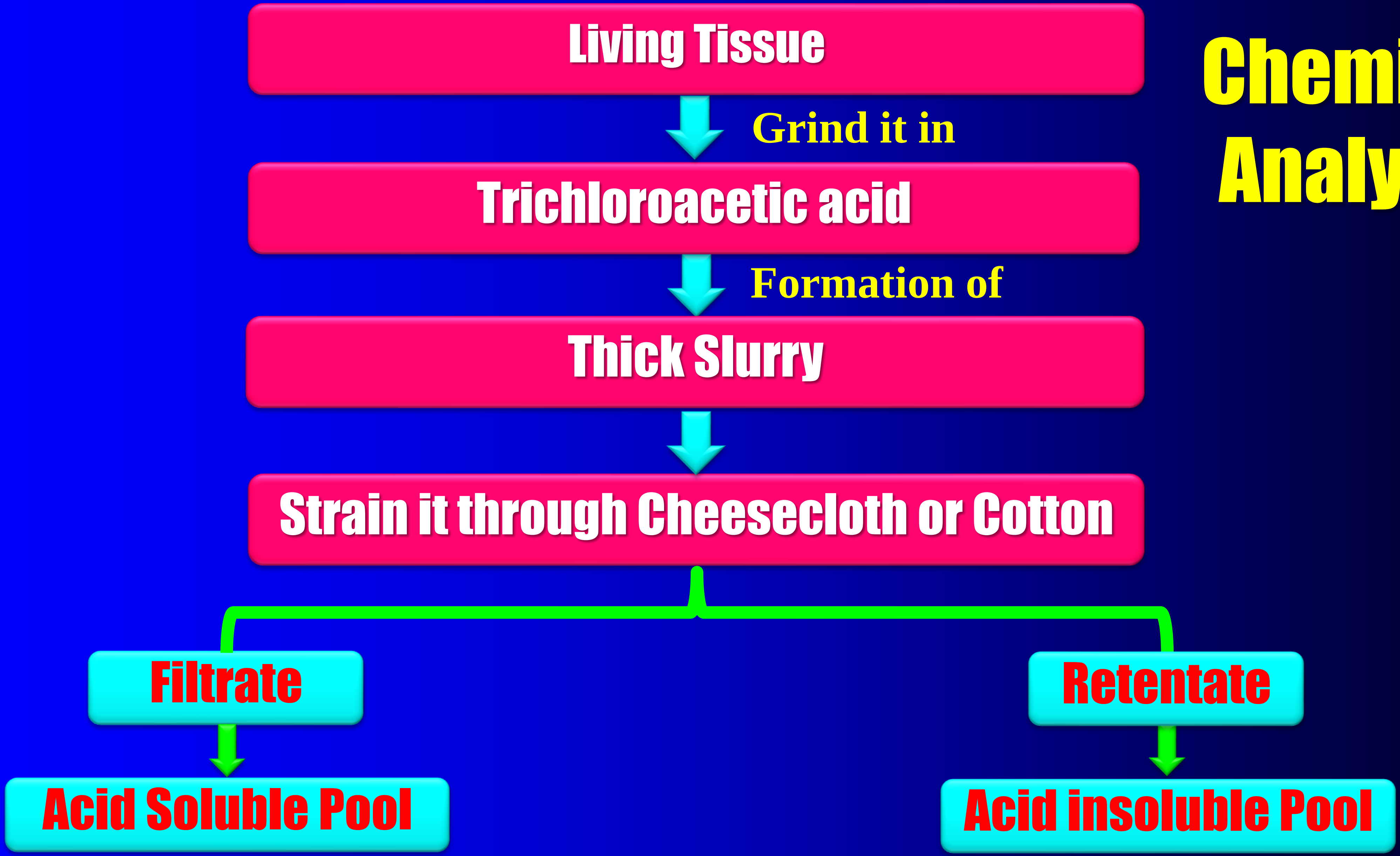
Biomolecules

Chemical Analysis



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Destructive Experiment

Living Tissue

↓ Dry

All the water evaporates

↓ The remaining material gives

Dry Weight

↓ Burn the Tissue

All the carbon compounds are oxidized to

↓ Gaseous form as

CO_2, Water vapour Removed

↓

Remaining is called Ash

This ash contains inorganic elements like **calcium, magnesium, sulphate, phosphate**

Metabolites

Primary and Secondary Metabolites

Primary Metabolites	Secondary Metabolites
The biomolecules that have identifiable functions and play known roles in normal physiological processes are primary metabolites.	The molecules whose functions are not known at the moment are known as secondary metabolites.
Eg., amino acids, sugars, etc.	e.g. alkaloids, flavonoids, rubber, essential oils, antibiotics, coloured pigments, scents, gums, spices.

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Some Secondary Metabolites

Pigments	Carotenoids, Anthocyanins etc
Alkaloids	Morphine, Codeine, etc
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Drugs	Vinblastin, curcumin, etc
Polymeric substances	Rubber, gums, cellulose

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Polysaccharides

Polysaccharides

Polysaccharides are long chains of monomers called glucose.

In a polysaccharide chain, the **right end is called the reducing end** and the **left end is called the non-reducing end.**

There are more complex polysaccharides in nature. They are as

- Building blocks
- Amino-sugars
- Chemically modified sugars (e.g., glucosamine, N-acetyl galactosamine, etc.)

Exoskeletons of arthropods have a complex polysaccharide called chitin.

These **complex polysaccharides are heteropolymers.**

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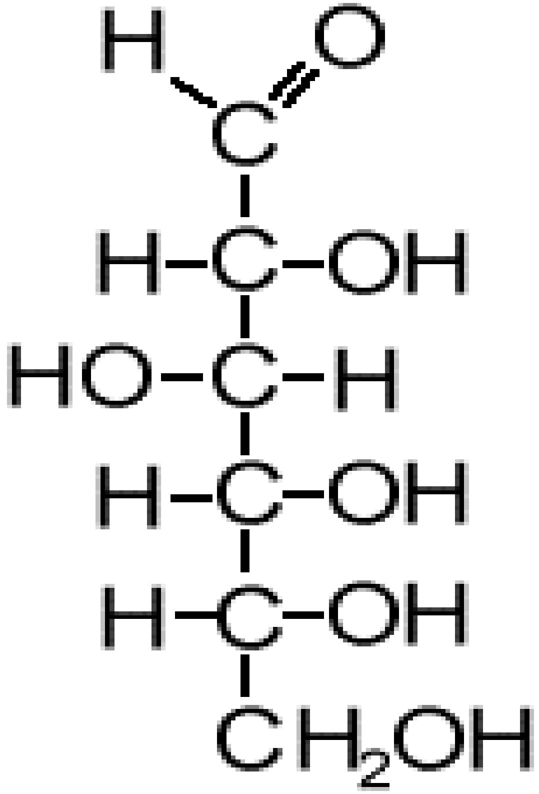
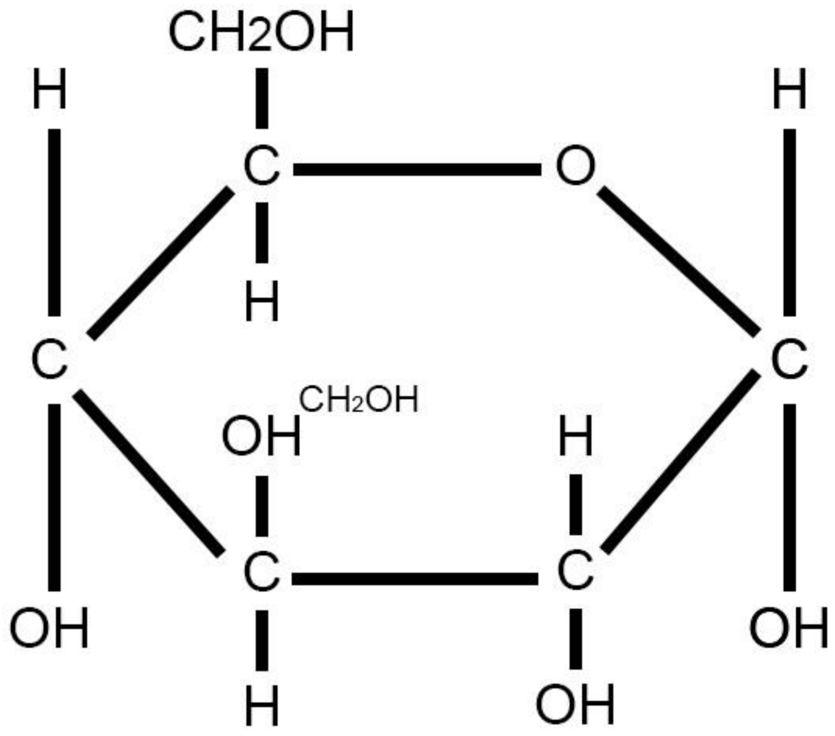
Polysaccharides



Glucose

Ring structure of a glucose unit



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Cellulose

Cellulose is a polymeric polysaccharide consisting of only one type of monosaccharide i.e., glucose.

Cellulose is a homopolymer.

Cellulose does not contain complex helices. hence cannot hold I_2.

Examples of cellulose

Plant cell walls are made of cellulose.

Paper made from plant pulp is cellulose.

Cotton fibre is cellulose.

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Starch

Starch is present as a store house of energy in plants.

Starch forms helical secondary structures.

In fact, starch can hold $\mathbf{I_2}$ molecules in the helical portion.

The starch-I_2 is blue in colour.

Animals have another variant called glycogen.

Inulin is a polymer of fructose.

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Lipids

Lipids

Why do lipids, whose molecular weights do not exceed 800 Da, come under acid insoluble fraction, i.e., macromolecular fraction?

Lipids are indeed small molecular weight compounds.

They are present not only as such but also in the form of cell membrane and other membranes.

When we grind a tissue, we are disrupting the cell structure. Cell membrane and other membranes are broken into pieces, and form vesicles which are not water soluble.

Therefore, these membrane fragments in the form of vesicles get separated along with the acid insoluble pool and hence in the macromolecular fraction.

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Lipids

Lipids are not strictly macromolecules.

The acid soluble pool represents roughly the cytoplasmic composition.

The macromolecules (Carbohydrates, Proteins and Nucleic acids) from cytoplasm and organelles become the acid insoluble fraction.

Together they represent the entire chemical composition of living tissues or organisms

Water is the most abundant chemical in living organisms

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Lipids

Straining of slurry

- **Filtrate**
  - **Acid Soluble Fraction**
    - **Cytoplasmic Composition only**
      - **Micromolecules**
        - Glucose
        - Aminoacids
        - Nucleotides
- **Retentate**
  - **Acid insoluble Fraction**
    - **Cytoplasmic Composition + Organelles**
      - **Vesicles**

        Cell Membrane
        and
        Membranes of Mitochondria, Chloroplast
        broken into pieces forming vesicles
      - **Macromolecules**
        - Carbohydrates
        - Proteins
        - Nucleic acids

Lipids

Lipids are water insoluble.

They could be simple fatty acids.

A fatty acid has a carboxyl group attached to an R group.

The R group could be a

Methyl (-CH3)

Ethyl (-C_2H_5)

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Lipids

Many lipids have both glycerol and fatty acids.

The fatty acids are found esterified with glycerol.

They can be then monoglycerides, diglycerides and triglycerides.

These are also called fats and oils based on the melting point.

Oils have lower melting point (e.g., gingely oil) and hence remain as oil during winters.

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Lipids

Some lipids have phosphorous and a phosphorylated organic compound in them. These are phospholipids.

They are found in cell membrane.

Lecithin is phospholipid.

Some tissues especially the neural tissues have lipids with more complex structures.

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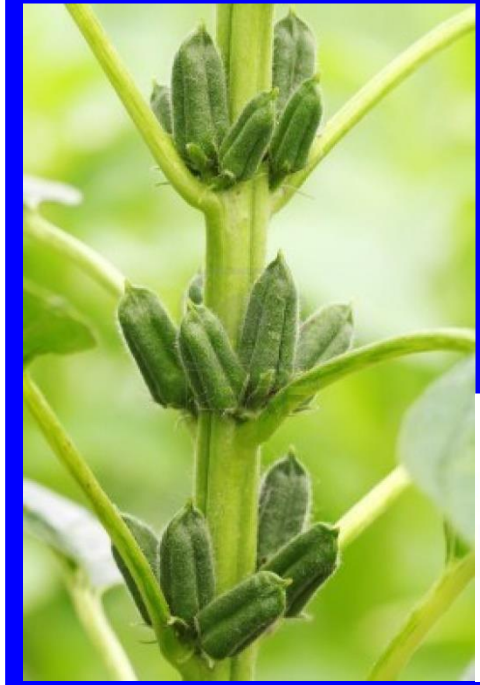

Saturated and Unsaturated Fatty acids

Saturated Fatty acids	Unsaturated Fattty acids
Fatty acids that do not have double bonds between the carbon atoms are saturated fatty acids.	Fatty acids that have one or more double bonds between the carbon atoms are unsaturated fatty acids.
They have higher melting point and remain as solid during winter. **eg., Coconut oil.**	They have lower melting point and hence remain as liquid during winter. e.g., gingely oil.

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Proteins

Proteins

Proteins are polypeptides.

They are linear chains of amino acids linked by peptide bonds.

Each protein is a polymer of amino acids.

As there are 20 types of amino acids in a protein molecule, protein is a heteropolymer and not a homopolymer.

(e.g., alanine, cysteine, proline, tryptophan, lysine, etc.),

A homopolymer has only one type of monomer repeating number of times.

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The R group in these amino acids could be a

Hydrogen (H) (the amino acid is called glycine)

Methyl group (CH_3) (alanine)

Hydroxy methyl (CH_2 OH) (serine)

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There are aromatic amino acids (tyrosine, phenylalanine, and tryptophan).

A particular property of amino acids is the ionizable nature of $-NH_2$ and -COOH (Amino and Carboxyl) groups.

Hence in solutions of different pHs, the structure of amino acids changes.

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Acidic Aminoacid

If the side chain contains an acid functional group, the whole amino acid produces an acidic solution.

Aspartic acid

Glutamic acid

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Basic Aminoacid

If the side chain contains an amine functional group, the amino acid produces a basic solution because the extra amine group is not neutralized by the acid group.

Lysine **Arginine**

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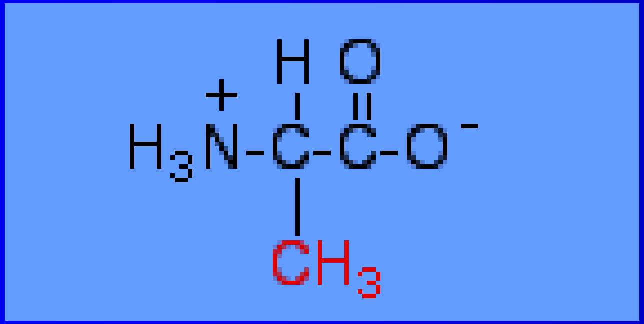
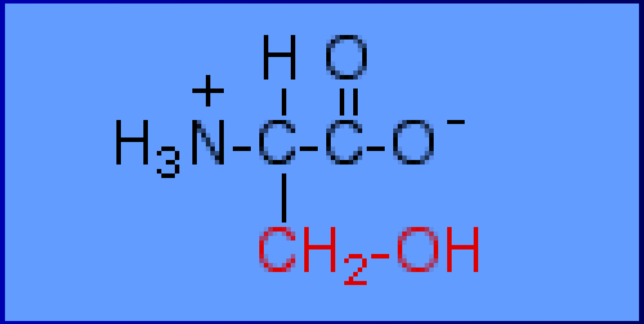
Neutral Aminoacid

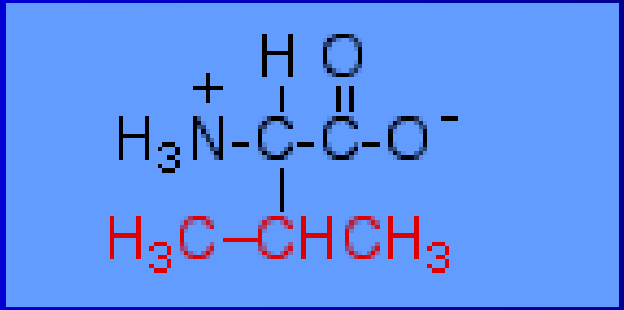
Alanine



Serine



Valine



Proteins

Proteins carry out many functions in living organisms.

Some proteins **transport nutrients** across cell membrane.

Some proteins **fight against pathogens**.

Some proteins are **hormones.**

Some proteins are **enzymes.**

Collagen is the most abundant protein in animal world.

Ribulose bisphosphate Carboxylase-Oxygenase **(RUBISCO)** is the most abundant protein in the whole of the biosphere.

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Examples of proteins

Type	Examples
• Structural Proteins	Tendons, cartilage, hair, nails
• Contractile Proteins	Muscles
• Transport Protein	Hemoglobin
• Storage Protein	Milk
• Hormonal Proteins	Insulin, Growth hormone
• Enzyme	catalyzes reactions in cells
• Protection	immune response

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Proteins

Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception(smell, taste, hormone,etc)
GLUT-4	Enables glucose transport into cells

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Primary Structure of Protein

The sequence of amino acids in a protein which is the first amino acid, which is second, and so on is called the **primary structure** of a protein.

A protein is imagined as a line, the left end represented by the first amino acid and the right end represented by the last amino acid.

The first aminoacid is also called as N-terminal amino acid.

The last amino acid is called the C-terminal amino acid.

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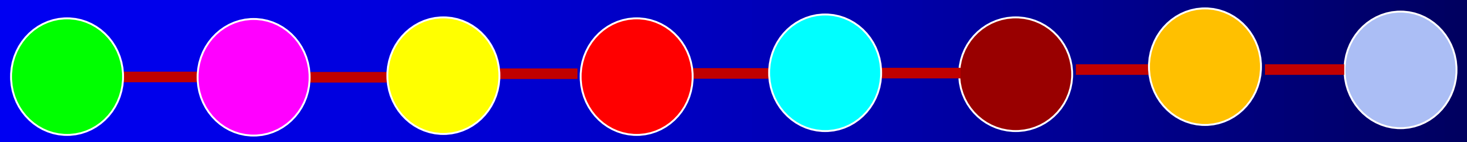
Primary Structure of Protein



Linear sequence of aminoacids

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Secondary Structure of Protein

A protein thread does not exist throughout as an extended rigid rod.

The **thread is folded in the form of a helix** (similar to a revolving staircase).

Only some portions of the protein thread are arranged in the form of a helix.

Other regions of the protein thread are **folded** into other forms called the **secondary structure.**

In proteins, only right-handed helices are observed.

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Tertiary Structure of Protein

The long protein chain is also folded upon itself like a **hollow woollen ball**, giving rise to the **tertiary structure**.

This gives us a 3-dimensional view of a protein.

Tertiary structure is absolutely necessary for many biological activities of proteins.

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Quaternary Structure of Protein

Some proteins are an assembly of **more than one polypeptide or subunits.**

The manner in which these individual folded polypeptides or subunits are arranged with respect to each other e.g.

Linear string of spheres

Spheres arranged one upon each other in the form of a cube

called the **quaternary structure** of a protein.

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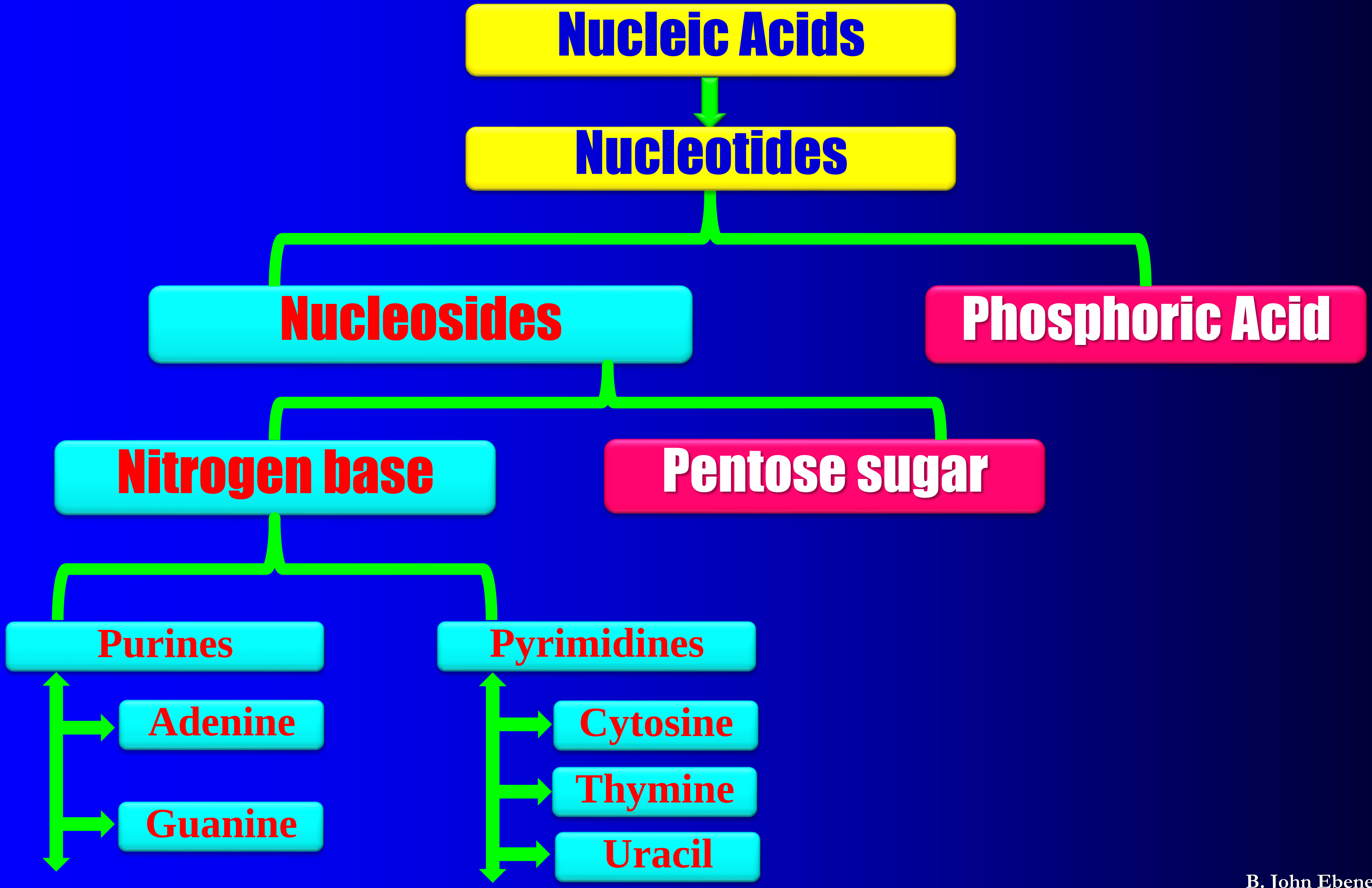
Nucleic Acids



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Nucleosides and Nucleotides

Adenosine, guanosine, cytidine thymidine, uridine and are nucleosides.

Adenylic acid, guanylic acid, cytidylic acid thymidylic acid,, uridylic acid and are nucleotides.

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Nucleic Acids

The monomers or building blocks of nucleic acids are nucleotides.

A nucleotide has three distinct components.

One is a **heterocyclic compound**, the second is a **monosaccharide** and the third a **phosphoric acid** or **phosphate**.

The heterocyclic compounds in nucleic acids are the nitrogen bases named adenine, guanine, cytosine, thymine and uracil.

Adenine and Guanine are purines while Cytosine and Thymine and Uracil are pyrimidines.

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The sugar found in nucleic acids is either ribose sugar or deoxyribose sugar.

A nucleic acid which contains ribose sugar is called ribonucleic acid (RNA) while that contains deoxyribose sugar is called deoxyribonucleic acid (DNA).

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Watson & Crick Model of DNA

According to Watson and Crick DNA exists as a double helix.

The two strands of polynucleotides are **antiparallel** i.e., they run in the opposite direction.

The backbone is formed by the **sugar-phosphate-sugar chain**.

The nitrogen bases are arranged perpendicular to this backbone facing inside.

Purine pairs with pyrimidine.

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Watson & Crick Model of DNA

DNA is a double stranded helical structure.

Each strand appears like a helical staircase.

Each helix has a distance of $34A^{o}$.

Each helix consists of ten nucleotides.

So the distance between any two nucleotide is $3.4A^{o}$.

This form of DNA is called B-DNA.

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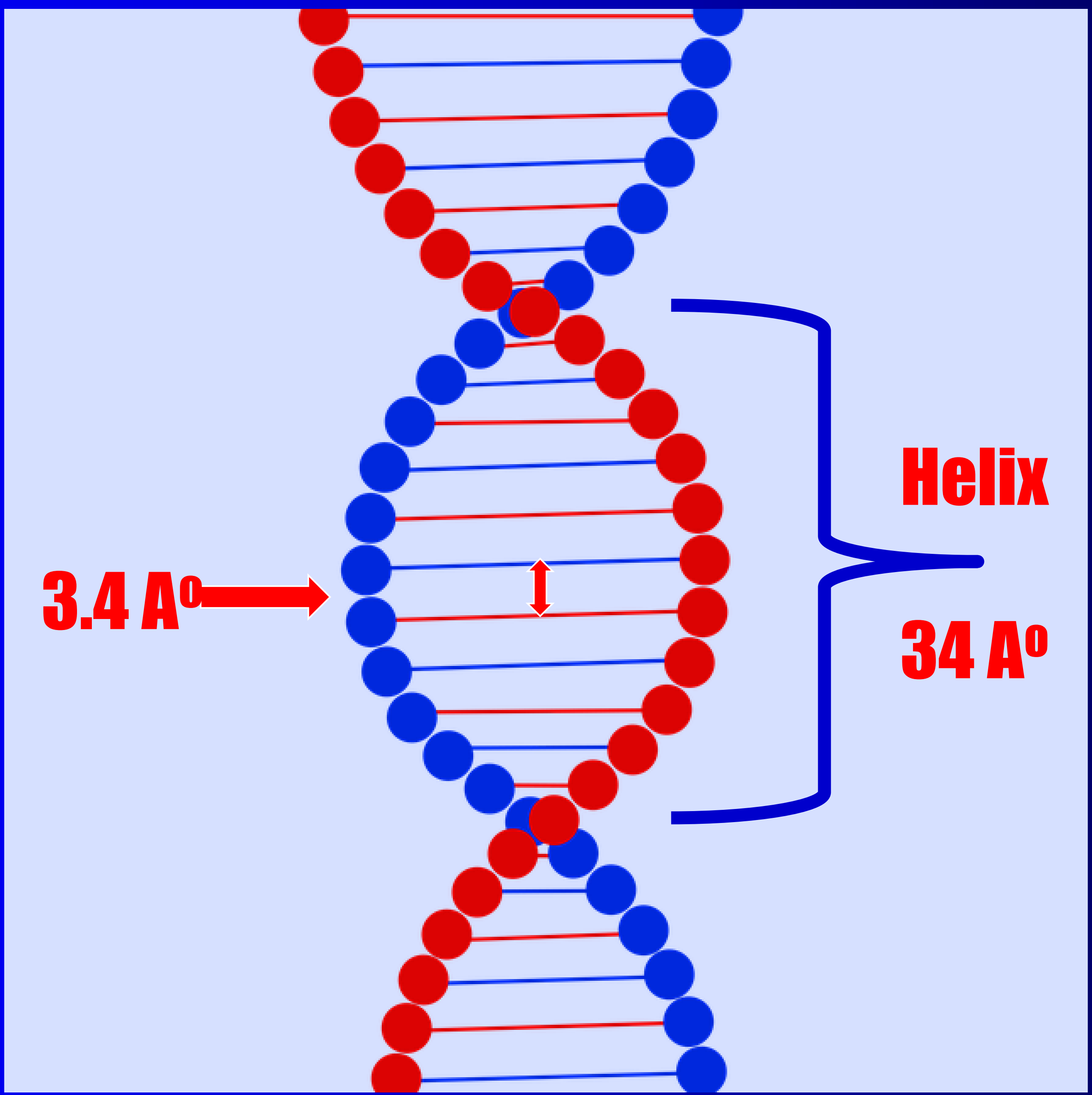
Sructure of DNA



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In DNA, Adenine pairs with Thymine with two hydrogen bonds.

Guanine pairs with Cytosine with three hydrogen bonds.

In RNA Adenine pairs with Uracil but Guanine pairs with Cytosine.

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Enzymes

Features of Enzymes

Enzymes are biocatalysts, they speed up the biochemical reactions.

Almost all enzymes are made of proteins. There are some nucleic acids that behave like enzymes. These are called ribozymes.

An enzyme like any protein has a primary structure, i.e., amino acid sequence of the protein.

An enzyme like any protein has the secondary and the tertiary structure.

An active site of an enzyme is a crevice or pocket into which the substrate fits. The enzymes catalyse the reactions at a high rate.

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Structure of Enzymes

Enzymes

- **Protein Part**
  - Apoenzyme
- **Non Protein part**
  - Cofactors
    - Prosthetic Group (Tightly Bound)
      - Haem
    - Coenzyme (Loosely Bound)
      - Vitamin
      - NAD
      - NADP
    - Metal Ion (Coordination Bond)
      - Zinc

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Structure of Enzyme

The protein portion of the enzyme is called the apoenzyme.

The non-protein components of the enzyme are called cofactors.

The cofactors are of three kinds: prosthetic groups, co-enzymes and metal ions.

Prosthetic groups are organic compounds that they are tightly bound to the apoenzyme.

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Peroxidase and catalase catalyze the breakdown of hydrogen peroxide to water and oxygen.

Haem is the prosthetic group and it is a part of the active site of these enzymes.

Peroxidase

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

Catalase

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

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Co-enzymes are organic compounds which are loosely bound to the apoenzyme.

The essential chemical components of many coenzymes are vitamins.

e.g., coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contain the vitamin niacin.

Metal ions form coordination bonds with **side chains at the active site** and at the same time form one or more coordination bonds with the **substrate.**

e.g., zinc is a cofactor for the proteolytic enzyme **carboxypeptidase**.

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The rate of enzyme catalysed reactions are vastly higher than the uncatalysed reactions

$$CO2 + H_2O \xrightarrow{\text{Carbonic anhydrase}} H_2CO_3$$

Carbon dioxide + Water → Carbonic acid

In the absence of enzyme

200 molecules of H_2CO_3 are formed in an hour.

In the presence of enzyme

6,00,000 molecules are formed for every second.

The enzyme has accelerated the reaction rate by about 10 million times.

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Mechanism of Enzyme Action

The substrate binds to the active site of the enzyme, fitting into the active site.

The binding of the substrate induces the enzyme to alter its shape, fitting more tightly around the substrate, forming **enzyme substrate complex**.

The active site of the enzyme **breaks the chemical bonds of the substrate** and the new product is formed.

The enzyme **releases the products**.

The free enzyme is ready to bind with another substrate molecule and run through the catalytic cycle once again.

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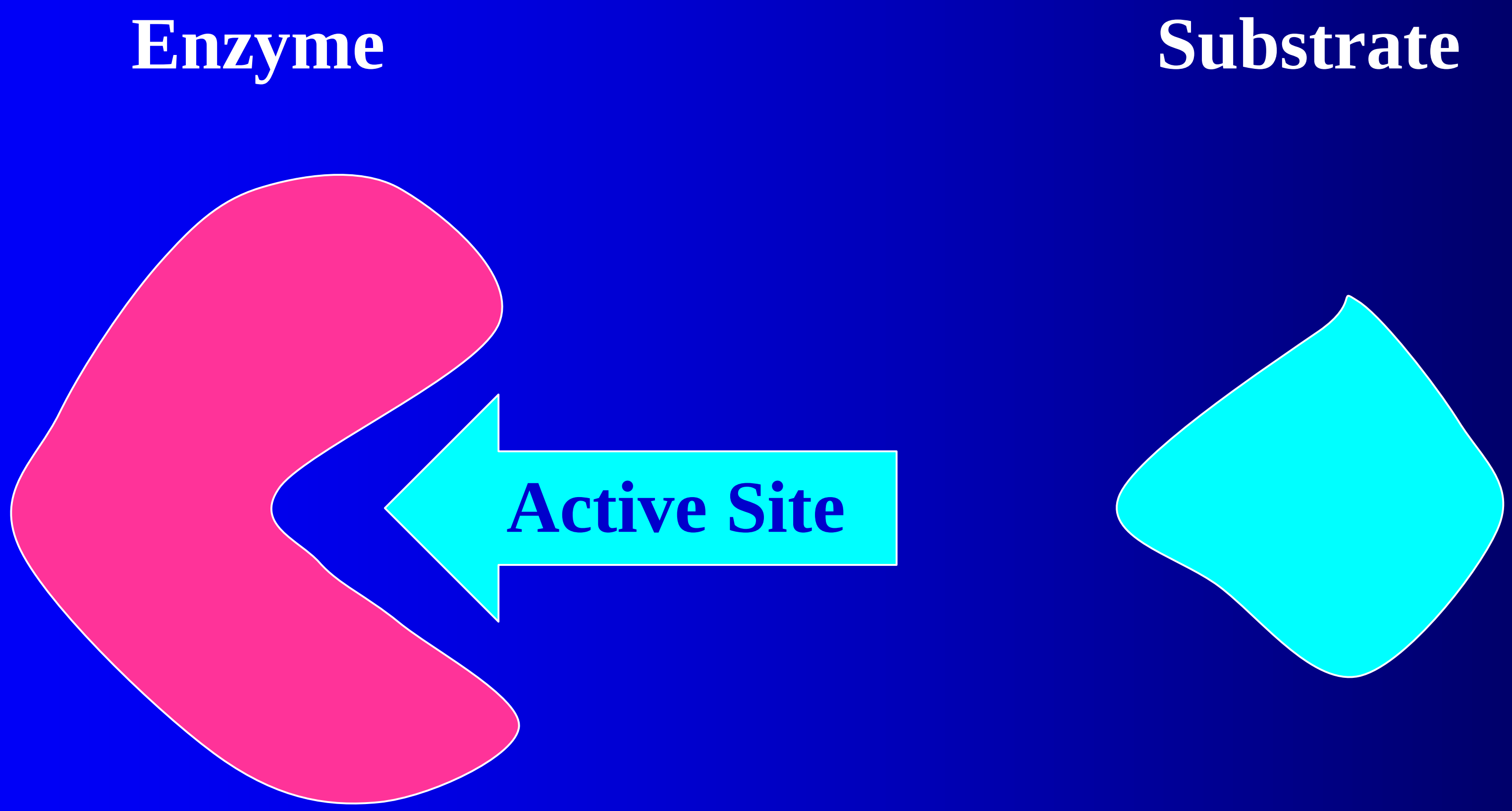
Model of Enzyme



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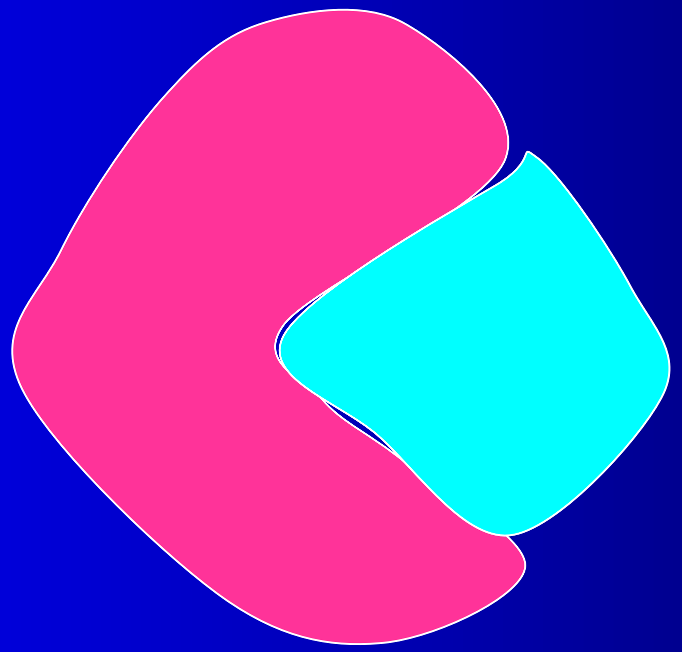
Enzyme Substrate Complex



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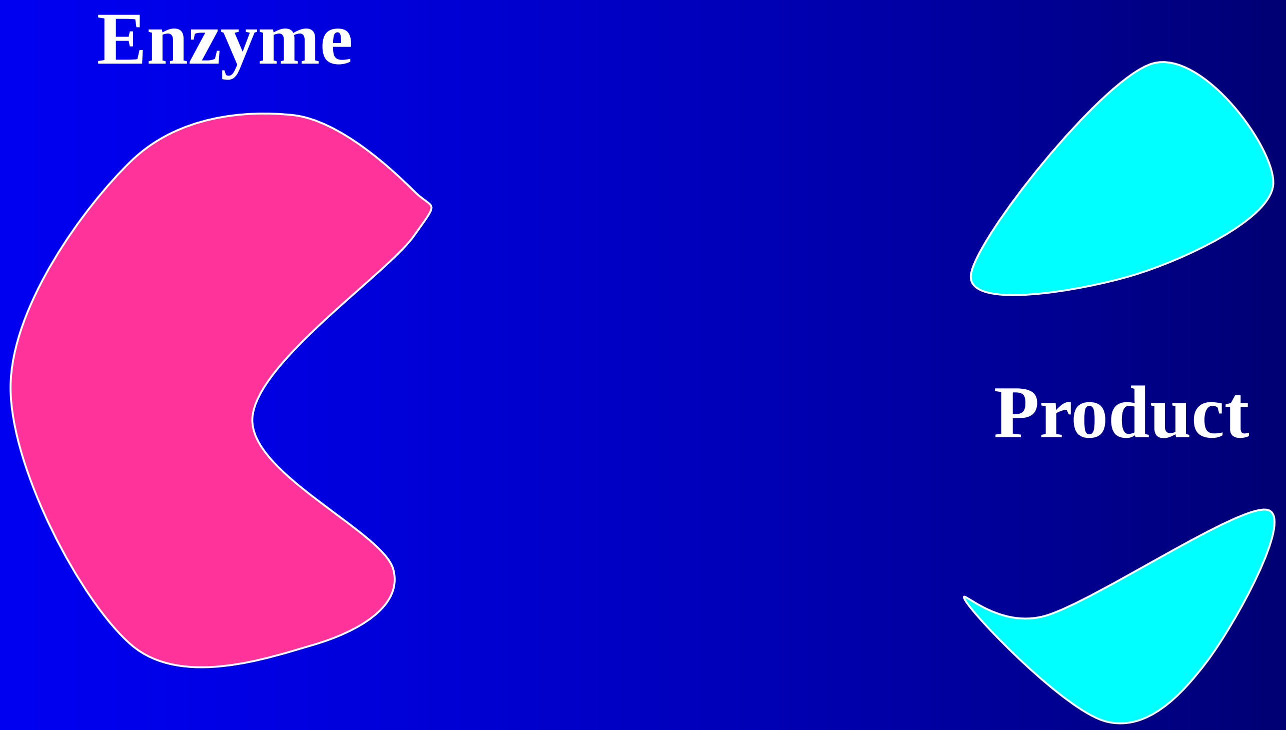
Enzyme and Products



Enzyme ready to bind with the substrate again

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Concentration of Substrate

With the increase in substrate concentration, the velocity of the enzymatic reaction rises at first.

The reaction ultimately reaches to a maximum velocity (V) which is not exceeded by any further rise in concentration of the substrate.

This is because the enzyme molecules are fewer than the substrate molecules and after saturation of these molecules; there are no free enzymes to bind with the additional substrate molecules.

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Inhibitor

The chemical which stops the enzymatic activity is called an inhibitor and the process is called inhibition.

When the **inhibitor closely resembles the substrate** in its molecular structure and **inhibits the activity of the enzyme**, it is known as competitive inhibitor.

Due to its close structural similarity with the substrate, the inhibitor competes with the substrate for the active site of the enzyme.

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Hence, the substrate cannot bind and as a result, the enzyme action declines.

e.g., Inhibition of succinic dehydrogenase by **malonate**, which closely resembles the substrate **succinate** in structure.

Such competitive inhibitors are often used in the control of bacterial pathogens.

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Classification of Enzymes

Enzymes are classified based on their function. You can remember the names easily with the help of the following mnemonic.

Over The HILL

Oxidoreductases/dehydrogenases

Transferases

Hydrolases

Isomerases

Lyases

Ligases

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Enzymes

The mnemonic **LEO the lion says GER** is a helpful to remember the major concepts of Oxidation-Reduction reactions.

When a molecule **L**oses **E**lectrons it is **O**xidized (**LEO**).

When a molecule **G**ains **E**lectrons it is **R**educed (**GER**).

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Oxidoreductases/dehydrogenases

Enzymes which catalyse oxidoreduction between two substrates are called oxidoreductases or dehydrogenases.

Lactate dehydrogenase

Pyruvate + NADH → Lactic acid + NAD^+

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Transferases

Enzymes that catalyse the **transfer of a functional group** from one molecule to the other are called transferases.

$$\text{Glucose + ATP} \xrightarrow{\text{Hexokinase}} \text{Glucose-6-Phosphate + ADP}$$

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Hydrolases

Enzymes catalyse **hydrolysis of molecules using water**.

Break down of covalent bonds occurs using water are called hydrolases.

$$\text{Sucrose} + H_2O \xrightarrow{\text{Sucrase}} \text{Glucose} + \text{Fructose}$$

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Isomerases

Enzymes catalyse the **inter-conversion** of optical, geometric or positional isomers are called isomerases.

Phospho Glucose Isomerase

Glucose 6 Phosphate → **Fructose 6 Phosphate**

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Lyases

Enzymes that catalyse the **removal of groups** from substrates by mechanisms other than hydrolysis leaving double bonds.

Pyruvate decarboxylase

Pyruvate → **Acetaldehyde + CO_2**

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Ligases

Enzymes catalyse the **linking together of two compounds** are called ligases.

DNA Ligase

Plasmid + Insert → **Recombinant DNA**

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God Bless You!