Cheat Sheet

DNA, the double helix

Shown here is a ribbon model of DNA, with each ribbon representing one of the sugar-phosphate backbones. As you will recall from Figure 16.7, the phosphate groups along the backbone contribute a negative charge along the outside of each strand. The TEM shows a molecule of naked DNA; the double helix alone is 2 nm across.

Histones

Proteins called **histones** are responsible for the first level of DNA packing in chromatin. Although each histone is small—containing only about 100 amino acids—the total mass of histone in chromatin approximately equals the mass of DNA. More than a fifth of a histone's amino acids are positively charged (lysine or arginine) and therefore bind tightly to the negatively charged DNA.

Four types of histones are most common in chromatin: H2A, H2B, H3, and H4. The histones are very similar among eukaryotes; for example, all but two of the amino acids in cow H4 are identical to those in pea H4. The apparent conservation of histone genes during evolution probably reflects the important role of histones in organizing DNA within cells.

The four main types of histones are critical to the next level of DNA packing. (A fifth type of histone, called H1, is involved in a further stage of packing.)

Nucleosomes, or "beads on a string" (10-nm fiber)

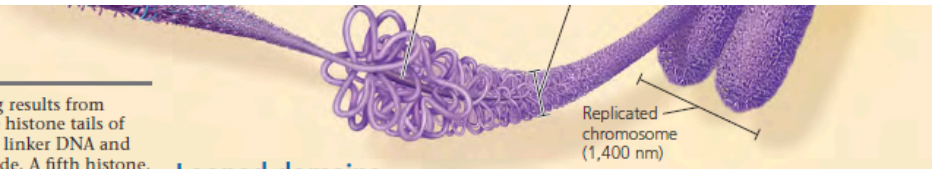
In electron micrographs, unfolded chromatin is 10 nm in diameter (the *10-nm fiber*). Such chromatin resembles beads on a string (see the TEM). Each "bead" is a **nucleosome**, the basic unit of DNA packing; the "string" between beads is called *linker DNA*.

A nucleosome consists of DNA wound twice around a protein core composed of two molecules each of the four main histone types. The amino end (N-terminus) of each histone (the *histone tail*) extends outward from the nucleosome.

In the cell cycle, the histones leave the DNA only briefly during DNA replication. Generally, they do the same during transcription, another process that requires access to the DNA by the cell's molecular machinery. Chapter 18 will discuss some recent findings about the role of histone tails and nucleosomes in the regulation of gene expression.

30-nm fiber

The next level of packing results from interactions between the histone tails of one nucleosome and the linker DNA and nucleosomes on either side. A fifth histone, H1, is involved at this level. These interactions cause the extended 10-nm fiber to coil or fold, forming a chromatin fiber roughly 30 nm in thickness, the *30-nm fiber*. Although the 30-nm fiber is quite prevalent in the interphase nucleus, the packing arrangement of nucleosomes in this form of chromatin is still a matter of some debate.



Looped domains (300-nm fiber)

The 30-nm fiber, in turn, forms loops called *looped domains* attached to a chromosome scaffold made of proteins, thus making up a *300-nm fiber*. The scaffold is rich in one type of topoisomerase, and H1 molecules also appear to be present.

Metaphase chromosome

In a mitotic chromosome, the looped domains themselves coil and fold in a manner not yet fully understood, further compacting all the chromatin to produce the characteristic metaphase chromosome shown in the micrograph above. The width of one chromatid is 700 nm. Particular genes always end up located at the same places in metaphase chromosomes, indicating that the packing [illegible] specific and precise.

Chapter 16 Questions

1. **What is transformation?**
2. **What are bacteriophages (phage for short)?**
3. **What is a virus?**
4. **What are Chargaff's rules?**
5. **What does antiparallel mean?**
6. **At what length does the double helix of DNA make a full turn?**
7. **What are the three models for DNA replication?**
8. **What is the DNA structure of *E. coli*?**
9. **How many nucleotide pairs do human somatic cells have?**
10. **What is the error rate in DNA replication?**
11. **What are origins of replication?**
12. **What does separating the strands at the origin of replication form?**
13. **What is a replication fork?**
14. **What are the helicases, single-strand binding proteins, and topoisomerase?**
15. **What is the initial nucleotide chain produced during DNA synthesis?**
16. **What are DNA polymerases?**
17. **What are the two main DNA polymerases in *E. coli* and how do they function?**
18. How many DNA polymerases have been discovered in eukaryotes?
19. **What are the leading and lagging strands?**
20. **What connects Okazaki fragments?**
21. **How are the various proteins that participate in DNA replication organized?**
22. **How often do initial pairing errors occur?**
23. **How are pairing errors decreased 100,000 fold?**
24. **What is mismatch repair?**
25. How many DNA repair enzymes have been found in *E. coli* and in humans?
26. **What occurs in nucleotide excision repair?**
27. **What genetic damage results from ultraviolet rays?**
28. **What is xeroderma pigmentosum (XP)?**
29. **What prevents erosion of genes of linear eukaryotic chromosomes?**
30. **What does telomerase do?**
31. **Describe the 6 stages of chromatin packing.**
32. **What are heterochromatin and euchromatin?**

Chapter 16 Answers

1. Change in genotype and phenotype due to the assimilation of external DNA by a cell
2. Viruses that infect bacteria
3. DNA or RNA enclosed by protective coat (often simply protein), must infect cell and take over metabolic machinery to reproduce
4. 1: DNA base composition varies between species, 2:[A]=[T] and [C]=[G]
5. Running in opposite directions
6. Every 3.4 nm along its length
7. Conservative - Parental strands reassociate after used as template(restores parent helix)
   Semiconservative - Two parental strands separate, function as template for new strand
   Dispersive - Each strand of both daughter molecules contains mixture of old/new DNA
8. single chromosome, 4.6 million nucleotide pairs
9. 6 billion
10. 1 in 10 billion nucleotides
11. Short stretches of DNA that have a specific sequence of nucleotides, where replication begins, in circular chromosomes there is a single origin, few thousand in eukaryotic chromosomes
12. Replication bubbles
13. Y-shaped region where parental strands of DNA are being unwound
14. Enzymes that untwist double helix at replication, separate parental strands

    Bind to unpaired DNA strands, keep from re-pairing

    Enzyme that relieves strain in ahead of replication fork caused by untwisting of double helix, breaks, swivels, and rejoins DNA strands
15. Short stretch of RNA called primer synthesized by primase (5-10 nucleotides long)
16. Enzymes that add nucleotides to 3’ end of preexisting chain
17. DNA polymerase III, DNA polymerase I. DNA pol III adds DNA nucleotide to RNA primer continues adding DNA nucleotides complementary to parental strand to end of new strand. Rate of elongation = 500 nucleotides per second (50 per second in humans cells). Each nucleotide has sugar, base, and 3 phosphates (dATP is adenine nucleotide). DNA polymerase catalyzes addition of monomer, as added, pyrophosphate (Ⓟ-$Ⓟ_i$) is lost, hydrolysis of pyrophosphate to two molecules of $Ⓟ_i$ helps drive DNA polymerization.

    DNA pol I replaces RNA nucleotides of primer with DNA nucleotides (on lagging strand)
18. 11
19. DNA pol III remains in replication fork, continuously adds nucleotides to new strand as fork progresses (only one primer required)

DNA strand elongating away from replication fork, synthesized as series of segments (Okazaki fragments about 1000-2000 nucleotides in *E. coli*, 100-200 in eukaryotes)

20. DNA ligase
21. In a single large complex (DNA replication complex), primase acts as molecular brake, complex may not move along DNA, DNA may move through complex, DNA pol molecules may reel in parental DNA and extrude new DNA (trombone model)
22. 1 in 10^5
23. DNA polymerases proofread each nucleotide, if finds error removes nucleotide and resumes synthesis
24. Enzymes remove and replace incorrectly paired nucleotides that have resulted from replication errors., defect associated with form of colon cancer (mutations accumulate)
25. 100 and 170 (act after replication)
26. A nuclease excises damaged segment and DNA pol and ligase fill in nucleotides
27. Adjacent thymine bases become covalently linked (thymine dimers), cause DNA to buckle and interfere with DNA replication
28. Disorder caused by inherited defect in nucleotide excision repair enzyme, causes hypersensitivity to sunlight (mutations in skin cells not corrected, skin cancer results)
29. Telomeres (special nucleotide sequences), do not contain genes, at ends, consists of multiple repetitions of one short nucleotide sequence (in humans, 6-nucleotide sequence TTAGGG repeated 100-1,000 times. Proteins associated with telomeres prevent staggered ends from activating cell's systems for monitoring DNA damage, telomere acts as buffer zone that provides protection against organism's genes shortening
30. Enzyme that catalyzes lengthening of telomeres in eukaryotic germ cells, restores original length (contains own RNA molecule used as template to artificially extend leading strand), activity high in germ cells. Activity abnormally high in cancerous somatic cells, allows cancer cells to persist
31. See picture
32. Denser, highly condensed state, appears as irregular clumps with LM, present during interphase

    Less compacted, more dispersed