Chapter 1
Genes Are DNA

Chapter Summary

This chapter provides evidence for DNA as the universal genetic material of prokaryotic and eukaryotic organisms and many viruses. Other viruses have an RNA genome, but for these the RNA is converted to DNA as part of the infection process. Prions are unusual small agents that are composed of protein but become pathogenic because of alterations of cellular proteins. DNA is a double helix with individual nucleotides joined in a 5′ to 3′ fashion, with the two strands running antiparallel, forming a major and minor groove. The two strands are separated during DNA replication and are copied in a semiconservative fashion, where each of the parental strands serves as a template for synthesis of a new daughter strand. Base pairing by hydrogen bonding between G and C and between A and T maintains the double-stranded nature of DNA, and hybridization using the same base pairing can be used to examine homology between DNA from different species. Mutations alter DNA sequence and can affect single base pairs (point mutations) or longer sequences (insertions or deletions). Reversions can restore or reactivate mutated genes except for deletions. Mutations may occur preferentially at hotspots, such as modified bases.

Keywords

1. **Genome** (pg. 2) The entire sequence of nucleic acid that provides the genetic information to construct a given organism.
2. **Gene** (pg. 3) A sequence within the genome that encodes a single protein.
3. **Transformation** (pg. 3) The transfer of a segment of genetic information from one organism to another, such as the transfer of a plasmid to a new host. Traditionally, this term has been applied to bacterial species.
4. **Transfection** (pg. 5) A similar term to transformation but applied more traditionally to eukaryotic cells, based on transfer of DNA such as a virus.
5. **Nucleotides** (pg. 6) The basic building block of nucleic acids, having three components: a nitrogenous base, a ribose or deoxyribose sugar, and a phosphate.
6. **Complementarity** (pg. 7) The base pairing of double-stranded nucleic acids, where G pairs with C (three H-bonds) and A pairs with T (two H-bonds).
7. **Antiparallel** (pg. 7) The two polynucleotide chains in double-stranded DNA run in opposite, or antiparallel, directions as related to the phosphodiester backbone.

8. **Minor and major grooves** (pgs. 8–9) The twisting of the two strands in double-stranded DNA forms a double helix with a minor groove (~12 Å across) and a major groove (~22 Å across). This is important for protein–DNA interactions.
9. **Semiconservative replication** (pg. 9) Each strand of the duplex parental DNA is used as a template for replication of a new daughter strand, resulting in new double-stranded DNA where one of the two strands originated from the parental duplex.
10. **Replication fork** (pg. 10) The junction formed by disruption of the parental duplex strands where DNA replication occurs. The fork moves along the DNA as replication progresses.
11. **Exonucleases** (pg. 10) Enzymes that remove nucleotide residues one at a time from either end of a linear molecule, generating mononucleotides.
12. **Endonucleases** (pg. 10) Enzymes that cut individual phosphodiester bonds within RNA or DNA molecules, generating discrete fragments.
13. **Central dogma** (pg. 10) The information in DNA is transcribed to RNA, which is then translated into protein. Reverse transcription can result in RNA being copied to DNA, but the transfer into protein is irreversible.
14. **Reverse transcription** (pg. 11) The process of conversion of a single-stranded RNA to single-stranded DNA by the enzyme reverse transcriptase.
15. **Retroviruses** (pg. 11) Animal viruses that contain a single-stranded RNA genome, which is converted during infection into double-stranded DNA that is then inserted into the host cell genome.
16. **T_m-melting temperature** (pg. 13) The midpoint of the range over which the two strands of DNA separate, which depends on the proportion of G–C base pairs.
17. **Renaturation** (pg. 13) The ability of two separated complementary strands to reform into a double helix, which depends on specific base pairing between the strands.
18. **Hybridization** (pg. 13) The process where any two complementary strands (usually from different sources) are allowed to react with each other to form a duplex structure, depending on their degree of complementarity.
19. **Mutagens/induced mutations** (pg. 14) Compounds (mutagens) that react with DNA to cause modifications to a particular DNA base or become incorporated into the nucleic acid, resulting in induced mutations.
20. **Spontaneous mutations** (pg. 15) Normal mutations that occur as a result of normal cellular operations or random interactions with the environment.
21. **Point mutations** (pg. 15) A mutation that changes only a single base pair, usually due to chemical modification of a base or to a malfunction during DNA replication.
22. **Transitions and transversions** (pg. 15) Transitions are substitutions of one pyrimidine by the other or of one purine by the other (i.e., G–C to A–T). Transversions are less common, where a purine is replaced by a pyrimidine or vice versa (i.e., A–T to T–A or C–G).
23. **Insertions** (pg. 16) Additional nucleic acid sequence inserted into a molecule.
24. **Deletions** (pg. 16) Removal of inserted or existing sequences from a polynucleotide.
25. **Transposable elements** (pg. 16) Sequences of DNA with the ability to move from one site to another.

26. **Revertants** (pg. 16) A mutation that has regained normal sequence and/or function; possible for point mutations and insertions but not deletions.
27. **Forward mutation** (pg. 16) Mutations that inactive a gene.
28. **Back mutation** (pg. 16) Reversal of a forward mutation, resulting in reactivation of a gene.
29. **Suppression** (pg. 17) Mutation in a second gene that circumvents the effects of a mutation in the original gene.
30. **Mutation hotspots** (pg. 18) Mutations that occur at nonrandom preferred sites; both spontaneous and induced mutations may occur at hotspots.
31. **Modified bases** (pg. 18) Alterations to bases in nucleic acids produced by chemical modifications to one or more of the four bases. The most common is 5-methylcytosine.
32. **Viroids** (pg. 19) Infectious small RNA agents that cause diseases in higher plants; the viroid RNA itself is the infectious agent and is usually not translated into protein.
33. **Virions** (pg. 19) Infectious nucleic acid (virus) encapsulated in a protein coat.
34. **Prions** (pg. 20) Proteinaceous infectious agents such as scrapie that does not contain any nucleic acid but is due to modified cellular proteins.

Fill-in-the-Blank Questions

Fill in the correct words in the following statements or paragraphs.

When 1. __________________ bacteria are killed by 2. __________________ treatment, they lose their ability to harm mice. But 3. __________________ heat-killed 4. __________________ bacteria and avirulent 5. ___________ bacteria, when jointly injected into mice, result in 6. __________________ of the mouse. Recovered bacteria from the dead mice were found to be 7. __________________ and 8. __________________.

The three components of nucleotides are 9. __________________, 10. __________________, and 11. __________________.

The x-ray diffraction of DNA modeled by Watson and Crick in 1953 showed that DNA has the form of a regular 12. __________________, making a complete turn every 13. __________________, with a diameter of 14. __________________ and 15. __________________ bases per turn.

The two major differences between uridine (in RNA) and thymidine (in DNA) are 16. ____________________________ and 17. ____________________________.

Cytosine is converted to uracil by oxidative 18. __________________ caused by 19. __________________ acid.

Most mutagens act on DNA to cause 20. __________________ mutations and act to either 21. __________________ a particular base of DNA or become 22. __________________ into the nucleic acid.

Multiple-Choice Questions

23. Which strain of *Pneumococcus* was found to be avirulent (nonlethal) when mice were infected with it?
    A. the smooth strain
    B. the rough strain
    C. both strains
    D. none was virulent

24. What isotope can be used to specifically label protein and not DNA or RNA?
    A. ^{14}C
    B. ^{3}H
    C. ^{32}P
    D. ^{35}S

25. The difference between RNA and DNA is the presence of
    A. a 2′ PO_4 group on the ribose sugar in RNA.
    B. a 3′ PO_4 group on the ribose sugar in RNA.
    C. a 2′ OH group on the ribose sugar in RNA.
    D. a 3′ OH group on the ribose sugar in RNA.

26. The predominant form of DNA in cells is
    A. A form.
    B. B form.
    C. Y form.
    D. Z form.

27. Which pair of scientists determined that DNA replication is semiconservative?
    A. Meselson and Stahl
    B. Watson and Crick
    C. Okazaki and Okazaki
    D. Griffith and Avery

28. In the density labeling experiment to study DNA replication, parental DNA in the cell was labeled with a high-density isotope and, after one or more generations of growth, subjected to density gradient centrifugation. Which of the following populations was not detected after the second generation?
    A. the light density population
    B. the hybrid density population
    C. the heavy density population
    D. both the light and heavy density populations

29. Which class of molecules is inserted into the host genome as a double-stranded DNA segment?
    A. retroviruses
    B. double-stranded RNA viruses
    C. double-stranded DNA viruses
    D. viroids
30. A DNA molecule with 40% G–C base pairs would have a T_m of about
    A. 54°C.
    B. 65°C.
    C. 87°C.
    D. 94°C.
31. The mutation rate in bacteria is about
    A. 10^{-6} per locus per generation.
    B. 10^{-7} per locus per generation.
    C. 10^{-8} per locus per generation.
    D. 10^{-9} per locus per generation.
32. Which of the following is the most common modified base in DNA?
    A. 5-methylthymine
    B. 5-methylcytosine
    C. 5-methyladenine
    D. 5-methylguanine
33. What does the presence of the modified base in the previous question often lead to?
    A. transitions
    B. transversions
    C. deletions
    D. insertions
34. About 30% of human point mutations are associated with which of the following modified bases?
    A. 5-methylguanine
    B. 5-methyladenine
    C. 5-methylthymine
    D. 5-methylcytosine
35. The reversal of an original base pair that was changed from A–T to G–C and then back to A–T is an example of
    A. true reversion.
    B. second-site reversion.
    C. forward mutation.
    D. suppression.

Matching Questions

Match the following events with the correct date from the list at the right.

36. Discovery that genes lie on chromosomes	A. 1910
37. Development of methods for DNA sequencing	B. 1927
38. Mutations are physical changes in genes	C. 1944
39. Elucidation of DNA double helix structure	D. 1951
40. The first protein sequence determined	E. 1953
41. The first bacterial genomes sequenced	F. 1961
42. Discovery of introns	G. 1977
43. Determination that DNA is the genetic material	H. 1995
44. Elucidation of the triplet codon nature of the genetic code	I. 1998

Match the following organisms/genomes with their correct size in base pairs from the list at the right.

45. Influenza	A. 5,000
46. Parvovirus	B. 13,500
47. Mycoplasma	C. 165,000
48. Flies	D. $<10^6$
49. Plants	E. $<10^7$
50. Phage T4	F. 1.6×10^8
51. Mammals	G. 3×10^9
52. Bacteria	H. $<10^{11}$

Thought Questions

53. What other cell components besides DNA could have been the primary genetic material?
54. What would have been the interpretation from the bacterial virus experiment if ^{35}S had been taken up into the bacterial cell rather than ^{32}P?
55. What would have been the interpretation from the bacterial virus experiment if both ^{35}S and ^{32}P had been taken up into the bacterial cell rather than just ^{32}P?