BIO506 –

BIOCHEMISTRY II

FINAL TERM IMPORTANT QUESTIONS

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1. How GAG synthesis is linked to ECM signaling?

Glycosaminoglycan (GAG) synthesis is linked to extracellular matrix (ECM) signaling because GAGs regulate the availability and activity of signaling molecules within the ECM. During their synthesis, specific sulfation patterns are introduced that determine the ability of GAGs to bind growth factors, cytokines, and morphogens. By sequestering these ligands, GAGs control their local concentration, gradient formation, and duration of signaling.

GAG-containing proteoglycans also act as co-receptors, facilitating interactions between growth factors and their cell-surface receptors, thereby enhancing downstream signaling pathways. In addition, GAGs influence the mechanical properties of the ECM, affecting mechanotransduction and cell behavior. Thus, changes in GAG synthesis directly modulate ECM-mediated cell signaling.

2. How GTP is linked to ATP in Kreb's cycle?

In the Krebs (TCA) cycle, GTP is directly linked to ATP through substrate-level phosphorylation. During the conversion of succinyl-CoA to succinate, catalyzed by succinyl-CoA synthetase, the energy released from the thioester bond of succinyl-CoA is used to form GTP (from GDP + Pi).

This GTP is energetically equivalent to ATP and is readily converted into ATP by the enzyme nucleoside diphosphate kinase, which transfers the phosphate group from GTP to ADP, yielding ATP and GDP. Thus, GTP formation in the Krebs cycle contributes directly to the cellular ATP pool.

3. What are cell signaling modes?

Cell signaling modes are the different ways by which cells communicate with each other to coordinate physiological functions. The main modes include:

- ***Autocrine signaling:*** A cell releases signaling molecules that act on receptors of the same cell, helping regulate its own activity.
- ***Paracrine signaling:*** Signaling molecules act on nearby neighboring cells; this is common in tissue-level regulation.
- ***Endocrine signaling:*** Hormones are released into the bloodstream and act on distant target cells.
- ***Juxtacrine (contact-dependent) signaling:*** Signal transmission requires direct cell–cell contact, often involving membrane-bound ligands and receptors.
- ***Synaptic signaling:*** Specialized form of signaling in neurons, where neurotransmitters are released across synapses to target cells.

4. What are competitive enzymes?

"Competitive enzymes" usually refers to competitive inhibition in enzyme kinetics. In this case, a competitive inhibitor competes with the substrate for binding at the enzyme's active site because it has a similar structure to the substrate.

When the inhibitor occupies the active site, the substrate cannot bind, so enzyme activity decreases. This inhibition can be overcome by increasing the substrate concentration, which outcompetes the inhibitor. Competitive inhibition increases the apparent Km but does not change the Vmax of the enzyme.

5. Define competitive and non-competitive inhibitors in high substrate.

Competitive inhibitors:

At high substrate concentration, competitive inhibition is overcome because the substrate outcompetes the inhibitor for the active site. As a result, enzyme activity approaches normal maximum velocity (Vmax remains unchanged).

Non-competitive inhibitors:

At high substrate concentration, non-competitive inhibition cannot be overcome because the inhibitor binds to a site other than the active site. Even with excess substrate, enzyme activity remains reduced, leading to a decreased Vmax.

6. What are allosteric molecules? Name any two.

Allosteric molecules are regulatory compounds that bind to a site on an enzyme other than the active site (the allosteric site) and induce a conformational change, thereby increasing or decreasing enzyme activity. ***Examples***: **ATP** and **citrate**.

7. Define glucogenesis and name three non-carboxylic sources of glucogenesis.

Gluconeogenesis is the metabolic process by which glucose is synthesized from non-carbohydrate precursors, mainly in the liver (and to some extent in the kidney), especially during fasting. Non-carbohydrate (non-carboxylic) sources of gluconeogenesis: Glycerol, glucogenic amino acids (e.g., alanine), and lactate.

8. What adaptations are made in C4 plants for photosynthesis?

C_4 plants show structural and biochemical adaptations to minimize photorespiration and increase photosynthetic efficiency. They exhibit Kranz anatomy, where vascular bundles are surrounded by bundle sheath cells, which in turn are encircled by mesophyll cells. CO_2 is initially fixed in mesophyll cells by PEP carboxylase into a four-carbon compound (oxaloacetate), which is converted to malate or aspartate. These C_4 acids are transported to bundle sheath cells, where CO_2 is released and refixed by RuBisCO via the Calvin cycle. This spatial separation maintains a high CO_2 concentration around RuBisCO, reduces photorespiration, and allows efficient photosynthesis under high light intensity, high temperature, and low CO_2 conditions.

9. What role GAG nucleotide plays in sugar role?

GAG nucleotides (also called activated sugar nucleotides, e.g., UDP-glucuronic acid, UDP-galactose) act as donors of sugar residues during glycosaminoglycan (GAG) synthesis. Each nucleotide-sugar carries a specific sugar in an activated form, which is enzymatically transferred to the growing GAG chain by glycosyltransferases. Without these nucleotide sugars, the sequential addition of monosaccharides to form GAGs (like heparan sulfate, chondroitin sulfate) would not occur. In short, GAG nucleotides provide both the energy and specificity for sugar incorporation into GAG chains.

10. High ACM levels in glycolysis affect in metabolism. How?

High acetyl-CoA (ACM) levels in glycolysis act as a key metabolic regulator by signaling that energy and biosynthetic precursors are abundant. Their effects include:

1. ***Inhibition of pyruvate dehydrogenase (PDH):*** High acetyl-CoA prevents conversion of pyruvate to acetyl-CoA, slowing glycolysis-derived entry into the TCA cycle.
2. ***Activation of gluconeogenesis:*** Excess acetyl-CoA promotes pyruvate carboxylase activity, converting pyruvate to oxaloacetate for glucose synthesis.
3. ***Feedback on glycolysis:*** High acetyl-CoA indirectly inhibits glycolysis by signaling energy sufficiency, reducing flux through the pathway.

11. Write role of inner mitochondrial membrane.

The inner mitochondrial membrane (IMM) plays a central role in energy metabolism and cellular respiration. Its key functions include:

1. ***Hosting the electron transport chain (ETC):*** The IMM contains complexes I–IV and mobile carriers that transfer electrons from NADH and $FADH_2$ to oxygen.
2. ***Establishing the proton gradient:*** As electrons move through the ETC, protons are pumped from the matrix into the intermembrane space, creating an electrochemical gradient.
3. ***ATP synthesis:*** The IMM houses ATP synthase, which uses the proton gradient to convert ADP + Pi into ATP (oxidative phosphorylation).
4. ***Selective transport:*** Specialized transporters in the IMM regulate the import/export of metabolites, ions, and cofactors between the matrix and cytosol.
5. ***Maintaining membrane potential:*** Its impermeability to ions ensures proper mitochondrial membrane potential, crucial for energy production.

12. What are effects of GAG synthesis?

The effects of GAG (glycosaminoglycan) synthesis are broad because GAGs are key components of the extracellular matrix (ECM) and cell surfaces. Major effects include:

1. ***ECM structure and hydration:*** GAGs attract water due to their negative charge, maintaining ECM turgidity and elasticity.
2. ***Cell signaling regulation:*** GAGs bind growth factors, cytokines, and morphogens, modulating their availability and activity.
3. ***Cell adhesion and migration:*** Proteoglycans with GAG chains influence how cells attach to and move through the ECM.
4. ***Tissue development and repair:*** Proper GAG synthesis is essential for organ morphogenesis, wound healing, and tissue remodeling.
5. ***Mechanical properties:*** GAGs contribute to ECM stiffness and viscoelasticity, affecting mechanotransduction.
6. ***Disease modulation:*** Abnormal GAG synthesis can lead to fibrosis, cancer progression, or metabolic disorders.

13. Write role of enzyme complex.

An enzyme complex is a group of enzymes that work together to carry out a series of biochemical reactions efficiently. Its key roles include:

1. ***Channeling substrates:*** Intermediates are passed directly from one enzyme to the next, reducing diffusion loss and increasing reaction speed.
2. ***Coordinating reactions:*** Multiple steps of a metabolic pathway are tightly regulated and synchronized within the complex.
3. ***Increasing efficiency:*** Proximity of enzymes minimizes the time and energy required for substrate conversion.
4. ***Regulation:*** The complex can be allosterically regulated as a unit, allowing coordinated control of the pathway.
5. ***Stability:*** Complex formation can stabilize individual enzymes and protect intermediates from degradation.

Examples: Pyruvate dehydrogenase complex, α-ketoglutarate dehydrogenase complex.

14. Define gluconeogenesis and name non-carbohydrate precursor.

Gluconeogenesis is the metabolic process by which glucose is synthesized from non-carbohydrate precursors, mainly in the liver and kidney, especially during fasting or low-carbohydrate intake.

Non-carbohydrate precursors: Lactate, glycerol, and glucogenic amino acids (e.g., alanine).

15. Define Catabolism and Anabolism.

Catabolism: The set of metabolic processes that break down complex molecules (like carbohydrates, fats, and proteins) into simpler ones, releasing energy (ATP) in the process. Example: glycolysis, fatty acid oxidation.

Anabolism: The set of metabolic processes that build complex molecules from simpler ones, requiring energy (ATP or NADPH). Example: protein synthesis, glycogen formation.

16. Define Hexokinase and Glucokinase.

Hexokinase: An enzyme that catalyzes the phosphorylation of glucose to glucose-6-phosphate (G6P) in most tissues. It has low Km (high affinity) for glucose, works at low glucose concentrations, and is inhibited by its product G6P.

Glucokinase: A liver- and pancreatic β-cell-specific isoform of hexokinase that also converts glucose to G6P. It has high Km (low affinity), is active only at high glucose levels, and is not inhibited by G6P, allowing the liver to store excess glucose as glycogen.

17. How C4 plant is better than C3 plant?

C_4 plants are more efficient than C_3 plants under high light, high temperature, and low CO_2 conditions because of their specialized adaptations:

1. ***Reduced photorespiration:*** CO_2 is first fixed into a 4-carbon compound in mesophyll cells and then released in bundle sheath cells, maintaining high CO_2 around RuBisCO.
2. ***Higher photosynthetic efficiency:*** Minimizing photorespiration allows more carbon to be fixed per unit of water and energy.
3. ***Better water use efficiency:*** C_4 plants can keep stomata partially closed, reducing water loss while still fixing CO_2 efficiently.
4. ***Adapted to harsh environments:*** They thrive in tropical, arid, or saline conditions where C_3 plants would lose efficiency.

18. Write agricultural importance of photorespiration.

The agricultural importance of photorespiration includes:

1. ***Protects plants under stress:*** Photorespiration helps dissipate excess light energy, preventing damage to chloroplasts under high light or drought.
2. ***Maintains metabolic balance:*** It recycles 2-phosphoglycolate into useful intermediates, preventing toxic accumulation.
3. ***Supports nitrogen metabolism:*** Photorespiration produces ammonia, which can be reassimilated, linking carbon and nitrogen metabolism.
4. ***Influences crop improvement:*** Understanding photorespiration allows breeding or engineering of crops (like C_4 or CAM plants) with higher productivity and stress tolerance.

19. Define with examples, cofactors and coenzymes.

Cofactors: Non-protein chemical compounds or ions that are required for an enzyme's activity. They can be inorganic (metal ions) or organic. ***Example*****:** Mg^{2+} for DNA polymerase, Zn^{2+} for carbonic anhydrase.

Coenzymes: Organic cofactors, often derived from vitamins, that bind temporarily or permanently to enzymes to help in catalysis, usually by carrying chemical groups or electrons. ***Example*****:** NAD^+ (from niacin) in dehydrogenase reactions, FAD (from riboflavin) in oxidation reactions.

20. Write names of 4 fermented products with microbes involved.

1. **Yogurt** – *Lactobacillus bulgaricus* and *Streptococcus thermophilus*
2. **Cheese** – *Lactococcus lactis* and *Penicillium* species (for some types)
3. **Alcoholic beverages (beer, wine)** – *Saccharomyces cerevisiae*
4. **Sauerkraut (fermented cabbage)** – *Leuconostoc mesenteroides* and *Lactobacillus plantarum*

21. What are defects of glycoprotein?

Defects of glycoproteins arise when glycosylation is abnormal or when glycoproteins are dysfunctional. Major consequences include:

1. ***Congenital disorders of glycosylation (CDG):*** Genetic defects in glycoprotein synthesis enzymes, leading to developmental delays, hypotonia, liver dysfunction, and coagulation problems.
2. ***Immune system defects:*** Improperly glycosylated antibodies or receptors can impair immune responses.
3. ***Hormonal and enzyme dysfunction:*** Many hormones and enzymes are glycoproteins; defects can disrupt signaling and metabolism.
4. ***Cell adhesion and signaling abnormalities:*** Defective glycoproteins on the cell surface can impair tissue formation, wound healing, and communication.
5. ***Neurological defects:*** Abnormal glycoproteins in the nervous system can lead to intellectual disability and neuropathies.

22. Write role of enzymes for complex enzyme system (such as pyruvate enzyme).

The role of enzymes in a complex enzyme system—like the pyruvate dehydrogenase complex (PDC)—is to work together to efficiently convert a substrate through multiple steps while channeling intermediates. For the pyruvate dehydrogenase complex, which converts pyruvate → acetyl-CoA, the roles are:

1. ***Pyruvate dehydrogenase (E1):*** Decarboxylates pyruvate, releasing CO_2 and forming hydroxyethyl-TPP.
2. ***Dihydrolipoamide acetyltransferase (E2):*** Transfers the acetyl group to CoA, forming acetyl-CoA.
3. ***Dihydrolipoamide dehydrogenase (E3):*** Regenerates the oxidized lipoamide cofactor by transferring electrons to NAD^+, forming NADH.

Key roles of the complex system:

- ***Substrate channeling:*** Intermediates are passed directly between enzymes, increasing speed and preventing side reactions.
- ***Coordination:*** Multiple steps occur in a synchronized manner.
- ***Regulation:*** The complex is allosterically regulated as a unit (e.g., by ATP, NADH, acetyl-CoA).

23. How to regulate glycolysis in reaction?

Glycolysis is regulated at key irreversible steps by allosteric effectors and energy status of the cell. The main regulatory points are:

1. **Hexokinase / Glucokinase (Step 1: Glucose → Glucose-6-phosphate):**
    - Inhibited by G6P (feedback inhibition).
    - Glucokinase in liver is regulated by **glucose levels** and glucokinase regulatory protein.
2. **Phosphofructokinase-1 (PFK-1, Step 3: F6P → F1,6BP):**
    - Activated by AMP, ADP, fructose-2,6-bisphosphate.
    - Inhibited by ATP, citrate (signals high energy).
3. **Pyruvate kinase (Step 10: PEP → Pyruvate):**
    - Activated by fructose-1,6-bisphosphate (feed-forward activation).
    - Inhibited by ATP, alanine, and by phosphorylation in liver (hormonal control).

Additional regulation:

- Hormones like insulin (stimulates glycolysis) and glucagon (inhibits glycolysis in liver).
- Substrate availability (glucose, NAD^+) also affects glycolytic flux.

24. How pancreatic enzymes work to digest lipids?

Pancreatic enzymes digest lipids by hydrolyzing triglycerides, phospholipids, and cholesterol esters in the small intestine. Bile salts emulsify large fat droplets into micelles, increasing the surface area for enzyme action. Pancreatic lipase, aided by colipase, breaks triglycerides into monoglycerides and free fatty acids. Phospholipase A_2 hydrolyzes phospholipids, and cholesterol esterase converts cholesterol esters into free cholesterol and fatty acids. The resulting products form micelles for absorption into the intestinal mucosa.

25. Define physical properties and how they relate to function?

Physical properties are measurable characteristics of a molecule or material, such as size, shape, charge, hydrophobicity, and solubility. These properties directly influence biological function. For example, the shape and charge of an enzyme determine substrate binding, hydrophobic regions allow membrane integration, and solubility affects transport in the cell. Essentially, a molecule's physical traits dictate how it interacts, moves, and performs its role in biological systems.

26. Explain that TCA coordination with gluconeogenesis help in fasting.

During fasting, the TCA cycle (Krebs cycle) and gluconeogenesis coordinate to maintain blood glucose and energy supply. Pyruvate and other substrates from amino acid and lactate breakdown enter the TCA cycle, generating intermediates like oxaloacetate. Oxaloacetate can be diverted from the TCA cycle to gluconeogenesis to produce glucose for tissues like the brain and red blood cells. At the same time, acetyl-CoA from fatty acid oxidation accumulates and inhibits pyruvate dehydrogenase, preventing pyruvate from entering the TCA cycle, which ensures more substrates are available for glucose synthesis. This coordination balances energy production and glucose supply during fasting.

27. Why ATP is the universal energy for molecules?

ATP is the universal energy currency because its structure allows easy storage and release of energy. The high-energy phosphate bonds (especially the terminal phosphate) can be hydrolyzed to release energy efficiently, which cells use to drive endergonic reactions. ATP is small, soluble, and can diffuse rapidly within the cell, linking energy-producing pathways (like glycolysis and the TCA cycle) to energy-consuming processes (like biosynthesis, transport, and muscle contraction). Its versatility, rapid turnover, and ability to couple with enzymes make it the universal energy molecule in all living organisms.

28. Name three major dietary lipids.

Three major dietary lipids are triglycerides, phospholipids, and cholesterol.

29. Name three cellular processes that require direct ATP.

Three cellular processes that require direct ATP are muscle contraction, active transport across membranes, and protein synthesis.

30. Write role of Lactate in cori cycle.

In the Cori cycle, lactate produced by anaerobic glycolysis in muscles is transported to the liver, where it is converted back into glucose via gluconeogenesis. This glucose is then released into the bloodstream to supply energy to muscles, allowing continued ATP production during intense exercise. Lactate thus acts as a shuttle for carbon and energy between muscles and liver.

31. What is the process of ATP in lipids digestion?

ATP is not directly used to break down lipids, but it plays an indirect role in lipid digestion and absorption. Pancreatic enzymes like lipase hydrolyze triglycerides into fatty acids and monoglycerides without ATP. However, ATP is required for: the secretion of digestive enzymes and bile, the active transport of absorbed fatty acids and monoglycerides into intestinal cells, and the re-esterification of lipids into triglycerides for chylomicron formation. Thus, ATP provides the energy for the cellular processes that enable lipid digestion and absorption, rather than the chemical hydrolysis itself.

32. What is the function of glycopolypeptides?

Glycopolypeptides are proteins with covalently attached carbohydrate chains. Their main functions include cell–cell recognition, signaling, and adhesion, stabilizing protein structure, and protecting cells from degradation. They are also important in immune responses, as in glycoprotein antigens, and in forming the extracellular matrix, where they help regulate tissue structure and interactions.

33. Define function of coenzyme in glycogenesis.

Function of coenzyme in glycogenesis:

- Coenzymes act as activators or carriers of sugar units for glycogen synthesis.
- UDP-glucose (uridine diphosphate glucose) serves as a coenzyme, donating glucose residues to the growing glycogen chain.
- They ensure specificity and energy supply for the enzymatic reaction catalyzed by glycogen synthase.
- Coenzymes help regulate the rate of glycogen formation in response to cellular energy needs.

34. What is the role of fermentation in preservation of food?

Role of fermentation in food preservation:

- Produces organic acids (like lactic acid) that lower pH, inhibiting growth of spoilage and pathogenic microbes.
- Generates alcohol and other antimicrobial compounds that prevent microbial contamination.
- Creates anaerobic conditions in the food, reducing oxidative spoilage.
- Enhances shelf life while improving flavor, texture, and nutritional value.

35. Write role of glycolysis in Liver, Brain and Muscles.

Role of glycolysis in different tissues:

- ***Liver:*** Produces ATP for liver functions and provides intermediates for gluconeogenesis and glycogen synthesis.
- ***Brain:*** Main source of rapid ATP, as the brain depends heavily on glucose for energy.
- ***Muscles:*** Generates ATP for contraction, especially during intense exercise, and produces lactate under anaerobic conditions for the Cori cycle.

36. Write role of ATP in Electron Transport Motive Force.

Role of ATP in electron transport and proton motive force (PMF):

- ATP itself is not directly involved in creating the PMF, but it is the end product generated by the PMF.
- The electron transport chain (ETC) pumps protons across the inner mitochondrial membrane, creating a proton gradient (PMF).
- ATP synthase uses this proton motive force to phosphorylate ADP into ATP.
- ATP production stores the energy derived from electron transfer in a usable form for cellular processes.

37. What do you know about the enzyme specificity?

Enzyme specificity refers to the ability of an enzyme to selectively bind and act on a particular substrate or type of reaction.

- Determined by the shape and chemical properties of the enzyme's active site.
- Ensures that enzymes catalyze specific reactions without affecting unrelated molecules.
- Types of specificity:
    - ***Absolute specificity:*** enzyme acts on a single substrate (e.g., urease acts only on urea).
    - ***Group specificity:*** enzyme acts on molecules with a specific functional group (e.g., hexokinase acts on hexoses).
    - ***Stereospecificity:*** enzyme acts on a specific isomer (e.g., L-amino acids in transaminases).
- Specificity is crucial for metabolic regulation and efficiency.

38. Define ethanol fermentation.

Ethanol fermentation is an anaerobic metabolic process in which glucose or other sugars are converted into ethanol and carbon dioxide, producing a small amount of ATP.

- Catalyzed mainly by yeast (*Saccharomyces cerevisiae***)** and some bacteria.
- Involves two key steps: pyruvate decarboxylation to acetaldehyde, followed by reduction of acetaldehyde to ethanol using NADH.
- Provides energy under oxygen-limited conditions and is widely used in alcoholic beverages and biofuel production.

39. What are defects of GAGs that effect matrix?

Defects of GAGs affecting the extracellular matrix (ECM):

- ***Reduced ECM integrity:*** Abnormal GAG synthesis weakens tissue structure, causing fragile cartilage, skin, or connective tissue.
- ***Impaired hydration and elasticity:*** GAGs normally attract water; defects lead to stiff or poorly hydrated ECM.
- ***Altered cell signaling:*** Abnormal GAG chains disrupt growth factor binding, affecting cell proliferation and differentiation.
- ***Skeletal and organ abnormalities:*** Seen in mucopolysaccharidoses, where defective GAG degradation leads to ECM accumulation and organ dysfunction.
- ***Delayed wound healing and tissue repair:*** Poor ECM remodeling due to defective GAGs slows regeneration.

40. What is Oxidative Pyrophospholaytion Retrograde?

Oxidative phosphorylation retrograde signaling is a cellular communication pathway where mitochondria send signals to the nucleus in response to changes in mitochondrial function or stress.

- When the electron transport chain or ATP production is impaired, mitochondria generate signals (like ROS, altered NAD^+/NADH ratio, or calcium flux).
- These signals modify nuclear gene expression, adjusting metabolism, stress responses, or mitochondrial biogenesis.
- It ensures coordination between energy production and cellular demands, maintaining metabolic balance and cell survival.

41. What are lipid dietary sources?

Dietary sources of lipids:

- ***Fats and oils:*** Butter, ghee, olive oil, sunflower oil, canola oil.
- ***Animal products:*** Meat, fish, eggs, milk, cheese.
- ***Nuts and seeds:*** Almonds, walnuts, flaxseeds, chia seeds.
- ***Avocados and coconut:*** Rich in healthy fats.
- ***Processed foods:*** Margarine, baked goods, and fried foods (contain added fats).