

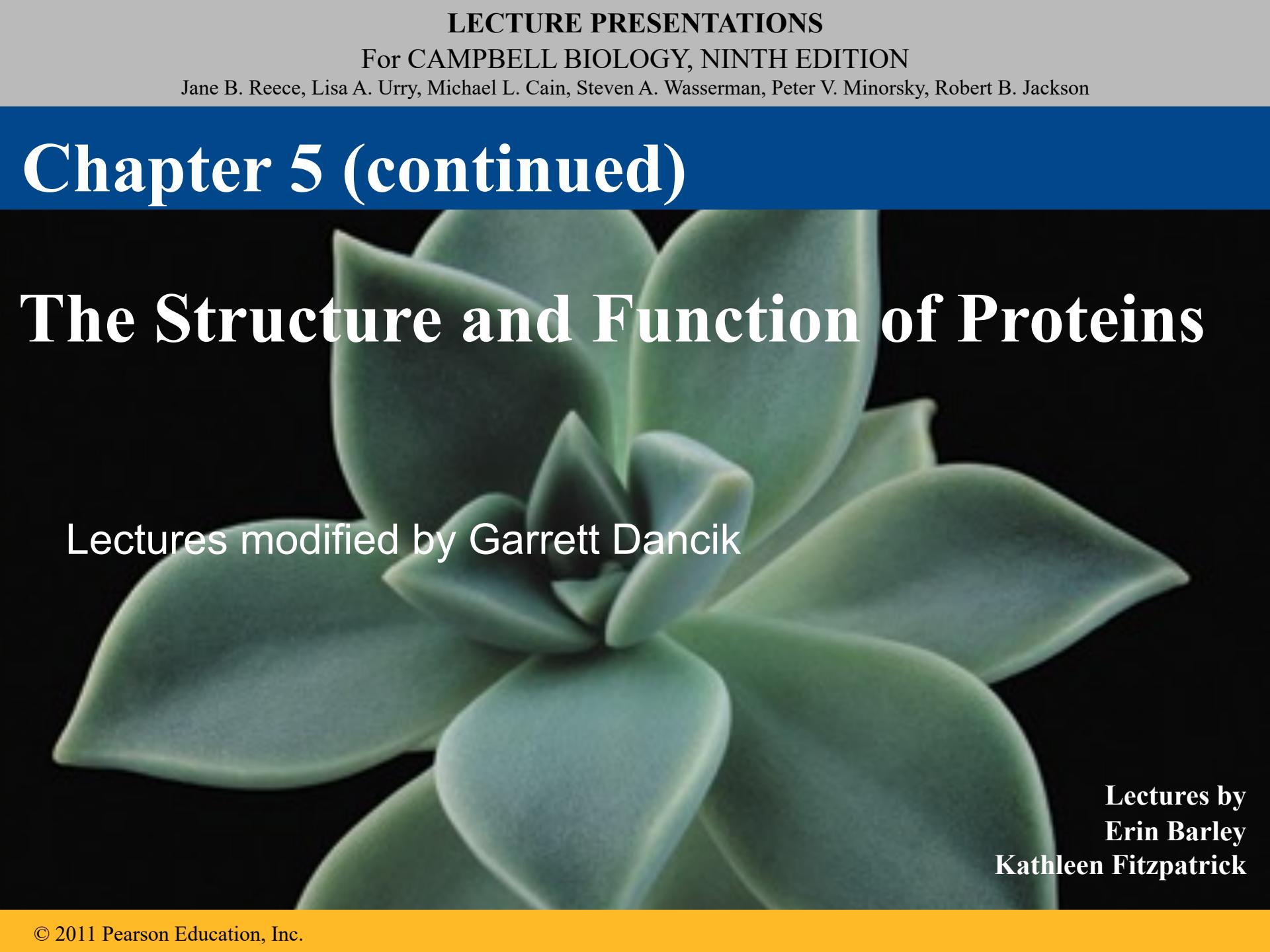
## LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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# Chapter 5 (continued)

## The Structure and Function of Proteins



Lectures modified by Garrett Dancik

Lectures by  
Erin Barley  
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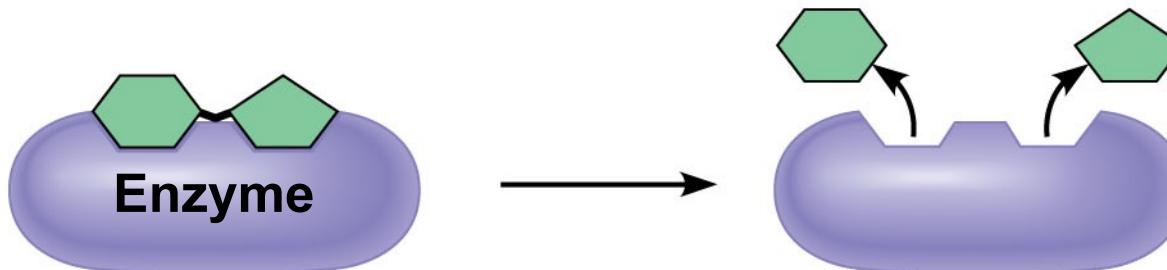
# Concept 5.4: Proteins include a diversity of structures, resulting in a wide range of functions

- Proteins account for more than 50% of the dry mass of most cells
- Protein functions include structural support, storage, transport, cellular communications, movement, and defense against foreign substances

## Enzymatic proteins

**Function:** Selective acceleration of chemical reactions

**Example:** Digestive enzymes catalyze the hydrolysis of bonds in food molecules.



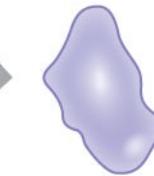
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- **Enzymes** are a type of protein that acts as a **catalyst** to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life
- <http://www.biotopics.co.uk/other/morinf.html>

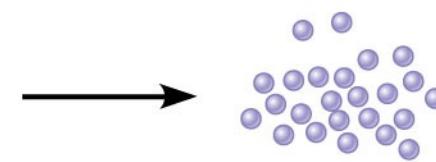
## Storage proteins

**Function: Storage of amino acids**

**Examples:** Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.



**Ovalbumin**

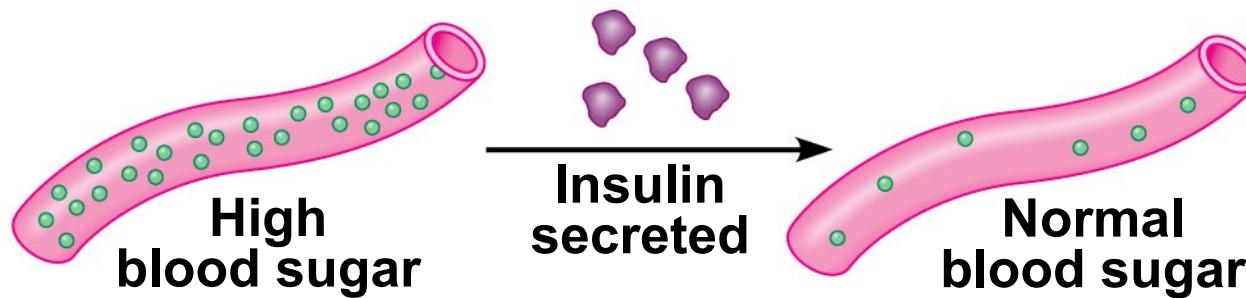


**Amino acids  
for embryo**

## Hormonal proteins

**Function: Coordination of an organism's activities**

**Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration**



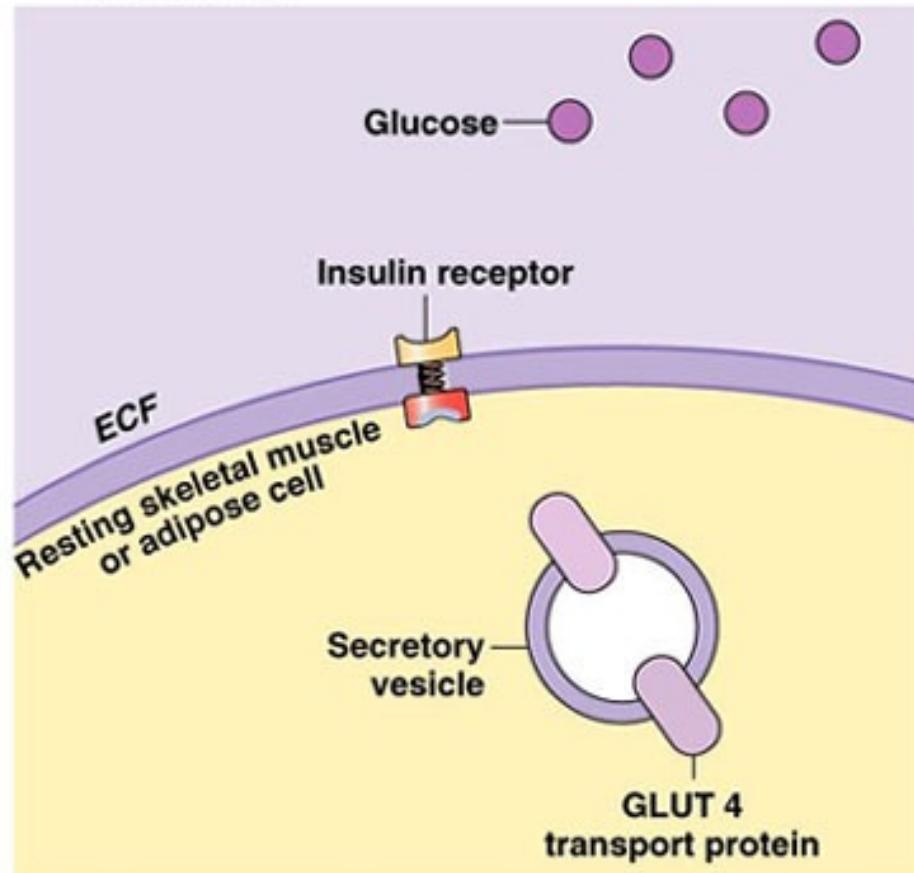
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Insulin protein entry:

<https://www.ncbi.nlm.nih.gov/protein/AAA59172.1>

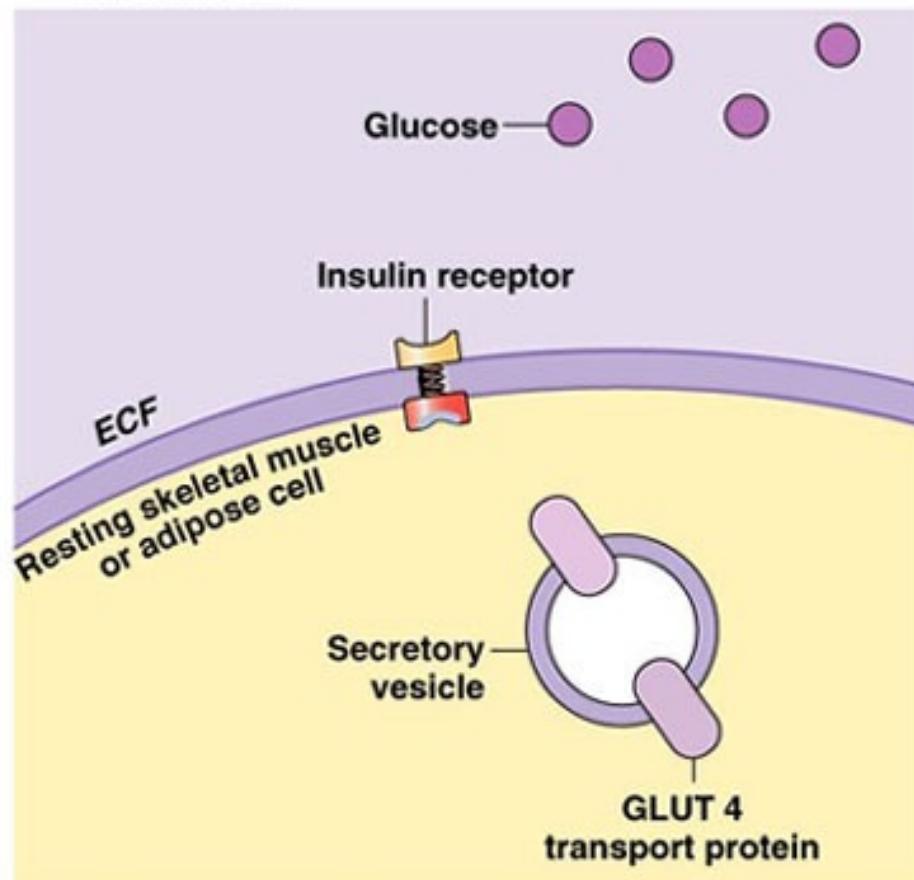
# Insulin and Glucose transport

**(a) In the absence of insulin, glucose cannot enter the cell.**

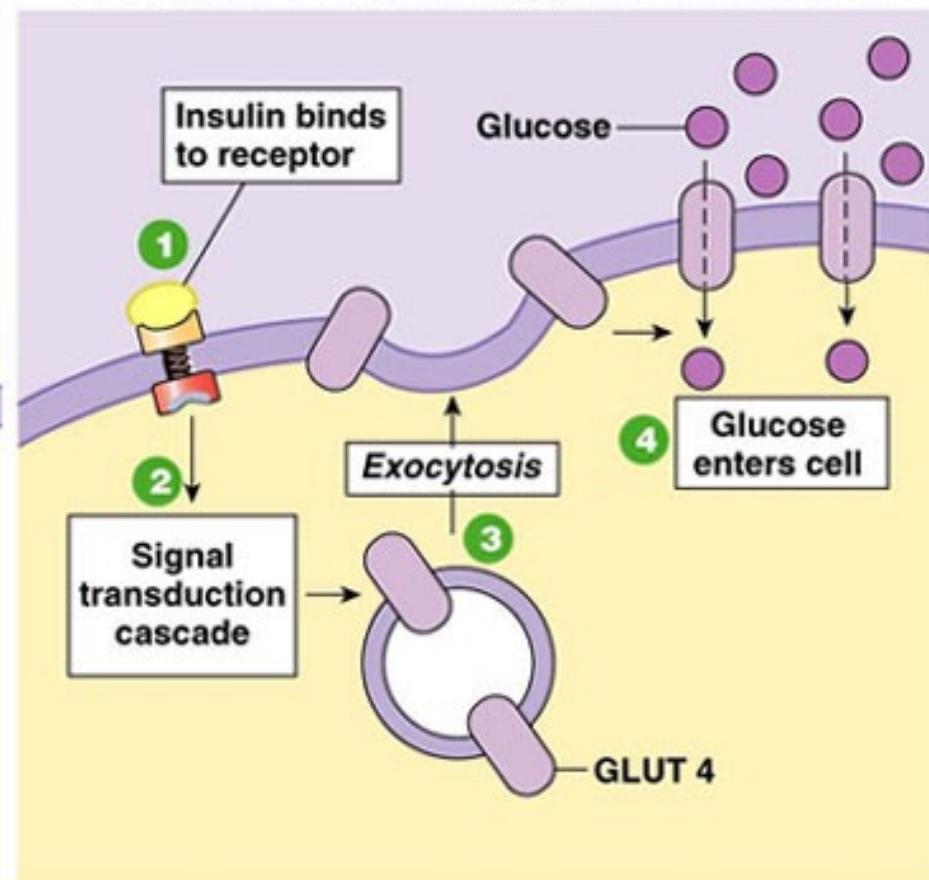


# Insulin and Glucose transport

**(a) In the absence of insulin, glucose cannot enter the cell.**



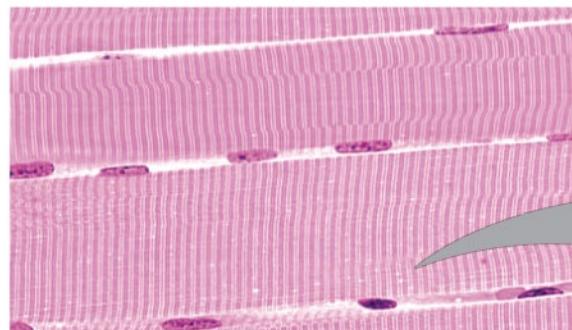
**(b) Insulin signals the cell to insert GLUT 4 transporters into the membrane, allowing glucose to enter cell.**



## Contractile and motor proteins

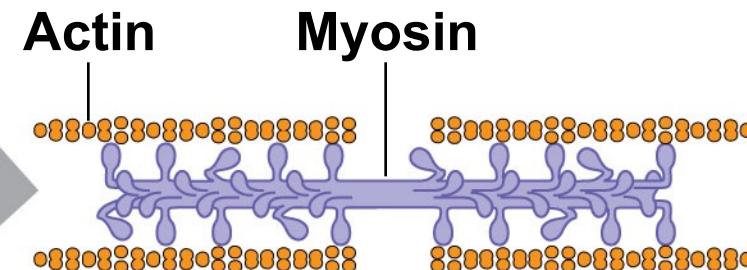
**Function: Movement**

**Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.**



**Muscle tissue**

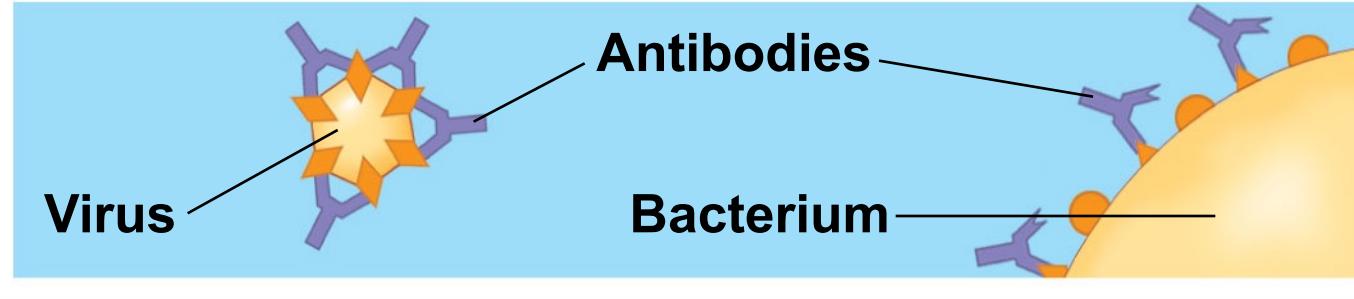
100  $\mu\text{m}$



## Defensive proteins

**Function: Protection against disease**

**Example: Antibodies inactivate and help destroy viruses and bacteria.**



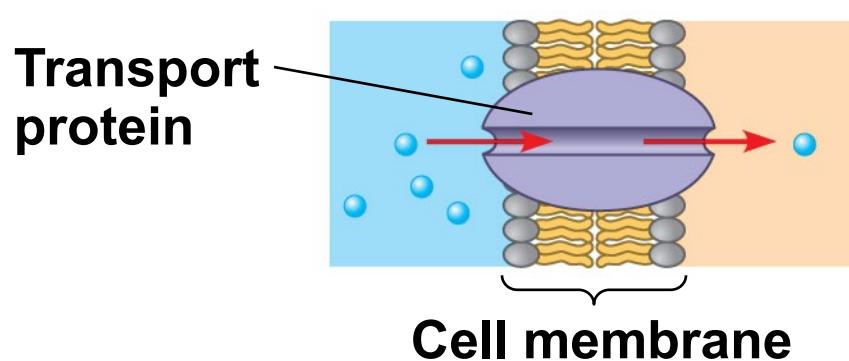
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COVID example: <https://www.ncbi.nlm.nih.gov/Structure/pdb/7R7N>

## Transport proteins

**Function: Transport of substances**

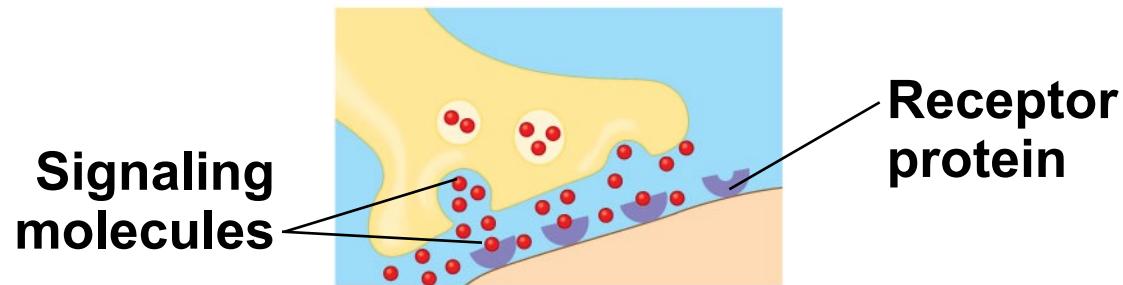
**Examples:** Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.



## Receptor proteins

**Function: Response of cell to chemical stimuli**

**Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.**

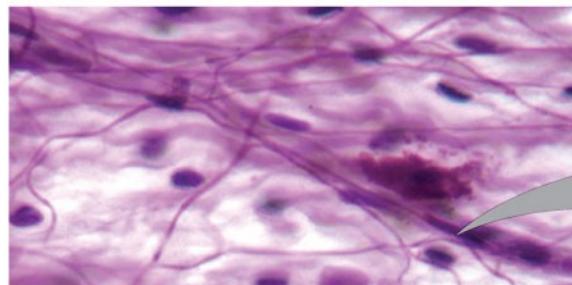


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## Structural proteins

**Function:** Support

**Examples:** Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.



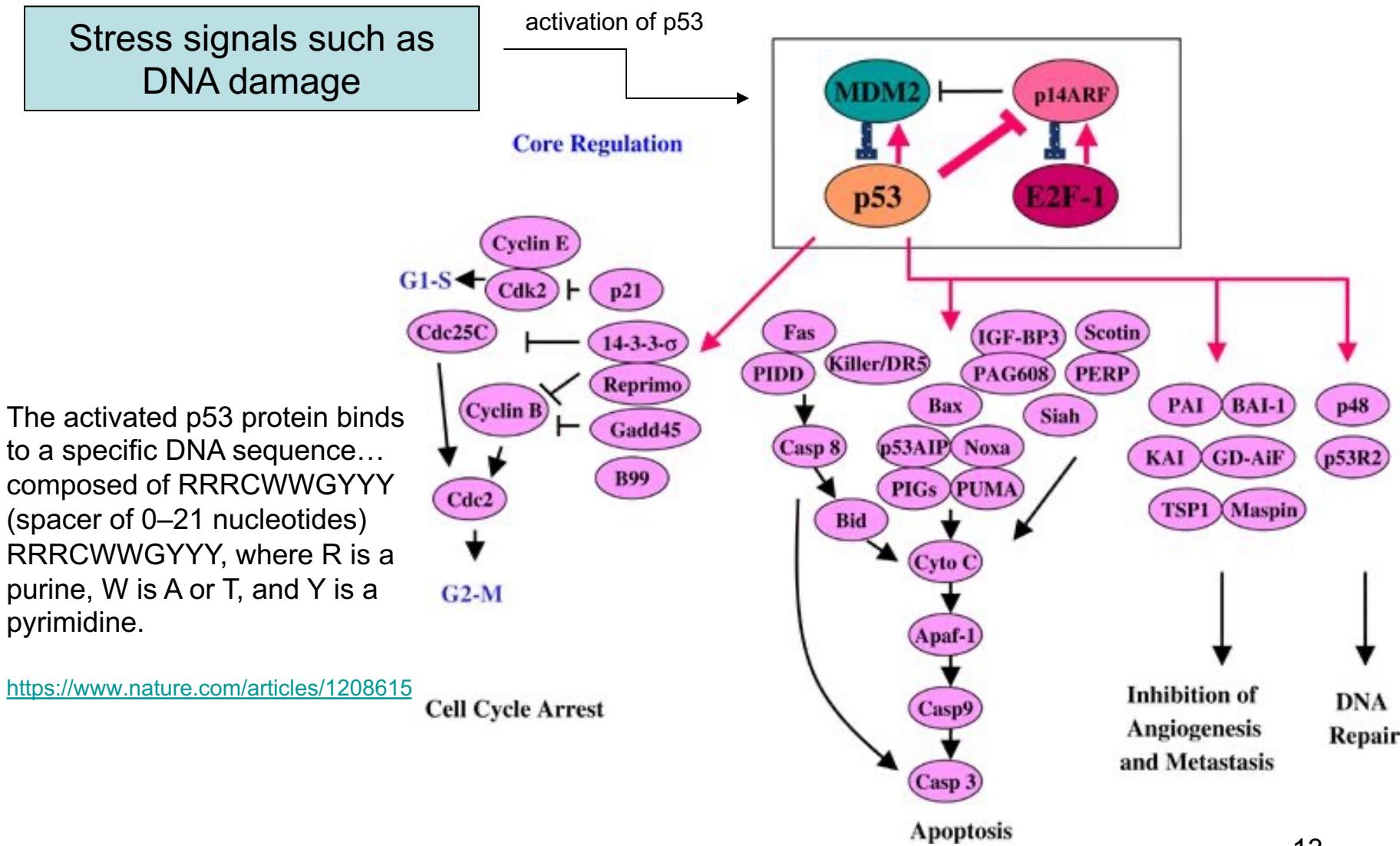
**Connective  
tissue**

60  $\mu\text{m}$



**Collagen**

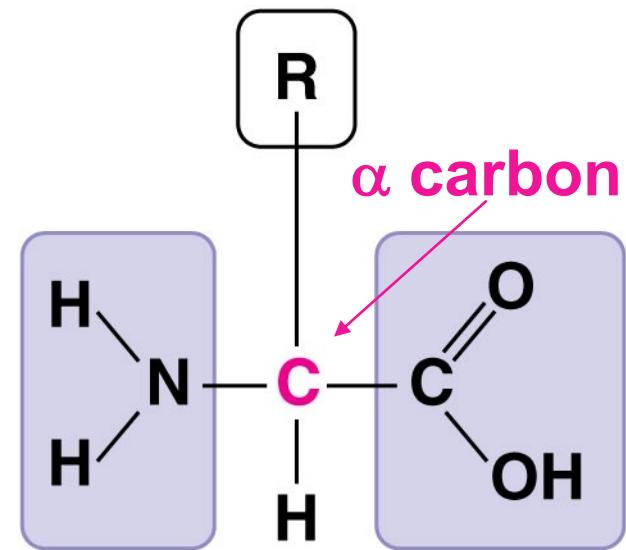
# p53 stress response pathway



# Proteins

- **Amino acids** are the building blocks (monomers) of proteins
  - Amino acids are organic molecules with carboxyl and amino groups
  - Amino acids differ in their properties due to differing side chains, called R groups (see next slide)
- **Polypeptides** are unbranched polymers built from the same set of 20 amino acids
- A **protein** is a biologically functional molecule that consists of one or more polypeptides

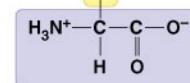
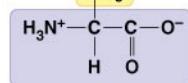
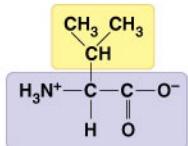
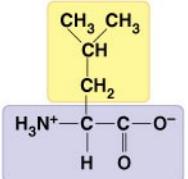
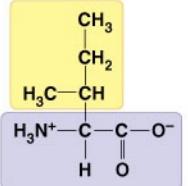
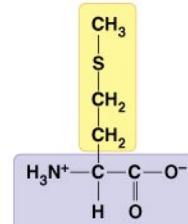
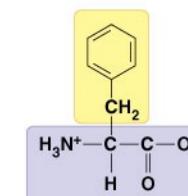
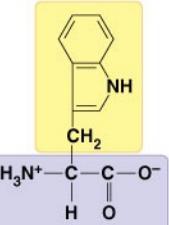
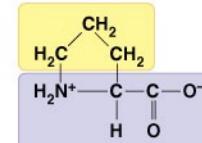
## Side chain (R group)



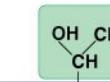
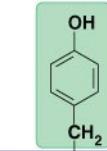
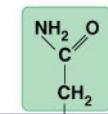
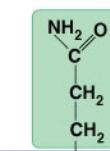
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Figure 5.16

## Nonpolar side chains; hydrophobic

Side chain  
(R group)Glycine  
(Gly or G)Alanine  
(Ala or A)Valine  
(Val or V)Leucine  
(Leu or L)Isoleucine  
(Ile or I)Methionine  
(Met or M)Phenylalanine  
(Phe or F)Tryptophan  
(Trp or W)Proline  
(Pro or P)

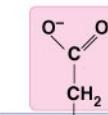
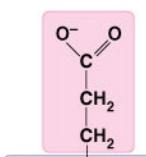
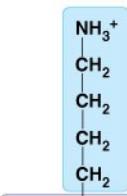
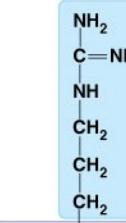
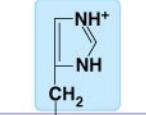
## Polar side chains; hydrophilic

Serine  
(Ser or S)Threonine  
(Thr or T)Cysteine  
(Cys or C)Tyrosine  
(Tyr or Y)Asparagine  
(Asn or N)Glutamine  
(Gln or Q)

## Electrically charged side chains; hydrophilic

## Basic (positively charged)

## Acidic (negatively charged)

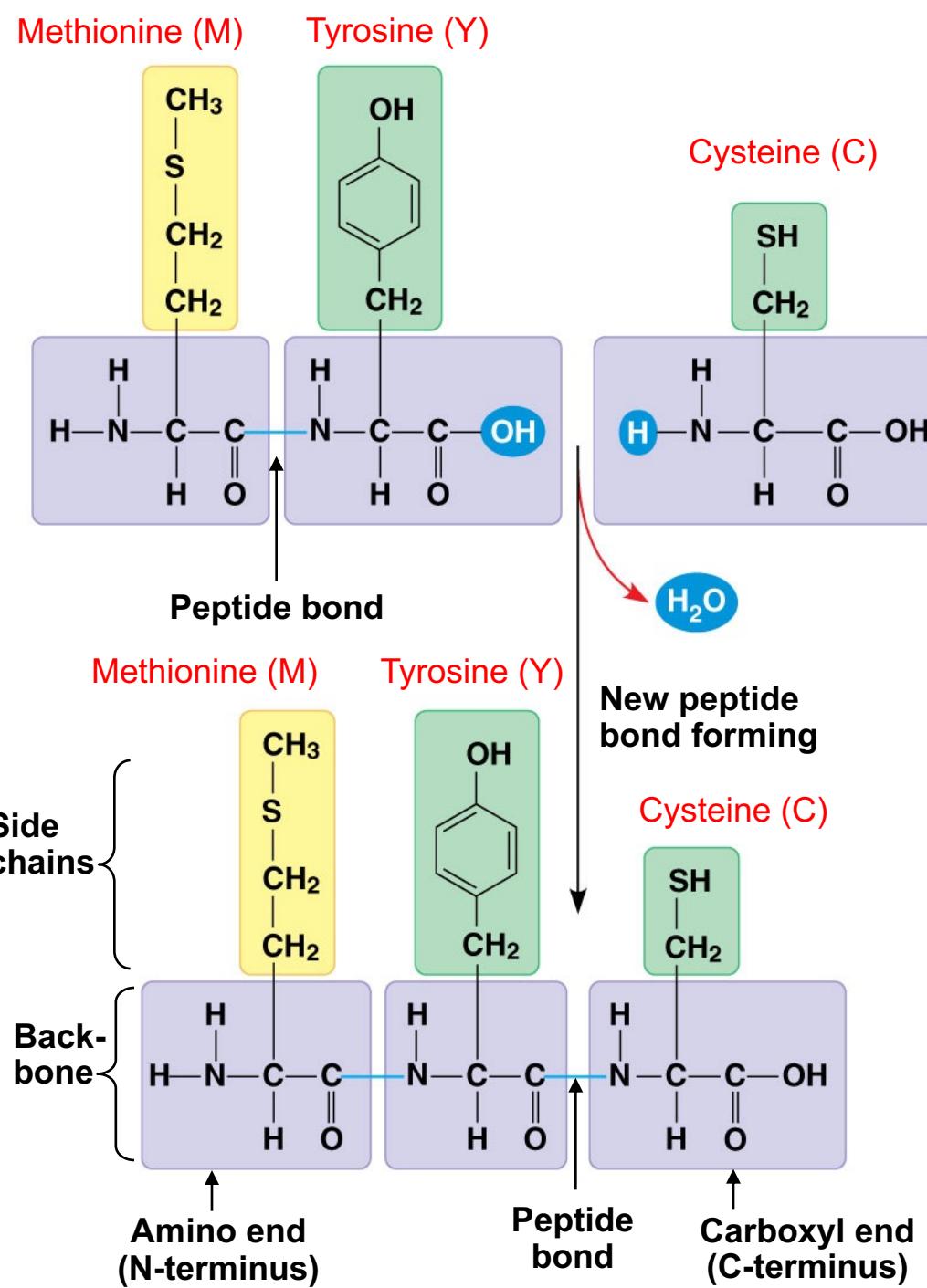
Aspartic acid  
(Asp or D)Glutamic acid  
(Glu or E)Lysine  
(Lys or K)Arginine  
(Arg or R)Histidine  
(His or H)

# *Amino Acid Polymers*

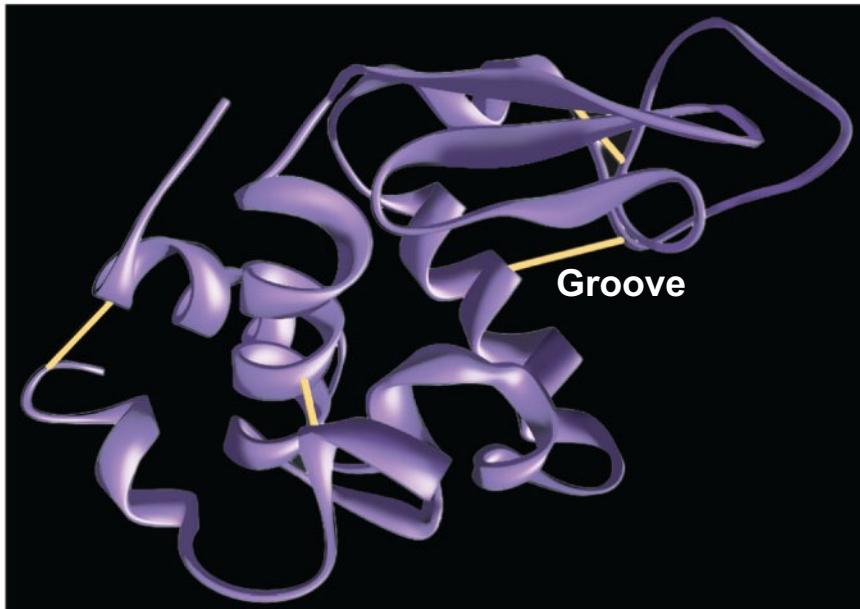
- Amino acids are linked by **peptide bonds**
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to more than a thousand monomers (amino acids)
- Each polypeptide has a unique linear sequence of amino acids, with a carboxyl end (C-terminus) and an amino end (N-terminus)

Figure 5.17

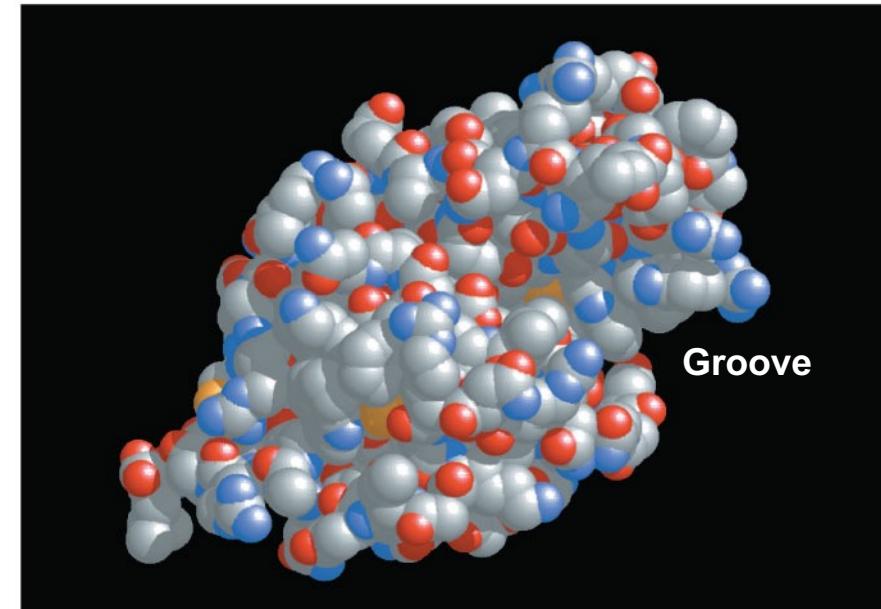
# How are peptide bonds formed?



- A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape
- The sequence of amino acids determines a protein's three-dimensional structure
- A protein's structure determines its function
- Bioinformatics uses computer programs to predict protein sequence, structure and function from amino acid sequences (or RNA or DNA sequences)

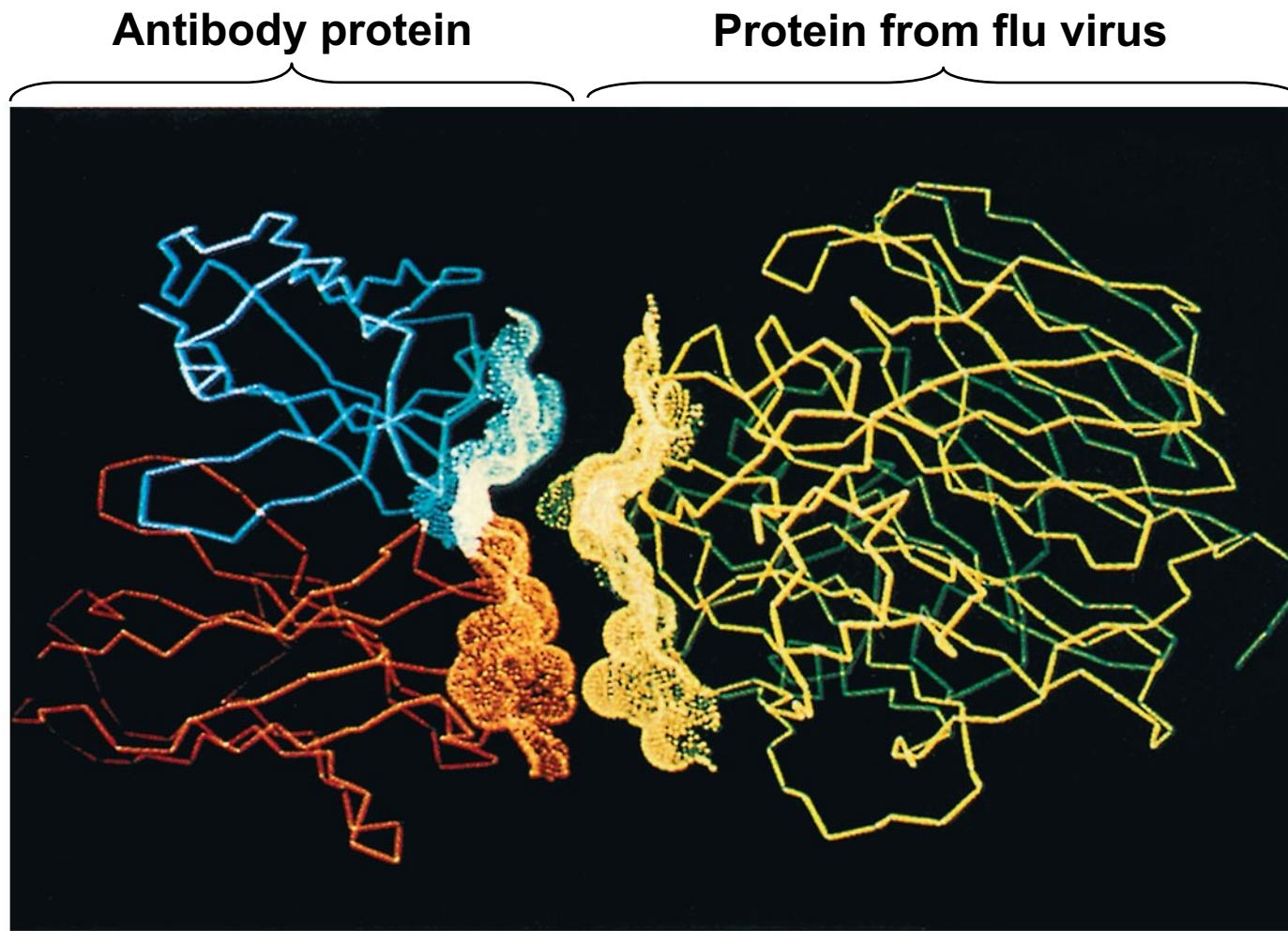


**(a) A ribbon model**



**(b) A space-filling model**

Figure 5.19



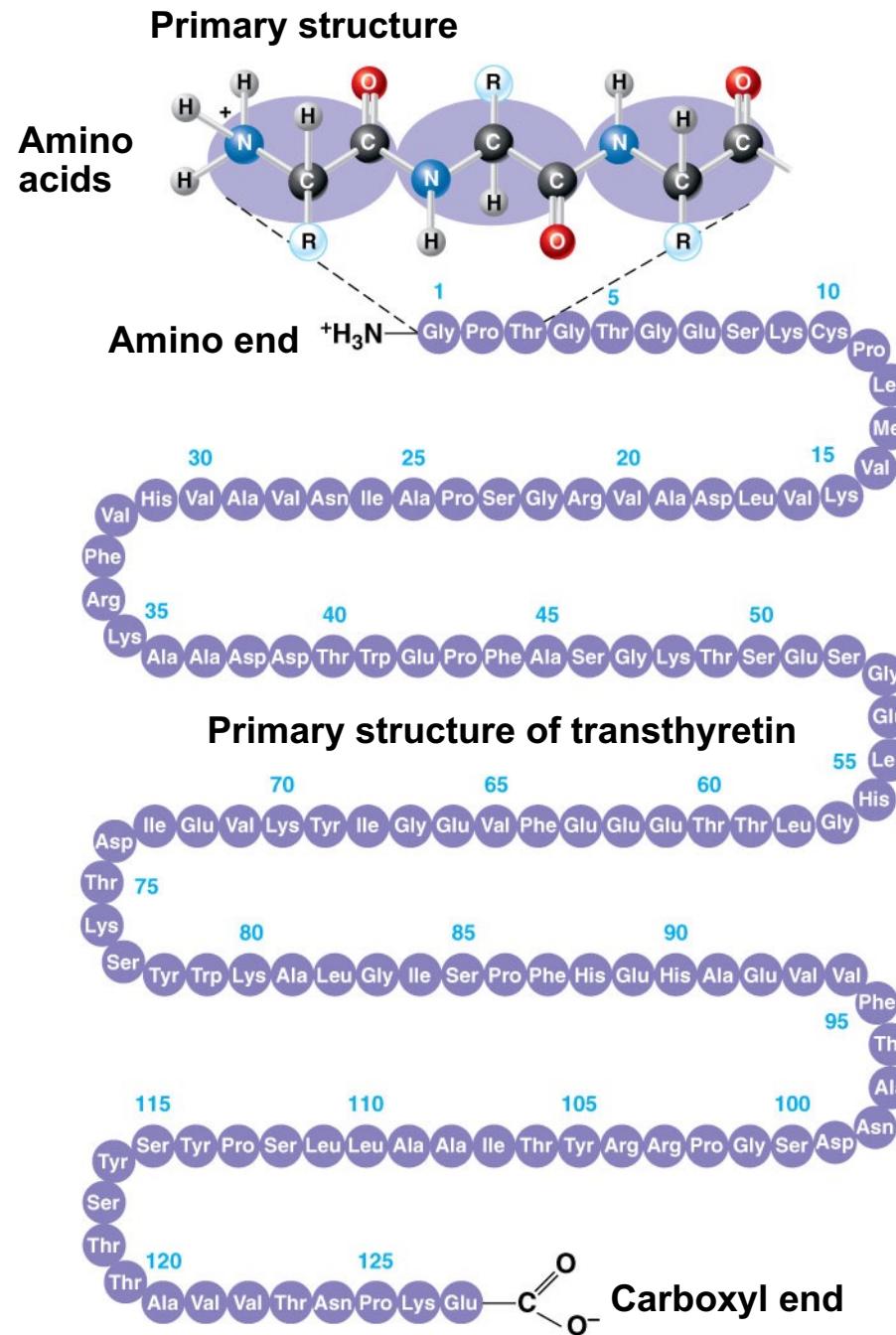
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# *Four Levels of Protein Structure*

- The primary structure of a protein is its unique sequence of amino acids
- Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain
- Tertiary structure is determined by interactions among various side chains (R groups)
- Quaternary structure results when a protein consists of multiple polypeptide chains

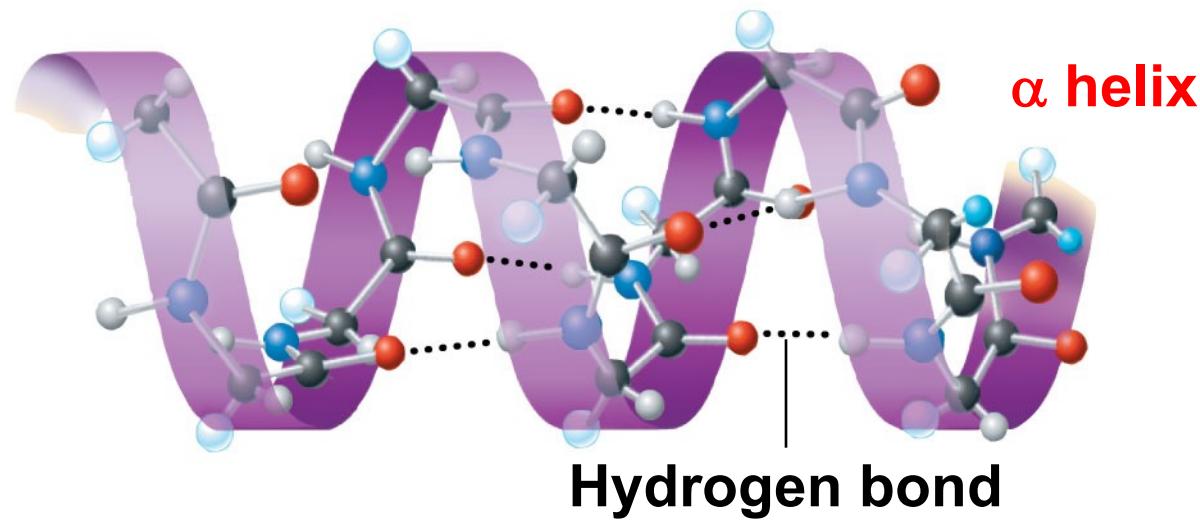
Figure 5.20a

- **Transthyretin polypeptide**
  - Transports thyroid hormones
  - Transports retinol (Vitamin A)
- **Primary structure**
  - The sequence of amino acids in a protein
  - Determined by inherited genetic information

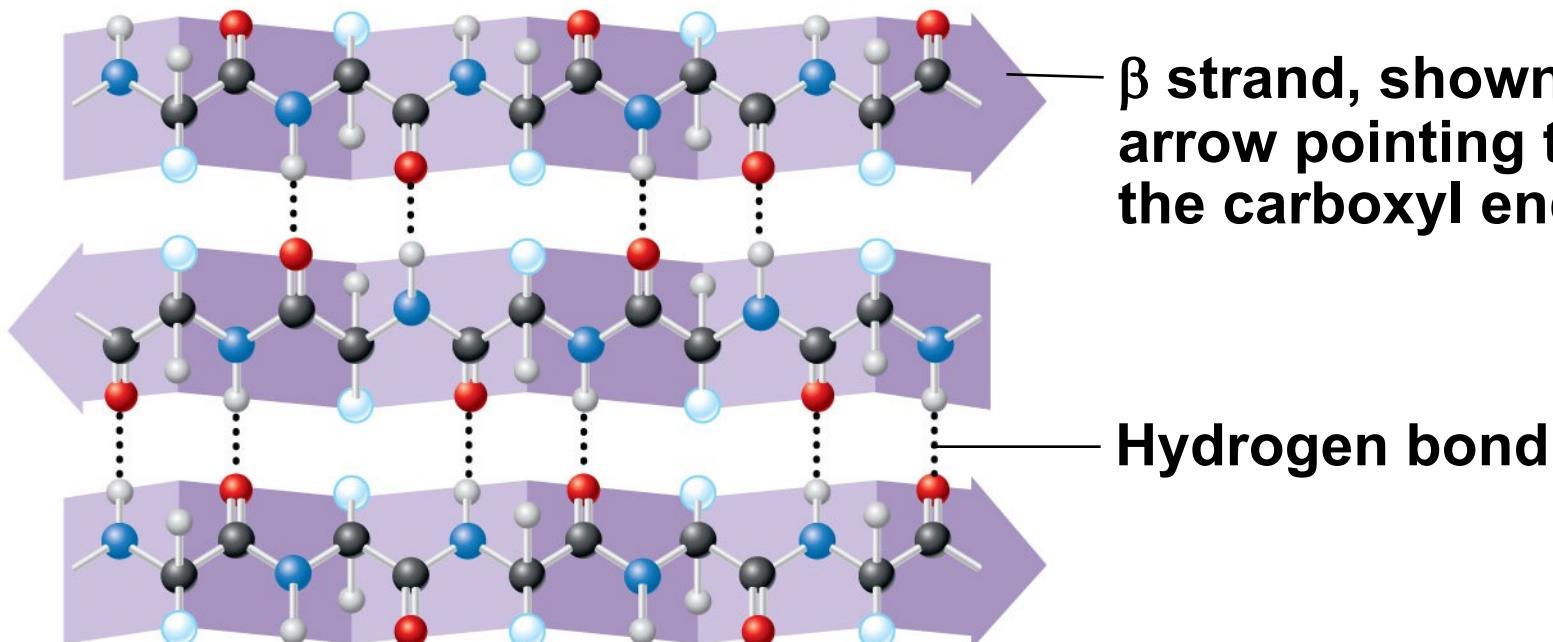


## Secondary structure

- **Secondary structure** results from hydrogen bonds between parts of the polypeptide backbone
- Includes the  $\alpha$  helix and  $\beta$  pleated sheet

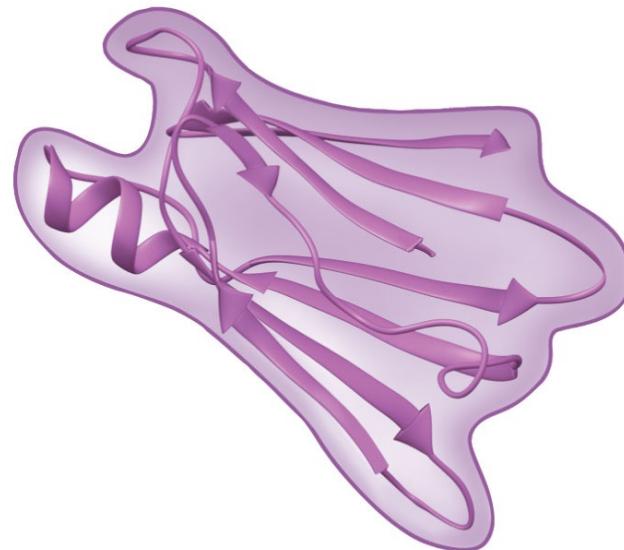


### $\beta$ pleated sheet

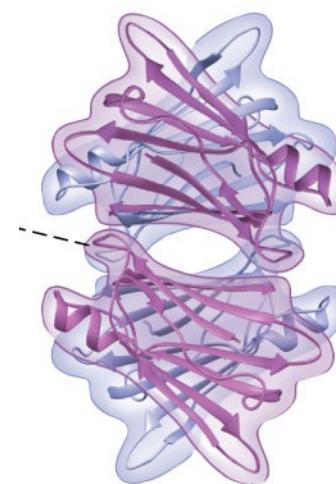


$\beta$  strand, shown as a flat arrow pointing toward the carboxyl end

- **Tertiary structure** is the shape of a polypeptide in three dimensions

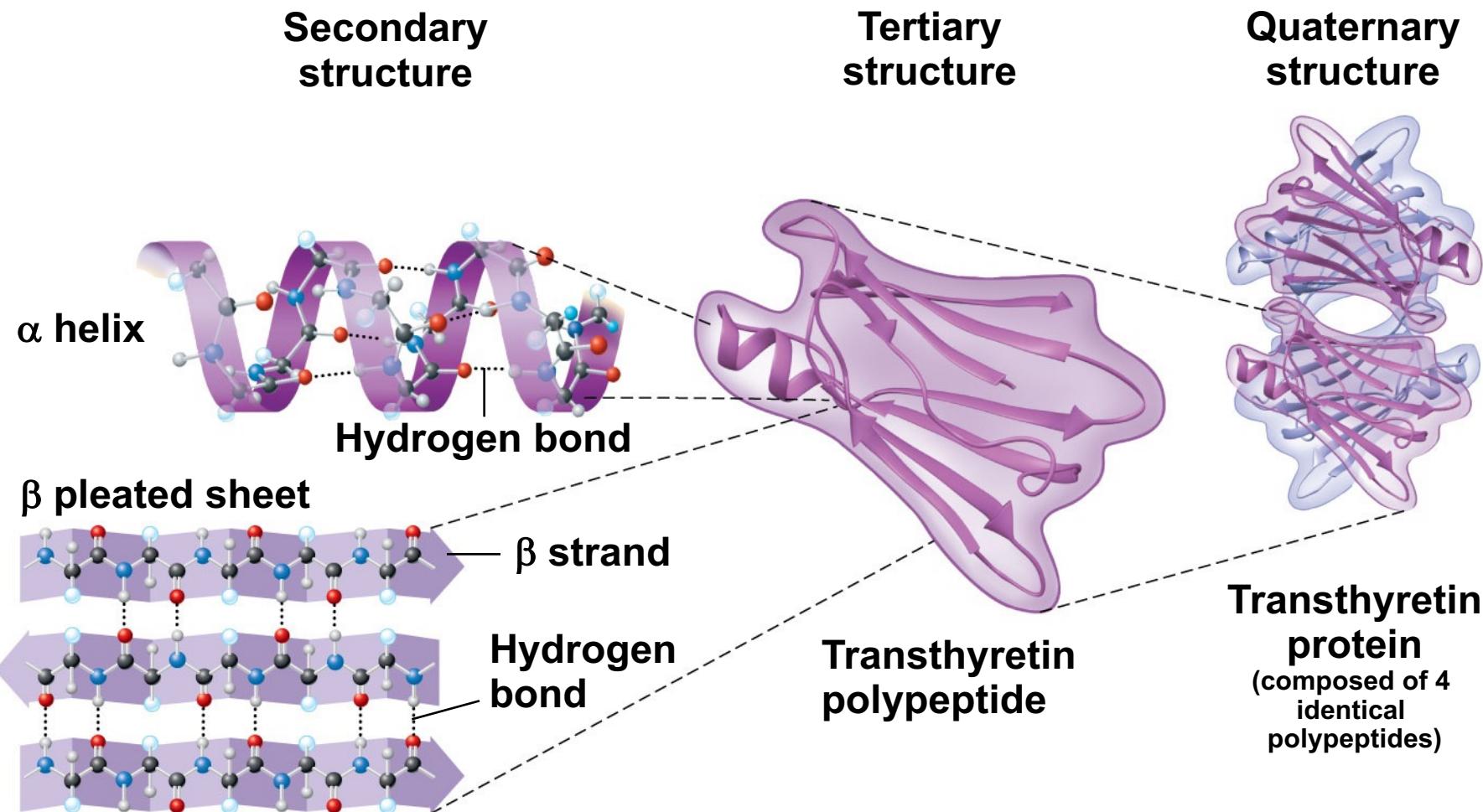


- **Quaternary structure** results when two or more polypeptide chains form one macromolecule  
(not all proteins have a quaternary structure)
  - Transthyretin is composed of 4 identical polypeptides



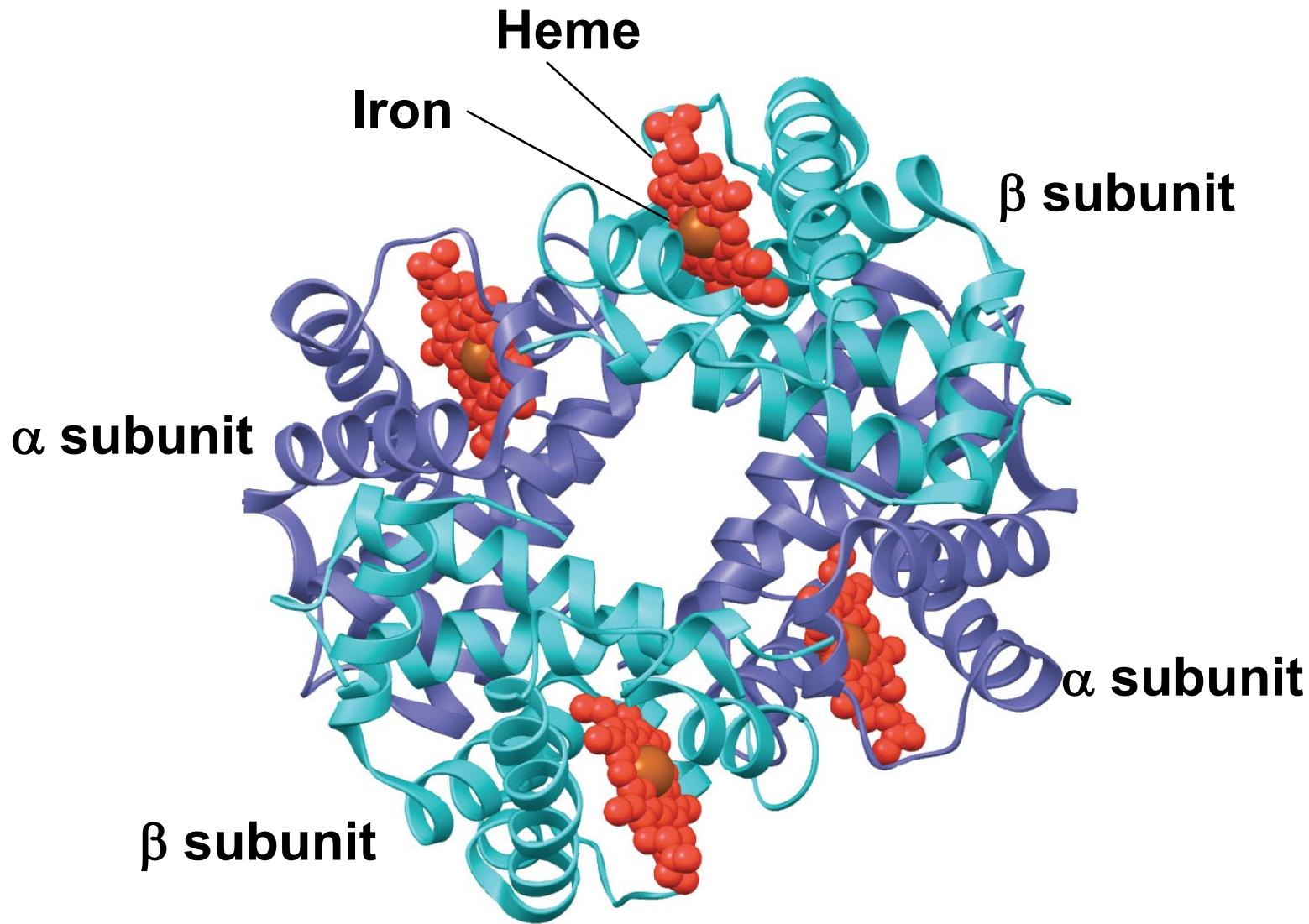
# Putting it all together...

(but primary structure is not shown)



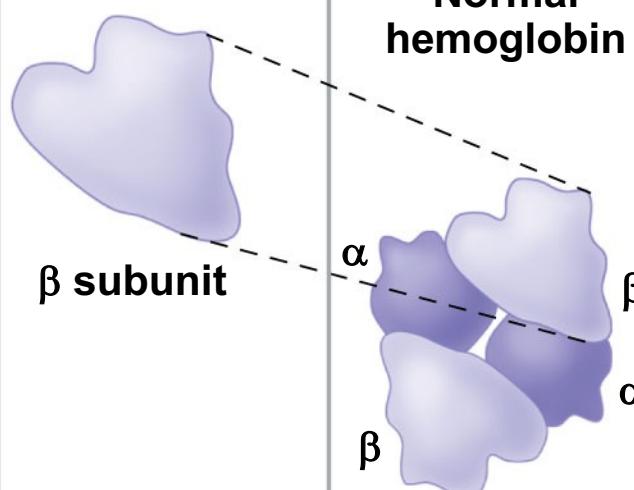
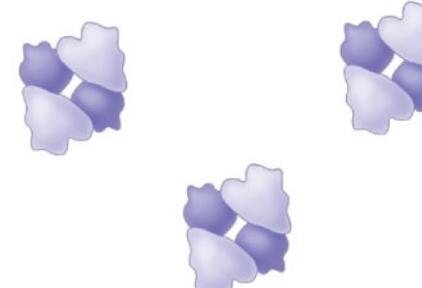
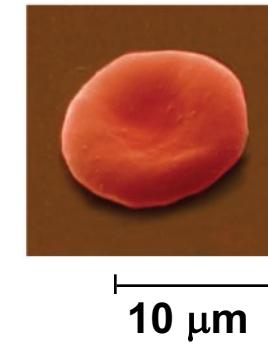
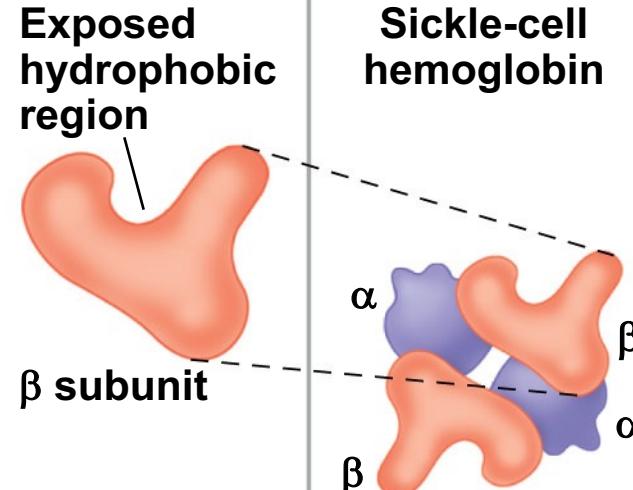
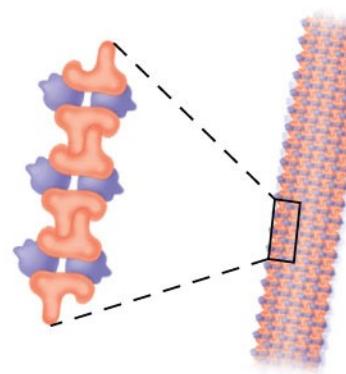
# *Sickle-Cell Disease: A Change in Primary Structure*

- A slight change in primary structure can affect a protein's structure and ability to function
  - How does the primary structure change?
- **Sickle-cell disease**, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin
- Genpept:
  - <https://www.ncbi.nlm.nih.gov/protein/4504349>



**Hemoglobin** is a protein made up of 4 polypeptide chains:  
two  $\alpha$  and two  $\beta$  subunits

Figure 5.21

	Primary Structure	Secondary and Tertiary Structures	Quaternary Structure	Function	Red Blood Cell Shape
Normal hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Glu 7 Glu	V H L T P E E	 <p><math>\beta</math> subunit</p> <p>Normal hemoglobin</p>	<p>Molecules do not associate with one another; each carries oxygen.</p> 	 <p>10 <math>\mu</math>m</p>
Sickle-cell hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Val 7 Glu	V H L T P V E	 <p>Exposed hydrophobic region</p> <p><math>\beta</math> subunit</p> <p>Sickle-cell hemoglobin</p>	<p>Molecules crystallize into a fiber; capacity to carry oxygen is reduced.</p> 	 <p>10 <math>\mu</math>m</p>