, defines the boundary of the cell.

It is a phospholipid bilayer with embedded proteins that encloses every living cell.

It regulates the movement of materials into and out of the cell and facilitates electrical signaling between them.

It is said to be semi-permeable because it allows certain molecules but not others to enter into the cell.

It serves some specific functions such as controlling the flow of nutrients and ions into and out of the cells, mediating the response of a cell to external stimuli (a process called signal transduction), and interacting with bordering cells.



Structure of Plasma membrane: All biological membranes are constructed according to a standard pattern. They consist of a continuous bilayer of amphipathic lipids approximately 5 nm thick, into which proteins are embedded. In addition, some membranes also carry carbohydrates (mono- and oligosaccharides) on their exterior, which are bound to lipids and proteins. The proportions of lipids, proteins, and carbohydrates differ markedly depending on the type of cell and membrane.

• The plasma membrane consists of a lipid bilayer containing embedded and peripheral proteins. The major component of membranes is lipids.

• The lipids in the plasma membrane are in the form of phospholipids, which contain a polar head group attached to two hydrophobic fatty acid tails; the head group faces the aqueous environment, the fatty acid tails the interior of the bilayer.

1. Glycerol-based lipids contain a glycerol backbone, and consist of phosphatidic acid (PA), phosphatidylethanolamine (PE), phosphatidylcholine (PC), phosphatidylserine (PS), phosphatidylglycerol (PG), phosphatidylinositol (PI), and cardiolipin (CL).

2. The one sphingosine-based lipid is sphingomyelin (SM).

3. Cholesterol is present in eukaryotic membranes and maintains membrane fluidity at a variety of temperatures. Fluidity is also determined by the content of unsaturated fatty acids in the membrane, which are liquids at room temperature, and the chain length of the fatty acids (shorter chains are more fluid than longer chains).

• The embedded proteins in the plasma membrane function as either channels or transporters for the movement of compounds across the membrane, as receptors for the binding of hormones and neurotransmitters, or as structural proteins.

• The peripheral membrane proteins provide mechanical support to the membrane through the inner membrane skeleton or the cortical skeleton. An example of this is spectrin in the red blood cell membrane. These can be removed from the membrane by ionic agents.

• The third type of membrane proteins is the glycophosphatidylinositol (GPI) glycan-anchored proteins. One example of a GPI-anchored protein is the prion protein, present in neuronal membranes.

• The plasma membrane glycocalyx consists of short chains of carbohydrates attached to proteins and lipids which extend in the aqueous media and both protects the cell from digestion and restricts the uptake of hydrophobic molecules.
Note:

• Membrane lipids are strongly amphipathic molecules with a polar hydrophilic "head group" and a polar hydrophobic "tail." In membranes, they are primarily held together by the hydrophobic effect and weak Van der Waals forces and are therefore mobile relative to each other. This gives membranes a more or less fluid quality.

• Lipids and proteins are mobile within the membrane. If they are not fixed in place by special mechanisms, they float within the lipid layer as if in a two-dimensional liquid; biological membranes are therefore also described as being a "fluid mosaic".

Functions of Plasma membrane: The most important membranes in animal cells are the plasma membrane, the inner and outer nuclear membranes, the membranes of the endoplasmic reticulum (ER) and the Golgi apparatus, and the inner and outer mitochondrial membranes. Lysosomes, peroxisomes, and various vesicles are also separated from the cytoplasm by membranes. In plants, additional membranes are seen in the plastids and vacuoles. Membranes and their components have the following functions:

1. Enclosure and insulation of cells and organelles. The enclosure provided by the plasma membrane protects cells from their environment both mechanically and chemically.

The plasma membrane is essential for maintaining differences in the concentration of many substances between the intracellular and extracellular compartments.

2. Regulated transport of substances This determines the internal milieu and is a precondition for homeostasis—i. e., the maintenance of constant concentrations of substances and physiological parameters. Regulated and selective transport of substances through pores, channels, and transporters is necessary because the cells and organelles are enclosed by membrane systems.

3. Signal Transduction Reception of extracellular signals and transfer of these signals to the inside of the cell as well as the production of signals.

4. Enzymatic catalysis of reactions. Important enzymes are located in membranes at the interface between the lipid and aqueous phases. This is where reactions with apolar substrates occur. Examples include lipid biosynthesis and the metabolism of apolar xenobiotics. The most important reactions in energy conversion—i. e., oxidative phosphorylation and photosynthesis also occur in membranes.

5. Interactions with other cells For the purposes of cell fusion and tissue formation, as well as communication with the extracellular matrix.

6. Anchoring of the cytoskeleton To maintain the shape of cells and organelles and to provide the basis for movement processes.

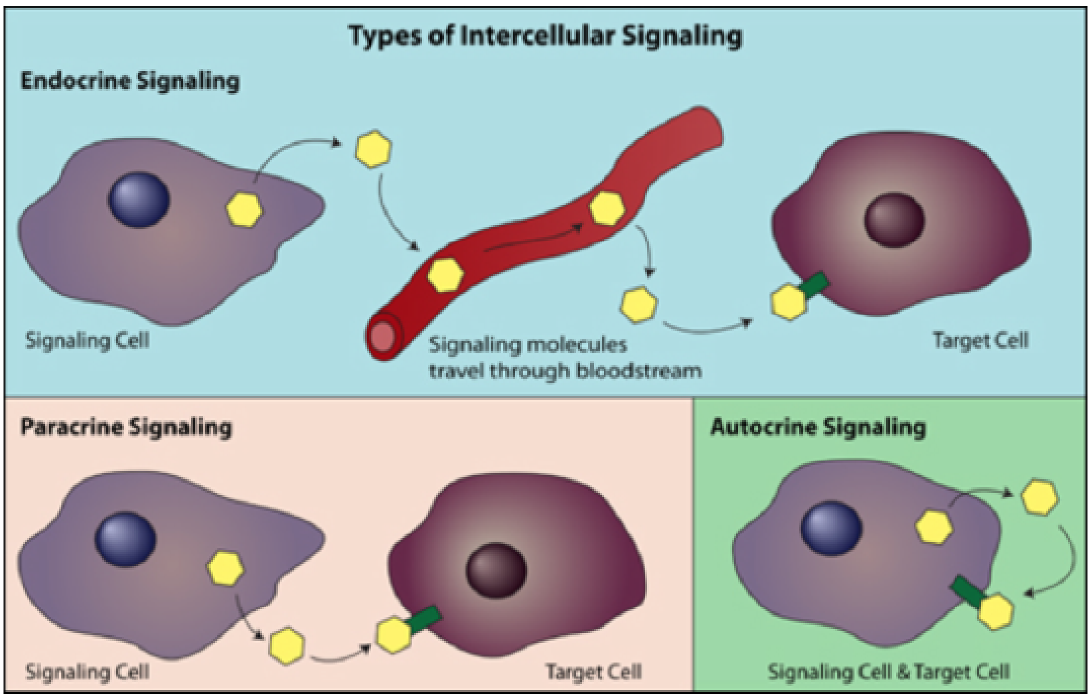
Generalise different Intracellular signal transduction pathways.

Description of Signal Transduction

As living organisms we are constantly receiving and interpreting signals from our environment. These signals can come in the form of light, heat, odors, touch or sound. The cells of our bodies are also constantly receiving signals from other cells. These signals are

important to keep cells alive and functioning as well as to stimulate important events such as cell division and differentiation.

Signals are most often chemicals that can be found in the extracellular fluid around cells. These chemicals can come from distant locations in the body (endocrine signaling by hormones), from nearby cells (paracrine signaling) or can even be secreted by the same cell (autocrine signaling).



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Signaling molecules may trigger any number of cellular responses, including changing the metabolism of the cell receiving the signal or result in a change in gene expression (transcription) within the nucleus of the cell or both.

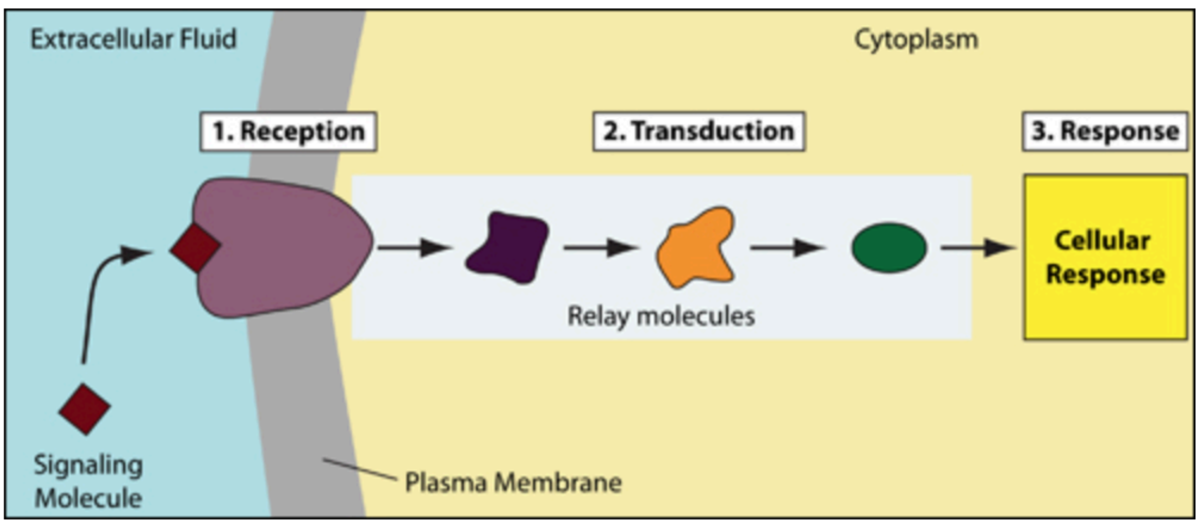
Overview of Cell Signaling

<u>Cell signaling can be divided into 3 stages.</u>

1. Reception: A cell detects a signaling molecule from the outside of the cell. A signal is detected when the chemical signal (also known as a ligand) binds to a receptor protein on the surface of the cell or inside the cell.

2. Transduction: When the signaling molecule binds the receptor it changes the receptor protein in some way. This change initiates the process of transduction. Signal transduction is usually a pathway of several steps. Each relay molecule in the signal transduction pathway changes the next molecule in the pathway.

3. Response: Finally, the signal triggers a specific cellular response.



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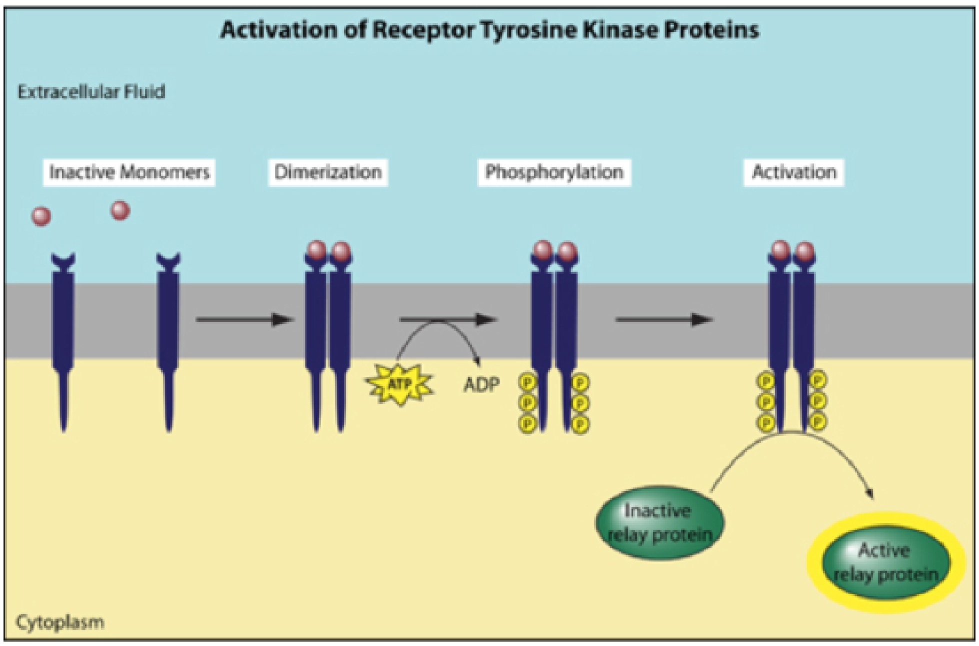
Reception

Membrane receptors function by binding the signal molecule (ligand) and causing the production of a second signal (also known as a

second messenger) that then causes a cellular response. These type of receptors transmit information from the extracellular environment to the inside of the cell by changing shape or by joining with another protein once a specific ligand binds to it. Examples of membrane receptors include G Protein-Coupled Receptors and Receptor Tyrosine Kinases.



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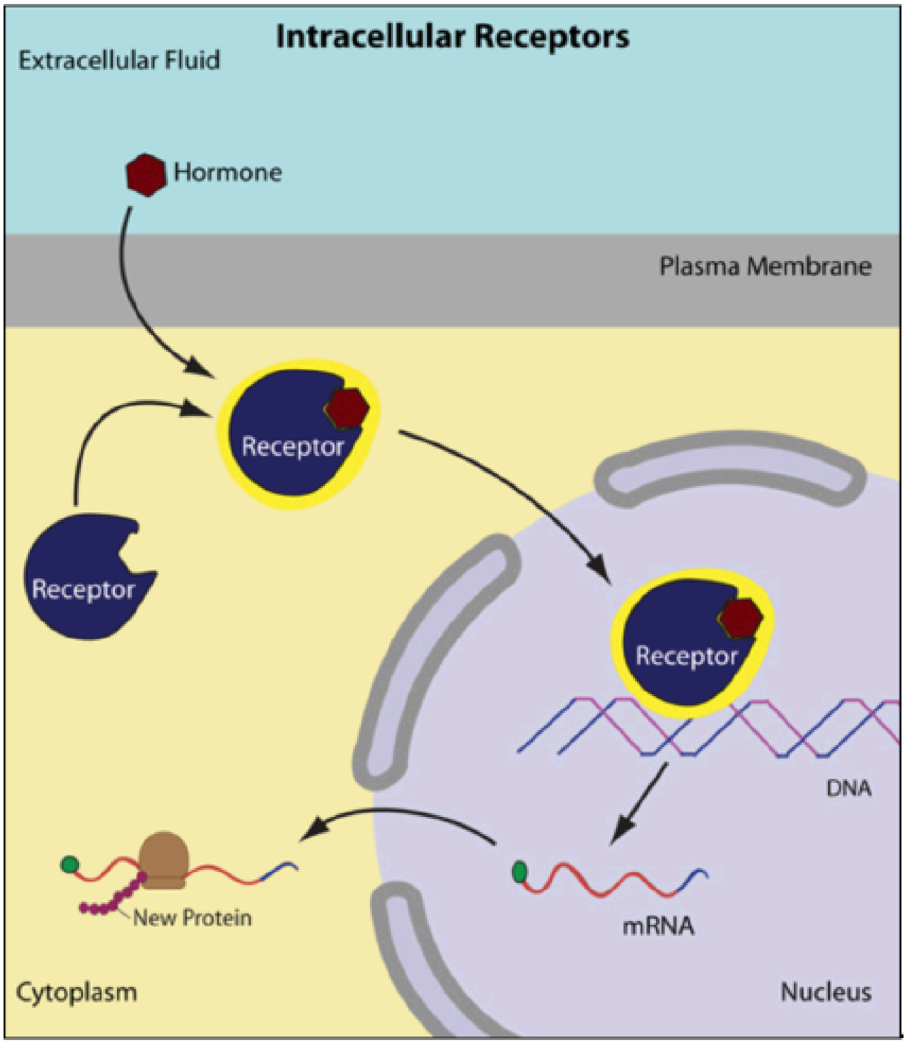
Intracellular receptors are found inside the cell, either in the cytopolasm or in the nucleus of the target cell (the cell receiving the signal). Chemical messengers that are hydrophobic or very small (steroid hormones for example) can pass through the plasma membrane without assistance and bind these intracellular receptors. Once bound and activated by the signal molecule, the activated receptor can initiate a cellular response, such as a change in gene expression.



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Transduction

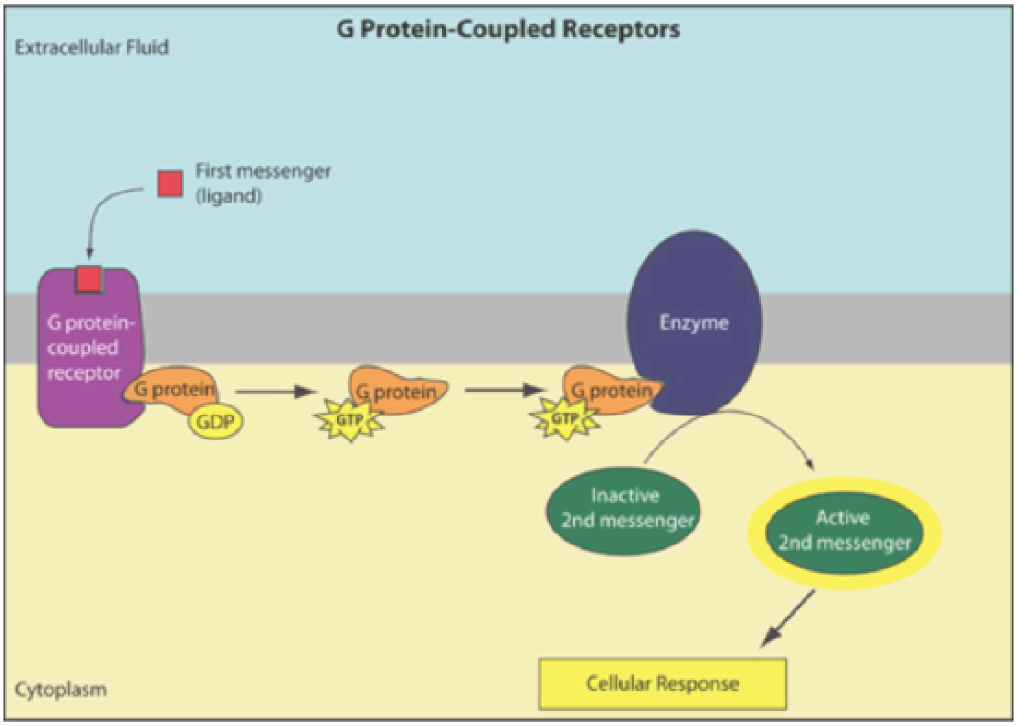
Since signaling systems need to be responsive to small concentrations of chemical signals and act quickly, cells often use a multi-step pathway that transmits the signal quickly, while amplifying the signal to numerous molecules at each step.

Steps in the signal transduction pathway often involve the addition or removal of phosphate groups which results in the activation of

proteins. Enzymes that transfer phosphate groups from ATP to a protein are called protein kinases. Many of the relay molecules in a signal transduction pathway are protein kinases and often act on other protein kinases in the pathway. Often this creates a phosphorylation cascade, where one enzyme phosphorylates another, which then phosphorylates another protein, causing a chain reaction.

Also important to the phosphorylation cascade are a group of proteins known as protein phosphatases. Protein phosphatases are enzymes that can rapidly remove phosphate groups from proteins (dephosphorylation) and thus inactivate protein kinases. Protein phosphatases are the "off switch" in the signal transduction pathway. Turning the signal transduction pathway off when the signal is no longer present is important to ensure that the cellular response is regulated appropriately. Dephosphorylation also makes protein kinases available for reuse and enables the cell to respond again when another signal is received.

Kinases are not the only tools used by cells in signal transduction. Small, nonprotein, water-soluble molecules or ions called second messengers (the ligand that binds the receptor is the first messenger) can also relay signals received by receptors on the cell surface to target molecules in the cytoplasm or the nucleus. Examples of second messengers include cyclic AMP (cAMP) and calcium ions.



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Response

Cell signaling ultimately leads to the regulation of one or more cellular activities. Regulation of gene expression (turning transcription of specific genes on or off) is a common outcome of cell signaling. A signaling pathway may also regulate the activity of a protein, for example opening or closing an ion channel in the plasma membrane or promoting a change in cell metabolism such as catalyzing the breakdown of glycogen. Signaling pathways can also lead to important cellular events such as cell division or apoptosis (programmed cell death).

Explain about Programmed cell death

Apoptosis is a normal genetically programmed cell death where an aging cell at the end of its life cycle shrinks and its remaining fragments are phagocytosed without any inflammatory reaction.

Apoptosis mechanisms

The process of apoptosis is highly complex and sophisticated, involving an energy-dependent series of molecular events.

Three different pathways work on different mechanisms to achieve apoptosis. All three of these pathways converge at the same terminal pathway, which results in the sequential degradation of cellular organelles.

1. Extrinsic or death receptor pathway

- **The extrinsic pathway that initiates apoptosis involves transmembrane receptor-mediated interactions.**
- **These interactions take place between ligands and their corresponding death receptors that are all part of the tumor necrosis factor (TNF) family.**
- **All members of the TNF receptor family share a common cysteine-rich extracellular domain with about 80 amino acids called the "death domain".**
- **The death domain plays a vital role in transmitting the death signal from the cell surface to the intracellular signaling pathways.**
- **The events or interactions that take place in the extrinsic phase of apoptosis involve two**

- **models; FasL/FasR and TNF-*α*/TNFR1 models, both of which include the clustering and binding of receptors and their ligands.**
- **Upon ligand binding, cytoplasmic adapter proteins are activated, which causes the receptors to exhibit death domains.**
- **The binding of FasL to FasR results in the activation of the adapter protein FADD whereas the binding of TNF ligand (TNF α)**

to TNF receptor (TNFR1) results in the binding of the adapter protein TRADD with activation of FADD and RIP.

- **These events cause the dimerization of the death effector domain, causing FADD to bind with procaspase-8.**
- **As a result of the binding, a death-inducing signaling complex (DISC) is formed, resulting in the auto-catalytic activation of procaspase-8.**
- **Once caspase-8 is activated, the terminal phase or execution phase of apoptosis is triggered.**

2. The intrinsic or mitochondrial pathway

- **The intrinsic pathway that initiates apoptosis involves a series of non-receptor-mediated**
- **processes that produce intracellular signals and act directly on targets within the cell.**
- **This pathway involves mitochondrial-initiated events.**
- **The factors that initiate the intrinsic pathway produce intracellular signals that might act in either a positive or negative fashion.**
- **Negative signals include the absence of certain growth factors, cytokines, and hormones that can lead to failure of inhibition of death programs, thereby triggering apoptosis. In simple words, the withdrawal of factors causes loss of apoptotic suppression and subsequent activation of apoptosis.**
- **The factors that act positively include, radiation, toxins, hypoxia, hyperthermia, viral infections, free radicals, among others.**
- **All of these factors cause changes in the inner mitochondrial membrane that causes the opening of the mitochondrial permeability transition (MPT) pore and release of two main groups of pro-apoptotic proteins from the intermembrane space into the cytosol.**
- **The first group consists of cytochrome *c that* binds and activates Apoptotic protease-activating factor – 1(Apaf-1) as well as procaspase-9, forming a protein complex termed, apoptosome.**

- The apoptosome cleaves the procaspase into the active form, caspase 9, which further cleaves and activates procaspase into the effector caspase 3.
- The first group also has other proteins like SMACs (second mitochondria-derived activator of caspases) and HtrA2/Omi that promote apoptosis by inhibiting the activity of IAPs (inhibitors of apoptosis proteins).
- The second group of pro-apoptotic proteins is released from the mitochondria during apoptosis, but this occurs as a part of the terminal phase after the cell has committed to die.
- These proteins translocate to the nucleus and cause DNA fragmentation and condensation of peripheral nuclear chromatin.

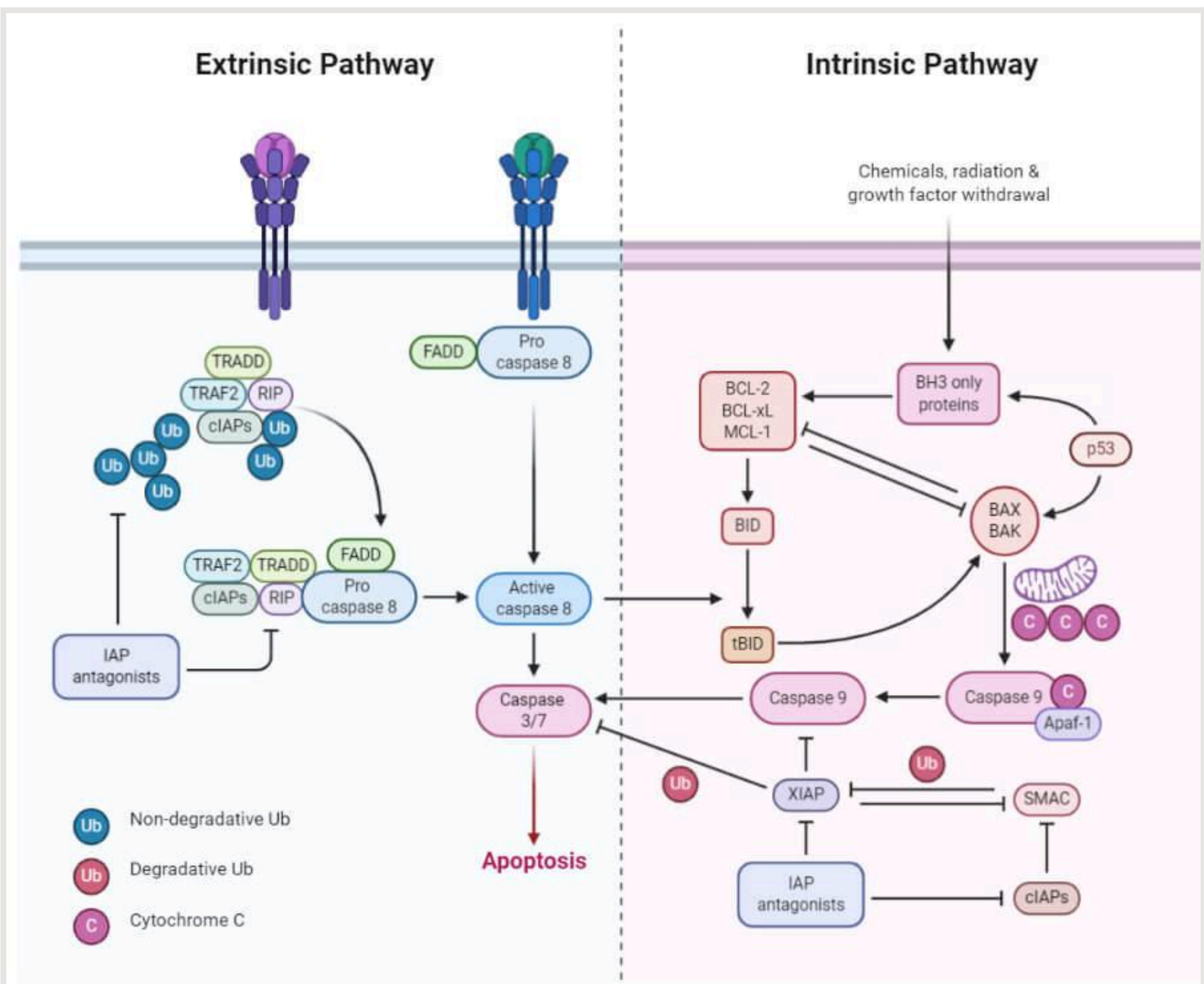


Figure: Extrinsic and Intrinsic Apoptosis. Image created using biorender.com.

3. Perforin/granzyme pathway

- **Perforin/granzyme pathway is a novel pathway employed by cytotoxic T lymphocytes that exert their cytotoxic effects on tumor cells and virus-infected cells.**
- **This involves secretion of the transmembrane pore-forming molecule, *perforin*, with a subsequent release of cytoplasmic granules through the pore and towards the target cell.**
- **The granules consist of two crucial serine proteases; granzyme A and granzyme B that activate different proteins in the pathway.**
- **Granzyme B cleaves proteins at aspartate residues and therefore activates procaspase-10 and can cleave factors like ICAD (Inhibitor of Caspase Activated DNAse.**
- **It has also been observed that granzyme B can utilize the mitochondrial pathway for amplification of the death signal by induction of cytochrome *c release*.**
- **But granzyme B can also directly activate caspase-3. In this pathway, there is a direct induction of the execution phase of apoptosis.**
- **Granzyme A also has an essential role in cytotoxic T cell-induced apoptosis and activates caspase-independent pathways.**
- **As granzyme A reaches the cell, it activates DNA nicking by DNAse enzyme that prevents cancer through the induction of tumor cell apoptosis.**
- **Granzyme A protease cleaves the SET complex that inhibits the production of the DNAse enzyme.**
- **The proteins that make up the SET complex together protect chromatin and DNA structure. Thus, the inactivation of the SET**

complex by granzyme A contributes to apoptosis by blocking the maintenance of DNA and chromatin structure integrity.

4. Execution pathway

- **Both the extrinsic and intrinsic pathways end at the point of the execution phase, considered the terminal pathway of apoptosis.**
- **This phase of apoptosis is initiated by the activation of various caspases that activate cytoplasmic endonucleases and proteases.**
- **The cytoplasmic endonucleases degrade the nuclear material, whereas the proteases degrade the nuclear and cytoskeletal proteins.**
- **Caspase-3 is the most important protein of the executioner caspases and is activated by any of the initiator caspases (caspase-8, caspase-9, or caspase-10).**
- **Caspase-3 precisely activates the endonuclease Caspase-activated DNase (CAD). CAD then causes chromatin condensation by degrading chromosomal DNA within the nuclei.**
- **Caspase-3 also causes cytoskeletal reorganization and disintegration of the cell into apoptotic bodies.**
- **Gelsolin, an actin-binding protein, is considered as one of the critical substrates of activated caspase-3. Caspase-3 cleaves gelsolin and the cleaved fragments of gelsolin, in turn, cleave actin filaments, resulting in disruption of the cytoskeleton and formation of apoptotic bodies.**
- **The later stages of apoptosis cause the appearance of phosphatidylserine on the outer leaflet of apoptotic cells.**
- **This facilitates noninflammatory phagocytic recognition, allowing for their early uptake and disposal.**
- **As the process takes place without the release of cellular components, no inflammatory response is elicited.**

Polytene chromosomes:

Introduction:

- **This special type of chromosome is observed by Balbiani in salivary glands of the Chironomus larvae of Dipteran insects.**

- **Since they were discovered in the salivary glands, they were also called salivary gland chromosomes.**

- **The present name polytene chromosome was suggested by Kollar due to the occurrence of many chromonemata(DNA) in them.**

- **Thus, some cells of Drosophila, Chironomus and mosquitoes become very large having high DNA content.**

- **Polyteny of giant chromosomes is achieved by replication of the DNA several times without nuclear division and the resulting daughter chromatids do not separate but remain aligned side by side.**

Detailed explanation:

- **Chromonema is required to form Polytene chromosomes which are formed by chromosomal replication without nuclear division.**

- **The giant chromosomes are also formed by the process of somatic pairing between homologous chromosomes.**

- **The resultant daughter chromosomes remain aligned with each other and not separated from each other.**

- **This is very useful for the analysis of many facets of eukaryotic interphase chromosome organization and the genome as a whole.**

- **The salivary gland cells do not undergo mitosis and die during metamorphosis.**

- **This chromosome is symbolized by Balbiani rings or puffs which are swollen or puffy areas in polytene chromosomes.**
- **This chromosome is the site of mRNA synthesis and is multi- stranded in nature.**
- **The action of the basic dyes can result in the bearing of the number of dark bands in the polytene chromosome of varying size and intensity.**
- **The dark bands are presumed to be formed by the juxtaposition of chromomeres of the different chromonemata of a polytene chromosome.**
- **They are found in the permanent prophase stage of mitosis.**
- **In puffs, DNA is uncoiled for rapid transcription of RNA.**
- **Hence, the main function is the synthesis of RNA and proteins.**

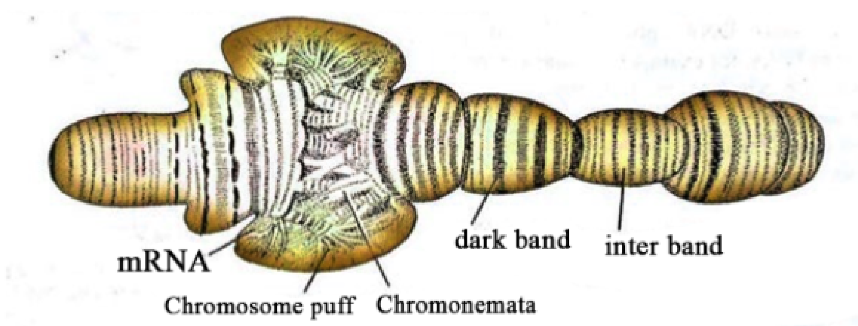


Fig.Polytene chromosome of an insect,showing bands and interbands and a puff or Balbiani ring.

Lampbrush chromosome :

Introduction:

- Lampbrush chromosomes were first observed in Salamander(amphibian) oocytes in 1882.
- He coined the name because the chromosomes look like the brushes which were used for cleaning the glass chimneys of old fashioned paraffin or kerosene lamps.
- This type of chromosome was observed by Flemming in 1882.
- Lampbrush chromosomes occur in the diplotene chromosomes bivalents of most in animal oocytes.
- It is also found in spermatocytes of several species, a giant cell of Acetabularia, and even in plants.
- These chromosomes are even larger than the polytene chromosomes.

Detailed explanation:

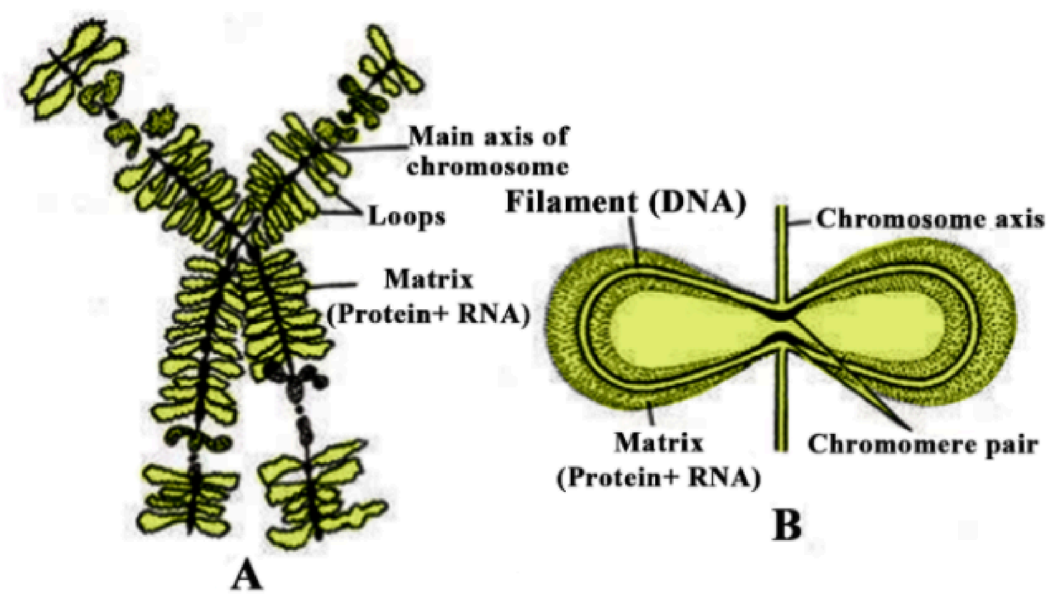


Fig. Lampbrush chromosome. A, Enlarge view of a part of lampbrush chromosome. B, One loop of a lampbrush chromosome

- Lampbrush Chromosomes are concerned with vitellogenesis (Yolk formation).

- **This is the special kind of synapsed mid prophase or the Diplotene bivalent stage**
- **This chromosome occurs in pairs containing homologous chromosomes containing the point of contact known as chiasmata.**
- **The chromatids forming the chromosomes bear a large number of chromomeres which are separated by interchromomeric stretches.**
- **Many of the chromomeres give out lateral projections or loops which provide a lampbrush-like appearance to the chromosome pair.**
- **These loops contain one to several transcriptional units which show transcription of mRNA required for the synthesis of the substances for growth and development of meiocytes.**
- **Some mRNAs produced by lampbrush chromosomes may be stored as informosomes (mRNA + protein) for producing biochemicals during the early development of the embryo.**
- **The lateral loops are withdrawn followed by the shortening of chromosomes, after the full development of meiocytes.**
- **The main function is synthesis of RNA and proteins.**
- **Lampbrush chromosome is a model useful for studying chromosome organization, genome function and gene expression during meiotic prophase.**
- **This also allows the visualization of the individual transcription units.**

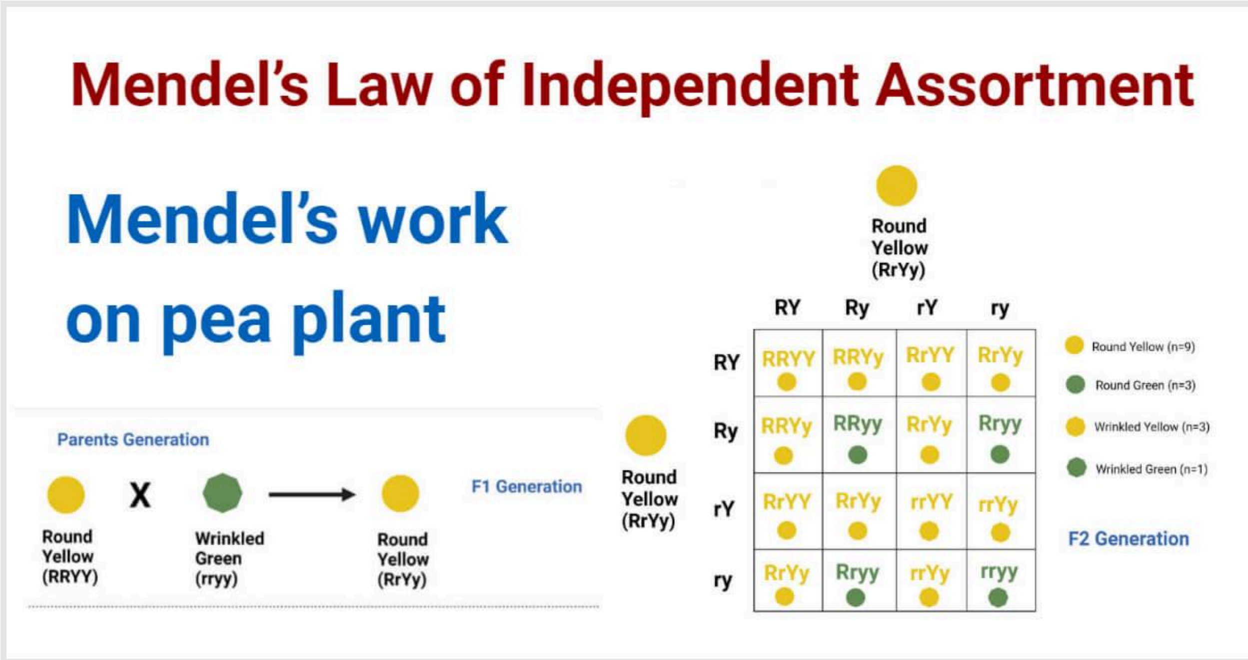
1. Characteristics and Principle of Mendel's Law of Independent Assortment

- The law of independent assortment, like the law of segregation, is based on meiosis cell division that occurs during sexual reproduction.
- During meiosis, the diploid chromosomes in the parents are separated to form the haploid gametes.
- The assortment of the chromosomes to the haploid gametes occurs independently of each other in a random manner.
- Thus, it is possible that the chromosomes from the same source can end up in different gametes, resulting in different characteristics.
- Independent assortment of genes is also based on recombination of chromosomes during meiosis which results in a further assortment of genes or characters.
- The pieces of chromosomes from the parents are assorted randomly during recombination resulting in the independent rearrangement.
- The mechanism of independent assortment can be studied by the example of a cross between a homozygous pea plant with yellow round seeds and a homozygous pea plant with green wrinkled seeds.
- The cross between these individuals produces distinct offspring where each pair of contrasting characters is expressed independently of the other characters.
- If the allele for the pea plant with yellow round seeds is YYRR and that with green wrinkled seeds is yyrr, the resulting offspring can have genotypes that include YyRR, YyRr, YYRr, YYrr, Yyrr, yyRR, and yyRr.
- This proves that even though the allele R is associated with the allele Y in the parent, it can express itself in other combinations.

Examples of Mendel's Law of Independent Assortment

1. Mendel’s work on pea plant

- **Mendel used the dihybrid cross between a homozygous pea plant with yellow round seeds and a homozygous pea plant with green wrinkled seeds. The parents have the alleles YYRR and yyrr, respectively.**
- **During meiosis, the chromosomes are separated so that only half the genes are transported to the gametes. The possible genotypes of the gametes then become YR and yr.**
- **As the parents are crossed, the fusion of the gametes results in the F1 hybrid with the YyRr genotype.**
- **The F1 hybrids have the phenotype of yellow round seeds as the dominant allele Y for yellow color, and the dominant allele R for the roundness is expressed.**
- **The alleles in F1 hybrids can now be segregated into four parts; Y for yellow color, y for green color, R for roundness, and r for wrinkledness.**
- **The four alleles can combine in a number of combinations to produce different genotypes and phenotypes.**
- **On further crossing, four types of gametes can be formed; YR, Yr. yR, and yr. These gametes fuse to form sixteen individuals in the F2 generation.**
- **The ratio of the F2 hybrids is 9 yellow round: 3 yellow wrinkled: 3 green round: 1 green wrinkled.**
- **This proves that both the characters are inherited independently of one another and are expressed according to their dominance.**



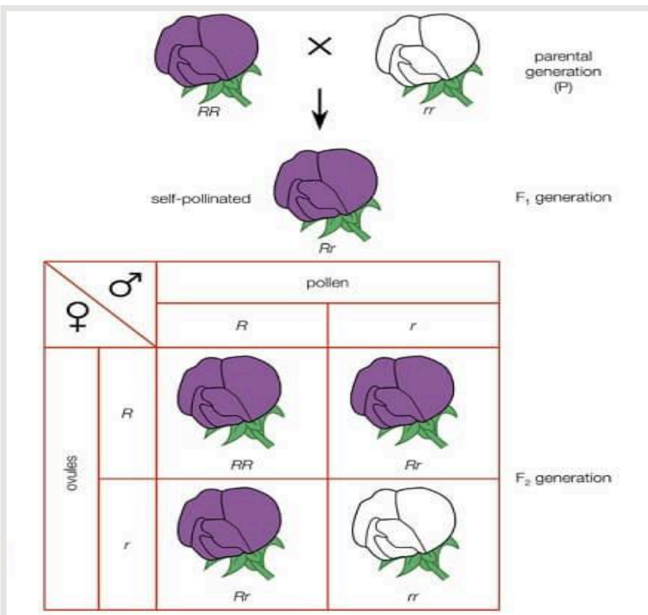
Mendel's Law of Segregation

Mendel's Law of Segregation Definition

Mendel's Law of Segregation states that 'The hybrids or heterozygotes of F1 generation have two contrasting characters of dominant and recessive nature where the alleles though remain together for a long time do not contaminate or mix with each other and separate or segregate at the time of gametogenesis so that each gamete receives only one allele of a character either dominant or recessive.'

- **In simple words, the law states that only a single gene copy from a parent is distributed in a gamete, and the allocation of the gene copies is entirely random.**
- **Mendel's law of segregation is based on a number of concepts;**
  - **a gene exists in more than one form of an allele.**
  - **during the formation of gametes, the allelic pair of a gene separate so that each gamete has a single allele.**
  - **all organisms inherit two alleles for a genetic trait.**
  - **the two alleles obtained for a trait are different as one is dominant and the other is recessive.**

- The law of segregation enables the use of Punnett square for the estimation of resulting genotypes from a cross as it is based on the equal segregation of alleles.
- The law of segregation is significant as it introduced the concept of hereditary factors that remain as separate entities even when present together with other similar entities.
- The law was used to disprove a blending theory by the generation of traits encoded by recessive alleles in the F1 generation.



Incomplete Dominance vs. Co-dominance:

Incomplete dominance definition

Incomplete dominance is a mechanism of dominance in heterozygotes, where the dominant allele does not entirely overcome the phenotypic expression of the recessive allele, and there occurs an intermediate phenotype in the heterozygote.

- **Incomplete dominance is also called partial dominance or semi-dominance as the phenotype resulting from the genotype is a blend of dominant and recessive alleles.**

- **An example of this is observed in flowers where the dominant allele is red, and the recessive is white. However, the heterozygous flowers from these alleles might appear pink due to incomplete dominance.**
- **In incomplete dominance, the dominant allele cannot completely dominate the recessive allele, as a result of which, the resulting phenotype becomes a mix of both.**
- **Incomplete dominance is important as it explains the existence of a mix of two alleles that are not described by Mendel in his experiment.**
- **Mendel explained the Law of dominance to indicate that one of the two alleles is dominant as it always dominates the recessive character.**

- **Mendel couldn't study incomplete dominance as the pea plant he selected for his experiment didn't show incomplete dominance.**
- **However, his model can still be used to determine the results of crosses of alleles by incomplete dominance. According to his model, the resulting F1 generation will be in the genotypic ratio of 1:2:1 and the phenotypic ratio will be red: pink: white.**
- **This result indicates that the alleles are still inherited according to Mendel's rule even with incomplete dominance.**
- **In quantitative genetics, if the phenotype of heterozygous alleles is exactly between (numerically) that of the two homozygotes, this is considered as no dominance. That is, for dominance to occur, the phenotype of heterozygote must lie closer to one of the homozygotes.**

Co-dominance definition

Co-dominance is the mechanism of dominance seen in some alleles where both alleles of a gene in a heterozygote lack the dominant and recessive relationship, and each allele is capable of some degree of phenotypic expression.

- **Co-dominance is sometimes considered as no dominance at all as the heterozygote shows the phenotypes of both homozygotes.**

- Thus, heterozygote genotype gives rise to a phenotype distinctly different from either of the homozygous genotypes.
- For codominant alleles, all upper case base symbols with different superscripts are used. The upper case letters indicate that each allele can express itself to some degree even when in the
- presence of its alternative allele.
- An example of co-dominance can be observed in plants where the dominant phenotype is red, and the recessive phenotype is white, and the heterozygote will have flowers with pink and white spots.
- Like incomplete dominance, co-dominance was also not explained by Mendel as the model he chose didn't express co-dominance.
- However, his model can still be used to determine the results of crosses of alleles by co-complete dominance. According to his model, the resulting F1 generation will be in the genotypic ratio of 1:2:1 and the phenotypic ratio will be red: spotted: white.
- Co-dominance can usually be easily detected in plants and animals with two different colors, but it might also occur in some less visible traits like the blood type.
- Thus, co-dominance is different from incomplete dominance as in co-dominance both the alleles co-exist but separately but in incomplete dominance, the phenotype will be a blend of the two alleles.

Examples of incomplete dominance

Wavy hair in humans

- Curly hair is the dominant trait in humans, whereas straight hair is the recessive trait.
- In heterozygous species, the resulting phenotype is wavy hair which is an intermediate between straight and curly.
- Thus, wavy hair results from incomplete dominance where the phenotype results due to the mixing of the two traits.

- **Wavy hair, thus, represents a novel phenotype different from straight or curly hair.**
- **Offsprings formed from two parents with homozygous genotypes will have a genotypic ratio of 1:2:1 with the phenotypic ratio or curly: wavy: straight.**

Examples of co-dominance

Blood type in humans

- **Blood type in humans is determined on the basis of the gene for the proteins that appear on the outside of the blood cells.**
- **The alleles present are A, B, and O, where A and B represent two different proteins, but O represents the absence of any proteins.**
- **The existence of A and B proteins, like two colors in flowers, can occur together as a result of co-dominance.**
- **Thus, if both the proteins A and B are inherited to the offsprings, and both are expressed, AB blood type might occur in the offsprings.**
- **However, the blood type O represents a dominant/recessive relationship where if A and B genes are expressed, then O doesn't get expressed.**

Define Multiple alleles, Lethal alleles, Epistasis and Pleiotropy.

Multiple allele:

different variants of a gene located at the same location on homologous chromosomes are known as alleles or allelomorphs. Multiple alleles refer to genes that have more than two allelic forms.

- **A haploid cell only has one allele, while a diploid cell might have either of the two alleles present on each homologous chromosome.**
- **Multiple allelism is the term used when more than one allele controls a characteristic. A gene may have many alleles that reside at the same chromosomal location.**
- **As different expressions of the same gene, multiple alleles affect the same trait.**
- **The wild-type allele predominates over the mutant alleles in most cases. All other alleles are viewed as variations of the wild type, which is the accepted norm.**
- **The mutant or variant allele may have an intermediate influence on phenotype or be either dominant or recessive.**
- **At the population level, there are several alleles, but an individual can only have two alleles for a specific gene.**
- **The ABO blood type system used by people is one of the most well-known examples of multiple alleles.**
- **Three alleles, A, B, and O, make up the ABO system. Specific glycoproteins found on the surface of red blood cells are encoded by these alleles.**
- **The O allele does not code for any antigen, while the A allele does for the A antigen, the B allele does for the B antigen, and so on. Because the A and B alleles are codominant, both antigens will be expressed on a person's red blood cells if they inherit one of each.**

Pleiotropy

Pleiotropy refers to the phenomenon in which one gene influences several attributes, wherein one allele may cause a variety of phenotypic features in several alleles. This is possible because a gene may produce a protein or RNA molecule that functions in several cellular or metabolic pathways. As a result, modifications to the gene sequence may affect a variety of biological functions, producing pleiotropic effects.

Ex; The gene that causes sickle cell anaemia is one instance of pleiotropy. This gene produces the haemoglobin protein, which is in charge of transporting oxygen in red blood cells.

Lethality

For the alleles that Mendel studied, it was equally possible to get homozygous dominant, homozygous recessive, and heterozygous genotypes. That is, none of these genotypes affected the survival of the pea plants. However, this is not the case for all genes and all alleles.

Many genes in an organism's genome are needed for survival. If an allele makes one of these genes nonfunctional, or causes it to take on an abnormal, harmful activity, it may be impossible to get a living organism with a homozygous (or, in some cases, even a heterozygous) genotype.

Example: The yellow mouse

A classic example of an allele that affects survival is the lethal yellow allele, a spontaneous mutation in mice that makes their coats yellow. The dominant allele progeny all will die in the F1 generation.

Epistasis:

Epistasis is the interaction between two non-allelic genes where the phenotypic expression of one gene is masked or suppressed by the expression of one or more other genes.

This states that certain characters are governed by the expression of two or more genes. Gene interaction occurs as a result of interaction between two or more allelic or non-allelic genes of the same genotype. As a consequence of this, variation in particular phenotypic characters occur.

The expression of one gene relies on the expression (i.e., presence or absence) of another gene, i.e., the expression of genes is not independent of each other.

- **Example: Fruit color in Summer Squash (*Cucurbita pepo*)**
- **It modifies the classical ratio of 9:3:3:1 into 12:3:1 for the F2 hybrid.**
- **White, yellow, and green are the three different colors of squash fruits.**
- **The allele for white color is dominant over both yellow and green. Similarly, yellow is dominant over green color.**
- **If the dominant allele W is present, it masks the phenotypic effect of the yellow and green allele, and thus, the fruit becomes white.**

COURSE 8: - CELL BIOLOGY AND GENETICS

UNIT-1

Multiple Choice Questions (MCQ)

1. Which statement is part of the cell theory?
   a) All organisms are made up of multiple cells.
   b) Cells arise only from pre-existing cells.
   c) Cells do not contain hereditary material.
   d) Energy flows outside of cells.
   Answer: b) Cells arise only from pre-existing cells.
2. Which organelle is responsible for packaging and modifying proteins in eukaryotic cells?
   a) Mitochondria
   b) Lysosomes
   c) Golgi apparatus

d) Endoplasmic reticulum
Answer: c) Golgi apparatus

3. What is the main function of peroxisomes?
a) Protein synthesis
b) Lipid synthesis
c) Detoxification of harmful substances
d) ATP production
Answer: c) Detoxification of harmful substances
4. Which phase of the cell cycle involves the duplication of DNA?
a) G1 phase
b) S phase
c) G2 phase
d) M phase
Answer: b) S phase
5. Which cytoskeletal structure is primarily involved in muscle contraction?
a) Microtubules
b) Intermediate filaments
c) Actin filaments
d) Golgi network
Answer: c) Actin filaments

Fill in the Blanks

6. Mitochondria are often referred to as the ________ of the cell because they produce ATP through cellular respiration.
Answer: powerhouse
7. The cytoskeleton is composed of actin filaments, intermediate filaments, and ________, each contributing to the cell's shape and internal organization.
Answer: microtubules
8. The G1 checkpoint in the cell cycle ensures that the cell is ready to enter the S phase and begin ________ replication.
Answer: DNA

True or False

9. True or False: Lysosomes are involved in the breakdown of cellular waste and damaged organelles.
Answer: True
10. True or False: Intermediate filaments are primarily involved in the transport of vesicles throughout the cell.
Answer: False

UNIT-2

Multiple Choice Questions (MCQ)

1. The primary function of the Na+/K+ pump in the cell membrane is to:
   a) Transport glucose into the cell
   b) Maintain the electrochemical gradient by moving 3 Na+ ions out and 2 K+ ions in
   c) Facilitate passive diffusion of ions
   d) Pump calcium ions into the endoplasmic reticulum
   Answer: b) Maintain the electrochemical gradient by moving 3 Na+ ions out and 2 K+ ions in
2. Which process involves the cell engulfing large particles or debris from the extracellular environment?
   a) Pinocytosis
   b) Phagocytosis
   c) Exocytosis
   d) Diffusion
   Answer: b) Phagocytosis
3. The nuclear pore complex primarily functions to:
   a) Regulate the movement of molecules between the nucleus and the cytoplasm
   b) Produce ribosomal RNA
   c) Anchor the nuclear envelope to the cytoskeleton
   d) Synthesize DNA
   Answer: a) Regulate the movement of molecules between the nucleus and the cytoplasm
4. Which gene, when mutated, is most commonly associated with promoting the development of cancer?
   a) p53
   b) BRCA1
   c) Ras
   d) Calmodulin
   Answer: c) Ras
5. Which of the following is a function of tumor suppressor genes?
   a) Promote cell growth and division
   b) Initiate DNA repair mechanisms
   c) Inhibit apoptosis
   d) Increase the rate of cellular metabolism
   Answer: b) Initiate DNA repair mechanisms

Fill in the Blanks

6. The calmodulin protein binds to ________ ions to regulate various cellular processes, including signal transduction pathways.
   Answer: calcium (Ca^{2+})
7. Exocytosis is a process where vesicles fuse with the plasma membrane to release their contents into the ________ space.
   Answer: extracellular
8. The nucleolus is the site within the nucleus responsible for synthesizing ________.
   Answer: ribosomal RNA (rRNA)

True or False

9. True or False: The nuclear lamina is a mesh-like structure that provides mechanical support to the nuclear envelope and regulates nuclear events such as DNA replication.
   Answer: True
10. True or False: Oncogenes normally function to suppress tumor growth, but when mutated, they can lead to uncontrolled cell division.
   Answer: False

UNIT-3

Multiple Choice Questions (MCQ)

1. Which organelle is primarily involved in the sorting and modification of proteins before they are transported to their destination?
   a) Mitochondria
   b) Golgi apparatus
   c) Lysosomes
   d) Nucleus
   Answer: b) Golgi apparatus
2. G protein-coupled receptors (GPCRs) activate which molecule after binding to a ligand?
   a) mTOR
   b) G proteins
   c) ERK
   d) DNA
   Answer: b) G proteins
3. Which signal transduction pathway is activated by growth factors and leads to cell proliferation?
   a) GPCR Pathway
   b) ERK/MAPK Pathway
   c) mTOR Pathway
   d) Apoptotic Pathway
   Answer: b) ERK/MAPK Pathway
4. Programmed cell death, or apoptosis, is characterized by all of the following EXCEPT:
   a) Cell shrinkage
   b) DNA fragmentation
   c) Inflammation
   d) Caspase activation
   Answer: c) Inflammation
5. Polytene chromosomes are primarily found in:
   a) Human liver cells
   b) Drosophila salivary glands
   c) Frog oocytes
   d) Mammalian neurons
   Answer: b) Drosophila salivary glands

Fill in the Blanks

6. The mTOR signaling pathway is crucial for regulating cell growth and ________, responding to nutrients, growth factors, and energy status.
   Answer: metabolism
7. Lampbrush chromosomes are large, extended chromosomes found in the oocytes of ________ and amphibians, with loops of chromatin active in transcription.
   Answer: birds
8. Stem cells have the ability to differentiate into specialized cell types and are also capable of ________ division, giving rise to identical stem cells.
   Answer: self-renewing

True or False

9. True or False: In the GPCR signaling pathway, GTP-bound G proteins activate downstream effectors such as adenylyl cyclase or phospholipase C.
   Answer: True
10. True or False: Apoptosis is an uncontrolled cell death process that results in damage to neighboring cells and tissue.
   Answer: False

UNIT-4

Multiple Choice Questions (MCQ)

1. In a monohybrid cross, which of the following is the phenotypic ratio observed in the F2 generation according to Mendel's law of dominance?
   a) 1:2:1
   b) 3:1
   c) 9:3:3:1
   d) 1:1
   Answer: b) 3:1
2. Which of Mendel's laws states that alleles for different traits are inherited independently of one another?
   a) Law of Segregation
   b) Law of Dominance
   c) Law of Independent Assortment
   d) Law of Linkage
   Answer: c) Law of Independent Assortment
3. What type of inheritance is shown when both alleles in a heterozygote are fully expressed, as in AB blood type?
   a) Incomplete dominance
   b) Co-dominance
   c) Pleiotropy
   d) Epistasis
   Answer: b) Co-dominance
4. In pedigree analysis, a filled-in square represents a(n):
   a) Male without the trait

b) Female without the trait
c) Male with the trait
d) Female with the trait
Answer: c) Male with the trait

5. In a dihybrid cross, the phenotypic ratio of the F2 generation is typically:
a) 1:2:1
b) 9:3:3:1
c) 3:1
d) 1:1
Answer: b) 9:3:3:1

Fill in the Blanks

6. Multiple alleles refer to a gene having more than two ________, such as the ABO blood group system.
Answer: alleles
7. Lethal alleles can cause death when present in the ________ state, often resulting in altered Mendelian ratios in offspring.
Answer: homozygous
8. Pleiotropy occurs when a single gene affects ________ traits, as seen in conditions like Marfan syndrome.
Answer: multiple

True or False

9. True or False: In incomplete dominance, the heterozygote exhibits a phenotype that is an intermediate between the two homozygous phenotypes.
Answer: True
10. True or False: Epistasis occurs when one gene masks or alters the expression of another gene at a different locus.
Answer: True

UNIT-5

Multiple Choice Questions (MCQ)

1. Linkage refers to:
a) Genes located on different chromosomes
b) Genes that are inherited together because they are located on the same chromosome
c) Genes that do not assort independently
d) Both b and c
Answer: d) Both b and c
2. During crossing over, genetic material is exchanged between:
a) Non-homologous chromosomes
b) Homologous chromosomes
c) Sister chromatids

d) None of the above
Answer: b) Homologous chromosomes

3. Recombination frequency is used to measure:
   a) The mutation rate in a population
   b) The intensity of linkage between genes
   c) The rate of natural selection
   d) The rate of genetic drift
   Answer: b) The intensity of linkage between genes
4. Genetic drift is most pronounced in:
   a) Large populations
   b) Small populations
   c) Stable environments
   d) Diverse ecosystems
   Answer: b) Small populations

Fill in the Blanks

5. Speciation occurs when populations of the same species become ________ and evolve into different species over time.
   Answer: reproductively isolated
6. Sex-linked inheritance typically involves genes located on the ________ chromosomes.
   Answer: sex
7. Extra-chromosomal inheritance refers to the transmission of genetic material found outside the _________.
   Answer: nucleus
8. Crossing over results in new combinations of alleles, which contributes to genetic ________ in a population.
   Answer: variation

True or False

9. True or False: The process of natural selection acts only on phenotypes, not genotypes.
   Answer: True
10. True or False: In linkage, genes that are located far apart on the same chromosome assort independently.
    Answer: False