INHERITANCE AND EVOLUTION

Competency: The learner appreciates the transmission of traits from one generation to the next, and the mechanisms that drive change in a gene pool, by analysing the concepts of inheritance and evolution, so as to make informed decisions regarding inheritable conditions, for genetic engineering, conservation biology, and health.

A) ANALYSE THE STRUCTURAL AND FUNCTIONAL SIGNIFICANCE OF NUCLEIC ACIDS IN MEIOSIS AND MITOSIS, THEIR ROLE IN CELLULAR FUNCTIONS, AND HOW MUTATIONS IN NUCLEOTIDE SEQUENCES CAN CONTRIBUTE TO DISEASE.

- 3D models of Deoxyribonucleic acid (DNA), Ribonucleic acid (RNA), and chromosome and base-pairing rules.
- properties of the genetic code.
- semi-conservative DNA replication.
- protein synthesis.
- mitosis and meiosis
- cancer causes risk factors, prevention, and management.

NUCLEIC ACIDS

These are made up of chains of individual units called **nucleotides**. Nucleic acids carry the genetic code that determines the order of amino acids in proteins. Genetic material stores information, can be replicated, and undergoes mutations. They differ from proteins as it has no sulphur.

There are two types of nucleic acids i.e.

- DNA (Deoxyribo-Nucleic Acid)
- RNA (Ribo Nucleic Acid)

1. Prophase

It is the first and the longest of all phases of mitosis. Prophase shows the following distinct changes within the cell:

- The beginning is marked by the appearance of thin thread-like condensing X-shaped chromosomes.
- Each chromosome is made of two coiled filaments called sister chromatids.
- As the stage progresses, the sister chromatids become increasingly shorter and thicker that join together at a site called the centromere.
- The two pairs of centrioles, formed during interphase, move away from each other to the opposite poles of the cell.
- Spindle fibers formed of microtubules and proteins begin to appear and gradually extend across the cell between the centrioles as they move towards opposite poles.
- On reaching the end of this phase, the nuclear envelope starts to breaks apart thus releasing the chromosome
- The nucleolus gradually disintegrates. The chromosomes begin to migrate towards the center of the cell, marking the end of prophase.

2. Metaphase

It is the second phase of mitosis and is marked with the complete disappearance of the nuclear envelope that had started during prophase.

- The chromosomes, which are at their shortest and thickest stage with two sister chromatids, get attached to the spindle fibers present at the opposite poles.
- They then align end to end along the middle of the cell.
- The spindle fibers then attach to each of the sister chromatids.

3. Anaphase

- It starts by splitting each paired chromosome into two sister chromatids, now known as daughter chromosomes.
- The daughter chromosomes are pulled towards the opposite end of the cell due to the contraction of the spindle fibers.
- At the end of this phase, each pole contains a complete set of chromosomes.

4. Telophase

- It is the last recognized phase of mitosis marked by the end of the daughter chromosome's migration to the opposite poles.
- Nuclear envelope redevelops around each group of chromosomes to form daughter nuclei.
- Mitotic apparatus disappears with a reduction in the viscosity of cytoplasm, followed by the synthesis of RNA.
- The nucleolus reappears with the chromosomes becoming slender and extended.

Cytokinesis

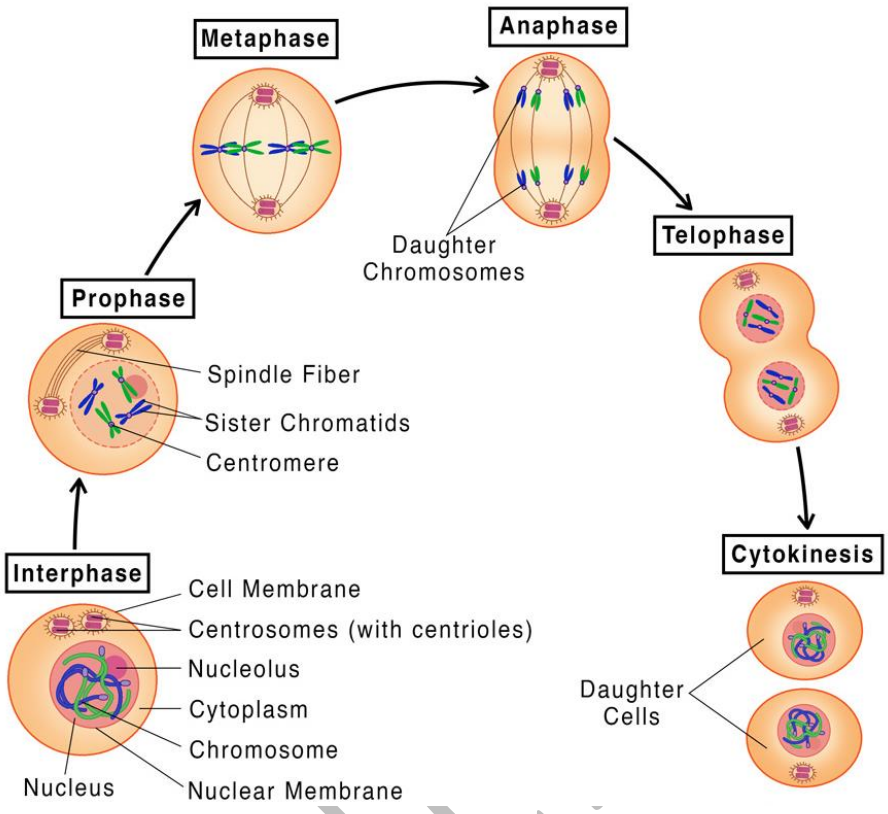
This is the process where the cytoplasm gets divided to produce two independent daughter cells, each containing a complete set of chromosomes. Cytokinesis begins at the anaphase stage and continues through telophase and into the interphase. In the end, mitosis results in two genetically identical daughter cells, each having diploid (2n) number of chromosomes.

The Difference in Cytokinesis between Plant and Animal Cells: In animals, cytokinesis occurs through a constriction of the cell membrane in-plane of the metaphase plate, while in plants the division happens through the formation of the cell plate.

What is the Purpose of Mitosis?

It is primarily important for its involvement in two cellular processes – cell division and reproduction. Some major roles played by mitosis are:

- Helping in growth and reproduction of new individual cells or organisms
- Repairing and regenerating body parts: dead and damaged cells such as skin, gut epithelial cells, and RBCs are replaced with the new ones.
- Maintaining the purity of the population having the same genetic makeup as the parent cell.
- Maintaining the same chromosome-count in cells generation after generation.
- Increasing the number of cells in higher organisms where each group of cells is specialized performs a distinct function in an organized way.
- Preserving a proper balance between DNA and RNA and thus maintaining the desired ratio between the cell's nuclear and cytoplasmic content



MEIOSIS

Meiosis is a type of cell division in sexually reproducing eukaryotes, resulting in four daughter cells (gametes), each of which has half the number of chromosomes as compared to the original diploid parent cell.

The haploid cells become gametes, which by union with another haploid cell during fertilization defines sexual reproduction and formation of a new generation of diploid organisms. Meiosis occurs in the germ cells of sexually reproducing organisms. In both plants and animals, germ cells are localized in the gonads, but the time at which meiosis takes place varies among different organisms.

Purpose of Meiosis

The process of meiosis is essential for all sexually reproducing organisms for the following reasons:

The meiosis maintains a constant number of chromosomes in sexually reproducing organisms through the formation of gametes.

By crossing over, the meiosis results in the exchange of the genes and, thus, causes the genetic variations among the species. These variations are the raw materials of the evolutionary process.

Stages/Phases of Meiosis

Meiosis is composed of two rounds of cell division, namely Meiosis I and Meiosis II. Each round of division contains a period of karyokinesis (nuclear division) and cytokinesis (cytoplasmic division).

The first meiotic division consists of prolonged prophase in which the homologous chromosomes come in close contact with each other and exchange hereditary material between them.

Similarly, in the first meiotic division, the reduction of chromosome number takes place and, thus, two haploid cells are resulted by this division.

The first meiotic division is also known as the heterotypic division.

Meiosis I consists of the following steps:

Interphase

Just like mitosis, meiosis also consists of a preparatory phase called interphase.

The interphase is characterized by the following features:

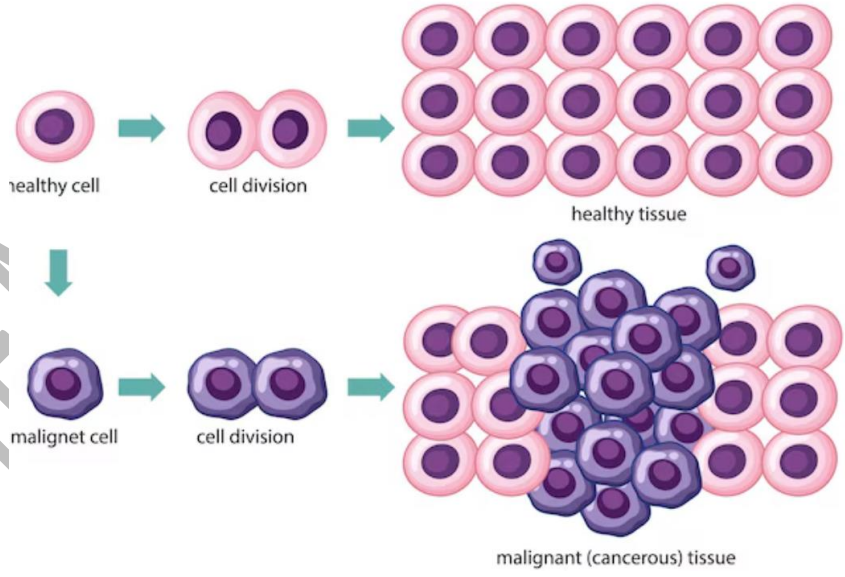
- The nuclear envelope remains intact, and the chromosomes occur in the form of diffused, long, coiled, and indistinctly visible chromatin fibers.
- The DNA amount becomes double. Due to the accumulation of ribosomal RNA (rRNA) and ribosomal proteins in the nucleolus, the size of the nucleolus is significantly increased.

- In animal cells, a daughter pair of centrioles originates near the already existing centriole and, thus, an interphase cell has two pairs of centrioles.
- In the G_2 phase of interphase, there is a decisive change that directs the cell toward meiosis, instead of mitosis.
- At the beginning of the first meiotic division, the nucleus of the dividing cell starts to increase in size by absorbing the water from the cytoplasm, and the nuclear volume increases about three folds.

CANCER CAUSES RISK FACTORS, PREVENTION, AND MANAGEMENT.

Cancer is the uncontrolled growth and division of abnormal cells in the body.

These cells can form tumors, invade nearby tissues, and sometimes spread (metastasize) to other parts of the body.



Causes of Cancer

Cancer does not usually have a single cause but results from multiple factors that damage cell DNA and disrupt normal cell growth.

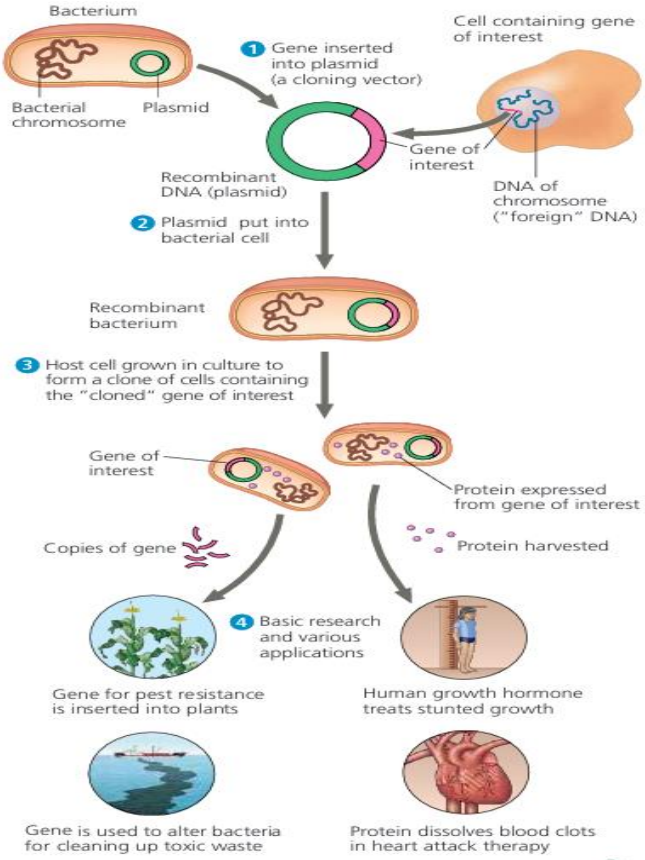
- Genetic mutations that are either inherited or acquired changes in DNA.
- Carcinogens: harmful substances such as tobacco, asbestos, certain chemicals.
- Radiation**:** ultraviolet (UV) radiation from the sun, ionizing radiation (X-rays).
- Infections**:** e.g., Human Papilloma Virus (HPV cervical cancer), Hepatitis B & C (liver cancer), Helicobacter pylori (stomach cancer).
- Hormonal imbalances: excessive estrogen can increase breast and endometrial cancer risks.
- Immune system problems**:** weakened immunity increases risk of certain cancers.

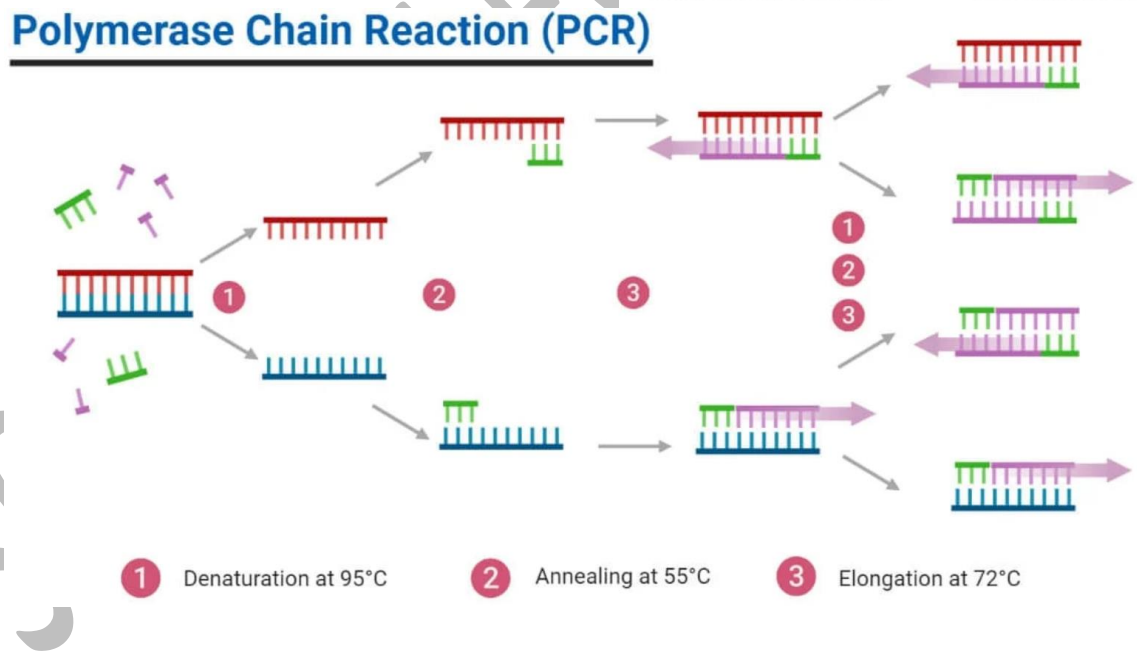
GENE CLONING

Steps in Gene cloning

I. Gene cloning starts with identification and extraction of DNA that contains the gene of interest from the organism.

II. This is followed by insertion of the DNA into a vector. Common vectors: **plasmids**, **bacteriophages**, or **yeast artificial chromosomes (YACs)**. The gene is inserted using **restriction enzymes** (molecular scissors) and **DNA ligase** (enzyme that joins DNA fragments).





Vaccine development

Examples of DNA/RNA Vaccines developed using DNA technologies

- **mRNA vaccines**: COVID-19 vaccines like Pfizer-BioNTech and Moderna.
- **DNA vaccines**: Experimental vaccines for Zika virus, Ebola, and some cancers.

The ethical, social, and environmental implications of gene technology, particularly GMOs

A Genetically modified organism (GMO) is any organism plant, animal, or microorganism whose genetic material (DNA) has been altered using modern biotechnology. This is done to introduce desirable traits such as resistance to pests, improved nutrition, or faster growth.

HARDY WEINBERG EQUATION AND ITS LINK TO PUBLIC HEALTH

Public health scientists use the Hardy-Weinberg equation to estimate how many people carry alleles for certain inherited diseases. Consider the case of **phenylketonuria (PKU),** an inherited inability to break down the amino acid phenylalanine that results in brain damage if untreated.

Newborns are routinely screened for PKU, which occurs in about one out of 10,000 babies born in the United States.

The health problems associated with PKU can be prevented by strict adherence to a diet that limits the intake of phenylalanine. Packaged foods with ingredients such as aspartame, a common artificial sweetener that contains phenylalanine, must be labeled clearly. PKU is due to a recessive allele, so the frequency of individuals born with PKU corresponds to the q2 in terms of the Hardy Weinberg equation.

Given one PKU occurrence per 10,000 births, q2 = 0.0001.

Therefore, the frequency of the recessive allele for PKU in the population, q, equals the square root of 0.0001, or 0.01 and the frequency of the dominant allele, p= 1- q, or 0.99. The frequency of carriers, heterozygous people who do not have PKU but may pass the PKU allele on to offspring, is 2pq, which equals 2 0.99 0.01, or 0.0198.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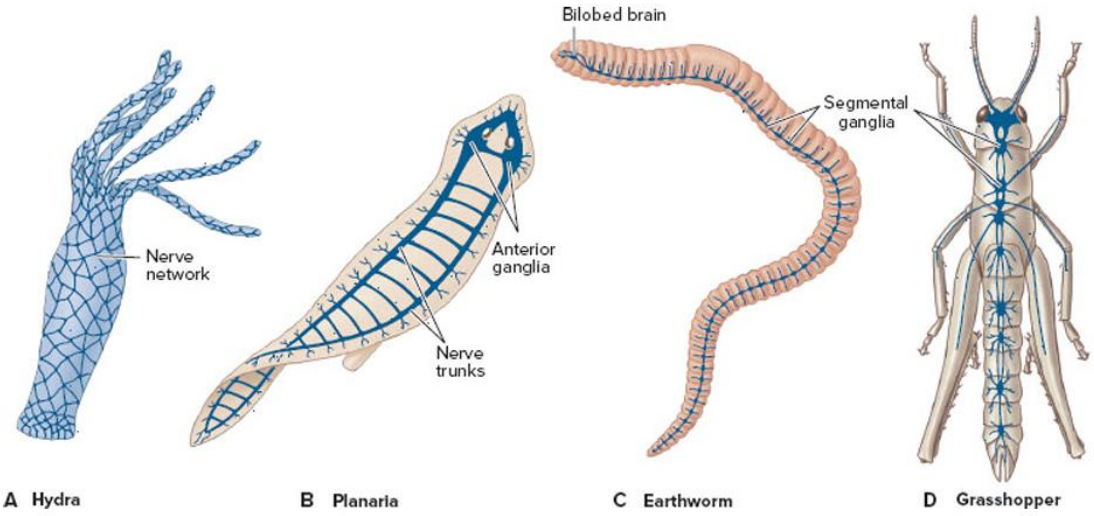
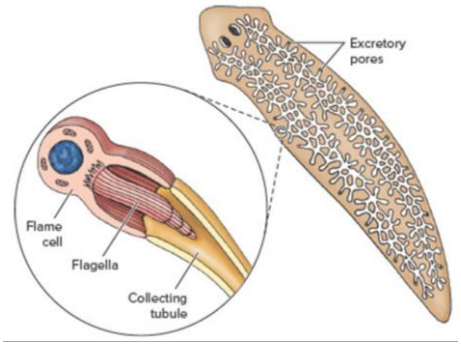
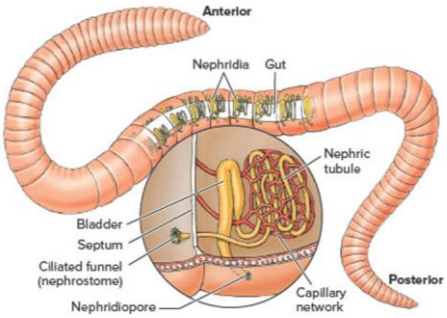
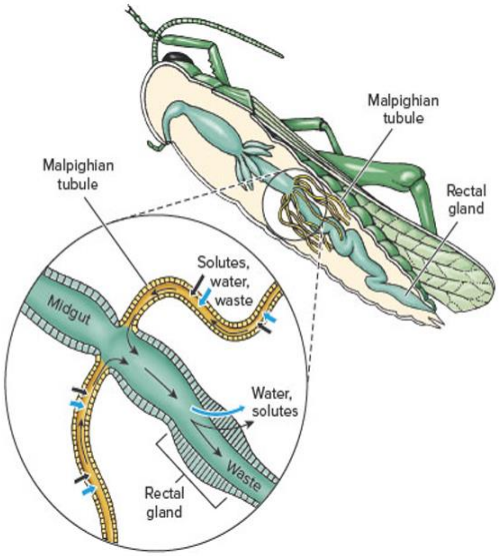

Nerve network
Anterior ganglia
Nerve trunks
Bilobed brain
Segmental ganglia
A Hydra
B Planaria
C Earthworm
D Grasshopper

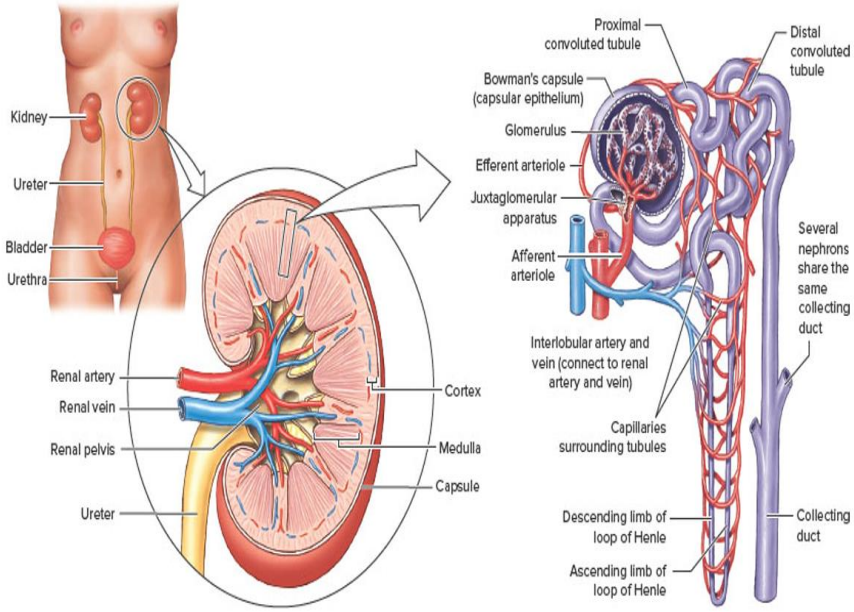




Protonephridia/ flame calls in a planarian

Meta-nephridia in an earthworm





Malpigian tubules in insects

Urinary system of humans, with enlargements showing detail of the kidney and a single nephron

E) ASSESS SPECIATION AND RESISTANCE, MECHANISMS DRIVING THEM, AND FACTORS CONTRIBUTING TO EXTINCTION EVENTS, THROUGH COMPARISON OF HISTORICAL AND CONTEMPORARY EXAMPLES.

- isolation mechanisms
- speciation

- factors that contribute to extinction
- analyse case studies of antimicrobial and pesticide resistance.
- the problems, causes and strategies to manage the challenges
- timelines of documented mass extinctions, highlighting key events, causes, and effects and the contribution of extinction to evolution.

Antimicrobial and pesticide resistance.

Antimicrobial resistance

Antibiotic resistance evolves primarily through genetic variation and selection pressure**,** enabling bacteria to survive and flourish despite antibiotic treatment. It arises as a result of the following factors:

Timelines of documented mass extinctions, highlighting key events, causes, and effects and the contribution of extinction to evolution.

TIMELINES OF DOCUMENTED MASS EXTINCTIONS

The first mass extinction took place at the end of the **Ordovician Period** (444 M years ago), 86% species lost. **Severe ice age** occurred that lowered sea levels, possibly triggered by the uplift of the Appalachians. The newly exposed silicate rock sucked carbondioxide out of the atmosphere, chilling the planet. Filter-feeding animals of the sea were lost