Chapter 8 Nucleotides and Nucleic Acids

Multiple Choice Questions

1. **Some basics**
   Pages: 273-275 Difficulty: 1 Ans: E
   The compound that consists of ribose linked by an *N*-glycosidic bond to N-9 of adenine is:

   A) a deoxyribonucleoside.
   B) a purine nucleotide.
   C) a pyrimidine nucleotide.
   D) adenosine monophosphate.
   E) adenosine.

2. **Some basics**
   Page: 274 Difficulty: 1 Ans: E
   A major component of RNA but not of DNA is:

   A) adenine.
   B) cytosine.
   C) guanine.
   D) thymine.
   E) uracil.

3. **Some basics**
   Page: 274 Difficulty: 1 Ans: A
   The difference between a ribonucleotide and a deoxyribonucleotide is:

   A) a deoxyribonucleotide has an —H instead of an —OH at C-2.
   B) a deoxyribonucleotide has α configuration; ribonucleotide has the β configuration at C-1.
   C) a ribonucleotide has an extra —OH at C-4.
   D) a ribonucleotide has more structural flexibility than deoxyribonucleotide.
   E) a ribonucleotide is a pyranose, deoxyribonucleotide is a furanose.

4. **Some basics**
   Pages: 274-275 Difficulty: 2 Ans: D
   Which one of the following is true of the pentoses found in nucleic acids?

   A) C-5 and C-1 of the pentose are joined to phosphate groups.
   B) C-5 of the pentose is joined to a nitrogenous base, and C-1 to a phosphate group.
   C) The bond that joins nitrogenous bases to pentoses is an *O*-glycosidic bond.
   D) The pentoses are always in the β-furanose forms.
   E) The straight-chain and ring forms undergo constant interconversion.

5. Some basics
Pages: 276-277 Difficulty: 2 Ans: E
The phosphodiester bonds that link adjacent nucleotides in both RNA and DNA:

A) always link A with T and G with C.
B) are susceptible to alkaline hydrolysis.
C) are uncharged at neutral pH.
D) form between the planar rings of adjacent bases.
E) join the 3′ hydroxyl of one nucleotide to the 5′ hydroxyl of the next.

6. Some basics
Pages: 276-277 Difficulty: 2 Ans: A
The phosphodiester bond that joins adjacent nucleotides in DNA:

A) associates ionically with metal ions, polyamines, and proteins.
B) is positively charged.
C) is susceptible to alkaline hydrolysis.
D) Links C-2 of one base to C-3 of the next.
E) links C-3 of deoxyribose to N-1 of thymine or cytosine.

7. Some basics
Page: 277 Difficulty: 2 Ans: D
The alkaline hydrolysis of RNA does *not* produce:

A) 2′- AMP.
B) 2′,3′-cGMP.
C) 2′-CMP.
D) 3′,5′-cAMP.
E) 3′-UMP.

8. Some basics
Page: 278 Difficulty: 2 Ans: B
The DNA oligonucleotide abbreviated pATCGAC:

A) has 7 phosphate groups.
B) has a hydroxyl at its 3′ end.
C) has a phosphate on its 3′ end.
D) has an A at its 3′ end.
E) violates Chargaff's rules.

9. Some basics
Page: 278 Difficulty: 2 Ans: D
For the oligoribonucleotide pACGUAC:

A) the nucleotide at the 3′ end has a phosphate at its 3′ hydroxyl.
B) the nucleotide at the 3′ end is a purine.
C) the nucleotide at the 5′ end has a 5′ hydroxyl.
D) the nucleotide at the 5′ end has a phosphate on its 5′ hydroxyl.
E) the nucleotide at the 5′ end is a pyrimidine.

10. Some basics
Page: 278 Difficulty: 2 Ans: D
The nucleic acid bases:

A) absorb ultraviolet light maximally at 280 nm.
B) are all about the same size.
C) are relatively hydrophilic.
D) are roughly planar.
E) can all stably base-pair with one another.

11. Some basics
Page: 278 Difficulty: 2 Ans: C
Which of the following statements concerning the tautomeric forms of bases such as uracil is correct?

A) The all-lactim form contains a ketone group.
B) The lactam form contains an alcohol group.
C) The lactam form predominates at neutral pH.
D) They are geometric isomers.
E) They are stereoisomers.

12. Some basics
Page: 279 Difficulty: 1 Ans: B
In a double-stranded nucleic acid, cytosine typically base-pairs with:

A) adenosine.
B) guanine.
C) inosine.
D) thymine.
E) uracil.

13. Some basics
Page: 279 Difficulty: 2 Ans: A
In the Watson-Crick model for the DNA double helix (B form) the A–T and G–C base pairs share which one of the following properties?

A) The distance between the two glycosidic (base-sugar) bonds is the same in both base pairs, within a few tenths of an angstrom.
B) The molecular weights of the two base pairs are identical.
C) The number of hydrogen bonds formed between the two bases of the base pair is the same.
D) The plane of neither base pair is perpendicular to the axis of the helix.
E) The proton-binding groups in both base pairs are in their charged or ionized form.

14. Nucleic acid structure
Pages: 280-281 Difficulty: 1 Ans: B
The experiment of Avery, MacLeod, and McCarty in which nonvirulent bacteria were made virulent by transformation was significant because it showed that:

A) bacteria can undergo transformation.
B) genes are composed of DNA only.
C) mice are more susceptible to pneumonia than are humans.
D) pneumonia can be cured by transformation.
E) virulence is determine genetically.

15. Nucleic acid structure
Page: 281 Difficulty: 1 Ans: E
Chargaff's rules state that in typical DNA:

A) A = G.
B) A = C.
C) A = U.
D) A + T = G + C.
E) A + G = T + C.

16. Nucleic acid structure
Pages: 281-283 Difficulty: 2 Ans: A
In the Watson-Crick structure of DNA, the:

A) absence of 2′-hydroxyl groups allows bases to lie perpendicular to the helical axis.
B) adenine content of one strand must equal the thymine content of the same strand.
C) nucleotides are arranged in the A-form.
D) purine content (fraction of bases that are purines) must be the same in both strands.
E) two strands are parallel.

17. Nucleic acid structure
Pages: 281-283 Difficulty: 2 Ans: E
In the Watson-Crick model of DNA structure:

A) both strands run in the same direction, $3' \rightarrow 5'$; they are parallel.
B) phosphate groups project toward the middle of the helix, where they are protected from interaction with water.
C) T can form three hydrogen bonds with either G or C in the opposite strand.
D) the distance between the sugar backbone of the two strands is just large enough to accommodate either two purines or two pyrimidines.
E) the distance between two adjacent bases in one strand is about 3.4 Å.

18. Nucleic acid structure
Pages: 281-283 Difficulty: 2 Ans: C
Which of the following is *not* true of all naturally occurring DNA?

A) Deoxyribose units are connected by 3′,5′-phosphodiester bonds.
B) The amount of A always equals the amount of T.
C) The ratio A+T/G+C is constant for all natural DNAs.
D) The two complementary strands are antiparallel.
E) Two hydrogen bonds form between A and T.

19. Nucleic acid structure
Pages: 282-283 Difficulty: 2 Ans: E
In the Watson-Crick model of DNA structure (now called B-form DNA):

A) a purine in one strand always hydrogen bonds with a purine in the other strand.
B) A–T pairs share three hydrogen bonds.
C) G–C pairs share two hydrogen bonds.
D) the 5′ ends of both strands are at one end of the helix.
E) the bases occupy the interior of the helix.

20. Nucleic acid structure
Page: 283 Difficulty: 2 Ans: D
The double helix of DNA in the B-form is stabilized by:

A) covalent bonds between the 3′ end of one strand and the 5′ end of the other.
B) hydrogen bonding between the phosphate groups of two side-by-side strands.
C) hydrogen bonds between the riboses of each strand.
D) nonspecific base-stacking interaction between two adjacent bases in the same strand.
E) ribose interactions with the planar base pairs.

21. Nucleic acid structure
Page: 284 Difficulty: 2 Ans: C
In nucleotides and nucleic acids, syn and anti conformations relate to:

A) base stereoisomers.
B) rotation around the phosphodiester bond.
C) rotation around the sugar-base bond.
D) sugar pucker.
E) sugar stereoisomers.

22. Nucleic acid structure
Page: 284 Difficulty: 2 Ans: D
B-form DNA in vivo is a ________-handed helix, _____ Å in diameter, with a rise of ____ Å per base pair.

A) left; 20; 3.9
B) right; 18; 3.4
C) right; 18; 3.6
D) right; 20; 3.4
E) right; 23; 2.6

23. Nucleic acid structure
Pages: 284-285 Difficulty: 2 Ans: E
In double-stranded DNA:

A) only a right-handed helix is possible.
B) sequences rich in A–T base pairs are denatured less readily than those rich in G–C pairs.
C) the sequence of bases has no effect on the overall structure.
D) the two strands are parallel.
E) the two strands have complementary sequences.

24. Nucleic acid structure
Page: 285 Difficulty: 2 Ans: D
Which of the following is a palindromic sequence?

A) AGGTCC
TCCAGG
B) CCTTCC
GCAAGG
C) GAATCC
CTTAGG
D) GGATCC
CCTAGG
E) GTATCC
CATAGG

25. Nucleic acid structure
Page: 286 Difficulty: 2 Ans: D
Triple-helical DNA structures can result from Hoogsteen (non Watson-Crick) interactions. These interactions are primarily:

A) covalent bonds involving deoxyribose.
B) covalent bonds involving the bases.
C) hydrogen bonds involving deoxyribose.
D) hydrogen bonds involving the bases.
E) hydrophobic interactions involving the bases.

26. Nucleic acid structure
Pages: 288-289 Difficulty: 2 Ans: C
Double-stranded regions of RNA:

A) are less stable than double-stranded regions of DNA.
B) can be observed in the laboratory, but probably have no biological relevance.
C) can form between two self-complementary regions of the same single strand of RNA.
D) do not occur.
E) have the two strands arranged in parallel (unlike those of DNA, which are antiparallel).

27. **Nucleic acid chemistry**
Page: 291 Difficulty: 2 Ans: B
When double-stranded DNA is heated at neutral pH, which change does *not* occur?

A) The absorption of ultraviolet (260 nm) light increases.
B) The covalent N-glycosidic bond between the base and the pentose breaks.
C) The helical structure unwinds.
D) The hydrogen bonds between A and T break.
E) The viscosity of the solution decreases.

28. **Nucleic acid chemistry**
Page: 291 Difficulty: 2 Ans: B
Which of the following deoxyoligonucleotides will hybridize with a DNA containing the sequence (5′)AGACTGGTC(3′)?

A) (5′)CTCATTGAG(3′)
B) (5′)GACCAGTCT(3′)
C) (5′)GAGTCAACT(3′)
D) (5′)TCTGACCAG(3′)
E) (5′)TCTGGATCT(3′)

29. **Nucleic acid chemistry**
Page: 291 Difficulty: 2 Ans: D
The ribonucleotide polymer (5′)GTGATCAAGC(3′) could only form a double-stranded structure with:

A) (5′)CACTAGTTCG(3′).
B) (5′)CACUAGUUCG(3′).
C) (5′)CACUTTCGCCC(3′).
D) (5′)GCTTGATCAC(3′).
E) (5′)GCCTAGTTUG(3′).

30. **Nucleic acid chemistry**
Page: 292 Difficulty: 2 Ans: E
In comparison with DNA-DNA double helices, the stability of DNA-RNA and RNA-RNA helices is:

A) DNA-DNA > DNA-RNA > RNA-RNA.
B) DNA-DNA > RNA-RNA > DNA-RNA.
C) RNA-DNA > RNA-RNA > DNA-DNA.
D) RNA-RNA > DNA-DNA > DNA-RNA.
E) RNA-RNA > DNA-RNA > DNA-DNA.

31. **Nucleic acid chemistry**
Page: 294 Difficulty: 1 Ans: E
In the laboratory, several factors are known to cause alteration of the chemical structure of DNA. The factor(s) likely to be important in a *living* cell is (are):

A) heat.
B) low pH.
C) oxygen.
D) UV light.

E) both C and D.

32. **Nucleic acid chemistry**
Page: 295 Difficulty: 2 Ans: B
Compounds that generate nitrous acid (such as nitrites, nitrates, and nitrosamines) change DNA molecules by:

A) breakage of phosphodiester bonds.
B) deamination of bases.
C) depurination.
D) formation of thymine dimers.
E) transformation of A $\rightarrow$ T.

33. **Nucleic acid chemistry**
Pages: 296-297 Difficulty: 2 Ans: D
In DNA sequencing by the Sanger (dideoxy) method:

A) radioactive dideoxy ATP is included in each of four reaction mixtures before enzymatic synthesis of complementary strands.
B) specific enzymes are used to cut the newly synthesized DNA into small pieces, which are then separated by electrophoresis.
C) the dideoxynucleotides must be present at high levels to obtain long stretches of DNA sequence.
D) the role of the dideoxy CTP is to occasionally terminate enzymatic synthesis of DNA where Gs occur in the template strands.
E) the template DNA strand is radioactive.

34. **Nucleic acid chemistry**
Page: 299 Difficulty: 3 Ans: D
In the chemical synthesis of DNA:

A) the dimethoxytrityl (DMT) group catalyzes formation of the phosphodiester bond.
B) the direction of synthesis is 5′ to 3′.
C) the maximum length of oligonucleotide that can be synthesized is 8-10 nucleotides.
D) the nucleotide initially attached to the silica gel support will become the 3′ end of the finished product.
E) the protecting cyanoethyl groups are removed after each step.

35. **Other functions of nucleotides**
Pages: 300-302 Difficulty: 1 Ans: E
In living cells, nucleotides and their derivatives can serve as:

A) carriers of metabolic energy.
B) enzyme cofactors.
C) intracellular signals.
D) precursors for nucleic acid synthesis.
E) all of the above.

Short Answer Questions

36. Some basics
Page: 273 Difficulty: 1
How are a nucleoside and a nucleotide similar and how are they different?

Ans: Both have a nitrogenous base and a pentose; nucleotides also have a phosphate group, which nucleosides lack.

37. Some basics
Pages: 273-279 Difficulty: 1
Match the type of bond with the role below:

Bond type	Role
(a) phosphodiester	___ links base to pentose in nucleotide
(b) *N*-glycosidic	___ joins adjacent nucleotides in one strand
(c) phosphate ester	___ joins complementary nucleotides in two strands
(d) hydrogen	___ difference between a nucleoside and a nucleotide

Ans: b; a; d; c

38. Nucleic acid structure
Pages: 273-279 Difficulty: 2
Compounds that contain a nitrogenous base, a sugar, and a phosphate group are called (a)_________________. Two purines found in DNA are (b)______________ and __________________. A pyrimidine found in all DNA but in only some RNA is (c)_________________. In DNA, the base pair (d)___-___ is held together by three hydrogen bonds; the base pair (e)___-___ has only two such bonds.

Ans: (a) nucleotides; (b) adenine and guanine; (c) thymidine; (d) G–C; (e) A–T

39. Nucleic acid structure
Page: 279 Difficulty: 2
Draw the structure of either an adenine-thymine or a guanine-cytosine base pair as found in the Watson-Crick double-helical structure of DNA. Include all hydrogen bonds.

Ans: (See Fig. 8-11. p. 279.)

40. Nucleic acid structure
Page: 279 Difficulty: 2
Draw the structures of hydrogen-bonded adenine and thymine.

Ans: (See Fig. 8-11, p. 279.)

41. Nucleic acid structure
Page: 280 Difficulty: 3
Briefly describe the experimental evidence of Avery, MacLeod, and McCarty that DNA is the genetic material.

Ans: Avery et al. showed that DNA isolated from a virulent (disease-causing) bacterium (*Streptococcus pneumoniae*), when mixed with living cells of a nonvirulent strain of this bacterium, provided the genetic instructions for transforming the nonvirulent strain to a virulent strain. (See Fig. 10-12, p. 333.)

42. Nucleic acid structure
Page: 281 Difficulty: 3
Briefly describe the Hershey-Chase experiment, which showed that DNA is the genetic material.

Ans: Hershey and Chase showed that when the bacteriophage (virus) T2 infected the bacterium *E. coli*, new genetic instructions appeared in the infected cells. Because only the DNA and not the proteins of T2 entered the infected cell, DNA must carry the new genetic instructions. (See Fig. 10-13, p. 334.)

43. Nucleic acid structure
Pages: 281-282 Difficulty: 3
The composition (mole fraction) of *one* of the strands of a double-helical DNA is [A] = 0.3, and [G] = 0.24. Calculate the following, if possible. If impossible, write "I."

For the *same* strand:
[T] = (a) ____
[C] = (b) ____
[T] + [C] = (c) ____
For the *other* strand:
[A] = (d) ____
[T] = (e) ____
[A] + [T] = (f) ____
[G] = (g) ____
[C] = (h) ____
[G] + [C] = (i) ____

Ans: (a) I; (b) I; (c) 0.46; (d) I; (e) 0.3; (f) I; (g) I; (h) 0.24; (i) I

44. Nucleic acid structure
Page: 282 Difficulty: 2
What is the approximate length of a DNA molecule (in the B form) containing 10,000 base pairs?

Ans: 3.4 Å × 10,000 = 34,000 Å = 3.4 µm. (See p. 338.)

45. Nucleic acid structure
Page: 283 Difficulty: 2
Describe briefly what is meant by saying that two DNA strands are complementary.

Ans: The nucleotide sequences of complementary strands are such that wherever an A occurs in one strand, there is a T in the other strand with which it can form a hydrogen-bonded base pair. Wherever a C occurs in one strand, a G occurs in the other. A is the base complementary to T, and C is the base complementary to G.

46. Nucleic acid structure
Pages: 284-285 Difficulty: 2
In one sentence, identify the most obvious structural difference between A-form (Watson-Crick) DNA and Z-form DNA.
Ans: A-form DNA is a right-handed helix; Z-form DNA is a left-handed helix. (See Fig. 10-19, page 338.)

47. Nucleic acid structure
Page: 285 Difficulty: 2
Write a double-stranded DNA sequence containing a six-nucleotide palindrome.

Ans: Any double-stranded sequence that has the form:
1-2-3-4-5-6-6′-5′-4′-3′-2′-1′
1′-2′-3′-4′-5′-6′-6-5-4-3-2-1
where each number and its prime represent correctly paired bases (A with T, C with G) all along the double-stranded molecule.

48. Nucleic acid structure
Pages: 288-289 Difficulty: 3
Describe briefly how noncovalent interactions contribute to the three-dimensional shapes of RNA molecules.

Ans: Hydrogen-bonding in regions of complementarity within an RNA chain can result in regions of double helix that are stabilized by base-stacking. Breaks in complementary regions can result in loops and bulges that together with the helical regions, can generate a precise three-dimensional structure.

49. Nucleic acid chemistry
Page: 292 Difficulty: 3
Why does lowering the ionic strength of a solution of double-stranded DNA permit the DNA to denature more readily (for example, to denature at a lower temperature than at a higher ionic strength)?

Ans: Lower ionic strength reduces the screening of the negative charges on the phosphate groups by positive ions in the medium. The result is stronger charge-charge repulsion between the phosphate, which favors strand separation.

50. Nucleic acid chemistry
Page: 292 Difficulty: 2
Describe qualitatively how the t_m for a double-stranded DNA depends upon its nucleotide composition.

Ans: In general, the higher the proportion of G and C, the higher the melting temperature, t_m. More thermal energy is required to break the three hydrogen bonds holding G≡C pairs than to break the two hydrogen bonds holding A=T pairs.

51. Nucleic acid chemistry
Page: 292 Difficulty: 2
A solution of DNA is heated slowly until the t_m is reached. What is the likely structure of the DNA molecules at this temperature?

Ans: The DNA molecules are partially denatured; in each molecule approximately 50% of the DNA is single-stranded and 50% is double-helical. The single-stranded regions, which appear as "bubbles" within the molecules, are those which denatured at lower temperatures because of their higher content of A–T base pairs.

52. Nucleic acid chemistry
Pages: 292-293 Difficulty: 2
Mouse DNA hybridizes more extensively with human DNA than with yeast DNA. Explain by describing the factor or factors that determine extent of hybridization.

Ans: In general, the more similar the sequences in two DNA molecules are, the more readily they will hybridize. Because the evolutionary distance between mouse and yeast is greater than that between mouse and human, mouse and human DNA sequences are more similar than those of mouse and yeast.

53. Nucleic acid chemistry
Page: 294 Difficulty: 2
What is the principal effect of ultraviolet radiation on DNA?

Ans: UV radiation causes the formation of a dimer between adjacent thymine bases on the same DNA strand. This results in a kink in the double helix at that site.

54. Other functions of nucleotides
Pages: 300-301 Difficulty: 2
Explain how nucleoside triphosphates (such as ATP) act as carriers of chemical energy.

Ans: In these molecules, there is a phosphoric anhydride linkage between the phosphates. Hydrolysis of this linkage (i.e., of ATP to ADP and phosphate) is a highly exergonic reaction that results in the release of a large amount of free energy. Conversely, the input of a large amount of free energy is required for the synthesis of the linkage; i.e., for the phosphorylation of ADP to form ATP. Thus, synthesis of ATP results in the storage of energy that can be released upon hydrolysis.