**Biology Class 07**

## Previous Class Topic

- Types of Viruses, with focus on retroviruses and adenoviruses
- Basics of Genetic Material (**DNA/RNA structure** and gene expression)

## Virus Types and Genetic Material

### Adenoviruses and Retroviruses

- Adenoviruses possess a **double-stranded DNA genome**.
- Retroviruses possess an **RNA genome**, not double-stranded DNA.
- The **common cold** can be caused by adenoviruses.
- **AIDS** is caused by a retrovirus, specifically the Human Immunodeficiency Virus (HIV).

## Recombinant DNA Technology

### Basic Principles of DNA Structure

- DNA is universal in composition: made of **phosphate**, **pentose sugar**, and **nitrogenous bases**.
- The chemical structure of DNA is **identical across organisms**.
- This universality allows **recombination of DNA fragments from different sources**.

## Creation of Recombinant DNA

- **Recombinant DNA** refers to a molecule formed by combining DNA from two different sources.
- The two main components for recombinant DNA are:
- **DNA fragment**: the segment/gene of interest.
- **Vector**: a DNA molecule that can carry foreign DNA into a host cell.

### Definition of Vector

- In genetics, a **vector** acts as a carrier of a foreign gene.
- Common vectors include **plasmids** (circular DNA in bacteria) and **certain viruses**.

## Applications of Recombinant DNA

### Production of Human Proteins

- **Pharmaceutical companies** use recombinant DNA technology to produce medicines like **human growth hormone** and **insulin**.
- The gene for the target protein is isolated from human DNA and embedded into a **bacterial plasmid**.
- After insertion, bacteria express the human gene and produce the required protein, which is then extracted for medical use.

**Steps in Recombinant DNA Technology**

| Step | Description |
|---|---|
| 1. Isolation of Desired Gene | Identify and extract the gene responsible for the required trait or product using **nucleases** (DNA-cutting enzymes). |
| 2. Vector Acquisition | Use plasmids or viruses as vectors to carry the desired gene. |
| 3. Joining of DNA | Employ **ligase enzymes** to join the desired gene to the vector, forming recombinant DNA. |
| 4. Introduction into Host | Insert recombinant DNA into the host organism for expression of the product. |

**Restriction enzymes**(a type of nuclease) cut DNA at specific sites and are used in genetic engineering.

## Application: Recombinant DNA in Vaccines

### Use in Vaccine Development

- Recombinant DNA technology enables the creation of **viral vector vaccines**.
- In vaccines like **Covishield** or **Sputnik V** (for COVID-19), the gene for the **viral antigen** (from COVID-19) is inserted into a vector virus.

### Design of Viral Vector Vaccines

- The gene encoding the **antigen** is integrated into a harmless **adenovirus** vector, often from a non-human source (e.g.,*chimpanzee adenovirus*) to avoid immune response.
- The resulting recombinant adenovirus is **attenuated** (weakened) to ensure safety.

### Mechanism of Action

- The vaccine delivers only the **COVID-19 antigen gene**, not the whole virus, into the body.
- The immune system recognizes the antigen and produces **B memory cells**, conferring immunity.

### Safety and Advantages

- Viral vectors are chosen for their **harmlessness to humans**.
- They ensure stimulation of immune memory without causing disease.

## Gene Transfer Across Species

### Genetic Engineering Possibilities

- Genes can be transferred:
- Between different species of plants
- From animals to plants
- From microorganisms to higher organisms
- Success relies on the universality of DNA’s chemical structure.
- Such transfers do not always yield useful traits but are **technically possible**.

## Gene Editing and Related Technologies

### Definition and Purpose

- **Gene editing** involves adding, deleting, or replacing defective genes in the genome.
- Applications include treatment and prevention of **genetic disorders** such as:
- **Sickle cell anemia**
- **Hemophilia**
- **Color blindness**

### Stages and Cells for Gene Editing

- Editing can occur at different biological stages:
- **Gametes** (egg/sperm): Prevents transmission to offspring.
- **Embryos**: Modifies all cells of the developing organism.
- **Somatic cells**: Corrects gene defects in specific tissues of an individual (does not transmit to next generation).

### Current Regulatory Status

- Most countries permit only somatic cell gene editing.
- **India** is developing gene editing for treating **sickle cell anemia**.
- Research involving gene editing in **embryos/gametes** is highly restricted; **South Africa** recently allowed it experimentally.

## CRISPR Technology

### Overview

**CRISPR (Clustered Regularly Interspersed Short Palindromic Repeats)**is a natural gene-editing mechanism discovered in bacteria and has been adopted as a gene-editing tool in biotechnology.

### CRISPR System Components

| Part | Description |
|---|---|
| **Guide molecule (sgRNA)** | Directs the system to the specific DNA location to be edited. In CRISPR, it is single-guide RNA (sgRNA), which is double-stranded (exceptional for RNA). |
| **Nuclease (Cas9 protein)** | Acts as molecular scissors to cut DNA at the targeted site for editing. |

After DNA cutting, repair allows gene addition, deletion, or replacement as desired.

### Applications

- Used in gene correction for diseases like **sickle cell anemia**.
- Editing is most effective when applied to bone marrow cells for blood-related disorders.

## Animal Cloning

### Concept and Process

| Step | Description |
|---|---|
| 1. Obtain Somatic Cell | Collect a cell (e.g., skin, muscle) from the individual to be cloned. These cells have a full set (2n) of chromosomes. |
| 2. Obtain Donor Egg | Retrieve an egg cell from a female donor. The egg contains cytoplasm and organelles but only n chromosomes. |
| 3. Enucleation | Remove the nucleus from both the somatic cell (retain for further use) and the donor egg (discard nucleus). |
| 4. Nuclear Transfer | Insert the somatic cell nucleus into the enucleated egg. |
| 5. Stimulation & Embryo Formation | Stimulate the egg in the lab to initiate embryogenesis. |
| 6. Embryo Implantation | Transfer the embryo into a surrogate uterus for gestation. |

Cloning results in an organism**genetically identical**to the somatic cell donor.

### Case Study: Dolly the Sheep

- **Dolly** was the first successfully cloned mammal.
- The process involved transferring the nucleus from an **udder cell** of an adult sheep into an enucleated egg from another sheep.
- The embryo was implanted into a surrogate, resulting in Dolly's birth.

### Limitations and Challenges

- High failure rates; many embryos are lost before a viable clone is obtained.
- Cloned animals often suffer from diseases and have reduced lifespan.
- Human cloning is **not legal or practiced** anywhere due to technical, ethical, and safety concerns.

### Uses of Cloning

- Preserving extinct or endangered species (practically limited by availability of viable DNA and the need for a close living surrogate species).
- Replicating individuals with valuable traits (e.g., high-quality wool in sheep).
- Not suitable for resurrecting long-extinct species (like dinosaurs) due to degraded DNA and lack of a birthing organism.

## Mitochondrial Replacement: Three-Parent Baby Technology

### Mitochondrial DNA (mtDNA) Inheritance

- **Mitochondria** have their own DNA (mtDNA), separate from nuclear DNA.
- Mitochondrial DNA is **maternally inherited**, as sperm contributes little or no mitochondria to the zygote.

### Disease Transmission & Prevention

- Defects in mtDNA can cause mitochondrial diseases (e.g., Leigh's disease).
- All children of a mother with mtDNA disease will inherit the defect.

**Mitochondrial Donation Process**

| Step | Description |
|---|---|
| 1. Select two eggs | One from the mother (with defective mtDNA), one from a healthy donor (with normal mtDNA). |
| 2. Enucleation | Remove the nucleus from both eggs. |
| 3. Nuclear Transfer | Transfer the mother's nucleus into the donor egg (which retains cytoplasm and mitochondria but lacks its own nucleus). |
| 4. Fertilization | Fertilize the reconstructed egg with sperm from the father. |
| 5. Embryo Development | Implant the embryo into a uterus for gestation. |

The resulting child has nuclear DNA from both parents, mtDNA from the donor. The term*three-parent baby*is used because the donor's DNA affects only mitochondrial function and does not influence inherited traits.

## Assisted Reproductive Technologies (ART)

### In Vitro Fertilization (IVF)

- Involves fertilizing egg and sperm in a laboratory dish to form a zygote.
- The zygote develops into an **embryo**, which is then placed into the uterus for gestation.

### Surrogacy

- A **surrogate mother** carries and delivers a baby for another individual or couple.
- The surrogate provides only nutritional support and does not contribute DNA.
- The birth mother is not a **biological parent**.

### Legal and Social Aspects

Regulations govern ART and surrogacy practices. Commercial surrogacy (paying for surrogacy) is not legally permitted in certain regions.

# Stem Cell Technology

## Definition and Properties

**Stem cells**are unspecialized cells capable of dividing and differentiating into various types of specialized cells.

## Types of Stem Cells

### Embryonic Stem Cells

- Present in the developing embryo.
- Can differentiate into all cell types of the body.

### Adult Stem Cells

- Found in certain organs/tissues after birth (e.g., **bone marrow**, liver, brain).
- Produce new cells for growth and repair of specific tissues (tissue-specific).

### Induced Pluripotent Stem Cells (iPSCs)

- Created artificially in the laboratory by reprogramming differentiated adult cells back to a pluripotent state.
- Can generate cells of any tissue, overcoming some ethical and technical limitations.

## Applications of Stem Cells

### Regenerative Medicine

- Used to repair or replace damaged tissues/organs, such as:
- **Blood**: bone marrow transplantation, treatment of leukemia.
- **Skin**: treatment of burns.
- **Heart muscles, cartilage, liver, brain, pancreas** (in diabetes).
- Particularly valuable for sports injuries and degenerative diseases (e.g., **Alzheimer's**).

### Treatment Limitations & Challenges

- The **source of stem cells** is a major obstacle.
- Embryonic stem cell sourcing is highly restricted due to ethical concerns.
- Adult stem cells are limited by tissue specificity and complexity in extraction.
- Using a patient's own cells reduces the risk of immune rejection.

### Use in Blood Disorders

- In conditions like **leukemia**, when the patient's own stem cells are defective, donor stem cells (from bone marrow) are transplanted.
- Requires genetic matching to minimize rejection.

## Biotechnology Applications (Imp. must study)

### Types of Biotechnology

| Domain | Description |
|---|---|
| **Blue Biotechnology** | Application in aquatic organisms. |
| **Green Biotechnology** | Applications in agriculture, e.g., GM crops. |
| **Red Biotechnology** | Medical applications, e.g., vaccines, therapies. |
| **White Biotechnology** | Industrial applications, e.g., enzyme production. |
| **Grey Biotechnology** | Environmental applications, e.g., bioremediation. |

Sources -
-> Current affairs
-> mains 365
-> Bio Economy (weekly focus)
-> Bio E3 policy
-> Biotechnology for economy, environment and employment.

## Genetically Modified Organisms (GMOs) and Crops

### Concept and Purpose

- A **genetically modified organism (GMO)** has its genetic material altered via genetic engineering (recombination, editing, transfer).
- GM crops are cultivated to improve:
- **Yield and productivity**
- **Pest/Disease resistance**
- **Climate resilience**
- **Nutrient content (biofortification)**

### Examples of GM Crops

| Example GM Crop | Trait Improved | Method/Source |
|---|---|---|
| **BT Cotton** | Pest resistance (against bollworm) | Bacterial gene insertion (toxin-producing gene) |
| **BT Brinjal** | Pest resistance | Same as BT cotton, but for brinjal; not cleared for food consumption |
| **GM Mustard** | Increased yield, potential oil sufficiency | Bacterial gene to boost production |
| **Golden Rice** | Increased vitamin A | Genetic modification for nutritional enhancement |
| **GM Potato** | Disease resistance (blight) | Genetic alteration for fungal resistance |
| **GM Rubber** | Climate resilience | Modified to withstand drought or salinity |

### Adoption in India

- **BT cotton** is the only GM crop approved for commercial cultivation.
- Food crops like GM brinjal and mustard face stringent regulatory checks and concerns about safety for consumption and environmental effects.

### Environmental and Economic Concerns

- **Biodiversity loss** due to replacement of traditional varieties with single GM types.
- Potential disturbance to **ecosystems**, especially effects on pollinators like bees and butterflies.
- **Resource use** concerns (soil, water), and unknown long-term effects.
- **Mutation and resistance** in pests may reduce effectiveness over time.
- **High costs** of seeds can burden farmers, many of whom work with limited resources.

### Health Concerns

- Uncertainty about long-term safety of consuming food crops with new genetic material.
- Need for extensive long-term studies before approval of GM food crops.

### Regulatory Framework

| Agency/Legislation | Role |
|---|---|
| **Ministry of Science and Technology** | Primary overseeing body |
| **Department of Biotechnology** | Specialized department for biotechnology |
| **GEAC (Genetic Engineering Appraisal Committee)** | Statutory authority for GM product approval |
| **Environmental Protection Act, Wildlife Act, Seed Act, Plant Variety Act** | Ancillary legislation affecting GM crop approval |

### Seed Patenting and Economic Monopoly

- Companies can use **terminal seed technology** to make seeds sterile after one generation.
- Farmers are required to purchase new seeds each season, leading to possible monopolistic practices by multinational corporations.

**Hybrids vs. GMOs**

| Term | Definition |
|---|---|
| **Hybrid** | Result of crossing two varieties or species, often via grafting or breeding, without direct modification of DNA. Involves only naturally possible changes. |
| **Genetically Modified (GM)** | Direct manipulation of an organism's DNA in the lab. Transfers genetic material between unrelated species (e.g., bacteria to cotton). May involve transgenic processes. |
| **Transgenic** | Specifically refers to transferring genes between different species (e.g., bacterial gene into a plant). Under law, this is regarded as GM. |