# 15BT101

# Biology for Engineers

## Unit - 2

# Biodiversity

## Biodiversity - Variety of life on earth, 3 levels classified

- Genetic diversity – Different gene in all individual plants, animals, fungi etc.,
- Species diversity - Occurs within species or between different species
- Ecosystem diversity – Different variety of habitats, biological communities, ecological processes

## Importance of biodiversity

- Food – species hunted, fished, agriculture, forestry, aquaculture
- Shelter & warmth – timbers, fibers, wool, cotton, other forest products
- Health – Medicines – Traditional medicines, others synthesized from biological resources & processes

# Threats to biodiversity

- Habitat loss and destruction
- Alteration in ecosystem composition
- Introduction of exotic (non-native) species
- Over-exploitation
- Pollution & contamination
- Global climatic change

# Chemistry of Life

# Chemistry of Life

- Atom - Simplest unit, positive nucleus made up of protons & neutrons, surrounded by negatively charged electrons

  - Atom Stable – When outer most electron orbit is completely filed (Doublet, Octet)

- Element - Atom of same kind combine

  - 6 Elements (C, H, O, P, S, N) – 98% Body weight

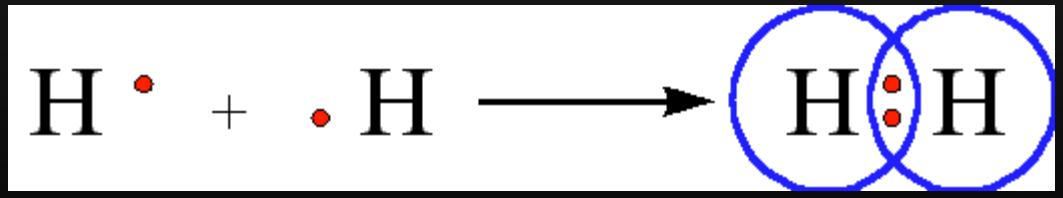
- Compound - 2 or more elements combined

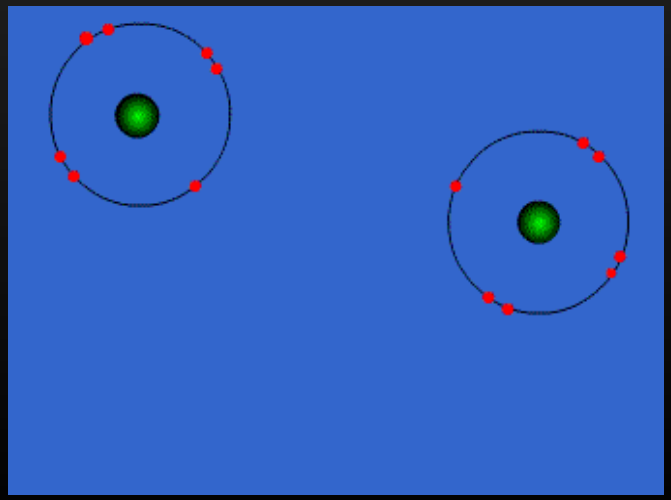
  - Elements join – Chemical bonding – Atoms lose their individual property

# Types of Bonding

## 1.Covalent Bonding

- Sharing of valence electron between 2 atoms
- Strong bond
- Formation of double & triple bonds
- Example – Hydrogen gas (Diatomic hydrogen molecule), Sharing valence electron – Doublet stable configuration



# 2. Non – Covalent

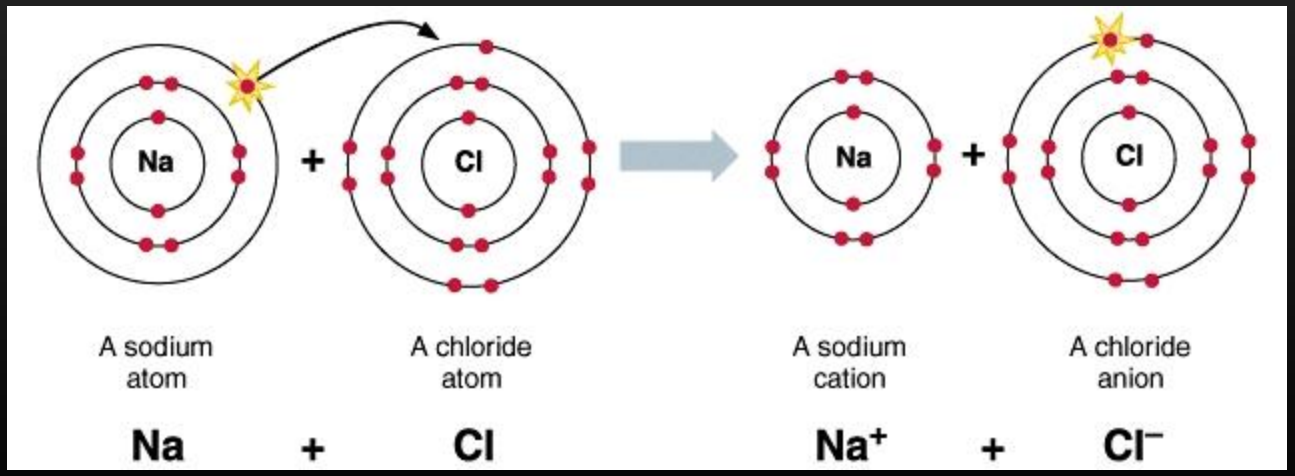
Weak forces, Interaction critical in maintaining shapes of nucleic acids, proteins & other macromolecules (Ex: DNA double helix). 4 types

- Hydrogen Bonds
- Ionic Bonds
- Van der Waals forces
- Hydrophobic Interactions

# Ionic Bonding

- Atom donates an electron – Cations (positively charged)
- Atom accepts donated electron – Anions (Negatively charged)
- Ionic bond arise between these 2 atoms (Cation, Anion)
- Example – NaCl - Na+ (2, 8, 1) – Cation

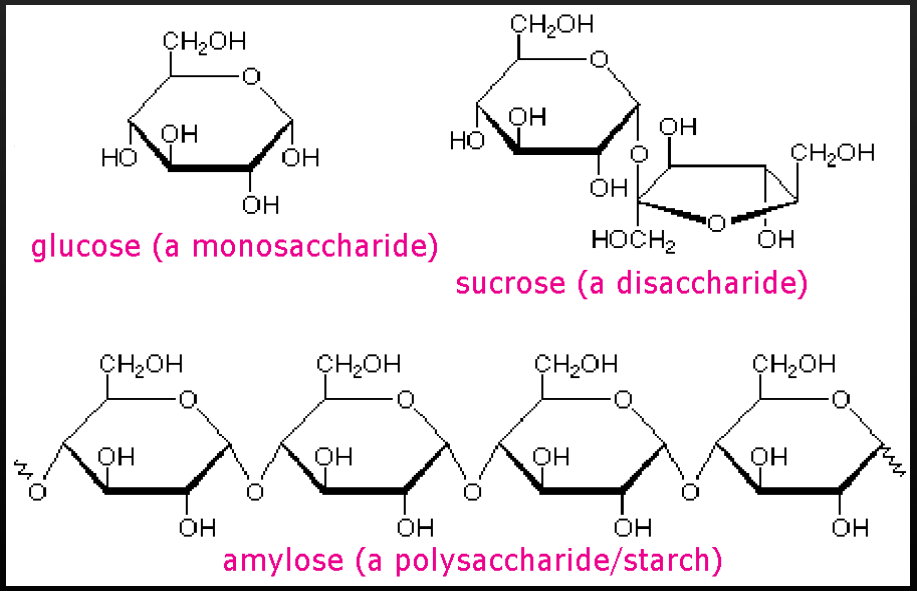
  - Cl- (2, 8, 7) – Anion (attains octet configuration)



# Biochemistry & Human Biology - Biomacromolecules

- Living processes – Metabolism – 2 types – Anabolism (building up of molecules) & Catabolism (breaking up of molecules)
- Biomacromolecules – Include protein, carbohydrate, lipid, nucleic acids & other biomolecules
- Smaller unit – Monomer – joins to form polymers
- Cell has water, rest – Carbon based molecules – Organic molecules

# 1) Carbohydrate

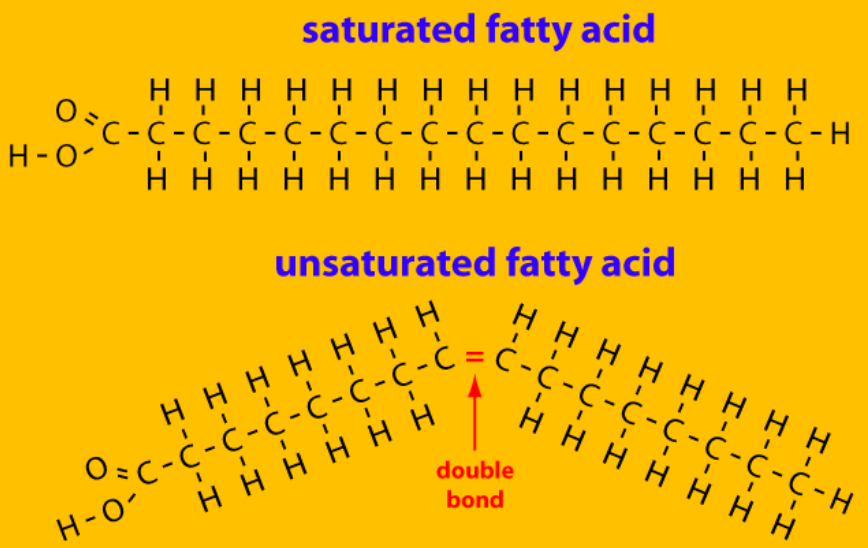



# 1) Carbohydrate

- Organic compound, Empirical formula – $C_m(H_2O)_n$ – Consists of Carbon, Hydrogen : Oxygen ratio (2:1)
- Divided into four types

| S.No. | Types | Properties | Example |
|---|---|---|---|
| 1. | Monosaccharides | Simple sugar, formula $(CH_2O)_n$, | Glucose, Fructose |
| 2. | Disaccharides | 2 monosaccharides joined by **glycosidic linkage** (covalent bond) – by dehydration reaction – H & OH removal from each monosaccharide | Sucrose, Lactose |
| 3. | Oligosaccharides | 3 – 6 monosaccharides joined | Mannose |
| 4. | Polysaccharides | Many monosaccharides joined . Joined into linear or branched chain | Cellulose |

# 2) Lipids



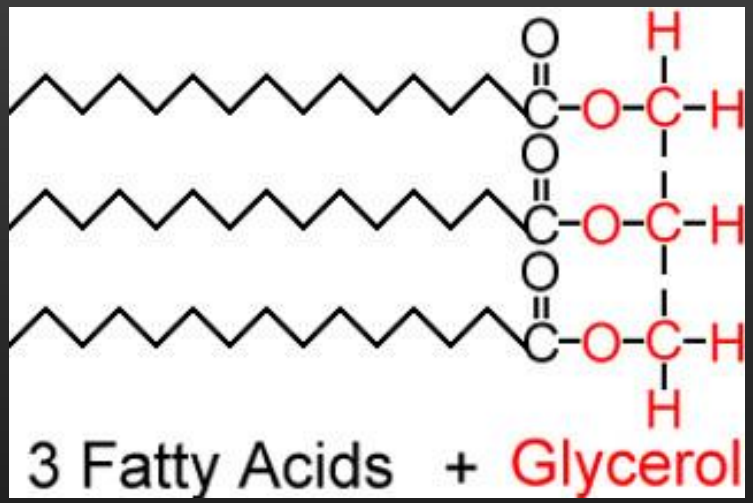
# 2) Lipids

- Organic compound, Soluble in non-polar solvents (ex: Ether, choloroform, acetone, benzene), insoluble in water

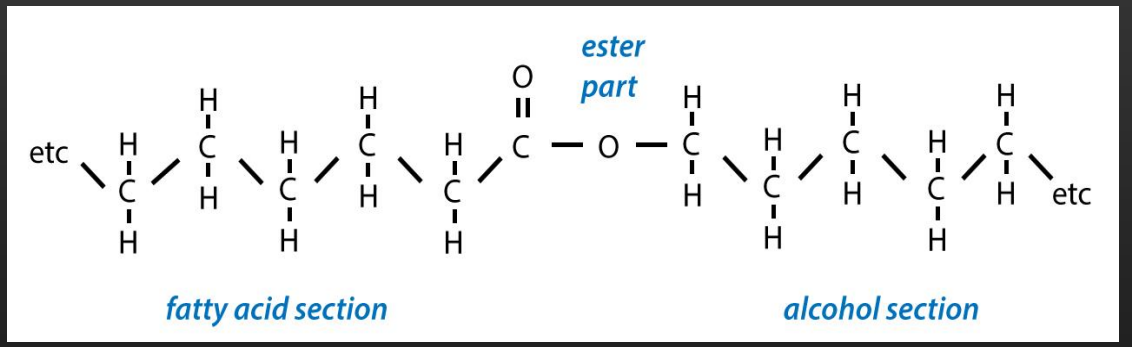
| S.No. | Types | Properties | Example |
|---|---|---|---|
| 1. | Fatty acids (FA) | ➢Composed of chain of **methylene group with Carboxyl group at one end**<br>➢10 – 20 Carbon atoms – in fatty acid chain<br>➢Head – Polar (Hydrophilic)<br>➢Tail – Non-Polar (Hydrophobic)<br>➢FA – Saturated - Many hydrogen bonded to Carbon<br>➢FA – Unsaturated - Few hydrogen - 1 or few double bond connecting carbon | Omega 3 fatty acid |
| 2. | Triglycerides | 3 fatty acid linked to a molecule of glycerol | Vegetable oil |
| 3. | Steroids | 4 Cycloalkane rings joined to each other | Cholesterol, Sex hormones – Estradiol & Testosterone |
| 4. | Waxes | Long chain of fatty acid joined to single complex alcohol in ester linkage<br>Found in protective coating - on leaves, hair, skin etc. | Cutin (Plant) |

# 2) Triglycerides, Steroids, Waxes

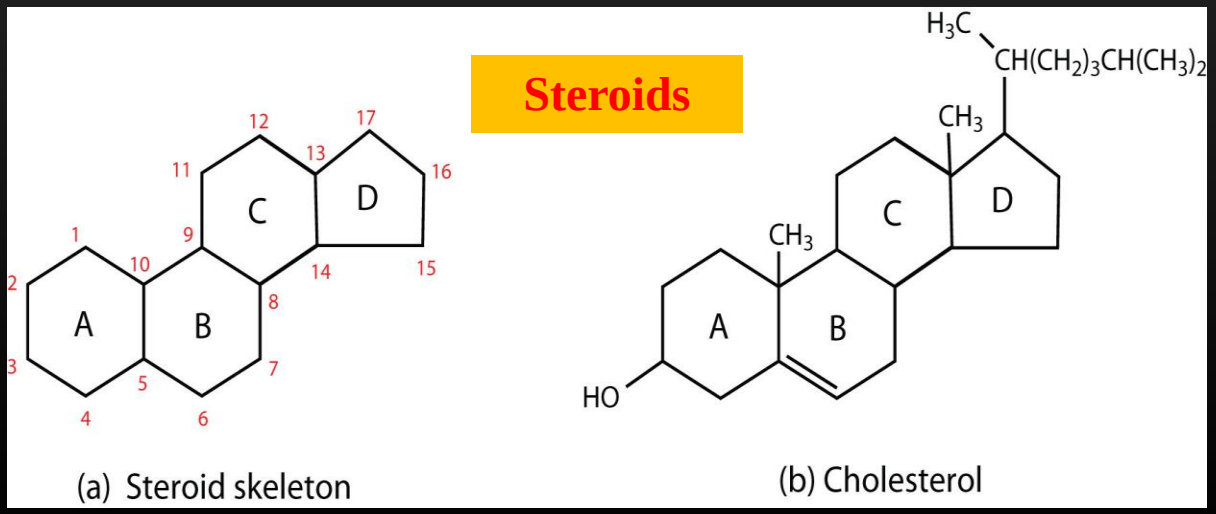
## Triglycerides



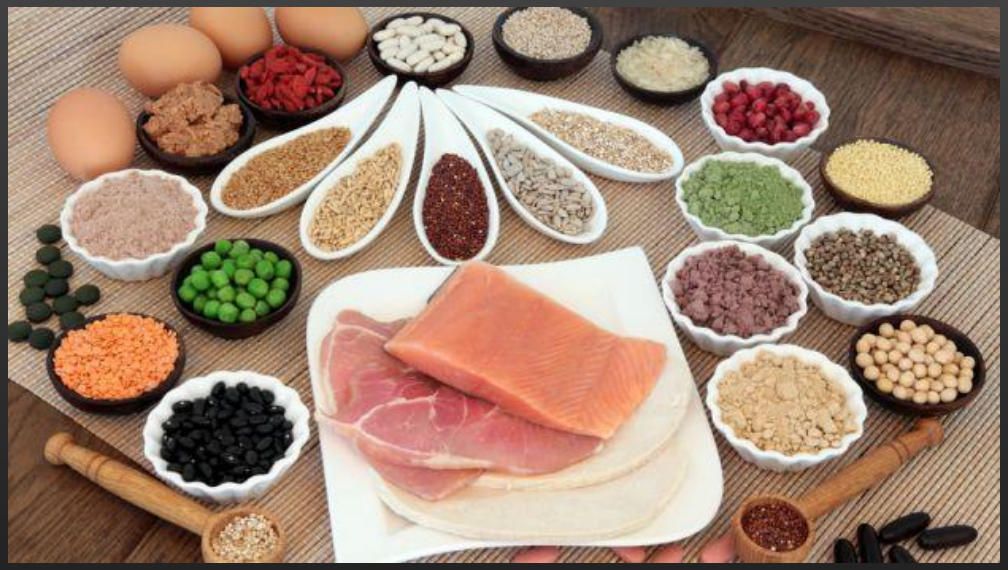

## Waxes

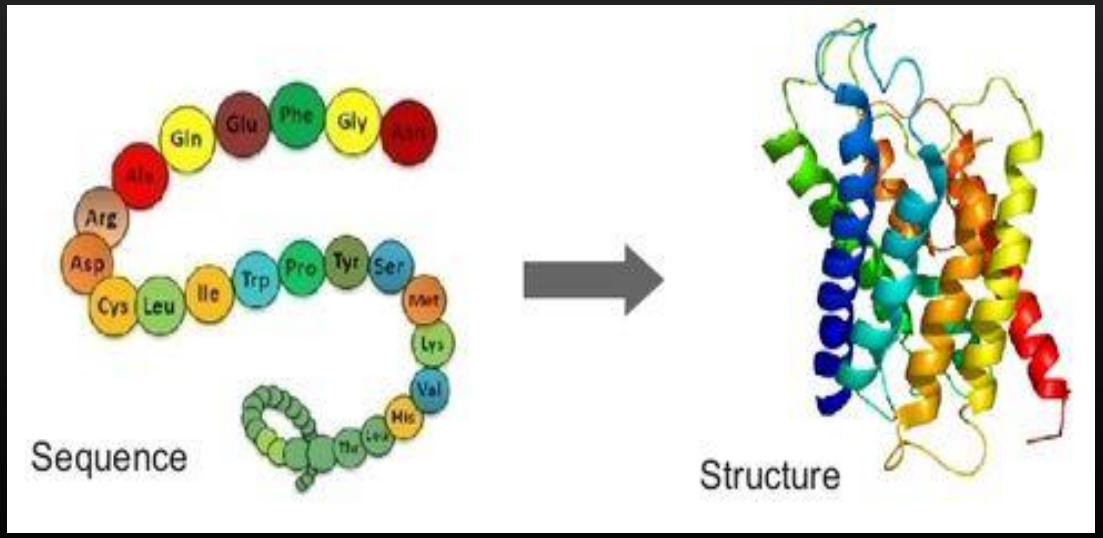



## Steroids



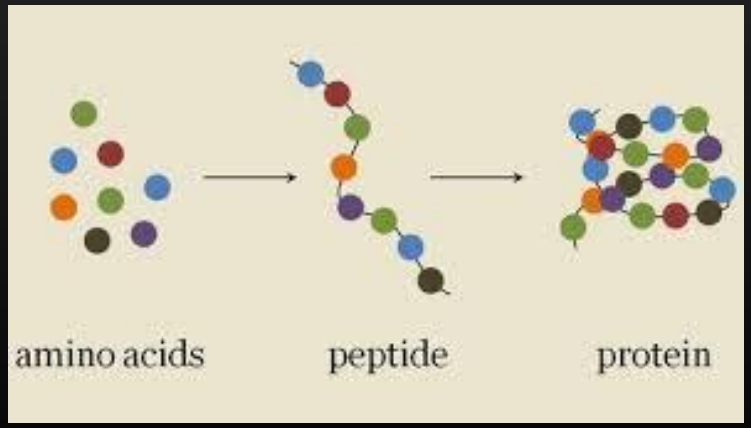
# 3) Proteins

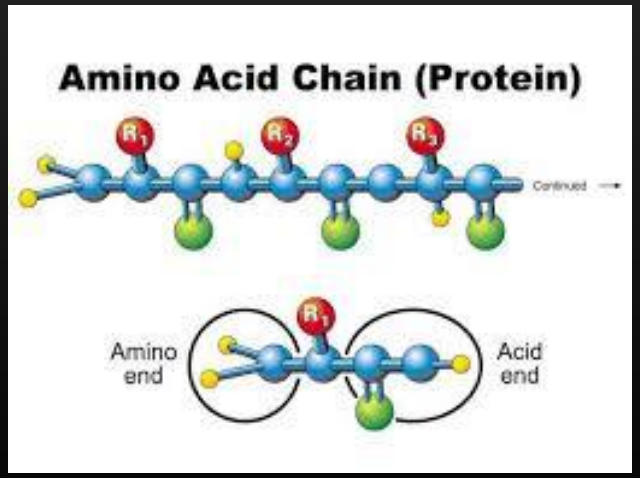



Gln
Glu
Phe
Gly
Arg
Asp
Cys
Leu
Ile
Trp
Pro
Tyr
Ser
Met
Lys
Val
His
Sequence
Structure

# 3) Proteins

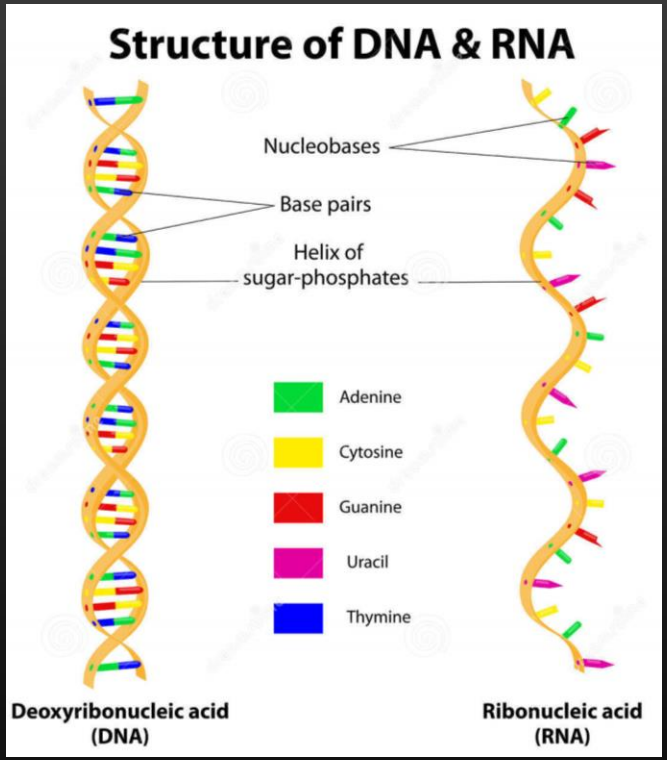
- Essential part of organism – every process within cells
- Functions – Act as hormones & enzymes, structural integrity, cellular transportation, used to build cells
- Polymer of amino acid – linked by peptide bond
- Amino acid – 20 types (both essential and non essential) linked to build various proteins



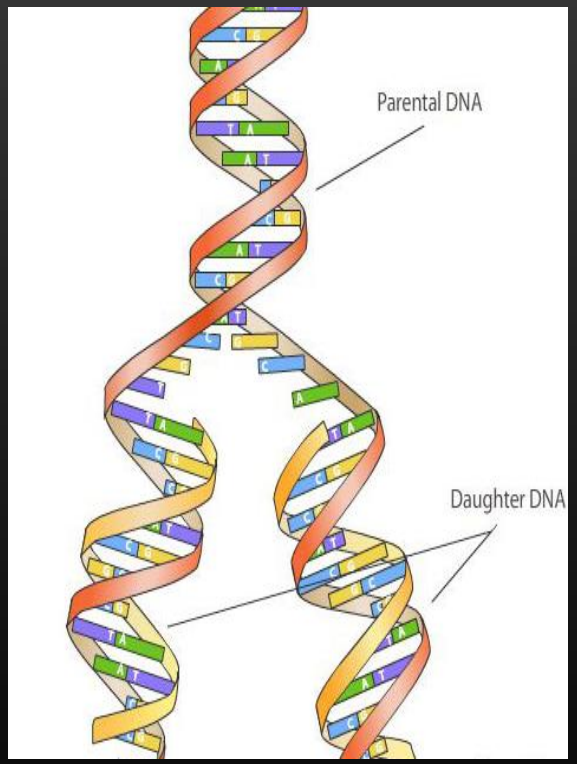
# 4) Nucleic Acids

- Nucleic acid – Essential for life – DNA (deoxyribonucleic acid) & RNA (ribonucleic acid)
- DNA differs from RNA by absence of "O" in "OH" group of sugar
- Made up of polymer nucleotide (nitrogenous base, sugar, phosphate molecule)



# DNA Replication

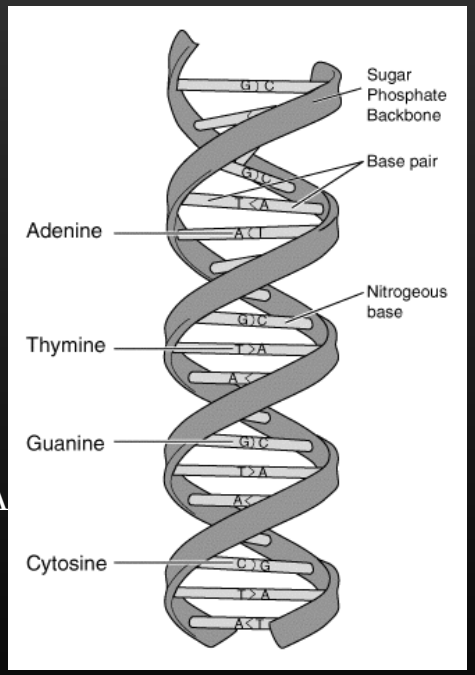
- Copies their own DNA – One double stranded DNA molecule produces 2 identical copies of the molecule
- DNA replication – begins at specific location in genome – called "Origins"
- Steps involved:
  - Unwinding of DNA at "Origin"
  - Hydrogen bond break – Strands unzips – by different enzymes & proteins
  - DNA polymerase (enzyme) – Adds bases & Synthesis new strand (Daughter DNA) from template strand (Parent DNA)



# DNA - Genetic Information

**DNA (deoxyribonucleic acid)**

- Storage of genetic information
- Watson & Crick – 1953 – Proposed DNA double helix model
- DNA – formed by Polynucleotide chains, 2 chain of DNA complementary to each – double helix – one turn 34Å with 10 pair of nucleotides – distance of 3.4Å, width - 20Å
- Antiparallel - one end is 5' & other 3'




**Nucleotide**

- Nucleoside (Pentose sugar + Nitrogenous bases)
- Phosphate group

**Nucleoside**

- Pentose sugar (DNA – deoxyribose) (RNA – ribose)
- Nitrogenous Bases
  - Purine – Adenine (A), Guanine (G)
  - Pyrimidine - Cytosine (C), Thymine (T) in DNA & Uracil (U) in RNA

**Chargaff's rule**

- Purine always pairs with pyrimidine
- A always pairs with T, 2 hydrogen bond
- G always pairs with C, 3 hydrogen bond
- Amount of A equal to T & G equal to C

# DNA - Genetic Information

Pentosugar

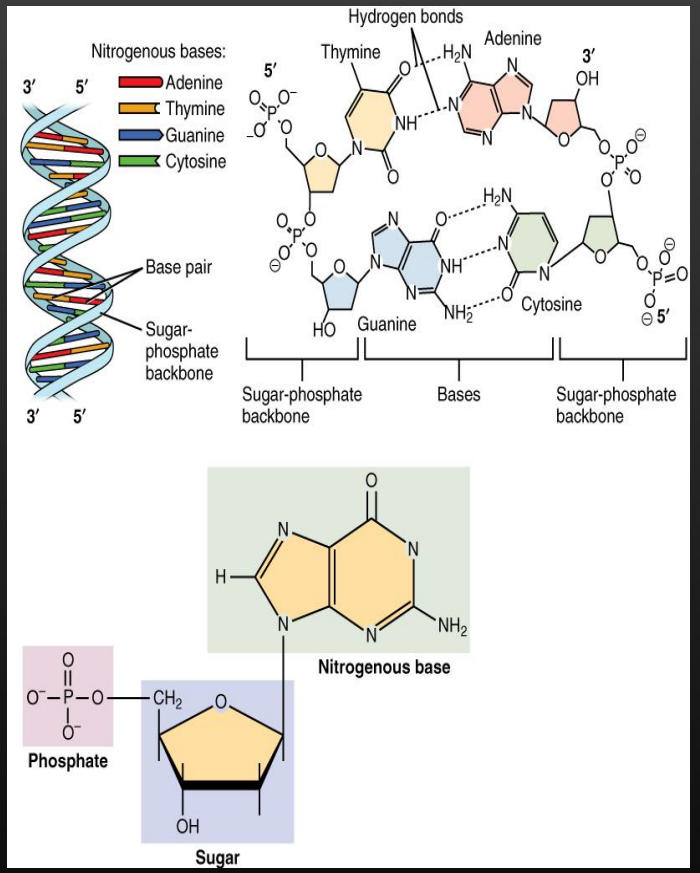
- A cyclic 5 carbon sugar, which connects two phosphate groups
- The type of sugar molecule in DNA is deoxyribose, where as in RNA is ribose.

Nitrogenous base

- Nucleic acids contains 5 major heterocyclic bases, adenine (A), guanine (G), cytosine (C), thymine (T) and uracil (U).
- First four bases are common in DNA, in case of RNA thymine is replaced with uracil

Phosphate

- A phosphate group attached to the 5’ carbon of the sugar by a phosphodiester linkage.
- This phosphate group responsible for the negative charge of the nucleic acids.



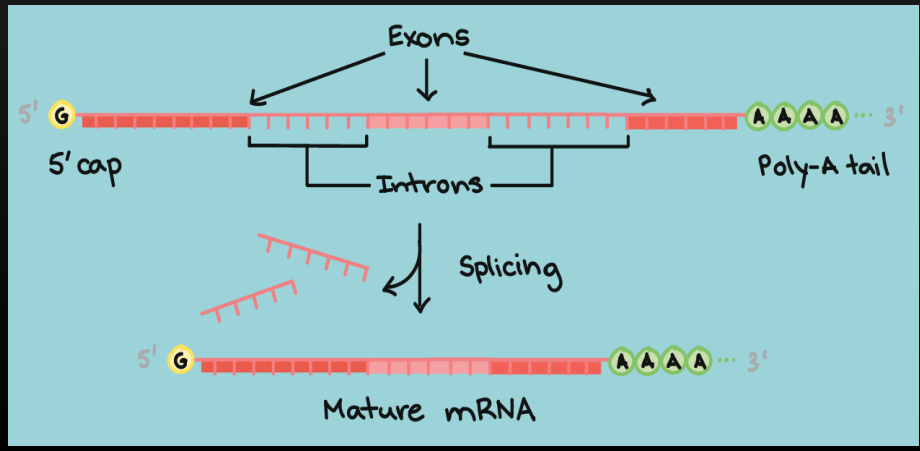
# RNA (Ribonucleic acid)

- Contains ribose sugar, single stranded, thymine replace by Uracil (U)
- More RNA in cytoplasm, less in nucleus
- 3 types –
    1. mRNA (Messenger RNA)
    2. tRNA (Transfer RNA)
    3. rRNA (Ribosomal RNA)

# 1. mRNA (Messenger RNA)

- 3-5% of total RNA
- Carries genetic information for protein synthesis (from DNA → Cytoplasm)
- Carries triplet codes
- One end of mRNA called 5' end - cap region present - binds with ribosome
- Other end 3' end – with poly A tail (adenylate nucleotides)
- Post-transcriptional modifications
  - Cap & Poly A tail
  - AUG (methionine) – translation initiation codon – Start codon
  - UAA – Stop codon

**mRNA**



# 2. tRNA (Transfer RNA)

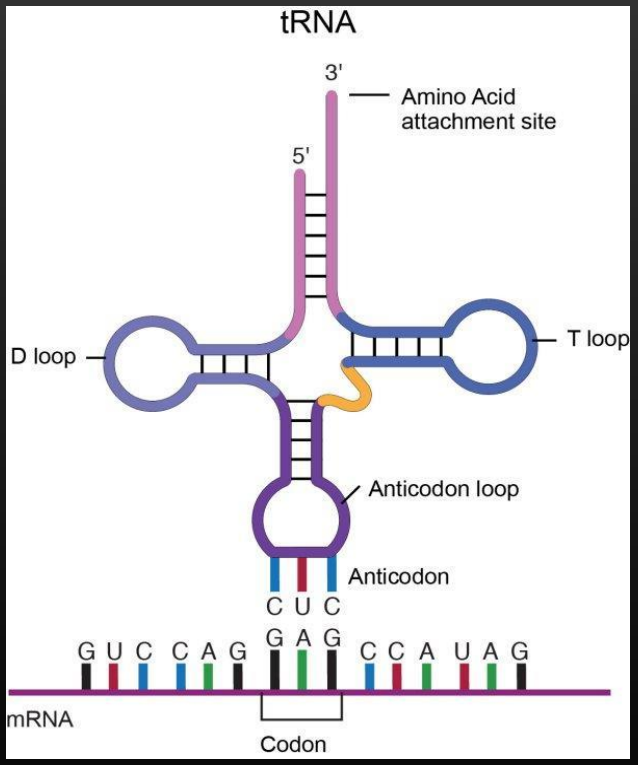
- 15-17% of total RNA, 60 types, contains 75 – 80 nucleotides
- Transport amino acid to site of protein synthesis – each tRNA transport only 1 amino acid
- Structure – Clover leaf – contains 4 arms

**1)Acceptor arm -** amino acid binding site

**2)D arm** – enzyme site

**3)T Ψ*C arm** – Ribosome site

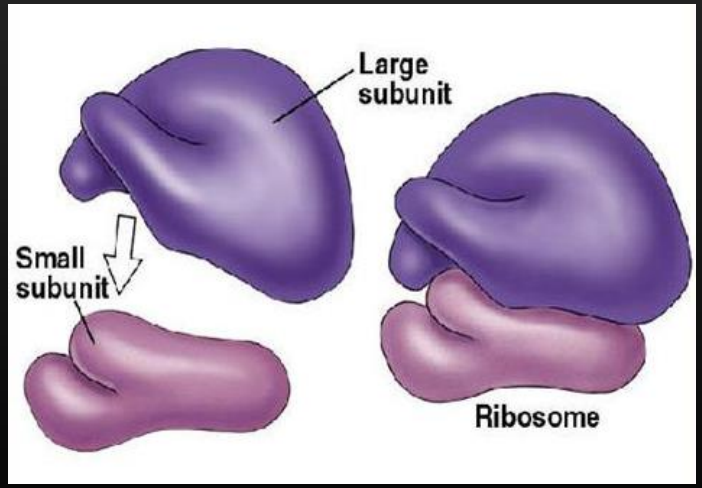
**4)Anticodon arm** – recognition site – has codon complementary to mRNA – makes respective amino acid bind to acceptor arm



# 3. rRNA (Ribosomal RNA)

- 80% of total RNA, 100-3000 nucleotides
- Associated with ribosome
- 7 types – based upon sedimentation coefficient – 2.8S, 18S, 5.8S, 5S, 23S, 16S, 55S
- Other small RNA – non coding RNA – involves in gene expression regulation

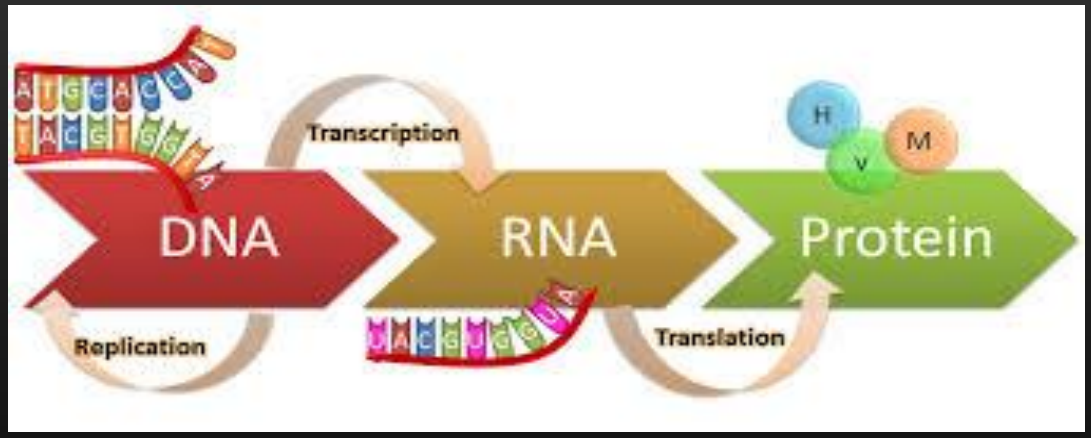
1. **snRNA (small nuclear RNA)**
2. **snoRNA (small nucleolar RNA)**
3. **microRNA**
4. **siRNA (small interference RNA)**



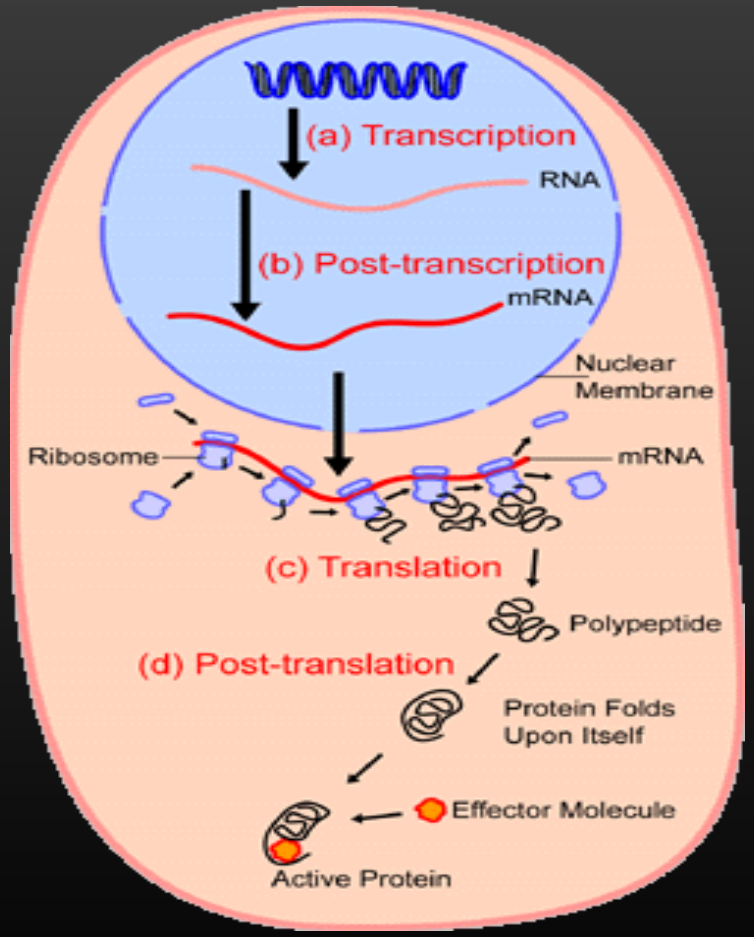
# Protein Synthesis

# Protein Synthesis

## 1 – Central Dogma




## 2 – Protein Synthesis



# Protein Synthesis

## Introduction

- Protein Synthesis – process – cells build proteins
- Steps involved;
    1) Transcription
    2) Post-transcriptional modifications
    3) Translation
    4) Post-translational modifications

# 1) Transcription

- Synthesis of RNA from complementary DNA strand
- Synthesis strand of DNA – antisense strand
- Other non-synthesizing strand of DNA – sense strand
- 3 steps – **Initiation, Elongation, Termination**

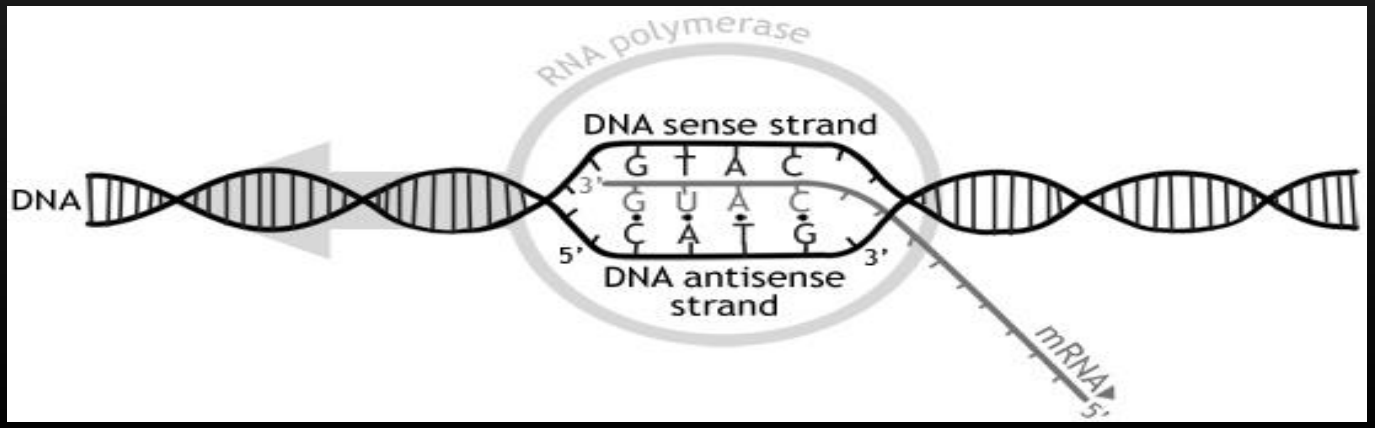
# 1) Transcription

## 1. Initiation:

- RNA polymerase binds to DNA – In Promoter sequence or TATA box
- DNA molecule unzips upto 20 basepairs
- Region/ sequence before promoter – called as Upstream sequence
- Region/ sequence after/ following promoter – called as Downstream sequence – Region to be transcribed – transcription initiation site – denoted as +1

## 2. Elongation:

- Unwinding of DNA
- RNA polymerase adds – complementary bases – RNA synthesized in 5' → 3' direction



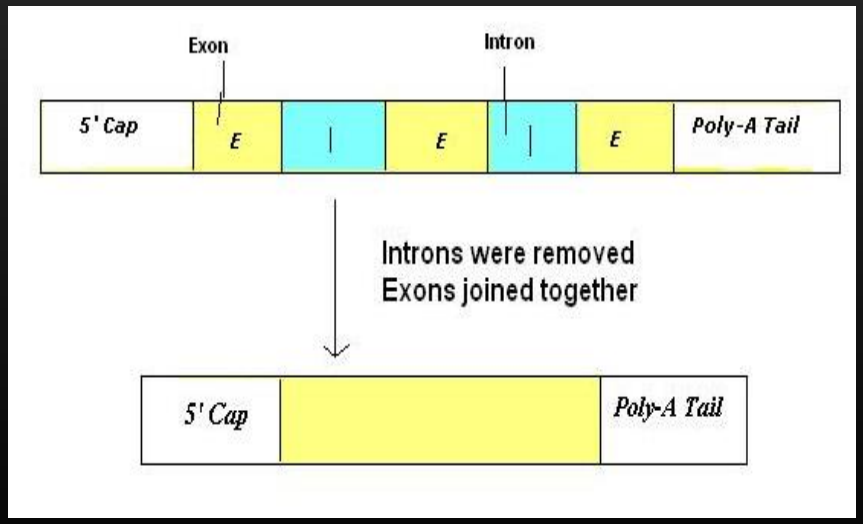
# 1) Transcription

**3. Termination:**

- Stop codon/ signal reached – RNA polymerase unbinds
- mRNA (pre-mRNA) falls off
- This mRNA called as pre-mRNA - has both Exons (coding sequences) & Introns (non-coding sequences)

# 2) Post-transcriptional modifications

- **Splicing – Spliceosome - Remove introns join exons – mature mRNA**
- **mature mRNA – leaves nucleus and enter cytoplasm for translation**



# 3) Translation

## Introduction

- Translation - transfer of genetic code in mRNA to protein (amino acid)
- Occurs in cytoplasm
- 3 steps – **Initiation, Elongation, Termination**
- Involves the following:

1) mRNA (codons)
2) tRNA (anticodons)
3) ribosomes (Large and small subunits)
4) amino acids

# 1. Initiation

- mRNA binds to smaller unit of ribosome (30S)
- Attachment made at 1st codon of mRNA– Start codon (AUG – methionine) – called as mRNA-30S complex

- Now tRNA with complementary anticodon UAC – attaches to AUG in mRNA - then tRNA transports methionine (AUG) to 30S subunit (smaller subunit of ribosome)
- mRNA + tRNA + 30S subunit → called **Pre-initiation complex**
- Later, 50S (larger subunit of ribosome) joins/ attaches to Pre-initiation complex
- mRNA + tRNA + 30S subunit + 50S subunit → called **Initiation complex**
- Has 2 slots for tRNA entry – **A site (aminoacyl site) & P site (peptidyl site)**

**1st tRNA attaches to P site**

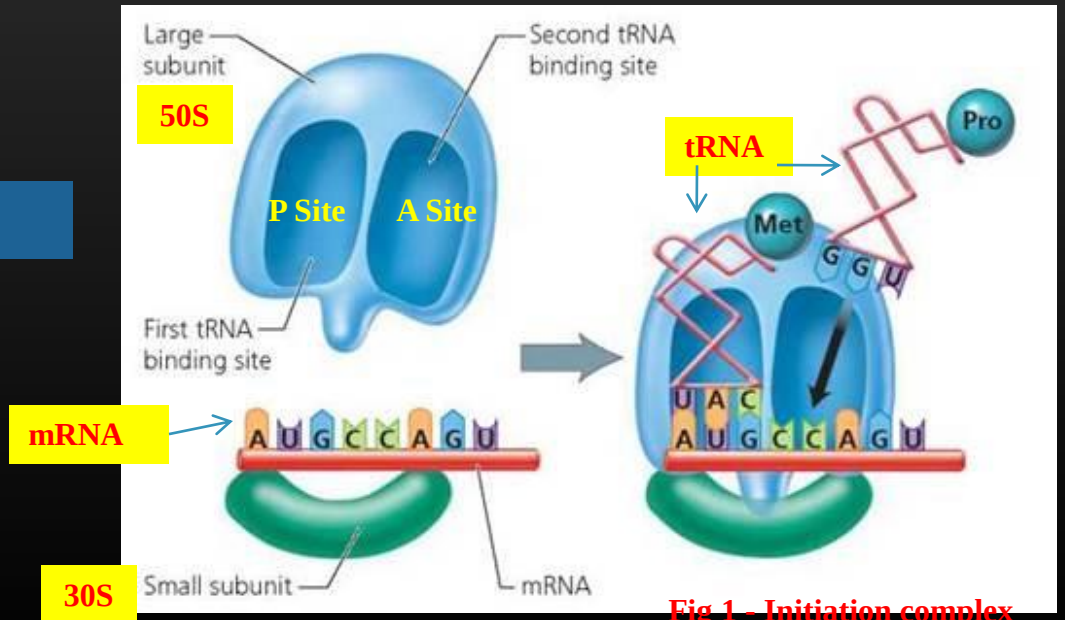
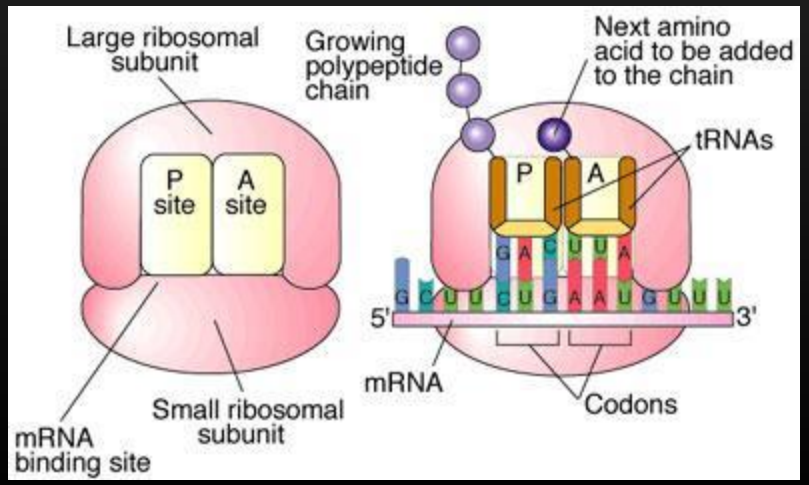



Fig 1 - Initiation complex

## 2. Elongation

- As per mRNA sequence – amino acid added
- 2nd mRNA codon recognized – by 2nd charged tRNA (with respective amino acid attached) – Enters via A site
- Peptide bond added between 1st & 2nd amino acid
- Ribosome complex moves – reads next mRNA codon (i.e - 3rd) – Now 1st tRNA (empty tRNA) leaves via P site and falls off, Now 2nd tRNA occupies P site and new tRNA (3rd) enters via A site
- Polypeptide chain elongates

**tRNA enter via A site and falls off from P site**



### 3. Termination:

- When stop codon (UAG, UAA, or UGA) reached – polypeptide chain terminates
- Protein synthesized
- Further post-translational modification

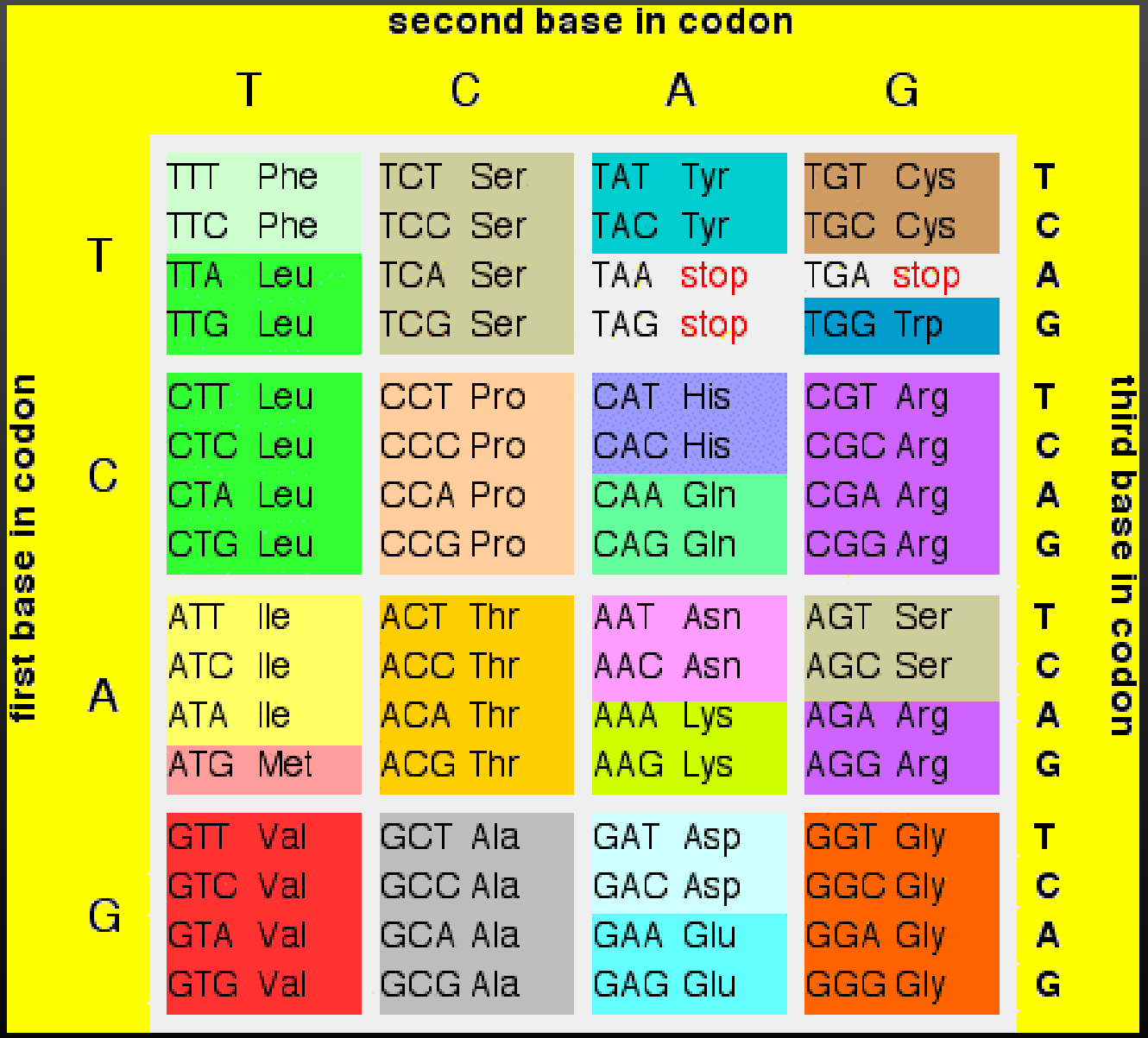
## 4) Post-translational modifications (PTM)

- PTM – for intracellular localization and other purposes of proteins
- Glycosylation, phosphorylation, acetylation, sumoylation

# Properties of genetic code

Triplet codon – total **64** (4*4*4)

- Universal
- Redundancy (Each amino acid more than one codon)
- Ambiguous (No codon codes for more than 1 amino acid)


second base in codon
T
C
A
G
first base in codon
third base in codon
T
C
A
G
TTT Phe
TTC Phe
TTA Leu
TTG Leu
TCT Ser
TCC Ser
TCA Ser
TCG Ser
TAT Tyr
TAC Tyr
TAA stop
TAG stop
TGT Cys
TGC Cys
TGA stop
TGG Trp
CTT Leu
CTC Leu
CTA Leu
CTG Leu
CCT Pro
CCC Pro
CCA Pro
CCG Pro
CAT His
CAC His
CAA Gln
CAG Gln
CGT Arg
CGC Arg
CGA Arg
CGG Arg
ATT Ile
ATC Ile
ATA Ile
ATG Met
ACT Thr
ACC Thr
ACA Thr
ACG Thr
AAT Asn
AAC Asn
AAA Lys
AAG Lys
AGT Ser
AGC Ser
AGA Arg
AGG Arg
GTT Val
GTC Val
GTA Val
GTG Val
GCT Ala
GCC Ala
GCA Ala
GCG Ala
GAT Asp
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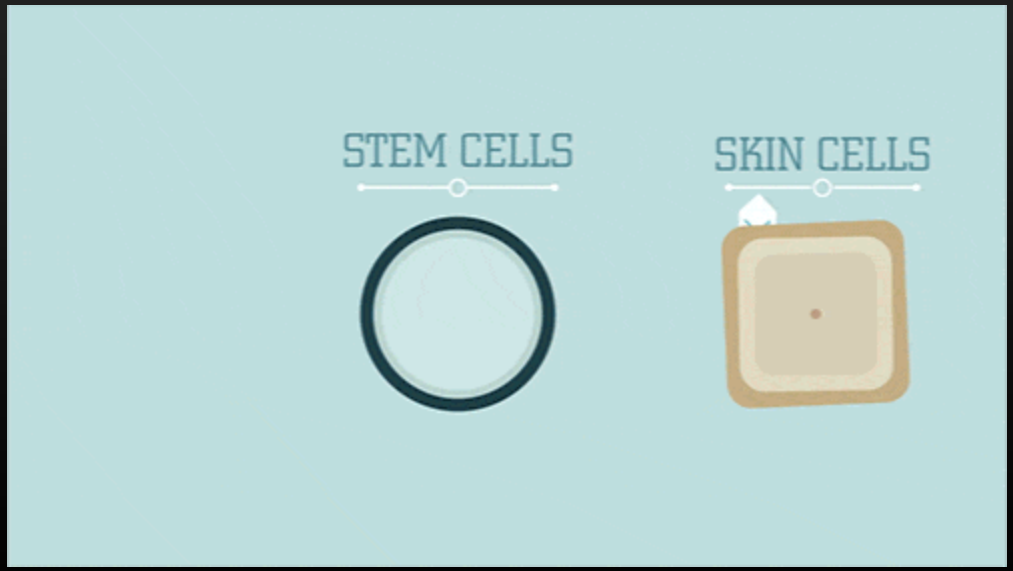
# Stem Cells
# and
# Their Application



# Stem Cells (SC)

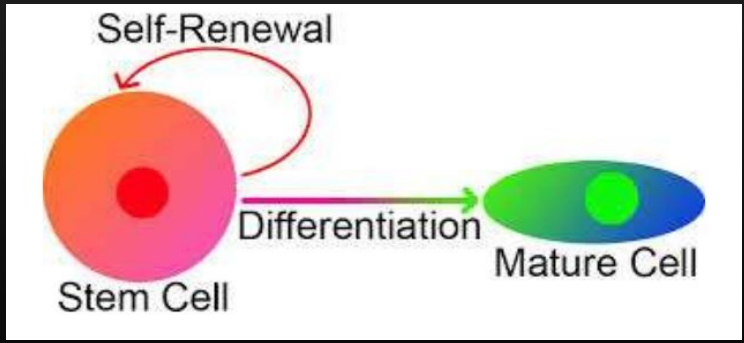
## Introduction

- **Stem cell** (SC)- Stem Cells are the cells which has the ability to divide for indefinite periods and which can give rise to specialized cells of various tissues of body.

- Stem cells – Unspecialized, can self-renew, when divides into 2 – one remains unspecialized & other becomes specialized

## Properties of stem cells

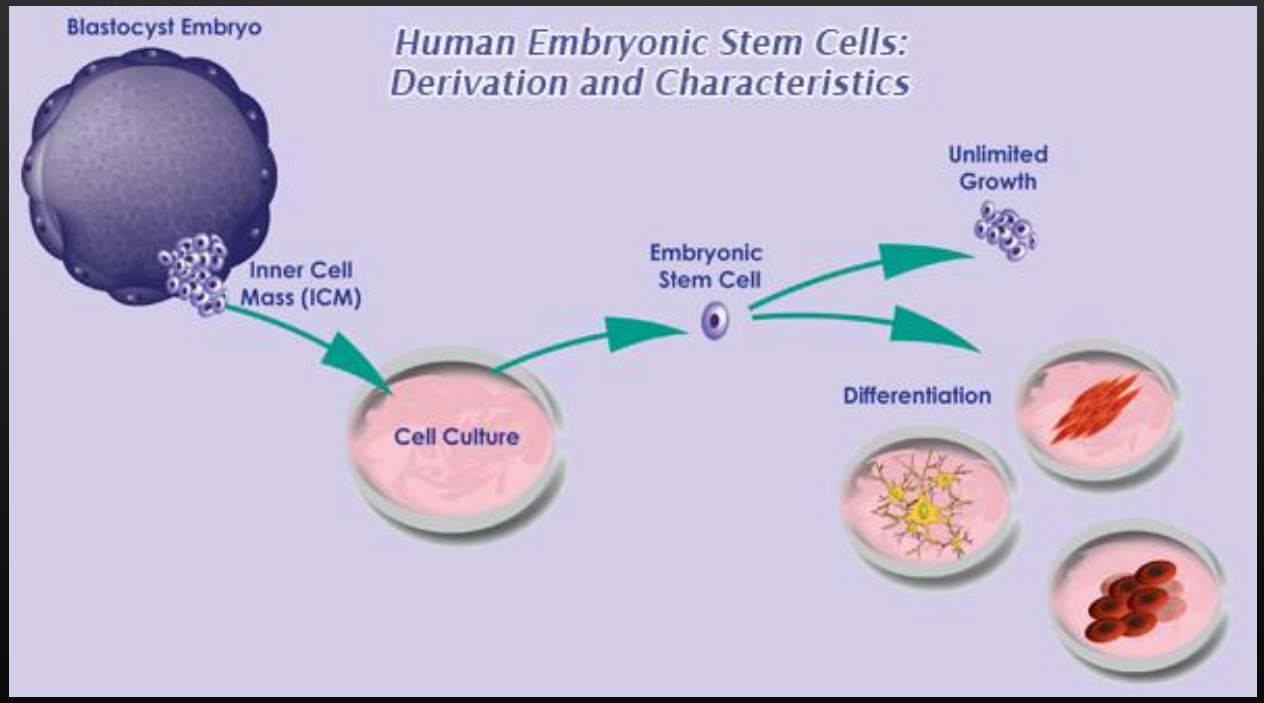
- Self – renewal
- Unspecialized
- Give rise to specialized cells



# Sources of Stem Cells

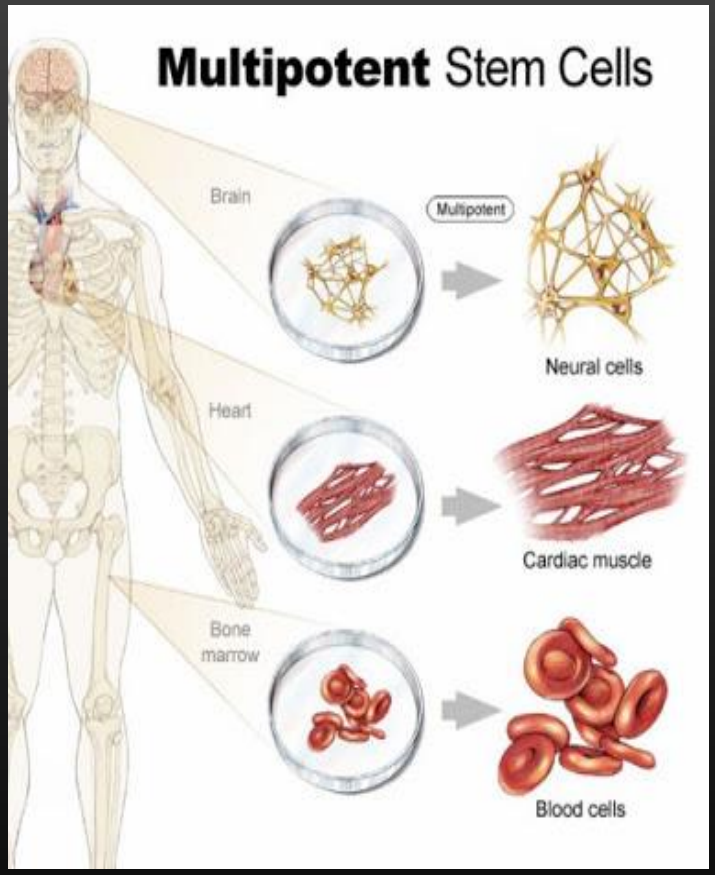
## Embryonic Stem Cells

- Isolated from blastocyst (ICM) stage of embryos
- Pluripotent (capable of developing into all cell types of body), except trophoblast



## 2) Adult Stem Cells

- It is present in all the organs (Ex: brain, bone marrow, skin, teeth, heart etc.), tissue-specific, undifferentiated, but very little amount
- Helps in tissue repair
- They are multipotent (differentiate into a closely related family of cells)
- Also derived from pregnancy-related tissues – **umbilical cords, placenta & amniotic fluids**
- Cadavers – within 20 hours of death – can remove neural stem cells from brain



# Classification of stem cells

**1) Totipotent**

- Can become any cell type
- Ex: Morula stage of Embryos

**2) Pluripotent**

- Almost any kind of cell except placenta
- Ex: Embryonic SC

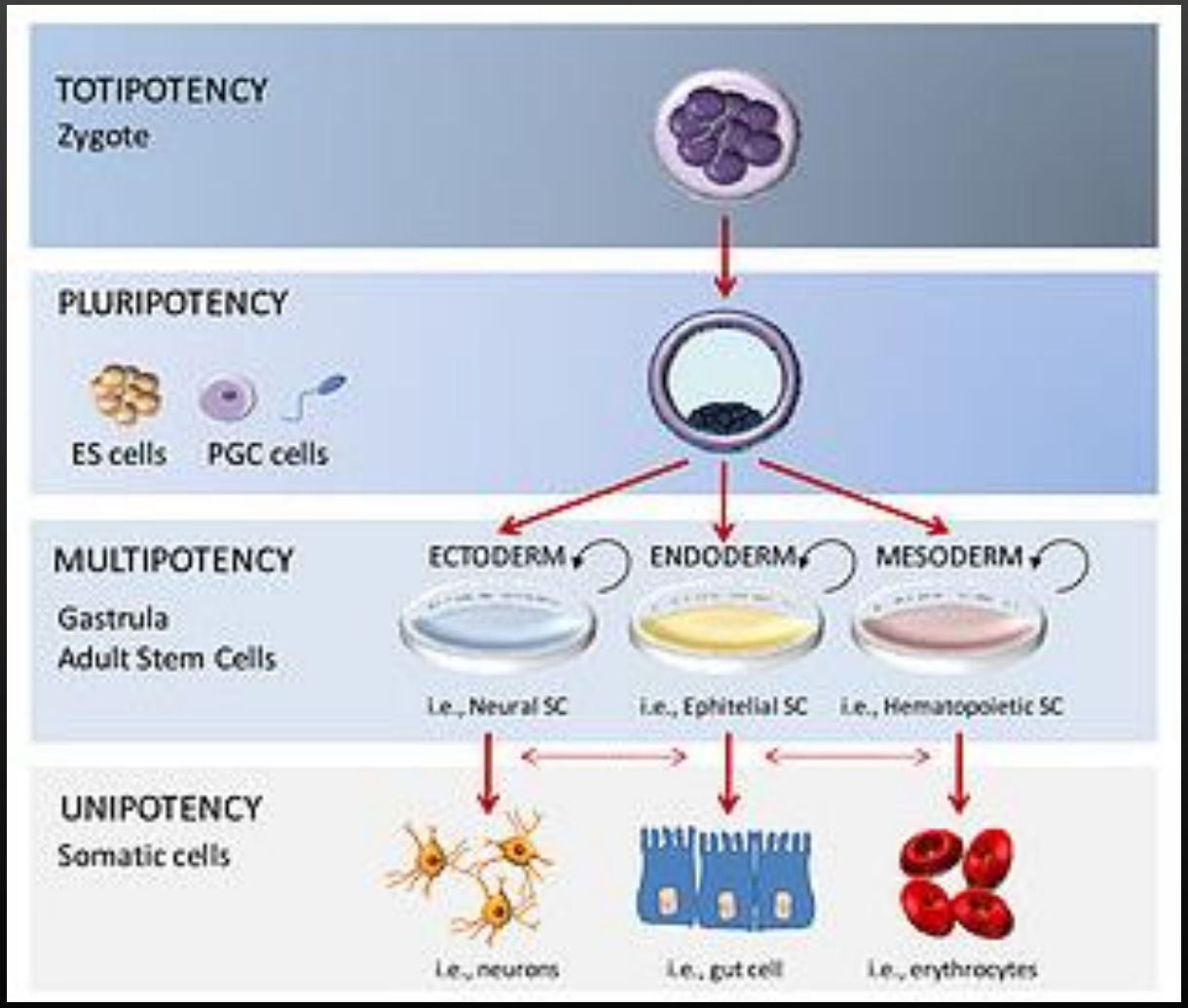
**3) Multipotent**

- Produces limited range of cell types
- Ex: Adult SC: nerve cells, blood cells, muscle cells, bone and skin cells

**4) Unipotent**

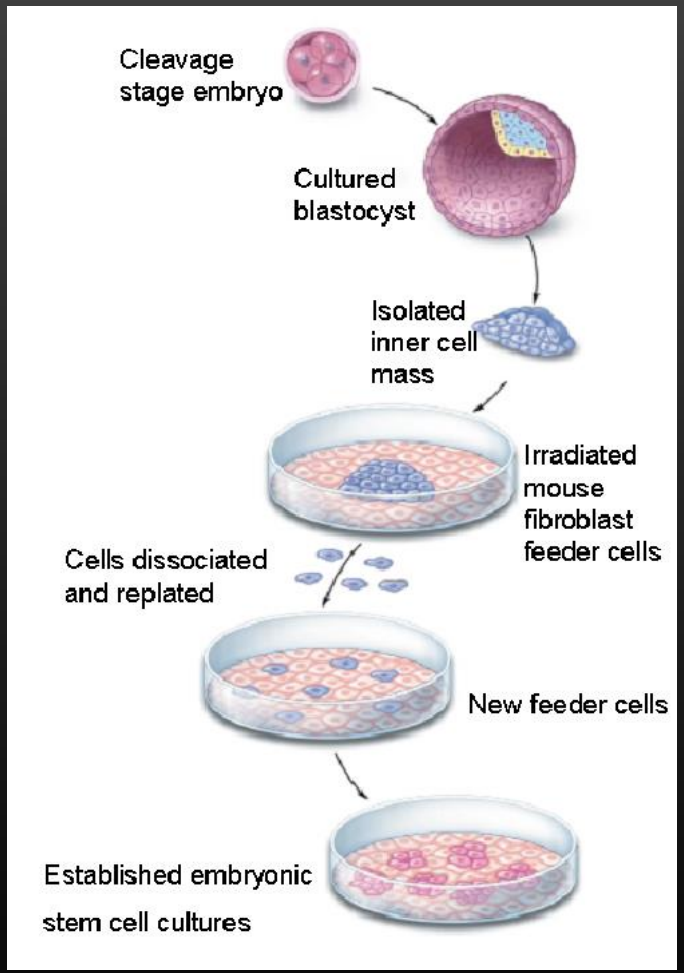
- Cell make exact copies of itself, can differentiate, produce same type of cells
- Ex: Adult muscle stem cell

# Classification of stem cells

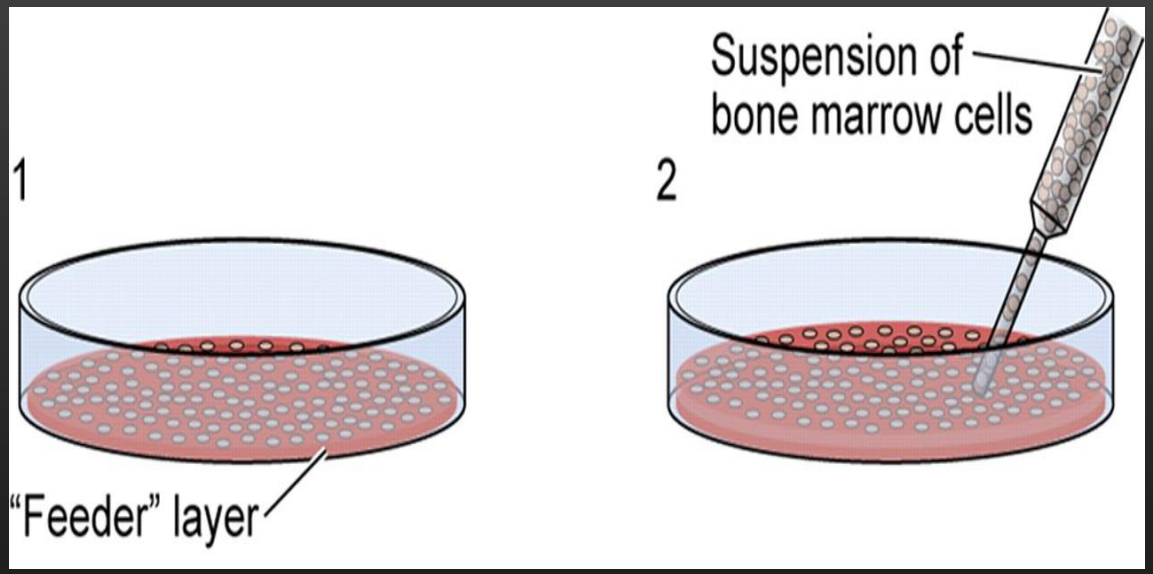


# Human embryonic stem cell (hESCs) isolation and culture

- hESC cultured from ICM of blastocyst
- Isolation of ICM (inner cell mass) from the blastocyst stage
- Transfer to culture medium
- Surface of culture dish – coated with mouse UV treated embryonic skin cells (feeder layer)
- Feeder layer – act as niche – release growth factors, cytokines etc.
- Sub-culture - Passage

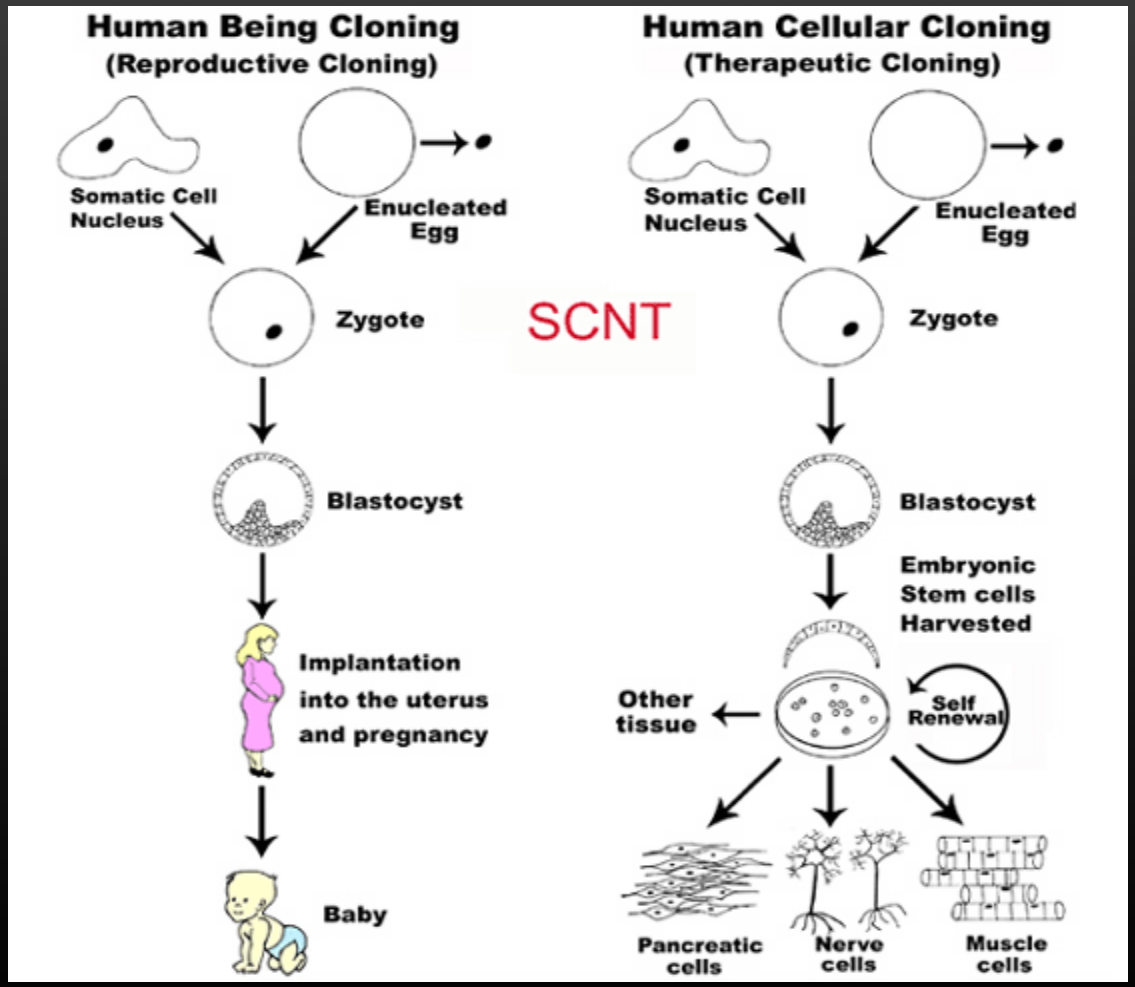


# Human embryonic stem cell (hESCs) isolation and culture



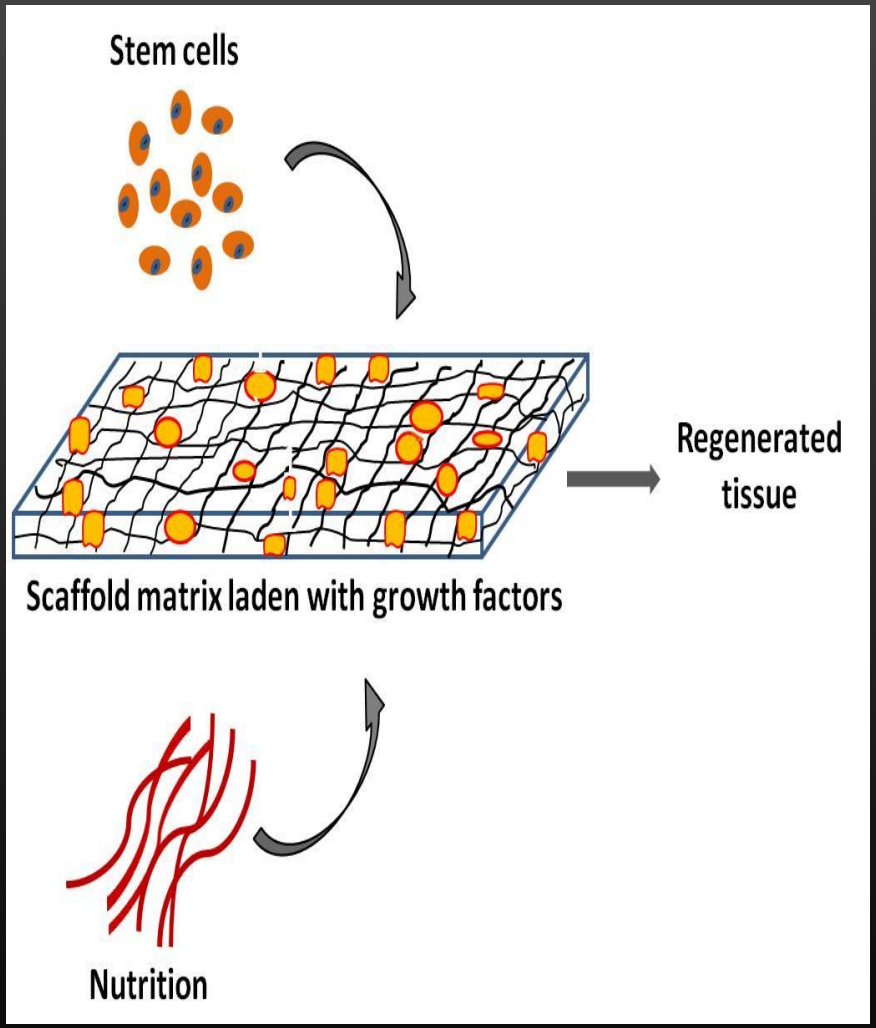

# Application of Stem Cells

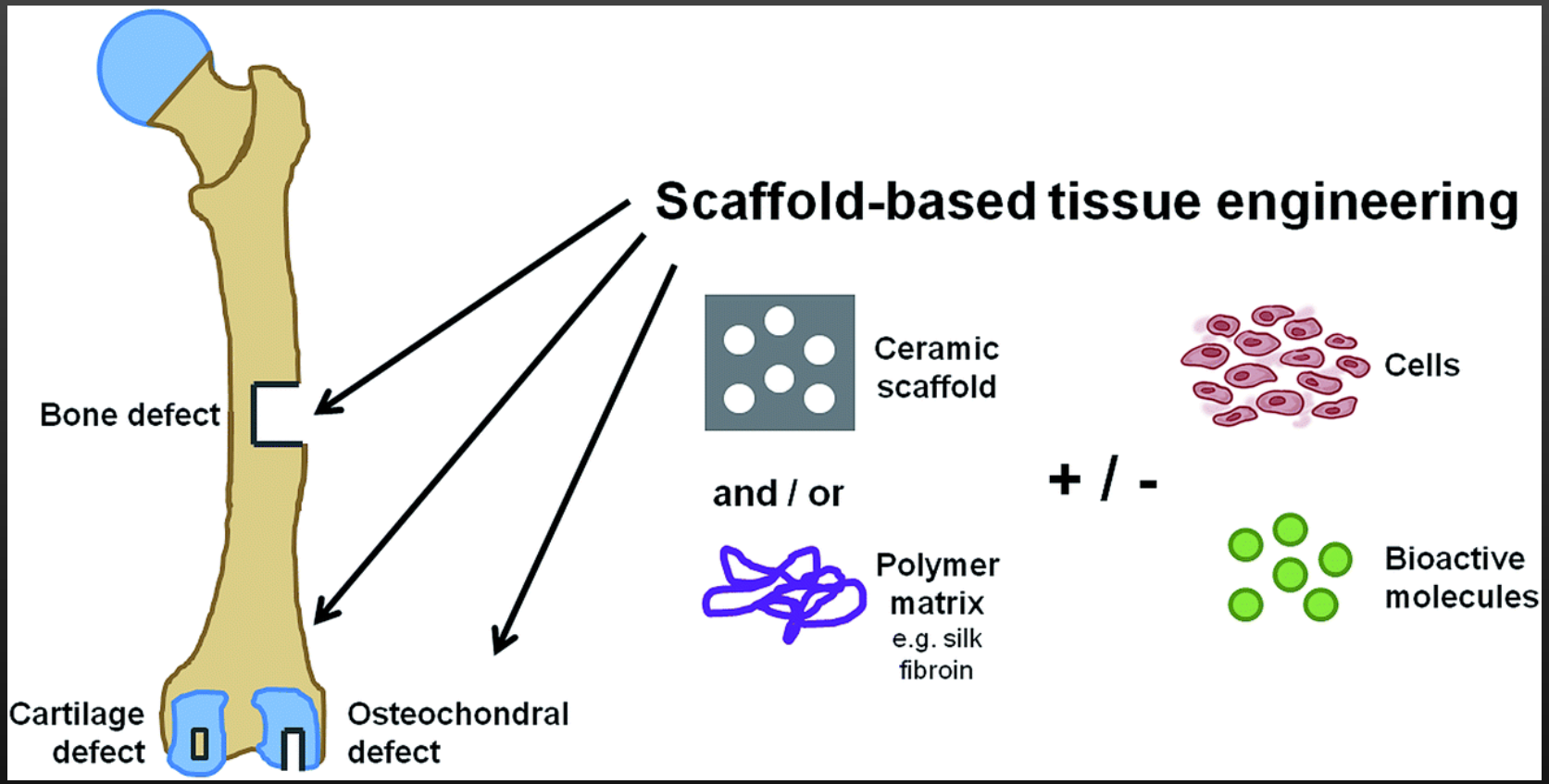
## 1) Therapeutic & Reproductive cloning



# 2) Regenerative Medicine

- Parkinson's disease – Stem cell (SC) injected – Nerve cell increases dopamine synthesis
- Muscular dystrophy – SC – Muscle damaged tissue gets healthy – patients walk faster
- Polio – SC – New spinal neurons grow
- Diabetes (Type – 1) – SC – Reduces hyper and hypoglycemia
- Bone tissue engineering – SC – Degradable scaffolds with bone morphogenetic proteins (BMPs) – helps in healing of facture, trauma, infections, skeletal development, biochemical disorder etc.

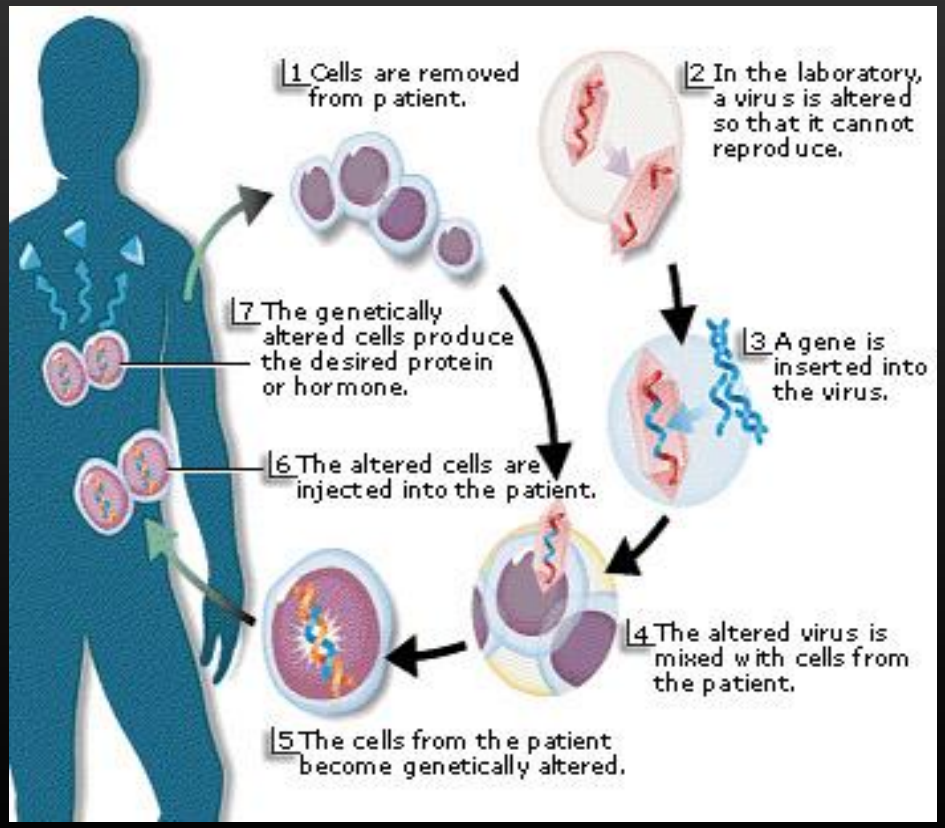

Stem cells
Regenerated tissue
Scaffold matrix laden with growth factors
Nutrition


Scaffold-based tissue engineering
Bone defect
Cartilage defect
Osteochondral defect
Ceramic scaffold
and / or
Polymer matrix
e.g. silk fibroin
+ / -
Cells
Bioactive molecules

# 3) Gene therapy

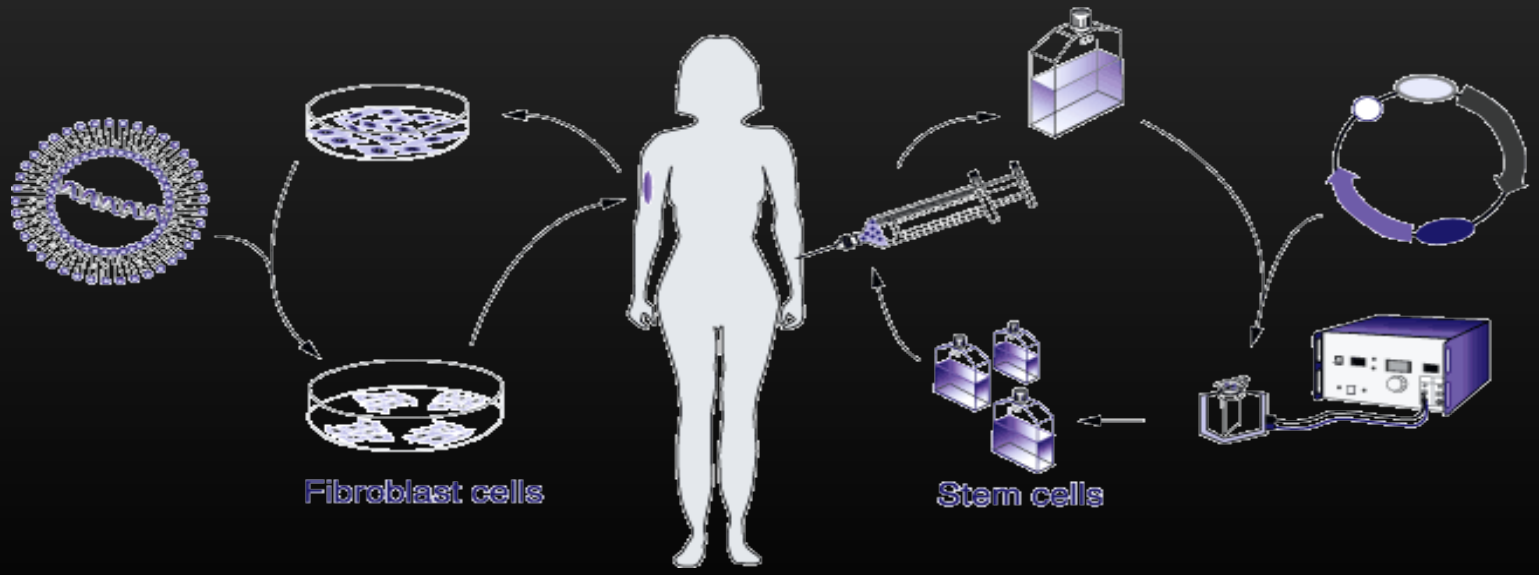
- Insertion of genes into an individual's cell to treat disease
- Defective gene → Replaced → Become Functional gene
- 2 delivering therapeutic transgenes into human recipients

## 1st BY VIRAL MEDIATED TRANSFER



# 2nd USE OF LIVING CELLS TO DELIVER TRANSGENES INTO BODY

- Delivering live cells – Ex: stem cell, lymphocyte, fibroblast are removed from patient's body
- Therapeutic transgenes introduced into those cells via **vehicles**
- This genetically modified cell is cultured & infused back into patient



# Application of Stem Cells