Trait	Bacteria	Archaea	Eukarya
Carbon linkage of lipids	Ester	*Ether*	Ester
Phosphate backbone of lipids	Glycerol-3-phosphate	*Glycerol-1-phosphate*	Glycerol-3-phosphate
Metabolism	Bacterial	Bacterial-like	Eukaryotic
Nucleus	No	No	Yes
Organelles	No	No	Yes
Spliceosomal introns	No	No	Yes
Telomeres	No	No	Yes
Chromosome shape	Mostly circular	Circular	Linear
DNA replication	Bacterial	Eukaryotic-like	Eukaryotic
Transcription	Bacterial	Eukaryotic-like	Eukaryotic
Translation	Bacterial	Eukaryotic-like	Eukaryotic

------Macromolecules

– Are large molecules composed of smaller molecules

- Each cell has thousands of different kinds of macromolecules; the collection varies from one type of cell to another even in the same organism.

- The diversity of macromolecules in the living world is vast, and the possible variety is effectively limitless.

What is the basis for such diversity in life's polymers?

These molecules are made from only 40 to 50 common monomers and some others that occur rarely.

Building a huge variety of polymers from such a limited number of monomers is analogous to constructing hundreds of thousands of words from only 26 letters of the alphabet.

The key is arrangement-the particular linear sequence that the units follow.

Most biological polymers have many monomers.

Proteins, for example, are built from 20 kinds of amino acids arranged in chains that are typically hundreds of amino acids long.

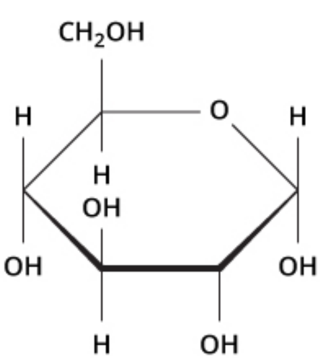
The molecular logic of life is simple but elegant: Small molecules common to all organisms are ordered into unique macromolecules.

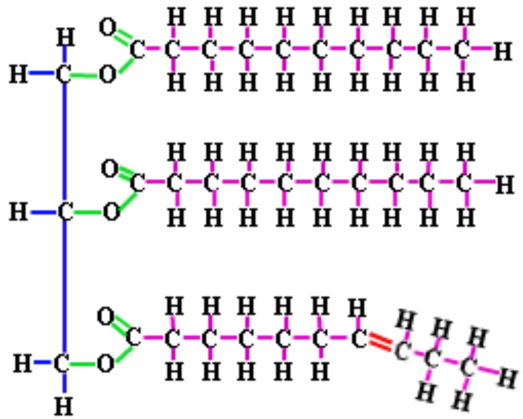
Despite this immense diversity, molecular structure and function can still be grouped roughly by class.

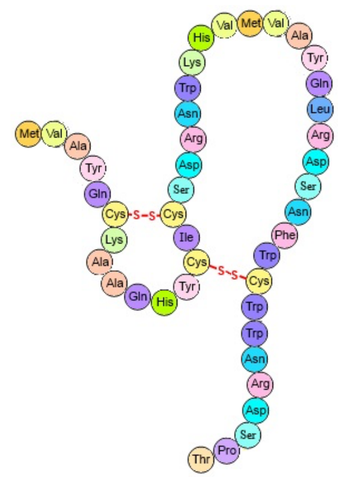
Each of the four major classes of large biological molecules:

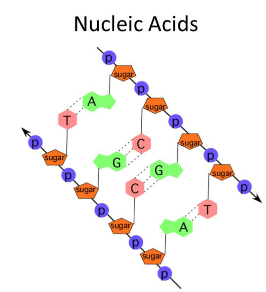
Sugars, Lipids, Proteins, Nucleic Acids

For each class, the large molecules have emergent properties not found in their individual building blocks.

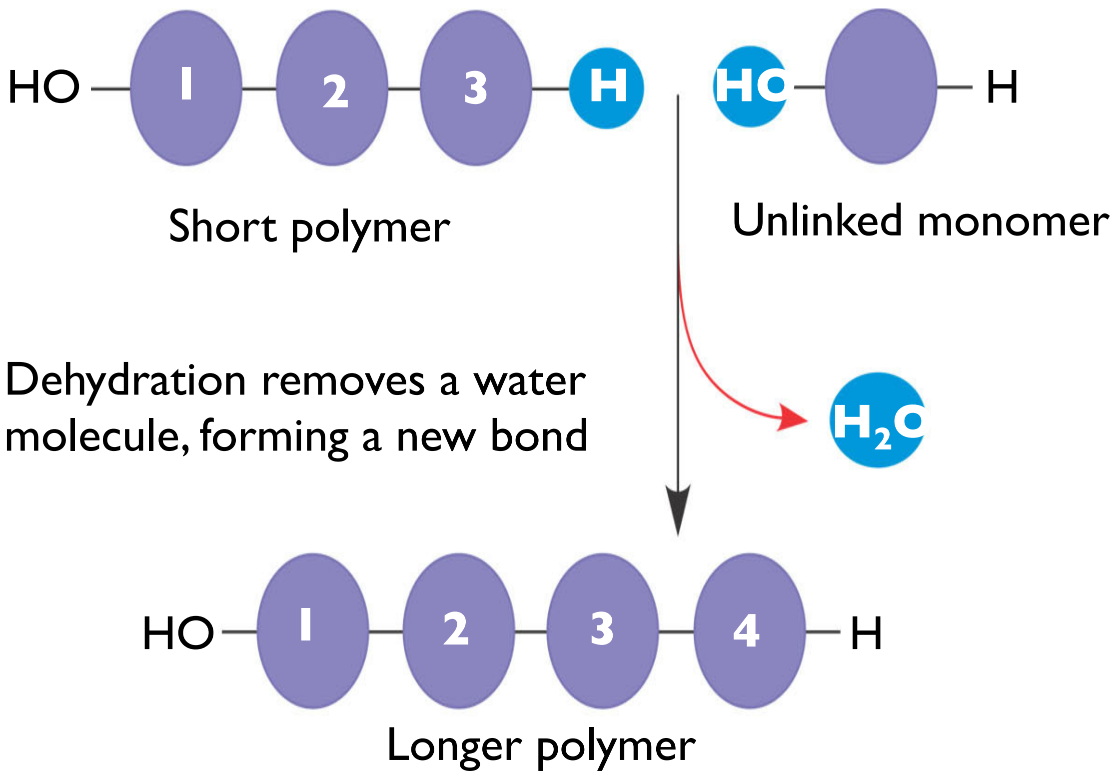




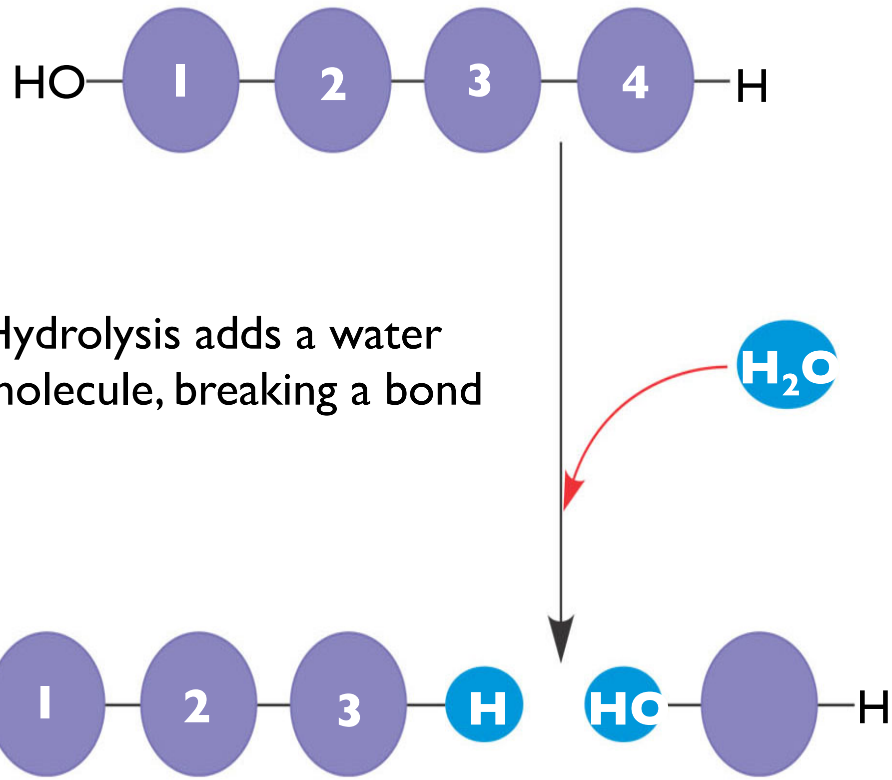




The Synthesis and Breakdown of Polymers



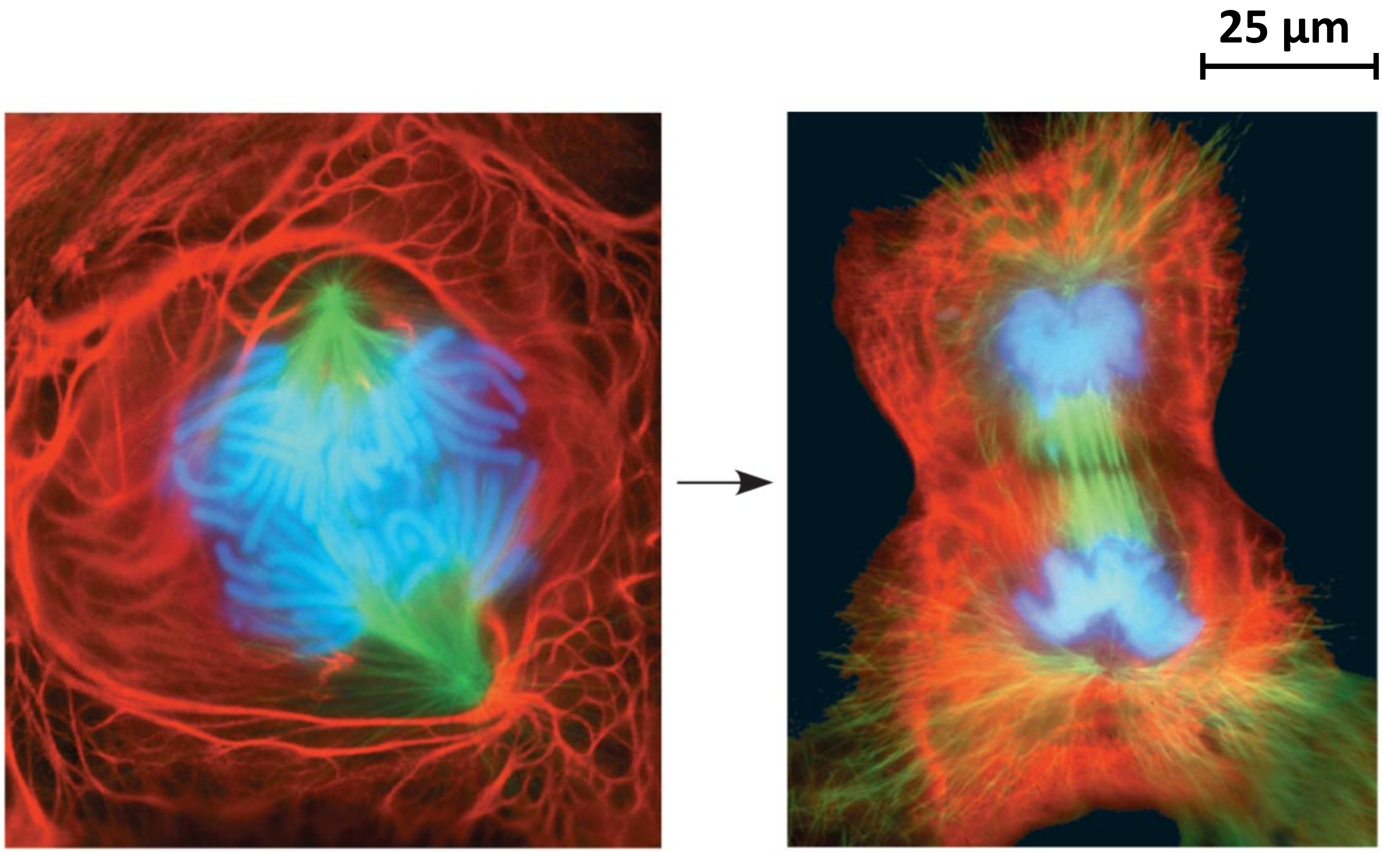
(a) Dehydration reaction in the synthesis of a polymer



(b) Hydrolysis of a polymer

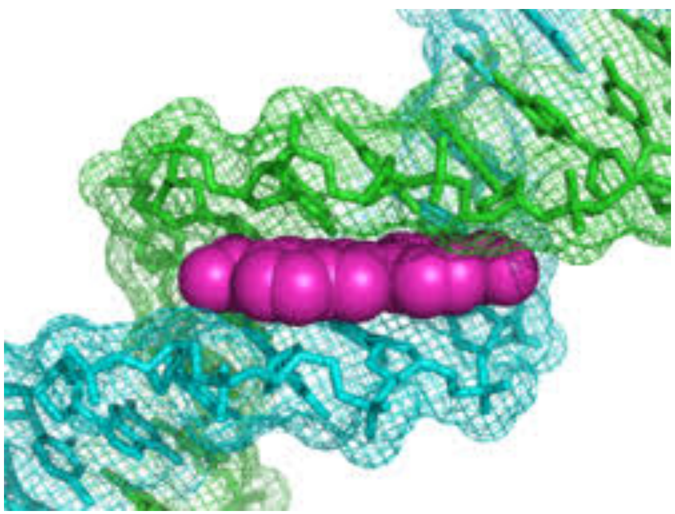
Figure 5.2B

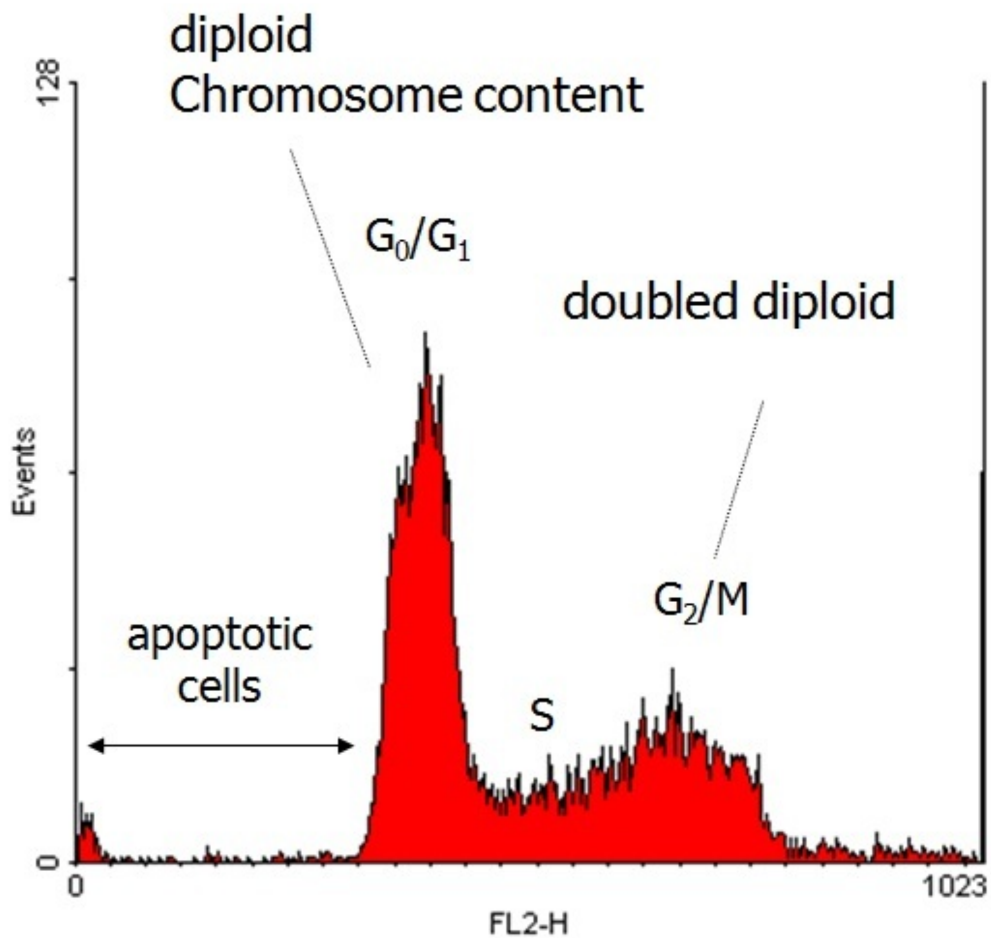
Fig. 1-7



Cell cycle analysis

Propidium iodide (PI) or 4',6'-diamidino-2-phenylindole (DAPI). Three major phases of the cycle (G1 vs S vs G2/M)

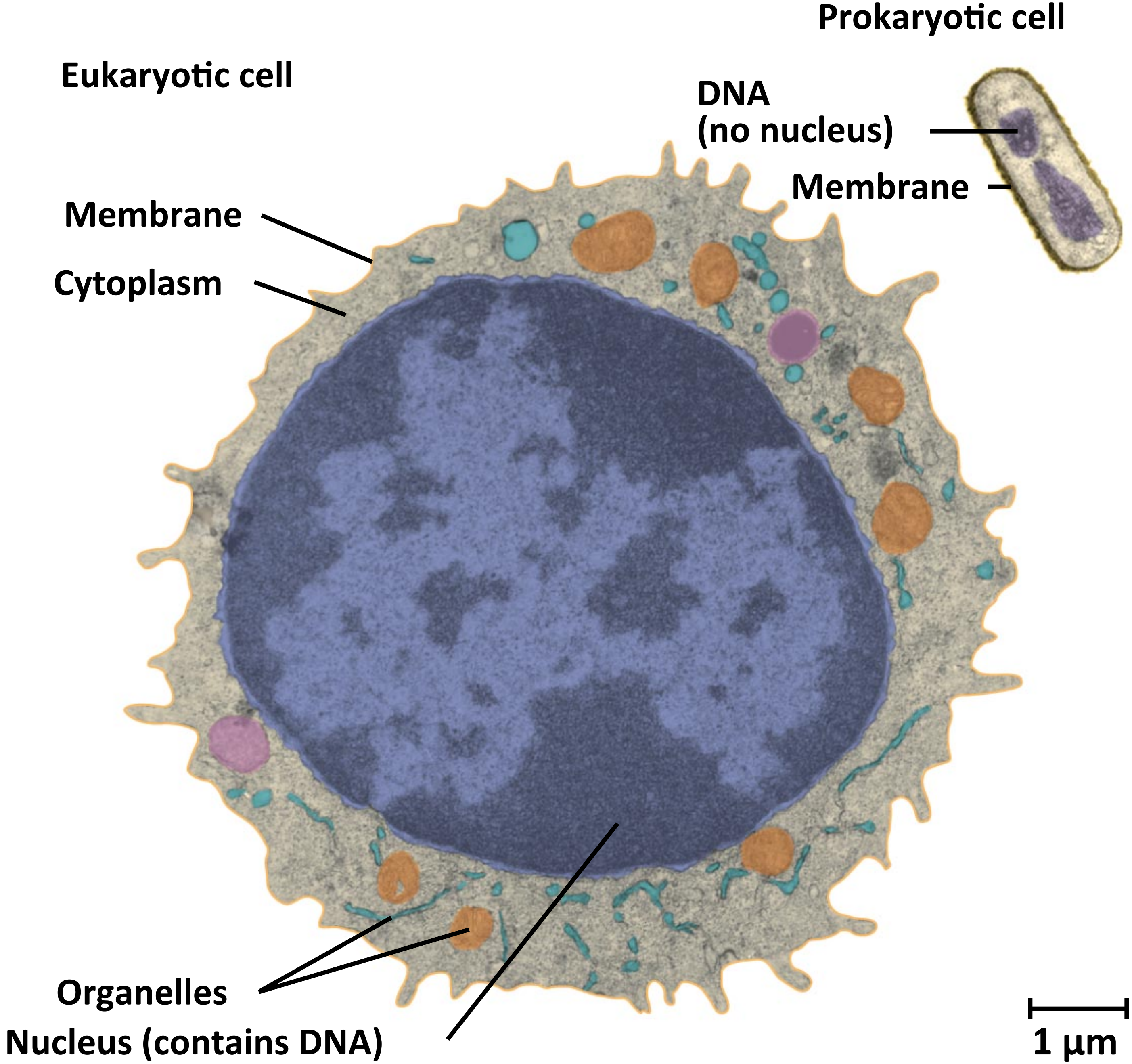




Eukaryotic vs Prokaryotic cells

- A **eukaryotic cell** has membrane-enclosed organelles, the largest of which is usually the nucleus
- By comparison, a **prokaryotic cell** is simpler and usually smaller, and does not contain a nucleus or other membrane-enclosed organelles
- Bacteria and Archaea are prokaryotic; plants, animals, fungi, and all other forms of life are eukaryotic

Fig. 1-8



Prokaryotic cell
Eukaryotic cell
DNA
(no nucleus)
Membrane
Membrane
Cytoplasm
Organelles
Nucleus (contains DNA)
1 µm

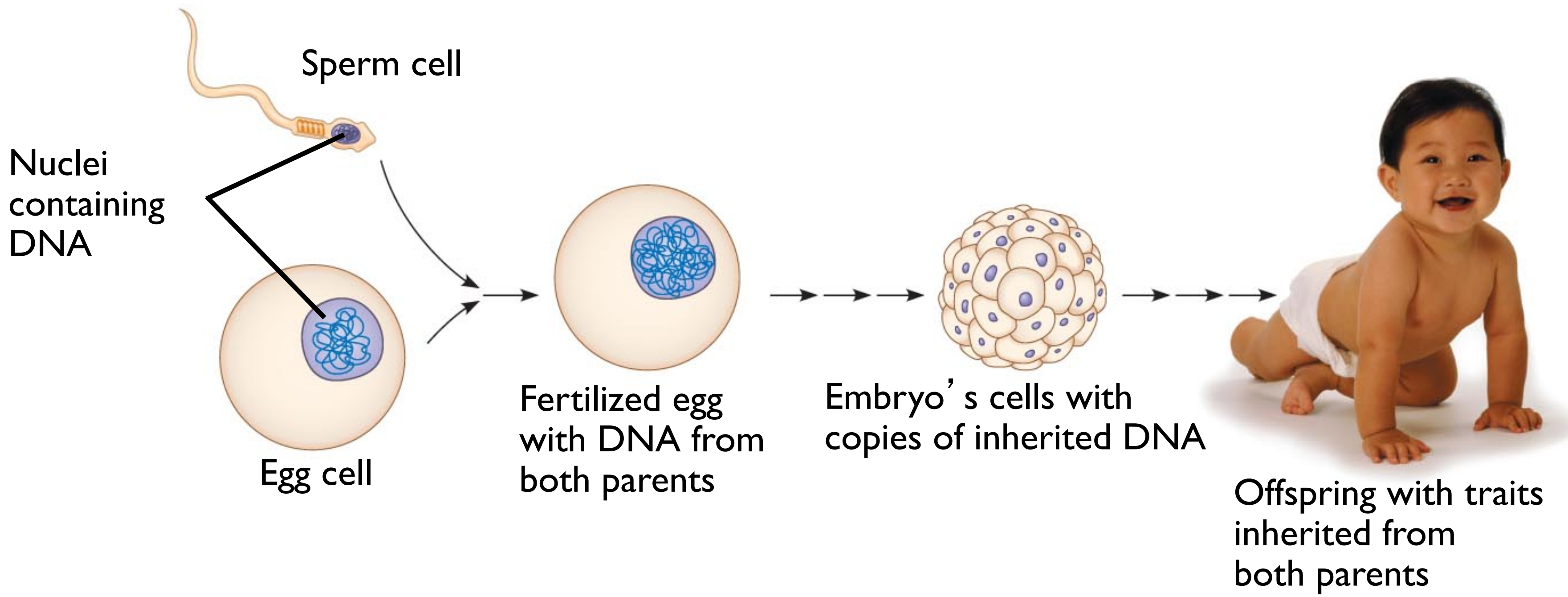
The continuity of life is based on heritable **information** in the form of DNA

- Chromosomes contain most of a cell’s genetic material in the form of **DNA** (deoxyribonucleic acid)
- DNA is the substance of genes
- **Genes** are the units of inheritance that transmit information from parents to offspring

DNA Structure and Function

- Each chromosome has one long DNA molecule with hundreds or thousands of genes
- DNA is inherited by offspring from their parents
- DNA controls the development and maintenance of organisms

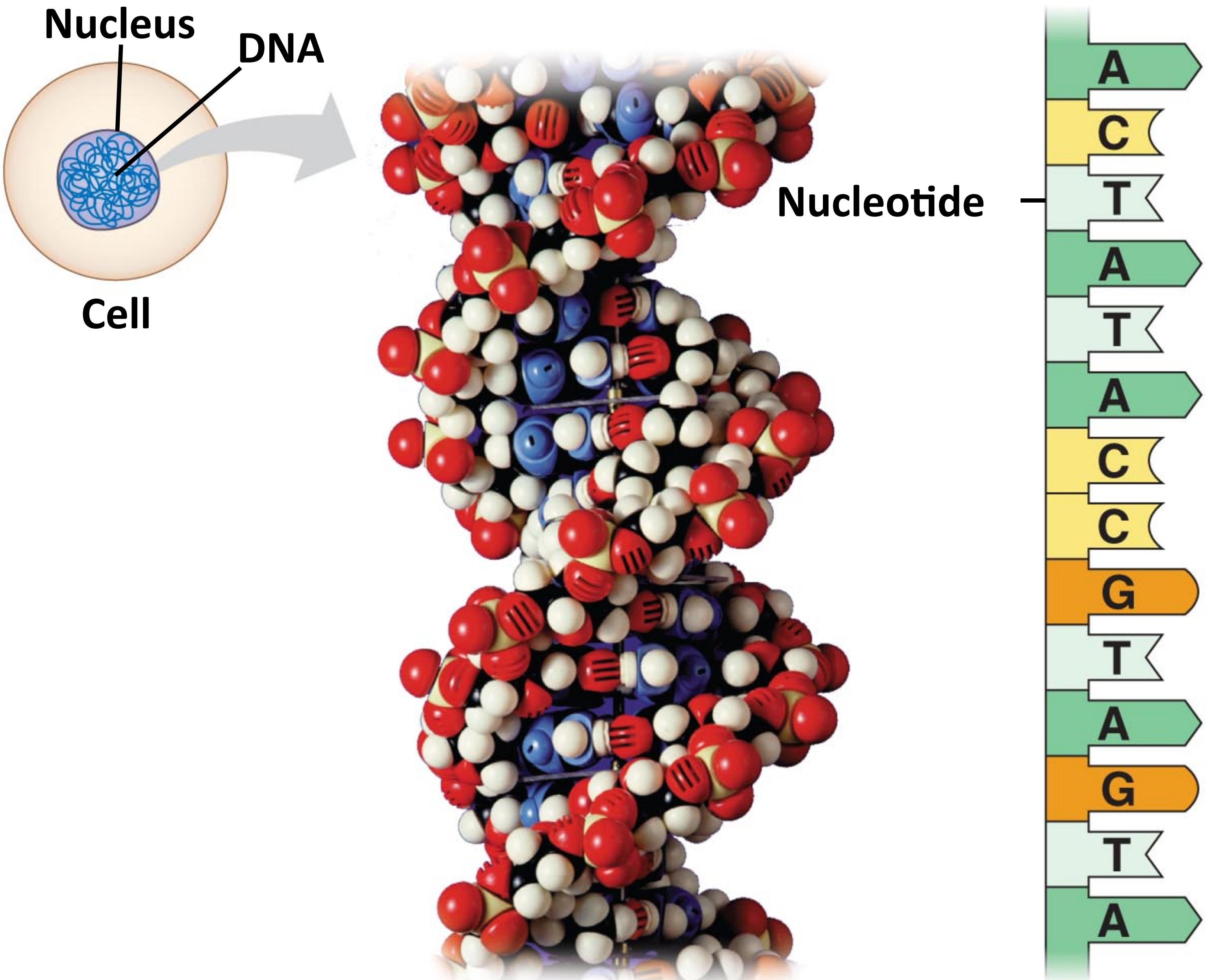
Fig. 1-9



Sperm cell
Nuclei containing DNA
Egg cell
Fertilized egg with DNA from both parents
Embryo's cells with copies of inherited DNA
Offspring with traits inherited from both parents

- Each DNA molecule is made up of two long chains arranged in a double helix
- Each link of a chain is one of four kinds of chemical building blocks called nucleotides

Fig. 1-10



(a) DNA double helix (b) Single strand of DNA

How did DNA:
1. Store information?
2. Duplicate itself easily?

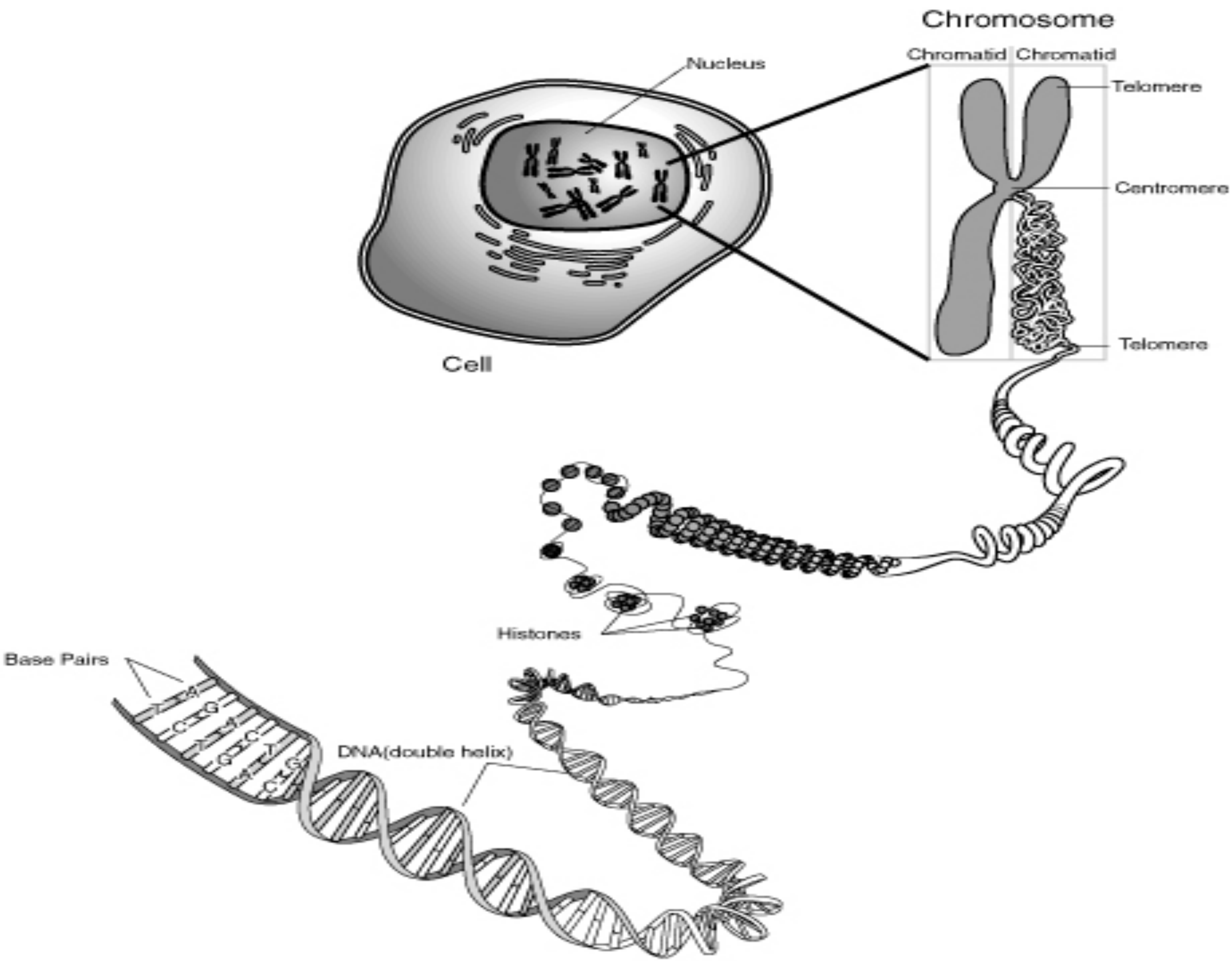
These questions would be answered by discovering DNA's structure

AMAZING DNA FACTS…

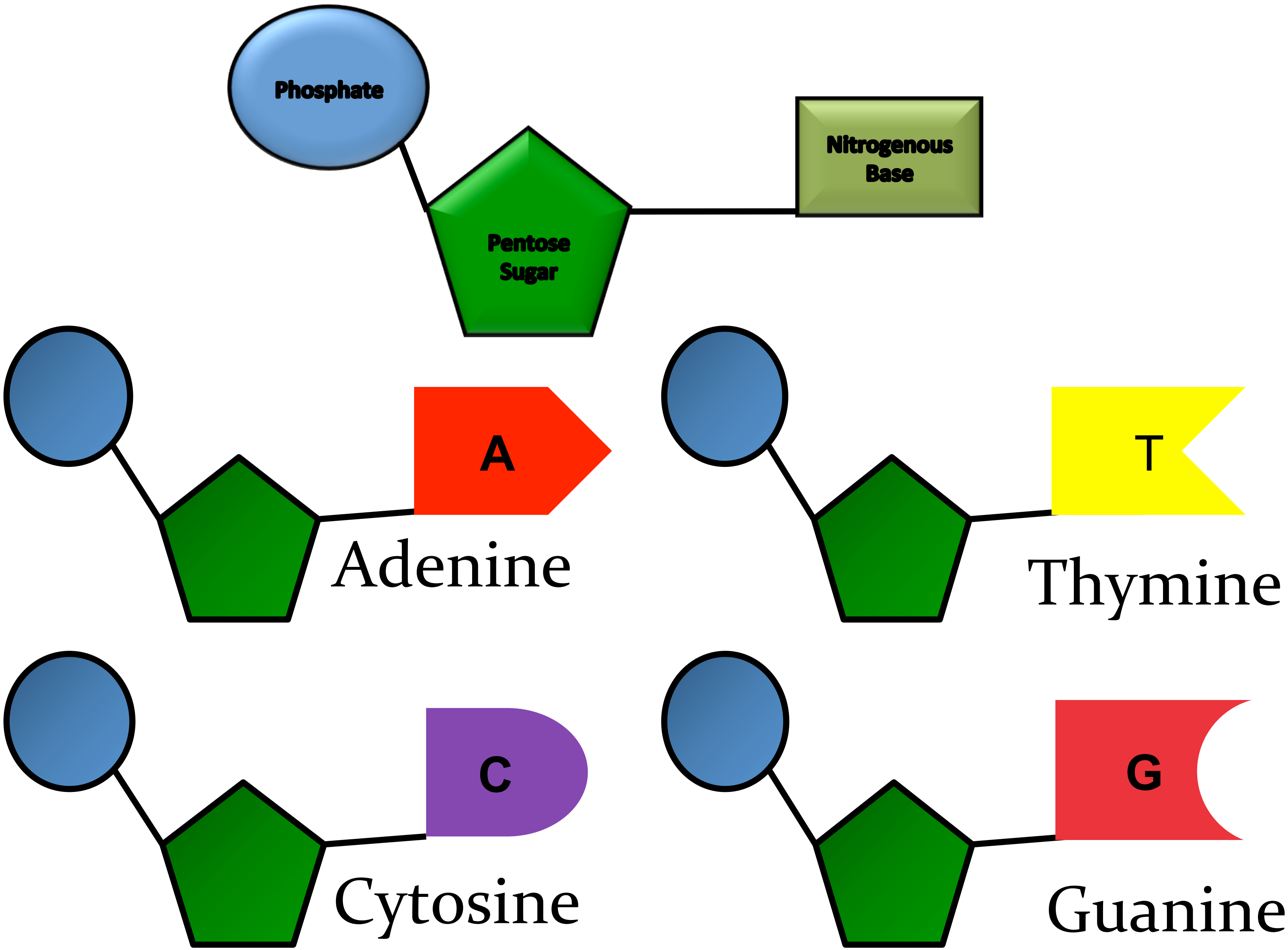
- DNA from a single human cell extends in a single thread for almost 2 meters long!!!

- It contains information equal to some 600,000 printed pages of 500 words each!!!

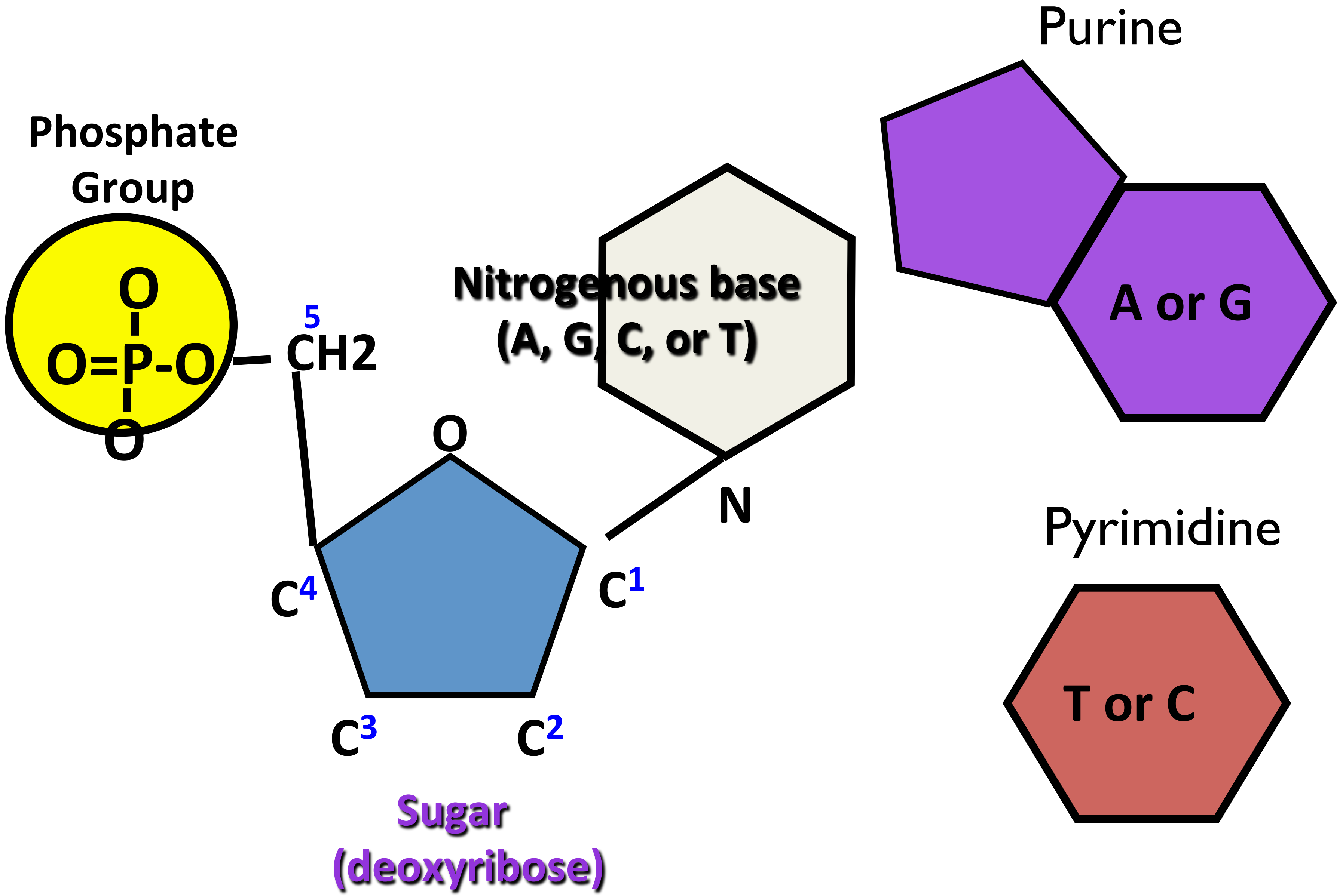
  (a library of about 1,000 books)


Chromosome
Chromatid
Chromatid
Nucleus
Telomere
Centromere
Telomere
Cell
Histones
Base Pairs
DNA(double helix)

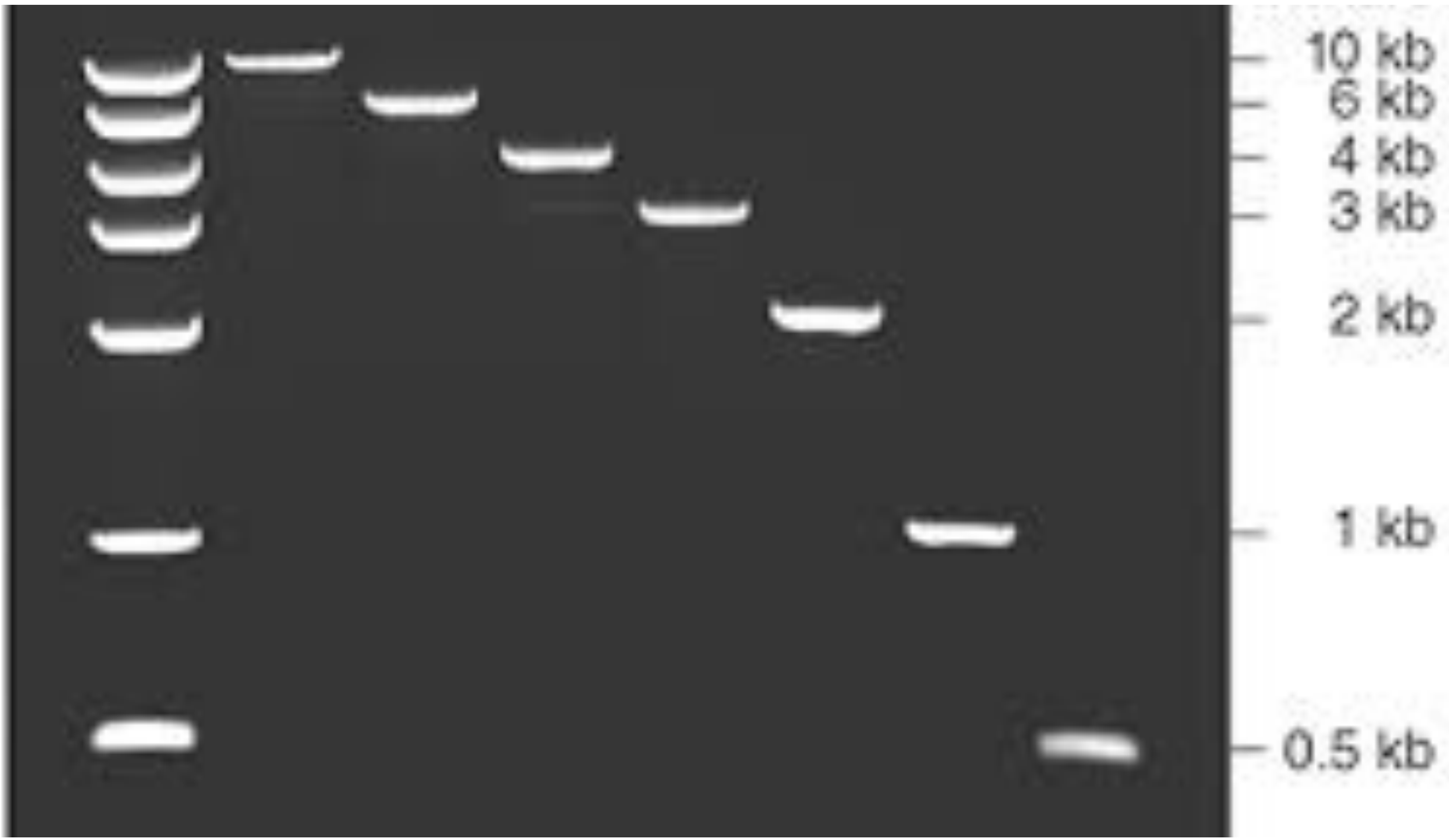
Building blocks



DNA Nucleotide

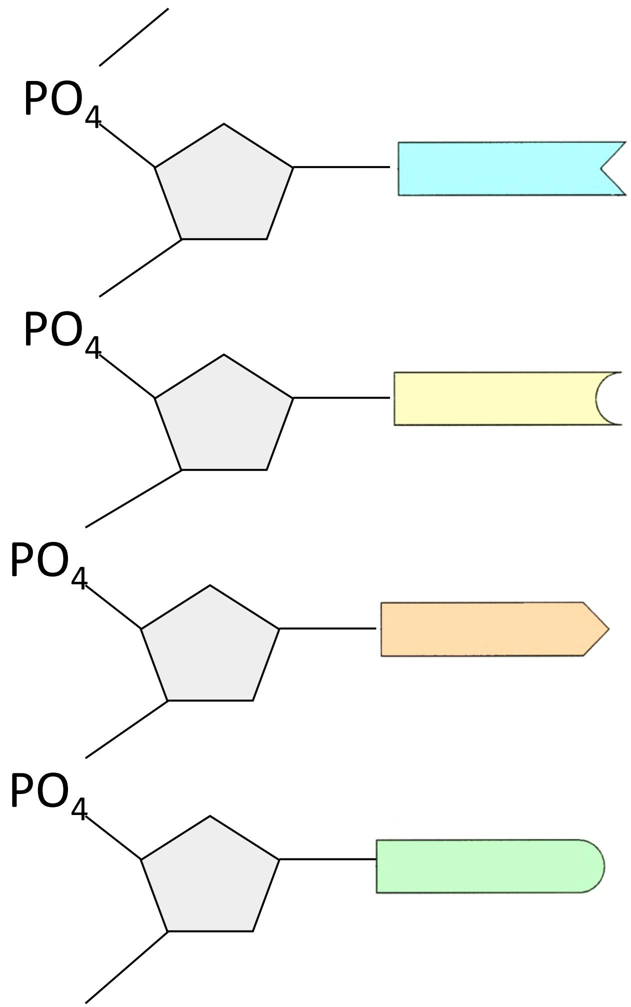


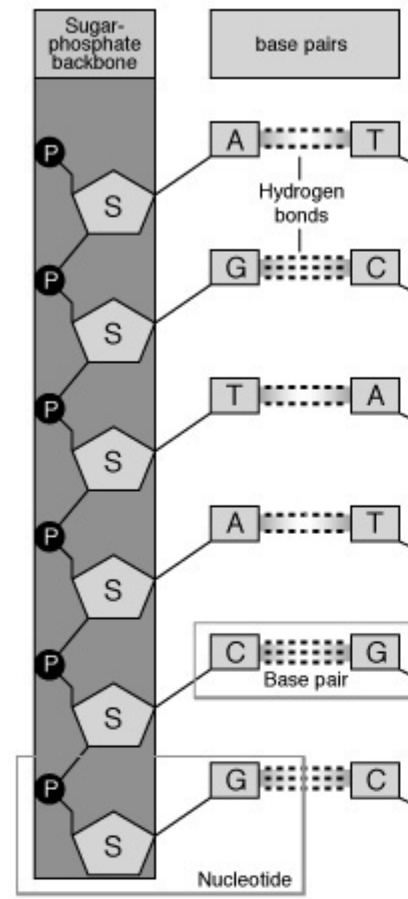
- charge



+ charge

DNA Double Helix

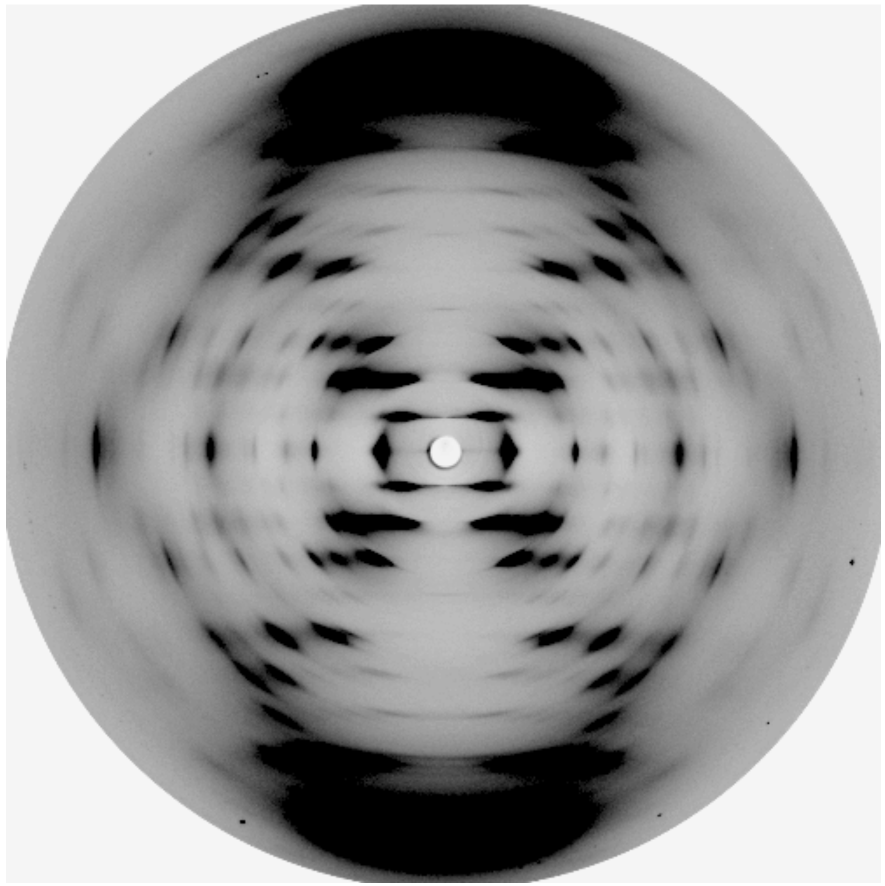




sugar-phosphate + bases
backbone

DNA's Structure

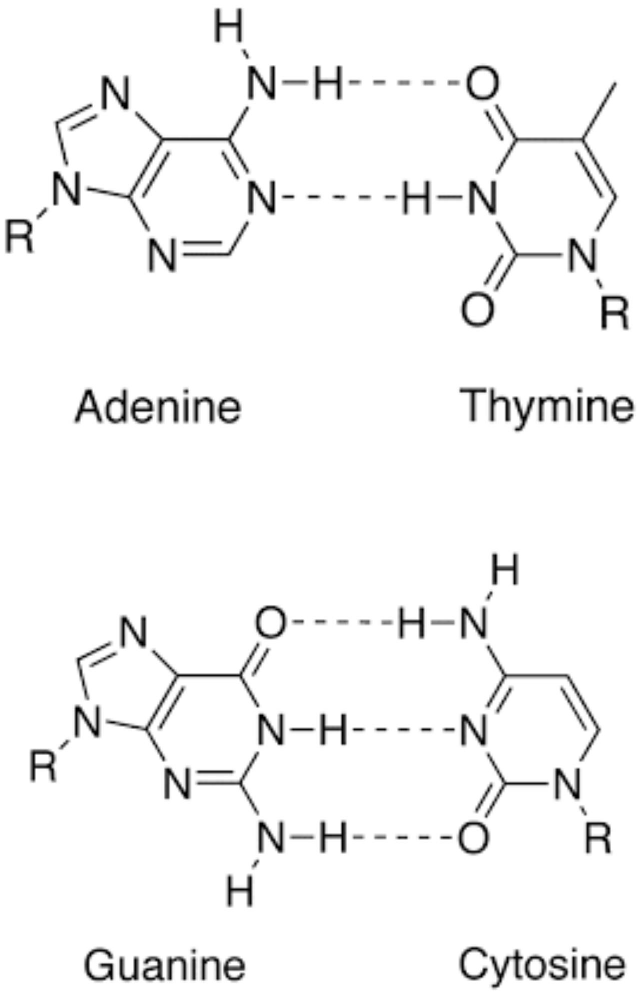
Maurice Wilkins

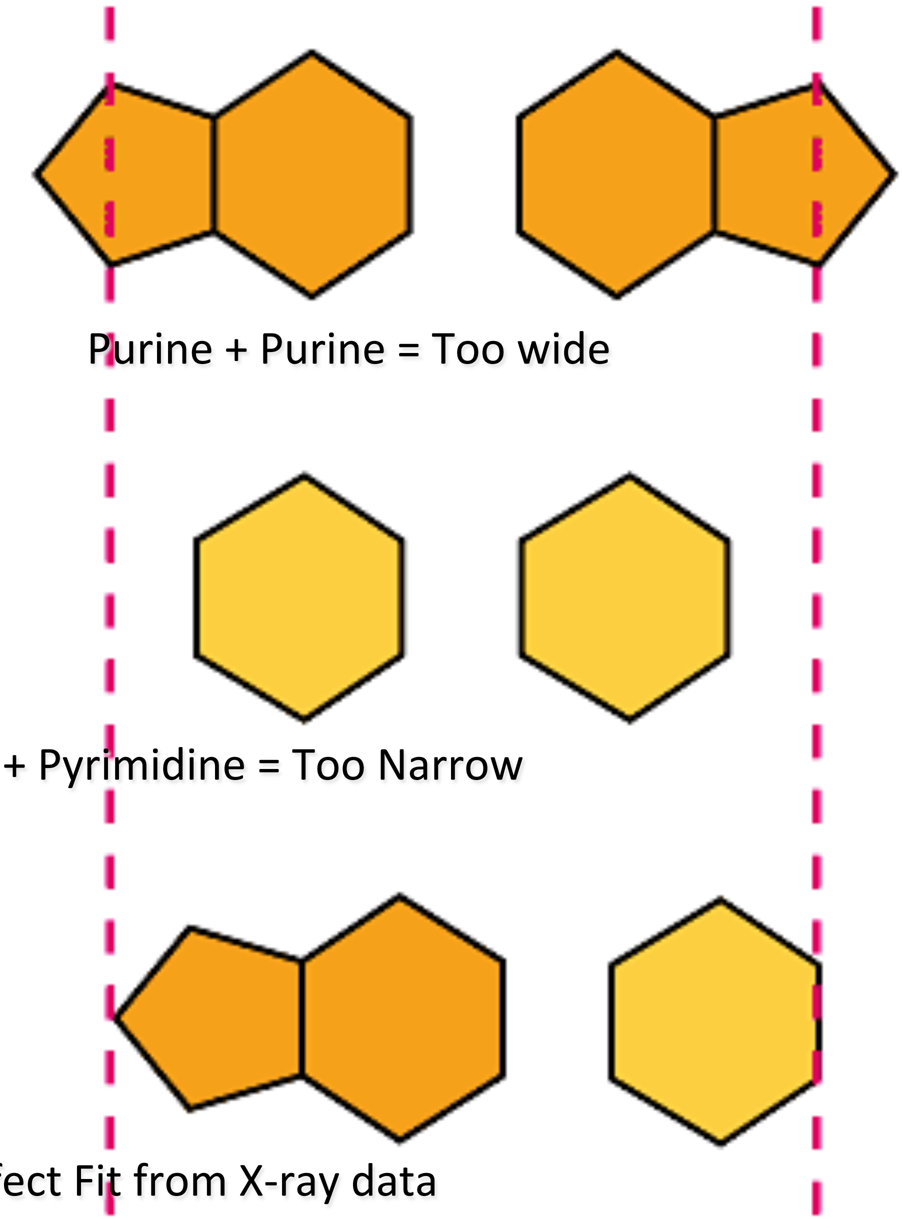


X-Ray diffraction image of DNA taken by Franklin in 1951

Rosalind Franklin

DNA’s Structure





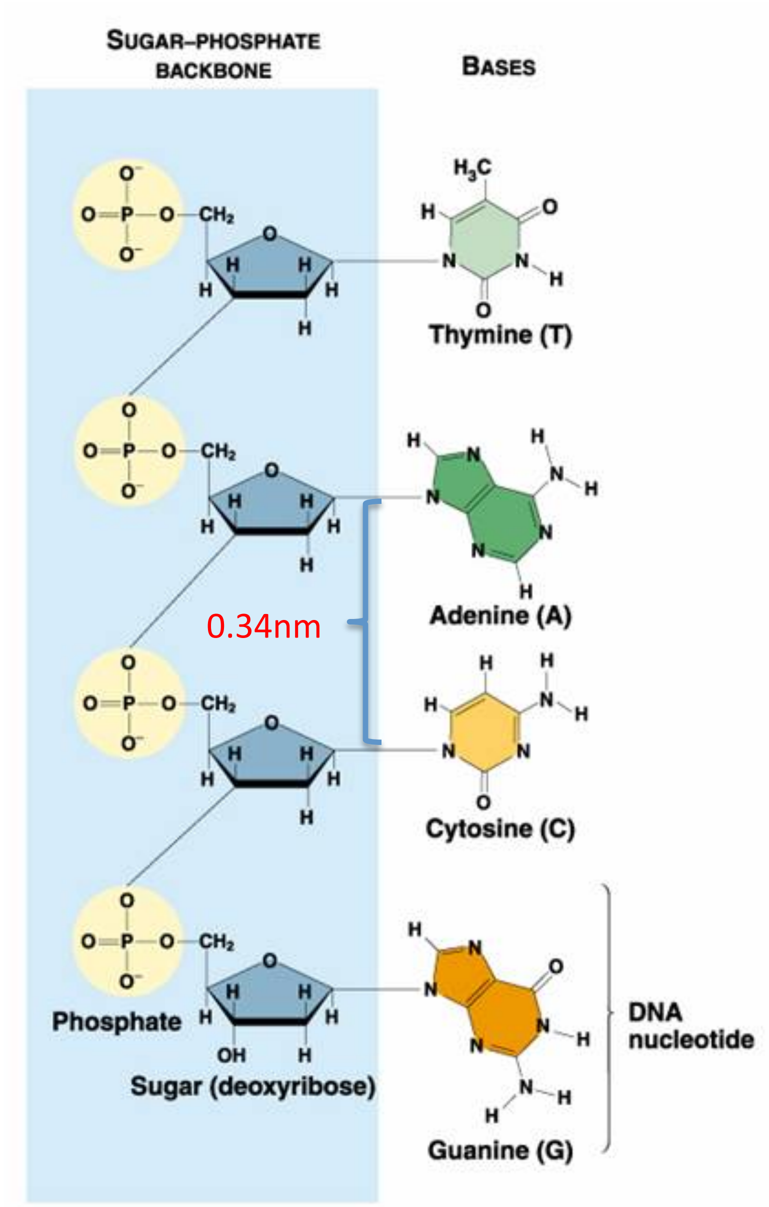
Purine + Purine = Too wide

Pyrimidine + Pyrimidine = Too Narrow

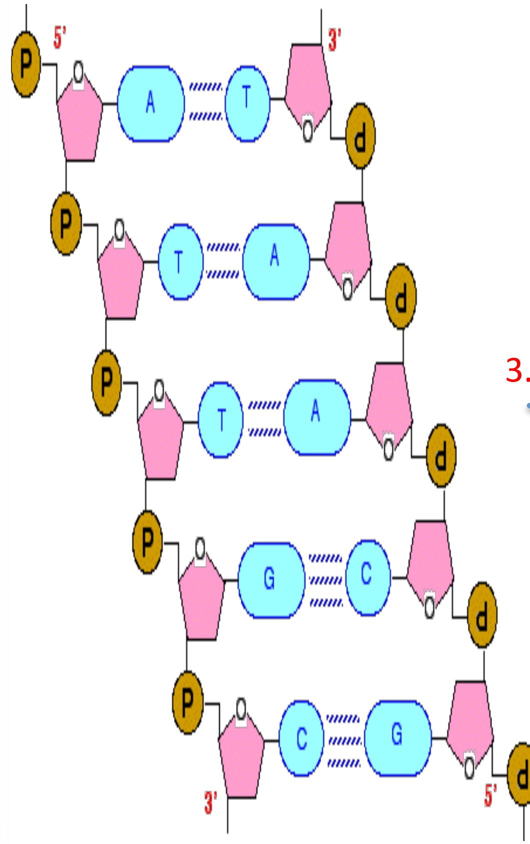
Purine + Pyrimidine = Perfect Fit from X-ray data

Chargaff's rule

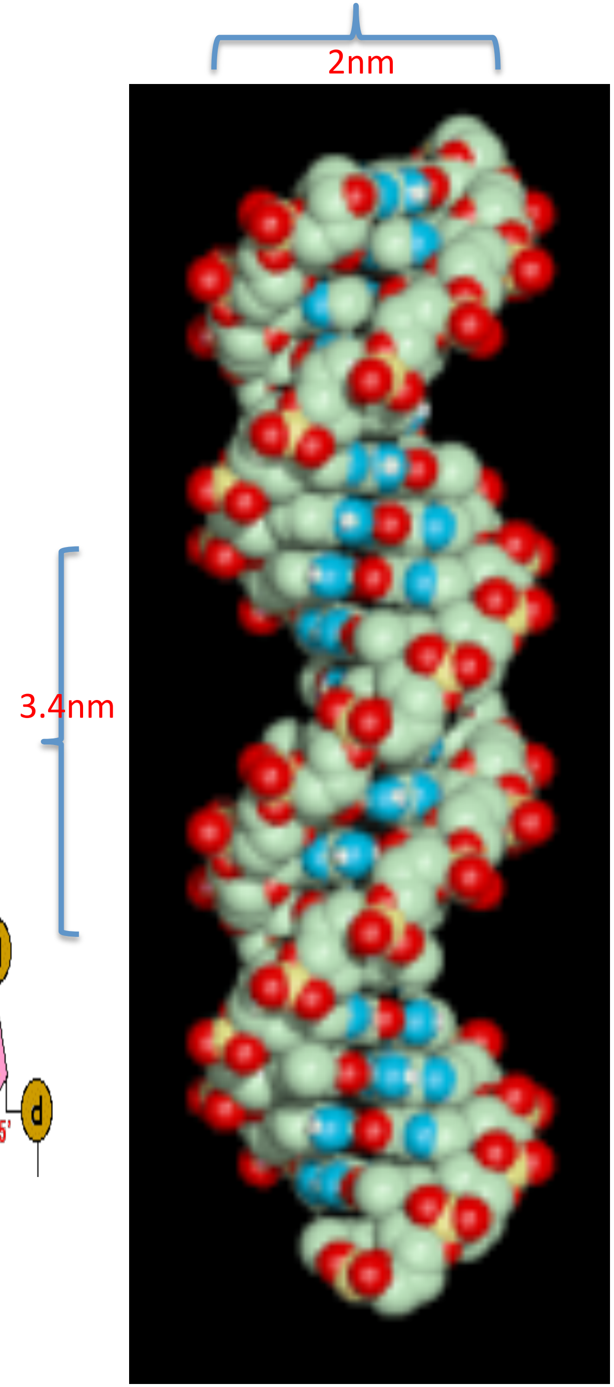
- Percent of adenine = percent of thymine (%A=%T)
- Percent of cytosine = percent of guanine (%C=%G)
- A+G = T+C (or purines = pyrimidines)



SUGAR–PHOSPHATE BACKBONE
BASES
Thymine (T)
Adenine (A)
Cytosine (C)
Guanine (G)
0.34nm
Phosphate
Sugar (deoxyribose)
DNA nucleotide



5'
3'
A
T
G
C



2nm
3.4nm

DNA Replication

- The double helix did explain how DNA copies itself

- DNA replication is a process that occurs in all living cells. They copy their DNA; it is the basis for biological inheritance. The process starts with one double-stranded DNA molecule and produces two identical copies of the molecule. Each strand of the original double-stranded DNA molecule serves as template for the production of the complementary strand. This process is referred to as semiconservative replication.

Replication

Before a cell divides, the DNA strands unwind and separate

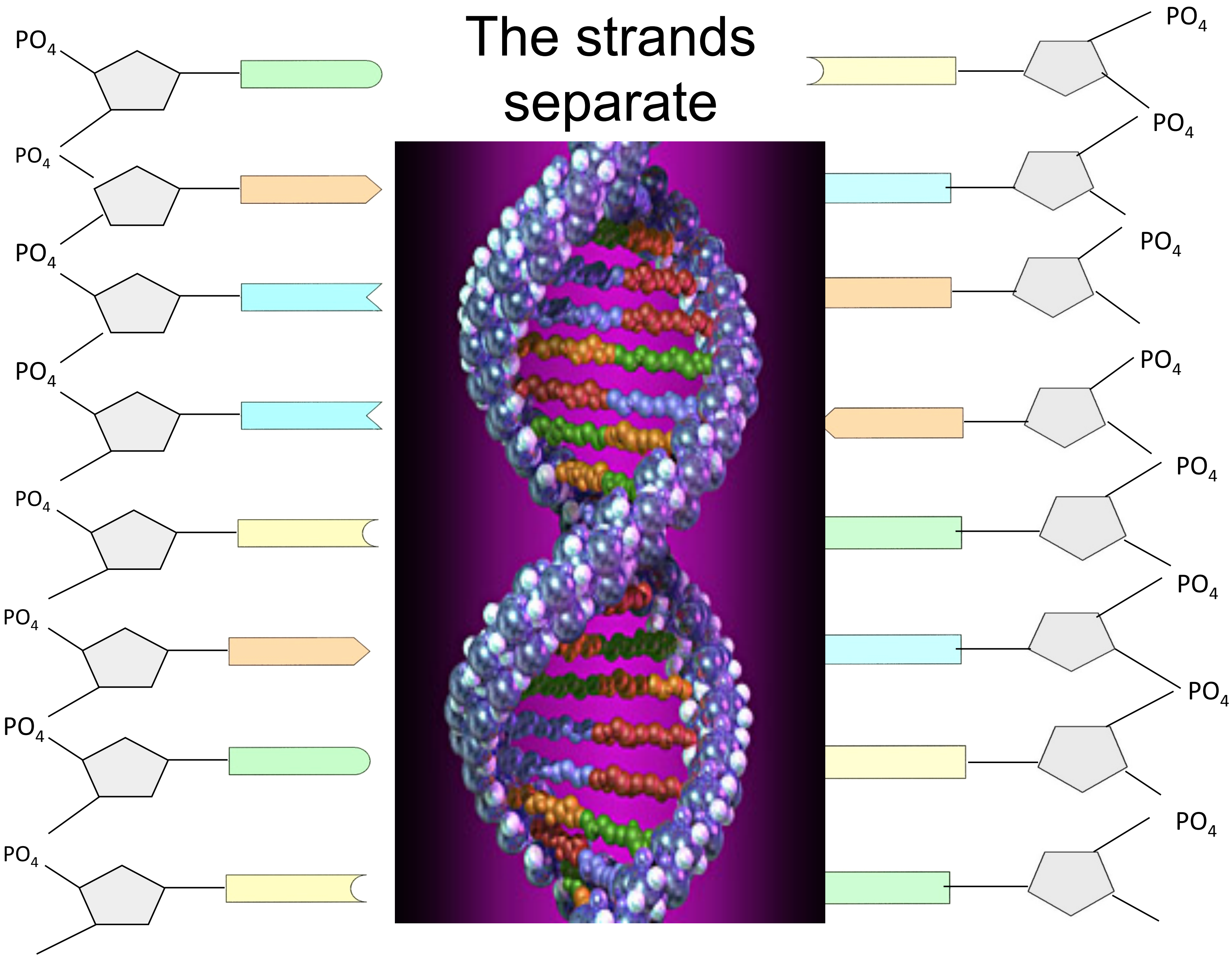
Each strand makes a new partner by adding the appropriate nucleotides

The result is that there are now two double-stranded DNA molecules in the nucleus

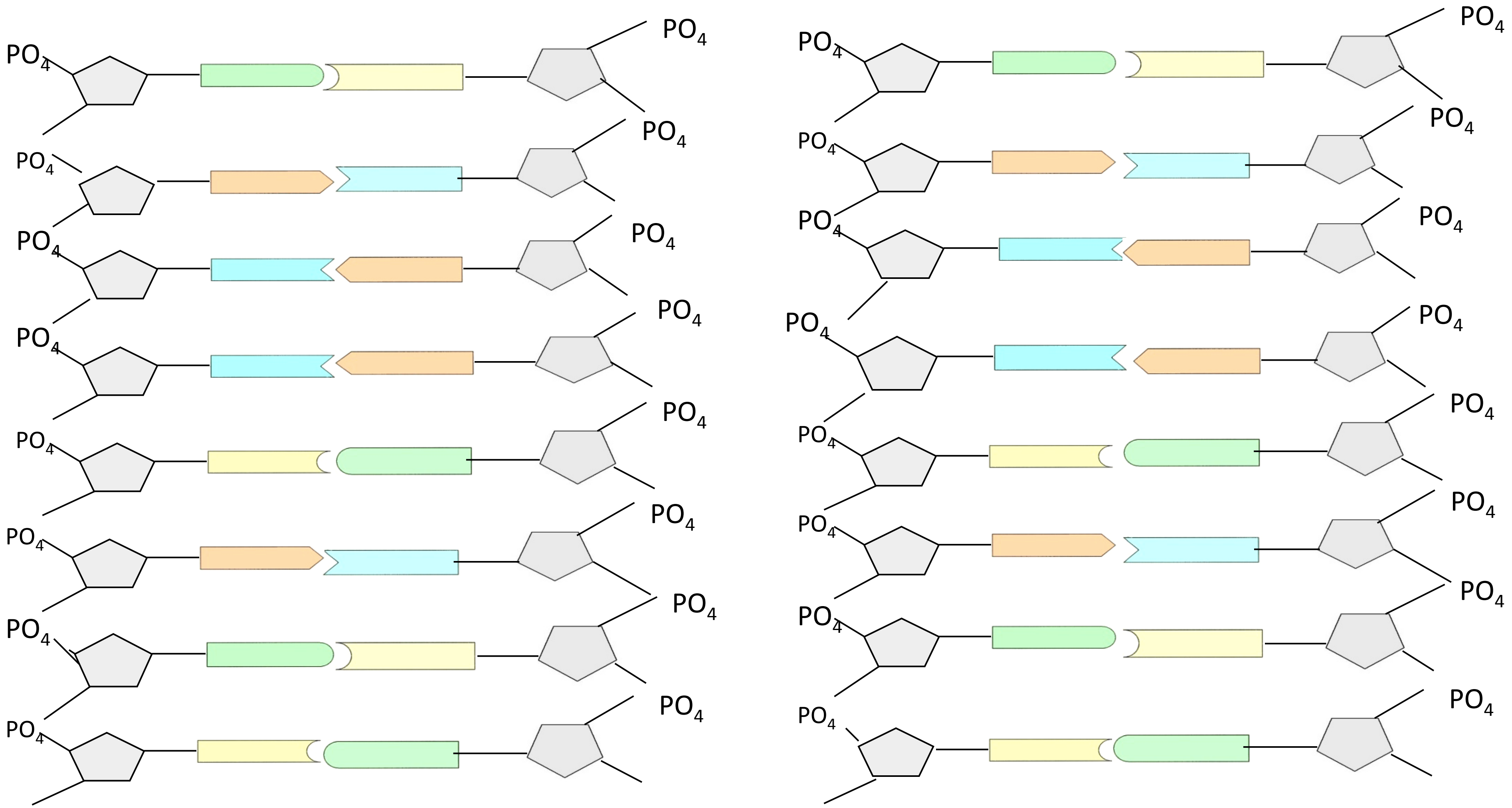
So that when the cell divides, each nucleus contains identical DNA

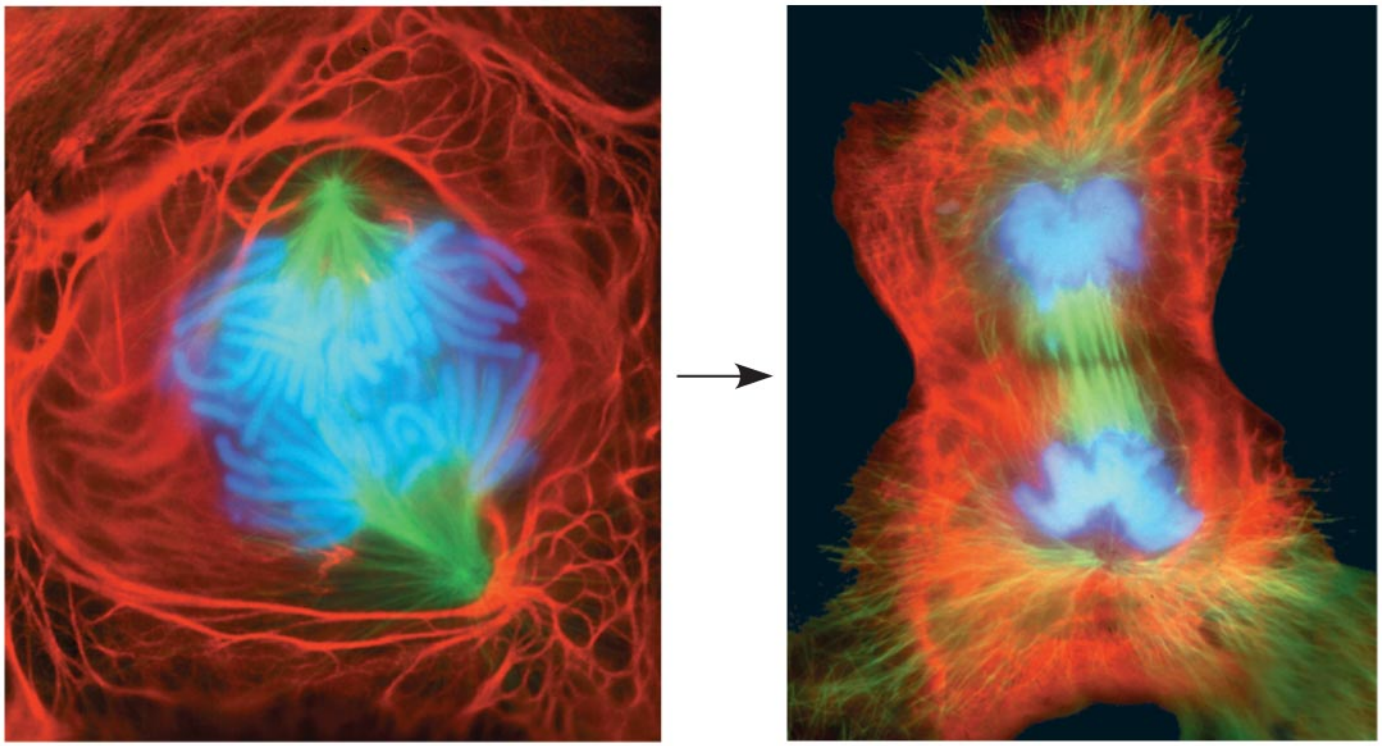
This process is called **replication**

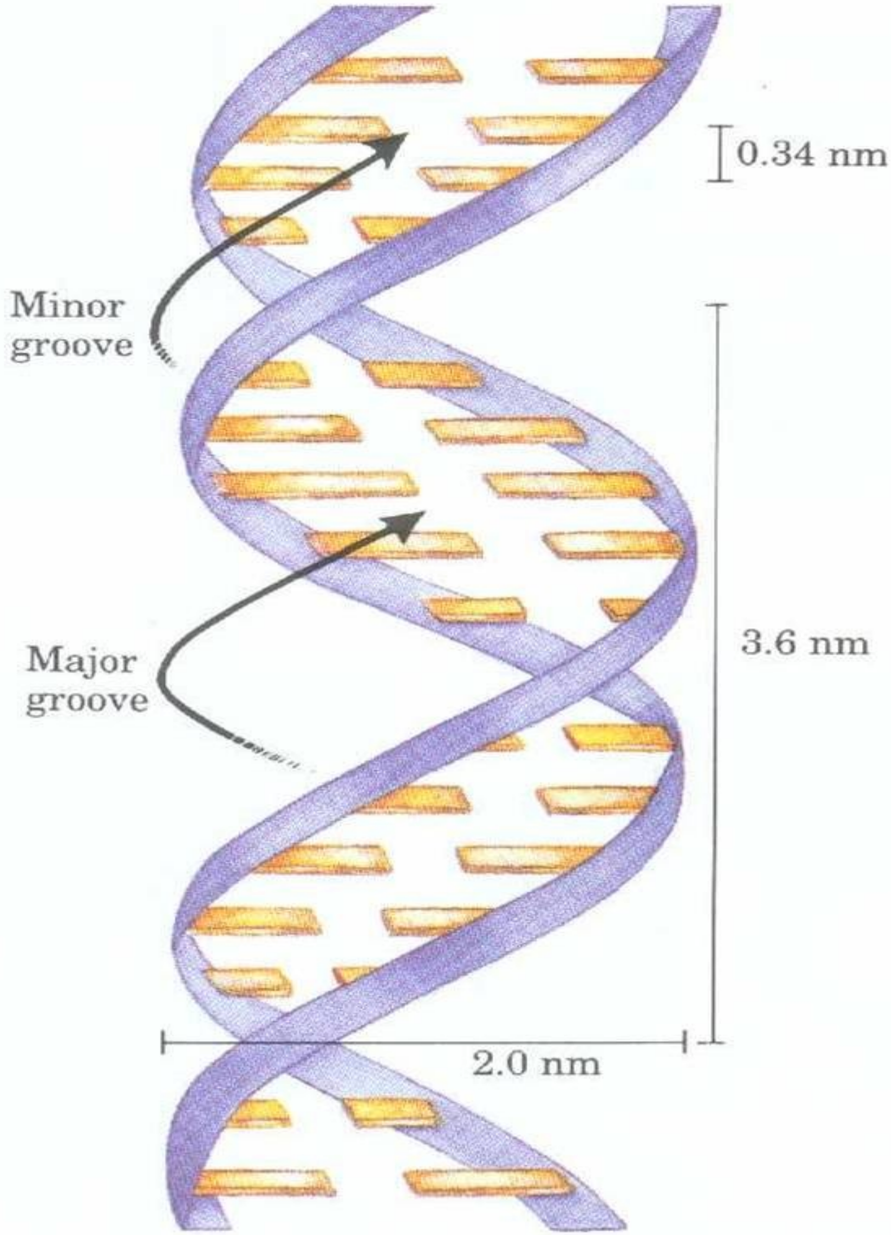
The strands separate



Each strand builds up its partner by adding the appropriate nucleotides

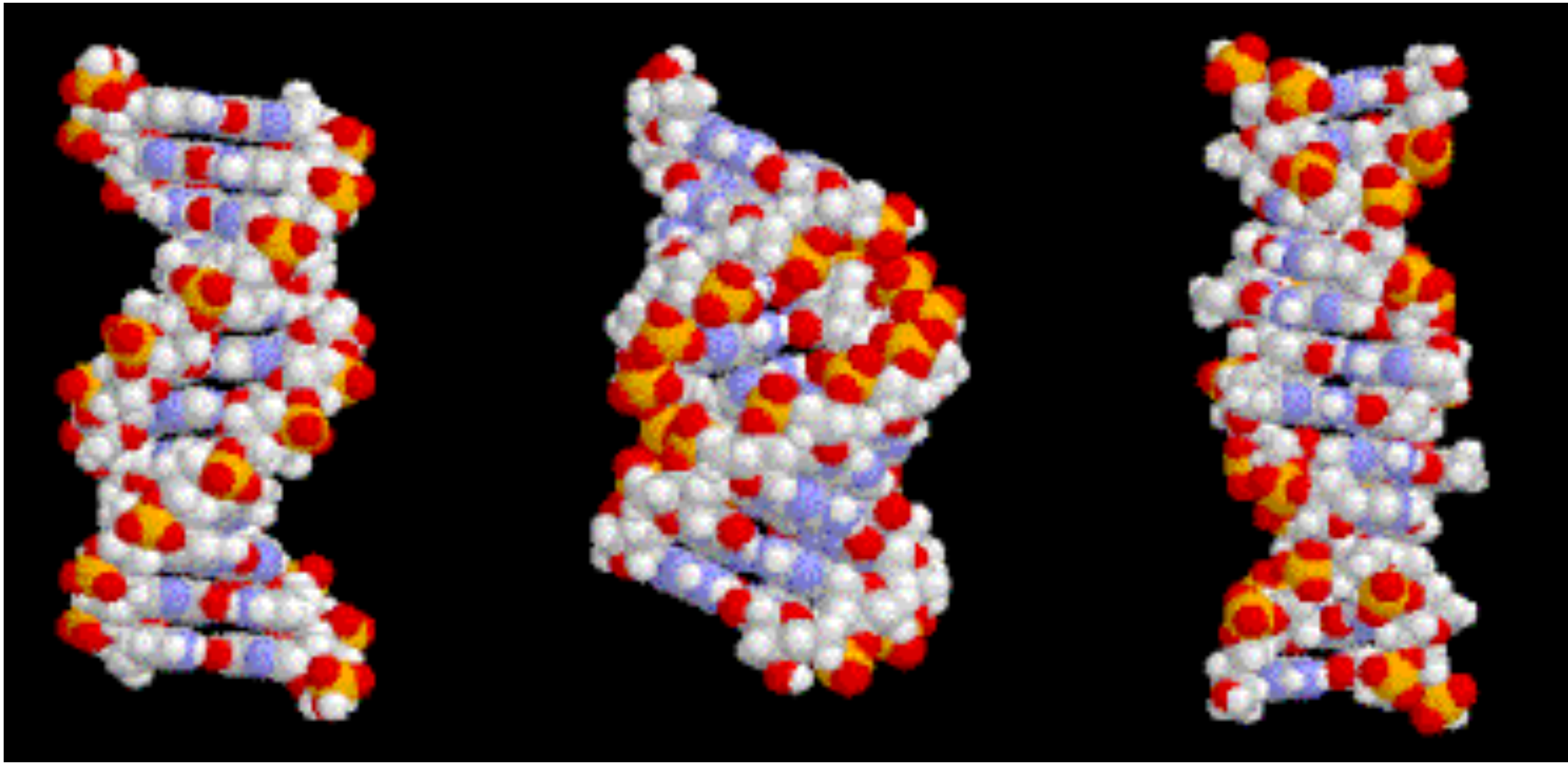






(a)

Forms of DNA



	B	A	Z
helix sense	RH	RH	LH
bp per turn	10	11	12
vertical rise per bp	3.4	2.56	3.7 Angstroms
rotation per bp	+36	+33	-30 degrees
helical diameter	19	23	18 Angstroms

- Genes control protein production indirectly
- DNA is transcribed into RNA then translated into a protein
- An organism's **genome** is its entire set of genetic instructions

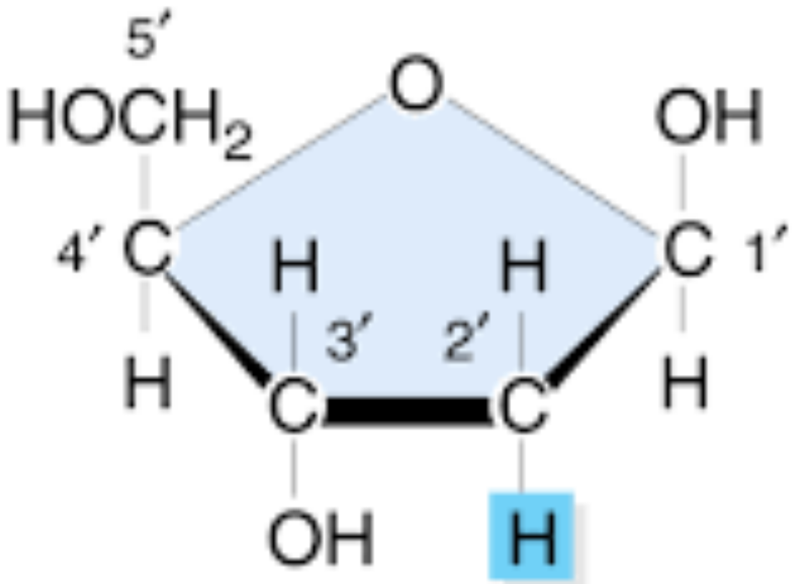
CENTRAL DOGMA

$$\text{DNA} \rightleftharpoons \text{RNA} \longrightarrow \text{protein}$$

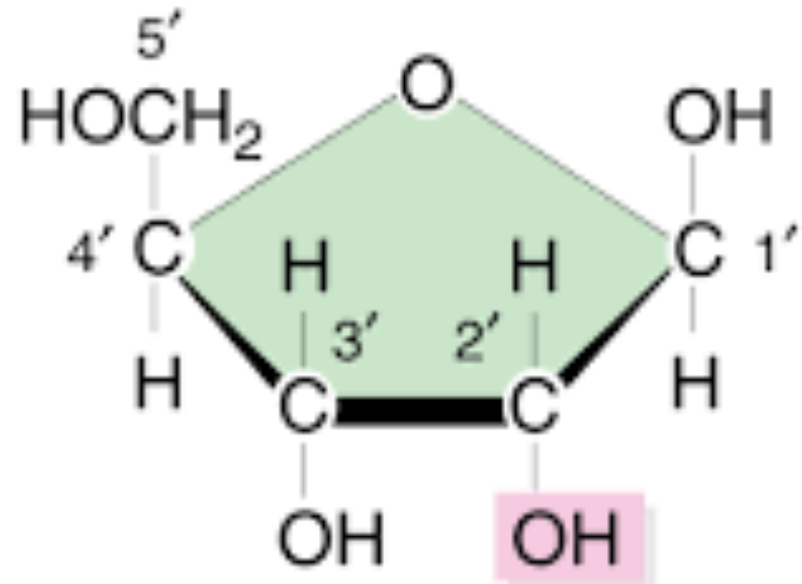
Properties of RNA

- Single stranded
- More flexible → 3D molecular shape
- Ribose sugar
- Uracil in place of Thymine
- RNA is short, only 1 gene long, where DNA is very long and contains many genes
- Act as enzymes: Ribozymes

- Classes: two
  - Informational: mRNA
  - Functional: tRNA and rRNA
    - Small nuclear in Eukaryotes for modification of rRNA as part of spliceosome

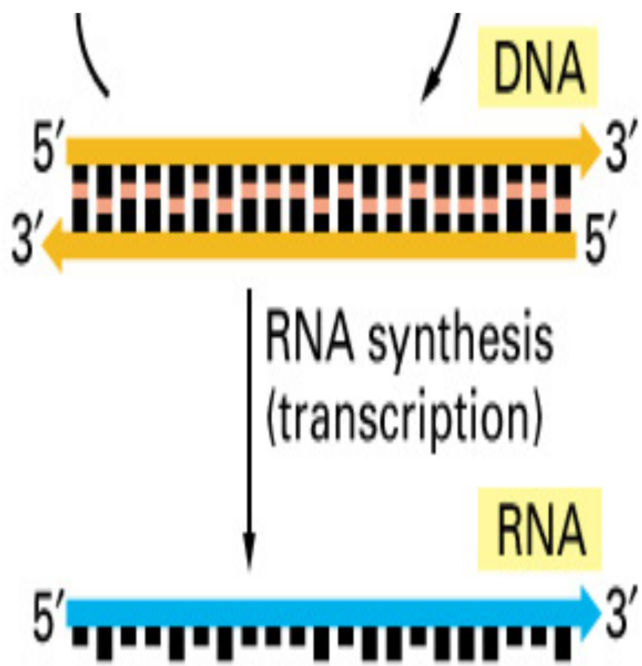


Deoxyribose



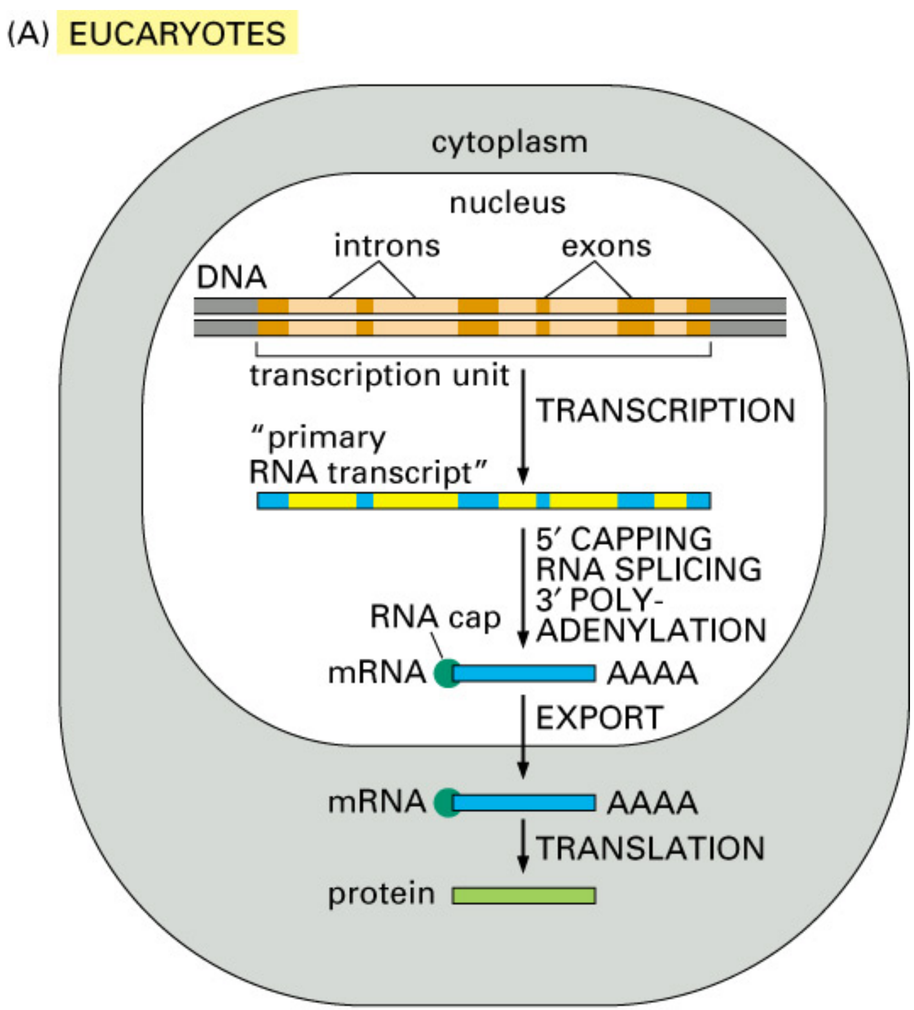
Ribose

Basic steps in transcription



- DNA and RNA function is based on two principles
  - Complementarity of bases
  - Sequence specific recognition of proteins
- Local separation of strand
- Any one strand serves as template for a particular gene
- Growth is from 5’ to 3’ and nt added to 3’
- Stages of transcription:
  - Initiation
  - Elongation
  - Termination

Transcription and Translation



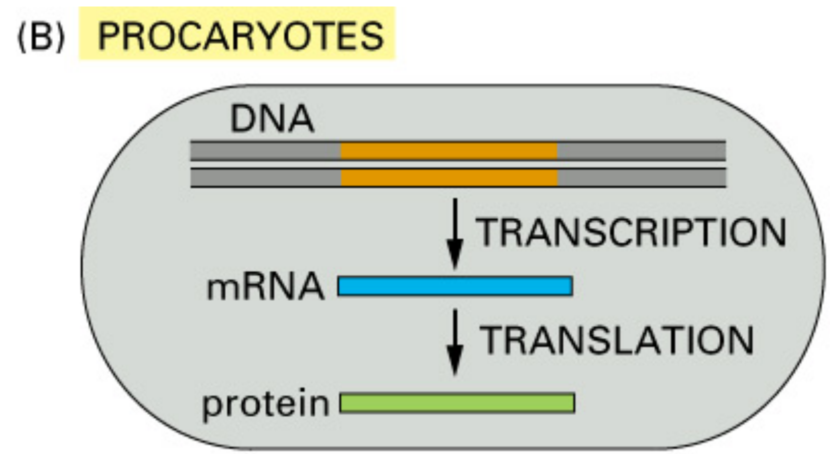


Figure 6–21 part 2 of 2. Molecular Biology of the C

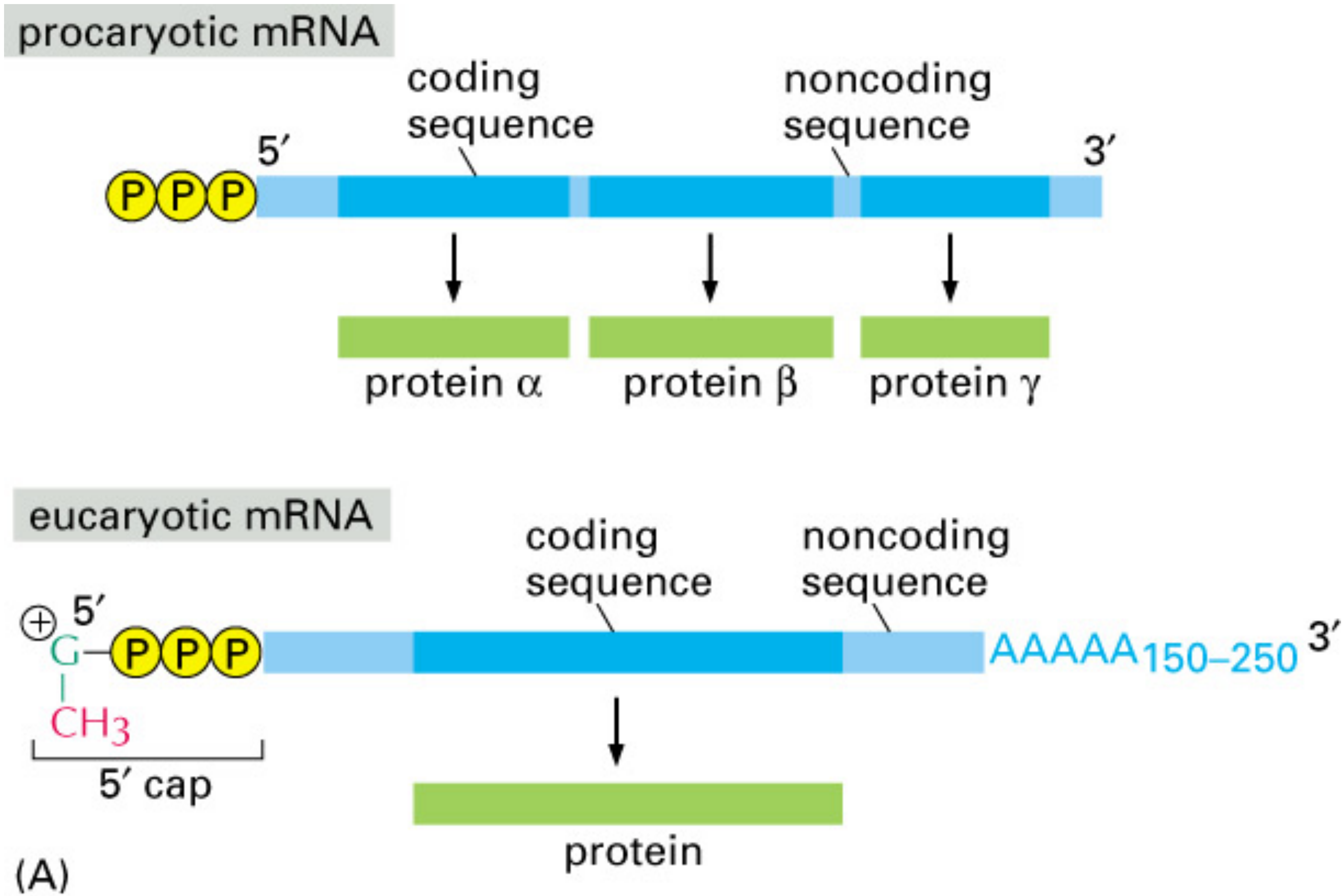


Figure 6–22 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

Different types of RNA processing

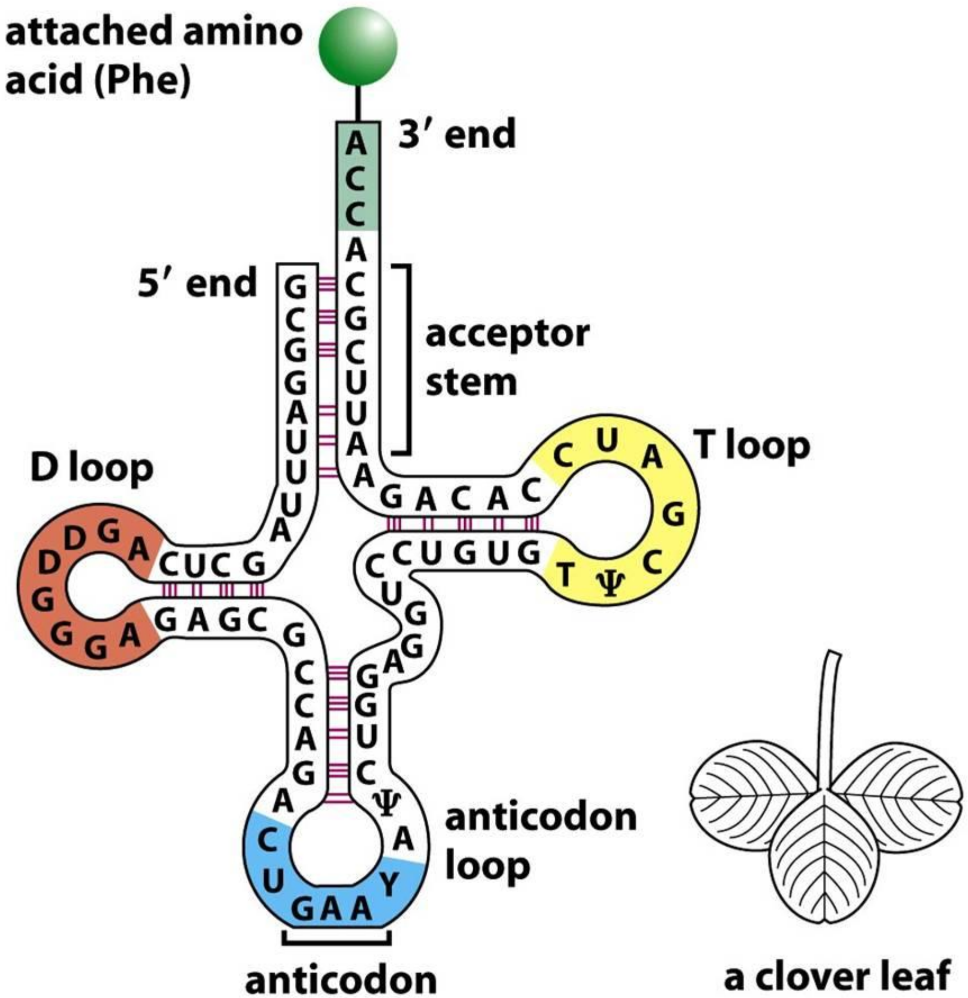
1. Splicing
2. Addition of Cap at 5’ end
3. Addition of poly A tail

Function of 5’ Cap

1. Facilitate export of mature mRNA from the nucleus
2. Help protect mRNA from degradation
3. Help ribosome attach to 5’end of mRNA once mRNA in cytoplasm

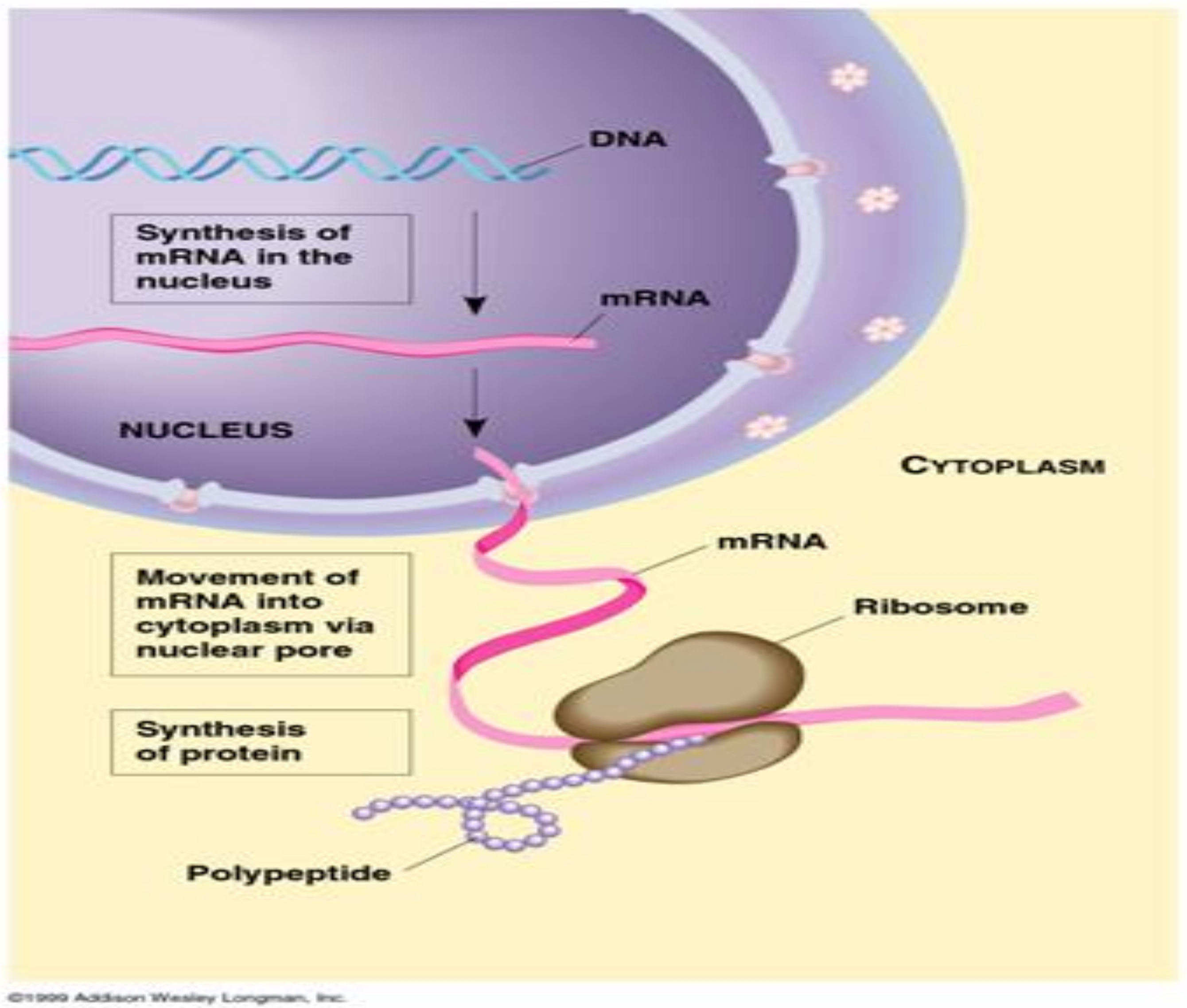
Function of 3’ poly A tail

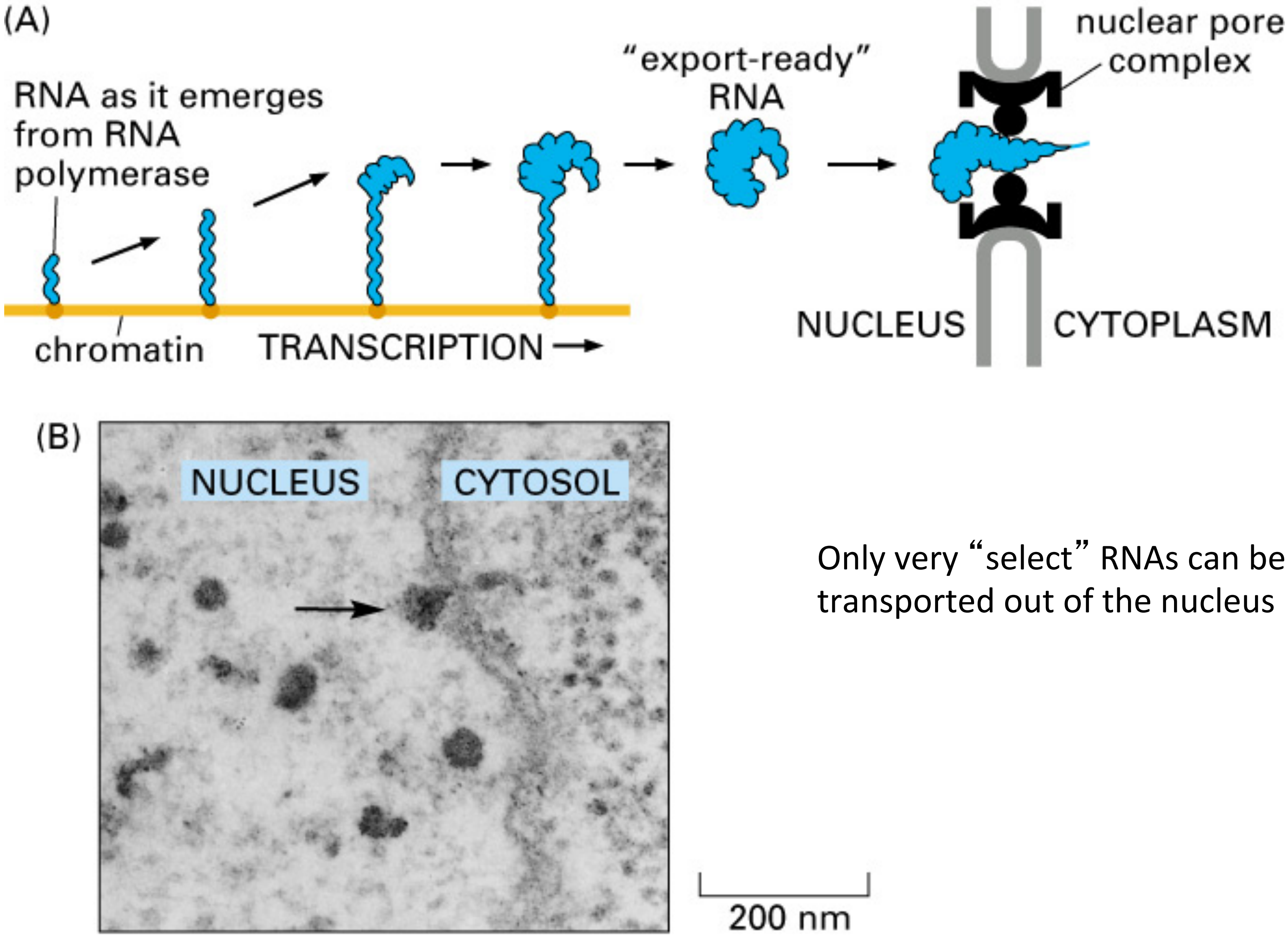
1. Stability
2. Termination of transcription



- anticodon- 3’ to 5’ sequence that matches the complementary 5’ to 3’ sequence (codon) on the mRNA
- Acceptor arm - Amino acid code on 3’ end
- T and D loops – provide structure for interface with aminoacyl-tRNA synthetase

DNA Transcription

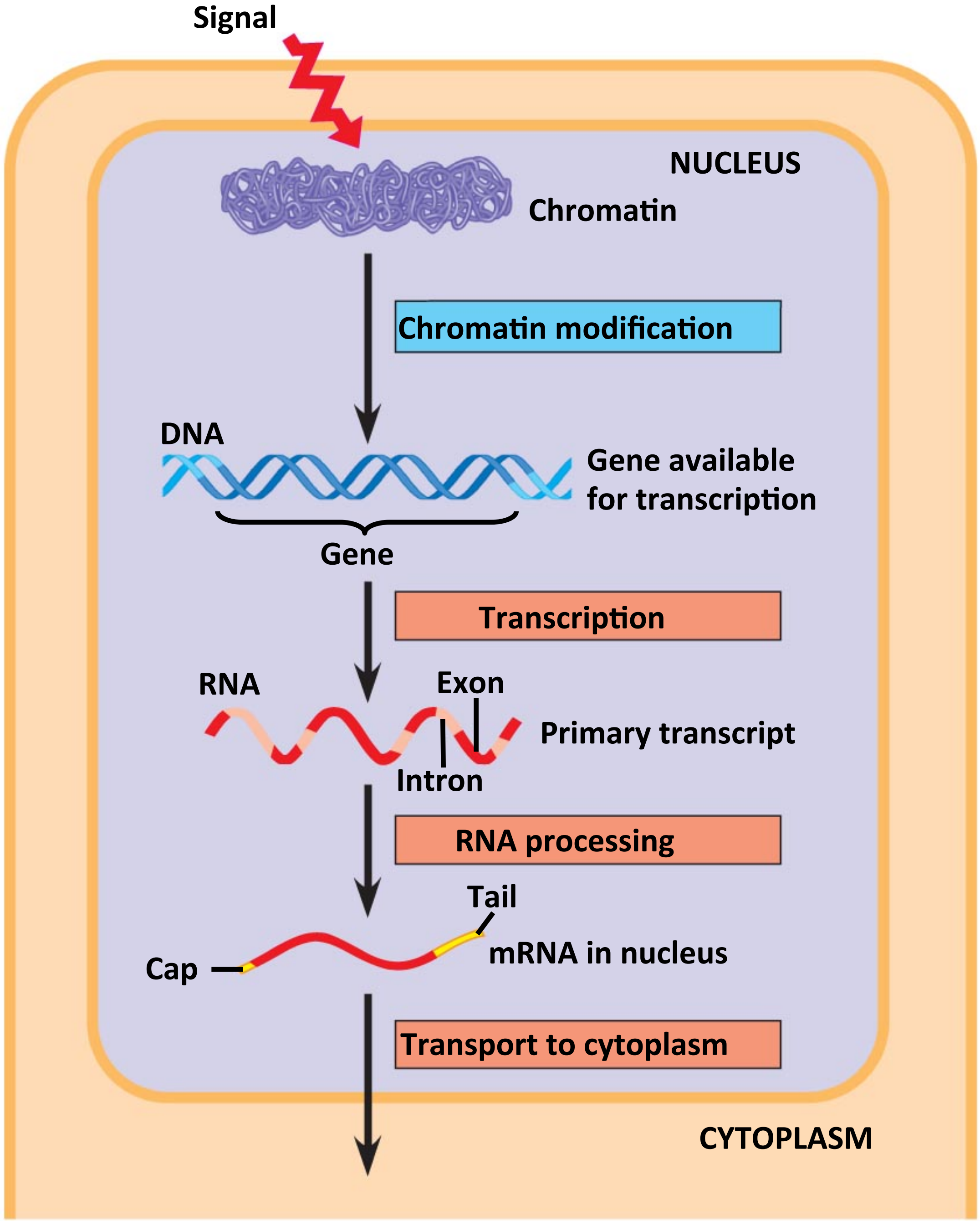




Only very "select" RNAs can be transported out of the nucleus

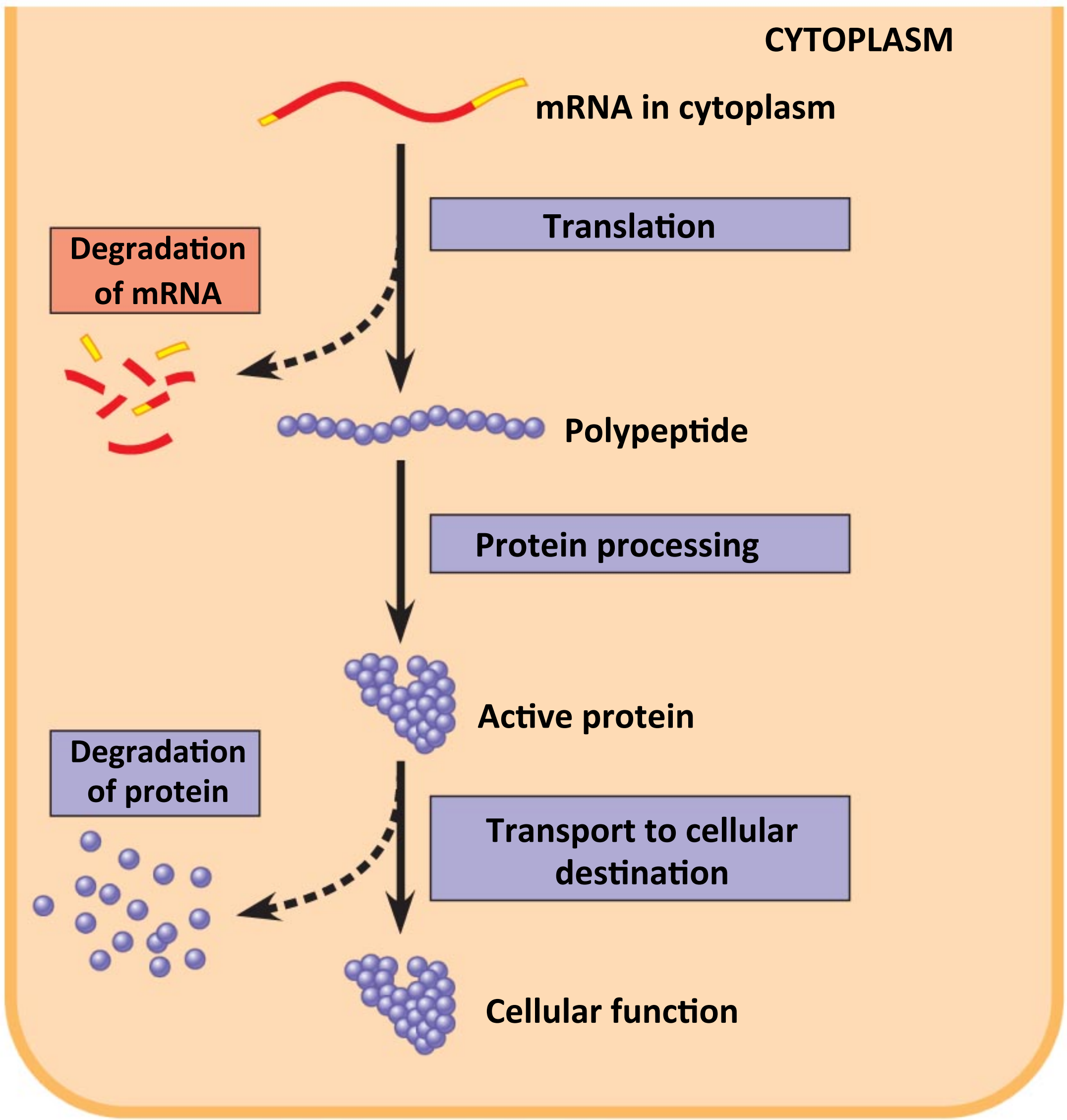
Figure 6–39. Molecular Biology of the Cell, 4th Edition.

Fig. 18-6a



Signal
NUCLEUS
Chromatin
Chromatin modification
DNA
Gene available for transcription
Gene
Transcription
RNA
Exon
Primary transcript
Intron
RNA processing
Tail
mRNA in nucleus
Cap
Transport to cytoplasm
CYTOPLASM

Fig. 18-6b


CYTOPLASM
mRNA in cytoplasm
Translation
Degradation of mRNA
Polypeptide
Protein processing
Active protein
Degradation of protein
Transport to cellular destination
Cellular function

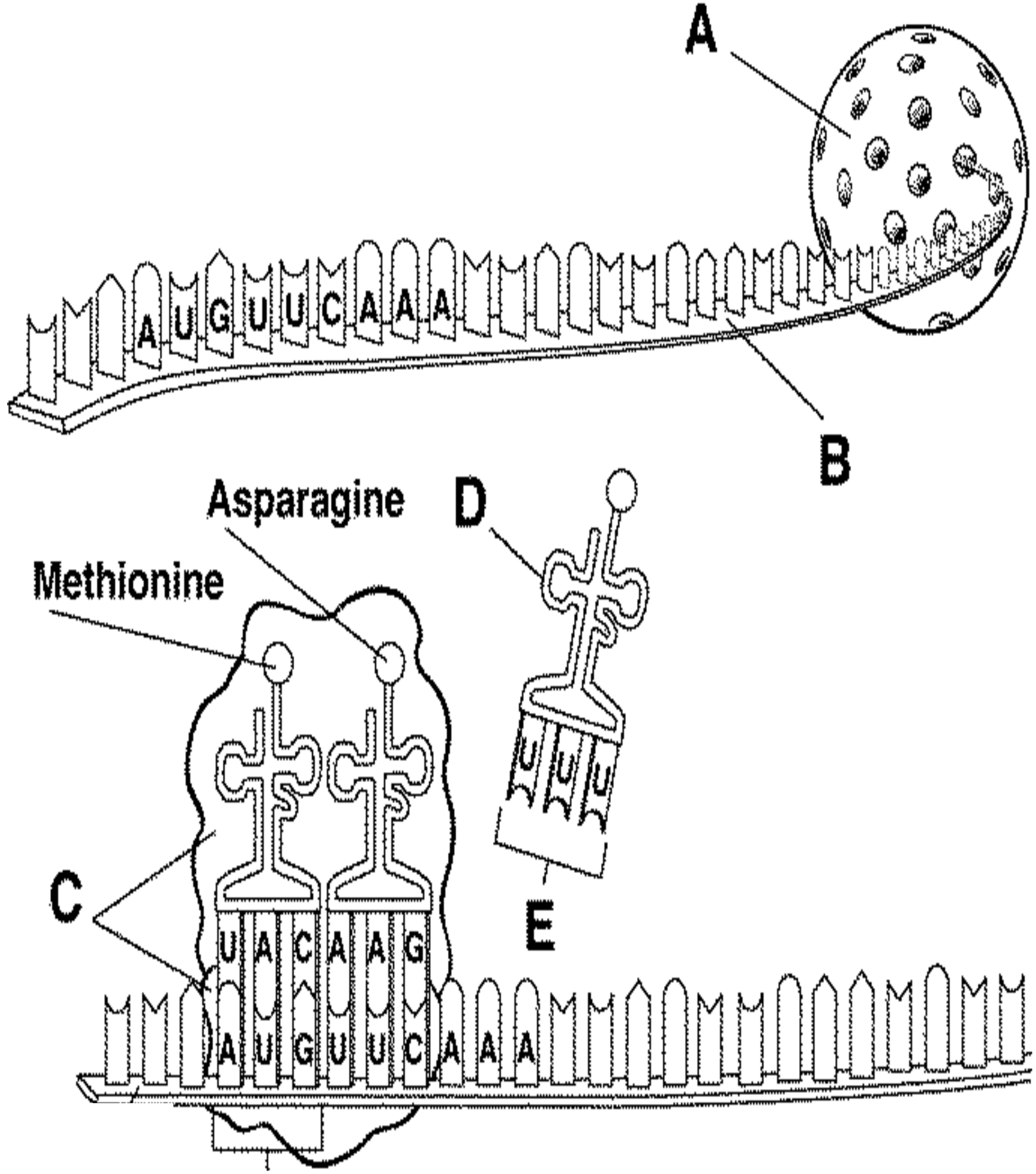
(1961) Watson & Crick proposed…

- …DNA controlled cell function by serving as a template for <u>PROTEIN</u> structure.

- 3 Nucleotides = a triplet or <u>CODON</u>

  (which code for a specific AMINO ACID)

- <u>AMINO ACIDS</u> are the building blocks of proteins.


A
AUGUUCAAA
B
Asparagine
D
Methionine
UUU
C
E
UACAAG
AUGUUCAAA

Triplet code:

A continuous sequence of three nucleotides codes for a specific amino acid

CGA - CAA - CCA - CCA - GCT - GGG - GAG - CCA -

Ala Val Gly Gly Arg Pro Leu Gly

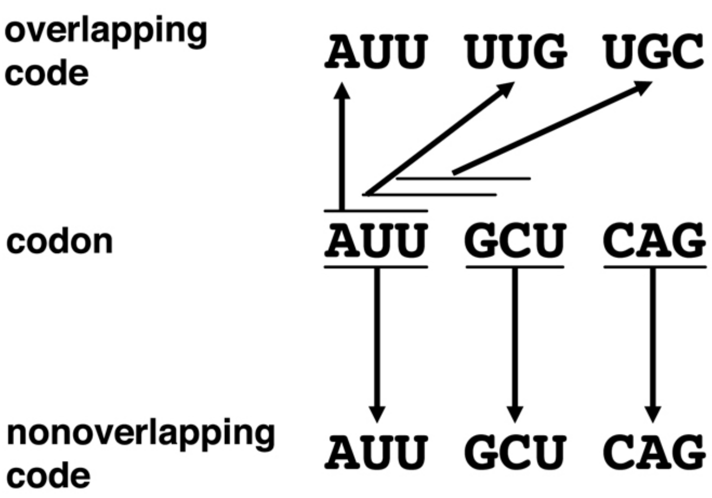
The amino acids are joined together in the correct sequence to make part of a protein

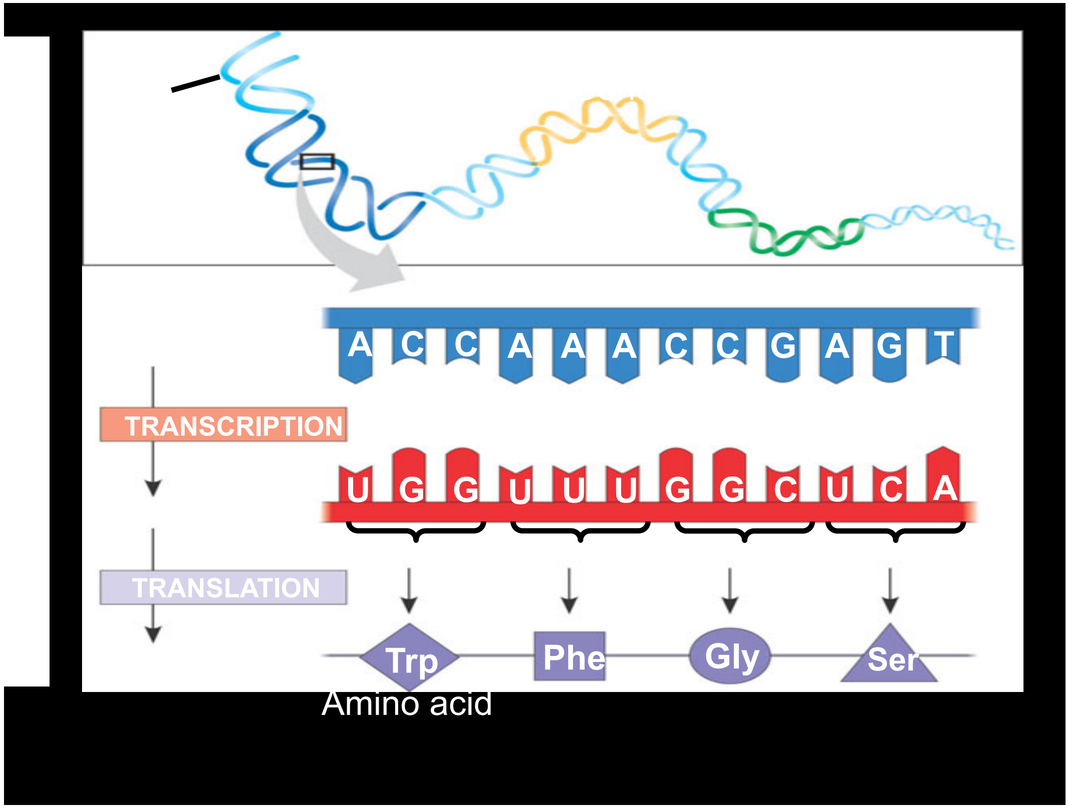
Peptide Bonds

—Ala —Val — Gly — Gly —Arg — Pro — Leu —Gly —

Genetic code is

1. Triplet, 2. Non-overlapping, 3. Degenerate





The Genetic Code

- A codon in messenger RNA is either translated into an amino acid or serves as a translational start/stop signal

First mRNA base (5′ end)	Second mRNA base: U	C	A	G	Third mRNA base (3′ end)
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
U	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
U	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
C	CUC Leu	CCC Pro	CAC His	CGC Arg	C
C	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
C	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
A	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
A	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
A	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
G	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
G	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
G	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

Proteins

Type of Protein	Function	Examples
Enzymatic proteins	Selective acceleration of chemical reactions	Digestive enzymes catalyze the hydrolysis of the polymers in food.
Structural proteins	Support	Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin provide a fibrous framework in animal connective tissues. Keratin is the protein of hair, horns, feathers, and other skin appendages.
Storage proteins	Storage of amino acids	Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo. Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds.
Transport proteins	Transport of other substances	Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.
Hormonal proteins	Coordination of an organism's activities	Insulin, a homone secreted by the pancreas, helps regulate the concentration of sugar in the blood of vertebrates.
Receptor proteins	Response of cell to chemical stimuli	Receptors built into the membrane of a nerve cell detect chemical signals released by other nerve cells.
Contractile and motor proteins	Movement	Actin and myosin are responsible for the movement of muscles. Other proteins are responsible for the undulations of the organelles called cilia and flagella.
Defensive proteins	Protection against disease	Antibodies combat bacteria and viruses.

Table 5.1

Structures of Proteins

Polypeptides or proteins : Are polymers of amino acid

- **Primary structure:** Peptide bonds

- **Secondary Structure:**

Hydrogen bonds between AAs at different locations, Electrostatic forces, van der Waals forces

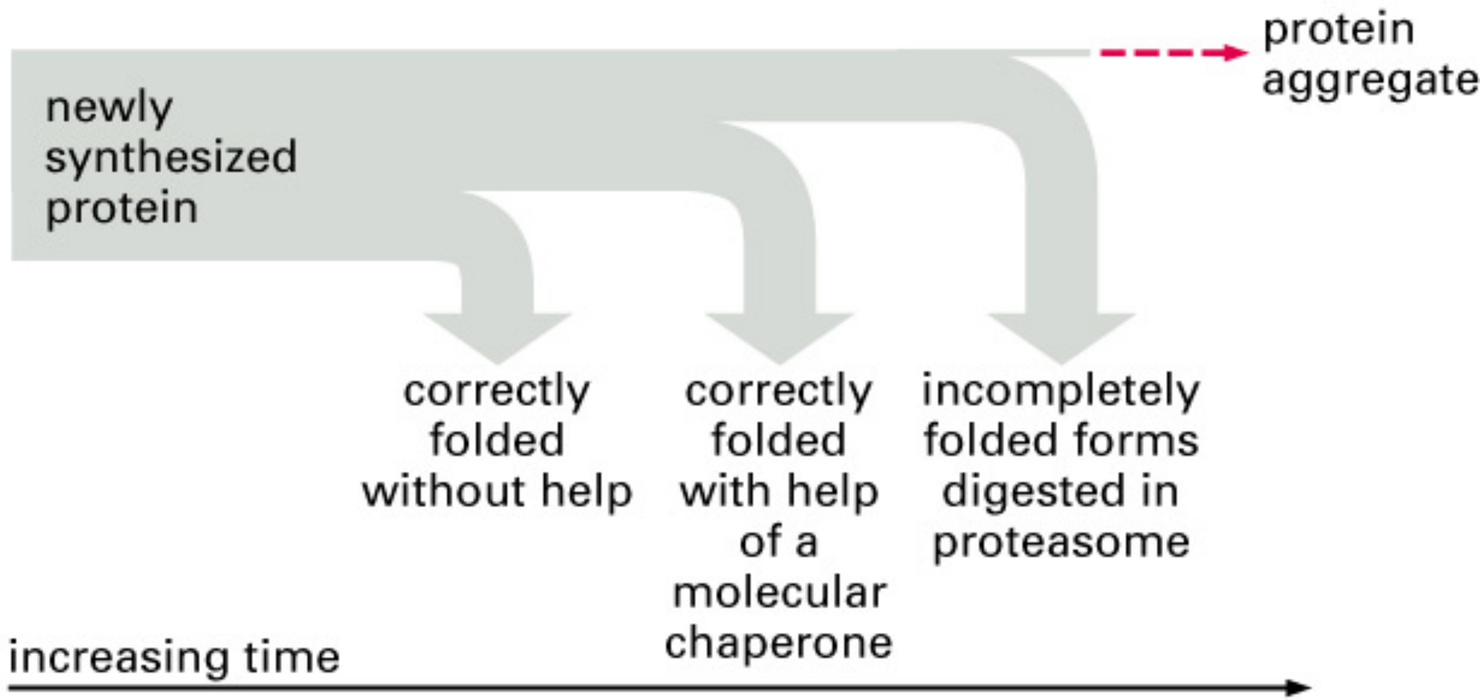
Types: Alpha helices and beta pleated sheets

- **Tertiary structure: +** disulphide bonds,

formed by folding

- **Quartenary structure:** weak bonds different polypeptides

Protein Folding kinetics



Levels of Protein Structure

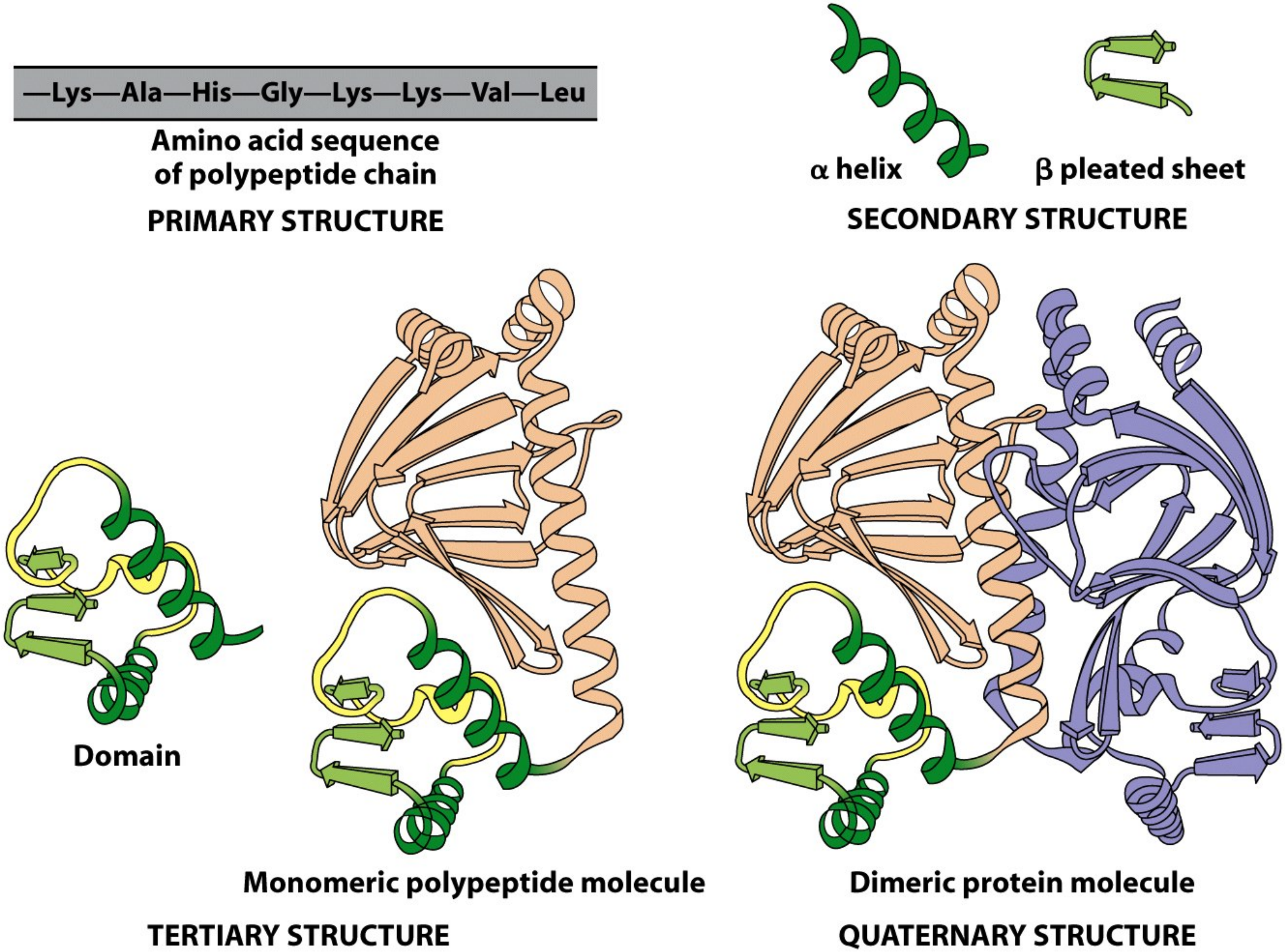
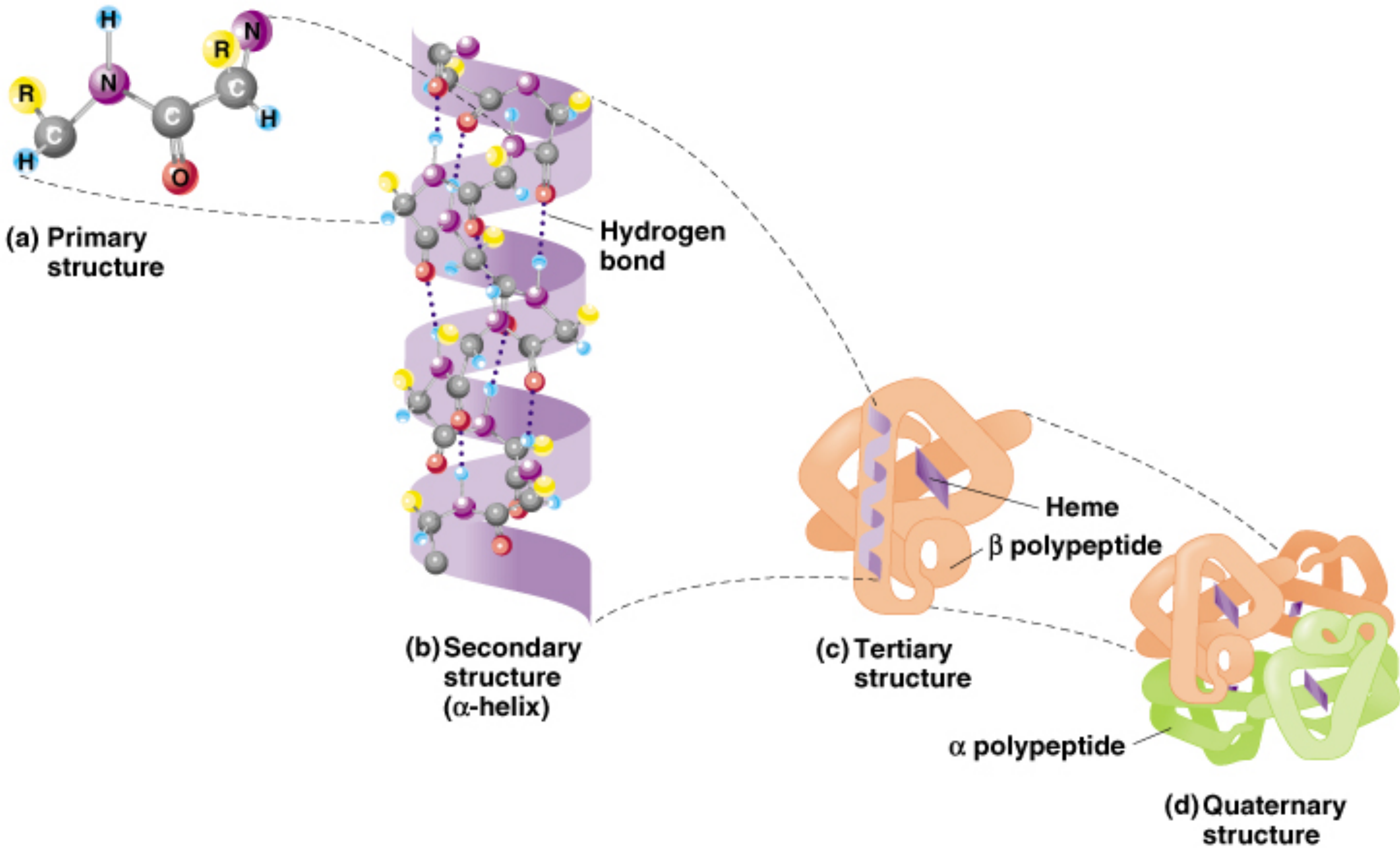
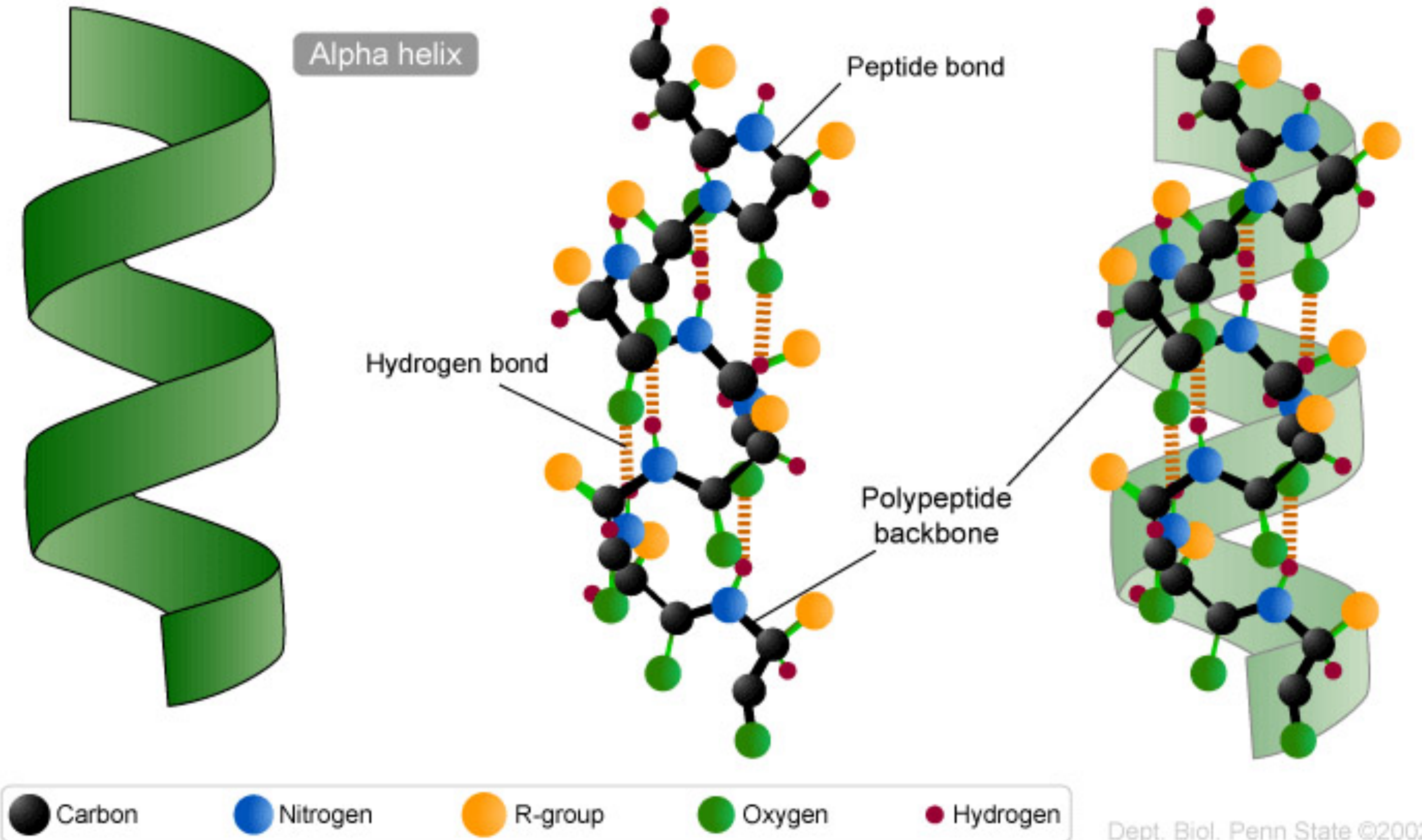


Figure 4-2
Kuby IMMUNOLOGY, Sixth Edition

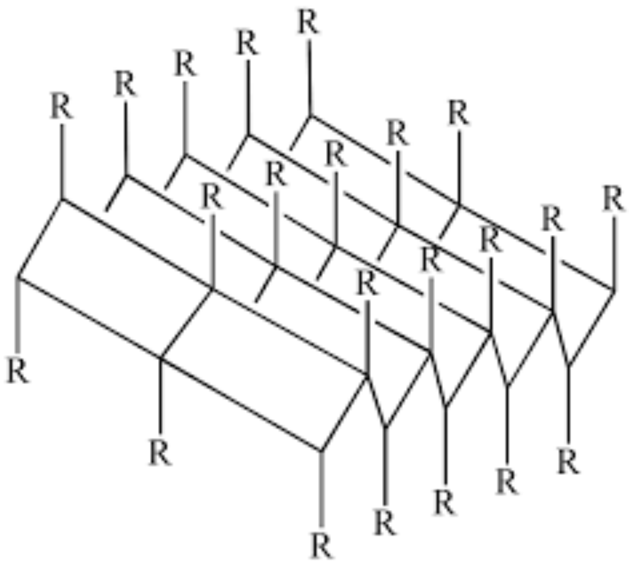
Polypeptides : Are polymers of amino acid

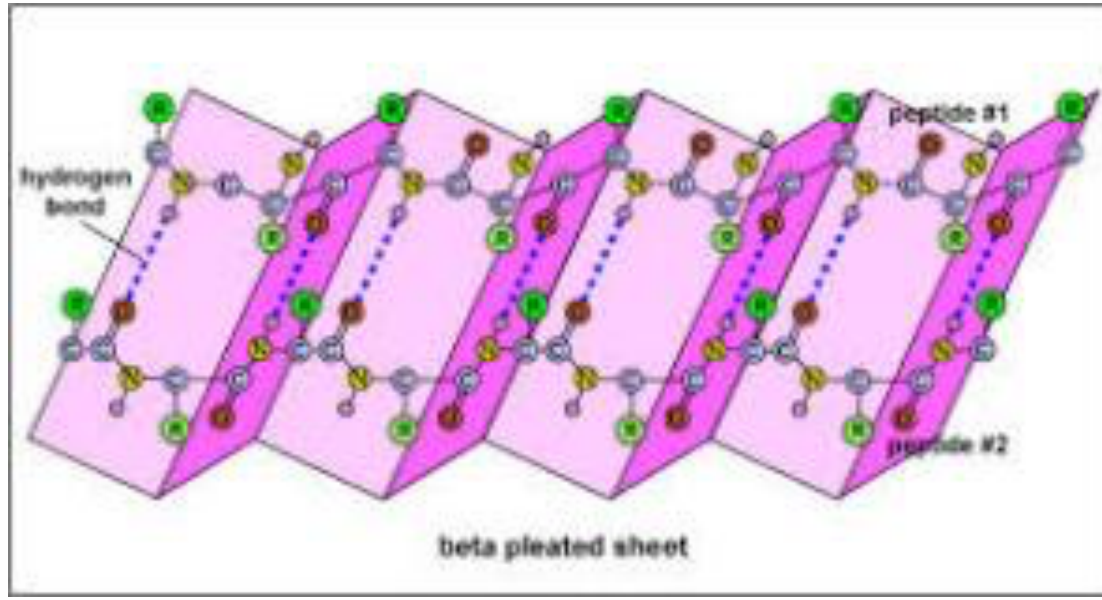


Alpha helical structure

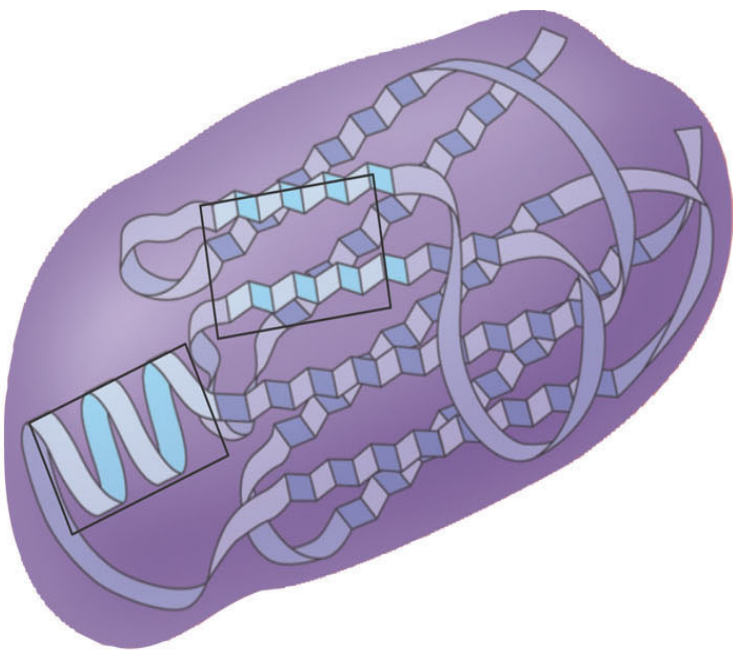


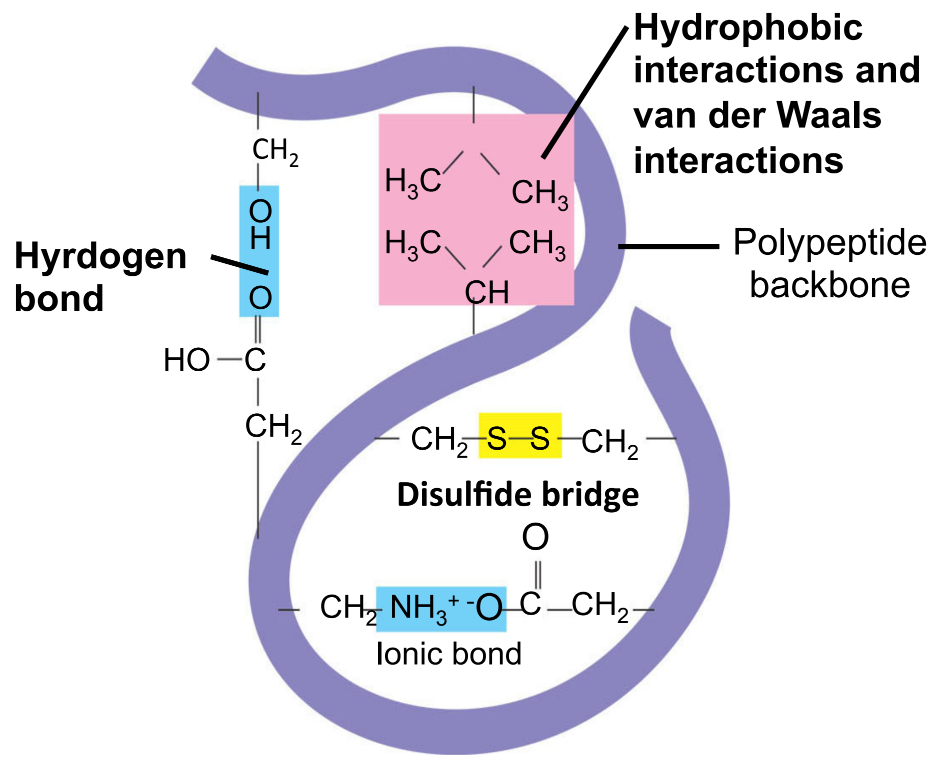
Beta pleated sheet structure





Protein Folding





- Denaturation and Renaturation

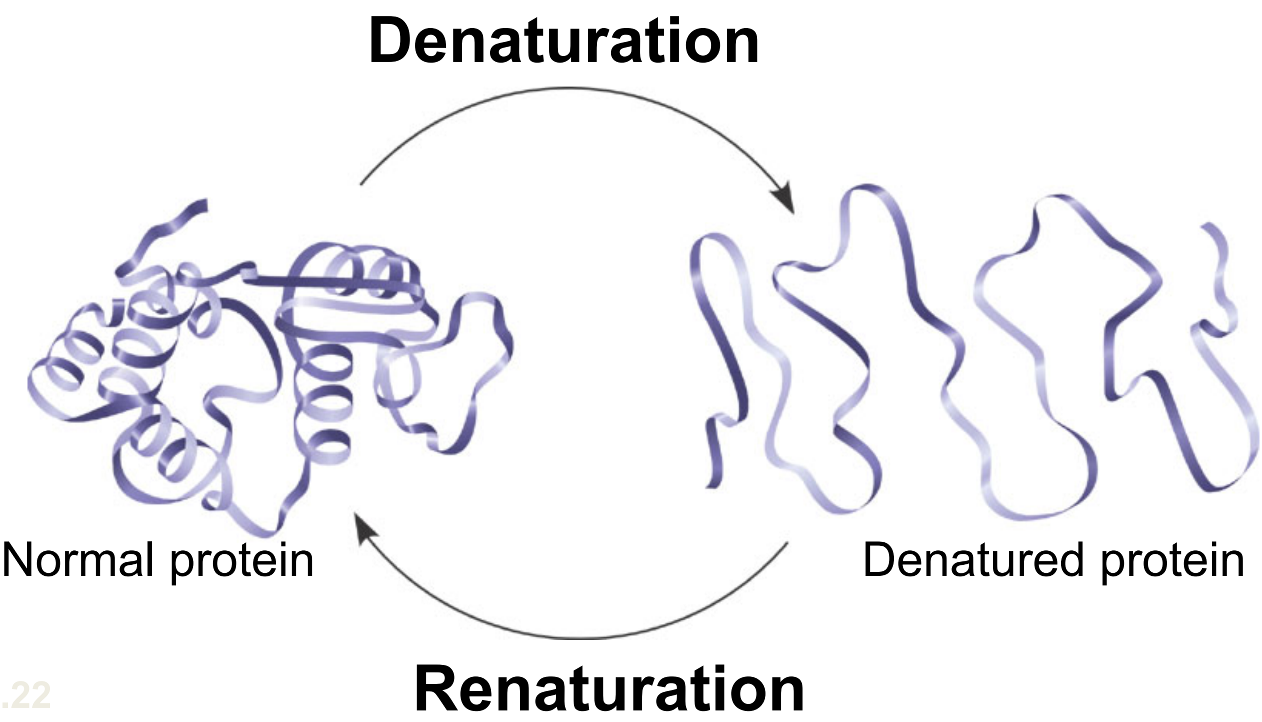
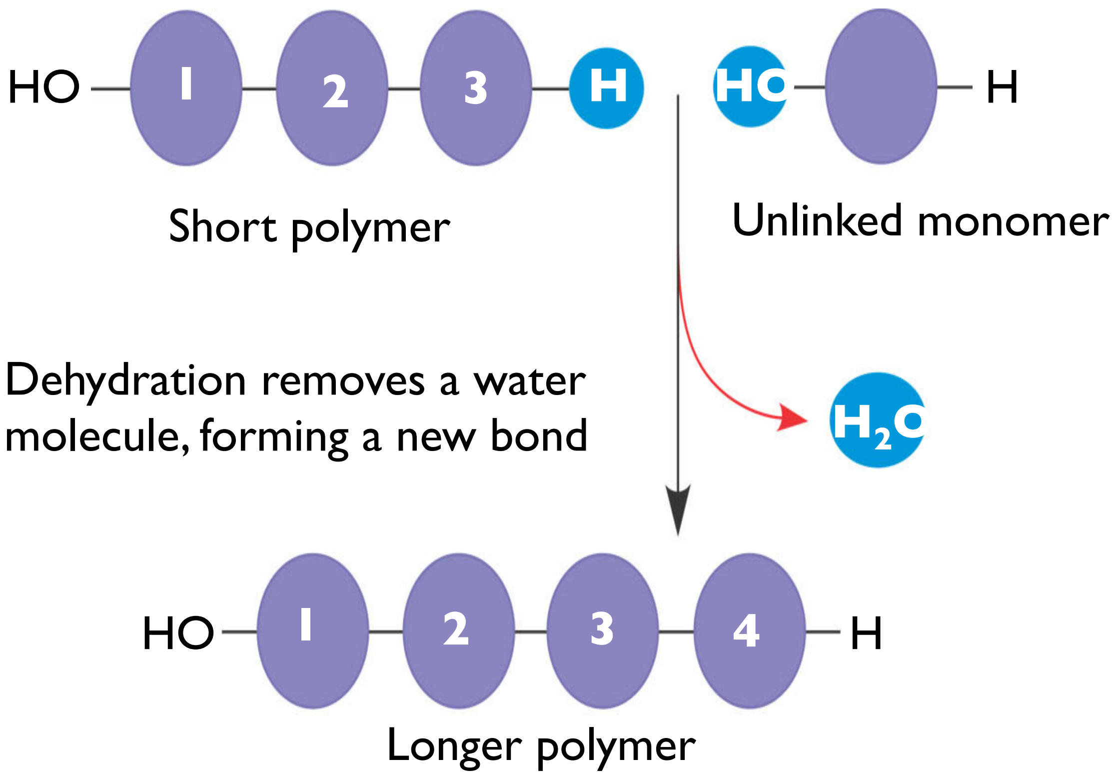
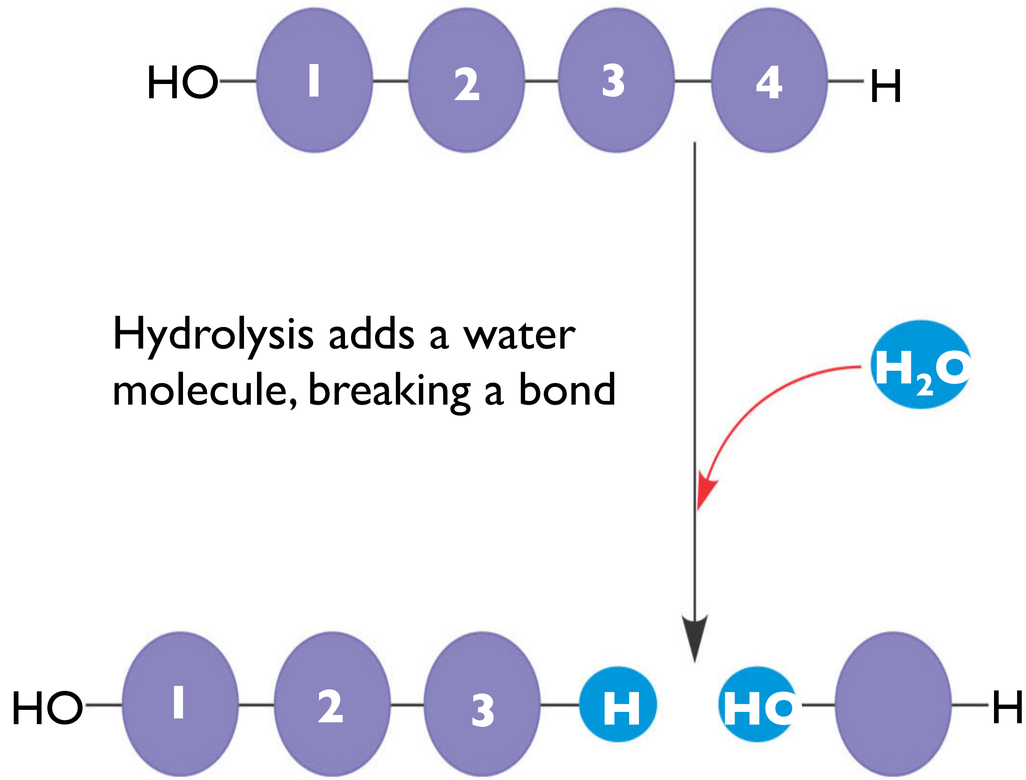


Figure 5.22

The Synthesis and Breakdown of Polymers



(a) Dehydration reaction in the synthesis of a polymer



(b) Hydrolysis of a polymer

Figure 5.2B

Amino Acid Polymers

- Amino acids
  - Are linked by peptide bonds

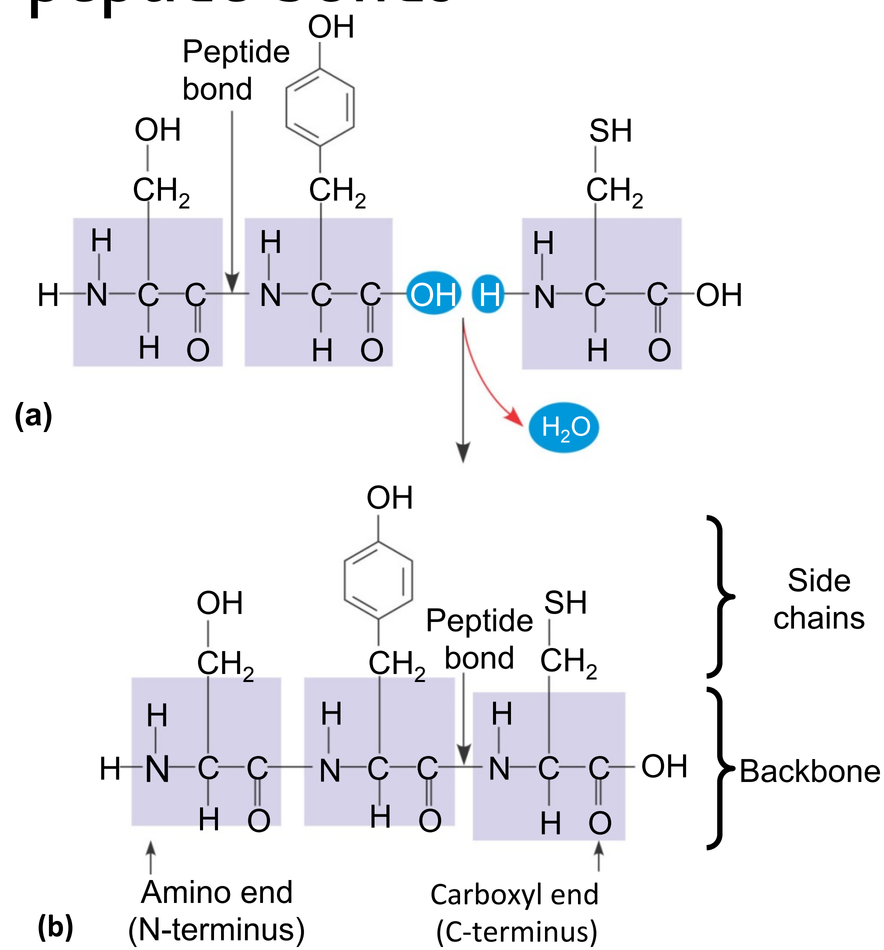


Figure 5.18