Chapter 1: DNA Structure and Function

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. In which body or cell area are most genes in humans located?
A. Nucleus
B. Mitochondrion
C. Cytoplasm
D. Plasma membrane

____ 2. Which condition or statement exemplifies the concept of genomics rather than genetics?
A. The gene for insulin is located on chromosome 11 in all people.
B. Expression of any single gene is dependent on inheriting two alleles.
C. Sex-linked recessive disorders affect males more often than females.
D. One allele for each gene is inherited from the mother, and one is inherited from the father.

____ 3. What is the purpose of phosphorous in a DNA strand?
A. Linking the nucleotides into a strand
B. Holding complementary strands together
C. Ensuring that a purine is always paired with a pyrimidine
D. Preventing the separation of double-stranded DNA into single-stranded DNA

____ 4. What is the term used to define alternative forms of a gene that may result in different expression of the trait coded for by that gene?
A. Alleles
B. Bases
C. Centromeres
D. Diploids

____ 5. What percentage of bases in a stretch of double-stranded DNA that contains 30% guanine (G) bases would be adenine (A)?
A. 70%
B. 60%
C. 30%
D. 20%

____ 6. What is the term used to describe the organized picture of the paired chromosomes within a cell used to determine whether chromosome numbers, structures, and banding patterns are normal?
A. Pedigree
B. Phenotype
C. Karyotype
D. Autotype

____ 7. What would be the sequence of DNA that is complementary to a DNA section with the base sequence of GGTCAATCCTTAG?
A. GATTCCTAACTGG

B. TTGACCGAAGGCT
C. AACTGGCTTCCGA
D. CCAGTTAGGAATC

____ 8. Which of these complementary base pairs form the strongest or "tightest" association?
A. Adenine and thymine
B. Cytosine and guanine
C. Guanine and thymine
D. Cytosine and adenine

____ 9. What activity occurs during M phase of the cell cycle?
A. The cell undergoes cytokinesis.
B. Activity stops, and the cell "sleeps."
C. All DNA is completely replicated.
D. The cell greatly increases protein synthesis.

____ 10. Which chromosome number represents the euploid state for normal human somatic cells?
A. 44
B. 46
C. 47
D. 48

____ 11. How does the proteome differ from the genome?
A. The proteome changes in response to intracellular and extracellular signals.
B. The genome changes in response to intracellular and extracellular signals.
C. The proteome is stable in somatic cells and unstable in germ cells, whereas the genome is stable in both somatic cells and germ cells.
D. The genome is stable in somatic cells and unstable in germ cells, whereas the proteome is stable in both somatic cells and germ cells.

____ 12. What is the most outstanding feature of a mature haploid cell?
A. It is usually homozygous.
B. The sex chromosomes are missing.
C. Only one chromosome of each pair is present.
D. DNA synthesis occurs after mitosis instead of before.

____ 13. At what phase of the cell cycle are chromosomes visible as separate structures?
A. G_1
B. G_2
C. S
D. M

____ 14. Which statement about the cell cycle phase of G_0 is true?
A. Hyperplastic growth in place of hypertrophic growth
B. Performance of specific differentiated functions
C. Initiation and completion of nucleokinesis
D. Replication of DNA

____ 15. What is the result of normal DNA replication?

A. Formation of two new daughter cells
B. Formation of two identical sets of DNA
C. Disappearance of the original parent cell
D. Activation and attachment of spindle fibers

____ 16. Which statement regarding chromosome structure or function is true?
A. The chromatids of any single chromosome are known as "sister chromatids."
B. The genes located on the telomeres of chromosomes are identical to the genes in the centromeres.
C. Immediately before the mitosis phase of cell division, the chromosomes of all somatic cells are haploid.
D. A specific gene allele on one chromosome has a complementary allele on the other chromosome of a pair.

____ 17. Why does a person with normal chromosomes only have two alleles for any single gene trait?
A. A minimum of two alleles is required for the expression of monogenic traits.
B. When a dominant allele is paired with a recessive allele, only the dominant allele is expressed, and the recessive allele is silent.
C. One allele for the monogenic trait is on the paternally derived chromosome, and the other allele is on the maternally derived chromosome.
D. Expression of more than two alleles of any single-gene trait results in enhanced expression of recessive alleles and suppressed expression of dominant alleles.

____ 18. Under what normal condition are genotype and phenotype *always* the same?
A. Euploidy of alleles
B. Aneuploidy of alleles
C. Homozygosity of alleles
D. Heterozygosity of alleles

____ 19. What would be the expected result of a drug that affected a particular tissue by causing new DNA to form with covalent bonds instead of hydrogen bonds?
A. None of the cells in the affected tissue would be able to leave G_0 and enter the cell cycle.
B. Replication of DNA would result in identical DNA strands instead of complementary strands.
C. Mitosis of cells in the tissue would result in the production of three new daughter cells instead of just two.
D. The new cells that formed within this tissue would not be able to complete the next round of mitosis successfully.

____ 20. How does the DNA enzyme topoisomerase contribute to DNA replication?
A. Unwinds the double helix and separates the double-stranded DNA
B. Creates a "nick" in the DNA supercoils, allowing them to straighten before replication
C. Initiates DNA synthesis in multiple sites down the strand, making the process more efficient
D. Connects and links the individual pieces of newly synthesized DNA to form a single strand

____ 21. Where is telomeric DNA located?
A. At the tips of the p and q arms of chromosomes.
B. In the mitochondria of all somatic cells
C. Only in the germ cells (ova and sperm)
D. Within the histones of the solenoid

____ 22. What is the purpose of a chromosome centromere?
A. Connecting sister chromatids to form a chromosome
B. Preventing the chromosome arm tips from unraveling
C. Allowing chromatids to separate during DNA replication
D. Ensuring that DNA replication proceeds only in the 3'-to-5' direction

____ 23. Which genetic process would be disrupted in one cell if it could not form chromosomes?
A. DNA replication
B. Gene-directed protein synthesis
C. Delivery of genetic information to new cells
D. Conversion of a nucleoside into a nucleotide

____ 24. What are the expected expressed blood types of children born to a mother who is B/O for blood type and a father who is A/B for blood type?
A. 25% A, 25% B, 25% O, 25% AB
B. 25% A, 50% B, 0% O, 25% AB
C. 50% A, 25% B, 25% O, 0% AB
D. 50% A, 25% B, 0% O, 25% AB

____ 25. A person's karyotype shows 44 autosomes and one X chromosome. What is the best interpretation of this karyotype?
A. The karyotype is aneuploid, and the individual has only one allele for each of the genes on the X chromosome.
B. The karyotype is aneuploid, and the individual is experiencing the pathologic condition of haploidy.
C. The karyotype is euploid, making the individual a genotypic female and a phenotypic male.
D. The karyotype is euploid, making the individual a genotypic male and a phenotypic female.

Chapter 1: DNA Structure and Function
Answer Section

MULTIPLE CHOICE

1. ANS: A
   Most genes are part of the DNA located in the nucleus of body cells. Only a few genes are located in a cell's mitochondrion or mitochondria. There are no genes or DNA in either the cytoplasm or the plasma membranes of any cell.

   PTS: 1
2. ANS: A
   Genetics is the study of the general mechanisms of heredity and the variation of inherited traits. Genomics is the study of the function of all the nucleotide sequences present within the entire genome of a species, including genes in DNA coding regions and DNA noncoding regions. Selections *B*, *C*, and *D* all refer to mechanisms of heredity. Only selection *A* refers to the function of a specific nucleotide sequence.

   PTS: 1
3. ANS: A
   Each nucleoside becomes a complete nucleotide when a phosphate group is attached. The phosphates have multiple binding sites, and each one can link to two nucleotides. These linkages allow the nucleotides to be connected when placed into the DNA strand. The nucleotides within each strand are held in position by the linked phosphate groups, which act like the string holding a strand of beads together, forming a necklace.

   PTS: 1
4. ANS: A
   For each single gene, two alternative forms of that gene, known as alleles, together control how that gene is expressed. The alleles may be identical in their sequence but do not have to be. When a dominant allele is paired with a recessive allele, only the dominant allele is expressed, and the recessive allele is silent. When a dominant allele is paired with another dominant allele, they are both expressed (usually equally). Recessive alleles are only expressed when they are homozygous. Bases are the essential part of a nucleotide, of which there are many within any gene region. Centromeres are the pinched-in part of a chromosome between the p arms and the q arms. The term *diploid* refers to the normal number of chromosome pairs within a cell. It is an adjective, not a noun. Therefore, the plural *diploids* does not exist.

   PTS: 1
5. ANS: D
   Because of complementary pairing, if 30% of the bases are guanine (G), which always pairs with cytosine C, these two bases account for 60% of the total bases in this stretch. The remaining bases make up 40% of the total. This 40% is composed of equal percentages of thymine (T) and adenine (A).

   PTS: 1
6. ANS: C

A karyotype is a picture of an organized arrangement of all of the chromosomes within one cell during the metaphase section of mitosis. The chromosomes are paired and then arranged by number according to size and centromere position. The banding pattern of each pair is analyzed to determine whether areas have been deleted, expanded, or translocated. A pedigree also is a picture, but it illustrates several generations of a family history. Phenotypes are observable traits. *Autotype* is not a genetic term.

PTS: 1

7. ANS: D
Because doubled-stranded DNA (ds-DNA) is complementary in that A always pairs with T and G always pairs with C, wherever a G is located on strand 1, the complementary base in the same position on strand 2 is C; wherever a C is located on strand 1, the complementary base in the same position on strand 2 is G; wherever a T is located on strand 1, the complementary base in the same position on strand 2 is A; and wherever an A is located on strand 1, the complementary base in the same position on strand 2 is T.

PTS: 1

8. ANS: B
Cytosine and guanine normally pair together, whereas adenine and thymine normally pair together. The reason for this specific and complementary pairing of bases is related to the forces that hold the two DNA strands together. The two strands are held loosely together, most of the time, by weak hydrogen bonds. Within a base pair, the hydrogen bonds form between the two nucleotides. Adenine and thymine each have a site for two hydrogen bonds to form, whereas cytosine and guanine each have three sites for hydrogen bonds to form. With three hydrogen bonds instead of just two, the cytosine–guanine pair is tighter (stronger) than an adenine–thymine pair. Note, a purine must always pair with a pyrimidine: they each can only pair with the base that can form the same number of hydrogen bonds. Adenine and cytosine do not pair, and neither do guanine and thymine.

PTS: 1

9. ANS: A
The M stands for *mitosis*. This is the time during the cell cycle after the DNA has successfully replicated completely into two identical sets of double-stranded DNA during S phase, and then progressed through G2 phase into M phase. During M phase, the chromatids separate, each half goes into a new separate nucleus (nucleokinesis), and the cell has two nuclei. Just after nucleokinesis, the cell pulls apart into two cells (cytokinesis), each with a complete set of chromosomes in the nucleus. These two new daughter cells are identical to the parent cell that initiated cell division. There is no "sleep" stage of the cell cycle, although there is a reproductive resting state (G_0) outside of the cell cycle.

PTS: 1

10. ANS: B
Ploidy is the actual number of chromosomes present in a single cell nucleus at mitosis. Humans have 46 chromosomes divided into 23 pairs. When the nucleus contains both pairs of all chromosomes, the number present is the diploid chromosome number (2N). Normal human somatic cells (body cells that are not reproductive cells) with a nucleus have the diploid number of chromosomes, 23 pairs. When a cell's nucleus contains the normal diploid number of chromosomes for the species, the cell is termed *euploid*.

PTS: 1

11. ANS: A
The proteome is the protein content of any given cell. It is dynamic, changing in response to intracellular and extracellular (environmental) signals. Therefore, the proteome is not an exact copy of the genome. The genome is stable in all cells, and the proteome expresses different proteins (both enzymes and structural proteins) at different times in different cells.

PTS: 1

12. ANS: C
A haploid cell has a nucleus that contains only half of each chromosome pair, 23 chromosomes (1N). In a normal haploid cell, one sex chromosome is present. Because there is only one chromosome of each pair present, only one allele of each gene is present, and the cell is not homozygous. A mature haploid cell does not undergo cell division (mitosis) and does not replicate its DNA.

PTS: 1

13. ANS: D
A chromosome is a temporary but consistent state of condensed DNA structure formed for the purpose of cell division during metaphase of mitosis (M phase). At other times in the cell cycle, the DNA is so loosely coiled as a double helix that the basic structure of a chromosome is not visible with a standard microscope. The DNA can be seen with an electron microscope as a double helix, not a chromosome, during G_1, G_2, and S phases.

PTS: 1

14. ANS: B
G_0 is a reproductive resting state of a cell outside of cell division in which the cell performs its normal differentiated functions. Therefore, nucleokinesis (a process of M phase of the cell cycle) and replication of DNA (a process of S phase of the cell cycle) do not occur. Hyperplastic growth is growth by cell division, which does not occur during the reproductive resting state of G_0.

PTS: 1

15. ANS: B
In S phase of the cell cycle, the DNA replicates completely into two identical sets of double-stranded DNA. This occurs in preparation for cell division, which then generates two new daughter cells. Spindle fiber formation, activation, and attachment are critical for mitosis but have no role in DNA replication. The process of DNA replication occurs inside the original parent cell that is undergoing mitosis but does not make the parent cell disappear.

PTS: 1

16. ANS: A
Each longitudinal left and right half of any one chromosome is a chromatid. The two chromatids of a chromosome are homologous and termed *sister chromatids*. Gene alleles on separate chromosomes of a pair are not considered “complementary”; only gene sequences are complementary.

PTS: 1

17. ANS: C

For each single gene at a specific chromosome location, two alleles together control how that gene is expressed even for single-gene traits that have more than two possible alleles. Regardless of how many different possible alleles are present in the entire human population, each person only has two because he or she has only two chromosomes (one inherited from his or her father and one inherited from his or her mother) per pair with one allele on each chromosome. Selection *B* is true but does not answer the question asked. Only two alleles for each monogenic trait should be present. Both are not required for the expression of all monogenic traits.

PTS: 1

18. ANS: C
Homozygous alleles are identical on both chromosomes of a pair and result in the expression of both of these identical alleles in the phenotype, regardless of whether the alleles are both recessive or both dominant. Heterozygous alleles are different on both chromosomes of a pair. Although they may both be expressed or one may be silent, the phenotype does not always reflect the genotype. Trisomy of alleles would require an extra chromosome. This condition, unless the alleles are homozygous, does not always result in identical genotype and phenotype. Triploidy, like trisomy, would require an extra chromosome copy (actually, a whole extra set of chromosomes). This condition, unless the alleles are homozygous, does not always result in identical genotype and phenotype.

PTS: 1

19. ANS: D
If, during S phase of one cell cycle, the replicated DNA had covalent bonds rather than hydrogen bonds, the cell could complete that round of cell division, resulting in two new daughter cells. When either of these two new daughter cells then reentered the cell cycle, it could not complete the cycle. The tight covalent bonds of the DNA in each of these cells would not break apart to allow each strand to separate and be used as templates for DNA replication and synthesis. Thus, the cycle would be arrested at this stage.

PTS: 1

20. ANS: B
Replication of DNA is performed when double-stranded DNA is separated and each strand is used as a template to guide the correct construction of a complementary strand. Synthesis of new DNA begins at multiple sites, creating many short pieces. The enzyme DNA ligase connects or links the individual pieces of newly synthesized DNA during replication, forming a new single strand complementary to the template strand. The enzyme DNA helicase unwinds the double helix and initially separates the ds-DNA. The group of topoisomerase enzymes creates a “nick” in the supercoils of ds-DNA, allowing them to loosen so that eventually the two strands can separate. The enzyme primase is responsible for initiating DNA synthesis in multiple sites down the single strand being copied.

PTS: 1

21. ANS: A
Telomeric DNA is a type of noncoding DNA located at the tips of chromosomes. Its purpose is to prevent DNA strands from unraveling. It is present in all linear DNA. The mitochondria do not contain linear DNA or true chromosomes. It is present in all somatic cells, as well as germ cells.

PTS: 1

22. ANS: A
A centromere is the pinched-in area of the chromosome that connects the two halves (sister chromatids) together in a metaphase chromosome. It also connects the chromosome segments above it and below it. The centromere has no role in DNA replication. The telomeres prevent chromosome unraveling. DNA replication proceeds in the 5'-to-3' direction and is determined by specific enzymes, not the centromere.

PTS: 1

23. ANS: C
Chromosomes are temporary structures that have the important job of making the delivery of DNA to the two new cells precise so that one new cell does not get more or less than the correct amount of DNA and the correct distribution of the genes. This precision is critical for the new cells to be able to function normally. Chromosomes are not involved in either DNA synthesis or protein synthesis.

PTS: 1

24. ANS: B
Blood type alleles A and B are codominant, and O is recessive. Thus when O is paired with either A or B, it is not expressed. When A and B are paired together, both are expressed, and the blood type is AB. In this situation both parents are heterozygous. For each pregnancy there is one chance out of four (25%) of the AB blood type being expressed, two chances out of four (50%) of the B blood type being expressed (with either a B/B genotype or a B/O genotype), one chance out of four (25%) of the A blood type being expressed (from an A/O genotype), and no chance (0%) of an O blood type (O/O genotype) being expressed.

PTS: 1

25. ANS: A
A euploid karyotype for humans has a total of 46 chromosomes, 44 autosomes, and a pair (2) of sex chromosomes. The fact that this karyotype has only 45 chromosomes makes it aneuploid. Because the person is missing a sex chromosome and only one X is present, the person is female but has only one allele for each gene on the X chromosome (and none of the alleles for genes on the Y chromosome).

PTS: 1