1. **What is an acid and base?**
   An acid is a substance that donates protons (H^+ ions) when dissolved in water, lowering the pH of the solution. Examples include hydrochloric acid (HCl) and sulfuric acid (H_2SO_4).
   A base is a substance that accepts protons or donates hydroxide ions (OH^-) in solution, increasing the pH. Examples include sodium hydroxide (NaOH) and potassium hydroxide (KOH).
2. **Define pH.**
   pH is a measure of hydrogen ion concentration in a solution, expressed as the negative logarithm of the H^+ concentration. A pH of 7 is neutral, below 7 is acidic, and above 7 is basic.
3. **What is a buffer?**
   A buffer is a solution that resists changes in pH when small amounts of acid or base are added. It typically consists of a weak acid and its conjugate base or a weak base and its conjugate acid.
4. **Explain the role of buffers in the human body.**
   Buffers in the human body, such as the bicarbonate buffer system, maintain stable pH levels in blood and tissues, essential for proper enzymatic function and metabolic processes.
5. **How does the Henderson-Hasselbalch equation help in physiology?**
   The equation is used to calculate the pH of buffer solutions, critical in understanding acid-base balance in blood, particularly in clinical settings like assessing respiratory or metabolic acidosis.
6. **What is the bicarbonate buffer system?**
   The bicarbonate buffer system is a major buffer in the blood, consisting of carbonic acid (H_2CO_3) and bicarbonate (HCO_3^-). It helps maintain blood pH around 7.4.
7. **How does the bicarbonate buffer system respond to acidosis?**
   In acidosis, excess H^+ ions combine with bicarbonate to form carbonic acid, which dissociates into water and carbon dioxide, reducing acidity and stabilizing pH.
8. **What happens during alkalosis in the bicarbonate buffer system?**
   During alkalosis, bicarbonate ions decrease, and carbonic acid dissociates to release H^+, thereby lowering pH back towards normal levels.
9. **Define metabolic acidosis and alkalosis?**
   Metabolic acidosis is a condition where there is an accumulation of acid or loss of bicarbonate in the body, leading to a decrease in blood pH.
   Metabolic alkalosis occurs when there is an excessive loss of acid or gain of bicarbonate, resulting in an increase in blood pH.
10. **How does the respiratory system compensate for metabolic acidosis and metabolic alkalosis??**
    In metabolic acidosis, the respiratory system increases the breathing rate to expel more

CO_2, reducing carbonic acid levels and increasing pH.
In metabolic alkalosis, the respiratory system slows down breathing, retaining CO_2, which increases carbonic acid and lowers pH.

11. **What is respiratory acidosis and alkalosis?**
Respiratory acidosis occurs when CO_2 builds up due to inadequate ventilation, leading to increased carbonic acid and decreased blood pH.
Respiratory alkalosis is caused by hyperventilation, where excessive CO_2 is exhaled, leading to decreased carbonic acid and increased blood pH.
12. **How does the kidney respond to acidosis?**
The kidneys respond to acidosis by excreting more H^+ ions and reabsorbing bicarbonate to neutralize the excess acid and stabilize pH.
13. **What is the renal response to alkalosis?**
In alkalosis, the kidneys excrete more bicarbonate and retain H^+ ions to lower blood pH back to normal.
14. **What is the importance of the carbonic acid-bicarbonate buffer system in the lungs?**
In the lungs, the carbonic acid-bicarbonate buffer system allows for the rapid conversion of CO_2 and water into carbonic acid, which dissociates into H^+ and bicarbonate, aiding in CO_2 exhalation and pH regulation.
15. **Explain the concept of pKa in relation to acids.**
pKa is the pH at which an acid is half dissociated, meaning equal concentrations of the acid and its conjugate base. It helps determine the acid's strength and buffer capacity.
16. **How is the Henderson-Hasselbalch equation derived?**
The Henderson-Hasselbalch equation is derived from the acid dissociation constant (Ka) expression by taking the logarithm of both sides, leading to the formula $pH = pKa + \log([A^-]/[HA])$.
17. **Why is blood pH tightly regulated?**
Blood pH is tightly regulated between 7.35-7.45 to ensure proper enzyme function, oxygen transport, and metabolic processes, with deviations leading to potentially life-threatening conditions.
18. **How do proteins act as buffers?**
Proteins, such as hemoglobin, act as buffers by accepting or donating H^+ ions through their amino acid residues, helping to stabilize pH in blood and tissues.
19. **What is the role of phosphate buffers in the body?**
Phosphate buffers, consisting of dihydrogen phosphate ($H_2PO_4^-$) and hydrogen phosphate (HPO_4^{2-}), regulate intracellular pH and are crucial in kidney function.
20. **How does hemoglobin contribute to acid-base balance?**
Hemoglobin buffers H^+ ions produced during CO_2 transport from tissues to the lungs, preventing significant pH changes in the blood.
21. **Explain the classification of carbohydrates.**

Carbohydrates are classified based on the number of sugar units they contain: **monosaccharides** (single sugar units, e.g., glucose), **disaccharides** (two sugar units, e.g., sucrose), **oligosaccharides** (3-10 sugar units, e.g., raffinose), and **polysaccharides** (more than 10 sugar units, e.g., starch and glycogen). Monosaccharides are the simplest form, serving as building blocks for more complex carbohydrates. Disaccharides form by the condensation of two monosaccharides. Oligosaccharides and polysaccharides are complex carbohydrates, with polysaccharides serving roles in energy storage (e.g., starch) and structural functions (e.g., cellulose).

22. **What are monosaccharides, and why are they important?**

Monosaccharides are the simplest form of carbohydrates, consisting of a single sugar unit. Examples include glucose, fructose, and galactose. They are crucial as they are the primary source of energy for cells, especially glucose, which is vital for cellular respiration. Monosaccharides also serve as building blocks for more complex carbohydrates like disaccharides and polysaccharides. In metabolic pathways, monosaccharides are involved in glycolysis and the TCA cycle, providing ATP, the energy currency of the cell.

23. **Describe the structure and function of disaccharides.**

Disaccharides are carbohydrates composed of two monosaccharide molecules linked by a glycosidic bond. Common examples include sucrose (glucose + fructose), lactose (glucose + galactose), and maltose (glucose + glucose). They function as an energy source, as they can be broken down into their monosaccharide components during digestion. Disaccharides also play roles in plant and animal metabolism, with sucrose serving as a transport form of carbohydrates in plants, and lactose being crucial in mammalian milk.

24. What are oligosaccharides and their biological significance?

Oligosaccharides are carbohydrates that consist of 3-10 monosaccharide units. They are less common than monosaccharides and polysaccharides and often found attached to proteins and lipids on the cell surface, forming glycoproteins and glycolipids. These structures play key roles in cell recognition, signaling, and immune responses. In addition, oligosaccharides can serve as prebiotics, promoting the growth of beneficial gut bacteria, thereby contributing to gut health and overall well-being.

25. Explain the structure and function of polysaccharides.

Polysaccharides are large, complex carbohydrates made up of more than 10 monosaccharide units. They can be either linear (e.g., cellulose) or branched (e.g., glycogen). Polysaccharides serve various functions, including energy storage (e.g., starch in plants, glycogen in animals) and providing structural support (e.g., cellulose in plant cell walls). They are crucial for maintaining energy balance and cellular structure in living organisms. Some polysaccharides, like chitin, also play protective roles in certain organisms.

26. Outline the key steps of glycolysis.

Glycolysis is a ten-step metabolic pathway that converts glucose into pyruvate, producing ATP and NADH in the process. It begins with glucose phosphorylation and ends with the formation of pyruvate. Key steps include the conversion of glucose to fructose-1,6-bisphosphate, its cleavage into two three-carbon molecules, and subsequent steps that generate ATP and NADH. Glycolysis occurs in the cytoplasm and is crucial for energy production, especially under anaerobic conditions.

27. Describe the importance of glycolysis in metabolism.

Glycolysis is a central metabolic pathway that breaks down glucose into pyruvate, yielding ATP and NADH, which are vital for cellular energy. It occurs in the cytoplasm and is the first step in both aerobic and anaerobic respiration. Glycolysis is essential because it provides quick energy, especially when oxygen levels are low, and intermediates for other metabolic pathways. Additionally, glycolysis is a universal pathway found in nearly all living organisms, emphasizing its evolutionary importance.

28. What is the TCA cycle, and where does it occur?

The TCA (tricarboxylic acid) cycle, also known as the Krebs cycle or citric acid cycle, is a series of enzymatic reactions that occur in the mitochondria of cells. It plays a key role in cellular respiration by oxidizing acetyl-CoA to carbon dioxide and generating high-energy molecules: NADH, FADH2, and ATP. These molecules are then used in the electron transport chain to produce further ATP. The TCA cycle is essential for energy production and provides intermediates for various biosynthetic pathways.

29. Explain the role of the TCA cycle in energy production.

The TCA cycle is crucial for energy production in aerobic organisms. It oxidizes acetyl-CoA, derived from carbohydrates, fats, and proteins, to carbon dioxide. This process generates NADH and FADH2, which carry electrons to the electron transport chain, where ATP is produced through oxidative phosphorylation. The TCA cycle also provides metabolic intermediates for biosynthetic processes, making it a central hub in cellular metabolism. Its efficiency in generating energy is vital for the survival and function of cells.

30. How do glycolysis and the TCA cycle connect?

Glycolysis and the TCA cycle are interconnected metabolic pathways. Glycolysis occurs in the cytoplasm, breaking down glucose into pyruvate, which is then transported into the mitochondria. In the mitochondria, pyruvate is converted into acetyl-CoA, which enters the TCA cycle. The TCA cycle then oxidizes acetyl-CoA, producing NADH and FADH2, which are used in the electron transport chain to generate ATP. This connection is crucial for efficient energy production and the integration of various metabolic pathways.

31. What are simple lipids, and what are their roles?

Simple lipids, such as triglycerides (fats and oils), consist of fatty acids esterified to glycerol. They are the most abundant form of lipids and serve as a major energy storage form in animals and plants. When metabolized, they provide more than twice the energy of carbohydrates or proteins. Simple lipids also play a role in insulating and protecting organs, as well as being precursors for signaling molecules like hormones.

32. **Describe the structure and function of compound lipids.**
    Compound lipids, such as phospholipids and glycolipids, consist of fatty acids, glycerol, and additional groups like phosphate or carbohydrates. Phospholipids, for instance, have a phosphate group attached to the glycerol backbone, forming a hydrophilic head and hydrophobic tail. This structure makes them essential components of cell membranes, where they provide structural integrity and are involved in signaling pathways. Glycolipids, with their carbohydrate groups, are important for cell recognition and signaling.

33. **What are derived lipids, and how are they formed?**
    Derived lipids are substances obtained from the hydrolysis of simple and compound lipids. They include fatty acids, glycerol, steroids, and fat-soluble vitamins (A, D, E, K). These lipids play various roles in the body; for example, fatty acids are key energy sources, and steroids like cholesterol are vital components of cell membranes and precursors for hormones. Derived lipids are essential for maintaining cellular functions and overall metabolic health.

34. **Explain the significance of triglycerides in energy metabolism.**
    Triglycerides are the primary form of stored energy in the body, consisting of three fatty acids attached to a glycerol molecule. They are stored in adipose tissue and can be mobilized during periods of energy demand. When broken down through lipolysis, triglycerides release fatty acids, which are oxidized in the mitochondria to generate ATP via beta-oxidation and the TCA cycle. This process provides a significant amount of energy, especially during prolonged exercise or fasting.

35. **What role do phospholipids play in cellular structure?**
    Phospholipids are crucial components of cell membranes, forming the lipid bilayer that acts as a barrier and platform for cellular functions. They have hydrophilic heads and hydrophobic tails, allowing them to form bilayers with the tails facing inward and heads facing outward. This structure is essential for maintaining cell integrity, regulating the passage of substances in and out of cells, and providing a fluid matrix for membrane proteins involved in signaling and transport.

36. **How are glycolipids involved in cell recognition?**
    Glycolipids are lipids with carbohydrate groups attached, found on the extracellular surface of cell membranes. They play a key role in cell recognition, communication, and adhesion. The carbohydrate portion of glycolipids can interact with specific receptors on other cells, facilitating cell-cell interactions and immune responses. For example, blood group antigens are glycolipids that determine blood type and are involved in the immune response during blood transfusions.

37. **Describe the process of beta-oxidation.**

Beta-oxidation is the metabolic process in which fatty acids are broken down in the mitochondria to generate acetyl-CoA, NADH, and FADH2. The process involves the sequential removal of two-carbon units from the fatty acid chain, which are converted to acetyl-CoA. Acetyl-CoA then enters the TCA cycle for further energy production. Beta-oxidation is crucial for the utilization of fatty acids as an energy source, especially during periods of fasting or prolonged exercise.

38. **What is the importance of cholesterol in the body?**
    Cholesterol is a vital lipid molecule that plays several important roles in the body. It is a key component of cell membranes, providing structural stability and fluidity. Cholesterol also serves as a precursor for the synthesis of steroid hormones (e.g., estrogen, testosterone), bile acids, and vitamin D. While essential for normal physiological functions, excessive cholesterol levels can lead to atherosclerosis and cardiovascular diseases, making its regulation crucial for health.
39. **How are lipids involved in signaling pathways?**
    Lipids play a significant role in cellular signaling pathways. For instance, phospholipids can be hydrolyzed to produce secondary messengers like diacylglycerol (DAG) and inositol triphosphate (IP3), which are involved in intracellular signaling cascades. Steroid hormones, derived from cholesterol, act as signaling molecules that regulate gene expression and various physiological processes, such as metabolism, immune response, and reproduction. Lipid-based signaling is essential for maintaining cellular communication and homeostasis.
40. **What is the role of lipoproteins in lipid transport?**
    Lipoproteins are complexes of lipids and proteins that transport lipids through the bloodstream. They are classified into several types, including chylomicrons, very-low-density lipoproteins (VLDL), low-density lipoproteins (LDL), and high-density lipoproteins (HDL), based on their density and composition. Lipoproteins carry triglycerides, cholesterol, and other lipids to tissues for energy utilization, storage, or cellular functions. HDL is often referred to as "good" cholesterol because it helps remove excess cholesterol from the bloodstream, reducing the risk of atherosclerosis.
41. **Explain the significance of essential fatty acids.**
    Essential fatty acids (EFAs) are polyunsaturated fatty acids that cannot be synthesized by the human body and must be obtained through the diet. The two primary EFAs are linoleic acid (omega-6) and alpha-linolenic acid (omega-3). They are vital for various physiological functions, including maintaining cell membrane structure, producing signaling molecules like eicosanoids, and supporting cardiovascular, immune, and neurological health. A deficiency in EFAs can lead to skin disorders, immune dysfunction, and other health issues.
42. **What is the electron transport chain, and where does it occur?**
    The electron transport chain (ETC) is a series of protein complexes located in the inner mitochondrial membrane. It is the final stage of cellular respiration, where electrons from

NADH and FADH2 are transferred through the complexes, ultimately reducing oxygen to water. The energy released during this electron transfer is used to pump protons across the membrane, creating a proton gradient. This gradient drives ATP synthesis through ATP synthase. The ETC is crucial for producing the majority of ATP in aerobic organisms.

43. **How does oxidative phosphorylation generate ATP?**
    Oxidative phosphorylation is the process by which ATP is generated as a result of the electron transport chain (ETC) in the mitochondria. As electrons pass through the ETC, protons are pumped across the inner mitochondrial membrane, creating an electrochemical gradient. This gradient generates potential energy, which is used by ATP synthase to phosphorylate ADP, forming ATP. Oxidative phosphorylation is the primary source of ATP in aerobic organisms, providing energy for various cellular processes.

44. **Describe the importance of ATP in cellular metabolism.**
    ATP (adenosine triphosphate) is the primary energy currency of the cell, providing the energy needed for various cellular processes, including muscle contraction, active transport, and biosynthesis. It is produced through cellular respiration, primarily during glycolysis, the TCA cycle, and oxidative phosphorylation. ATP releases energy when its phosphate bonds are hydrolyzed, converting it to ADP or AMP. The continuous regeneration of ATP is essential for sustaining life, as it powers nearly all cellular activities.