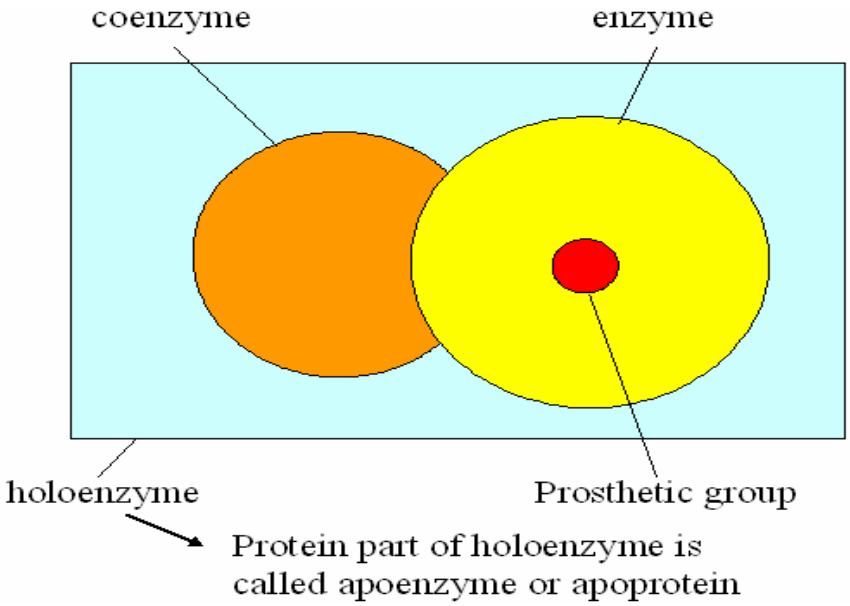
Enzymes

- With the exception of a small group of catalytic RNA molecules, all enzymes are proteins. Their catalytic activity depends on the integrity of their native protein conformation.
- **Cofactor** – is a chemical component having either one or more inorganic ions, such as Fe2+, Mg2+, Mn2+, or Zn2+ or a complex organic or metallorganic molecules called a **coenzymes.**
- Some enzymes require both a coenzyme and one or more metal ions for activity. A coenzyme or metal ion that is very tightly or even covalently bound to the enzyme protein is called a **prosthetic group**.
- A complete, catalytically active enzyme together with its bound coenzyme and/or metal ions is called a **holoenzyme**.
- The protein part of such an enzyme is called the **apoenzyme** or **apoprotein**.



Some Inorganic Elements That Serve as Cofactors for Enzymes

Cu^{2+}	Cytochrome oxidase
Fe^{2+} or Fe^{3+}	Cytochrome oxidase, catalase, peroxidase
K^{+}	Pyruvate kinase
Mg^{2+}	Hexokinase, glucose 6-phosphatase, pyruvate kinase
Mn^{2+}	Arginase, ribonucleotide reductase
Mo	Dinitrogenase
Ni^{2+}	Urease
Se	Glutathione peroxidase
Zn^{2+}	Carbonic anhydrase, alcohol dehydrogenase, carboxypeptidases A and B

Some Coenzymes That Serve as Transient Carriers of Specific Atoms or Functional Groups*

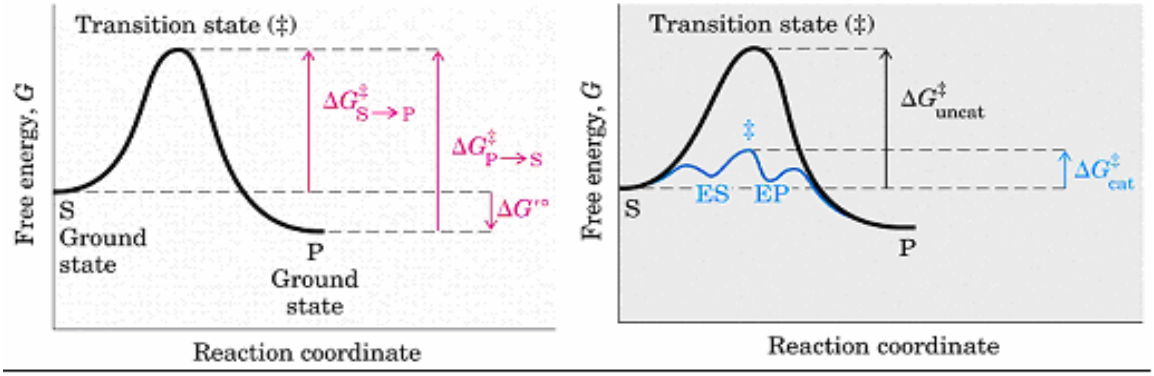
Coenzyme	Examples of chemical groups transferred	Dietary precursor in mammals
Biocytin	CO_2	Biotin
Coenzyme A	Acyl groups	Pantothenic acid and other compounds
5′-Deoxyadenosylcobalamin (coenzyme B_{12})	H atoms and alkyl groups	Vitamin B_{12}
Flavin adenine dinucleotide	Electrons	Riboflavin (vitamin B_2)
Lipoate	Electrons and acyl groups	Not required in diet
Nicotinamide adenine dinucleotide	Hydride ion ($:H^-$)	Nicotinic acid (niacin)
Pyridoxal phosphate	Amino groups	Pyridoxine (vitamin B_6)
Tetrahydrofolate	One-carbon groups	Folate
Thiamine pyrophosphate	Aldehydes	Thiamine (vitamin B_1)

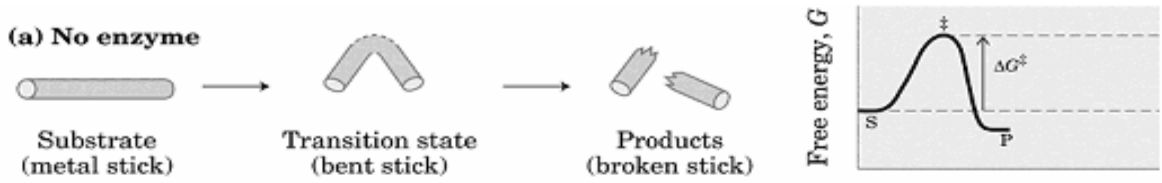
International Classification of Enzymes*

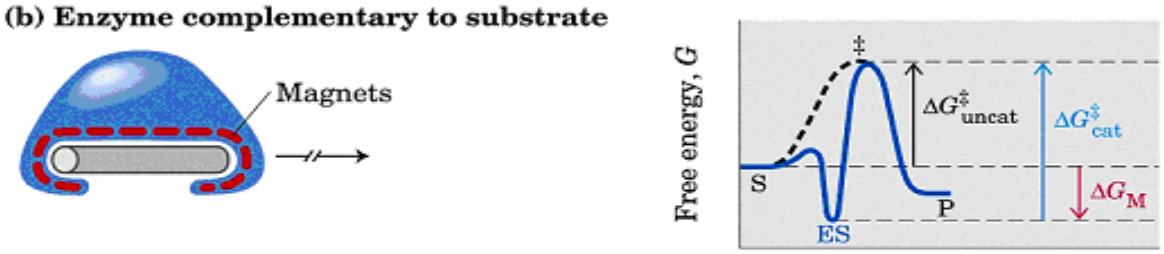
No.	Class	Type of reaction catalyzed
1	Oxidoreductases	Transfer of electrons (hydride ions or H atoms)
2	Transferases	Group-transfer reactions
3	Hydrolases	Hydrolysis reactions (transfer of functional groups to water)
4	Lyases	Addition of groups to double bonds, or formation of double bonds by removal 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

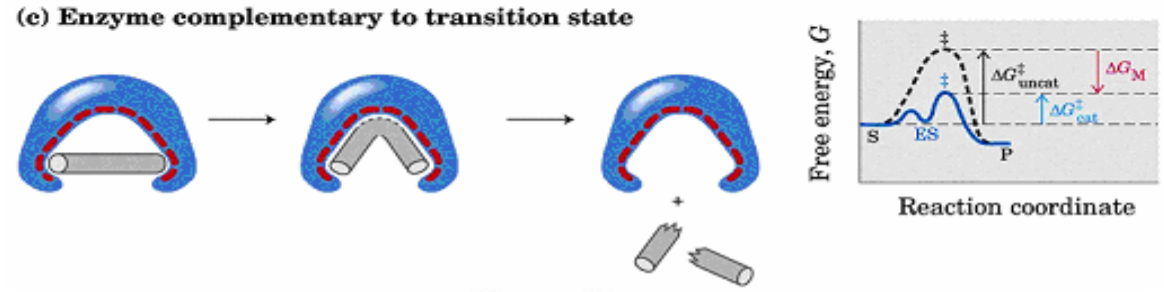
*Most enzymes catalyze the transfer of electrons, atoms, or functional groups. They are therefore classified, given code numbers, and assigned names according to the type of transfer reaction, the group donor, and the group acceptor.

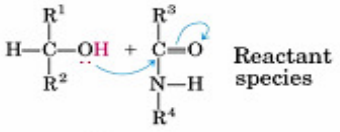
Enzyme-catalyzed reactions $E + S \leftrightarrow ES \leftrightarrow EP \leftrightarrow E + P$



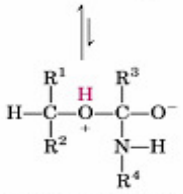




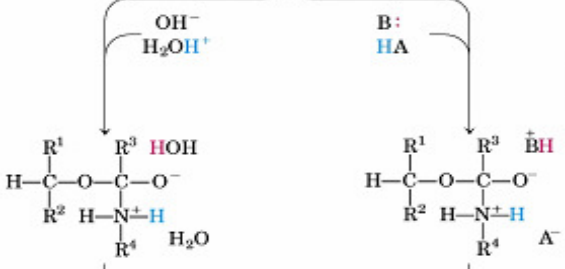




Without catalysis, unstable (charged) intermediate breaks down rapidly to from reactants.

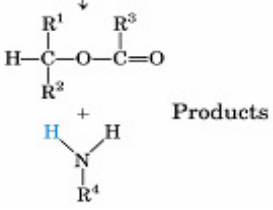


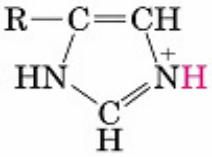
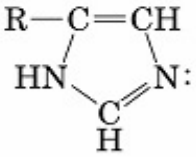
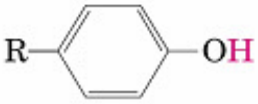
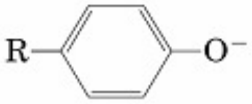
specific acid-base catalysis | general acid-base catalysis

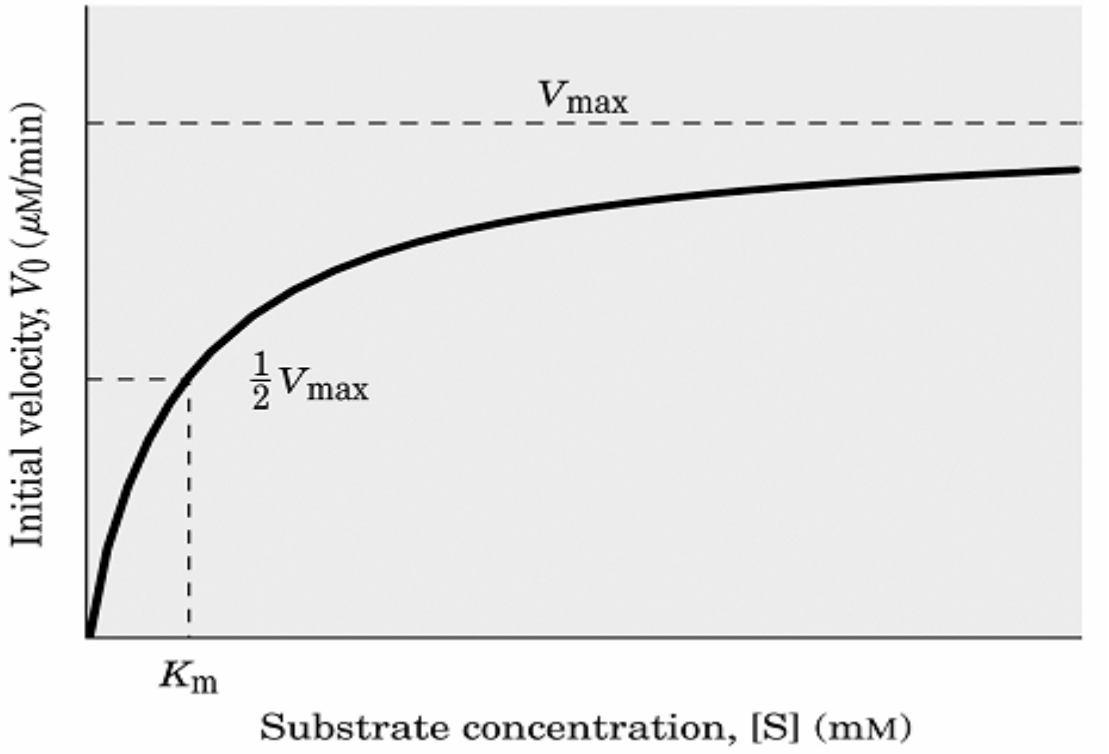


When proton transfer to or from H_2O is faster than the rate of breakdown of intermediates, the presence of other proton donors or acceptors does not increase the rate of the reaction.

When proton transfer to or from H_2O is slower than the rate of breakdown of intermediates, only a fraction of the intermediates formed with be stabilized. The presence of alternate proton donors (HA) or acceptors (B:) increases the rate of the reaction

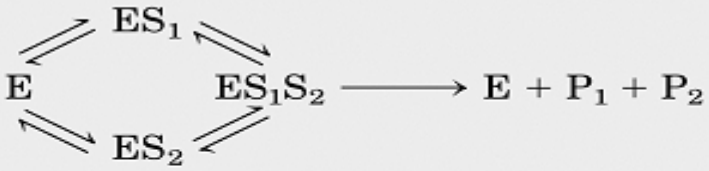


Amino acid residues	General acid form (proton donor)	General base form (proton acceptor)
Glu, Asp	R—COOH	R—COO⁻
Lys, Arg	R—$\overset{+}{\underset{H}{\overset{H}{N}}}$H	R—$\ddot{N}H_2$
Cys	R—SH	R—S⁻
His		
Ser	R—OH	R—O⁻
Tyr		

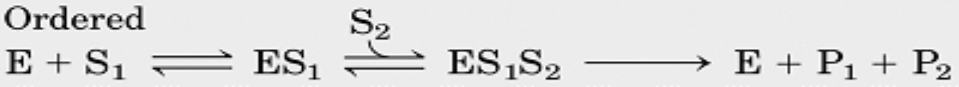


(a) Enzyme reaction involving a ternary complex

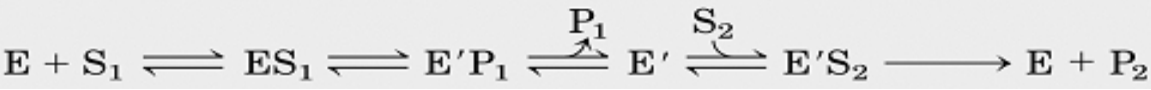
Random order

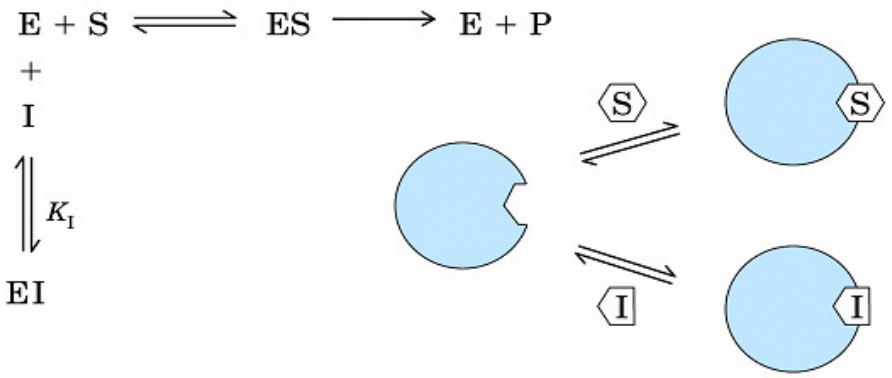


Ordered

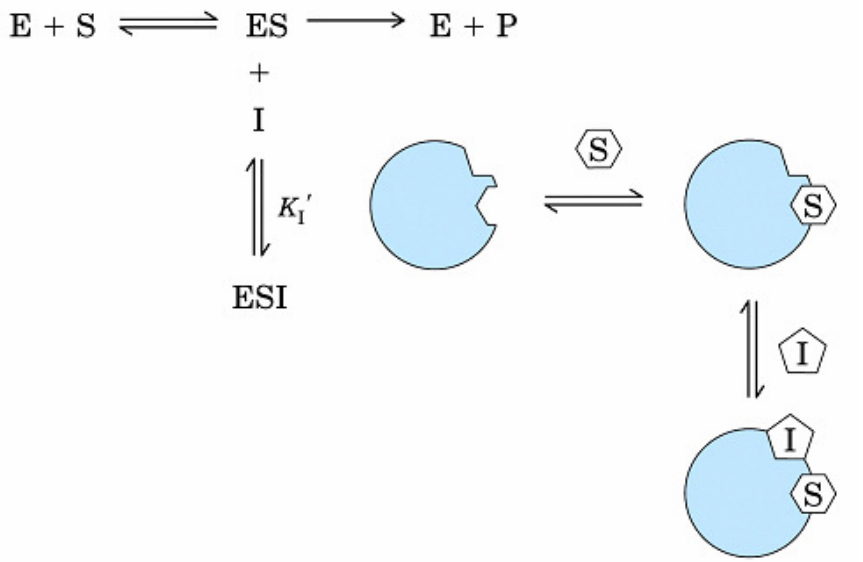


(b) Enzyme reaction in which no ternary complex is formed

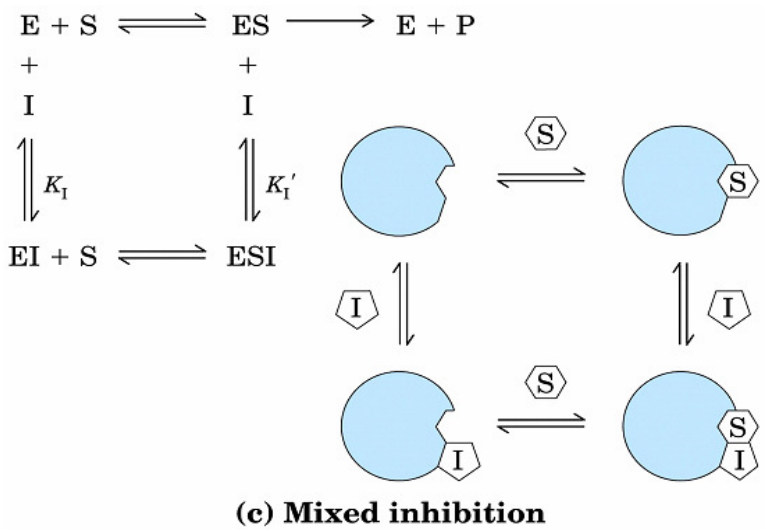




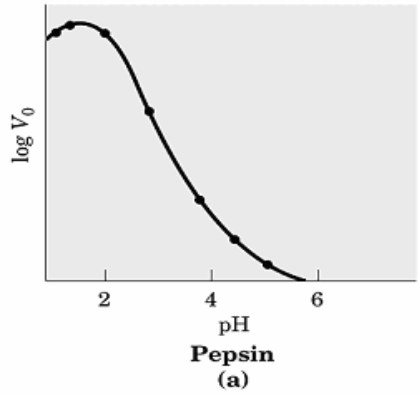
(a) Competitive inhibition



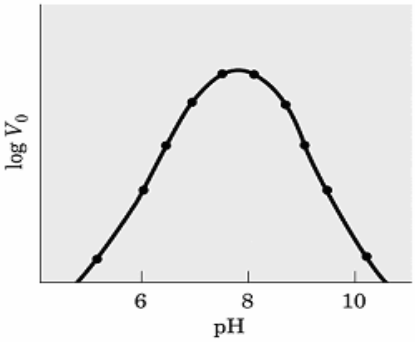
(b) Uncompetitive inhibition



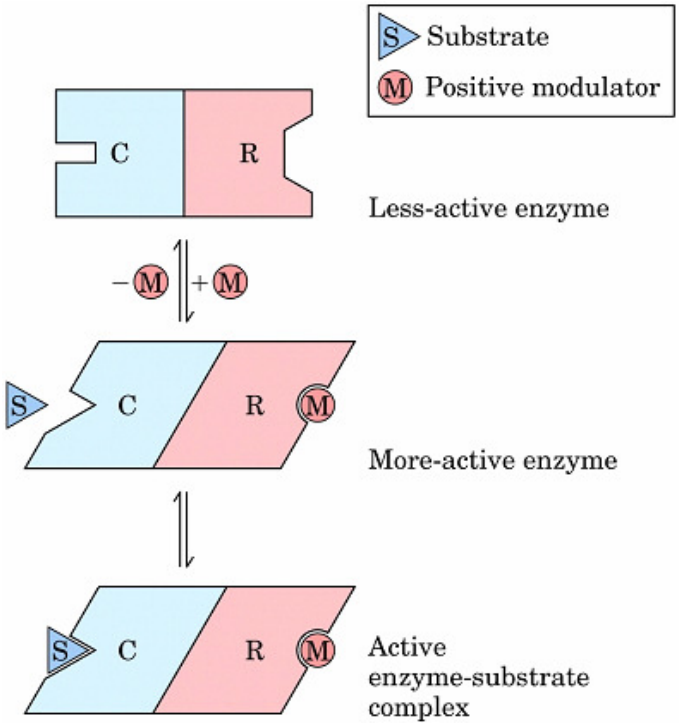
(c) Mixed inhibition



Pepsin
(a)



Glucose 6-phosphatase
(b)



Feedback inhibition