
Chapter 1 The Foundations of Biochemistry

Multiple Choice Questions

1. Cellular foundations

Pages: 3-4 Difficulty: 1 Ans: C

In a bacterial cell, the DNA is in the:

- A) cell envelope.
- B) cell membrane.
- C) nucleoid.
- D) nucleus.
- E) ribosomes.

2. Cellular foundations

Page: 4 Difficulty: 1 Ans: E

A major change occurring in the evolution of eukaryotes from prokaryotes was the development of:

- A) DNA.
- B) photosynthetic capability.
- C) plasma membranes.
- D) ribosomes.
- E) the nucleus.

3. Cellular foundations

Page: 4 Difficulty: 1 Ans: B

In eukaryotes, the nucleus is enclosed by a double membrane called the:

- A) cell membrane.
- B) nuclear envelope.
- C) nucleolus.
- D) nucleoplasm.
- E) nucleosome.

4. Cellular foundations

Page: 4 Difficulty: 1 Ans: C

The dimensions of living cells are limited, on the lower end by the minimum number of biomolecules necessary for function, and on the upper end by the rate of diffusion of solutes such as oxygen. Except for highly elongated cells, they usually have lengths and diameters in the range of:

- A) 0.1 μm to 10 μm .
- B) 0.3 μm to 30 μm .
- C) 0.3 μm to 100 μm .
- D) 1 μm to 100 μm .
- E) 1 μm to 300 μm .

5. Cellular foundations**Page: 5 Difficulty: 2 Ans: B**

The bacterium *E. coli* requires simple organic molecules for growth and energy—it is therefore a:

- A) chemoautotroph.
- B) chemoheterotroph.
- C) lithotroph.
- D) photoautotroph.
- E) photoheterotroph.

6. Cellular foundations**Page: 10 Difficulty: 2 Ans: B**

Which one of the following has the cellular components arranged in order of *increasing* size?

- A) Amino acid < protein < mitochondrion < ribosome
- B) Amino acid < protein < ribosome < mitochondrion
- C) Amino acid < ribosome < protein < mitochondrion
- D) Protein < amino acid < mitochondrion < ribosome
- E) Protein < ribosome < mitochondrion < amino acid

7. Cellular foundations**Page: 11 Difficulty: 2 Ans: A**

The three-dimensional structure of macromolecules is formed and maintained primarily through noncovalent interactions. Which one of the following is *not* considered a noncovalent interaction?

- A) carbon-carbon bonds
- B) hydrogen bonds
- C) hydrophobic interactions
- D) ionic interactions
- E) van der Waals interactions

8. Chemical foundations**Page: 12 Difficulty: 2 Ans: E**

Which one of the following is *not* among the four most abundant elements in living organisms?

- A) Carbon
- B) Hydrogen
- C) Nitrogen
- D) Oxygen
- E) Phosphorus

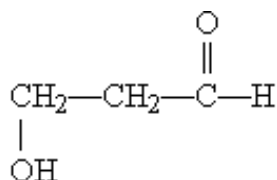
9. Chemical foundations**Page: 13 Difficulty: 1 Ans: B**

The four covalent bonds in methane (CH_4) are arranged around carbon to give which one of the following geometries?

- A) linear
- B) tetrahedral
- C) trigonal bipyramidal
- D) trigonal planar
- E) trigonal pyramidal

10. Chemical foundations**Page: 14 Difficulty: 1 Ans: B**

What functional groups are present on this molecule?



- A) ether and aldehyde
- B) hydroxyl and aldehyde
- C) hydroxyl and carboxylic acid
- D) hydroxyl and ester
- E) hydroxyl and ketone

11. Chemical foundations**Page: 16 Difficulty: 1 Ans: D**

The macromolecules that serve in the storage and transmission of genetic information are:

- A) carbohydrates.
- B) lipids.
- C) membranes.
- D) nucleic acids.
- E) proteins.

12. Chemical foundations**Page: 17 Difficulty: 1 Ans: D**

Stereoisomers that are nonsuperimposable mirror images of each other are known as:

- A) anomers.
- B) cis-trans isomers.
- C) diastereoisomers.
- D) enantiomers.
- E) geometric isomers.

13. Chemical foundations**Page: 20 Difficulty: 3 Ans: E**

The enzyme fumarase catalyzes the reversible hydration of fumaric acid to l-malate, but it will not catalyze the hydration of maleic acid, the cis isomer of fumaric acid. This is an example of:

- A) biological activity.
- B) chiral activity.
- C) racemization.
- D) stereoisomerization.
- E) stereospecificity.

14. Physical foundations**Pages: 21-22 Difficulty: 2 Ans: A**

Humans maintain a nearly constant level of hemoglobin by continually synthesizing and degrading it. This is an example of a(n):

- A) dynamic steady state.
- B) equilibrium state.
- C) exergonic change.
- D) free-energy change.
- E) waste of energy.

15. Physical foundations**Page: 23 Difficulty: 1 Ans: C**

If heat energy is absorbed by the system during a chemical reaction, the reaction is said to be:

- A) at equilibrium.
- B) endergonic.
- C) endothermic.
- D) exergonic.
- E) exothermic.

16. Physical foundations**Page: 23 Difficulty: 2 Ans: D**

If the free energy change ΔG for a reaction is -46.11 kJ/mol, the reaction is:

- A) at equilibrium.
- B) endergonic.
- C) endothermic.
- D) exergonic.
- E) exothermic.

17. Physical foundations**Page: 23 Difficulty: 2 Ans: C**

The major carrier of chemical energy in all cells is:

- A) acetyl triphosphate.
- B) adenosine monophosphate.
- C) adenosine triphosphate.
- D) cytosine tetraphosphate.
- E) uridine diphosphate.

18. Physical foundations**Page: 26 Difficulty: 2 Ans: A**

Enzymes are biological catalysts that enhance the rate of a reaction by:

- A) decreasing the activation energy.
- B) decreasing the amount of free energy released.
- C) increasing the activation energy.
- D) increasing the amount of free energy released.
- E) increasing the energy of the transition state.

19. Physical foundations**Page: 27 Difficulty: 1 Ans: B**

Energy requiring metabolic pathways that yield complex molecules from simpler precursors are:

- A) amphibolic.
- B) anabolic.
- C) autotrophic.
- D) catabolic.
- E) heterotrophic.

20. Genetic foundations**Page: 29 Difficulty: 1 Ans: A**

Hereditary information (with the exception of some viruses) is preserved in:

- A) deoxyribonucleic acid.
- B) membrane structures.
- C) nuclei.
- D) polysaccharides.
- E) ribonucleic acid.

21. Genetic foundations**Page: 29 Difficulty: 2 Ans: C**

When a region of DNA must be repaired by removing and replacing some of the nucleotides, what ensures that the new nucleotides are in the correct sequence?

- A) DNA cannot be repaired and this explains why mutations occur.
- B) Specific enzymes bind the correct nucleotides.
- C) The new nucleotides basepair accurately with those on the complementary strand.
- D) The repair enzyme recognizes the removed nucleotide and brings in an identical one to replace it.
- E) The three-dimensional structure determines the order of nucleotides.

22. Genetic foundations**Page: 30 Difficulty: 2 Ans: E**

The three-dimensional structure of a protein is determined primarily by:

- A) electrostatic guidance from nucleic acid structure.
- B) how many amino acids are in the protein.
- C) hydrophobic interaction with lipids that provide a folding framework.
- D) modification during interactions with ribosomes.
- E) the sequence of amino acids in the protein.

23. Evolutionary foundations**Page: 32 Difficulty: 2 Ans: D**

According to Oparin's theory for the origin of life, the prebiotic atmosphere:

- A) already contained some primitive RNA molecules.
- B) basically was very similar to the atmosphere of today.
- C) contained many amino acids.
- D) had an abundance of methane, ammonia, and water.
- E) was rich in oxygen.

Short Answer Questions

24. Cellular foundations

Pages: 1-2 Difficulty: 1

What six characteristics distinguish living organisms from inanimate objects?

Ans: Living organisms (1) are chemically complex and highly organized; (2) extract, transform, and use energy from their environment; (3) have the capacity to precisely self-replicate and self-assemble; (4) exploit a chemical interplay with their environment; (5) possess programmatically defined functions; and (6) evolve to new forms over many generations.

25. Cellular foundations

Page: 3 Difficulty: 1

All cells are surrounded by a plasma membrane composed of lipid and protein molecules. What is the function of the plasma membrane?

Ans: The plasma membrane acts as a barrier to the free passage of inorganic ions and most other charged or polar compounds into or out of the cell. It contains proteins that can transport specific ions or molecules. Other membrane proteins act as receptors that transmit signals from the outside to the inside of the cell.

26. Cellular foundations

Page: 6 Difficulty: 1

E. coli is known as a gram-negative bacterial species. (a) How is this determined? (b) How do gram-negative bacteria differ structurally from gram-positive bacteria?

Ans: (a) Gram-negative bacteria have little affinity for the dye gentian violet used in Gram's stain, but gram-positive bacteria retain Gram's stain. (b) Gram-negative bacteria have an outer membrane and a peptidoglycan layer; gram-positive bacteria lack an outer membrane and the peptidoglycan layer is much thicker.

27. Cellular foundations

Page: 7 Difficulty: 1

Most cells of higher plants have a cell wall outside the plasma membrane. What is the function of the cell wall?

Ans: The cell wall provides a rigid, protective shell for the cell. It is porous, allowing water and small molecules to pass readily, but it is rigid enough to resist the swelling of the cell caused by the accumulation of water. (See Fig. 1-7, p. 7.)

28. Cellular foundations

Page: 11 Difficulty: 2

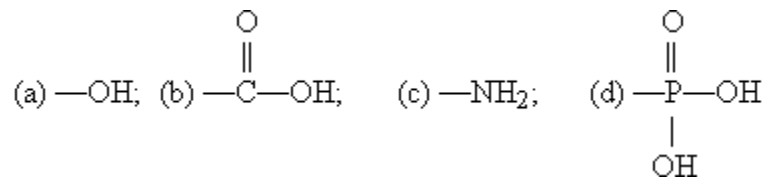
(a) List the types of noncovalent interactions that are important in providing stability to the three-dimensional structures of macromolecules. (b) Why is it important that these interactions be noncovalent, rather than covalent, bonds?

Ans: (a) Noncovalent interactions include hydrogen bonds, ionic interactions between charged groups, van der Waals interactions, and hydrophobic interactions. (b) Because noncovalent interactions are weak, they can form, break, and re-form more rapidly and with less energy input than can covalent bonds. This is important to maintain the flexibility needed in macromolecules.

29. Chemical foundations**Page: 14 Difficulty: 1**

Draw the structures of the following functional groups in their un-ionized forms:

(a) hydroxyl, (b) carboxyl, (c) amino, (d) phosphoryl.

Ans:**30. Chemical foundations****Pages: 15-16 Difficulty: 2**

What is the underlying, organizing biochemical principle that results in the chemical similarity of virtually all living things? Given this biochemical similarity, how is the structural and functional diversity of living things possible?

Ans: Living things are composed primarily of macromolecules, polymers of simple compounds of just a few different types. The properties of these polymers are determined by their sequence of monomers and these can be combined in many different ways. Diversity is thus achieved through the nearly limitless variety of sequences that can exist when amino acids are linked to form proteins, nucleotides are linked to form nucleic acids, and monosaccharides are linked to form polysaccharides. Branching in the latter can contribute additional heterogeneity. Each type of organism constructs a unique set of macromolecules from these monomeric units, resulting in the structural and functional diversity among species.

31. Chemical foundations**Page: 16 Difficulty: 2**

Name two functions of (a) proteins, (b) nucleic acids, (c) polysaccharides, (d) lipids.

Ans: Many answers are possible including: (a) proteins function as enzymes, structural elements, signal carriers, transporters; (b) nucleic acids store and transmit genetic information and act as both structural and catalytic elements; (c) polysaccharides serve as energy-yielding fuel stores and cellular and extracellular structural and recognition elements, (d) lipids function as membrane components, fuel stores, and cellular signals.

32. Chemical Foundations**Pages: 17-18 Difficulty: 2**

Why is an asymmetric carbon atom called a chiral center?

Ans: An asymmetric carbon has four different substituents attached, and cannot be superimposed on its mirror image—as a right hand cannot fit into a left glove. Thus a molecule with one chiral carbon will have two stereoisomers, which may be distinguishable from one another in a biological system.

33. Chemical foundations**Pages: 17, 20 Difficulty: 3**

Differentiate between configuration and conformation.

Ans: Configuration denotes the spatial arrangement of the atoms of a molecule that is conferred by the presence of either double bonds, around which there is no freedom of rotation, or chiral centers, which give rise to stereoisomers. Configurational isomers can only be interconverted by temporarily breaking covalent bonds. Conformation refers to the spatial arrangement of substituent groups that, without breaking any bonds, are free to assume different positions in space because of the freedom of bond rotation.

34. Chemical foundations**Pages: 17, 19 Difficulty: 3**

(a) What is optical activity? (b) How did Louis Pasteur arrive at an explanation for the phenomenon of optical activity?

Ans: (a) Optical activity is the capacity of a substance to rotate the plane of plane-polarized light. (b) Using fine forceps, he was able to separate the two types of crystals found in tartaric acid (racemic acid) that are identical in shape, but mirror images of each other. One sample rotated polarized light to the left; the mirror image crystals rotated polarized light to the right.

35. Chemical foundations**Pages: 20-21 Difficulty: 3**

A chemist working in a pharmaceutical lab synthesized a new drug as a racemic mixture. Why is it important that she separate the two enantiomers and test each for its biological activity?

Ans: Biomolecules such as receptors for drugs are stereospecific, so each of the two enantiomers of the drug may have very different effects on an organism. One may be beneficial, the other toxic; or one enantiomer may be ineffective and its presence could reduce the efficacy of the other enantiomer.

36. Physical foundations**Pages: 21-22 Difficulty: 2**

Proteins are constantly being synthesized in a living cell. Why doesn't the number of protein molecules become too great for the cell to contain, leading to cell destruction?

Ans: The proteins in a cell are continuously being synthesized and degraded. The cell maintains a dynamic steady state in which the amount of each protein remains fairly constant at the level required under given conditions.

37. Physical foundations**Page: 22 Difficulty: 2**

Describe the relationship between a living organism and its surroundings in terms of both matter and energy.

Ans: Living organisms are open systems and exchange both matter and energy with their surroundings. They are not at equilibrium with their surroundings; that is, the concentrations of molecules inside the cells of the organism are not the same as their concentrations in the surroundings. To maintain this situation, the organism must acquire energy from its surroundings, either in the form of chemical energy or directly from sunlight.

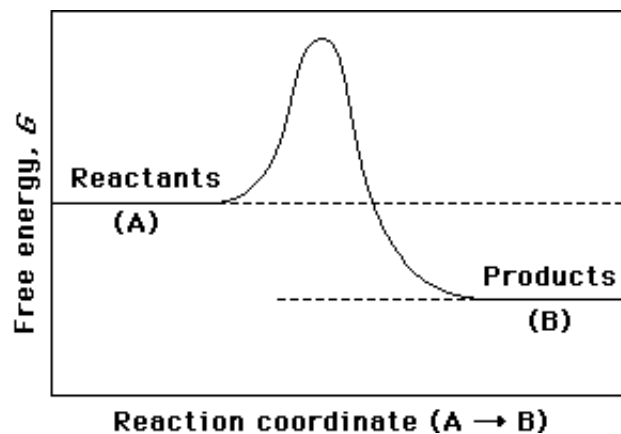
38. Physical foundations**Page: 23 Difficulty: 2**

The free-energy change for the formation of a protein from the individual amino acids is positive and is thus an endergonic reaction. How, then, do cells accomplish this process?

Ans: The endergonic (thermodynamically unfavorable) reaction is coupled to an exergonic (thermodynamically favorable) reaction through a shared intermediate, so that the overall free-energy change of the coupled reactions is negative (the overall reaction is exergonic).

39. Physical foundations**Pages: 26-27 Difficulty: 2**

(a) On the reaction coordinate diagram shown below, label the transition state and the overall free-energy change (ΔG) for the uncatalyzed reaction $A \rightarrow B$. (b) Is this an exergonic or endergonic reaction? (c) Draw a second curve showing the energetics of the reaction if it were enzyme-catalyzed.



Ans: (a) and (c) (See Fig. 1-27, p. 27.) (b) exergonic reaction

40. Physical foundations**Page: 28 Difficulty: 2**

What is meant by feedback inhibition and why is it important in a living organism?

Ans: Feedback inhibition is the regulation of a biochemical pathway in which a reaction product inhibits an earlier (usually the first) step in the pathway. It is an important type of regulation because it ensures that energy is not wasted by an organism producing molecules it does not need.

41. Genetic foundations**Page: 29 Difficulty: 2**

How is the genetic information encoded in DNA and how is a new copy of DNA synthesized?

Ans: The genetic information is encoded in the linear sequence (order) of the four different deoxyribonucleotides in the DNA. When a new copy of DNA is needed, the two strands of the DNA unwind and each strand serves as a template on which a new strand is synthesized.

42. Genetic foundations**Pages: 29-32 Difficulty: 3**

Hereditary transmission of genetic information can be viewed as a balance between stability and change. Explain.

Ans: Hereditary transmission of genetic information occurs via replication of DNA, the information-containing molecule. This process is very accurate and thus results in relatively few changes in genetic information. This stability is important to maintain individual and species characteristics over long periods of time. On the other hand, regular changes in genetic information (mutations) do occur, primarily as a result of infrequent errors in replication. These mutations are essential for generating genetic diversity, which allows for adaptation of species.

43. Genetic foundations**Pages: 31-32 Difficulty: 3**

Discuss how a mutation in DNA could be harmful or beneficial to an organism.

Ans: Some mutations lead to the synthesis of an inactive or defective enzyme or other protein that can no longer carry out its proper function, which is thus harmful to the organism. However, other mutations may lead to a more stable enzyme or to a protein that is better able to carry out its function in a particular environment, making it beneficial to the organism.

44. Evolutionary foundations**Pages: 32-33 Difficulty: 3**

Describe Stanley Miller's experiment (1953) and its relevance.

Ans: Miller subjected a gaseous mixture of ammonia, methane, water vapor, and hydrogen to electrical sparks for periods of a week or more. When he analyzed the contents of the closed reaction vessel, the gas phase contained CO and CO₂, as well as unreacted starting materials. The water phase contained a variety of organic compounds, including some amino acids, hydroxy acids, aldehydes, and hydrogen cyanide. This experiment established the possibility of abiotic production of biomolecules in relatively short times under relatively mild conditions.

45. Evolutionary foundations**Pages: 32-33 Difficulty: 2**

Describe the "RNA world" hypothesis.

Ans: Initially, RNA molecules were both genes and catalysts. Self-replication of these molecules over long periods of time produced variants that were able to catalyze polymerization of amino acids to form peptides that assumed the function of catalysts. Eventually, genomic RNA was copied into DNA, which assumed the function of genetic information storage.

46. Evolutionary functions**Page: 34 Difficulty: 1**

Describe how the rise of O₂-producing bacteria might have led to the eventual predominance of aerobic organisms on earth.

Ans: The rise of O₂-producing bacteria would result in an increase in the levels of O₂ in the earth's atmosphere. This would give a selective advantage to aerobic organisms (which utilized O₂ as electron acceptor) over anaerobic organisms for which O₂ was toxic.

47. Evolutionary foundations**Page: 35 Difficulty: 2**

What is meant by endosymbiotic association? How can this concept explain the evolution of eukaryotic cells that are capable of carrying out photosynthesis and/or aerobic metabolism?

Ans: An endosymbiotic association is the envelopment of one organism by another to form a relationship that is beneficial to both organisms. It is believed that primitive eukaryotic cells, which were incapable of photosynthesis or aerobic metabolism, formed endosymbiotic associations with photosynthetic and/or aerobic bacteria. The aerobic bacteria then evolved into the mitochondria found in modern eukaryotic cells, and the photosynthetic bacteria evolved into the chloroplasts found in plant cells. (See Fig. 1-36, p. 35.)