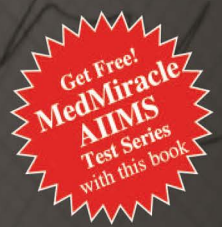
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AIIMS

The Precise Version



MAY 2019

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Vishnu Prasad



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Biochemistry

1. A person starts eating raw egg for proteins intake. After 3 days, he started developing fatigue on moderate exercise. The doctor prescribes him a vitamin. Which of the following enzymes is likely to be deficient?

a. Pyruvate carboxylase
b. PEPCK
c. Glucose 6 phosphatase
d. Glycogen phosphorylase

Ans. a. Pyruvate carboxylase

Biotin

- Biotin acts as cofactor in a number of carboxylation reactions involving- acetyl-CoA carboxylase, pyruvate carboxylase, propionyl-CoA carboxylase, and methylcrotonyl-CoA carboxylase.
- It is also involved in catabolism of certain amino acids (leucine) and gene regulation by histone biotinylation.

Biotin functions to transfer carbon dioxide in reactions

- *Pyruvate carboxylase*: Pyruvate is converted to oxaloacetate in gluconeogenesis
- *Acetyl-CoA carboxylase*: Acetyl-CoA is converted to malonyl-CoA in fatty acid synthesis
- *Propionyl-CoA carboxylase*: Propionyl-CoA is converted to methylmalonyl-CoA in gluconeogenesis
- *Methylmalonyl CoA carboxyl transferase*: Propionic acid synthesis in bacteria
- *Methylcrotonyl-CoA carboxylase*: Leucine catabolism

Source:

- Meat, soya beans, yeast and egg yolks
- Egg white contains protein avidin, which strongly binds to biotin, reducing its bioavailability.

Deficiency:

- Biotin deficiency due to low dietary intake is rare (deficiency is due to inborn errors of metabolism)
- Mental changes (depression, hallucinations), paresthesia, anorexia and nausea.
- A scaling, seborrheic, erythematous rash around eyes, nose, mouth and extremities.

2. Functional assay for thiamine estimation is:

a. Serum thiamine
b. RBC transketolase level
c. RBC glutathione reductase
d. RNA editing

Ans. b. RBC transketolase level

Thiamine (Vitamin B1)

- Thiamine pyrophosphate (TPP) is the biologically active form of vitamin B1, formed by transfer of pyrophosphate group from ATP.

Functions of Thiamine

Thiamine diphosphate is the coenzyme for the following enzymes:

- Branched-chain ketoacid dehydrogenase involved in the metabolism of leucine, isoleucine and valine
- Alpha-ketoglutarate dehydrogenase in the citric acid cycle
- Pyruvate dehydrogenase in carbohydrate metabolism
- Transketolase reaction in the pentose phosphate pathway

Thiamine triphosphate has a role in nerve conduction—it phosphorylates and activates a chloride channel in the nerve membrane.

Thiamine nutritional status is best assessed by erythrocyte or whole blood transketolase activity.

Thiamine Deficiency Diseases

Beriberi:

- *Wet beriberi*: High-output congestive heart failure, peripheral edema and peripheral neuritis.
- *Dry beriberi*: Symmetric peripheral neuropathy of the motor and sensory systems, with diminished reflexes. Neuropathy mainly affects the lower limbs.
- *Infantile beriberi*: Occurs in infants born to mothers who are thiamine deficient. Features include tachycardia, vomiting, convulsions and death.

Wernicke encephalopathy with Korsakoff's psychosis:

- Alcoholic patients with chronic thiamine deficiency also may have CNS manifestations known as Wernicke's encephalopathy.
- *Wernicke's encephalopathy*: Involves periaqueductal gray matter, and presents with horizontal nystagmus, ophthalmoplegia (due to weakness of one or more extraocular muscles), cerebellar ataxia, and mental impairment.
- It then progreses into Korsakoff psychosis consisting of loss of memory and confabulations, a syndrome is known as Wernicke-Korsakoff syndrome.

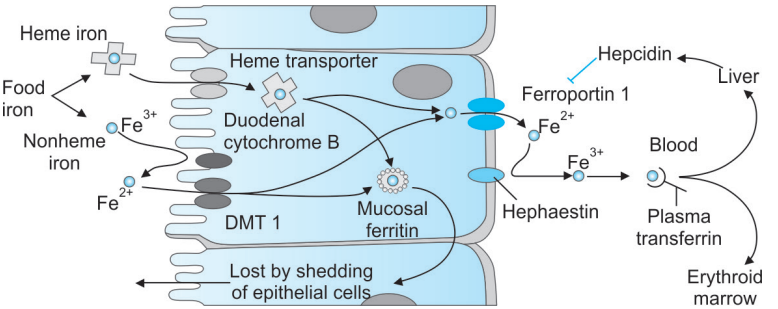
3. Hepcidin decreases iron absorption by inhibition of:

a. Hephaestin
b. Ferroportin
c. Divalent metal ion transporter
d. Transferrin

Ans. b. Ferroportin

Iron Absorption

Iron absorption from the intestine is summarized in the following diagram:



Regulation of Iron Absorption

- Hepcidin, synthesized by the liver, is the major regulator of iron absorption. Its levels are regulated by intrahepatic iron levels.
- Hepcidin binds to ferroportin, resulting in its endocytosis, thus inhibiting iron transfer from enterocyte to plasma. Iron becomes trapped within duodenal cells and is subsequently lost as these cells are sloughed.
- Conversely, with low body stores of iron, hepcidin synthesis falls and this in turn facilitates iron absorption.
- Hepcidin also acts on macrophages, suppressing iron release. It thus reduces the amount of iron available for erythroid precursors for hemoglobin synthesis.
- In iron deficiency, there is upregulation of Transferrin mRNA and receptor expression. Thus, transferrin receptor maintains cellular iron homeostasis.
- While ferritin synthesis decreases as it is a storage form of Iron. There is no change in ferritin mRNA concentration.
- TfR production in the cell is regulated according to iron levels by iron- responsive element-binding proteins, IRP1 and IRP2.

Ferroportin and Ceruloplasmin: Iron that enters the duodenal cells can follow one of two pathways: transport to the blood or storage as mucosal iron. This distribution is influenced by body iron stores. Fe^{2+} iron destined for the circulation is transported from the cytoplasm across the basolateral enterocyte membrane by **ferroportin**. This process is coupled to the oxidation of Fe^{2+} iron to Fe^{3+} iron, which is carried out by the iron oxidases hephaestin and **ceruloplasmin**.

4. Which of the following TCA cycle intermediate is a part of heme metabolism?

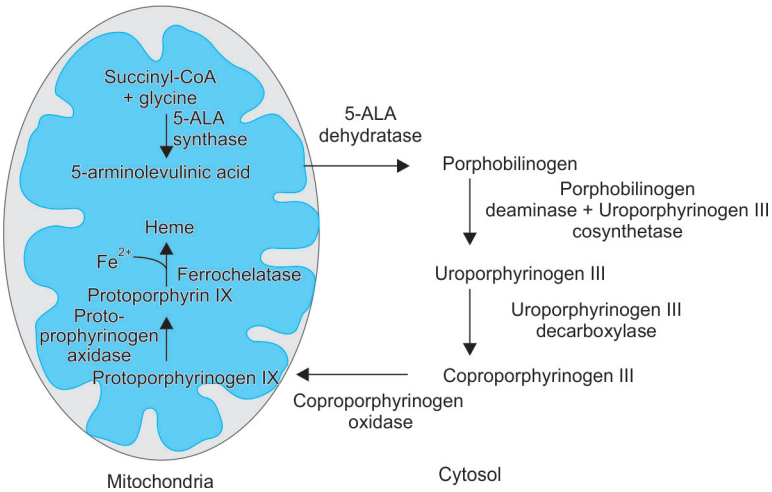
a. Succinyl CoA
b. Fumarate
c. Alpha ketoglutarate
d. Malate

Ans. a. Succinyl CoA

Heme Biosynthesis

- Heme biosynthesis occurs in most mammalian cells except RBCs, which do not contain mitochondria.
- *Sites*: 85% of heme synthesis occurs in erythroid precursor cells in the bone marrow, and the majority of the remainder in hepatocytes.
- The enzymatic process that produces heme is properly called porphyrin synthesis. In humans, this pathway serves almost exclusively to form heme.
- The pathway is initiated by the synthesis of δ-Aminolevulinic acid (δALA) from glycine and succinyl- CoA.
- This step is catalyzed by the rate-limiting enzyme of the pathway, ALA synthase, which is negatively regulated by glucose and heme concentration.
- It takes place in both cytoplasm and mitochondria.
- Most important heme containing molecule is hemoglobin, but it also forms part of other biologically important proteins such as myoglobin, cytochrome, catalase and endothelial nitric oxide synthase.

Steps of heme synthesis are depicted in the following diagram:



5. Enzyme involved in gluconeogenesis are all *except*:

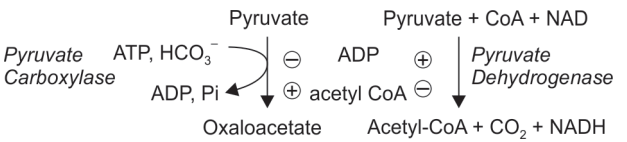
a. Pyruvate carboxylase
b. PEP carboxykinase
c. Pyruvate kinase
d. Glucose-6 phosphatase

Ans. c. Pyruvate kinase

In gluconeogenesis, the steps of glycolysis are reversed to regenerate glucose from various molecules to supply energy for various tissues of the body. All steps in glycolysis are reversible except three, which are circumvented by reactions undertaken by the following molecules.

Regulatory and adaptive enzymes associated with gluconeogenesis				
	Inducer	***Repressor***	***Activator***	***Inhibitor***
Pyruvate carboxylase	Glucocorticoids, glucagon, epinephrine	Insulin	Acetyl CoA	ADP
Phosphoenol pyruvate carboxykinase	Glucocorticoids, glucagon, epinephrine	Insulin	Glucagon	
Glucose 6-phosphatase	Glucocorticoids, glucagon, epinephrine	Insulin		

- Liver and kidneys are the major gluconeogenic tissues.
- Glucogenic key enzymes are expressed in small intestine but their role in fasting state is unclear.
- Gluconeogenesis prevent hypoglycemia during short and long-term fasting.
- Allosteric activation by acetyl Co-A appears to play the most essential part in gluconeogensis: Acetyl Co-A derived from fatty acid oxidation inhibits pyruvate dehydrogenase (PDH) enzyme and stimulates pyruvate carboxylase, shunting pyruvate to gluconeogenesis.



Glucose-6-phosphate is formed in the cytoplasm of hepatocytes while glucose-6-phosphatase is present in the endoplasmic reticulum of cell. Hence, the reaction does not take place until gluconeogenesis is favored. In liver, but not muscle, glucose-6-phosphatase catalyzes hydrolysis of glucose-6-phosphate, yielding glucose that is exported, leading to an increase in the blood glucose concentration. Glucose-6-phosphatase is in the lumen of the smooth endoplasmic reticulum, and

genetic defects of the glucose-6-phosphate transporter can cause a variant of type I glycogen storage disease.

Substrates of gluconeogenesis

- Glucogenic amino acids (all except leucine and lysine which are purely ketogenic); most important is alanine
- Lactate
- Pyruvate
- Propionate
- Glycerol
- Fumarate

6. Exclusive mother to children's transmission is a key feature of which pattern of inheritance?

a. Codominance
b. Autosomal dominant inheritance
c. Recessive inheritance
d. Mitochondrial inheritance

Ans. d. Mitochondrial inheritance

Human Mitochondrial DNA

- It is circular, double-stranded.
- Contains 16 kbp (nuclear genome- 3.3 billion bp)
- Encodes 13 protein subunits of the respiratory chain (of a total of about 67 i.e. 20%)
- Encodes large (16S) and small (12S) mt ribosomal RNAs
- Encodes 22 mt tRNA molecules
- Genetic code differs slightly from the standard code
  - UGA (standard stop codon) is read as Trp
  - AGA and AGG (standard codons for Arg) are read as stop codons
- Contains very few untranslated sequences (3% noncoding vs 93% in nuclear DNA)
- High mutation rate (5–10 times that of nuclear DNA)
- Inheritance is strictly maternal—During fertilization, cytoplasm of the embryo is formed entirely by that of the ovum. Hence, only the maternal mitochondria is inherited by the embryo.

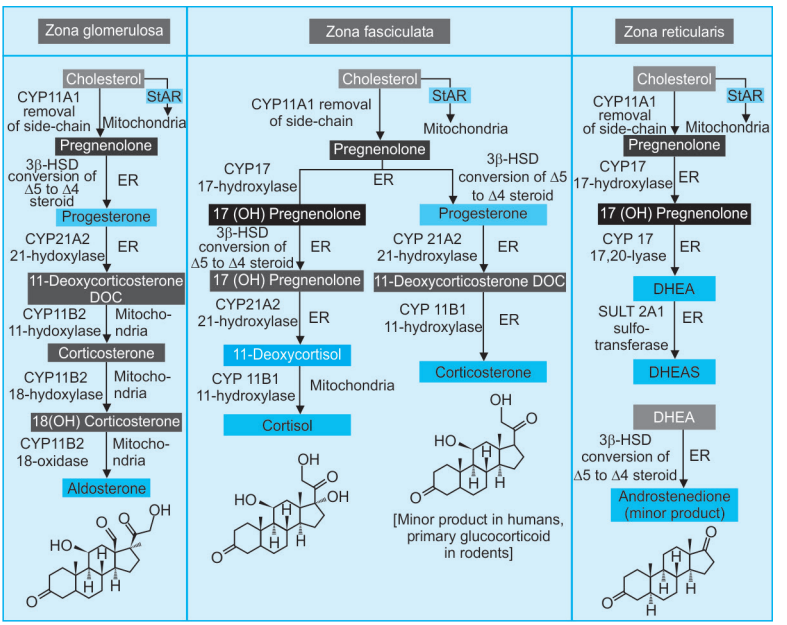
7. Which of the following hormones is secreted by the female adrenal gland?

a. Progesterone
b. Testosterone
c. Estrogen
d. DHEA

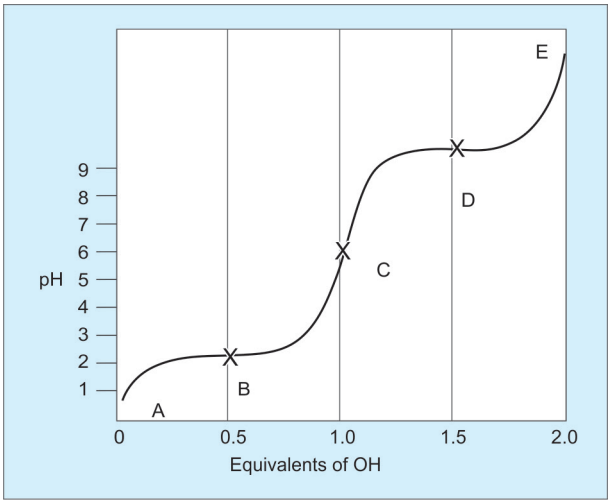
Ans. d. DHEA

Adrenal Steroidogenesis

- Cholesterol is mostly derived from plasma, but a small portion is synthesized in situ from acetyl-CoA via mevalonate and squalene.
- Much of cholesterol in adrenal is esterified and stored in cytoplasmic lipid droplets
  - Upon stimulation of adrenal by ACTH, an esterase is activated and free cholesterol formed is transported into mitochondrion, where a cytochrome P450 side chain cleavage enzyme (P4SOscc) converts cholesterol to pregnenolone.
- Cleavage of the side chain involves sequential hydroxylations first at C22 and then at C20, followed by side chain cleavage (removal of the six-carbon fragment iso caproaldehyde) to give 21-carbon steroid.
- An ACTH-dependent steroidogenic acute regulatory (StAR) protein is essential for transport of cholesterol to P450scc in inner mitochondrial membrane.
  - All mammalian steroid hormones are formed from cholesterol via pregnenolone through a series of reactions that occur in either mitochondria or endoplasmic reticulum of adrenal cell as depicted below:



8. The graph shown below is the titration curve of glycine. Which of the following statements are true?



a. Point A represents the region where glycine is deprotonated
b. Points C represent the region of maximum buffer activity
c. Point C represents the region where the net charge on glycine is zero
d. Point D represents the pK of glycine's carboxyl group
e. Point E represents the pI for glycine.

Ans. a-F, b-T, c-T, d-F, e-F

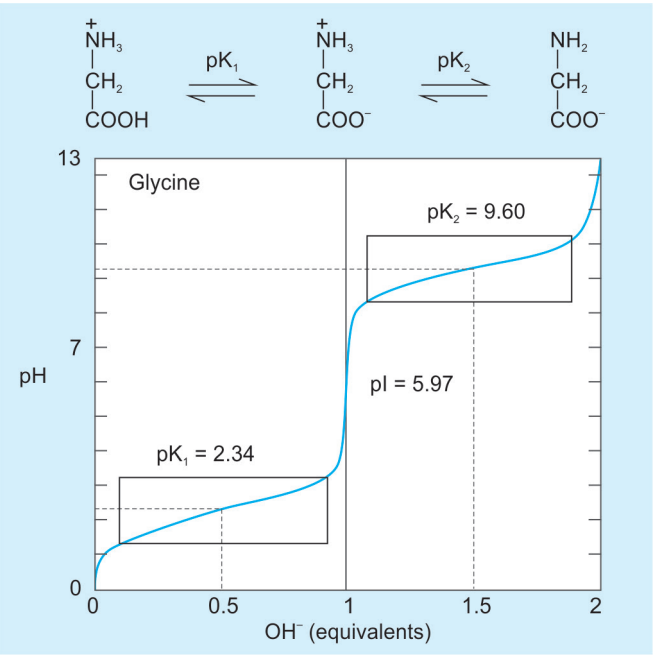
- C represents the isoelectric point or pI, and as such is midway between pk1 and pk2 for glycine
- Glycine is fully protonated at Point A. Point C represents a region of maximum buffering.
- Point E represents the region where glycine is fully deprotonated

Titration Curve of Amino Acids

- Titration curves are obtained when the pH of a given volume of a sample solution varies on addition of acid or alkali.
- pH is plotted against the volume of the titrant added or the number of equivalents added per mole of the sample.
- *The shape of the curve depends upon*: Number of ionizing groups, pKa of ionizing group and buffer region.
- *Amino acids are weak polyprotic acids*: At neutral pH, they exist as zwitterions with equal number of negative and positive charges. They are amphoteric in character and can be titrated with both acid and alkali.

- All amino acids have an acidic group (COOH) and a basic group (NH_2) attached to a carbon and contain ionizable groups that act as weak acids or bases, giving off or taking on protons when the pH is altered.
- *Isoelectric point (pI)*: pH of an aqueous solution of an amino acid at which the molecules have no net charge.
- When dissolved in water, it exists predominantly in the isoelectric form.
- When titrated with acid, it acts as a base and with base, it acts as an acid.
- These ionizations follow the Henderson-Hesselbalch equation: pH = pKa + log [Unprotonated form (base)] / [Protonated form (acid)]
- When the concentration of unprotonated form equals that of unprotonated form, ratio of their concentrations equals 1, and log 1 = 0.
  - *pKa*: pH at which concentrations of protonated and unprotonated forms of ionizable species are equal (pH at which ionizable group is at its best buffering capacity)
  - *pK*: pH at the midpoint of buffering region (pK is the pH corresponding to inflection point in titration curve)
  - For a simple diprotic amino acid, pI falls halfway between two pK values.

A theoretical titration curve for glycine is given below:



9. Kcat/km is a measure of:

a. Enzyme efficiency
b. Speed of enzymatic reaction
c. Concentration of substrate
d. Enzyme turn over

Ans. a. Enzyme efficiency

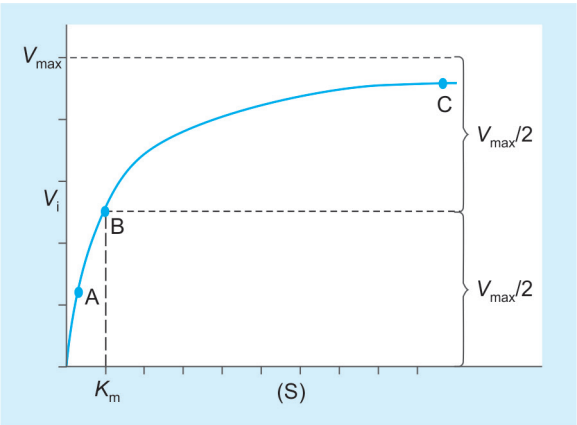
The Michaelis-Menten Equation

The Michaelis-Menten equation illustrates in mathematical terms the relationship between initial reaction velocity v_i and substrate concentration [S]:

$$v_i = \frac{V_{max}[S]}{K_m + [S]}$$

The Michaelis constant K_m is the substrate concentration at which v_i is half the maximal velocity ($V_{max}/2$) attainable at a particular concentration of the enzyme. K_m thus has the dimensions of substrate concentration.

Effect of substrate concentration on the initial velocity of an enzyme-catalyzed reaction:



The dependence of initial reaction velocity on [S] and K_m may be illustrated by evaluating the Michaelis-Menten equation under three conditions:

1. When [S] is much less than K_m (point A in Figure), the term $K_m + [S]$ is essentially equal to K_m. Replacing $K_m + [S]$ with K_m reduces equation to

$$v_i = \frac{V_{max}[S]}{K_m + [S]} \quad v_i \approx \frac{V_{max}[S]}{K_m} \approx \left[\frac{V_{max}}{K_m}\right][S]$$

where ≈ means "approximately equal to." Since V_{max} and K_m are both constants, their ratio is a constant. In other words, when [S] is considerably below K_m, v_i is proportionate to k[S]. The initial reaction velocity therefore is directly proportional to [S].

2. When [S] is much greater than K_m (point C in Figure), the term K_m + [S] is essentially equal to [S]. Replacing K_m + [S] with [S] reduces equation to

$$v_i = \frac{F_{max}[S]}{K_m + [S]} \quad v_i \approx \frac{V_{max}[S]}{[S]} \approx V_{max}$$

Thus, when [S] greatly exceeds K_m, the reaction velocity is maximal (V_{max}) and unaffected by further increases in the substrate concentration.

3. When [S] = K_m (point B in Figure):

$$v_i = \frac{F_{max}[S]}{K_m + [S]} = \frac{V_{max}[S]}{[S]} \approx \frac{V_{max}}{2}$$

When [S] equals K_m, the initial velocity is half-maximal. Equation also reveals that K_m is—and may be determined experimentally from—the substrate concentration at which the initial velocity is half-maximal.

Turnover number/ catalytic constant (kcat) – It represents the speed in which enzyme-substrate complex forms the product. It is the number of catalytic cycles that each active site undergoes per unit time. It is the rate constant of the reaction when enzyme is saturated with substrate.

Turnover number = kcat = V_{max}/[ET]

[ET] = total enzyme concentration

kcat/KM = catalytic efficiency—It represents both binding and catalytic events. It indicates how the velocity varies according to how often the enzyme and substrate combine. It is the best value to represent the enzyme's overall ability to convert substrate to product.

10. Which of the following statements regarding reducing activation energy is/are true?

a. ΔG_F is lowered
b. Stability of transition state is reduced
c. It depends upon complementarity of active site of enzyme and substrate
d. Conformational change may occur at the active site of enzyme at the time of binding to substrate

Ans. a-T, b-F, c-T, d-T

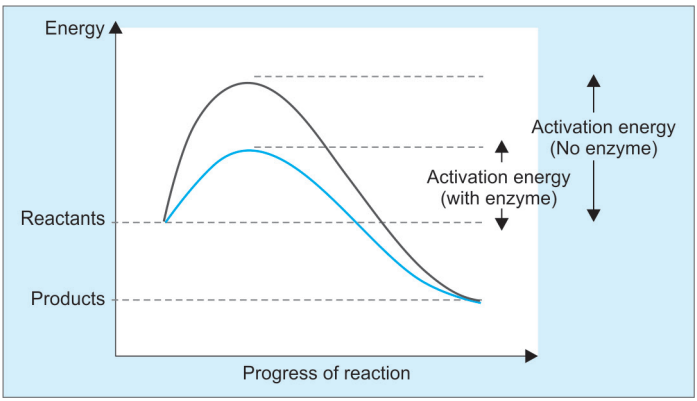
Enzyme Catalysis

Reactions proceed via formation of an intermediate molecule. This transient intermediate—in which neither free substrate nor product exists—is termed the transition state. ΔG refers to the change in free energy when substrate is converted into product. ΔG_F refers to difference

between the free energy of substrate and transition state. Regardless of the sign or magnitude of ΔG, ΔG_F for the overwhelming majority of chemical reactions has a positive sign, which indicates that formation of the transition state requires surmounting one or more energy barriers. For this reason, ΔG_F for reaching a transition state is often termed the activation energy, E_{act}. The ease—and hence the frequency—with which this barrier is overcome is inversely related to E_{act}. For a simple reaction,

$$\text{Rate } \alpha\ e^{-E}act^{/RT}$$

The activation energy for the reaction proceeding in the opposite direction to that drawn is equal to $-\Delta G_D$. Enzymes Lower the Activation Energy Barrier for a Reaction. All enzymes accelerate reaction rates by lowering ΔG_F for the formation of transition states. However, they may differ in the way this is achieved. While the sequence of chemical steps at the active site parallels those which occur when the substrates react in the absence of a catalyst, the environment of the active site lowers ΔG_F by stabilizing the transition state intermediates. The enzyme binds to the transition state intermediate more tightly than it does to either substrates or products. Catalysis by enzymes that proceeds via a unique reaction mechanism typically occurs when the transition state intermediate forms a covalent bond with the enzyme (covalent catalysis).



11. Which type of mutation occurs in sickle cell anemia?

a. Insertion
b. Deletion
c. Point mutation
d. Frame shift

Ans. c. Point mutation

Sickle Cell Anemia

- Characterized by point mutation in the beta globin chain of hemoglobin, which results in coding of valine instead of glutamate at position 6.

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Dr. Apurv Mehra is The Leading Faculty of Orthopedics & is recognized Nationally & Internationally as an outstanding teacher, world class scholar & dedicated mentor. He is best known for his stupendous efforts in teaching, motivating & inspiring budding doctors. The quality that sets him apart is his unique style of teaching with fun & passion. Dr. Apurv Mehra is also Co-Founder of MedMiracle – Online Platform To Guide Students Preparing for Medical Entrance Exams. Dr. Apurv Mehra is a youth icon, guide, mentor & role model for aspiring doctors. He is known for his highly inspirational & motivational Speeches. Inspired from his lectures, students not only 'learn' but actually follow Dr. Apurv Mehra & also implement his advice & guidance in their day to day lives.



Dr. Thameem Saif

MD Medicine is a renowned teacher head in very high regard by medicos both in India and the US. He is an intellect of high order with brilliant teaching skills. His input have been found to be very valuable by his students across the country and he has helped lots of students achieve their dreams of clearing the tough Indian Medical PG Entrance Exam and The USMLE. Most of the toppers in the country today thank him in their heart for playing an important role in their success. He is well known for solving MCQs in an organised approach to reach towards the answer. His Orientation about how to approach MCQs with latest patterns proposed for national Eligibility Entrance Test is an important aspect of his session.



Dr. Akhil Monga

MD Radiodiagnosis, AIIMS, New Delhi cleared his AIIMS PGMEE in November 2015. It was the exam that saw the introduction of the image based questions. He proved then, that as long as you have strong concepts and have strong hold on the commonly asked topics, you shall not be surprised by any new element in the exam. Ever since he has been actively following the exam pattern and developing intuitive study material for the online platform "MedMiracle". Now, with the introduction of the seven pattern of questions in the AIIMS entrance exam, he along with Dr. Vishnu Prasad has come up with this book to emphasize that though practising new MCQs and understanding the scoring pattern of these questions is important, the subject matter needed to do a focussed revision is still similar. The goal is to reduce the "last month anxiety" of revising 19 subjects before the exam.



Dr. Vishnu Prasad

I did my MBBS from AIIMS, new delhi. Secured rank 2 in AIIMS PG entrance in first attempt. Currently pursuing MD in radiodiagnosis, AIIMS, New Delhi.

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