## **DNA Molecular Structure**

- DNA deoxyribonucleic acid a long threadlike molecule with uniform diameter, but varied length
  - 46 DNA molecules in the nucleus of most human cells
    - total length of 2 meters
    - average DNA molecule 2 inches long
- DNA and other nucleic acids are polymers of nucleotides
- Each nucleotide consists of
  - one sugar deoxyribose
  - one phosphate group
  - one nitrogenous base
    - Either pyrimidine (single carbon-nitrogen ring) or purine (double ring)

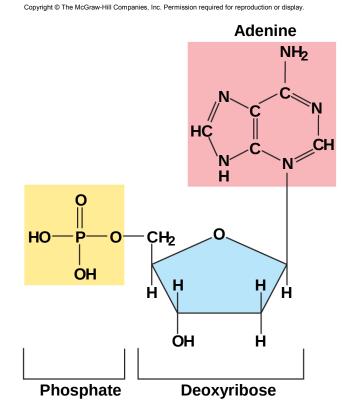


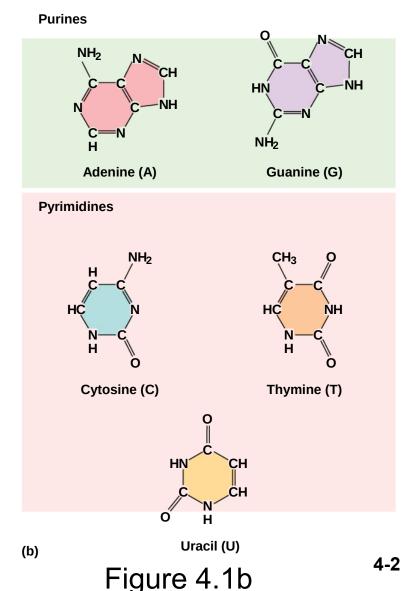
Figure 4.1a

(a)

## **Nitrogenous Bases of DNA**

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

- Purines double ring
  - Adenine (A)Guanine (G)
- **Pyrimidines** single ring
  - Cytosine (C)
  - -Thymine (T)
- DNA bases ATCG



## **DNA Structure**

- Molecular shape is a double helix (resembles a spiral staircase)
  - each sidepiece is a backbone composed of phosphate groups alternating with the sugar deoxyribose.
  - steplike connections between the backbones are pairs of nitrogen bases

Figure 4.2

Sugar-phosphate

backbone

Hydrogen bond

Sugar-phosphate

backbone

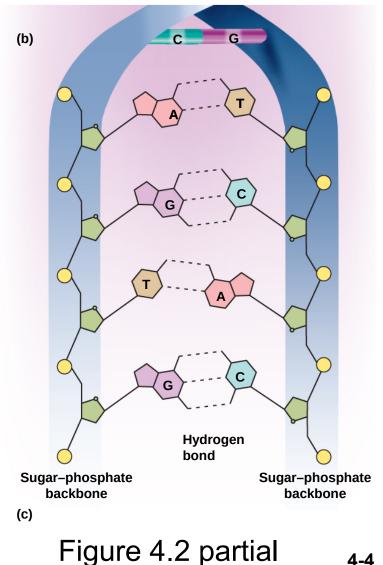
(a)

(b)

# **Complementary Base Pairing**

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

- Nitrogenous bases united by hydrogen bonds
  - a purine on one backbone with a pyrimidine on the other
  - A T two hydrogen bonds
  - **C G** three hydrogen bonds
- DNA base pairing
  - A T
  - C G
- Law of Complementary Base Pairing
  - one strand determines base sequence of other



Δ\_Δ

## **DNA Function**

- Genes genetic instructions for synthesis of proteins
- Gene segment of DNA that codes for a specific protein
- Genome all the genes of one person
  - -humans have estimated 25,000 to 35,000 genes
    - 2% of total DNA
    - other 98% is noncoding DNA
      - plays role in chromosome structure
      - regulation of gene activity
      - no function at all "junk" DNA

## **Chromatin and Chromosomes**

 chromatin – fine filamentous DNA material complexed with proteins Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

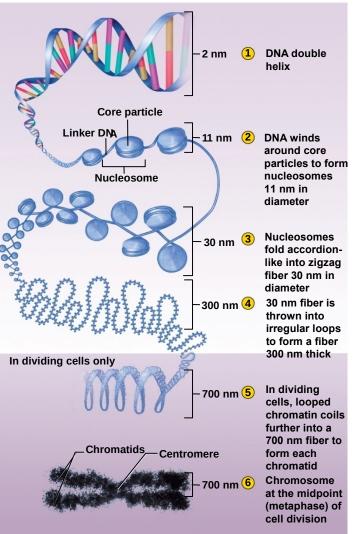
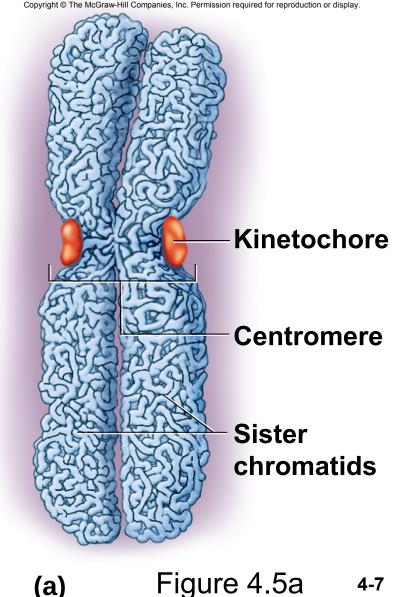


Figure 4.4b 4-6

## **Cells Preparing to Divide**

- exact copies are made of all the nuclear DNA
- each chromosome consists of two parallel filaments of identical DNA sister chromatids
- in prophase, final coiling and condensing
  - now visible with light microscope
- final compaction enables the two sister chromatids to be pulled apart and carried to separate daughter cells without damage to the DNA
  - joined at centromere
  - kinetochore protein plaques on either side of the centromere



## **RNA: Structure and Function**

- **RNA** smaller than DNA (fewer bases)
  - messenger RNA (mRNA) over 10,000 bases
  - ribosomal RNA (rRNA)
  - transfer RNA (tRNA) 70 90 bases
  - DNA averages 100 million base pairs

### • one nucleotide chain (not a double helix as DNA)

- ribose replaces deoxyribose as the sugar
- uracil replaces thymine as a nitrogenous base
- Essential function
  - interprets code in DNA
  - uses those instructions for protein synthesis
  - leaves nucleus and functions in cytoplasm

## What is a Gene?

- Previous definition gene a segment of DNA that carries the code for a particular protein???
  - Body has millions of proteins but only 35,000 genes?
  - Small % of genes produce only RNA molecules
  - Some segments of DNA belong to 2 different genes
- Current Definition gene an information-containing segment of DNA that codes for the production of a molecule of RNA that plays a role in synthesizing one or more proteins
- Amino acid sequence of a protein is determined by the nucleotide sequence in the DNA

### Human Genome

- **Genome** all the DNA in one 23-chromosome set
  - 3.1 billion nucleotide pairs in human genome
- 46 human chromosomes comes in two sets of 23 chromosomes
  - one set of 23 chromosomes came form each parent
  - each pair of chromosomes has same genes but different versions (alleles) exist
- Human Genome Project (1990-2003) identified the nitrogenous base sequences of 99% of the human genome
  - genomics the comprehensive study of the whole genome and how its genes and noncoding DNA interact to affect the structure and function of the whole organism.

## Human Genome

#### • Findings of Human Genome Project

- Homo sapiens has only about 25,000 to 35,000 genes
  - not the 100,000 formerly believed
- genes generate millions of different proteins
  - not the old one gene one protein theory
  - single gene can code for many different proteins
- genes average about 3,000 bases long
  - range up to 2.4 million bases
- all humans are at least 99.99% genetically identical
  - 0.01% variations that we can differ from one another in more than 3 million base pairs
  - various combinations of these single-nucleotide polymorphisms account for all human variation
- some chromosomes are gene-rich and some gene-poor
- we now know the locations of more than 1,400 disease-producing mutations

## **Genetic Code**

- body can make millions of different proteins, all from the same 20 amino acids, and encoded by genes made of just 4 nucleotides (A,T,C,G)
- **Genetic code** a system that enables these 4 nucleotides to code for the amino acid sequence of all proteins
- minimum code to symbolize 20 amino acids is 3 nucleotides per amino acid
- Base triplet a sequence of 3 DNA nucleotides that stands for one amino acid
  - **codon** the 3 base sequence in mRNA
  - 64 possible codons available to represent the 20 amino acids
    - 61 code for amino acids
    - Stop Codons UAG, UGA, and UAA signal the 'end of the message', like a period at the end of a sentence
    - Start Codon AUG codes for methionine , and begins the amino acid sequence of the protein

## **Overview of Protein Synthesis**

- all body cells, except sex cells and some immune cells, contain identical genes.
- different genes are activated in different cells
- any given cell uses 1/3 to 2/3rds of its genes
  - rest remain dormant and may be functional in other types of cells

#### activated gene

- **messenger RNA** (mRNA) a mirror-image copy of the gene is made
  - migrates from the nucleus to cytoplasm
  - its code is read by the ribosomes
- ribosomes cytoplasmic granules composed of ribosomal RNA (rRNA) and enzymes
- transfer RNA (tRNA) delivers amino acids to the ribosome
- ribosomes assemble amino acids in the order directed by the codons of mRNA

## **Summary of Protein Synthesis**

- process of protein synthesis
  DNA mRNA protein
- transcription step from DNA to mRNA
  occurs in the nucleus where DNA is located
- translation step from mRNA to protein
  - most occurs in cytoplasm
  - -15-20% of proteins are synthesized in the nucleus

## Transcription

- **Transcription** copying genetic instructions from DNA to RNA
- RNA Polymerase enzyme that binds to the DNA and assembles the mRNA
  - The start and end of the gene are determined by codes in the DNA sequence.

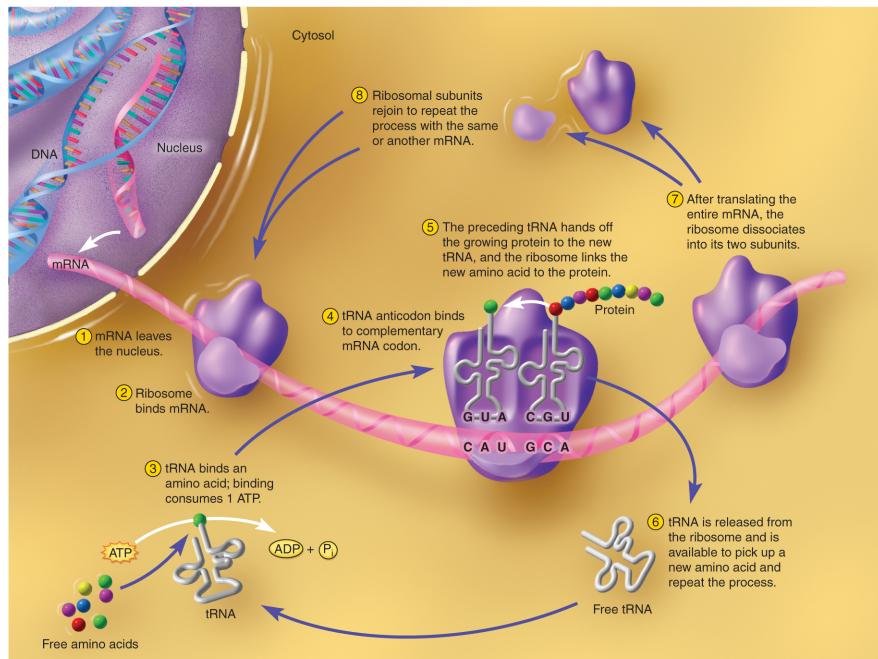
### Translation

- translation the process that converts the language of nucleotides into the language of amino acids
- ribosomes translate sequence of nucleotides into the sequence of amino acids
  - occur mainly in cytosol, on surface of rough ER, and nuclear envelope
  - consists of two granular subunits, large and small
    - each made of several rRNA and enzyme molecules

### **Translation of mRNA**

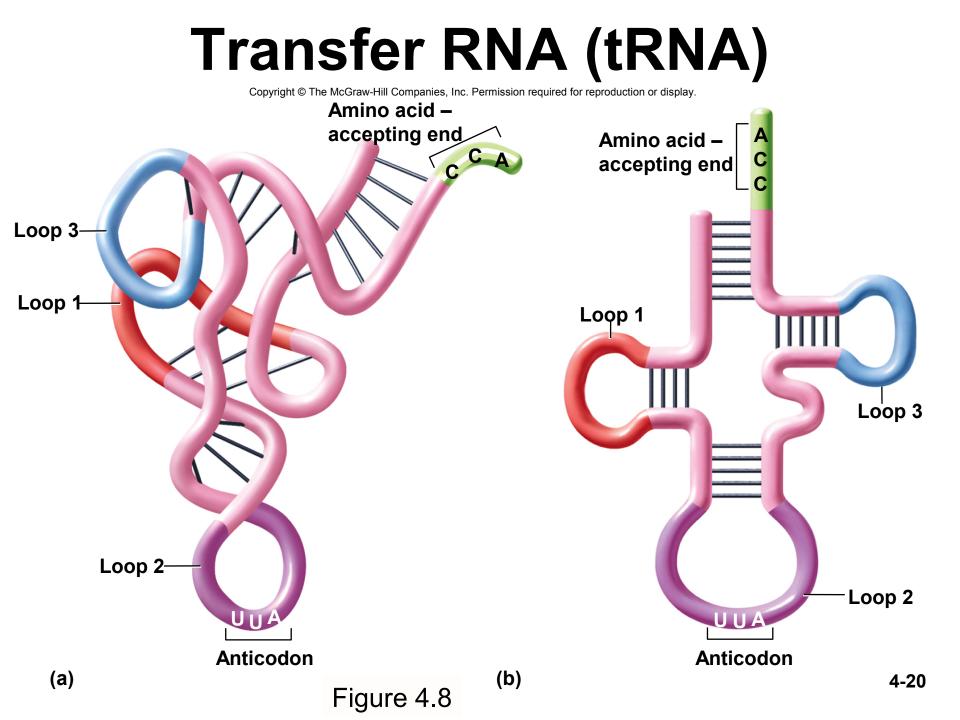
- ribosome pulls mRNA molecule through it like a ribbon, reading the bases as it goes
  - when start codon (AUG) is reached, protein synthesis begins
  - all proteins begin with **methionine** when first synthesized

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



### Translation

- requries the participation of transfer RNA (tRNA)
  - one end of the tRNA includes three nucleotides called an anticodon
  - other end has binding site specific for one amino acid
  - ribosome binds and holds tRNA with its specific amino acid
  - ribosome contains an enzyme that forms peptide bond that links amino acids together



### **Review of Peptide Formation**

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

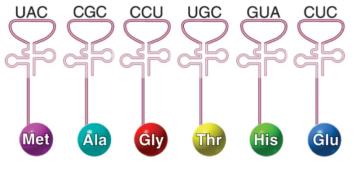
DNA double helix



Seven base triplets on the template strand of DNA

AUG	GCG	GGA	ACG	CAU	GAG	UGA	)
"Start"						"Stop"	

3 The corresponding codons of mRNA transcribed from the DNA triplets





The anticodons of tRNA that bind to the mRNA codons

Figure 4.10

- 5 The amino acids carried by those six tRNA molecules
- 6 The amino acids linked into a peptide chain

### **Gene Regulation**

 genes are turned on and off from day to day

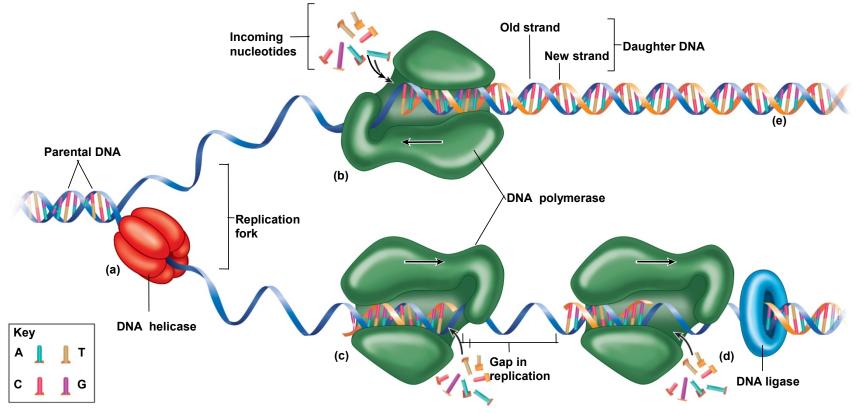
• their products are need or not

 many genes are permanently turned off in any given cell

### **DNA Replication and Cell Cycle**

- before cells divide, it must duplicate its DNA so it can give a complete copy of all its genes to each daughter cell.
- since DNA controls all cellular function, this replication process must be very exact
- Law of Complementary Base Pairing we can predict the base sequence of one DNA strand if we know the sequence of the other
  - enables a cell to reproduce one strand based on the information in another

## **DNA Replication**



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Figure 4.14

## **Steps of DNA Replication**

Double helix unwinds from histones

enzyme **DNA helicase** opens one short segment of helix at a time -exposing its nitrogen bases

**replication fork** – the point where the DNA is opened up (like two separated halves of a zipper)

**DNA polymerase** molecules move along each strand -read the exposed bases -matches complementary free nucleotides

the two separated strands of DNA are copied by separate polymerase molecules proceeding in opposite directions

-the polymerase molecule moving toward the replication fork makes a

long, continuous, new strand of DNA

-the polymerase molecule moving away from the replication fork makes short segments of DNA at a time...**DNA ligase** joins then**4-25** together

## **Steps of DNA Replication**

from the old *parental DNA* molecule, two new *daughter* DNA molecules are made

**semiconservative replication** - each daughter DNA consists of one new helix synthesized from free nucleotides and one old helix conserved from the parental DNA

new histones are synthesized in cytoplasm

- -millions of histones are transported into the nucleus within a few minutes after DNA replication
- -each new DNA helix wraps around them to make a new nucleosome

each DNA polymerase works at a rate of 100 base pairs per second

-would take weeks for one polymerase to replicate one chromosome

-thousands of polymerase molecules work simultaneously on each DNA molecule

10. all 46 chromosomes are replicated in 6 - 8 hours

### **Errors and Mutations**

- **DNA polymerase** does make mistakes
  - multiple modes for correction of replication errors
  - double checks the new base pair and tend to replace incorrect, biochemically unstable pairs with more stable correct pairs
  - result is only 1 error per 1 billion bases replicated
- mutations changes in DNA structure due to replication errors or environmental factors (radiation, viruses, chemicals)
  - some mutations cause no ill effects. others kill the cell, turn it cancerous or cause genetic defects in future generations.