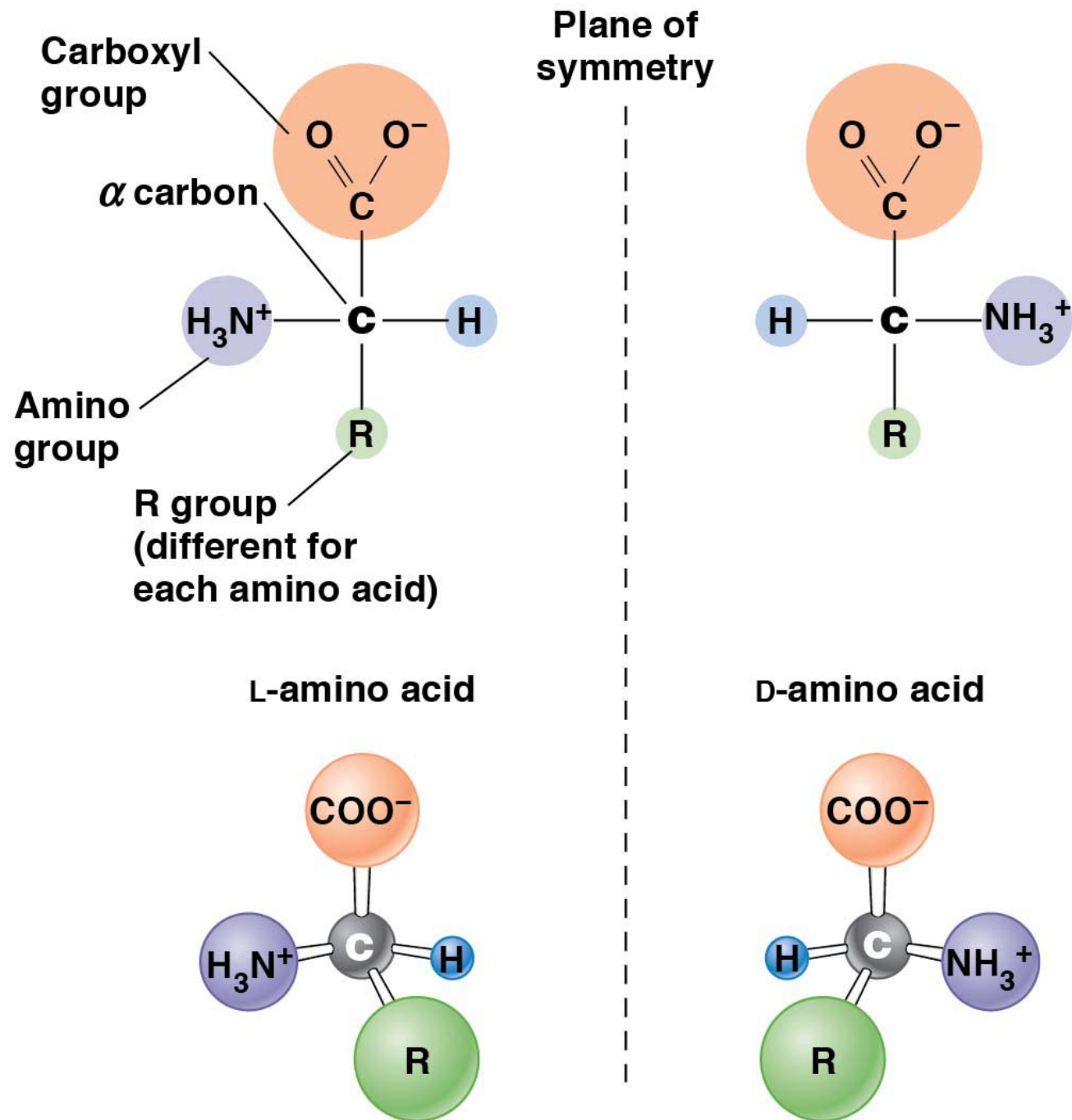


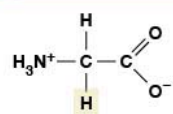
**Table 3-1** Common Small Molecules in Cells

| Kind of Molecules | Number Present | Names of Molecules    | Role in Cell  | Figure Number for Structures |
|-------------------|----------------|-----------------------|---|------------------------------|
| Amino acids       | 20             | See list in Table 3-2 | Monomeric units of all proteins                     | 3-2                          |
| Aromatic bases    | 5              | Adenine               | Components of nucleic acids                         | 3-15                         |
|                   |                | Cytosine              |   |                              |
|                   |                | Guanine               |   |                              |
|                   |                | Thymine               |   |                              |
|                   |                | Uracil                |   |                              |
| Sugars            | varies         | Ribose                | Component of RNA                                    | 3-15                         |
|                   |                | Deoxyribose           | Component of DNA                                    |                              |
|                   |                | Glucose               | Energy metabolism; component of starch and glycogen | 3-24                         |
| Lipids            | varies         | Fatty acids           | Components of phospholipids and membranes           | 3-27a                        |
|                   |                | Cholesterol           |   | 3-27e                        |

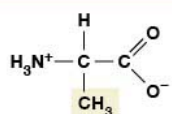
Source: Adapted from Wald, G. The origins of life. *Proc. Natl. Acad. Sci. USA* 52 (1994): 595.



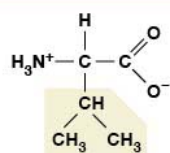
### Group A: Nonpolar amino acids (hydrophobic)



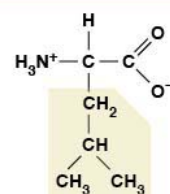
Glycine



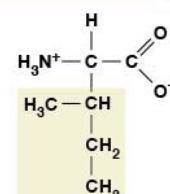
Alanine



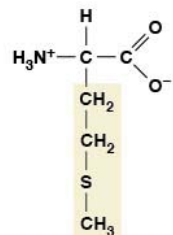
Valine



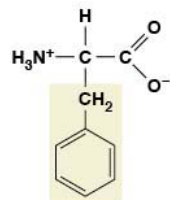
Leucine



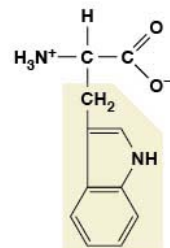
Isoleucine



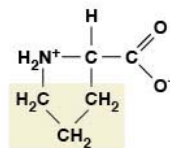
Methionine



Phenylalanine

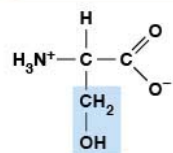


Tryptophan

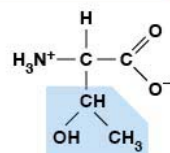


Proline

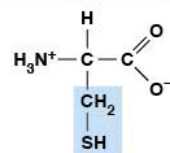
### Group B: Polar, uncharged amino acids (hydrophilic)



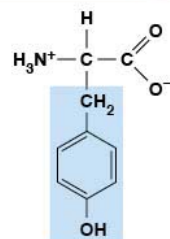
Serine



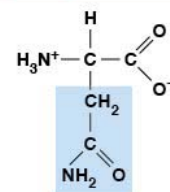
Threonine



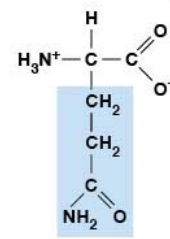
Cysteine



Tyrosine



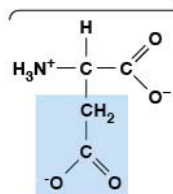
Asparagine



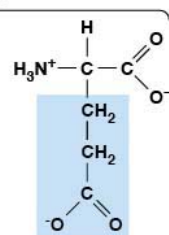
Glutamine

### Group C: Polar, charged amino acids (hydrophilic)

#### Acidic

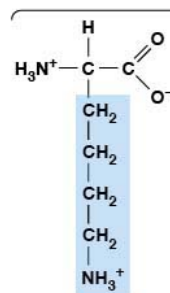


Aspartate

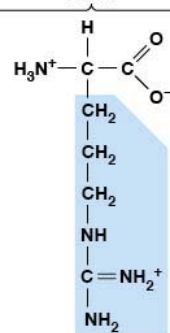


Glutamate

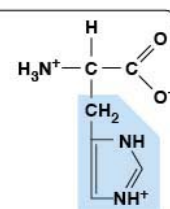
#### Basic



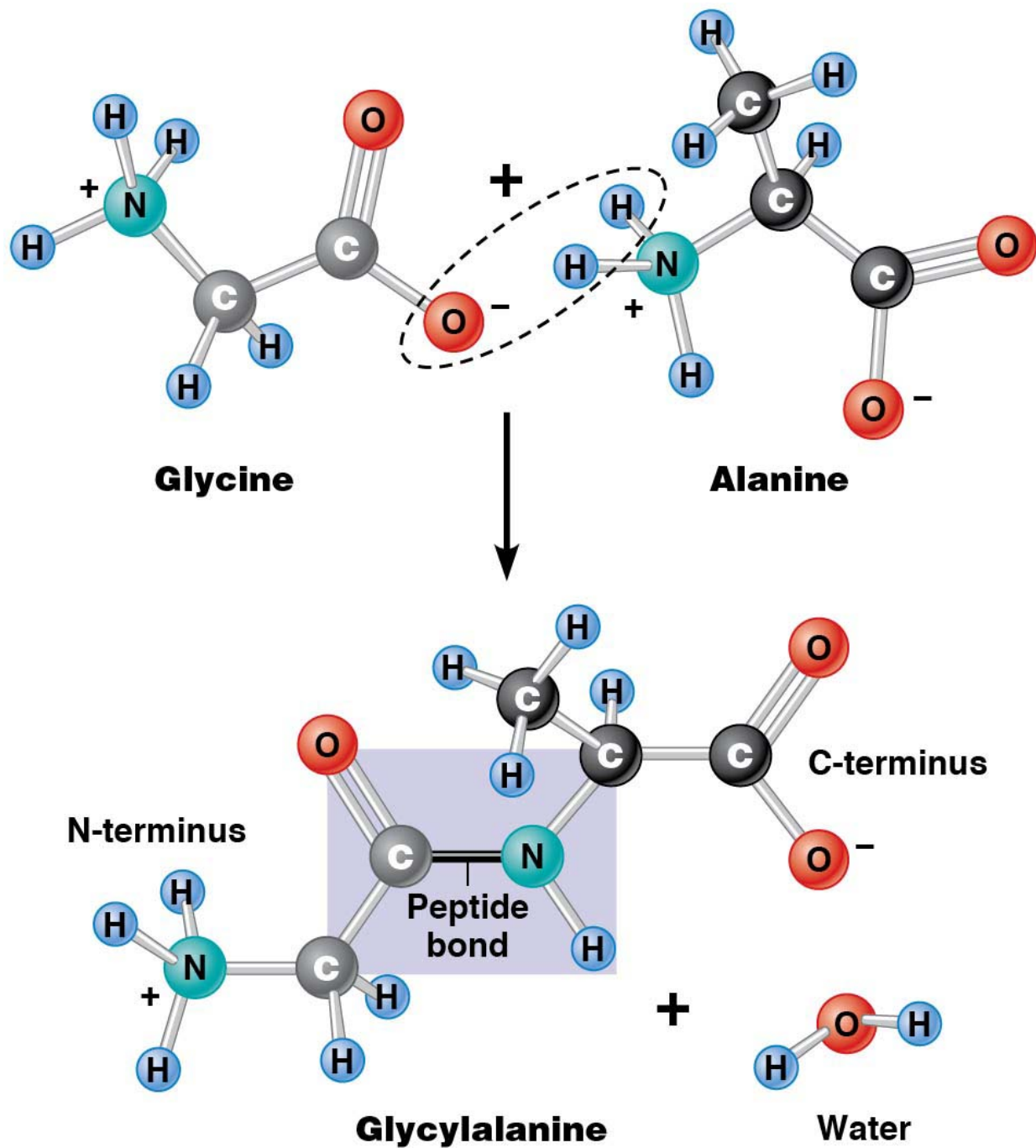
Lysine

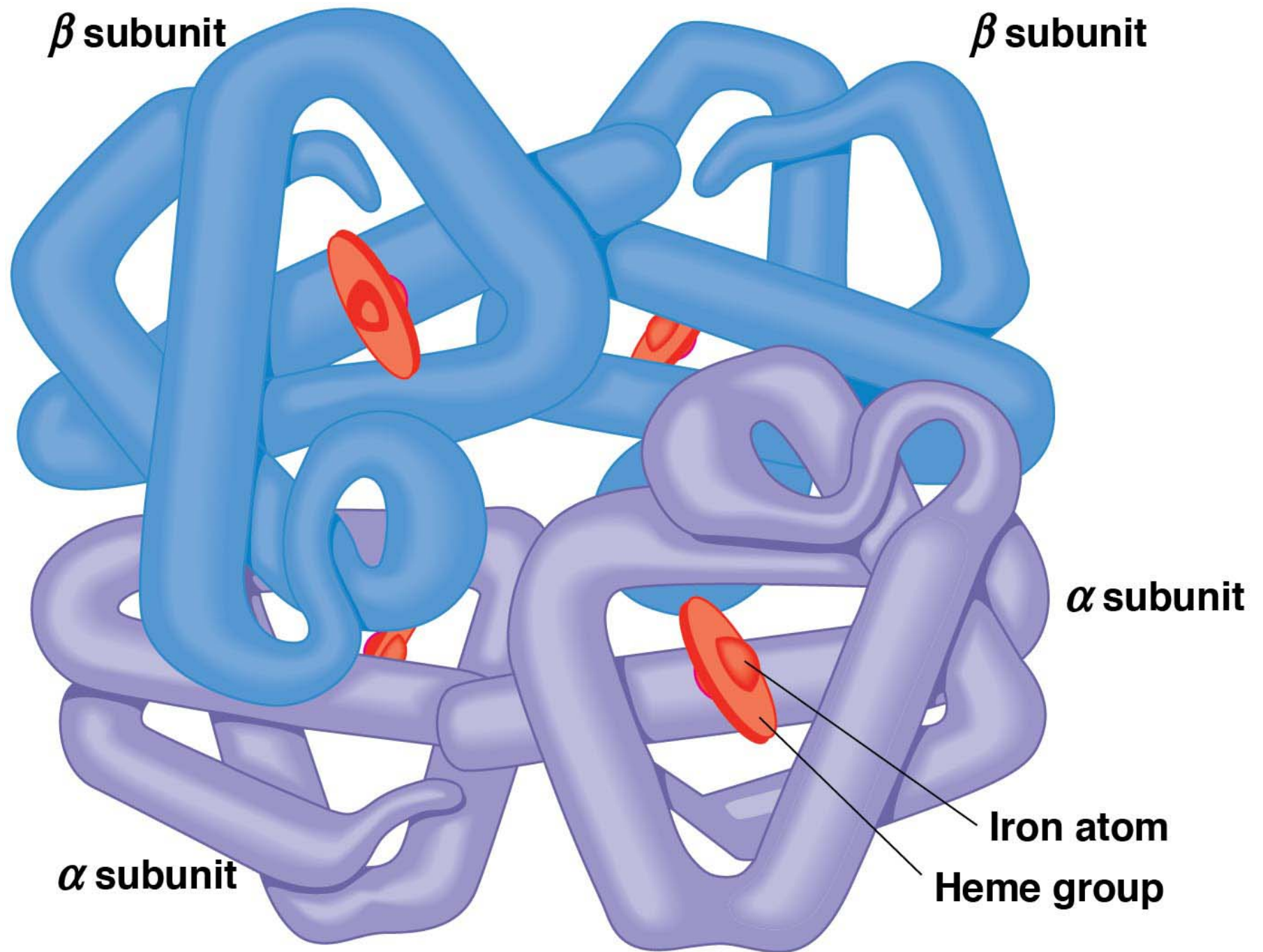


Arginine

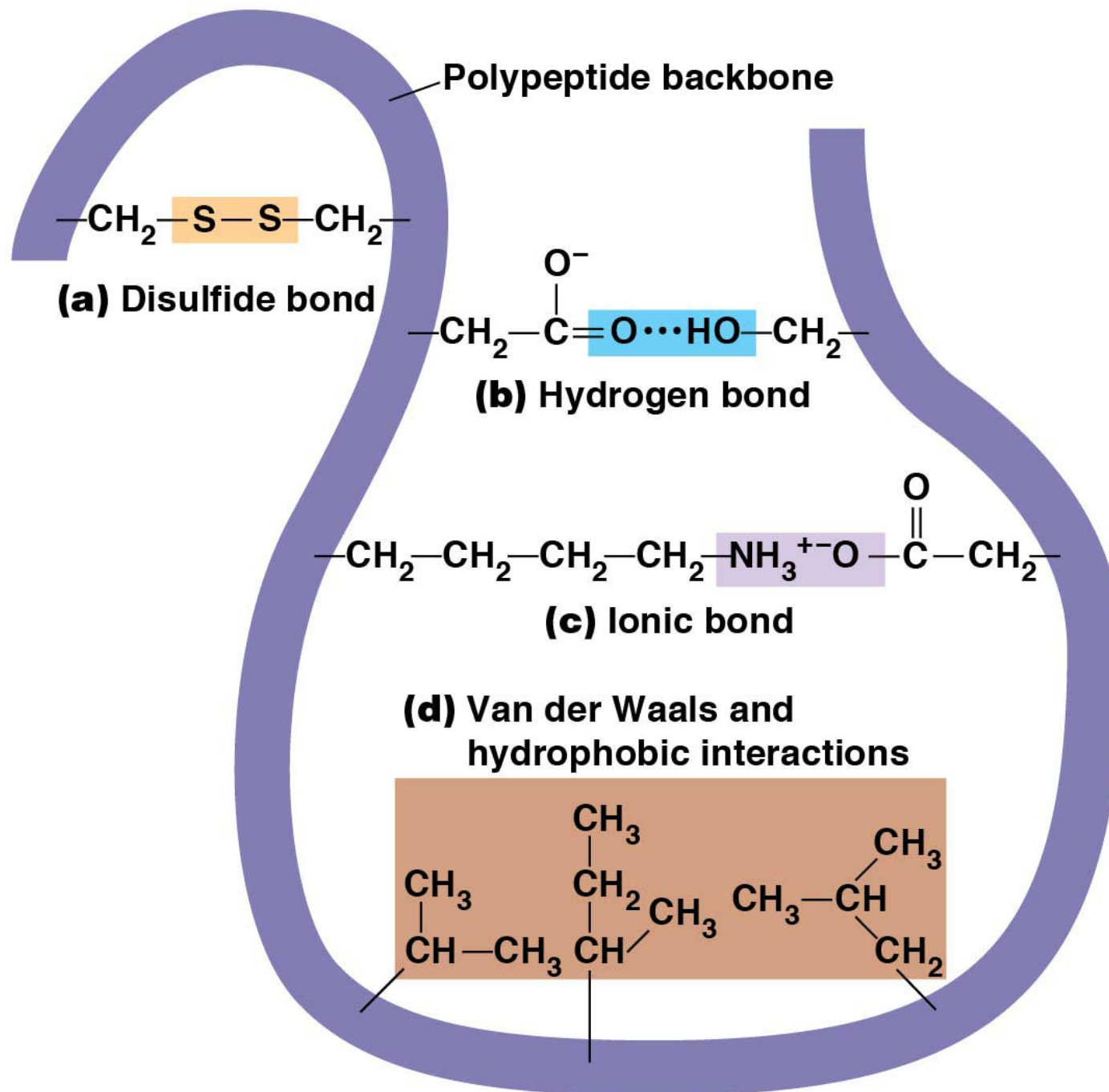


Histidine

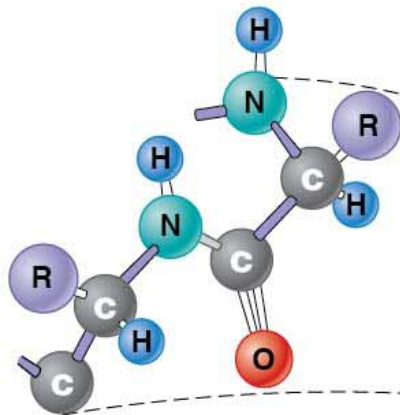




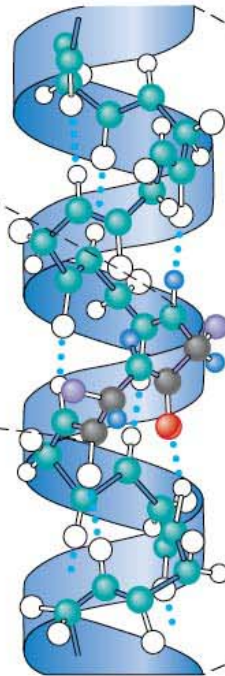




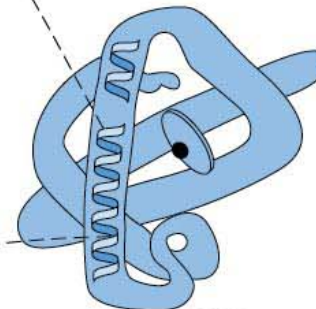
**(a) Primary structure.** The primary structure of a protein is a sequence of amino acids linked together by peptide bonds, forming a polypeptide.



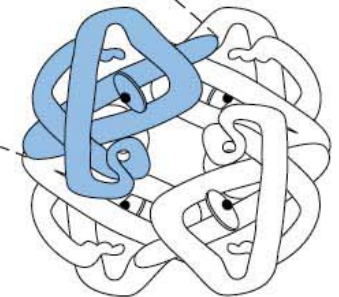
**(b) Secondary structure.** Local regions of the resulting polypeptide can then be coiled into an  $\alpha$  helix, one form of secondary structure.

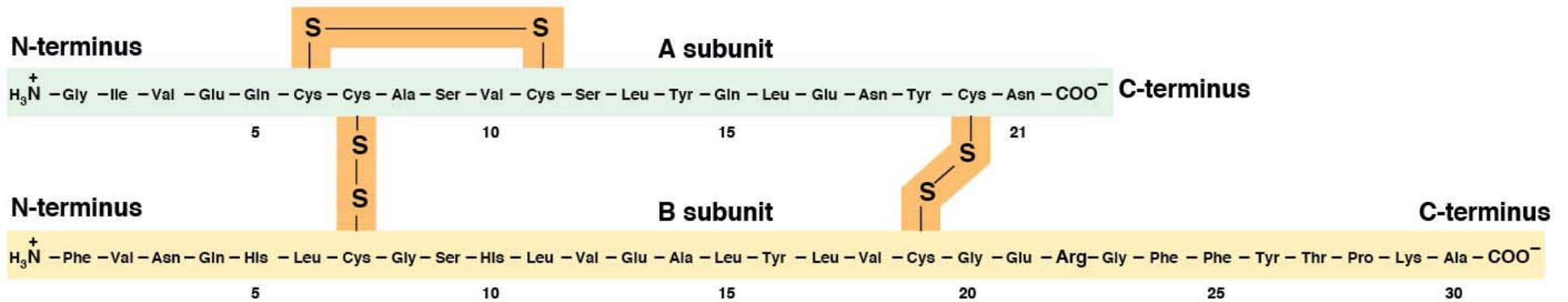


**(c) Tertiary structure.** Regions of secondary structure associate in a specific manner to form the tertiary structure, which describes the final folding of the polypeptide.

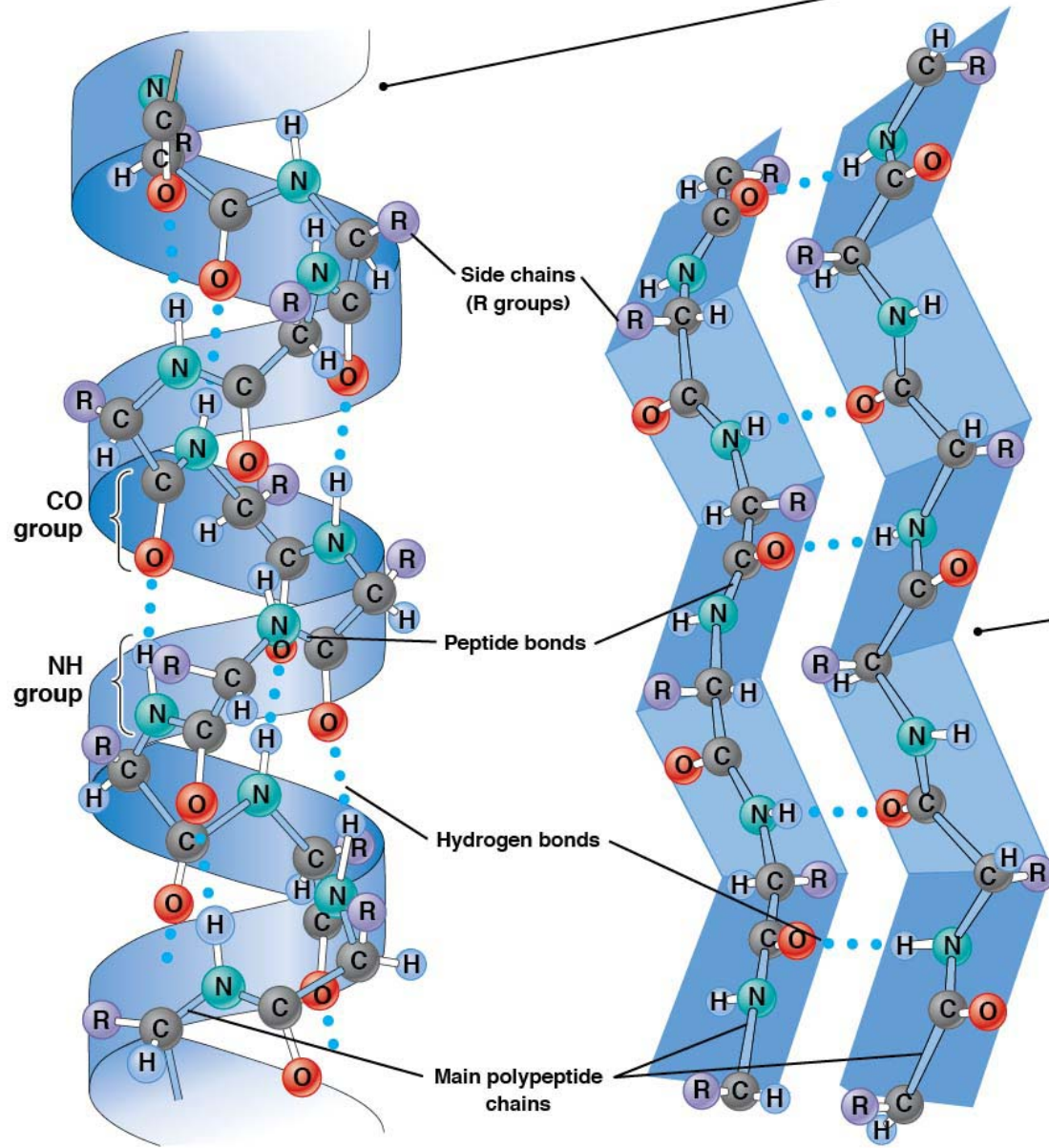


**(d) Quaternary structure.** The quaternary structure describes the association of two or more polypeptides as they interact to form a functional multimeric protein.







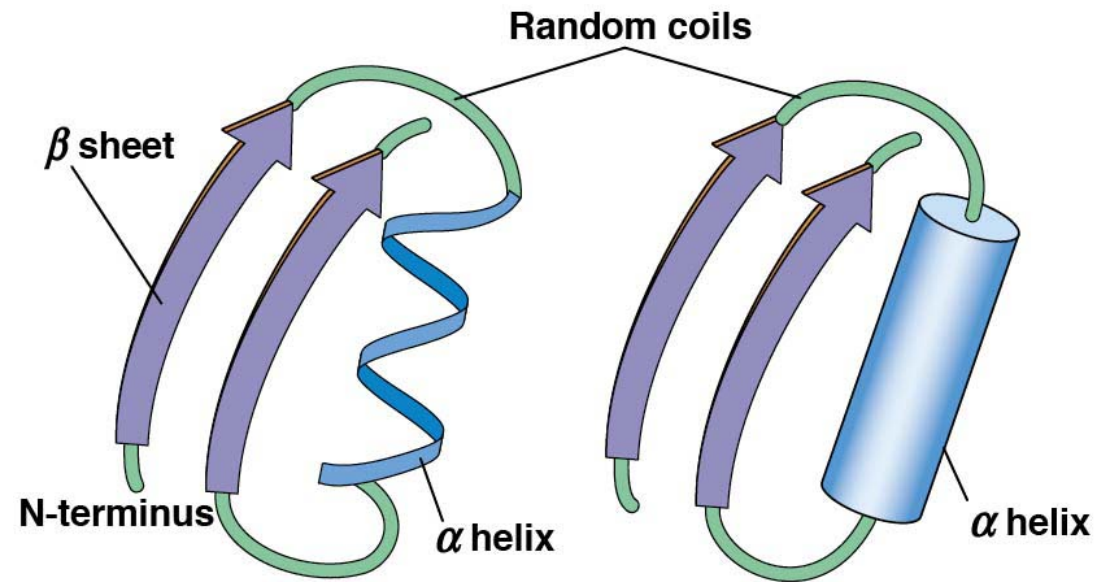


**(a) The  $\alpha$  helix.** The  $\alpha$  helix resembles a coil stabilized by hydrogen bonds between the CO and NH groups next to one peptide bond and those next to the peptide bonds four amino acids away in each direction.

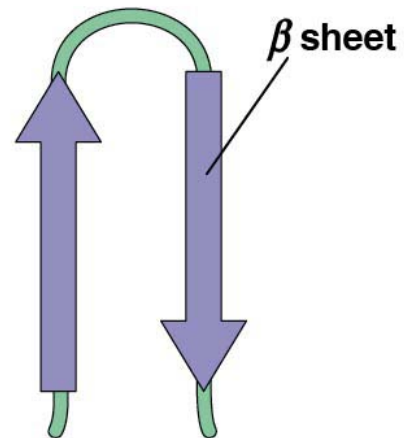
**(b) The  $\beta$  sheet.** The  $\beta$  sheet involves two polypeptide regions whose backbones are parallel, with the R groups of the amino acids sticking out on alternating sides of the sheet. This structure is stabilized by hydrogen bonds between the CO and NH groups next to peptide bonds in the adjacent polypeptide regions.

**(a)  $\alpha$  helix**

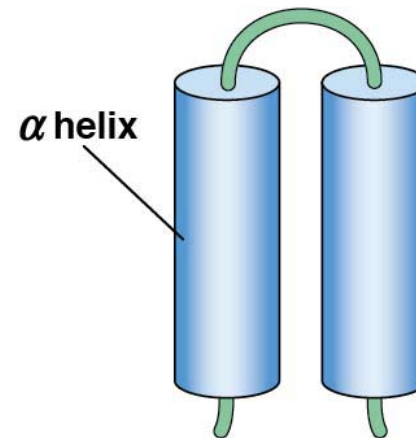
**(b)  $\beta$  sheet**



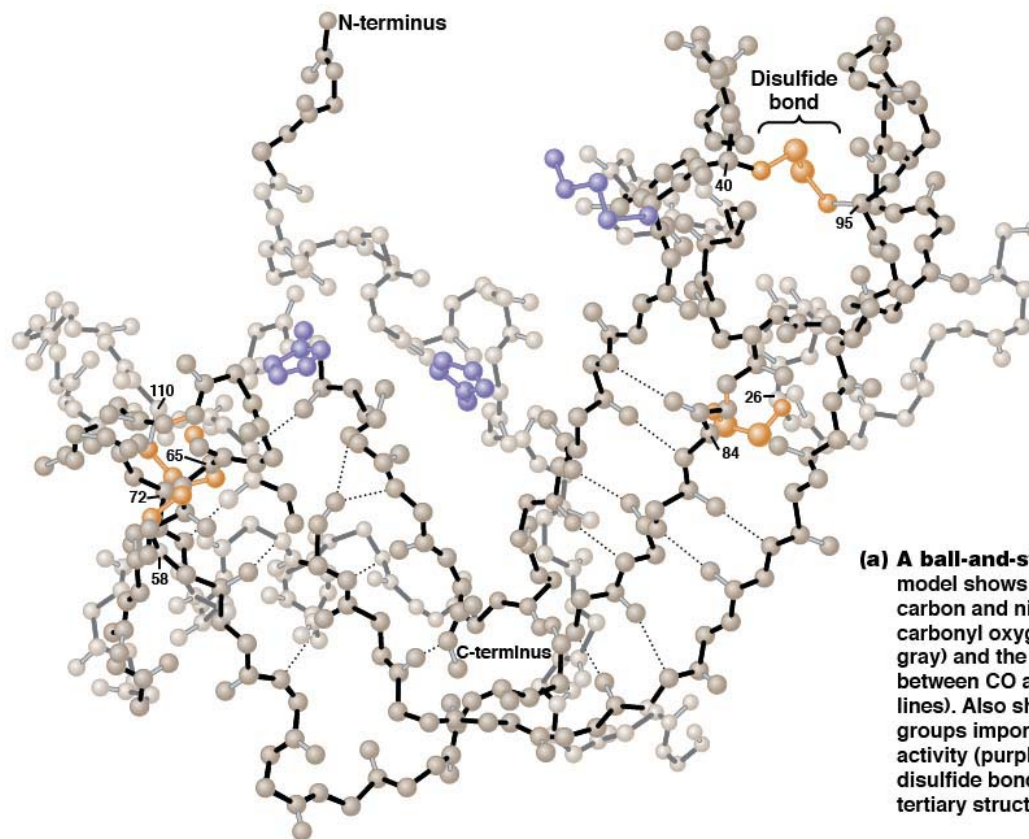
**(a)**  $\beta$ - $\alpha$ - $\beta$  motif with  $\alpha$  helix represented as a spiral (left) or a cylinder (right)



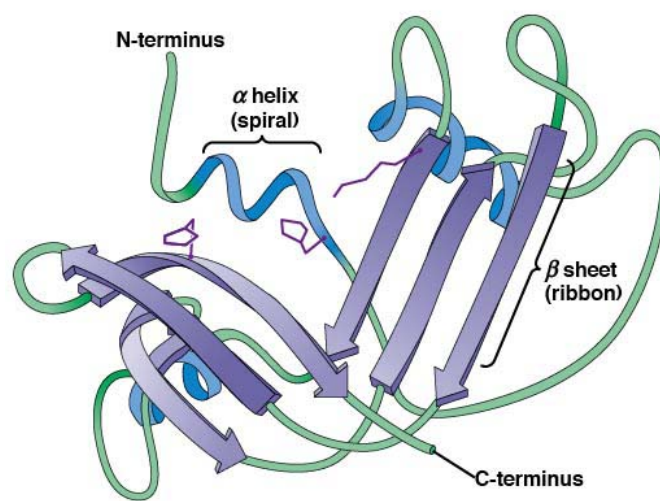
**(b)** Hairpin loop motif



**(c)** Helix-turn-helix motif

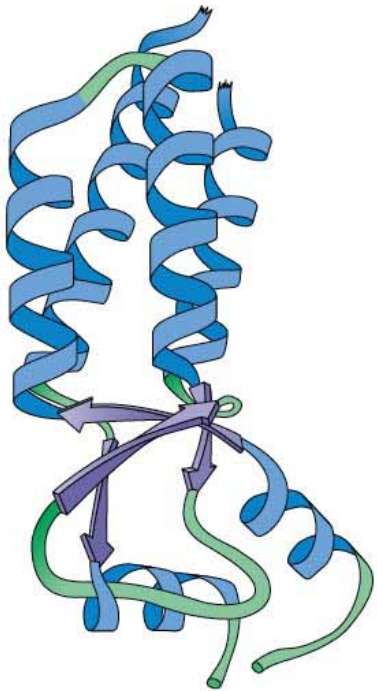


**(a) A ball-and-stick model.** This model shows mainly the backbone carbon and nitrogen atoms plus the carbonyl oxygen atoms (all in light gray) and the hydrogen bonds between CO and NH groups (dotted lines). Also shown are three R groups important for catalytic activity (purple) and several disulfide bonds important for tertiary structure (gold).



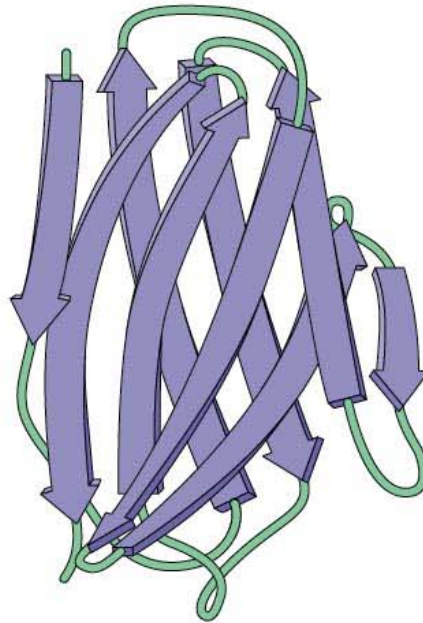
**(b) A spiral-and-ribbon model.** In this model,  $\alpha$ -helical regions are shown as blue spirals and  $\beta$ -sheet regions are shown as purple ribbons with arrows pointing in the direction of the C-terminus. Amino acid R groups and disulfide bonds have been omitted for clarity. Notice that the  $\beta$ -sheet structure is antiparallel and highly twisted and occurs in two distinct sections.





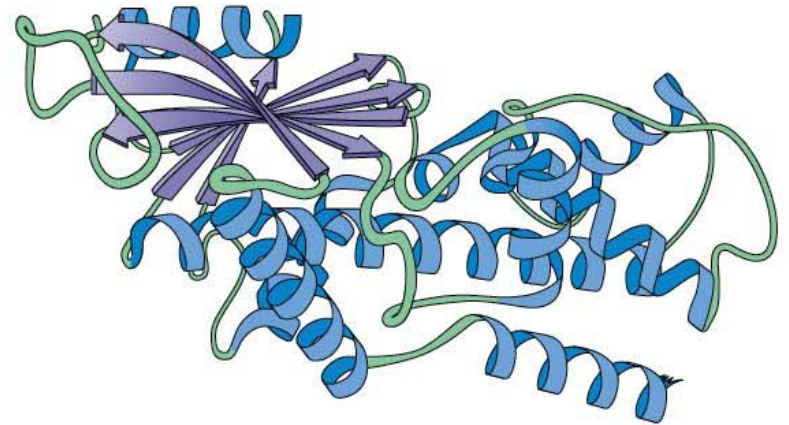
Tobacco mosaic virus coat protein

**(a)** Predominantly  $\alpha$  helix



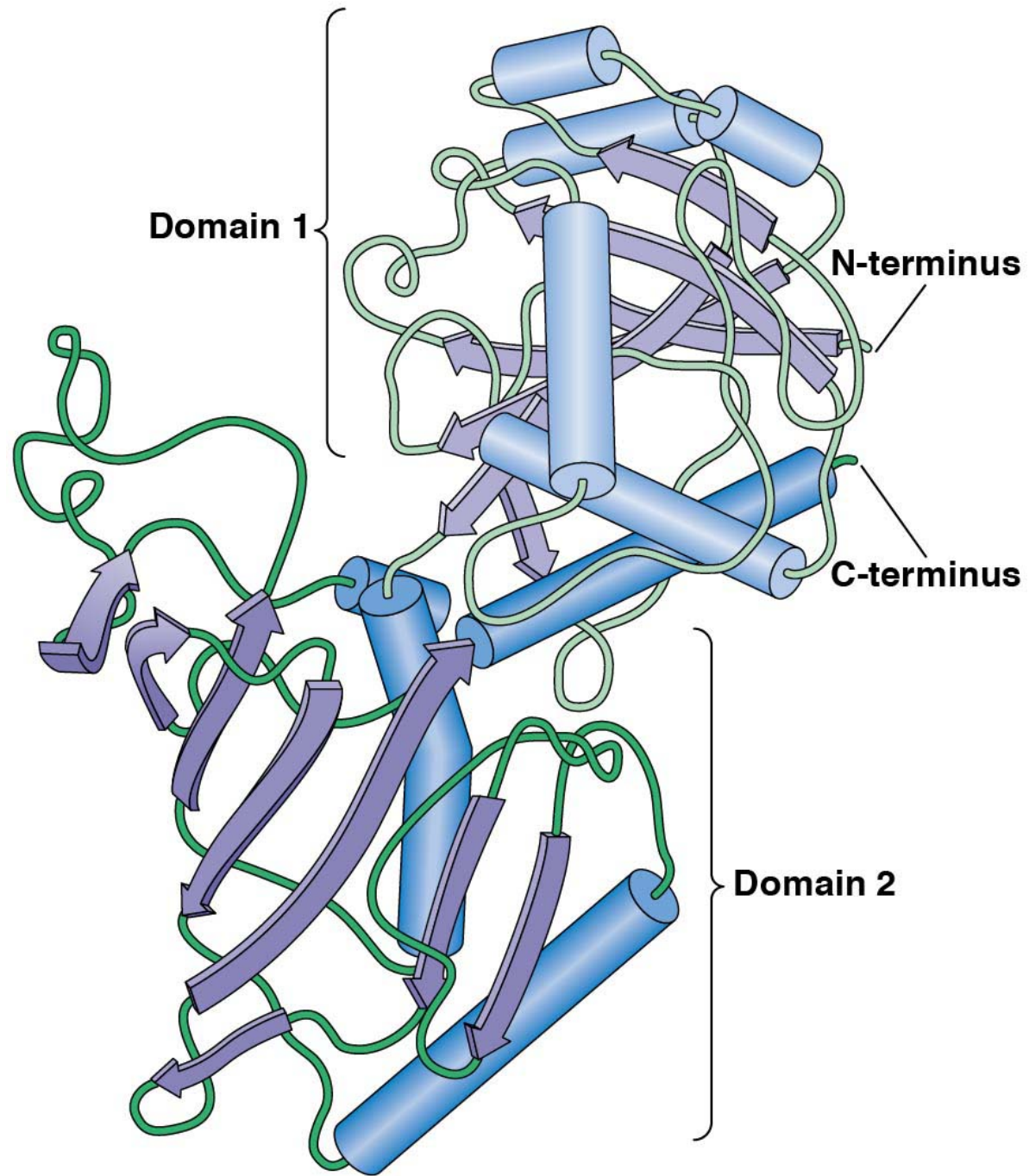
Immunoglobulin, V<sub>2</sub> domain

**(b)** Predominantly  $\beta$  sheet


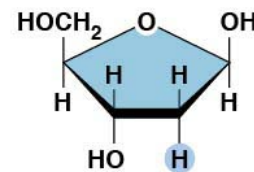
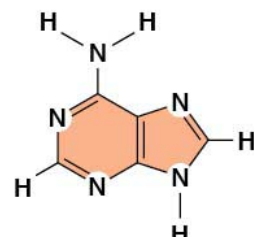
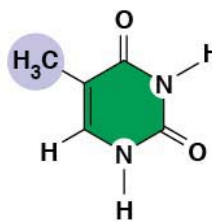
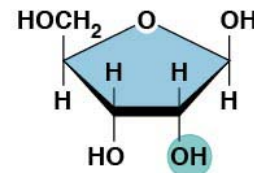

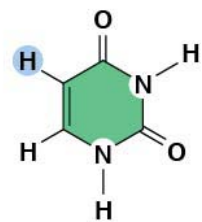
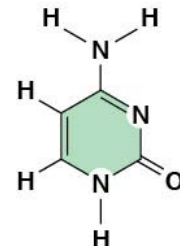


Hexokinase, domain 2

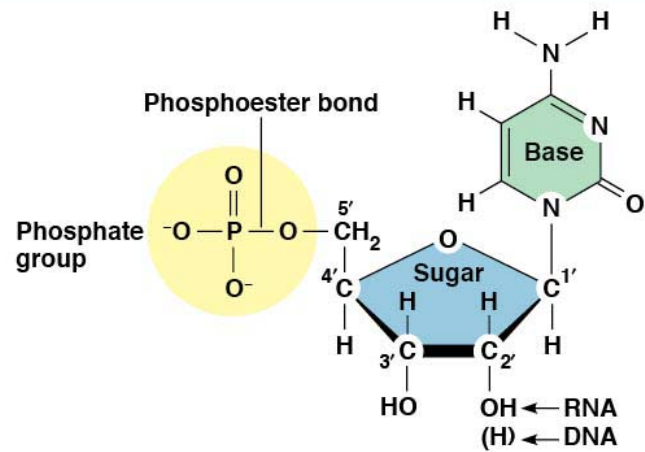
**(c)** Mixed  $\alpha$  helix and  $\beta$  sheet





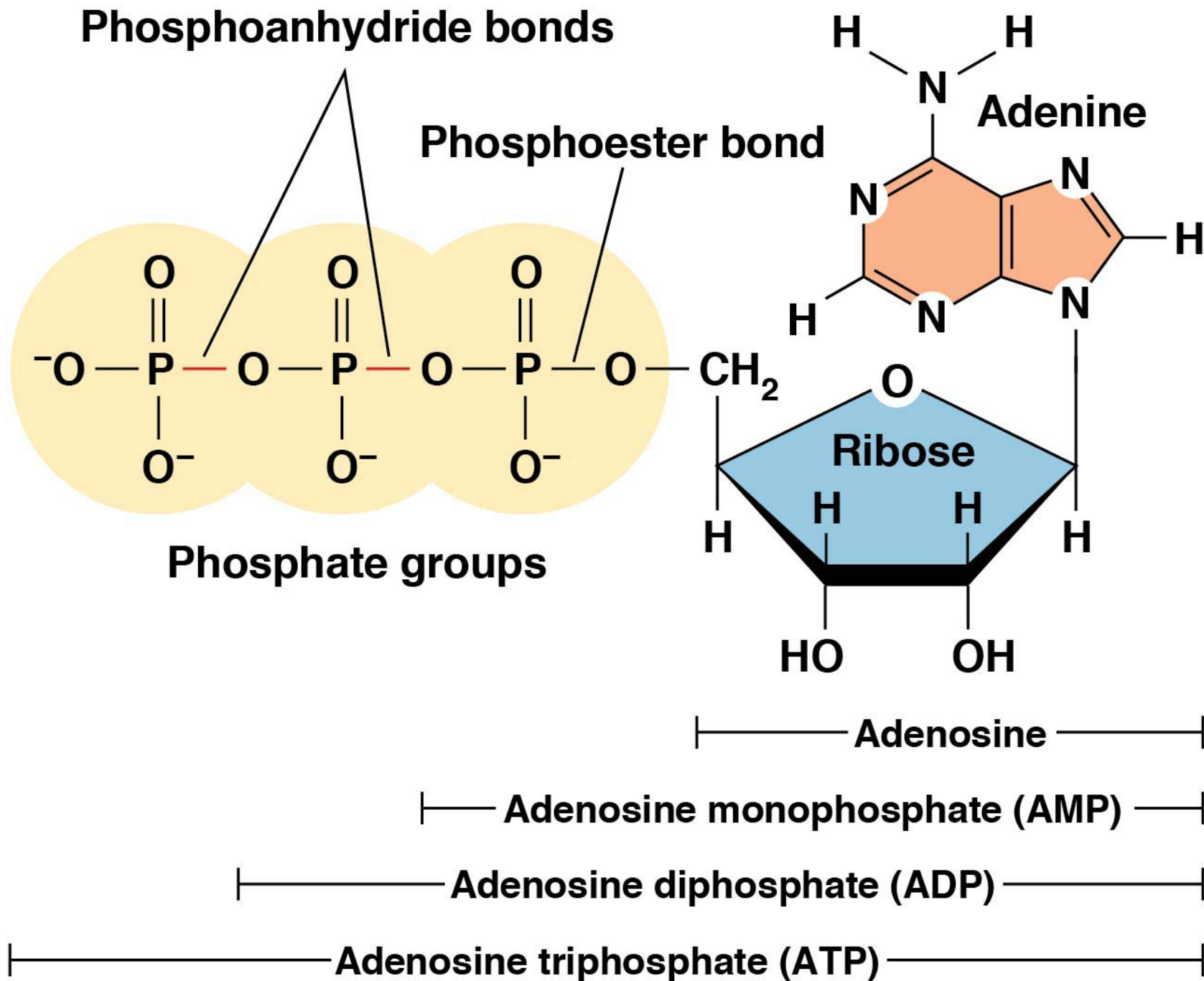
| PHOSPHATE GROUP   | SUGARS  | BASES   |  |
|---|---|---|--|
|   |   | Purines   | Pyrimidines  |
|  | <br>D-deoxyribose (in DNA) | <br>Adenine (A) | <br>Thymine (T)<br>(in DNA) |
|   | <br>D-ribose (in RNA)      | <br>Guanine (G) | <br>Uracil (U)<br>(in RNA)  |
|   |   |   | <br>Cytosine (C)            |

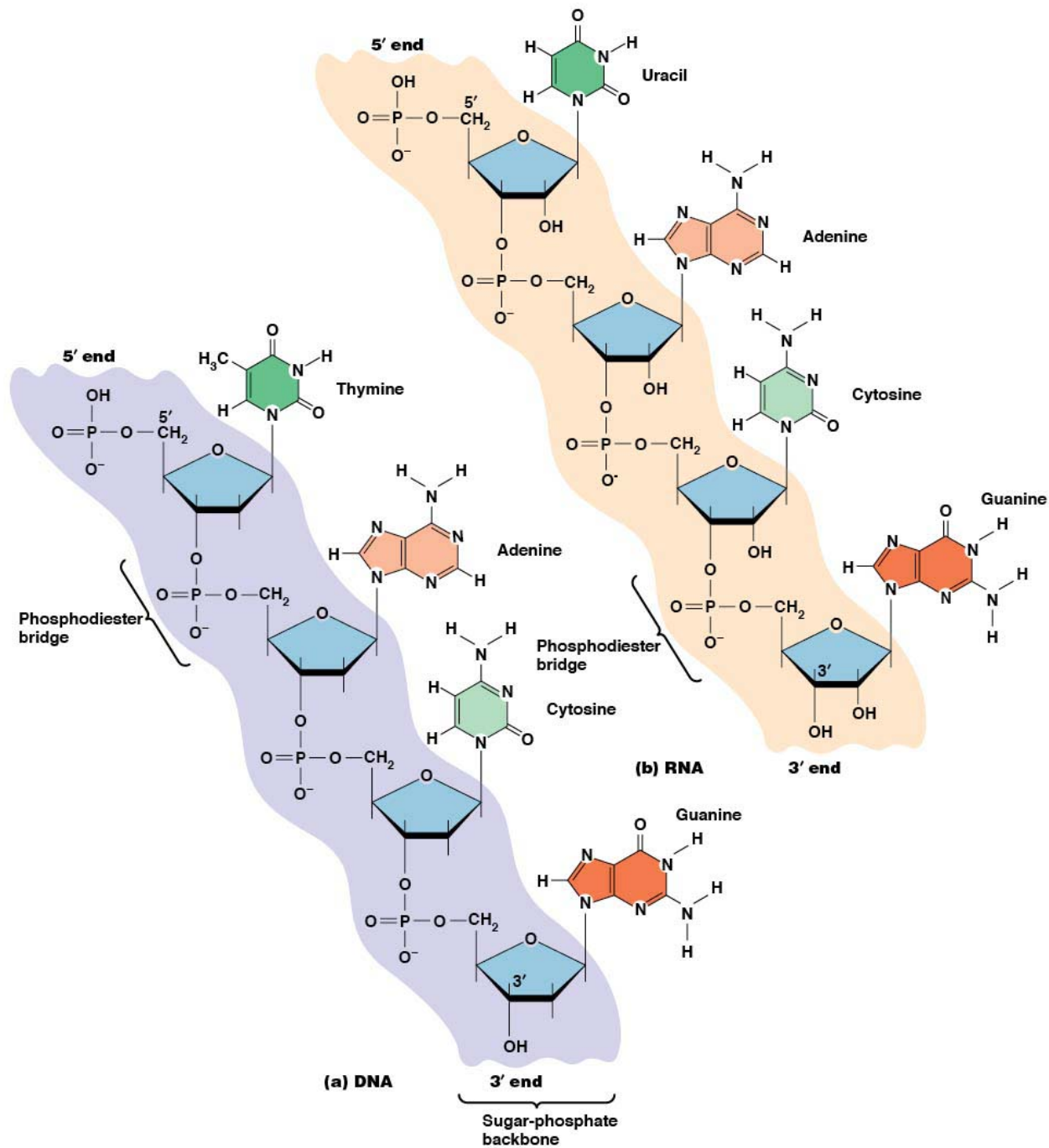
### NUCLEOTIDE

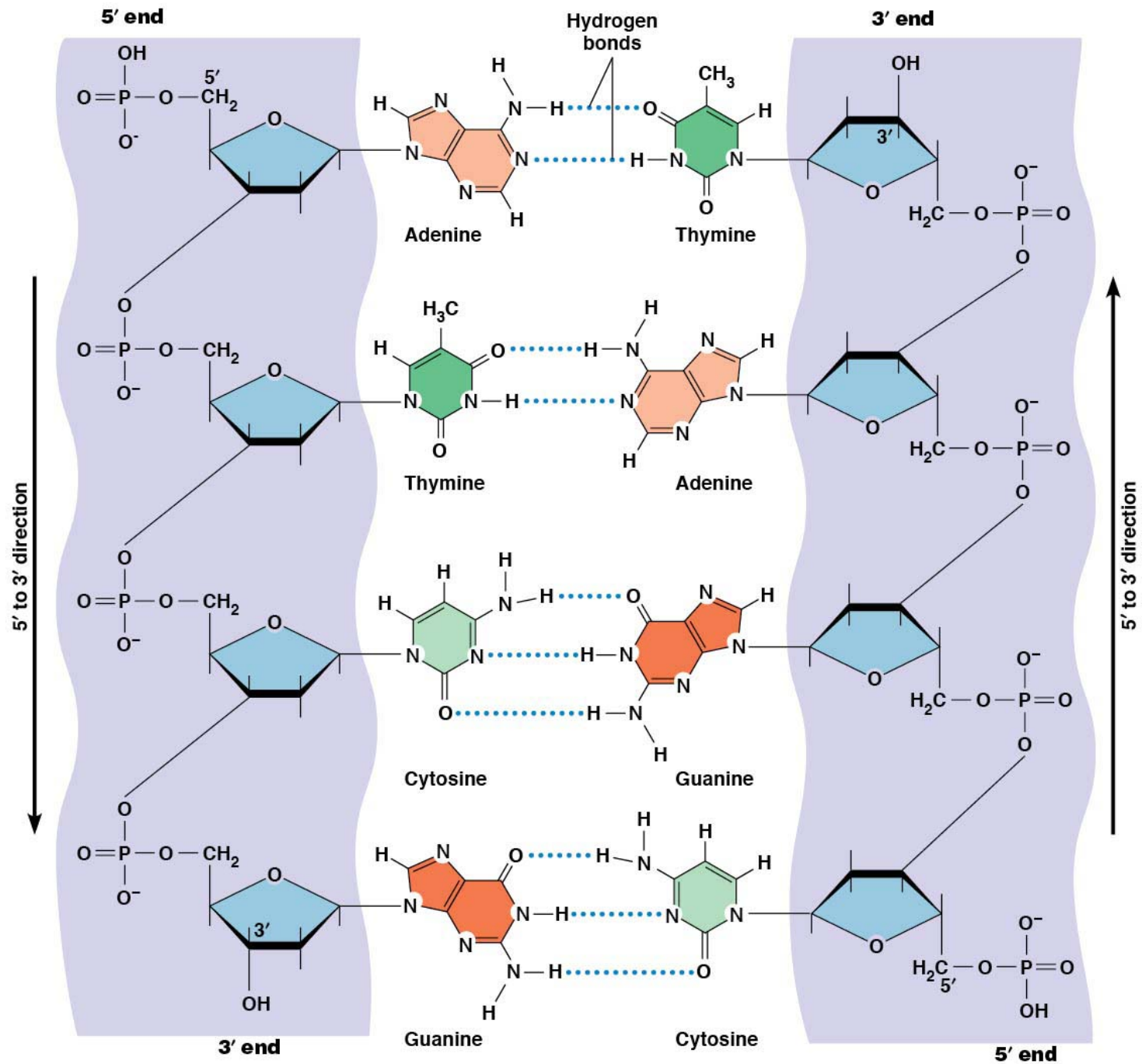


**Table 3-4**    **The Bases, Nucleosides, and Nucleotides of RNA and DNA**

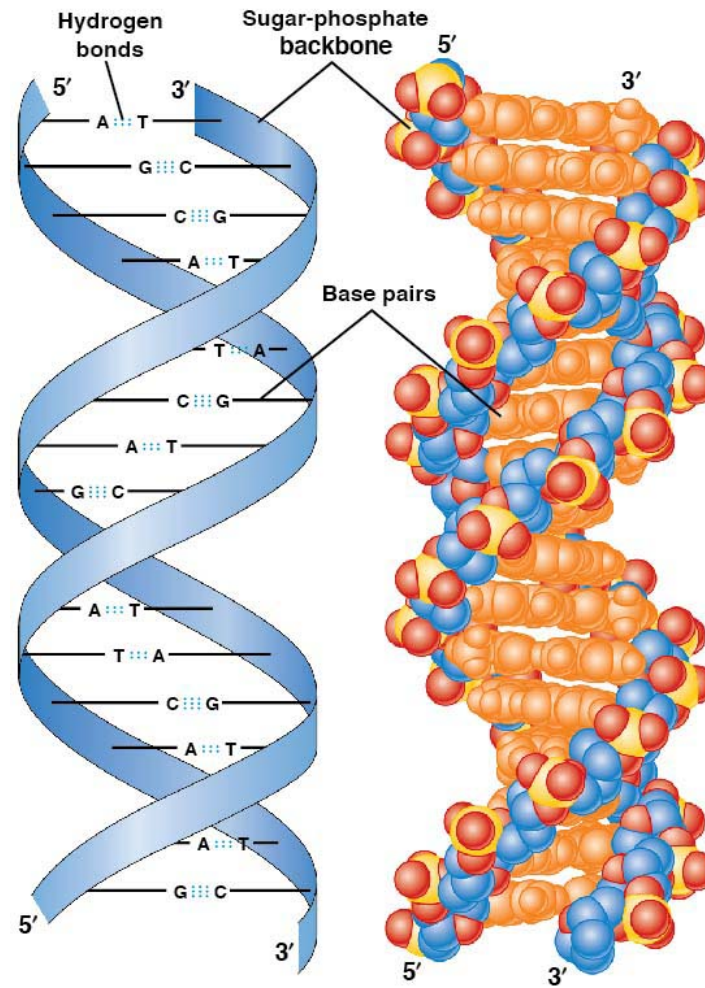
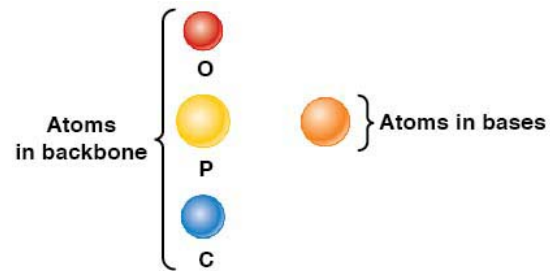
| <b>Bases</b>              | <b>RNA</b>        |                               | <b>DNA</b>             |                                     |
|---------------------------|-------------------|-------------------------------|------------------------|-------------------------------------|
|                           | <b>Nucleoside</b> | <b>Nucleotide</b>             | <b>Deoxynucleoside</b> | <b>Deoxynucleotide</b>              |
| <i><b>Purines</b></i>     |                   |                               |                        |                                     |
| Adenine (A)               | Adenosine         | Adenosine monophosphate (AMP) | Deoxyadenosine         | Deoxyadenosine monophosphate (dAMP) |
| Guanine (G)               | Guanosine         | Guanosine monophosphate (GMP) | Deoxyguanosine         | Deoxyguanosine monophosphate (dGMP) |
| <i><b>Pyrimidines</b></i> |                   |                               |                        |                                     |
| Cytosine (C)              | Cytidine          | Cytidine monophosphate (CMP)  | Deoxycytidine          | Deoxycytidine monophosphate (dCMP)  |
| Uracil (U)                | Uridine           | Uridine monophosphate (UMP)   | —                      | —                                   |
| Thymine (T)               | —                 | —                             | Deoxythymidine         | Deoxythymidine monophosphate (dTMP) |





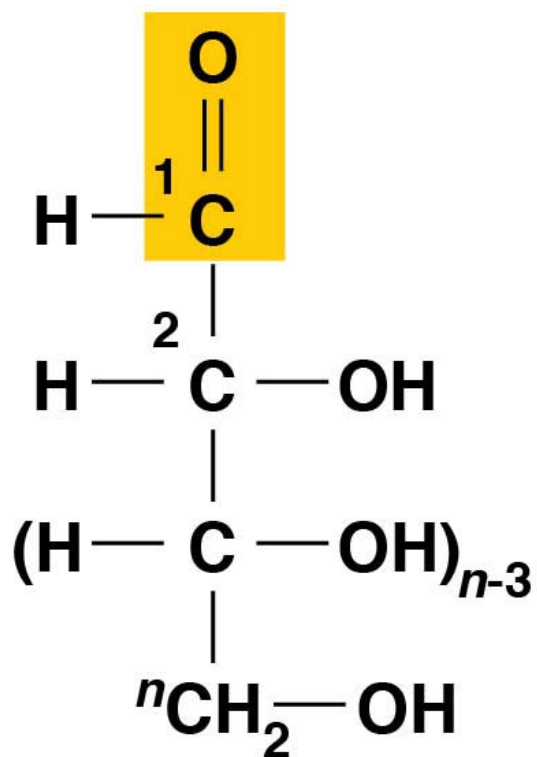




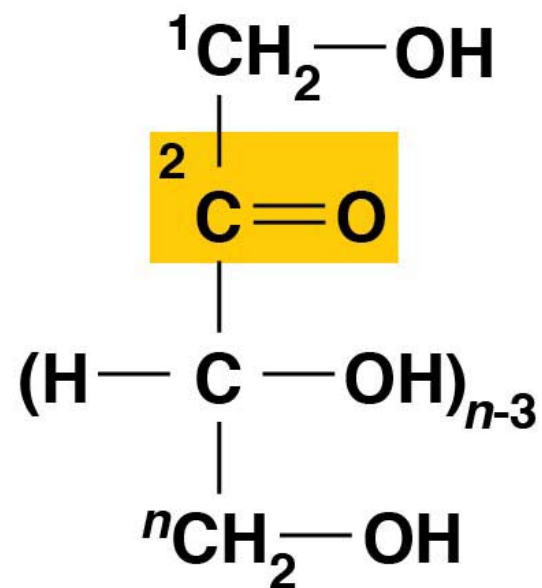


(a) DNA double helix

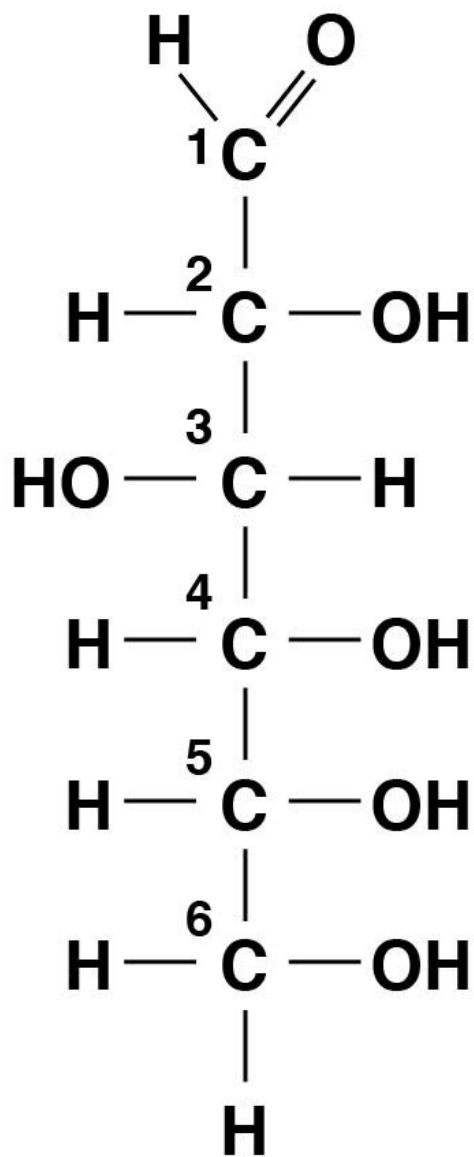
(b) Space-filling model



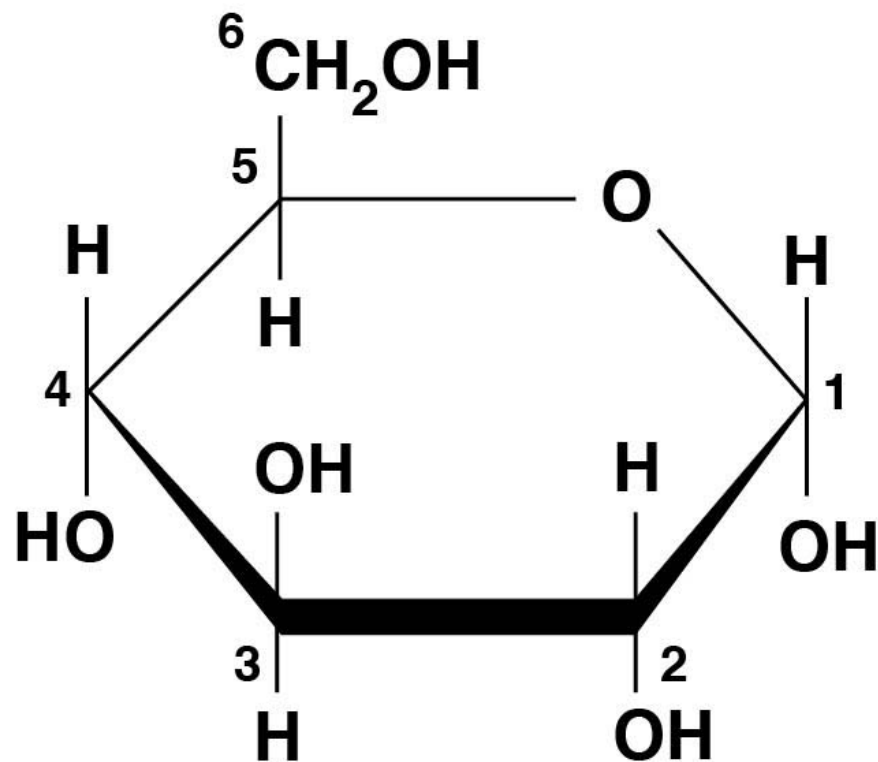
**(a) Aldosugar**



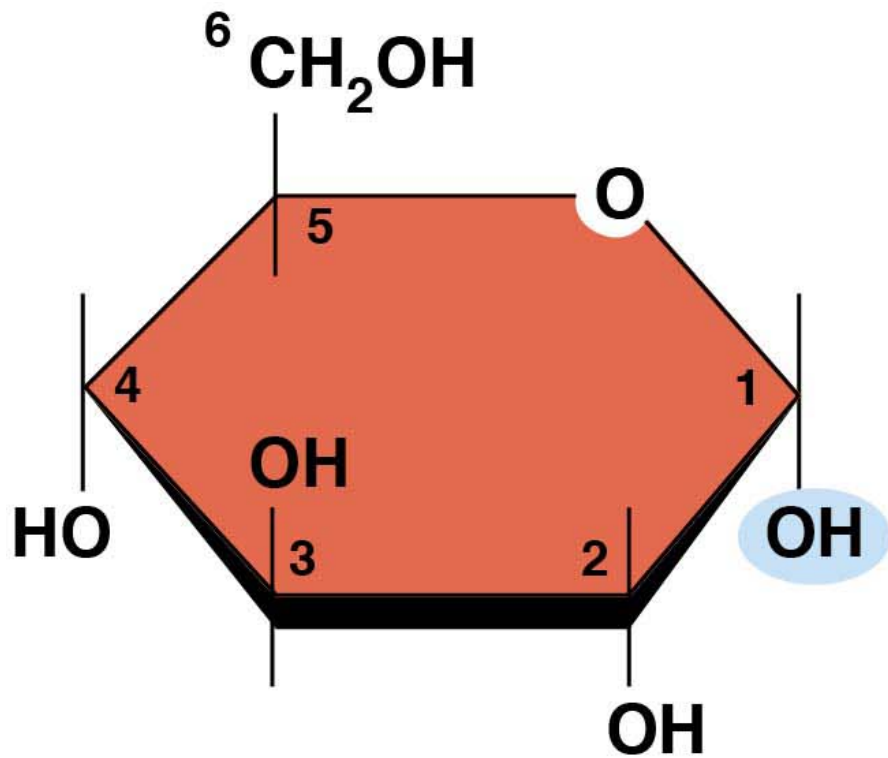
**(b) Ketosugar**



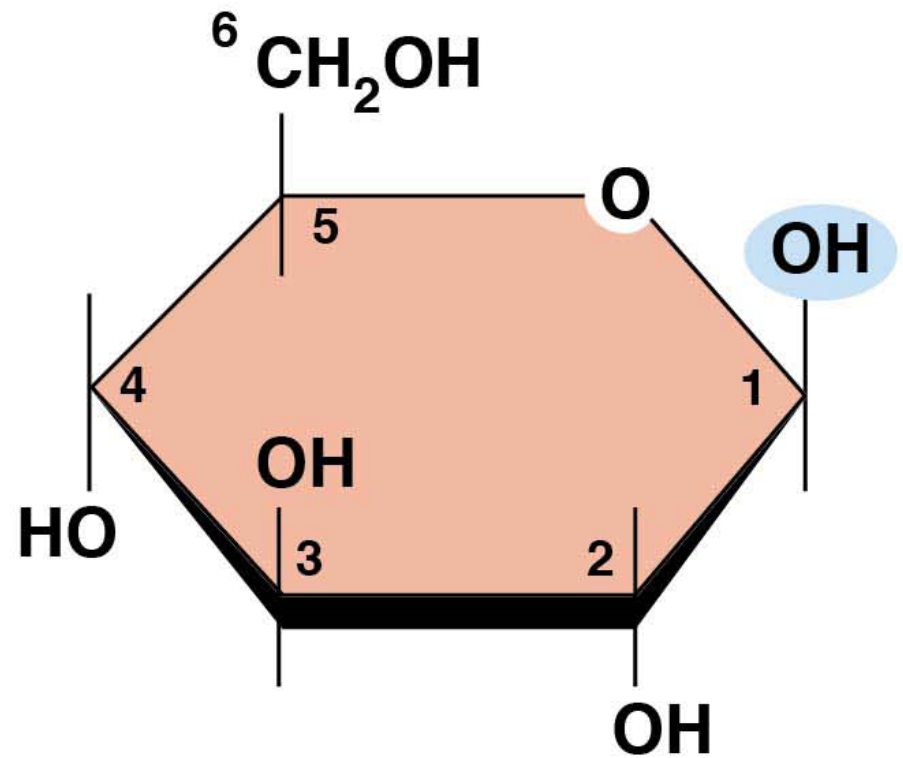
**(a) Fischer projection**



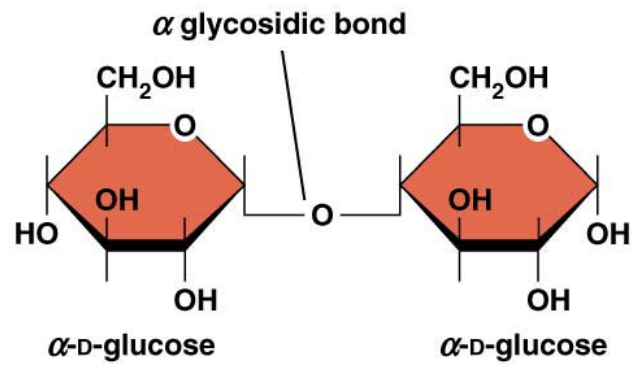
**(b) Haworth projection**



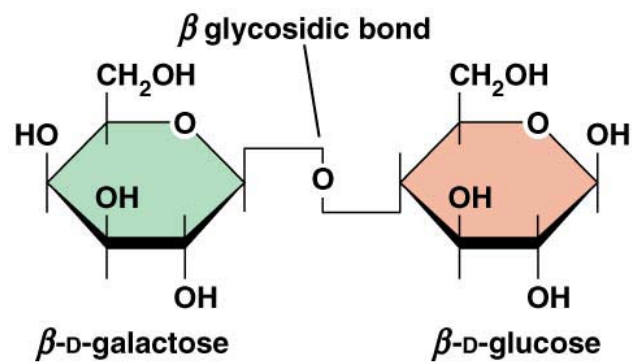
**$\alpha$ -D-glucose, the repeating unit of starch and glycogen**



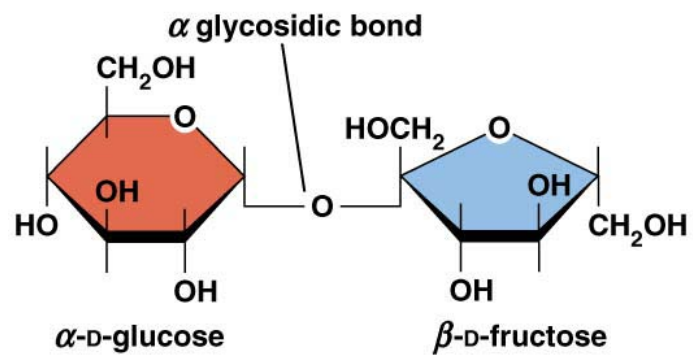
**$\beta$ -D-glucose, the repeating unit of cellulose**



**(a) Maltose**

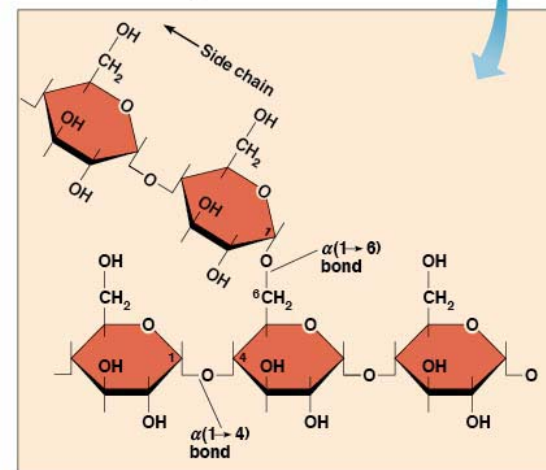
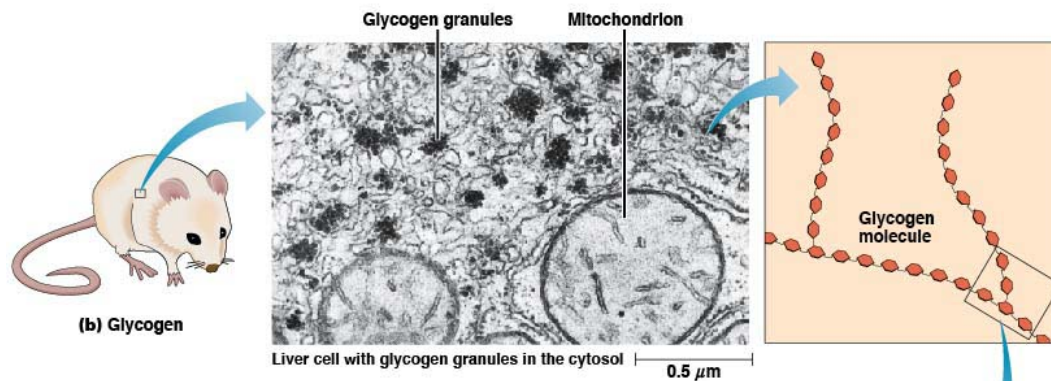
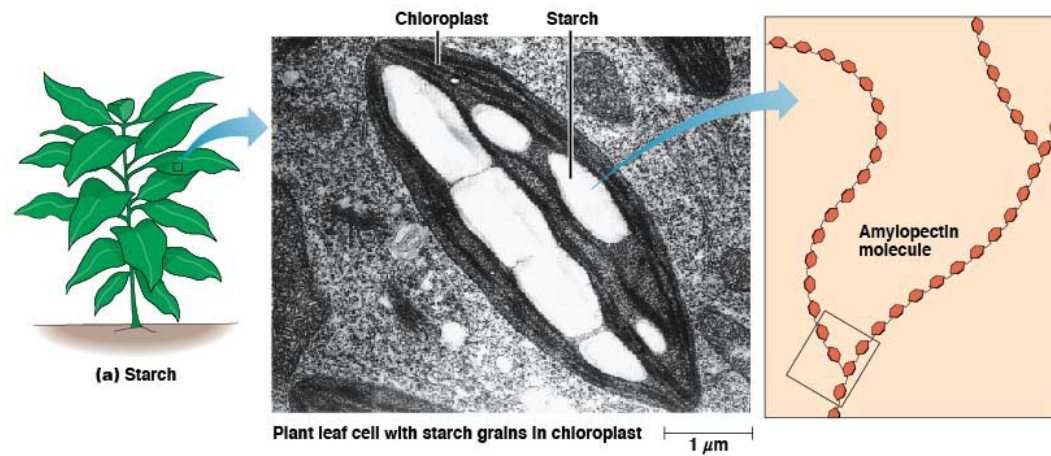


**(b) Lactose**

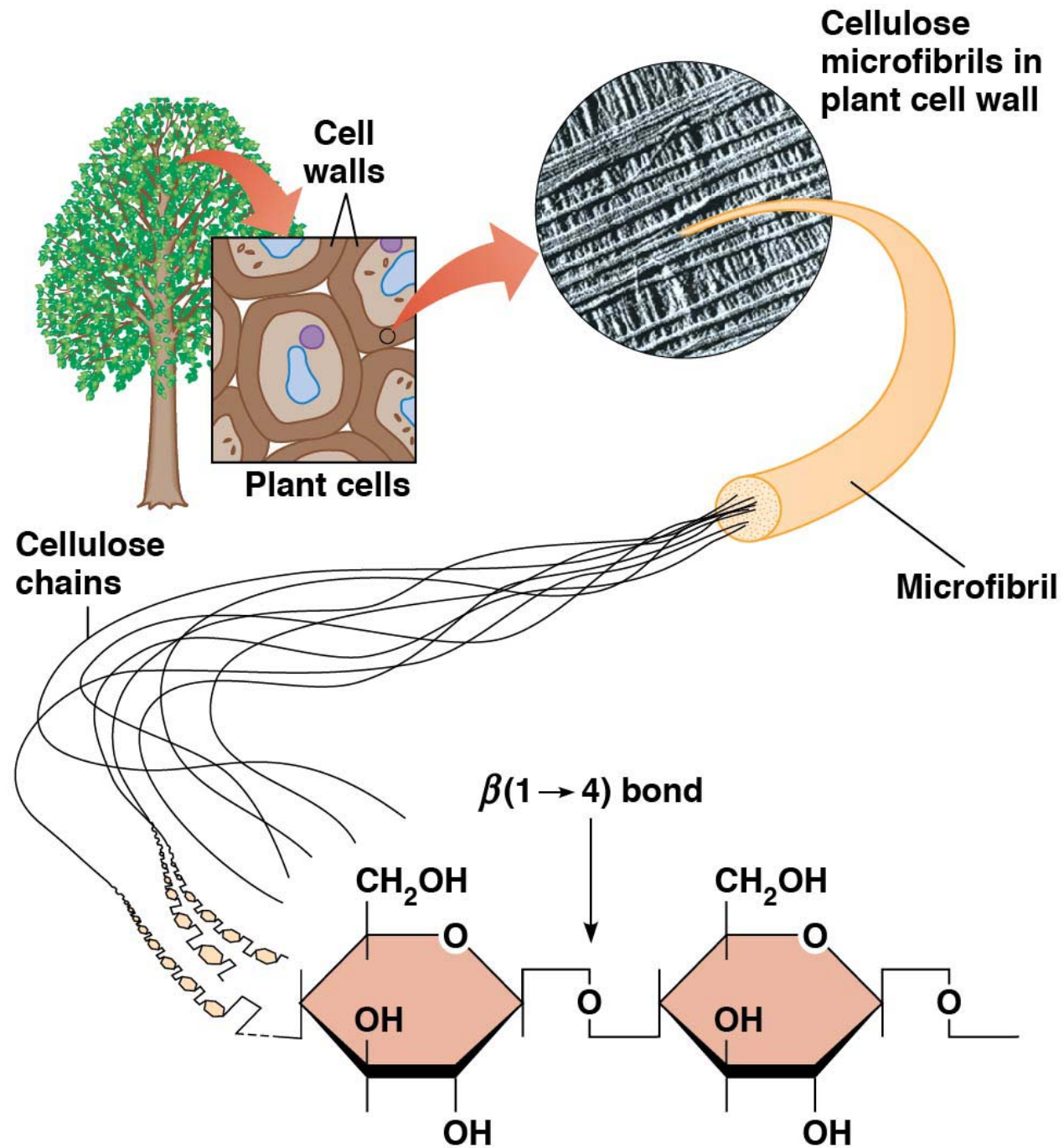


**(c) Sucrose**

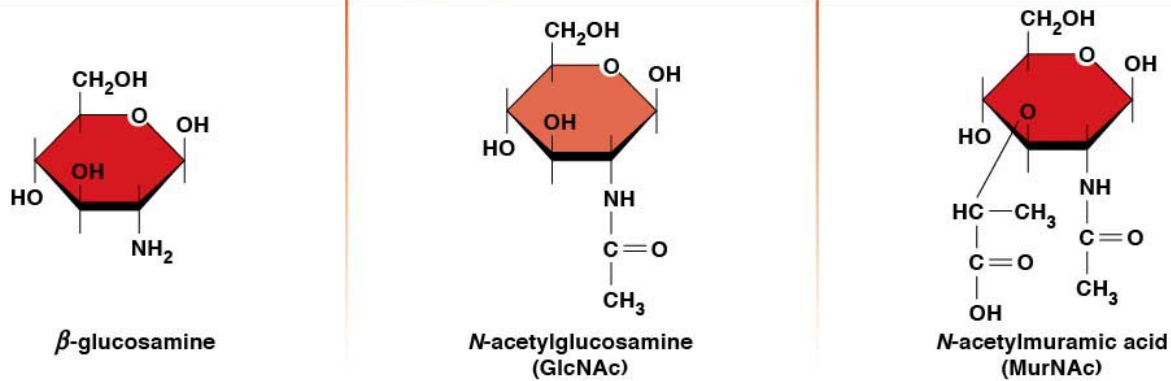




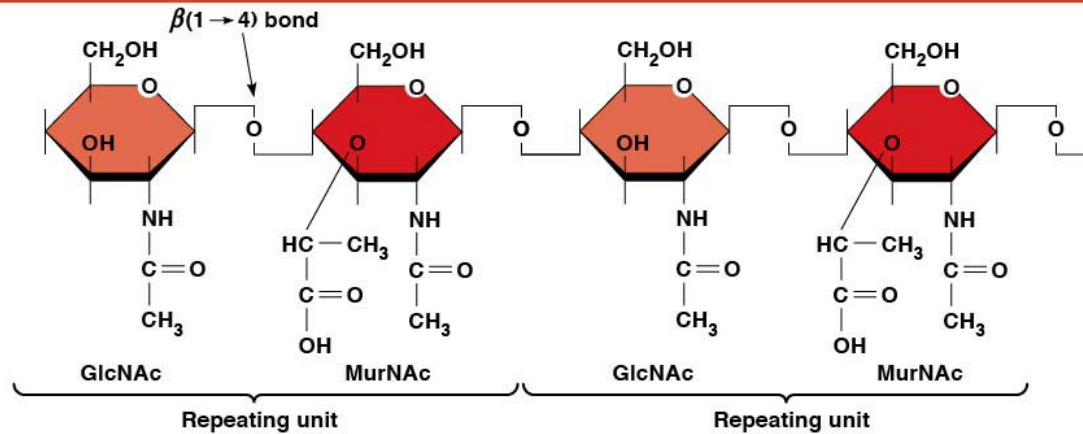
**(c) Glycogen or amylopectin structure**



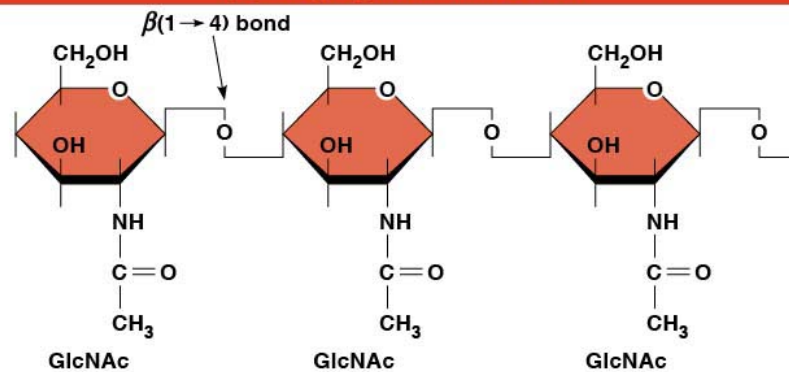
### (a) Polysaccharide subunits



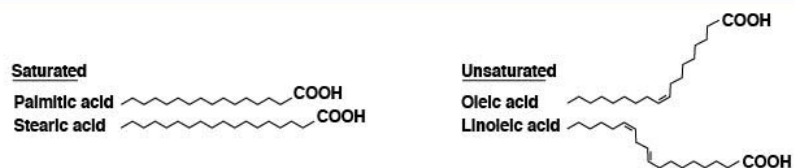
### (b) A bacterial cell wall polysaccharide



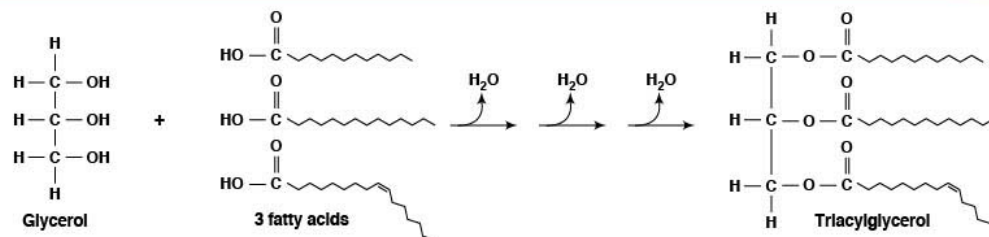
### (c) The polysaccharide chitin



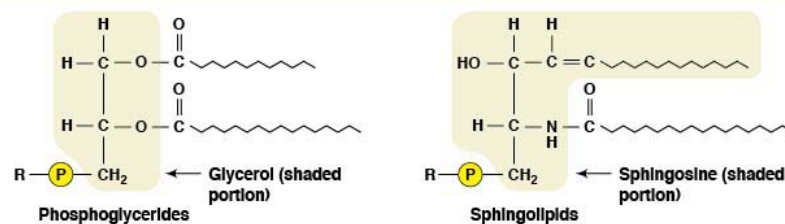
### (a) Fatty acids



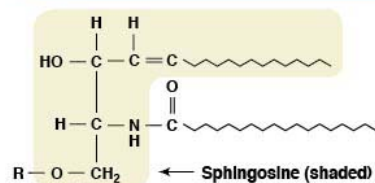
### (b) Triacylglycerols and their synthesis



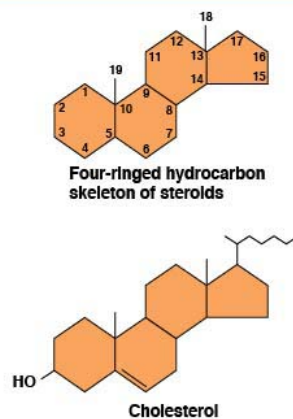
### (c) Phospholipids (R = any of several hydrophilic compounds)



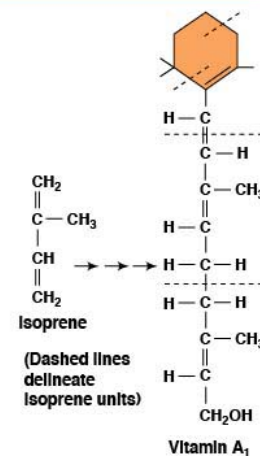
### (d) Glycolipids (R = carbohydrate chain of 1 to 6 monosaccharide units)



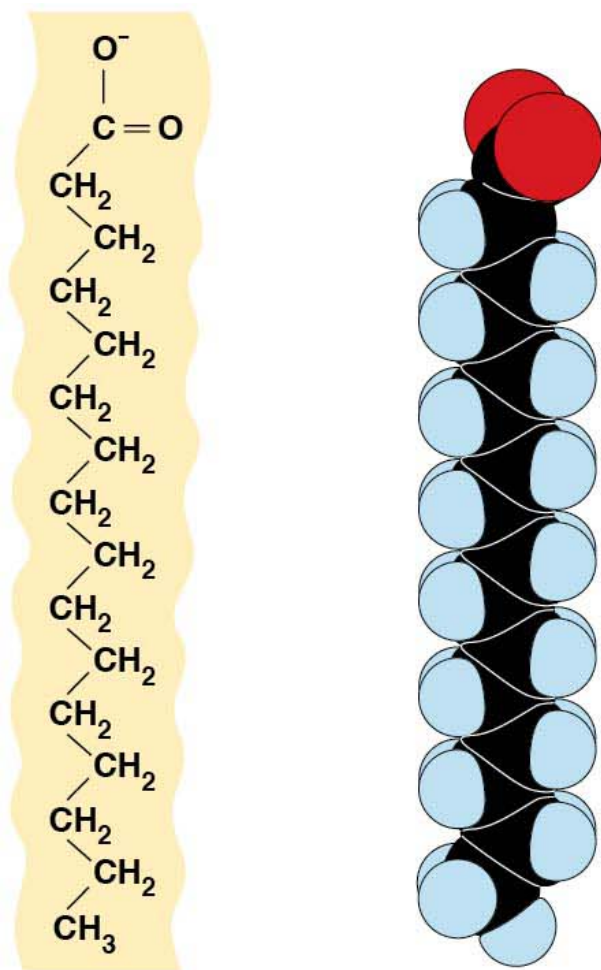
### (e) Steroids



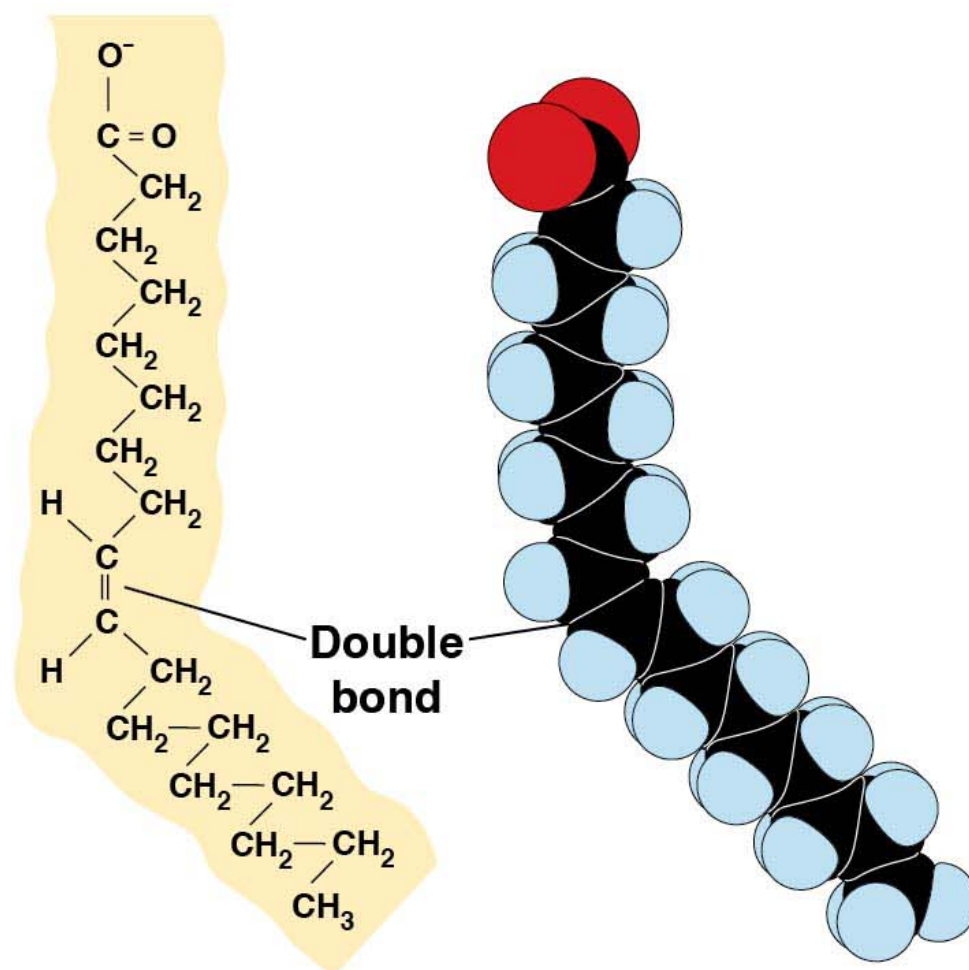
### (f) Terpenes





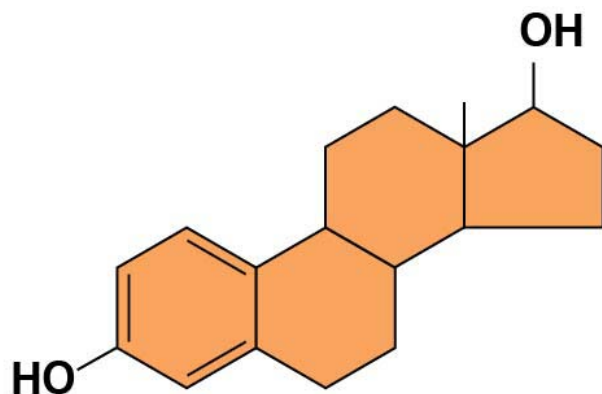


**(a) Palmitate (saturated)**

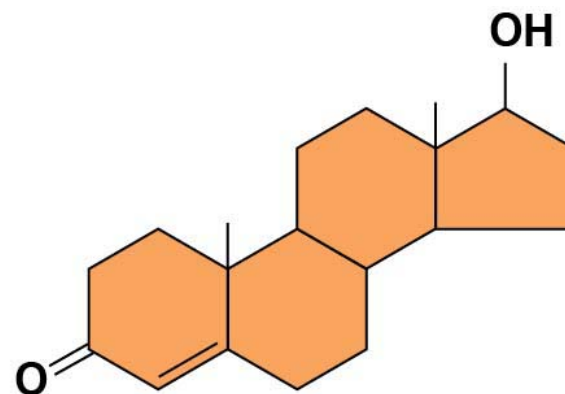


**(b) Oleate (unsaturated)**

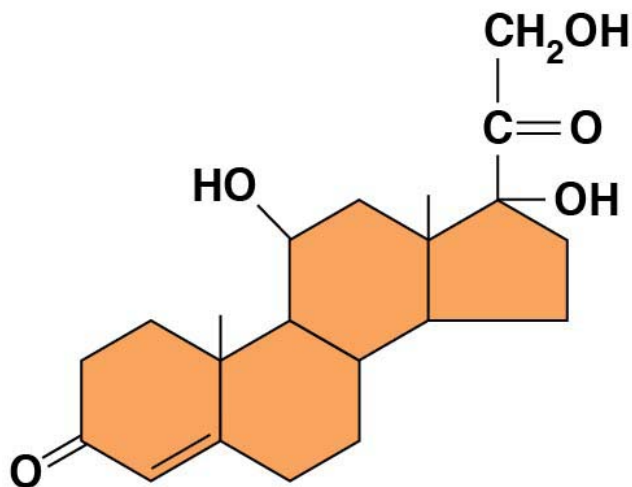




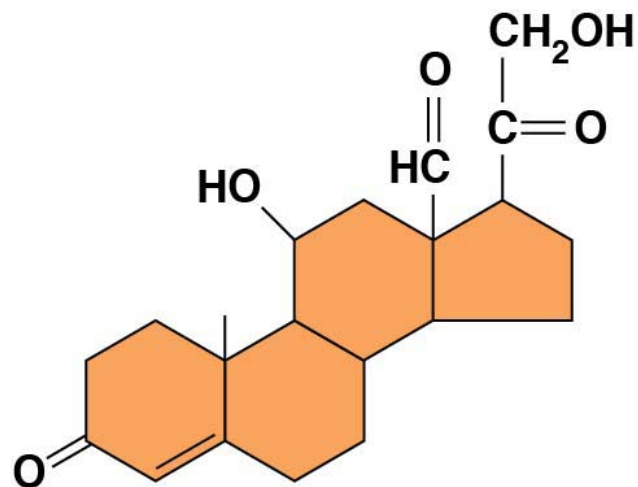
**(a) Estradiol**  
(an estrogen)



**(b) Testosterone**  
(an androgen)



**(c) Cortisol**  
(a glucocorticoid)



**(d) Aldosterone**  
(a mineralocorticoid)