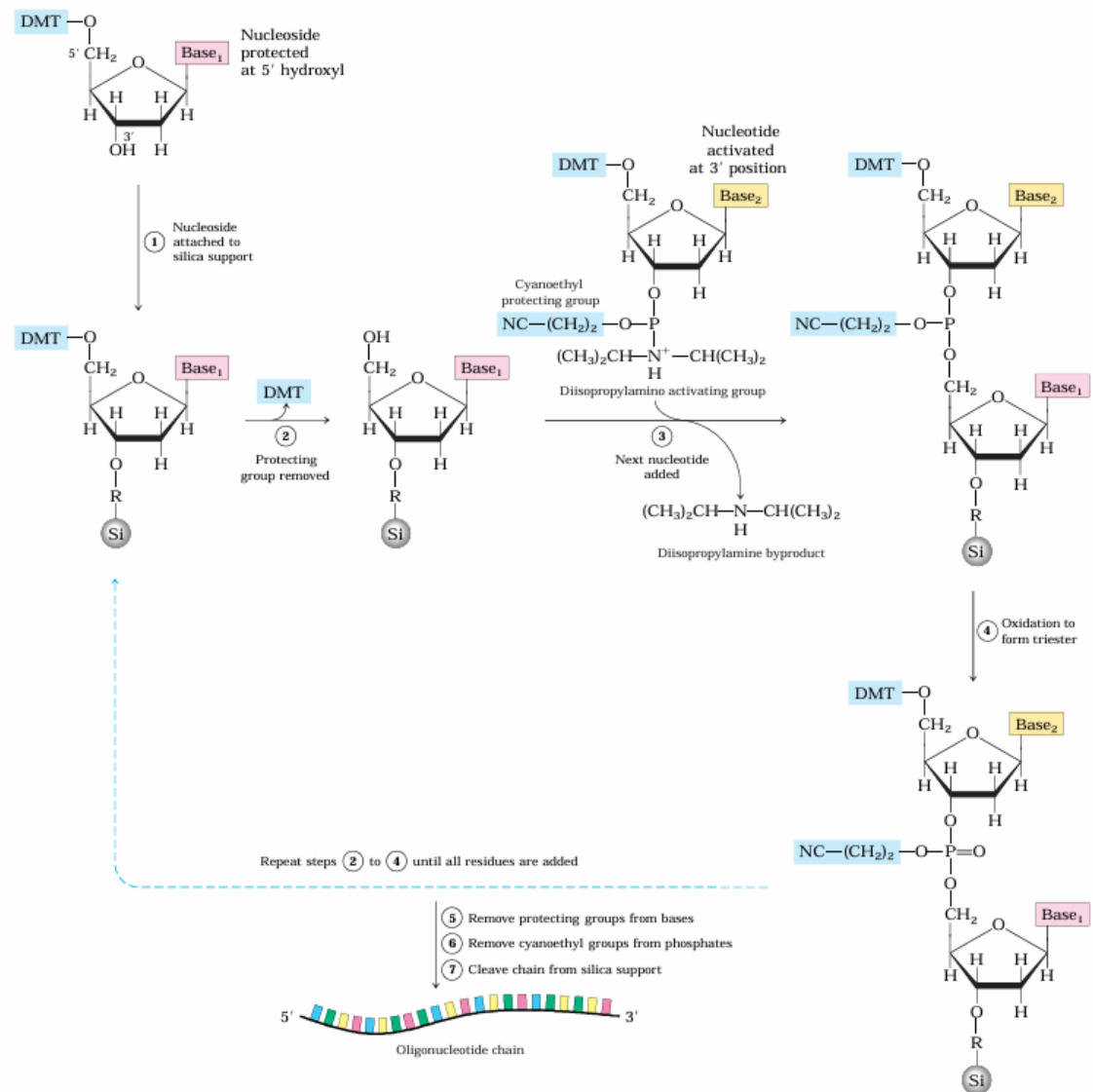




Comparison of A, B, and Z forms of DNA

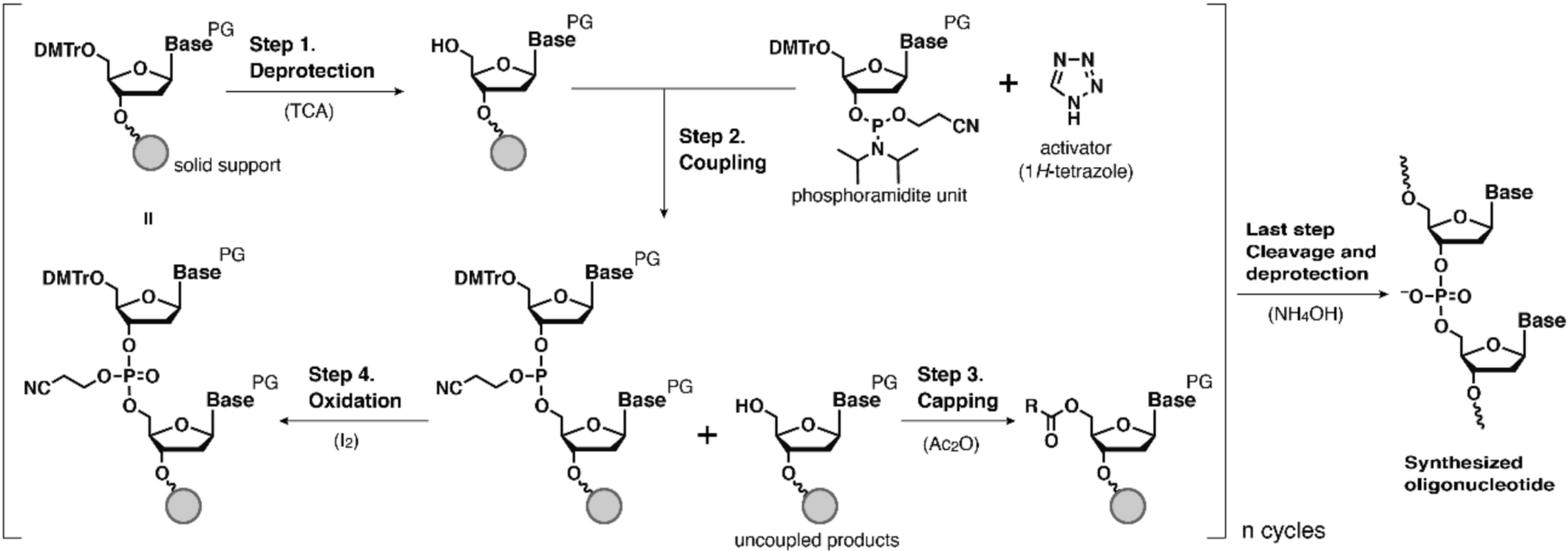
	<i>A form</i>	<i>B form</i>	<i>Z form</i>
Helical sense	Right handed	Right handed	Left handed
Diameter	~26 Å	~20 Å	~18 Å
Base pairs per helical turn	11	10.5	12
Helix rise per base pair	2.6 Å	3.4 Å	3.7 Å
Base tilt normal to the helix axis	20°	6°	7°
Sugar pucker conformation	C-3' endo	C-2' endo	C-2' endo for pyrimidines; C-3' endo for purines
Glycosyl bond conformation	Anti	Anti	Anti for pyrimidines; syn for purines

Chemical synthesis of DNA



Chemical synthesis of DNA is an automated, stepwise process similar to solid-phase peptide synthesis. The DNA strand is built one nucleotide at a time on a solid silica support, starting from the 3' end, using chemically protected nucleotides. The cycle involves removing protecting groups, adding activated nucleotides, forming phosphodiester bonds, and finally deprotecting and releasing the oligonucleotide. Each step ensures precise addition of bases, and the process is monitored (e.g., via colored DMT group). RNA synthesis is more complex due to the need to protect the 2'-hydroxyl group on ribose.

Chemical synthesis of DNA



Introduction to Lipids

Lipids are the organic compounds insoluble in water but soluble in nonpolar organic solvents

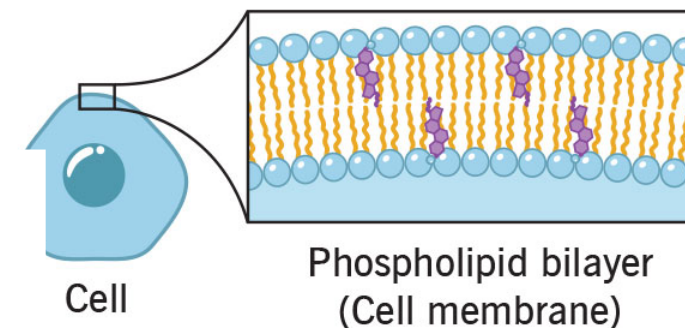
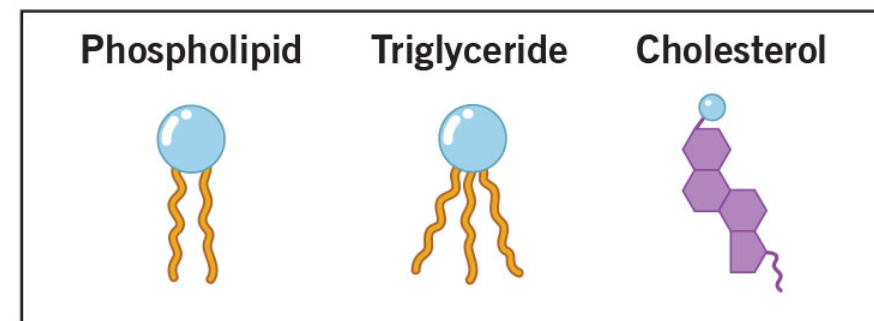
Examples: fats, oils, waxes, steroids, phospholipids

They are found in all living cells, essential for structure and energy

General Properties of Lipids

- Nonpolar or amphipathic nature.
- High energy content: 1g of fat = ~9 kcal.
- Do not form polymers like proteins or carbohydrates.
- Can form micelles, bilayers, and vesicles in aqueous environments.

Lipids

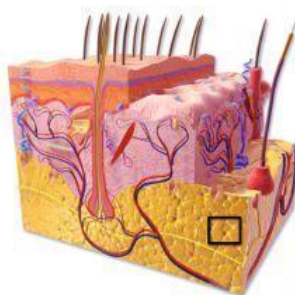


Introduction to Lipids

Biological Functions

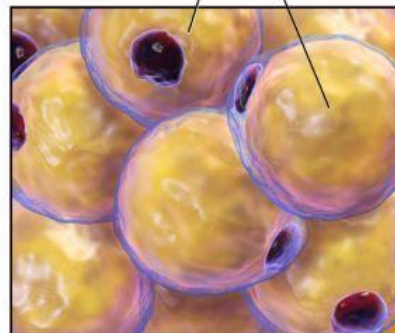
- Energy storage: Triglycerides in adipose tissue.
- Structural role: Lipid bilayer of cell membranes.
- Insulation: Thermal protection (blubber in whales).
- Signaling: Steroid hormones, prostaglandins.
- Vitamin transport: Fat-soluble vitamins (A, D, E, K).

Functions of Lipids

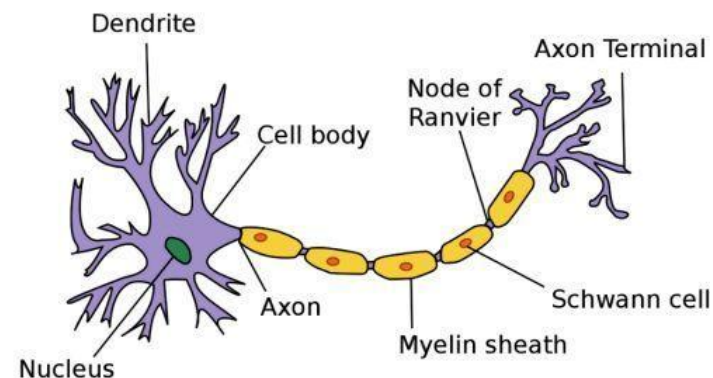
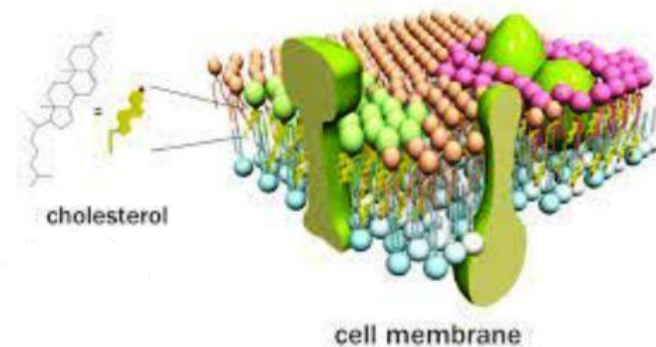


Adipose Tissue

Adipocytes
(white adipose cells)

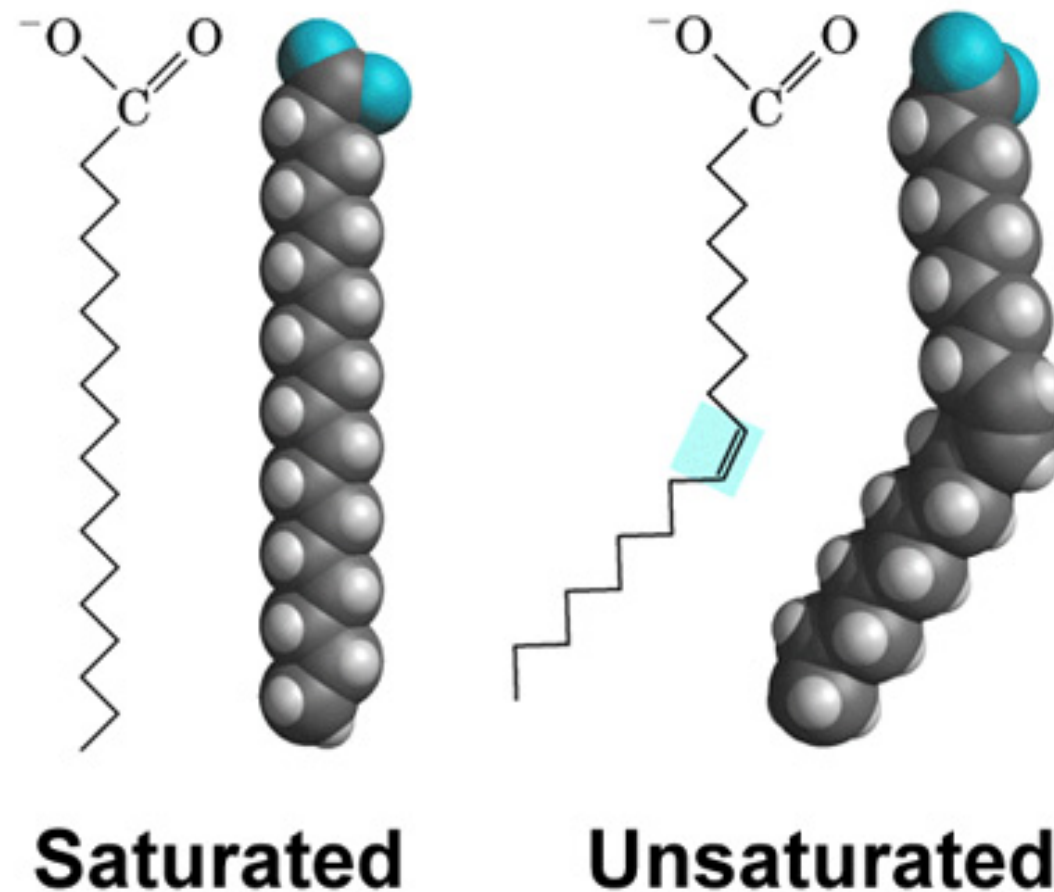


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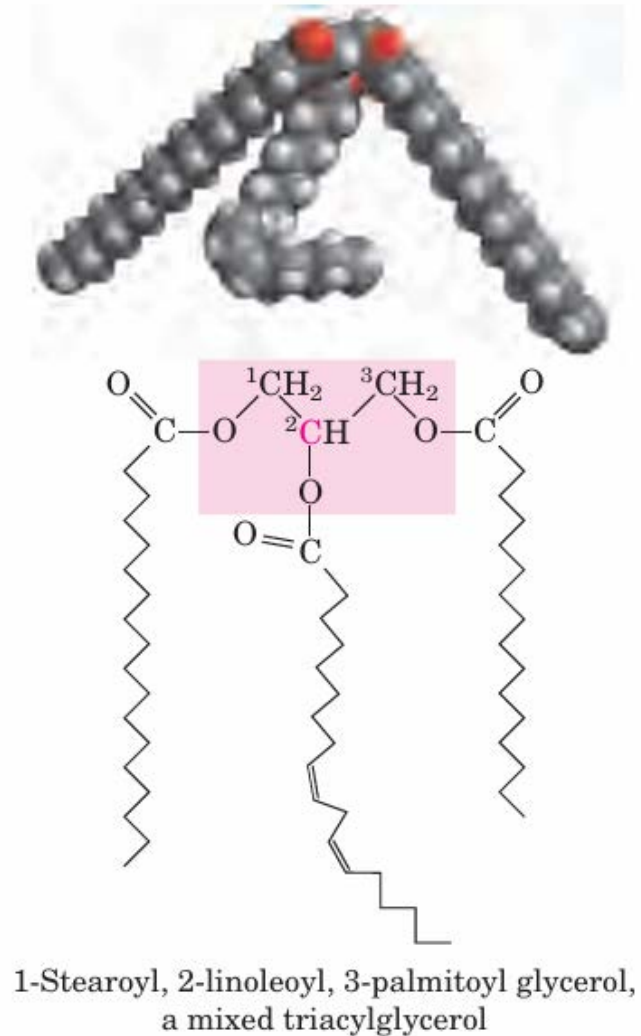
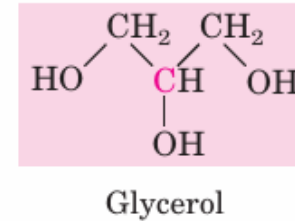
Fatty Acids: The Building Blocks

- Long hydrocarbon chains with a terminal carboxyl ($-\text{COOH}$) group.
- **Saturated fatty acids:** No double bonds; solid at room temp.
- **Unsaturated fatty acids:** One or more double bonds; liquid at room temp.
- **Essential fatty acids:** Must be taken through diet (e.g., linoleic acid).



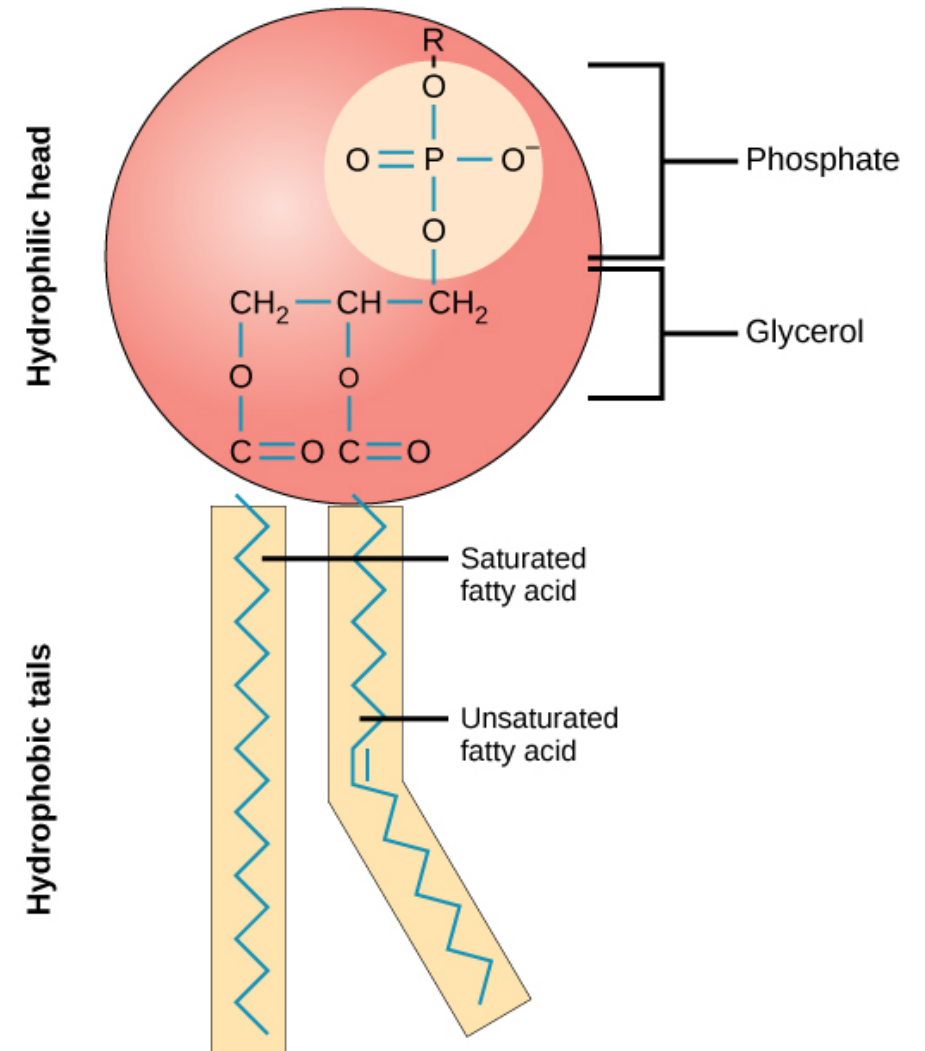
Triacylglycerols

- The simplest lipids constructed from fatty acids are the **triacylglycerols**, also referred to as triglycerides, fats, or neutral fats.
- The mixed triacylglycerol shown here has three different fatty acids attached to the glycerol backbone. When glycerol has two different fatty acids at C-1 and C-3, the C-2 is a chiral center.
- Primary energy storage molecule in animals.
- Stored in adipose tissue and broken down during fasting.



Phospholipids

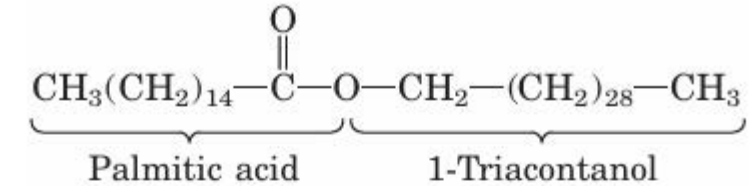
- Glycerol backbone + 2 fatty acids + phosphate group + head group (e.g., choline).
- Amphipathic nature: Hydrophilic head, hydrophobic tails.
- A major component of cell membranes.
- Form lipid bilayers in aqueous environments.



Waxes

Biological wax.

(a) Triacontanoylpalmitate, the major component of beeswax, is an ester of palmitic acid with the alcohol triacontanol.



(a)

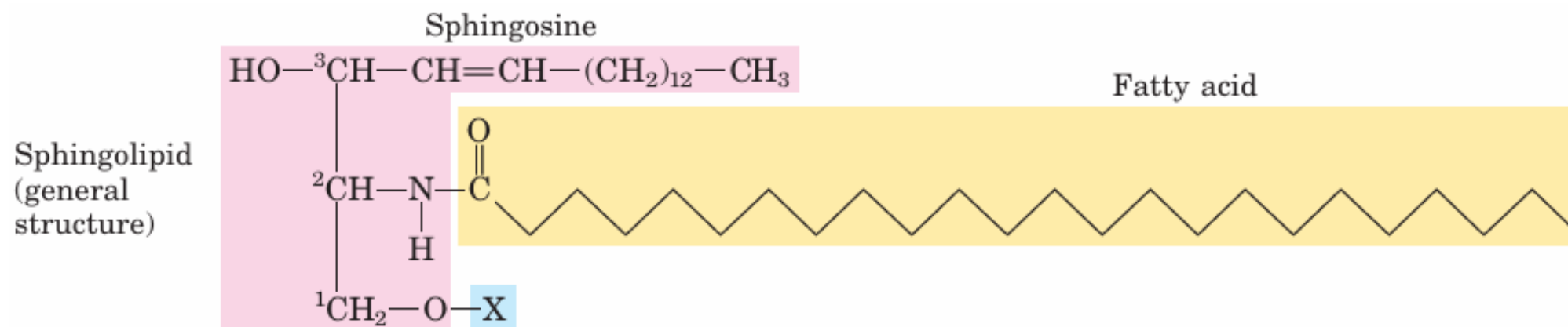
(b) A honeycomb, constructed of beeswax, is firm at 25 °C and completely impervious to water. The term “wax” originates in the Old English weax, meaning “the material of the honeycomb.”



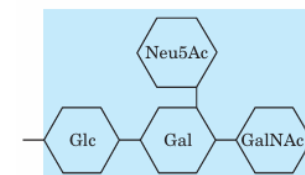
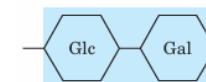
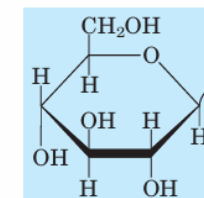
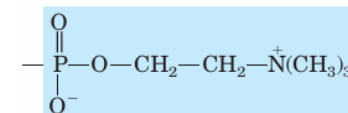
(b)

Sphingolipids

- Based on **sphingosine** (instead of glycerol).
- Important in nerve cell membranes (e.g., **sphingomyelin**).
- Some are glycolipids (contain sugar groups).
- Involved in cell signaling and recognition.

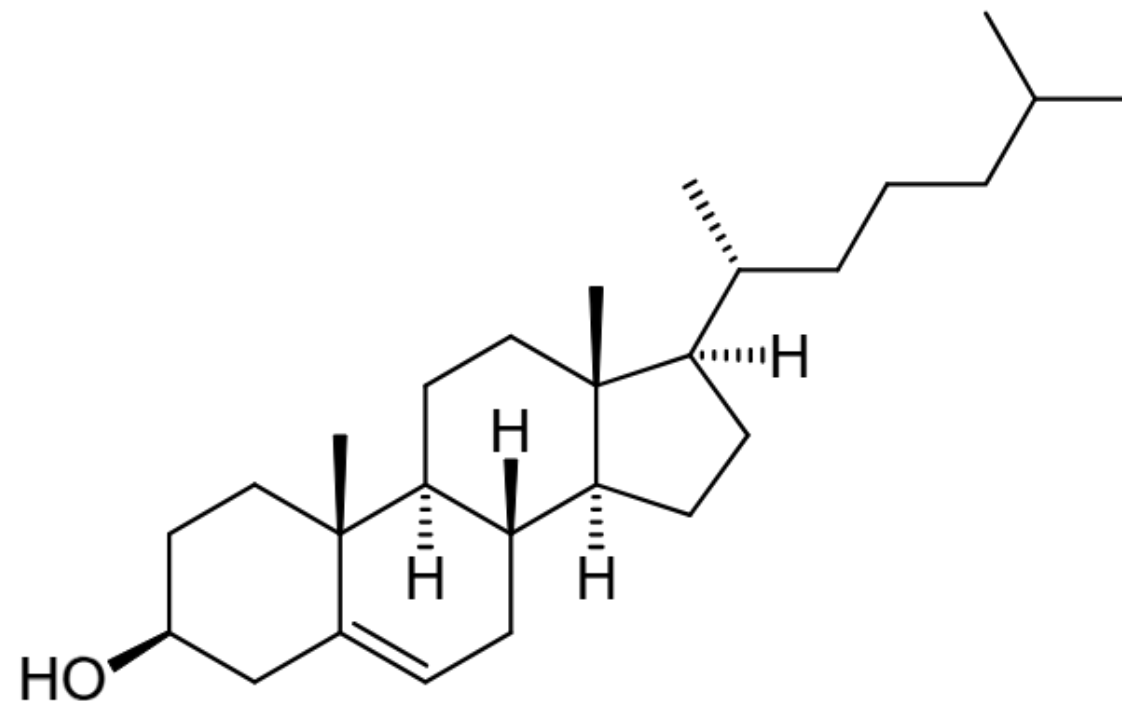
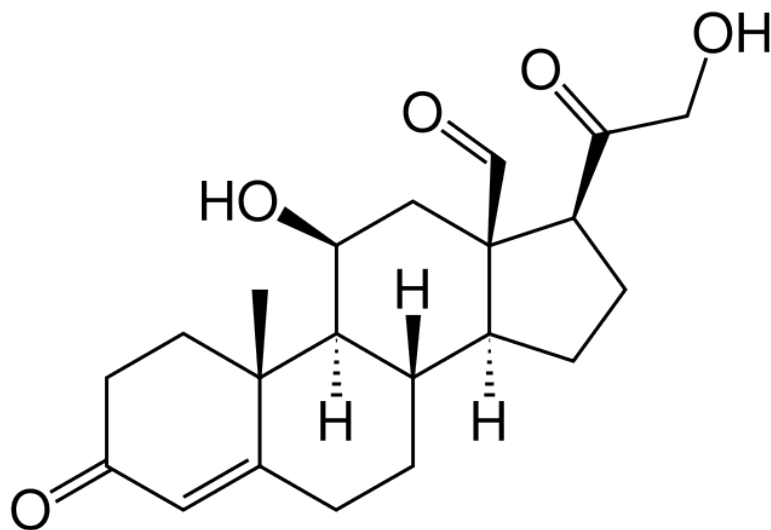


Formula of X



Steroids and Cholesterol

- Steroids: Four fused carbon rings.
- Cholesterol: The Most common steroid in animals.
- Precursor for bile acids, vitamin D, and steroid hormones (e.g., cortisol, testosterone).
- Regulates membrane fluidity.



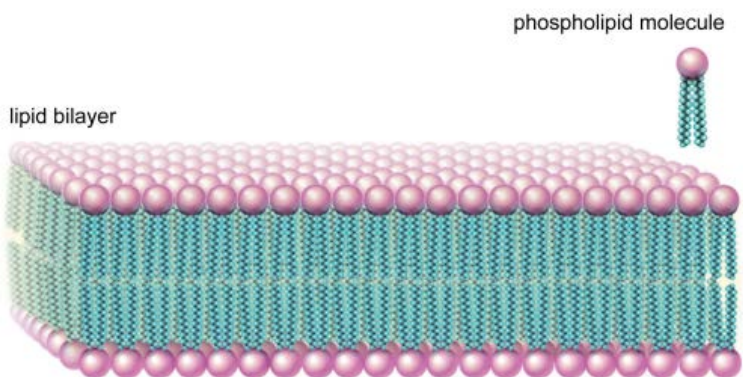
Cholesterol



Classification of Lipids

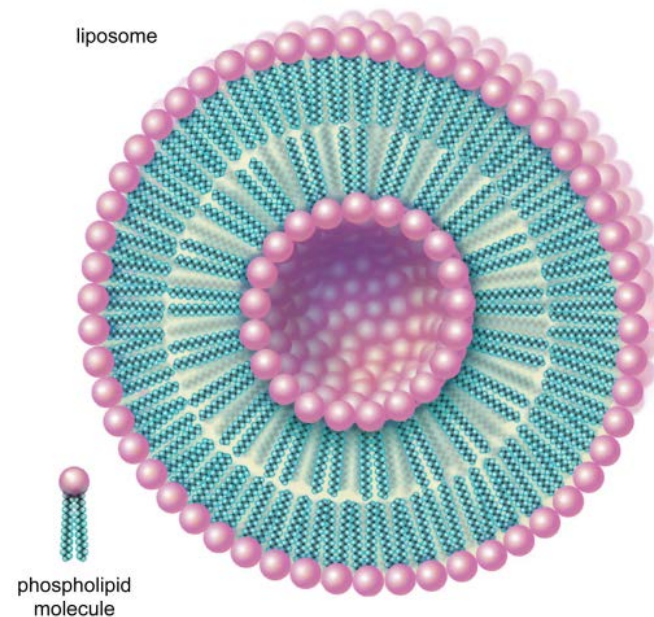
Type	Example	Function
Triglyceride	Fats/Oils	Energy storage
Phospholipid	Phosphatidylcholine	Membrane structure
Steroid	Cholesterol	Hormone precursor
Glycolipid	Cerebroside	Cell recognition
Waxes	Beeswax	Water repellent coating

Biological Membrane Lipids



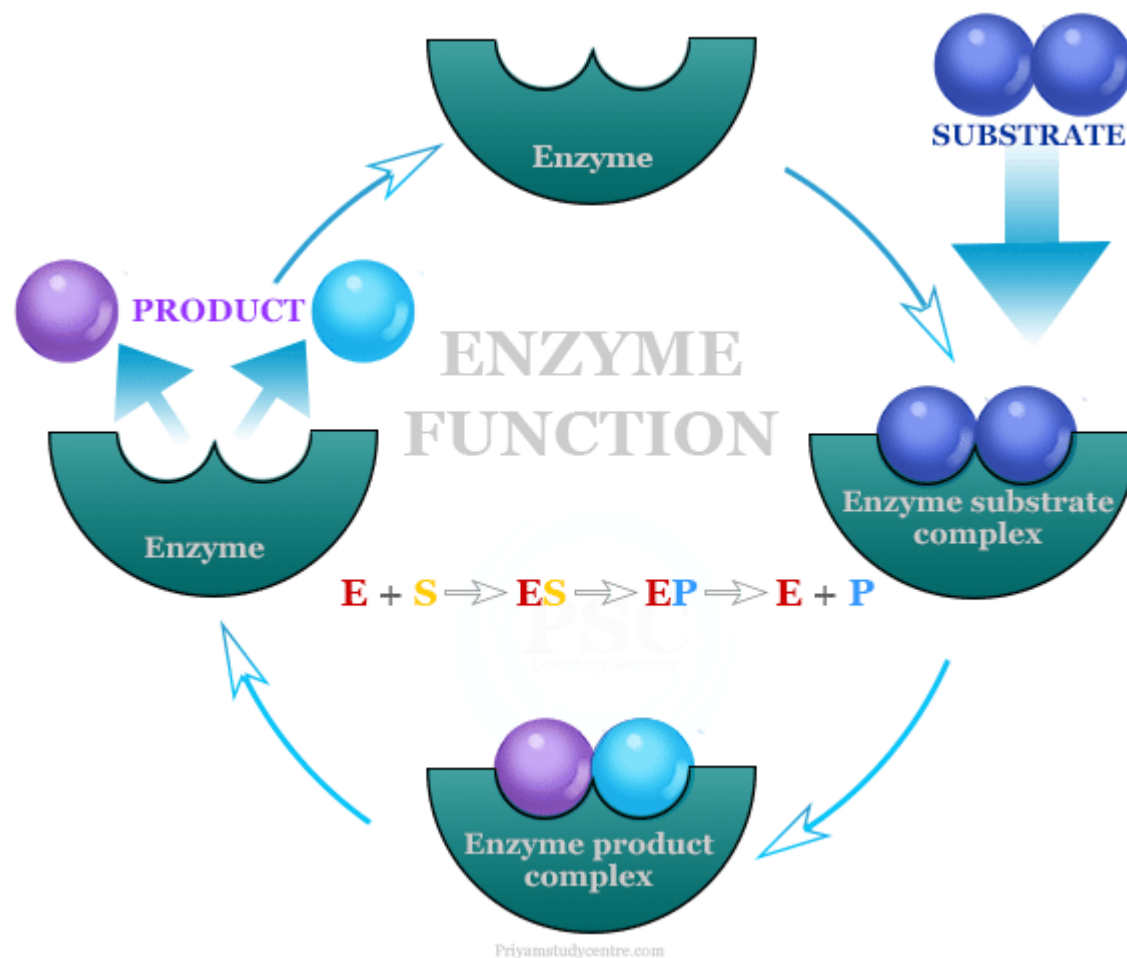
Lipid bilayer; cell membrane Phospholipid molecules, like molecules of many lipids, are composed of a hydrophilic “head” and one or more hydrophobic “tails.” In a water medium, the molecules form a lipid bilayer, or two-layered sheet, in which the heads are turned toward the watery medium and the tails are sheltered inside, away from the water. This bilayer is the basis of the membranes of living cells

Liposome; Phospholipids can be used to form artificial structures called liposomes, which are double-walled hollow spheres useful for encapsulating other molecules such as pharmaceutical drugs.



Enzymes: Biological Catalysts of Life

- Enzymes are biological macromolecules (**mostly proteins**) that catalyze biochemical reactions.
- Increase reaction rate without being consumed.
- Operate under mild conditions.
- Highly specific for substrate(s)
- Structure: Primary to quaternary structure (protein nature)
- Enzymes, like other proteins, have molecular weights ranging from about 12,000 to more than 1 million



Cofactor and Coenzyme

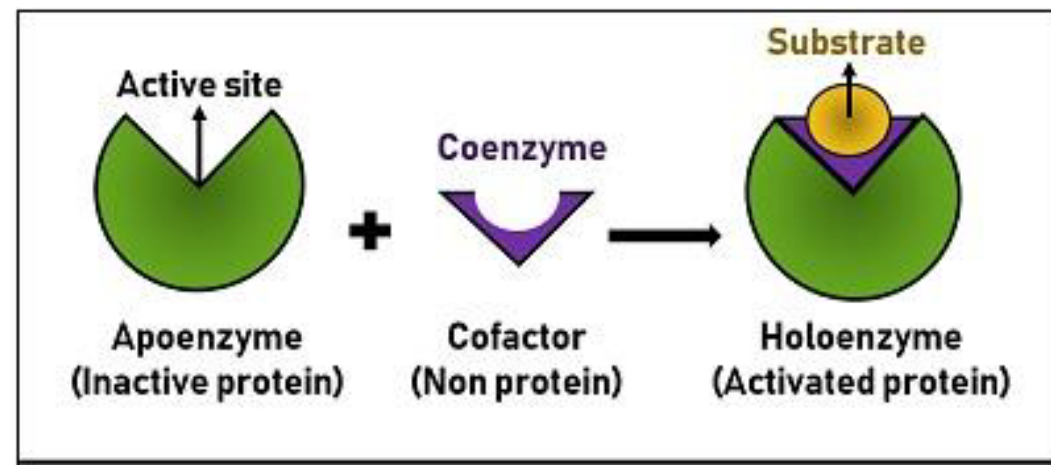
Cofactor is a non-protein chemical compound or metallic ion that is required for the biological activity of an enzyme. It helps the enzyme to function properly, often by stabilizing its structure or participating directly in the chemical reaction.

Types of Cofactors:

1. **Inorganic Cofactors:** Zn^{2+} (zinc), Mg^{2+} (magnesium), $\text{Fe}^{2+}/\text{Fe}^{3+}$ (iron), Cu^{2+} (copper), etc. Example: Carbonic anhydrase requires Zn^{2+} .
2. **Organic Cofactors (Coenzymes):** NAD^+ (from vitamin B3), FAD (from vitamin B2), Coenzyme A (from vitamin B5)

Apoenzyme: the inactive enzyme without its cofactor.

Holoenzyme: the active enzyme with its cofactor bound.

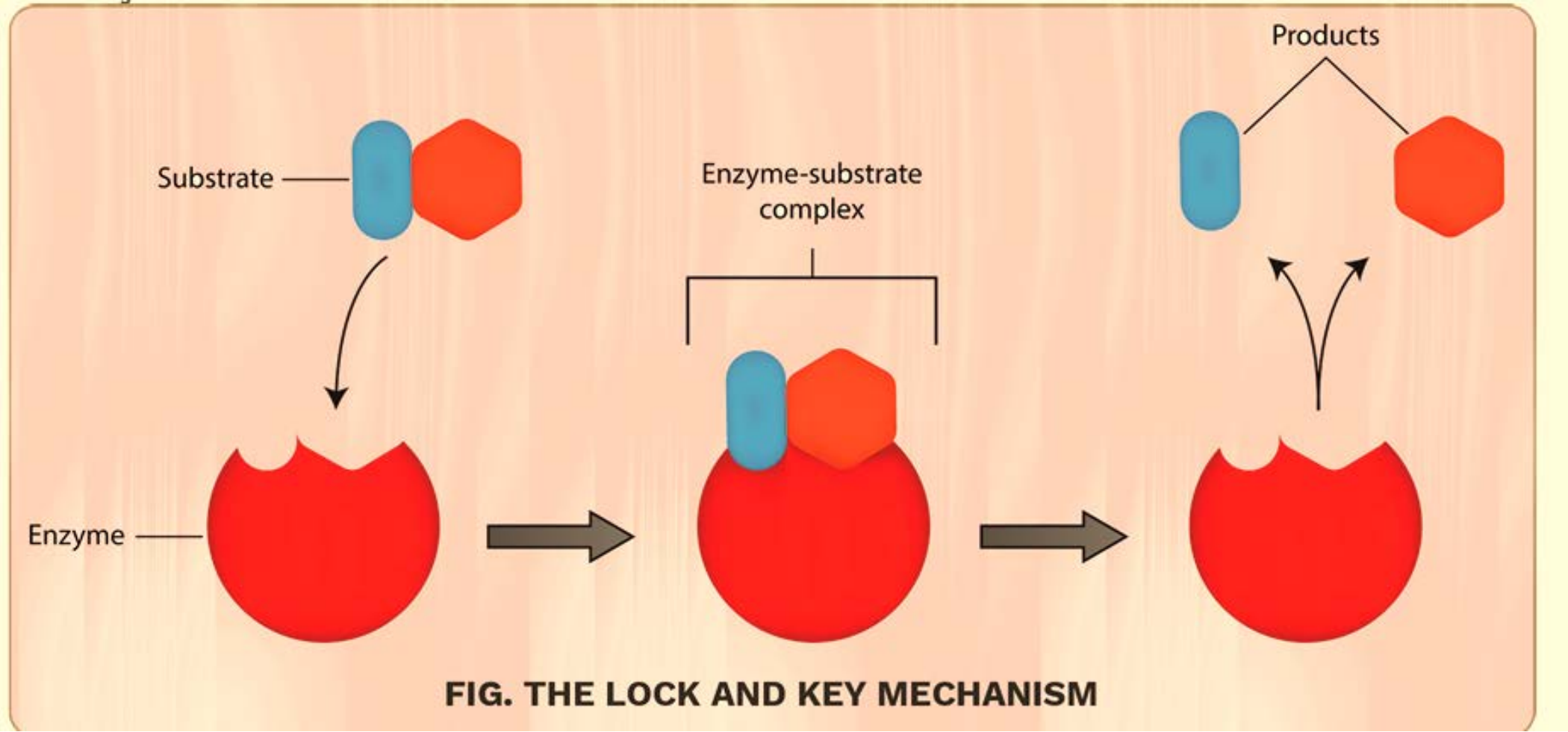




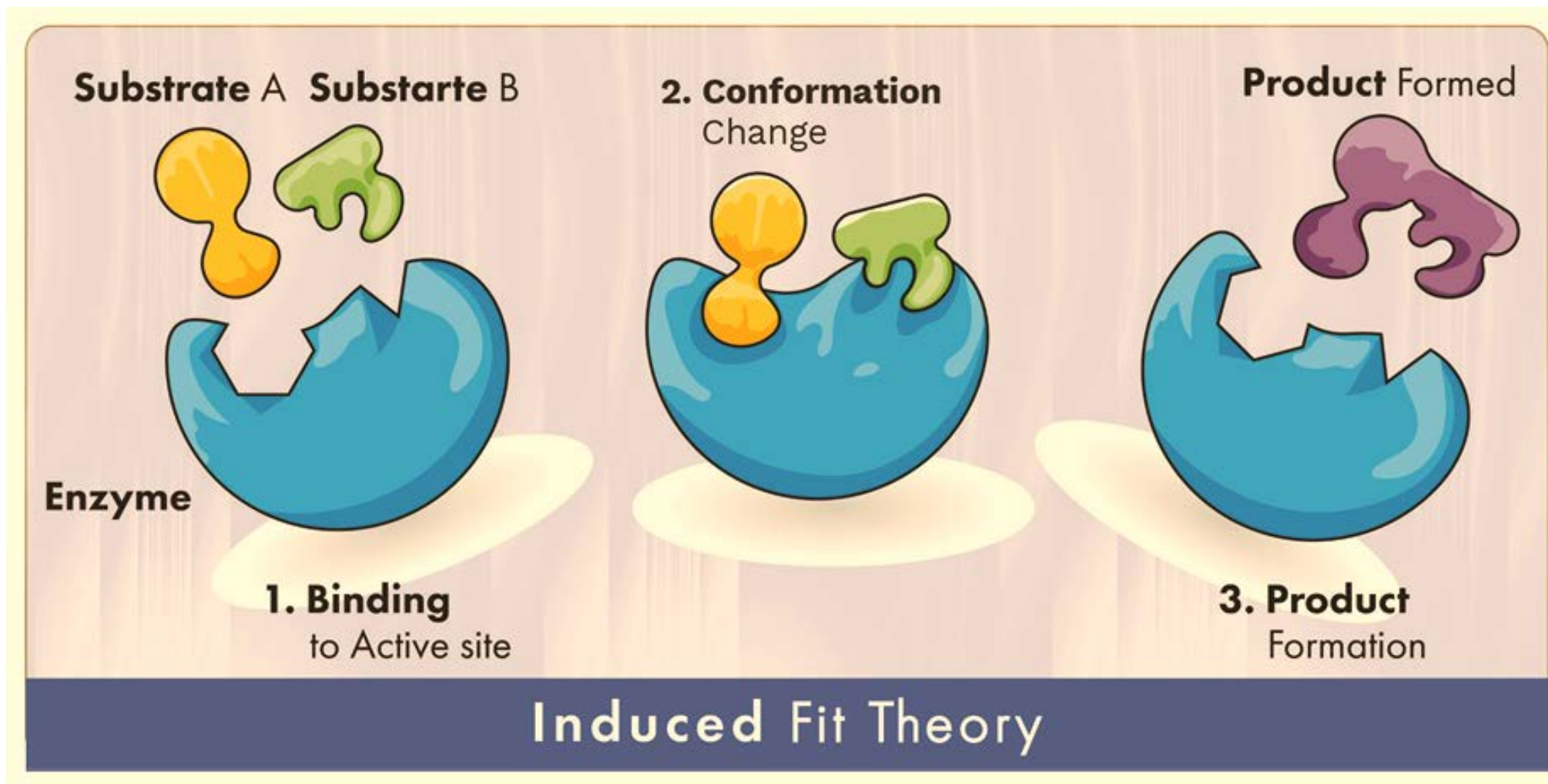
International Classification of Enzymes

<i>No.</i>	<i>Class</i>	<i>Type of reaction catalyzed</i>
1	Oxidoreductases	Transfer of electrons (hydride ions or H atoms)
2	Transferases	Group transfer reactions
3	Hydrolases	Hydrolysis reactions (transfer of functional groups to water)
4	Lyases	Addition of groups to double bonds, or formation of double bonds by removal of groups
5	Isomerases	Transfer of groups within molecules to yield isomeric forms
6	Ligases	Formation of C—C, C—S, C—O, and C—N bonds by condensation reactions coupled to ATP cleavage

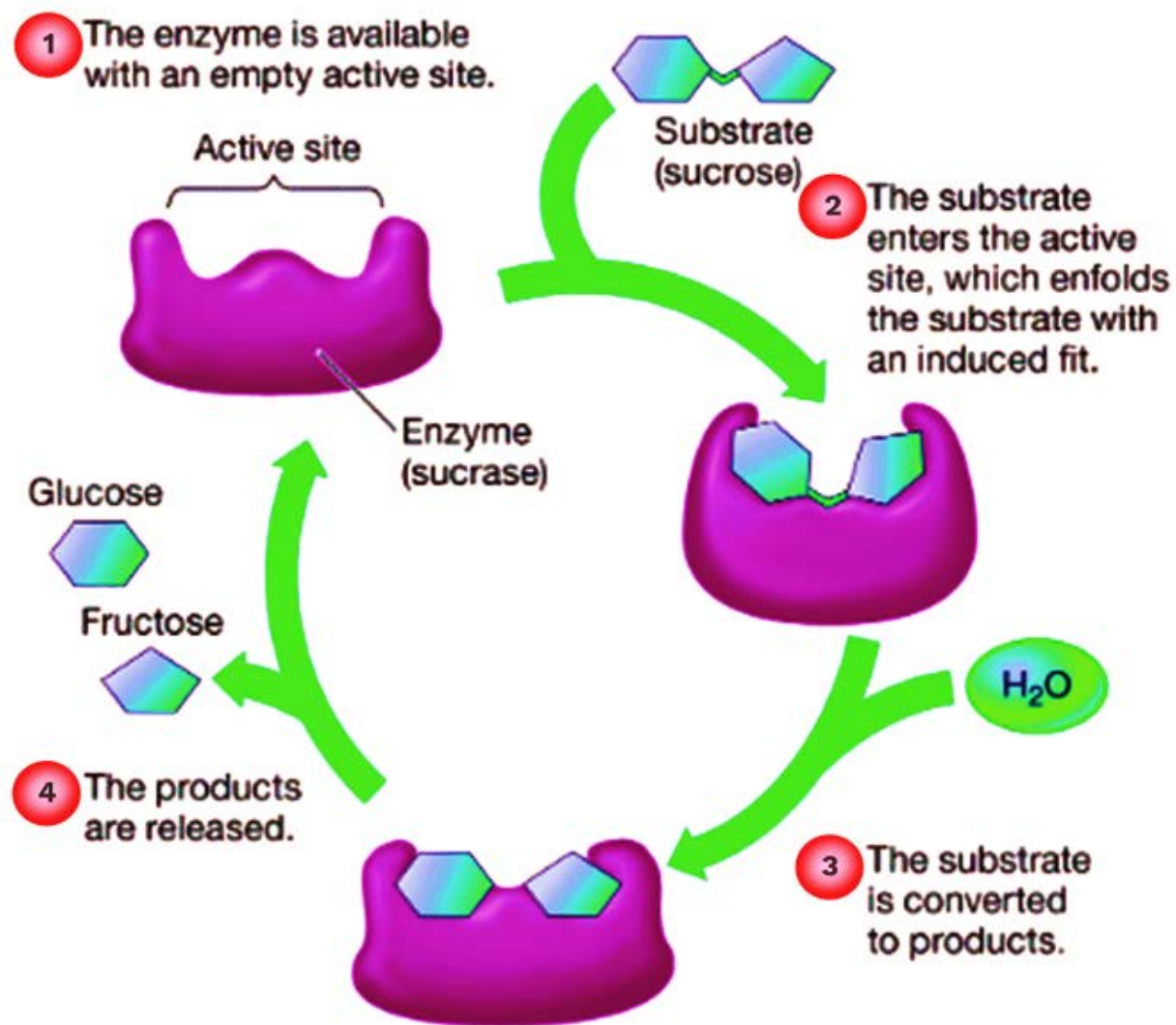
Mechanism of Enzymatic Reactions



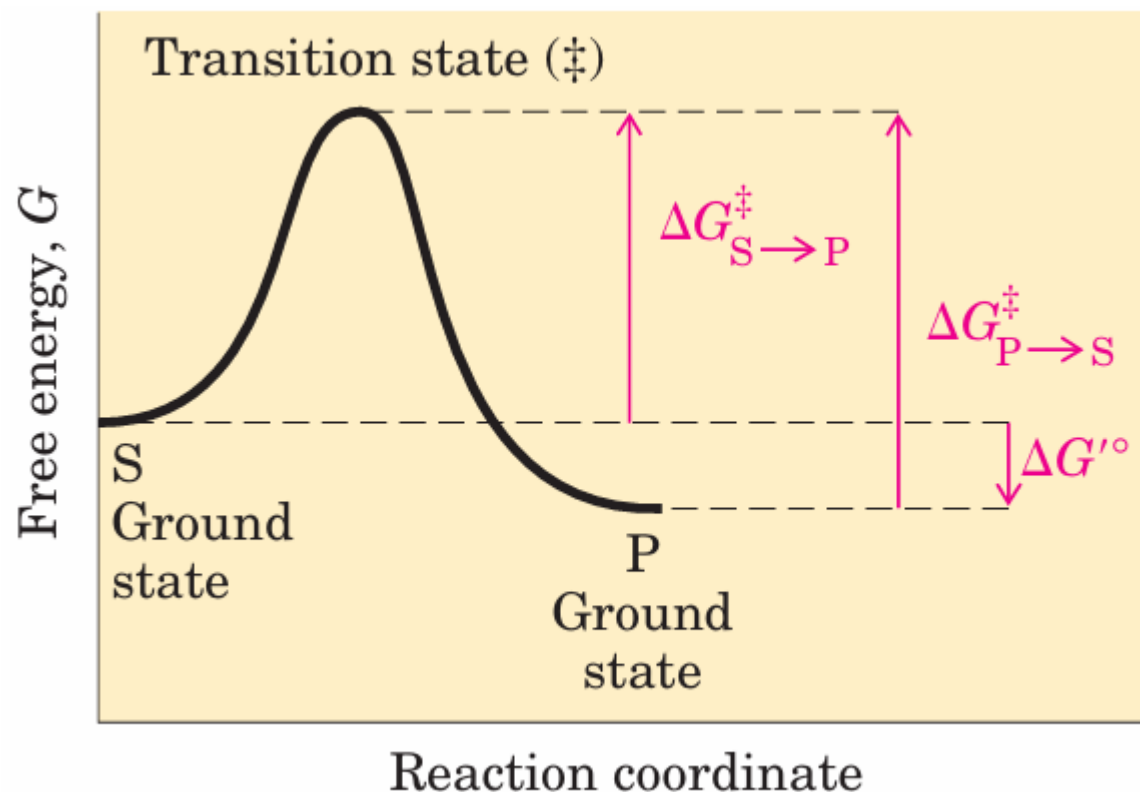
Mechanism of Enzymatic Reactions



Catalytic Cycle of Enzymatic Reactions



Reaction Coordinate Diagram for a Chemical Reaction

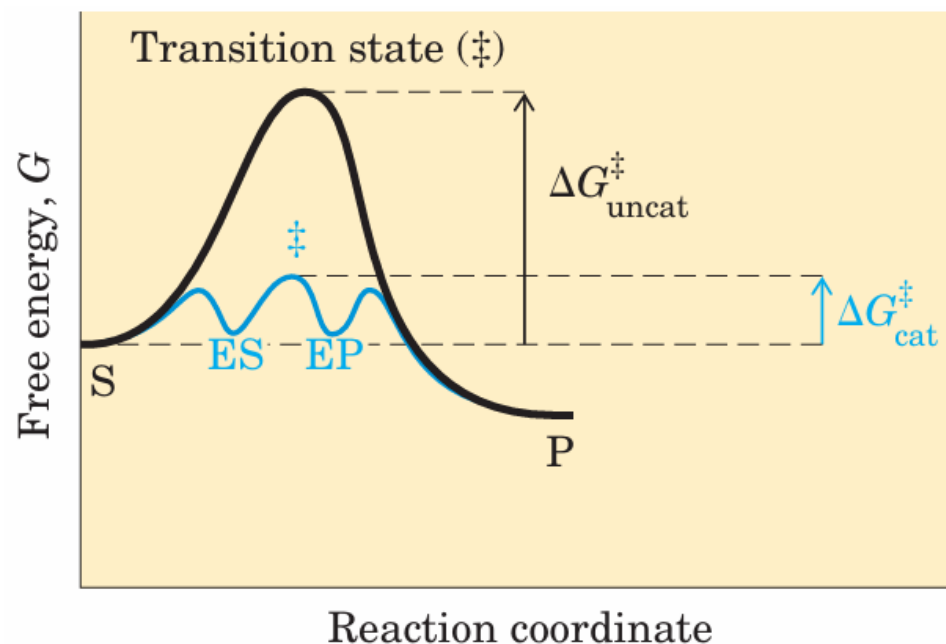


The free energy of the system is plotted against the progress of the reaction $S \rightarrow P$. A diagram of this kind is a description of the energy changes during the reaction, and the horizontal axis (**reaction coordinate**) reflects the progressive chemical changes (e.g., bond breakage or formation) as S is converted to P . The activation energies, G^{\ddagger} , for the $S \rightarrow P$ and $P \rightarrow S$ reactions are indicated. G is the overall **standard free-energy change** in the direction $S \rightarrow P$.

Enzymatic Reaction



where **E**, **S**, and **P** represent the enzyme, substrate, and product; **ES** and **EP** are transient complexes of the enzyme with the substrate and with the product.



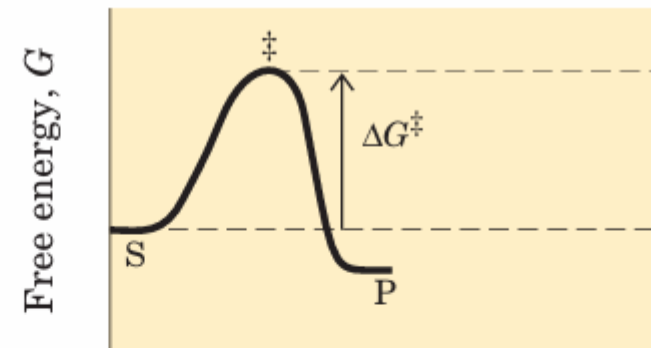
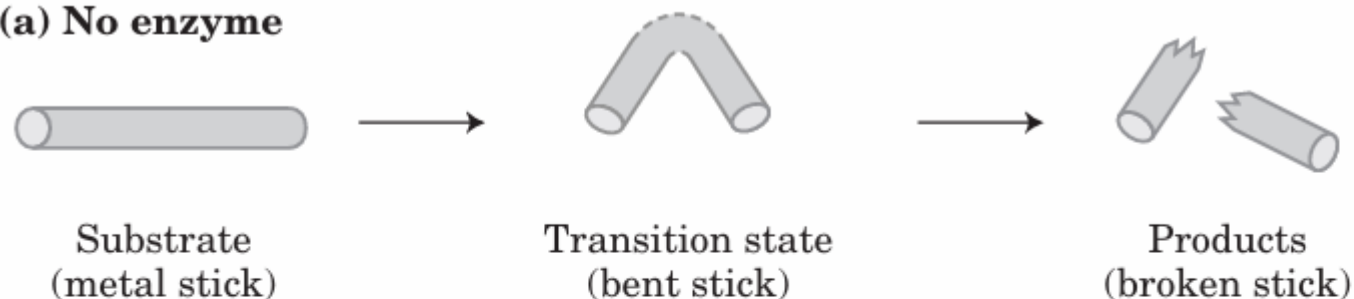
Reaction coordinate diagram comparing enzymecatalyzed and uncatalyzed reactions.

In the reaction **S** \rightarrow **P**, the **ES** and **EP** intermediates occupy minima in the energy profile of the enzyme-catalyzed reaction. The terms **G \ddagger _{uncat}** and **G \ddagger _{cat}** correspond to the activation energy for the uncatalyzed reaction and the overall activation energy for the catalyzed reaction, respectively. The activation energy is lower when the enzyme catalyzes the reaction.

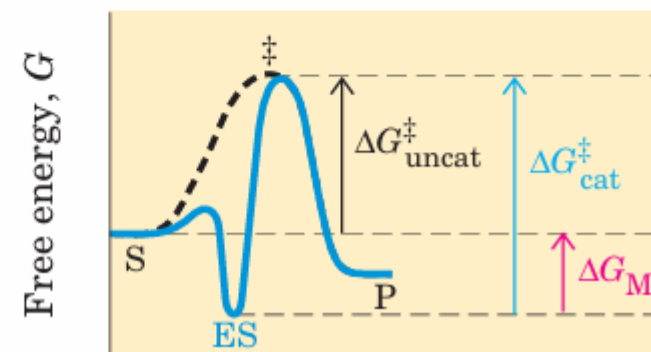
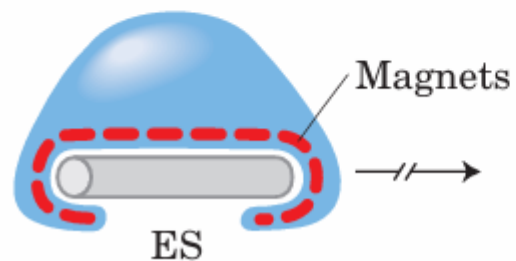


An Imaginary Enzyme (Stickase) Designed to Catalyze Breakage of a Metal Stick.

(a) No enzyme



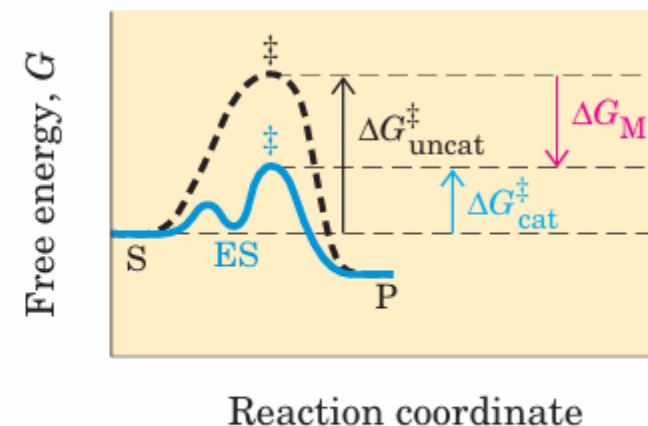
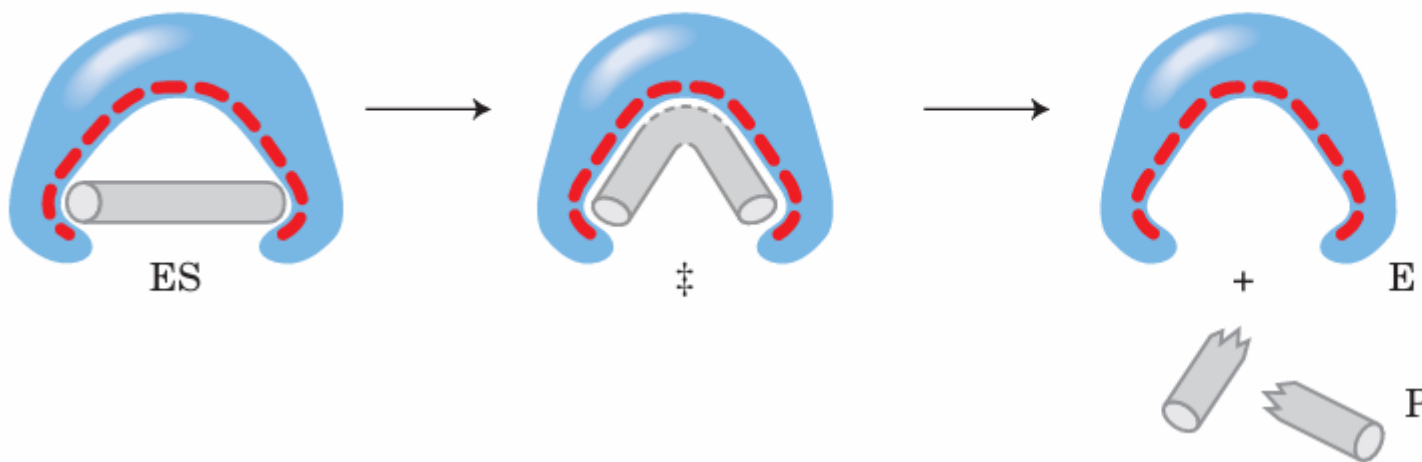
(b) Enzyme complementary to substrate



(a) Before the stick is broken, it must first be bent (**the transition state**). In both stickase examples, magnetic interactions take the place of weak bonding interactions between the enzyme and substrate. (b) A stickase with a magnet-lined pocket complementary in structure to the stick (the substrate) stabilizes the substrate. Bending is impeded by the magnetic attraction between the stick and the stickase.

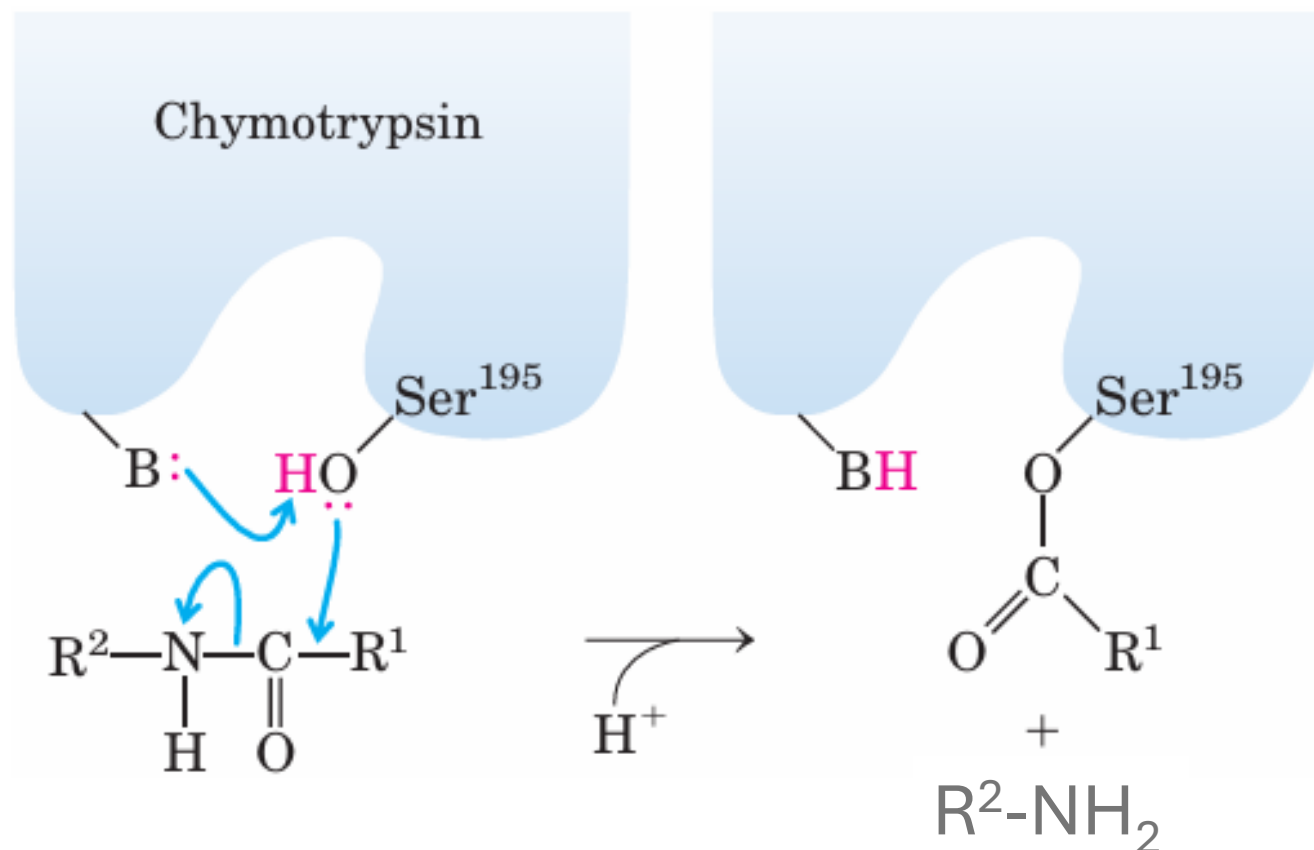
An Imaginary Enzyme (Stickase) Designed to Catalyze Breakage of a Metal Stick.

(c) Enzyme complementary to transition state



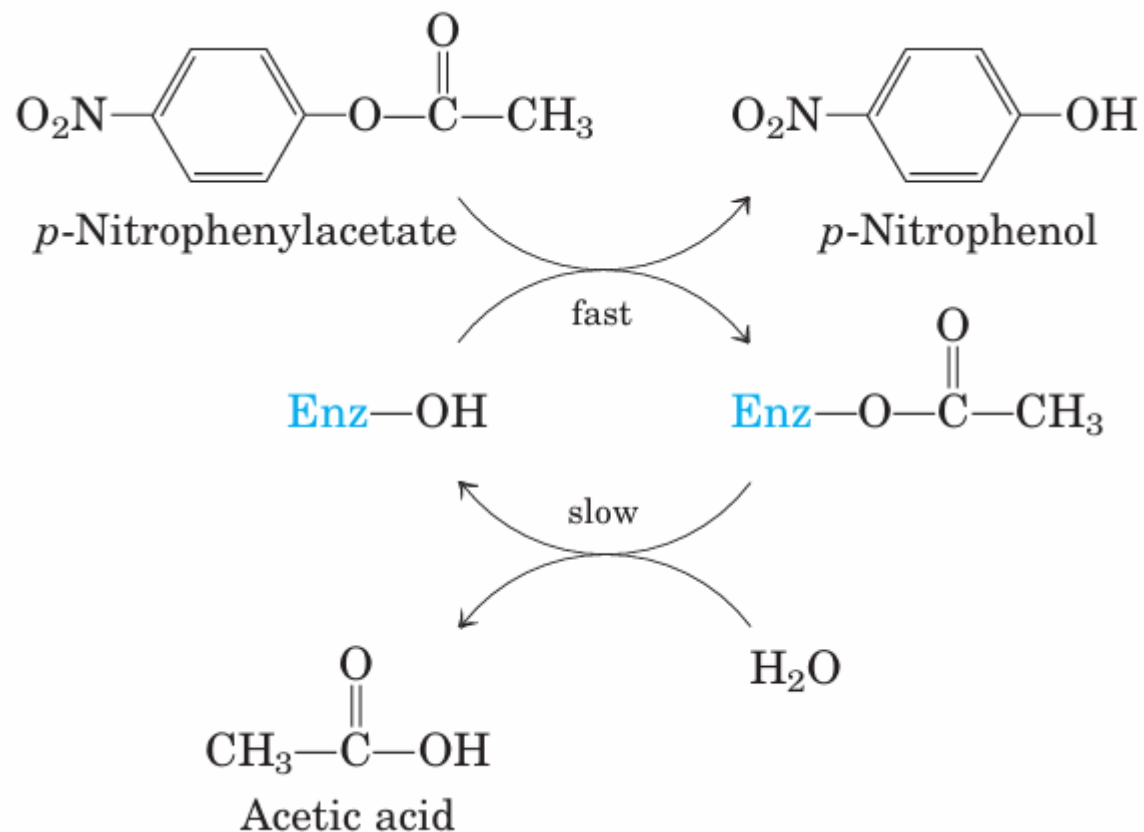
(c) An enzyme with a pocket complementary to the reaction transition state helps to destabilize the stick, contributing to catalysis of the reaction. The binding energy of the magnetic interactions compensates for the increase in free energy required to bend the stick. Reaction coordinate diagrams (right) show the energy consequences of complementarity to substrate versus complementarity to the transition state (EP complexes are omitted). ΔG_M , the difference between the transition-state energies of the uncatalyzed and catalyzed reactions is attributed to the magnetic interactions between the stick and the stickase. When the enzyme is complementary to the substrate (b), the ES complex is more stable and has less free energy in the ground state than the substrate alone. The result is an increase in the activation energy.

Covalent and General Acid-Base Catalysis.



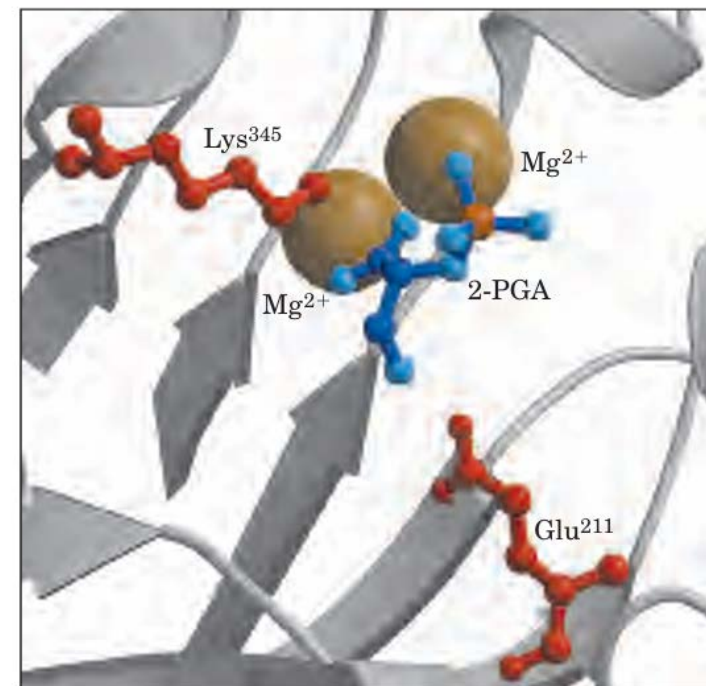
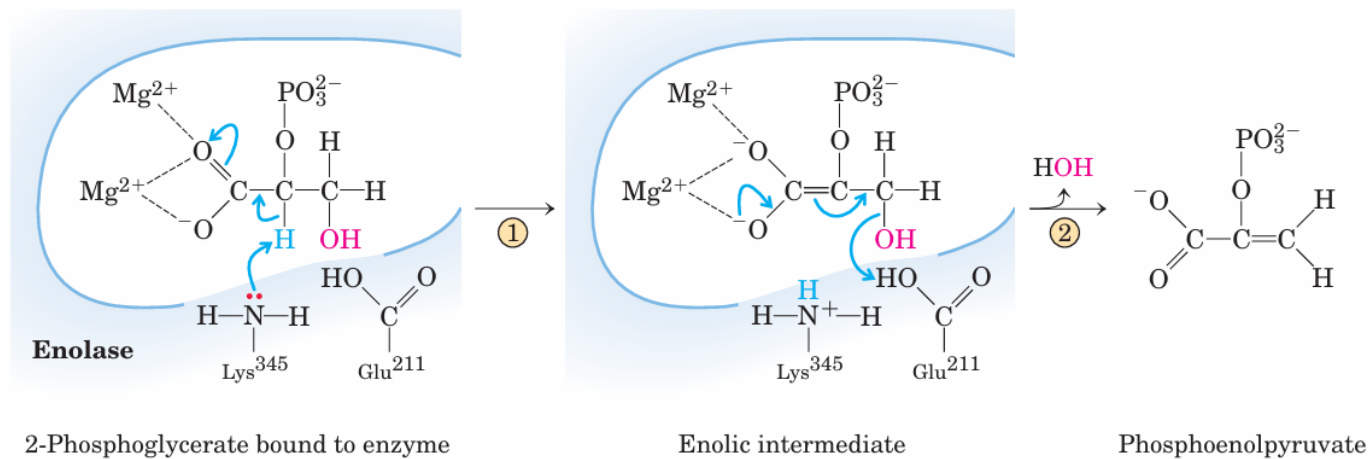
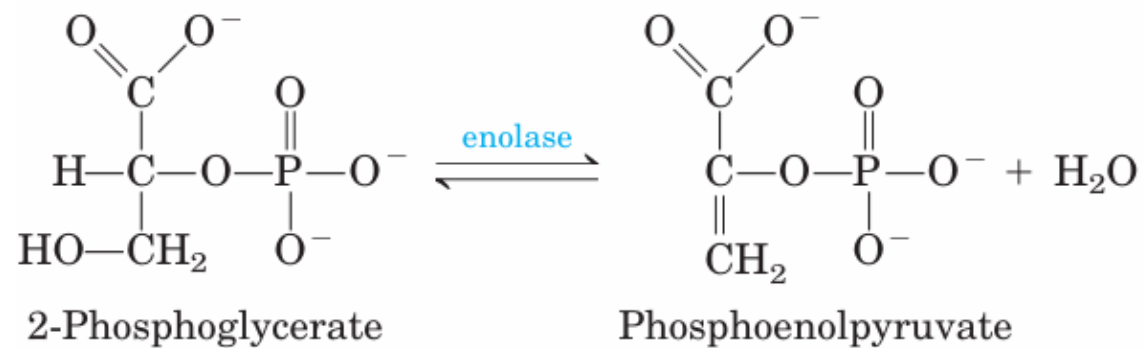
The first step in the reaction catalyzed by **chymotrypsin** is the acylation step. The hydroxyl group of **Ser195** is the nucleophile in a reaction aided by general base catalysis (the base is the side chain of **His57**). This provides a new pathway for the hydrolytic cleavage of a peptide bond. Catalysis occurs only if each step in the new pathway is faster than the uncatalyzed reaction.

hydrolysis of *p*-nitrophenylacetate



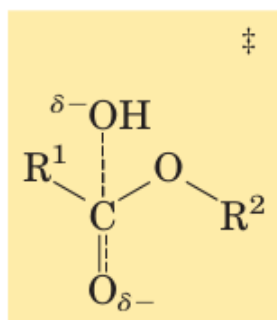
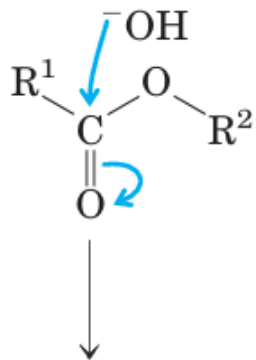
The hydrolysis of *p*-nitrophenylacetate by chymotrypsin is measured by the release of *p*-nitrophenol (a colored product). Initially, the reaction releases a rapid burst of *p*-nitrophenol nearly stoichiometric with the amount of enzyme present. This reflects the fast acylation phase of the reaction. The subsequent rate is slower, because enzyme turnover is limited by the rate of the slower deacylation phase.

Enolase Reaction



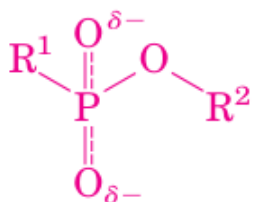
Hydrolysis Reaction

Ester hydrolysis



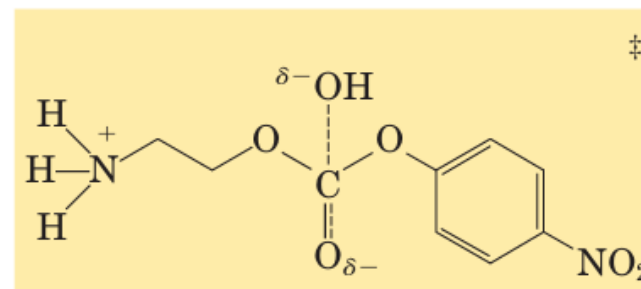
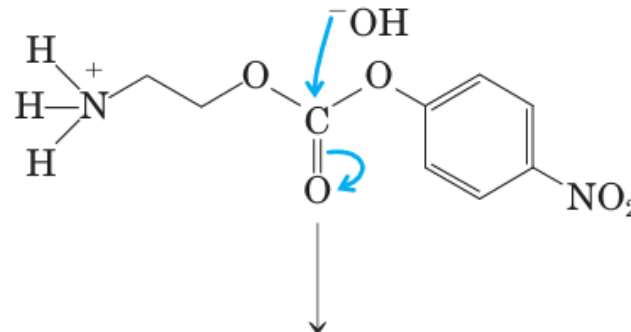
Transition state

Several steps → Products



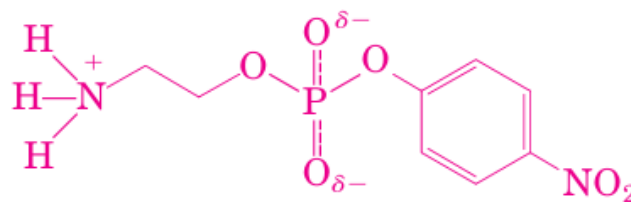
Analog (phosphonate ester)

Carbonate hydrolysis



Transition state

Several steps → Products



Analog (phosphate ester)

Vitamins

- The word vitamin was originally derived from the term "**vital amine.**"
- They are **micronutrients.**
- The body is unable to synthesize them, and therefore, they should be provided from outside

Classification:

- **Fat-soluble:** vitamin A, D, E, K
- **Water-soluble:** Vitamins of the B group and Vitamin C

A:



B1:



B2:



B3:



B5:



B6:



B8:



B9:



B12:



C:



D



E:



K:



MEALPRO 

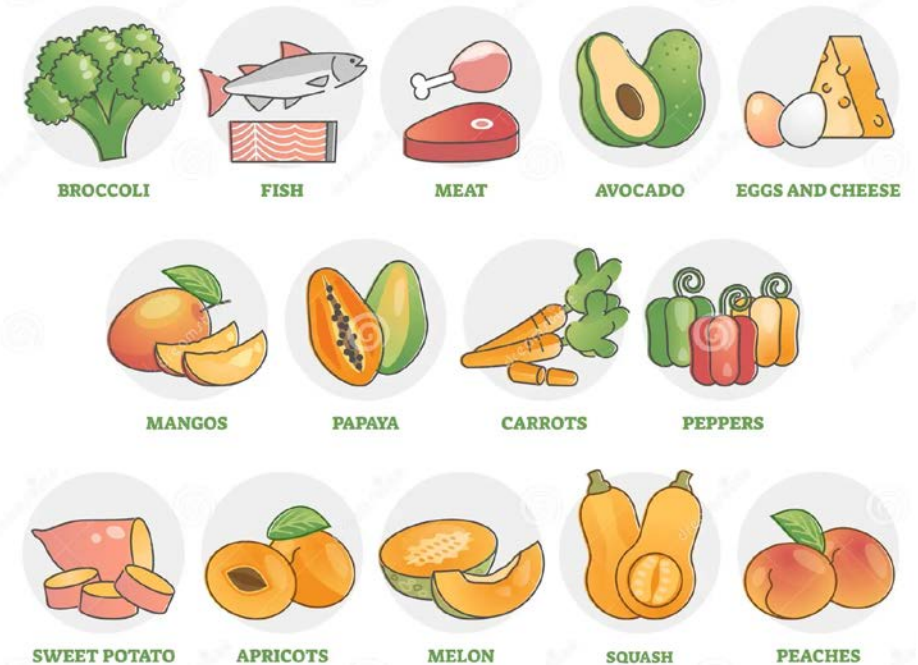
VITAMIN-A

It was the 1st fat-soluble vitamin to be discovered.

Sources

- **ANIMAL FOODS:** Liver, eggs, butter, cheese, whole milk, fish, and meat. (Richest natural source: fish liver oil).
- **PLANT FOODS:** Green leafy vegetables (cheapest source), most green and yellow fruits (papaya, mango, pumpkin), some roots (carrots).
- **FORTIFIED FOODS:** Foods fortified with vitamin A (vanaspati, milk, etc.)

SOURCES OF VITAMIN A



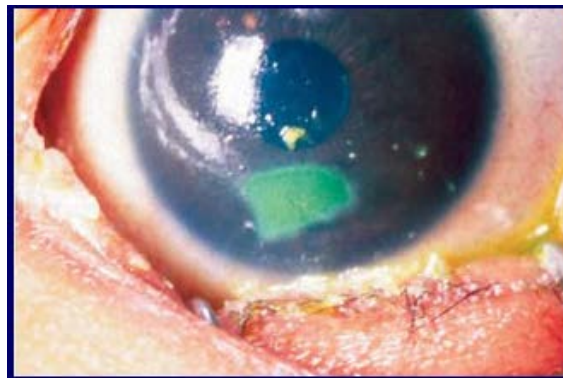
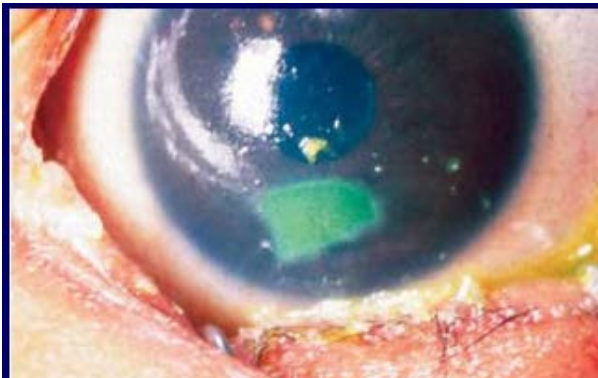
Functions

- **Vision:** indispensable for normal vision. Production of retinal pigments is needed for vision in dim light.
- **Cellular Differentiation.**
- Necessary for maintaining the integrity and normal functioning of glandular and epithelial tissue, which lines the intestinal, respiratory, urinary tracts, skin, and eyes.
- **Growth:** Supports skeletal growth (Bone development and remodeling).

VITAMIN-A: Deficiency

Corneal xerosis

- The cornea appears dull, dry, and non-wettable and eventually opaque.
- In a more severe deficiency, there may be corneal ulceration, which may heal, leaving a scar



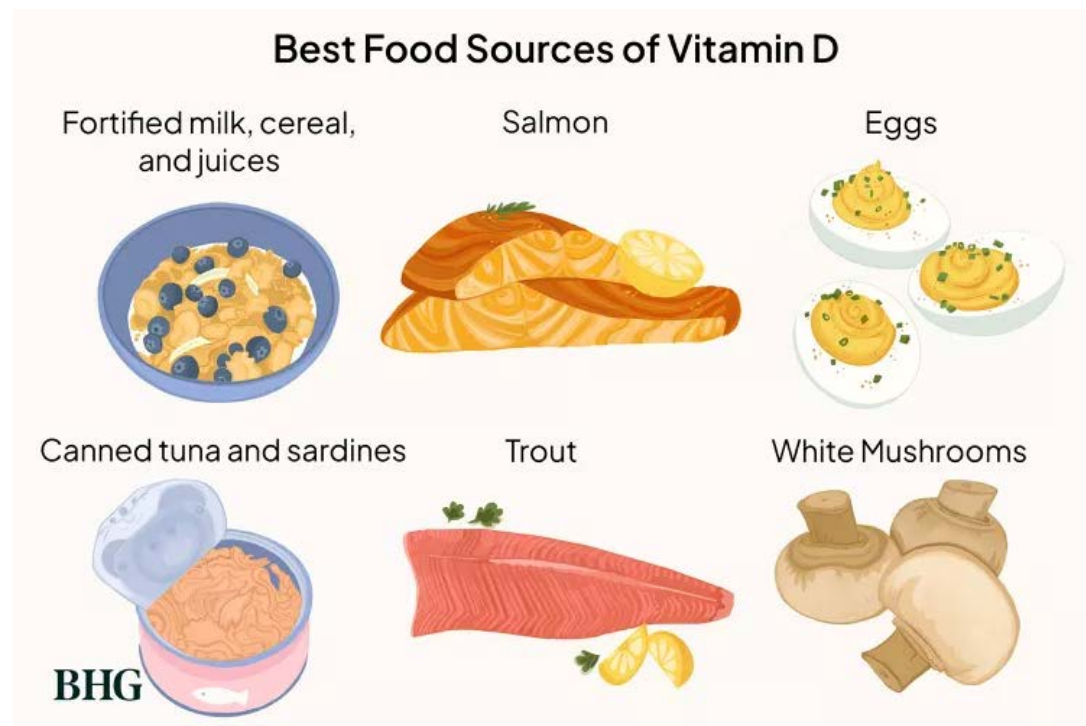
VITAMIN-D

The nutritionally important forms are:

- **Calciferol (Vitamin D2)**– derived by irradiation of the plant sterol.
- **Cholecalciferol (Vitamin D3)**– Naturally occurring (preformed) vitamin D found in animal fats and fish liver oils.

Sources

- **Sunlight:** Synthesized by the body by the action of UV rays on 7-dehydrocholesterol stored in the skin.
- **Foods:** Liver, egg yolk, butter, cheese, milk, and other fortified foods.
- Fish liver oil is the richest source

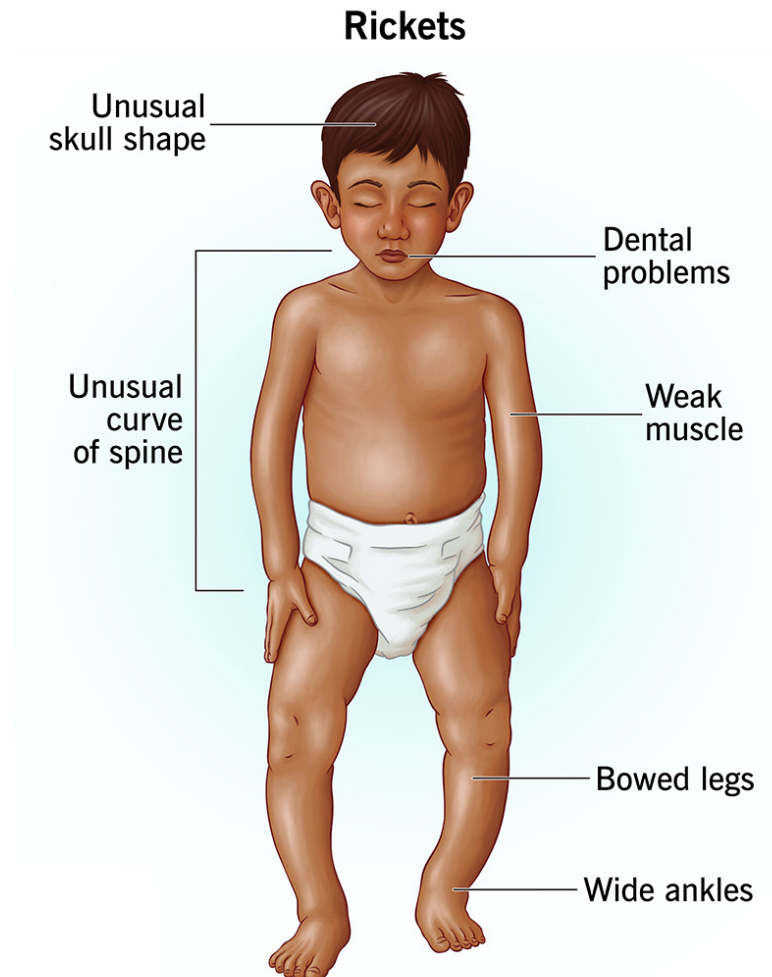


Functions

- **Intestine:** Promotes intestinal absorption of calcium and phosphorus.
- **Bone:** Stimulates normal mineralization, enhances bone reabsorption, and affects collagen maturation.
- **Kidney:** Increases tubular reabsorption of phosphate.
- **Other:** Permits normal growth

VITAMIN-D: Deficiency

Rickets: failure of osteoid to calcify in young children (6m–2 yrs).



THIAMINE (Vitamin B1)

- It is essential for the utilization of carbohydrates.
- Thiamine pyrophosphate (TPP), the coenzyme of cocarboxylase, plays a part in activating transketolase, an enzyme involved in the direct oxidative pathway for glucose.
- **Deficiency:** accumulation of pyruvic and lactic acids in tissues and body fluids
- **Sources:** Whole grain cereals, wheat, gram, yeast, pulses, oilseeds, and nuts

HIGH THIAMINE (B1) FOODS



pork loin (lean)
1.4 mg/120 g serve



leg ham
0.62 mg/150 g serve



salmon
0.61 mg/64 g serve



pili nuts
0.52 mg/48 g serve



oatmeal (steel cut)
0.35 mg/73 g serve



macadamia nuts
0.35 mg/29 g serve



liver
0.3 mg/77 g serve



whole wheat bread
0.28 mg/68 g serve



sunflower seeds
0.26 mg/17 g serve



brown rice
0.26 mg/115 g serve



lentils
0.25 mg/34 g serve



peanuts
0.25 mg/37 g serve

RIBOFLAVIN (Vitamin B2)

- **Functions:** Cellular oxidation, acts as a cofactor in a number of enzymes involved with energy metabolism.
- **Sources:** Milk, eggs, liver, kidney, and GLV. Germination increases the riboflavin content.
- **Deficiency:** Angular stomatitis



RIBOFLAVIN (B2) RICH FOODS



mushrooms
45 mg/2000 cal



kidney
38 mg/2000 cal



liver
37 mg/2000 cal



spirulina
26 mg/2000 cal



heart
23 mg/2000 cal



spinach
20 mg/2000 cal



egg whites
17 mg/2000 cal



asparagus
13 mg/2000 cal



bok choy
11 mg/2000 cal



kale
10 mg/2000 cal



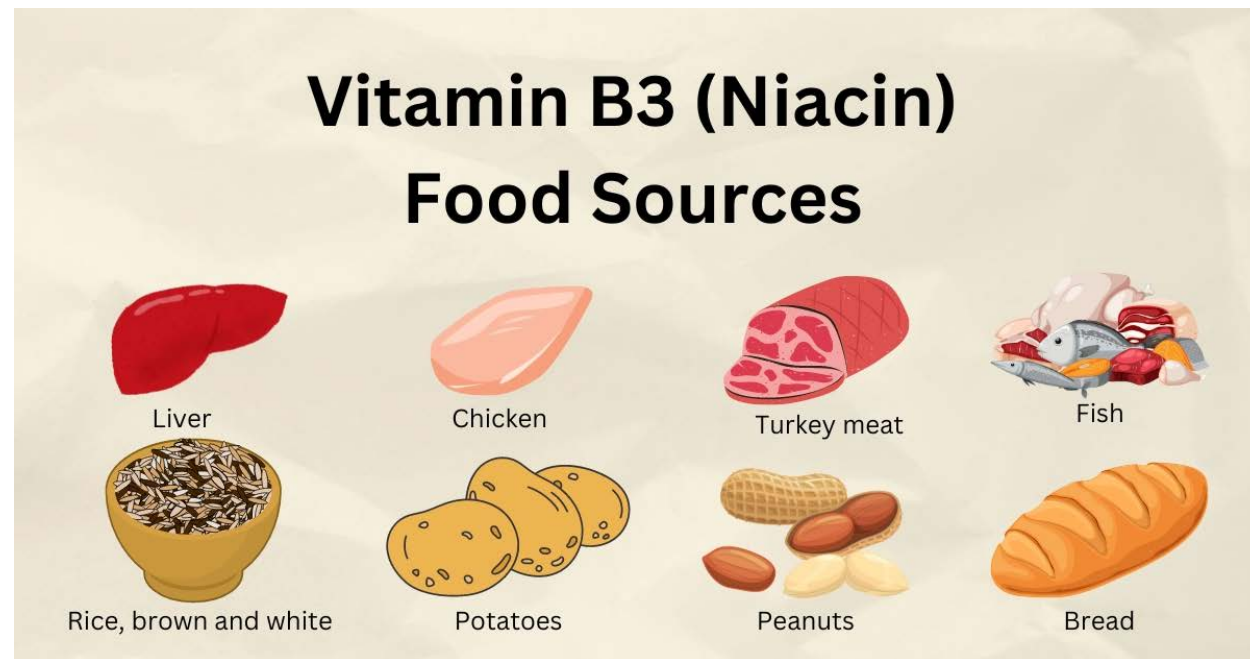
dill pickles
10 mg/2000 cal



Greek yogurt (non-fat)
9 mg/2000 cal

NIACIN (Vitamin B3)

- **Functions:** For the metabolism of carbohydrates, fat, and protein. Also essential for the normal functioning of the skin, the intestinal, and the nervous systems.
- **Sources:** Liver, kidney, meat, poultry, fish, legumes, and groundnuts. Milk is a poor source
- **Deficiency:** Pellagra (3 D's- Diarrhea, dermatitis, and dementia). In addition, Glossitis and stomatitis. Dermatitis is bilaterally symmetrical on body surfaces exposed to sunlight



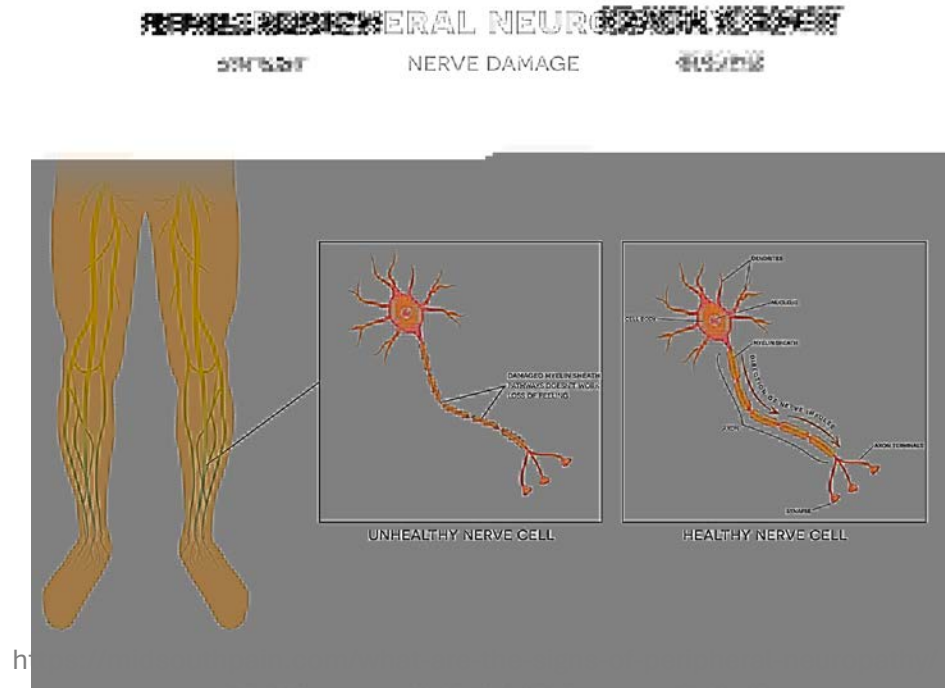
<https://foodstruct.com/articles/vitamin-b3>



<https://en.wikipedia.org/wiki/Dermatitis>

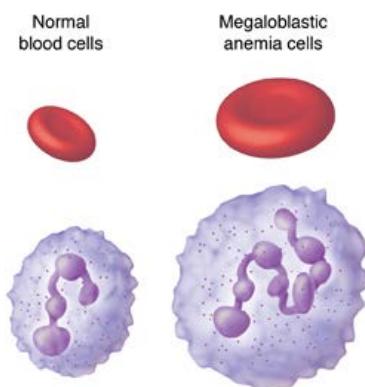
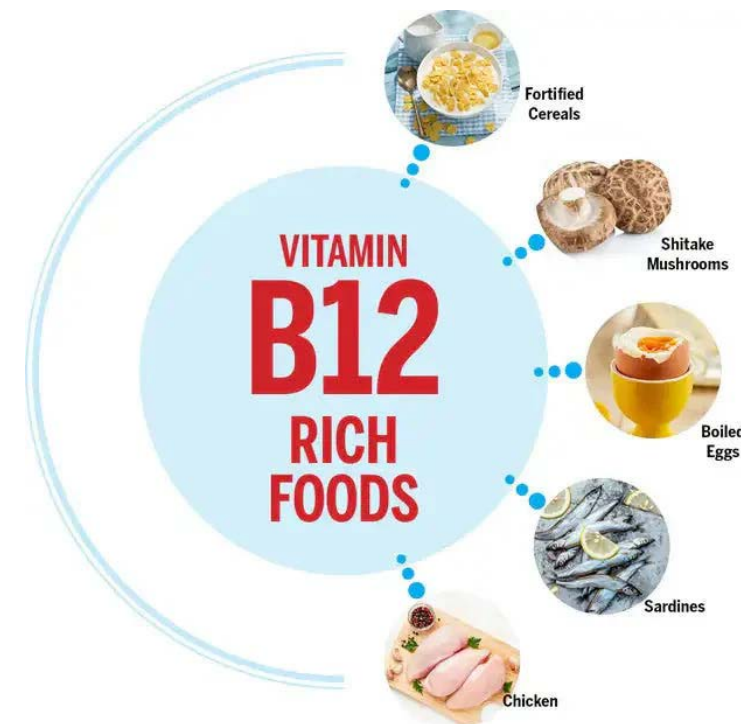
PYRIDOXINE (Vitamin B6)

- **Functions:** Important role in the metabolism of amino acids, fats, and carbohydrates.
- **Sources:** Milk, liver, meat, egg yolk, fish, whole grain cereals, legumes, and vegetables.
- **Deficiency:** Riboflavin deficiency impairs its optimal utilization. Associated with **peripheral neuritis**.



VITAMIN B12

- **Functions:** It cooperates with folate in the synthesis of DNA. Useful in the synthesis of fatty acids in myelin.
- **Sources:** Liver, kidney, meat, fish, eggs, milk, and cheese. Not found in foods of vegetable origin.
- **Deficiency:** Megaloblastic anaemia (pernicious anaemia), Demyelinating neurological lesions in the spinal cord, and Infertility (in animal species).



VITAMIN C

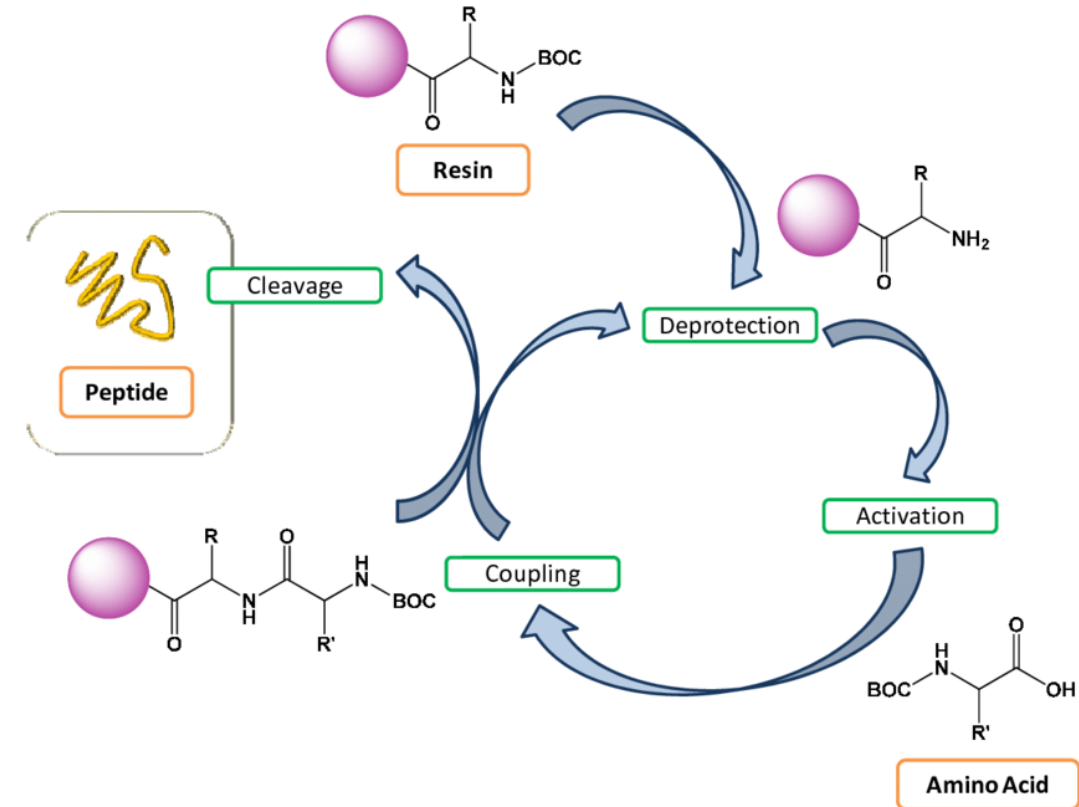
- **Functions:** In tissue oxidation. Formation of collagen, which accounts for 25% of total body protein. Collagen provides a supporting matrix for the blood vessels, connective tissues, bones, and cartilage. Facilitates the absorption of iron from vegetable foods.
- **Sources:** fresh fruits, GLV, germinating pulses. Amla is one of the richest sources, both in fresh and dry form.
- **Deficiency: Scurvy**

HIGH VITAMIN C FOODS			
			
Brussels sprouts 130 mg/110 g serve	orange 90 mg/165 g serve	bell peppers 90 mg/50 g serve	broccoli 80 mg/100 g serve
			
kiwi fruit 80 mg/76 g serve	grapefruit 80 mg/240 g serve	cauliflower 70 mg/115 g serve	strawberries 60 mg/82 g serve
			
kale 60 mg/45 g serve	mango 50 mg/130 g serve	cabbage 40 mg/97 g serve	bananas 40 mg/440 g serve



Introduction to Solid Phase Synthesis

Traditional Solid Phase Synthesis (specifically Solid Phase Peptide Synthesis or SPPS) refers to a method first introduced by Bruce Merrifield in the early 1960s for the efficient chemical synthesis of peptides. It involves anchoring the growing peptide chain to an insoluble solid support (resin) and assembling it step-by-step by adding protected amino acids.

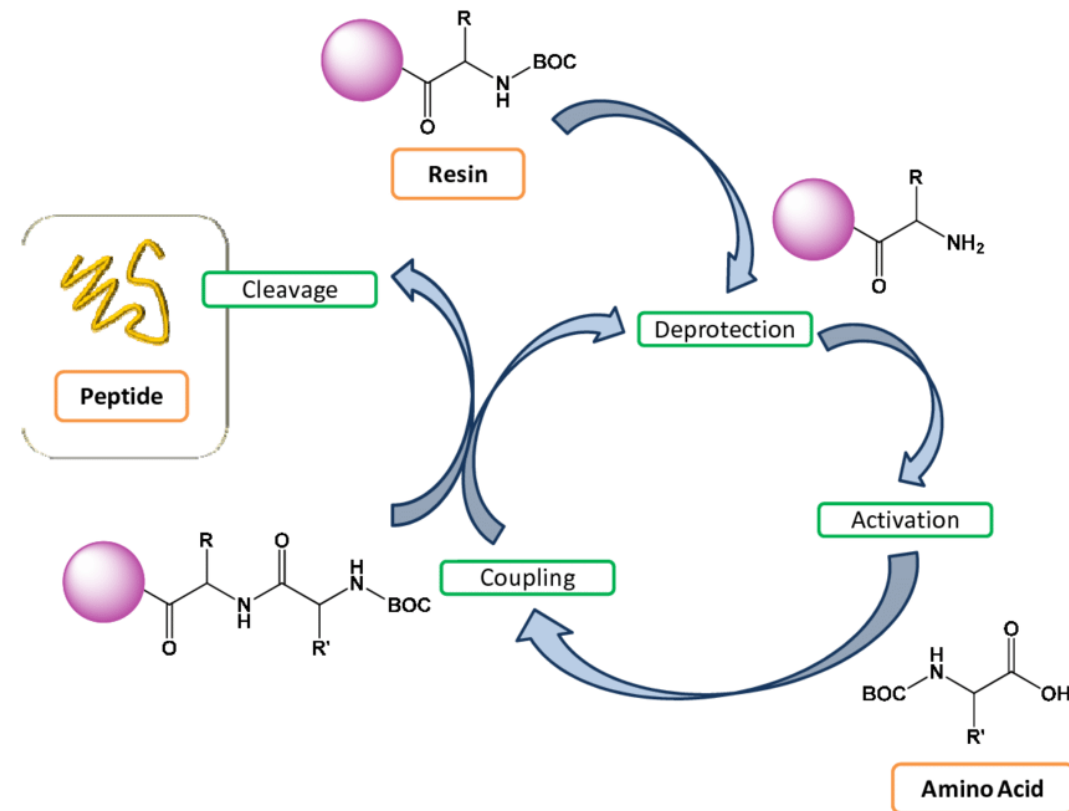


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Introduction to Solid Phase Synthesis

Concept of Solid Phase Peptide Synthesis (SPPS)

- The peptide chain is assembled stepwise on a **solid support**.
- Each monomer is added after the previous one is deprotected.
- Intermediates remain anchored—simplifies washing and purification.
- Reactions occur between liquid-phase reagents and solid-phase peptide.



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Introduction to Solid Phase Synthesis

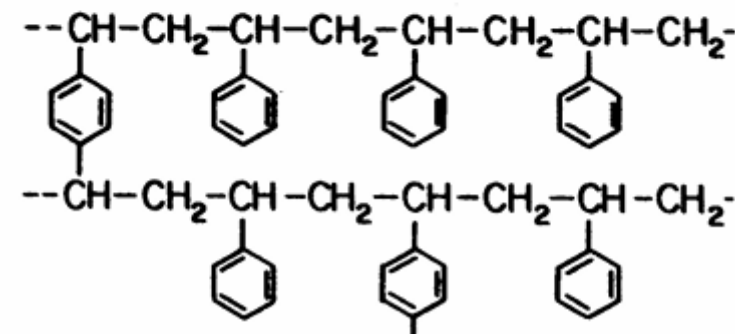
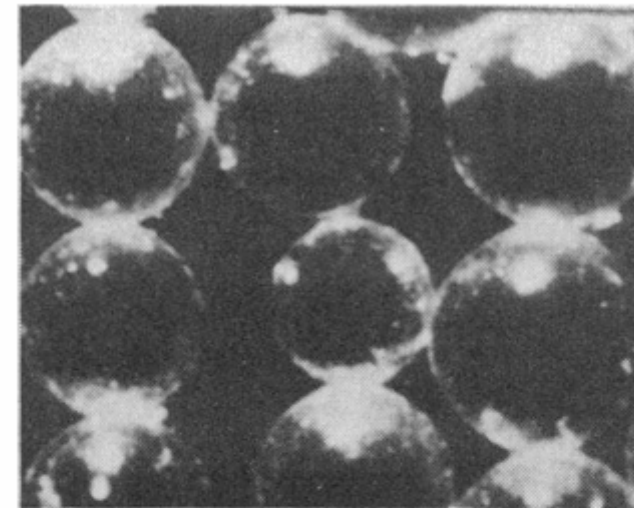
Advantages of SPPS

- Simplified purification (filtration instead of chromatography)
- High efficiency and yield
- Automation-friendly
- Less material loss during intermediate isolation
- Suitable for large-scale peptide and protein synthesis

Introduction to Solid Phase Synthesis

Resin and Matrix Details

- Polystyrene resin crosslinked with divinylbenzene



Science **1986**, 232(4748), 341–347.

References

Book: *Lehninger PRINCIPLES OF BIOCHEMISTRY*; DAVID L. NELSON and MICHAEL M. COX

Research Paper:

Science **1986**, 232(4748), 341–347.

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