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Chapter 16

The DNA Molecule: The Molecular Basis of Inheritance

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

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The Structure of Nucleic Acids

- What are the nucleic acids monomers called?

  ____

- What are the nucleic acid polymers called?

  ____

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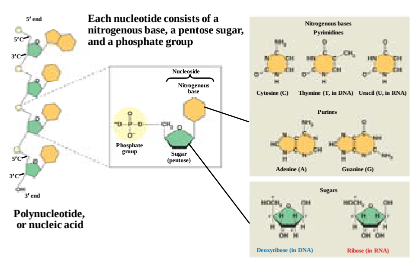
Fig. 5-27

Each nucleotide consists of a nitrogenous base, a pentose sugar, and a phosphate group



The nucleotide without the phosphate is called a *nucleoside*

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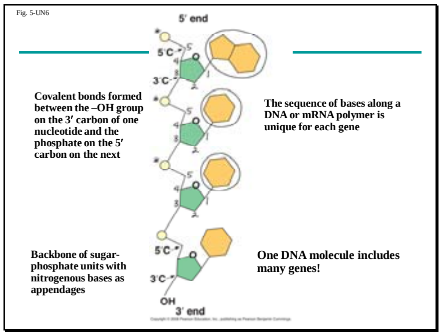

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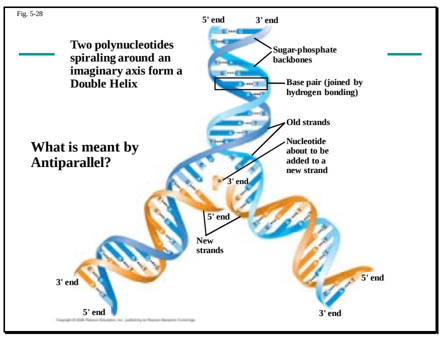

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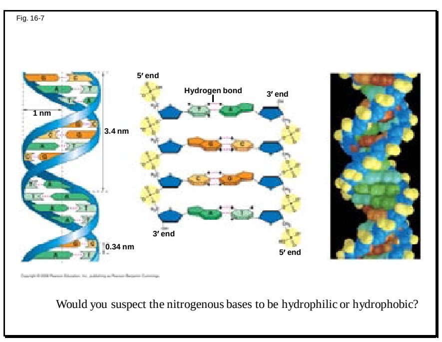

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What DNA bases can pair up?

___________ and ___________

___________ and ___________

How many DNA molecules do we have? _________

How many do bacteria have? _________

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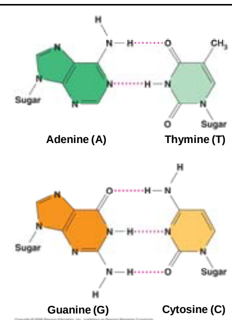
Fig. 16-8



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1953: Watson and Crick Publish the Structure of DNA

"It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." Watson and Crick

One-page paper in the journal, Nature

- Structure of DNA suggests its function (DNA replication)

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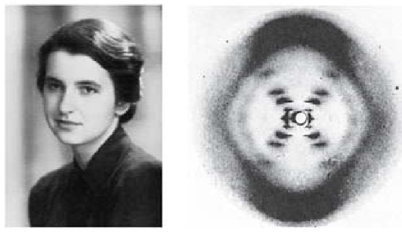
Fig. 16-6

Maurice Wilkins and Rosalin Franklin were using X-ray crystallography to study molecular structure of DNA



(a) Rosalind Franklin (b) Franklin's X-ray diffraction photograph of DNA

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Fig. 16-10

Which model is correct?

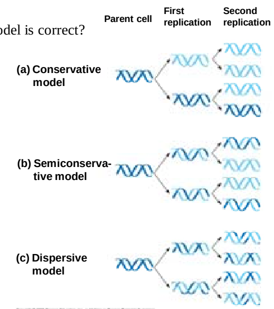

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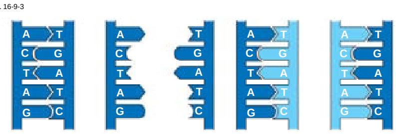
Fig. 16-9-3



(a) Parent molecule (b) Separation of strands (c) "Daughter" DNA molecules, each consisting of one parental strand and one new strand

Since the two strands of DNA are <u>complementary</u>, each strand acts as a template for building a new strand in replication

In DNA replication, the <u>parent</u> molecule unwinds, and two new <u>daughter</u> strands are built based on base-pairing rules

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DNA Replication: *A Closer Look*

- The copying of DNA is remarkable in its speed and accuracy
- More than a dozen enzymes and other proteins participate in DNA replication

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Getting Started

- Replication begins at special sites called **origins of replication**, where the two DNA strands are separated, opening up a replication "bubble"
- A eukaryotic chromosome may have hundreds or even thousands of origins of replication
- Replication proceeds in both directions from each origin, until the entire molecule is copied

PLAY Animation: Origins of Replication

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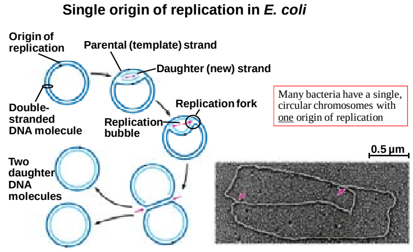
Fig. 16-12a

Single origin of replication in *E. coli*



Many bacteria have a single, circular chromosomes with one origin of replication

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Fig. 16-12b

Multiple origins of replication in eukaryotes

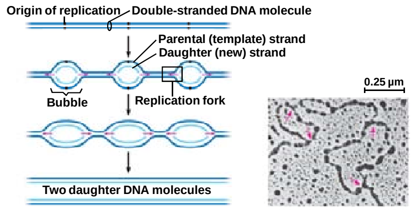

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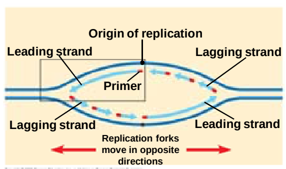
Fig. 16-15a

Overview: 2 Different Things Going On

1. Leading strand synthesis
2. Lagging strand synthesis



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Leading Strand Synthesis

- DNA polymerases add nucleotides only to the free 3′ end of a growing strand; therefore, a new DNA strand can elongate only in the 5′ to 3′ direction
- Along one template strand of DNA, the DNA polymerase synthesizes a **leading strand** continuously, moving toward the replication fork

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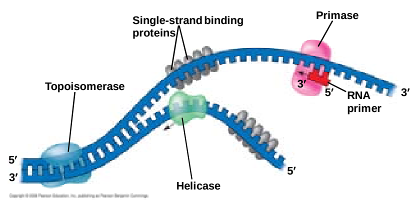
Fig. 16-13

Replication Fork



What function do each of these enzymes perform?

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DNA polymerases can't initiate synthesis of a polynucleotide; they can only add nucleotides to the 3′ end

- The initial nucleotide strand is a short RNA **primer**
- An enzyme called **primase** can start an RNA chain from scratch and adds RNA nucleotides one at a time using the parental DNA as a template
- The primer is short (5–10 nucleotides long), and the 3′ end serves as the starting point for the new DNA strand

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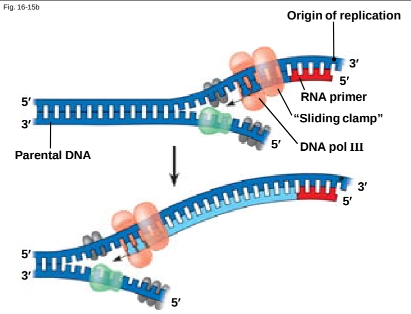
Fig. 16-15b



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- Each nucleotide that is added to a growing DNA strand is a nucleoside triphosphate
- dATP supplies adenine to DNA and is similar to the ATP of energy metabolism
- The difference is in their sugars: dATP has deoxyribose while ATP has ribose
- As each monomer of dATP joins the DNA strand, it loses two phosphate groups as a molecule of pyrophosphate

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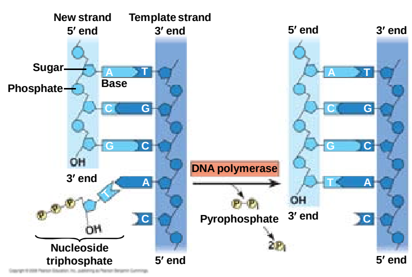
Fig. 16-14



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Lagging Strand Synthesis

- To elongate the other new strand, called the **lagging strand**, DNA polymerase must work in the direction away from the replication fork
- The lagging strand is synthesized as a series of segments called **Okazaki fragments**, which are joined together by **DNA ligase**

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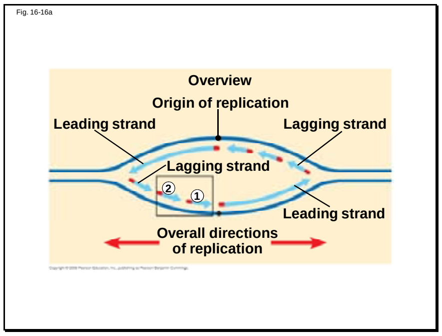

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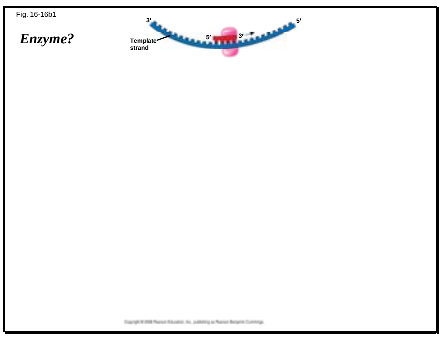

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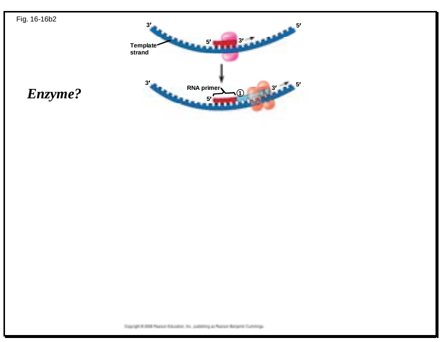

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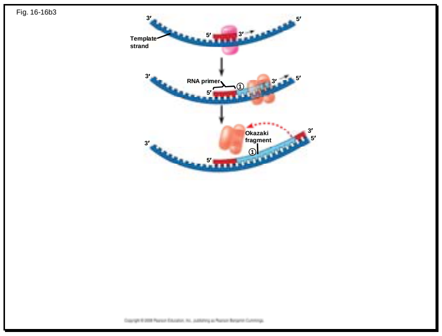

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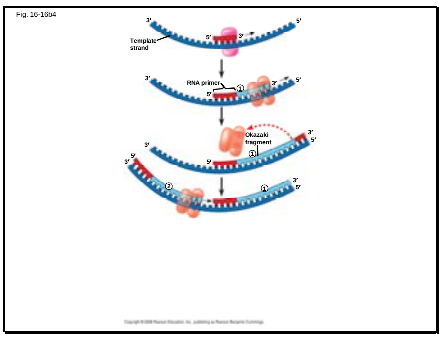

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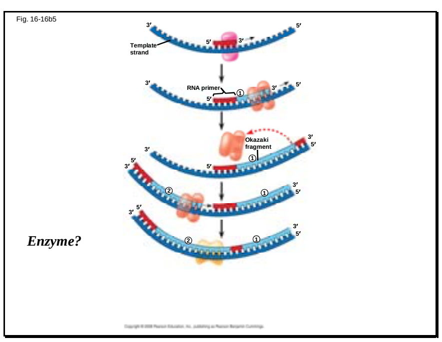

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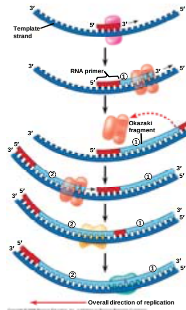
Fig. 16-16b6



Enzyme?

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Table 16-1

Table 16.1 Bacterial DNA Replication Proteins and Their Functions

Protein	Function
Helicase	Unwinds parental double helix at replication forks
Single-strand binding protein	Binds to and stabilizes single-stranded DNA until it can be used as a template
Topoisomerase	Relieves "overwinding" strain ahead of replication forks by breaking, swiveling, and rejoining DNA strands
Primase	Synthesizes an RNA primer at 5′ end of leading strand and of each Okazaki fragment of lagging strand
DNA pol III	Using parental DNA as a template, synthesizes new DNA strand by covalently adding nucleotides to the 3′ end of a pre-existing DNA strand or RNA primer
DNA pol I	Removes RNA nucleotides of primer from 5′ end and replaces them with DNA nucleotides
DNA ligase	Joins 3′ end of DNA that replaces primer to rest of leading strand and joins Okazaki fragments of lagging strand

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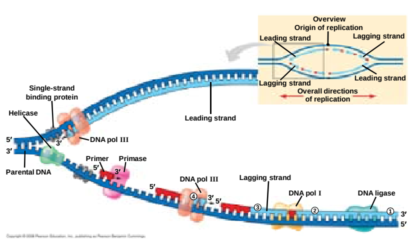
Fig. 16-17

Describe this figure – What is each enzyme doing?



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The DNA Replication Complex

- The proteins that participate in DNA replication form a large complex, a “DNA replication machine”
- The DNA replication machine is probably stationary during the replication process
- Recent studies support a model in which DNA polymerase molecules “reel in” parental DNA and “extrude” newly made daughter DNA molecules

PLAY Animation: DNA Replication Review

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Proofreading and Repairing DNA

- Replication has an error rate at ~1 in 100,000 nucleotides, but DNA polymerases proofread newly made DNA, replacing any incorrect nucleotides (only 1 in 10 billion errors occur following this process).
- In **mismatch repair** of DNA, repair enzymes correct errors in base pairing (usually just after replication)
- DNA can also be damaged by chemicals, radioactive emissions, X-rays, UV light, and certain molecules (in cigarette smoke for example)
- In **nucleotide excision repair**, a **nuclease** cuts out and replaces damaged stretches of DNA

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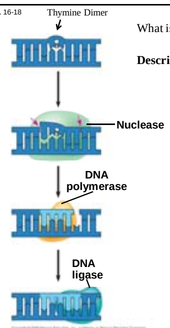
Fig. 16-18



What is a thymine dimer?

Describe the Steps in Nucleotide Excision Repair

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Replicating the Ends of DNA Molecules

- Limitations of DNA polymerase create problems for the linear DNA of eukaryotic chromosomes
- The usual replication machinery provides no way to complete the 5′ ends of daughter DNA strands, so repeated rounds of replication produce shorter DNA molecules

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Fig. 16-19

Describe the shortening of linear DNA molecules with each round of replication.

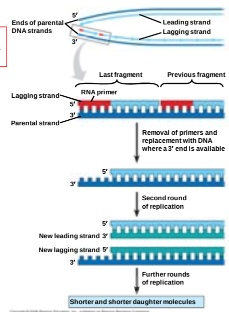

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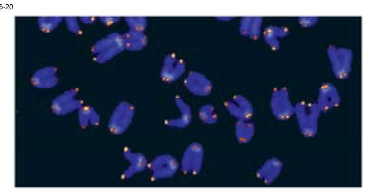
Fig. 16-20



- Eukaryotic chromosomal DNA molecules have at their ends nucleotide sequences called **telomeres** (stained dots above)
- Telomeres do not prevent the shortening of DNA molecules, but they do postpone the erosion of genes near the ends of DNA molecules
- It has been proposed that the shortening of telomeres is connected to aging

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- If chromosomes of germ cells became shorter in every cell cycle, essential genes would eventually be missing from the gametes they produce
- An enzyme called **telomerase** catalyzes the lengthening of telomeres in germ cells
- The shortening of telomeres might protect cells from cancerous growth by limiting the number of cell divisions
- There is evidence of telomerase activity in cancer cells, which may allow cancer cells to persist

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Concept 16.3 A chromosome consists of a DNA molecule packed together with proteins

- In Bacteria:
  - The chromosome is a double-stranded, circular DNA molecule associated with a small amount of protein
  - the DNA is "supercoiled" and found in a region of the cell called the **nucleoid**
- In Eukaryotes:
  - chromosomes have linear DNA molecules associated with a large amount of protein
  - **Chromatin** is a complex of DNA and protein found in the nucleus of eukaryotic cells
  - **Histones** are proteins that are responsible for the first level of DNA packing in chromatin

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Fig. 16-21a

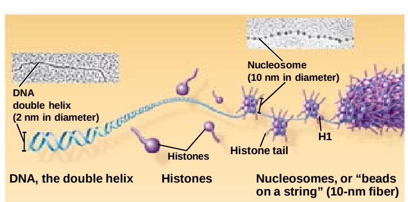

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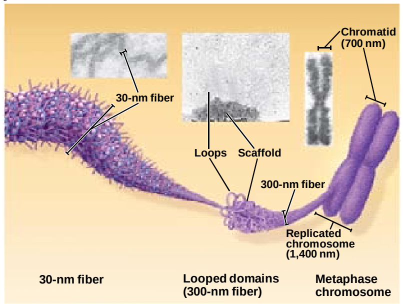
Fig. 16-21b



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Chromatin is organized (packed) into fibers

- **10-nm fiber:**
  - DNA winds around histones to form **nucleosome** "beads"
  - Nucleosomes are strung together like beads on a string by linker DNA
- **30-nm fiber**
  - Interactions between nucleosomes cause the thin fiber to coil or fold into this thicker fiber
- **300-nm fiber**
  - The 30-nm fiber forms **looped domains** that attach to proteins
- **Metaphase chromosome**
  - The looped domains coil further
  - The width of a chromatid is 700 nm

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Chromatin undergoes changes in its degree of packing during the cell cycle – it is dynamic

- Most chromatin is loosely packed in the nucleus but condenses prior to cell division
- Loosely packed chromatin is called **euchromatin**
- **Heterochromatin,** or highly condensed chromatin is inaccessible to gene expression machinery
- Histones can undergo chemical modifications that result in changes in chromatin organization
  - For example, phosphorylation of a specific amino acid on a histone tail affects chromosomal behavior during meiosis