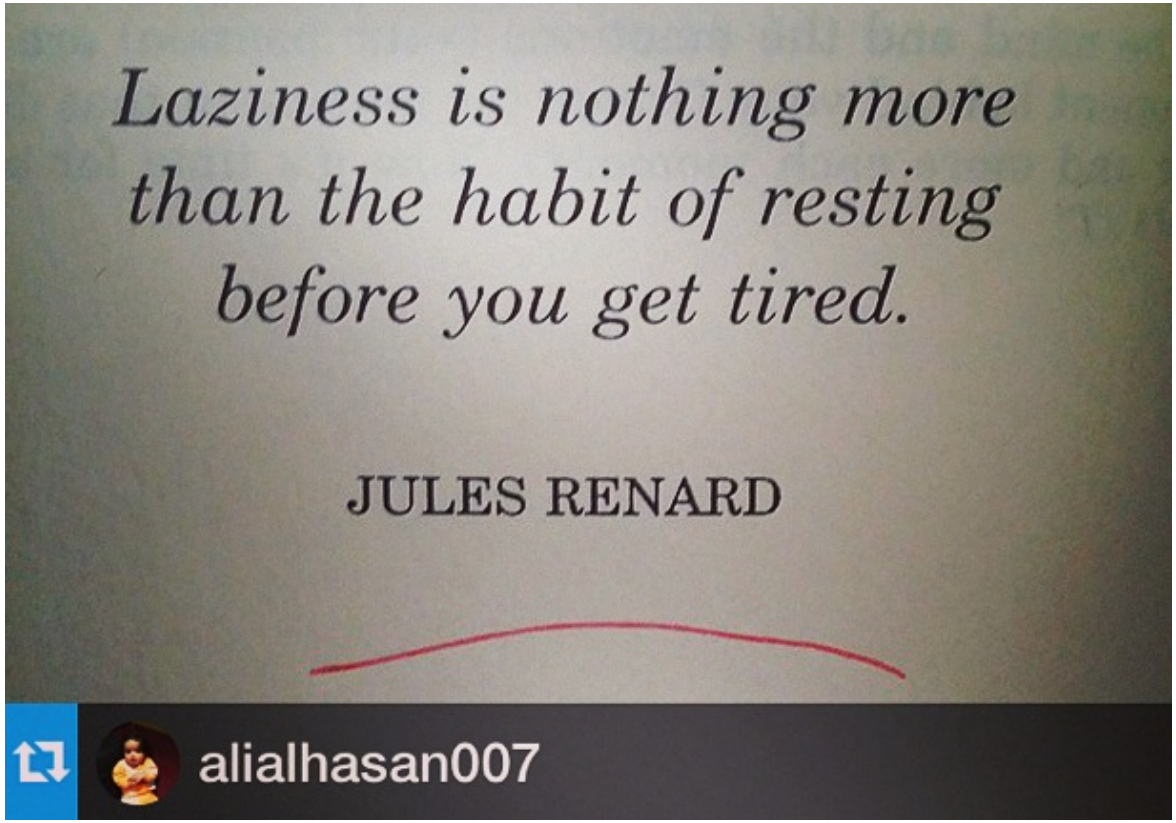
Lecture 15:

Amino acids and proteins

Course 281

Lessons for life



AIMS

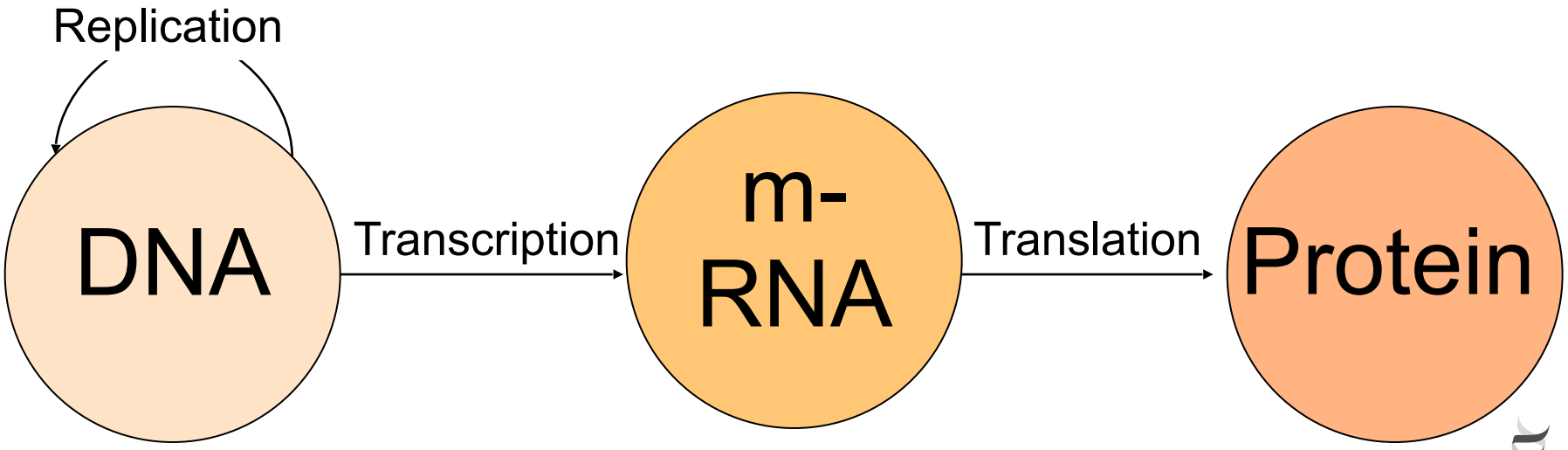
- Understand the chemical composition of proteins and the building block of them.
- Understand the structural organization of proteins.

Gene expression

- Translating a protein coding gene is called **gene expression.**

- The path from genes to proteins go through an intermediate molecule called **m-RNA.**

What molecule gets translated into a protein?



Translation

- The three major types of RNA: mRNA, rRNA and tRNA work together to synthesize proteins by the process called translation
- The sequence of amino acids in the protein being synthesized is specified by the sequence of nucleotides in the mRNA molecule that is being translated

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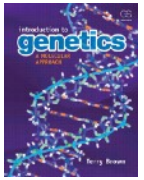


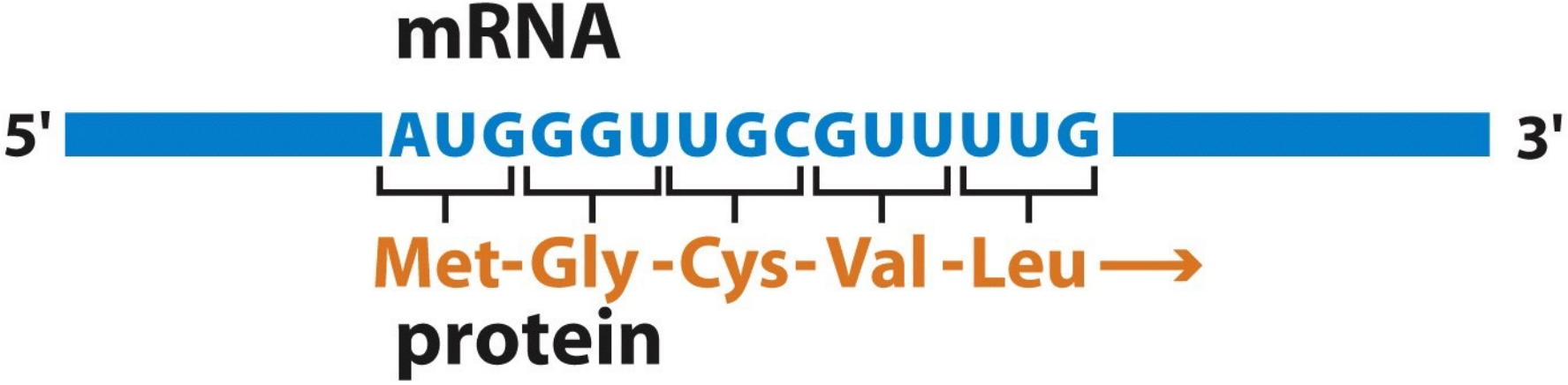
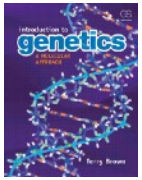
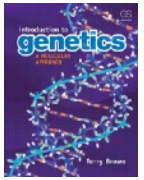


Figure. During translation, each triplet of nucleotides in the RNA specifies a particular amino acid, the identity of this amino acid being set by the genetic code.



Protein Structure

- A linear unbranched polymer
- The monomeric subunits of protein are called **amino acids**
- The resulting **polymers** or **polypeptides** are rarely more than 2000 units in length



Proteins

What are proteins?

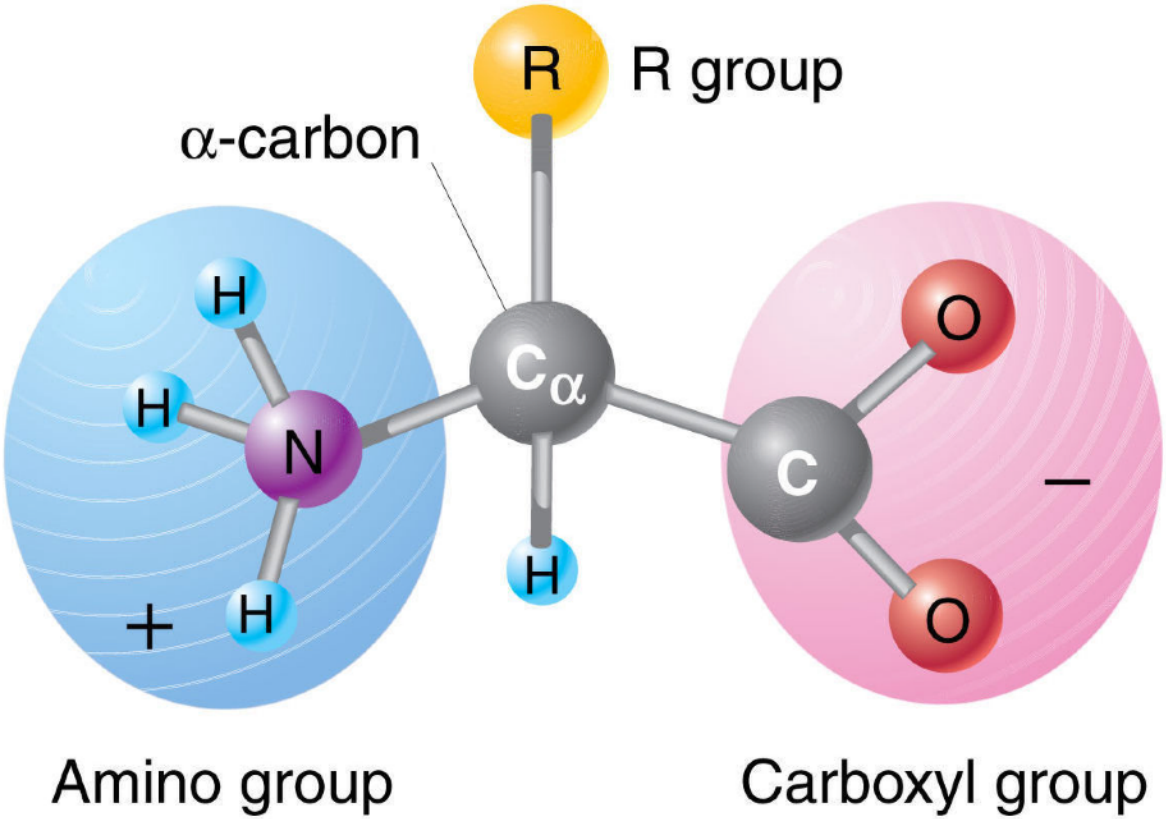
1. Macromolecule.
2. Nitrogen containing organic compound.
3. Can form many structures.
4. Many have catalytic activities.
5. Made of polypeptides.
6. Composed of building blocks called **amino acids.**

Proteins

What is the general structure of the building block of proteins (amino acids)?

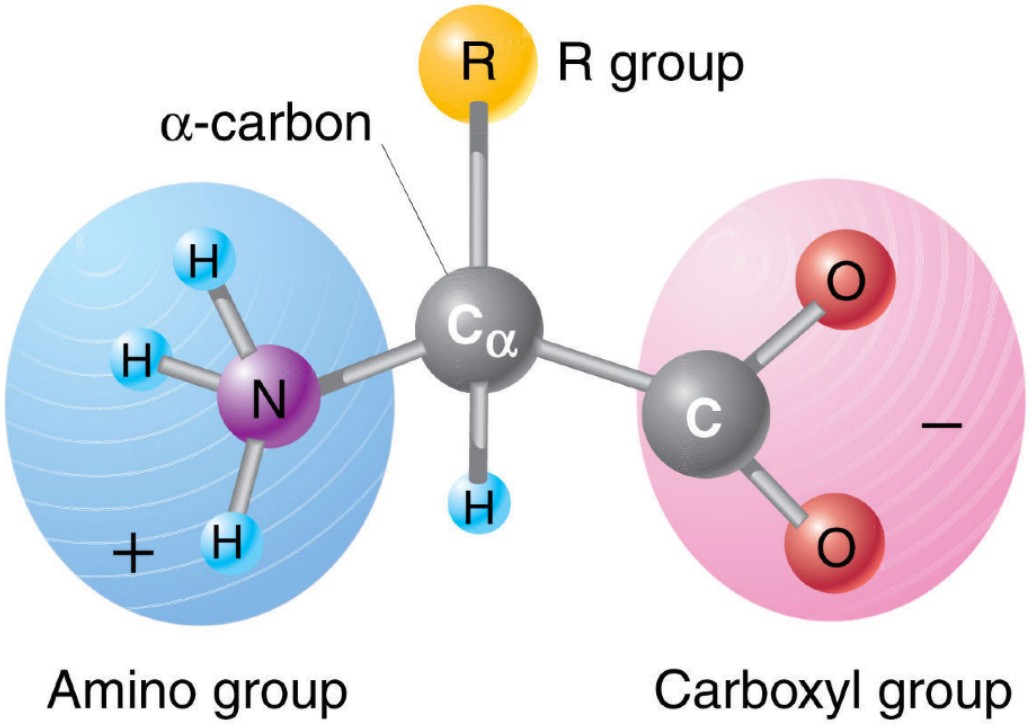
Amino acid structure

An amino acid is composed of **(1)** an amino group, **(2)** a carboxyl group, **(3)** and alpha carbon to which **(4)** an R group is attached.



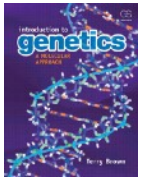
Amino acid structure

- **R group:** is an organic group.
- The R group is different from one amino acid to another.
- There are 20-21 amino acids each with different R groups.



Amino acids are linked by peptide bonds

- Twenty different amino acids are found in protein molecules
- Each has the general structure comprising a central α carbon atom to which four groups are attached:
  - Hydrogen atom
  - Carboxyl group (–COO–)
  - Amino group (–NH3+),
  - **R group**
    - which is different for each amino acid



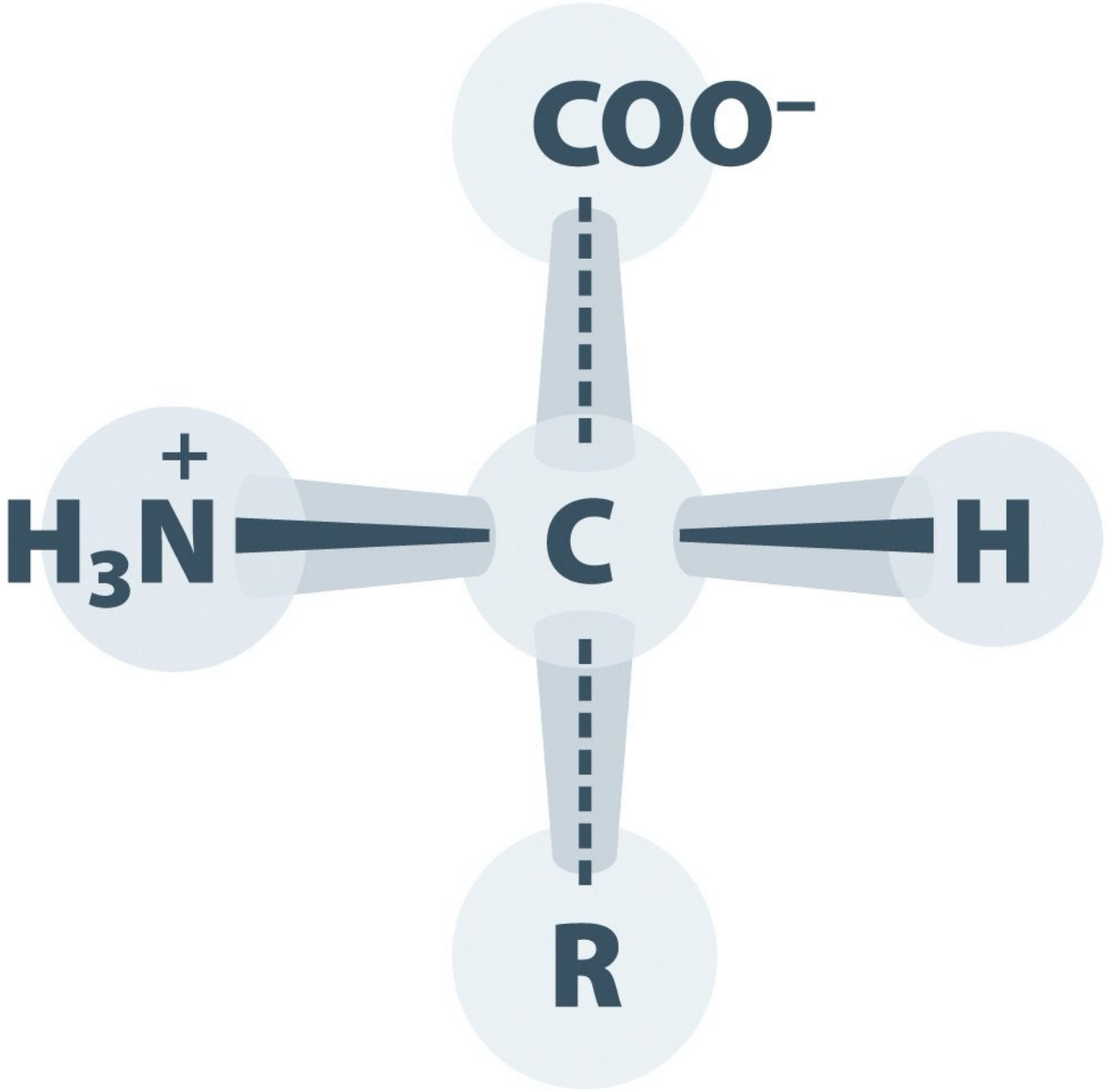
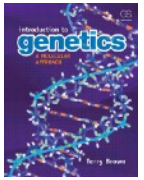
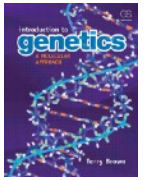


Figure. The general structure of an amino acid



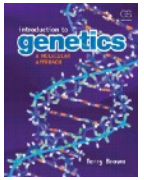
R Groups

- The R groups vary considerably in chemical complexity
- The majority of R groups are uncharged
- Two amino acids have negatively charged R groups
  - Aspartic acid and glutamic acid
- Three have positively charged R groups
  - Lysine, arginine, and histidine



R Groups

- Could be polar or nonpolar
- These differences mean that although all amino acids are closely related, each has its own specific chemical properties.



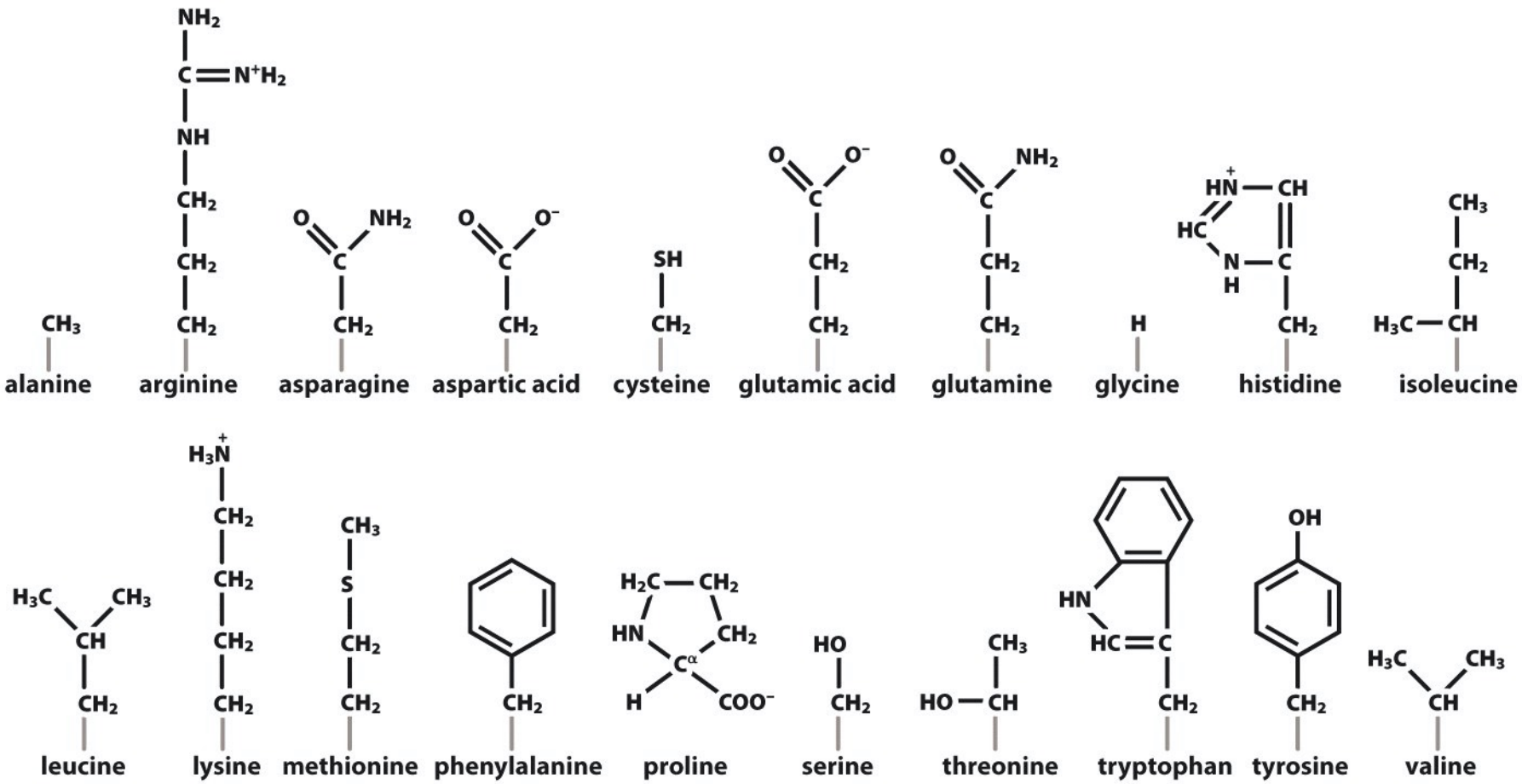


Figure. The structures of amino acid R groups

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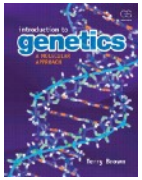
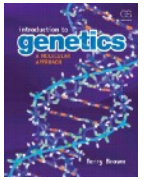
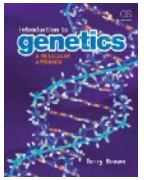


- The 20 amino acids are specified by the genetic code.
- They are the amino acids that are linked together when mRNA molecules are translated into proteins
- The 20 amino acids do not on their own represent the limit of the chemical diversity of proteins.



- Two additional amino acids: selenocysteine and pyrrolysine can be inserted into a polypeptide chain during protein synthesis
- Their insertion directed by a modified reading of the genetic code



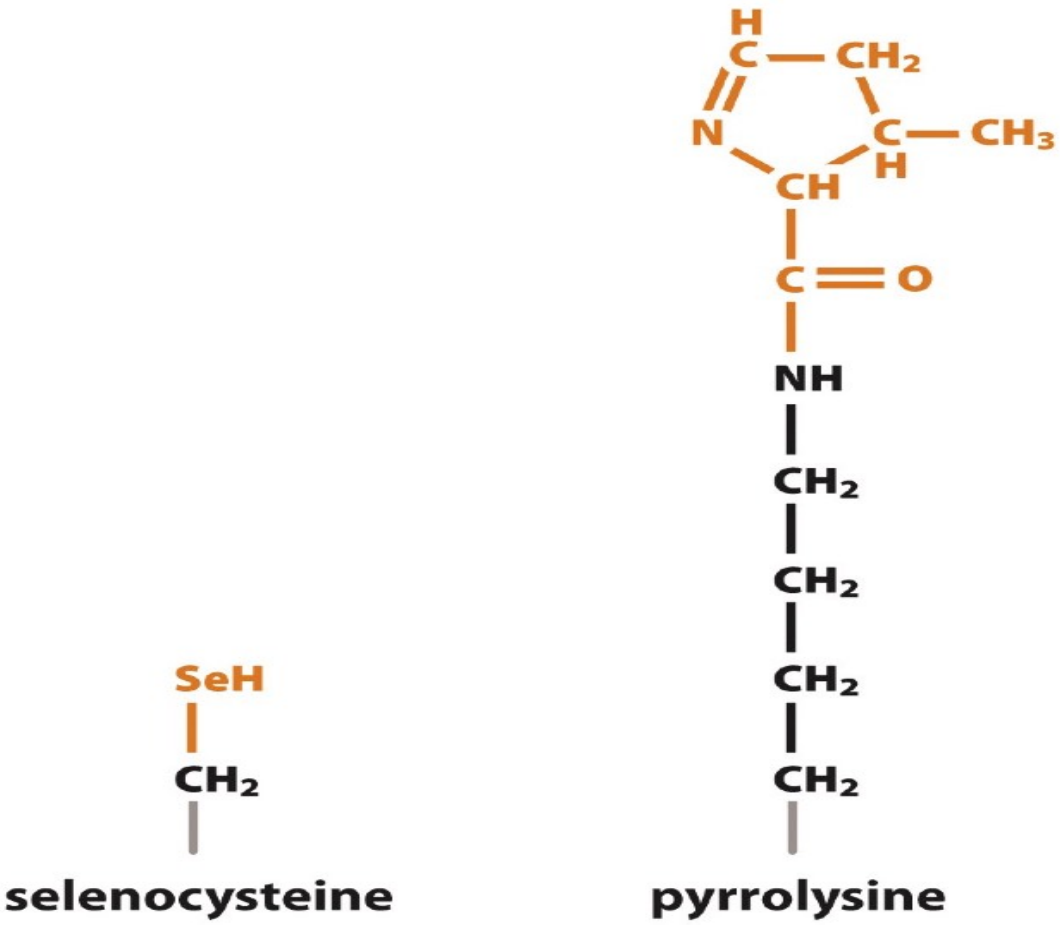
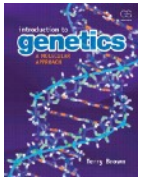
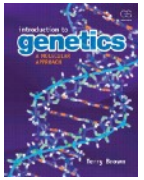


Figure. The structures of the R groups of selenocysteine and pyrrolysine.



- After a protein has been synthesized, some amino acids might be modified by the addition of new chemical groups by:
  - Phosphorylation
  - Attachment of large side chains made up of sugar units

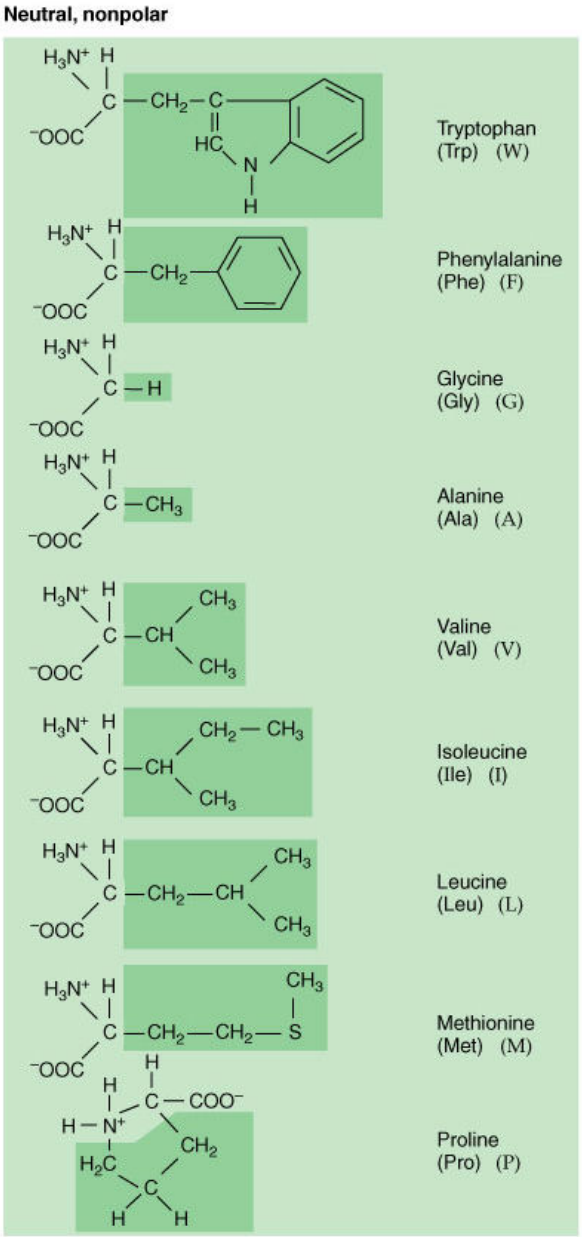


Amino acid grouping

Amino acids are grouped based on chemical characteristics:

(1)Neutral nonpolar
(2)Neutral polar
(3)Acidic
(4)Basic

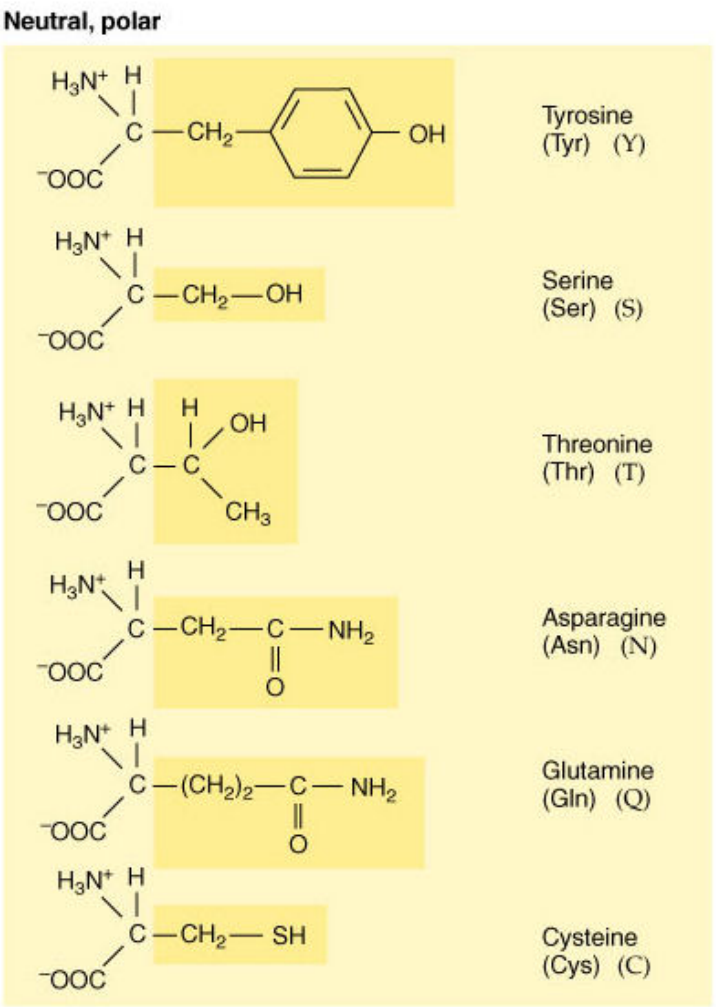
Amino acid grouping



Neutral nonpolar amino acids

How can you identify these amino acids?

Amino acid grouping



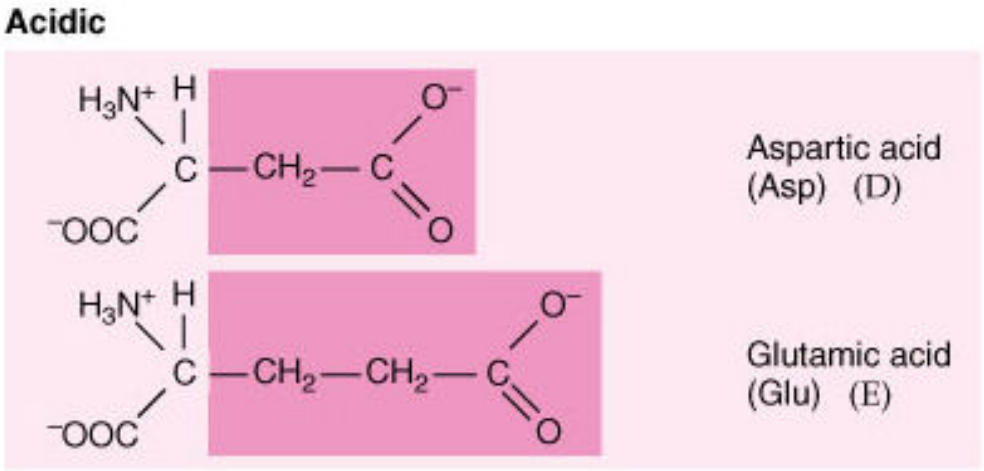
Neutral polar amino acids

How can you identify these amino acids?

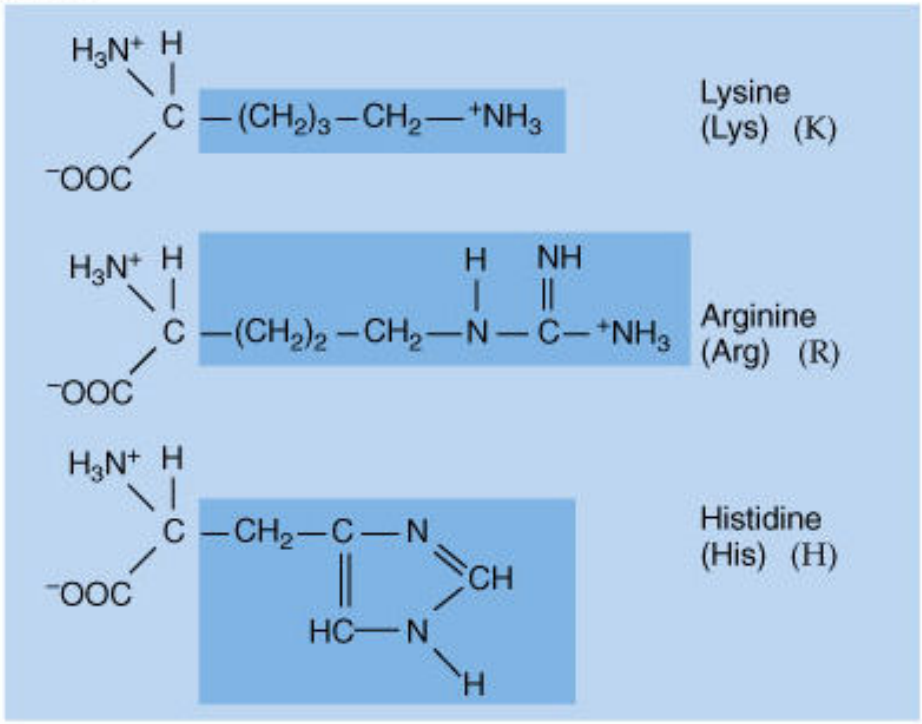
Amino acid grouping

Acidic amino acids

How can you identify these amino acids?



Amino acid grouping



Basic amino acids

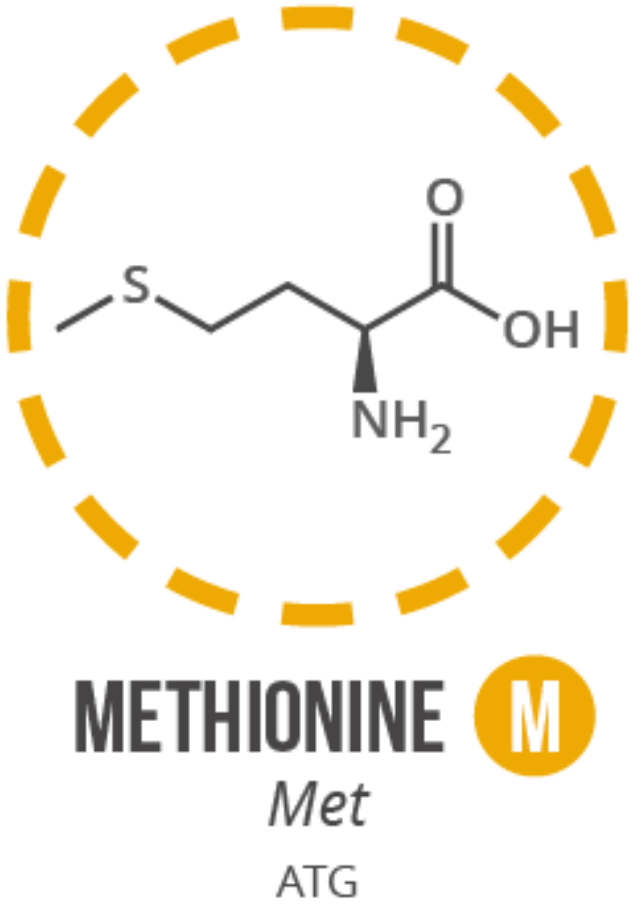
How can you identify these amino acids?

Amino acid naming

Amino acids have three letter abbreviation or a single letter abbreviation

Example:

- Methionine
- Met
- M

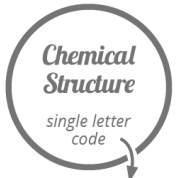


Cool chart

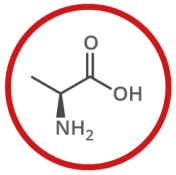
A GUIDE TO THE TWENTY COMMON AMINO ACIDS

AMINO ACIDS ARE THE BUILDING BLOCKS OF PROTEINS IN LIVING ORGANISMS. THERE ARE OVER 500 AMINO ACIDS FOUND IN NATURE - HOWEVER, THE HUMAN GENETIC CODE ONLY DIRECTLY ENCODES 20. 'ESSENTIAL' AMINO ACIDS MUST BE OBTAINED FROM THE DIET, WHILST NON-ESSENTIAL AMINO ACIDS CAN BE SYNTHESISED IN THE BODY.

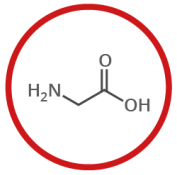
Chart Key: ALIPHATIC · AROMATIC · ACIDIC · BASIC · HYDROXYLIC · SULFUR-CONTAINING · AMIDIC · NON-ESSENTIAL · ESSENTIAL



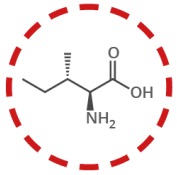
NAME (A)
three letter code
DNA codons



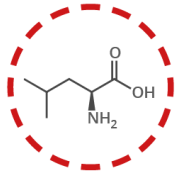
ALANINE (A)
Ala
GCT, GCC, GCA, GCG



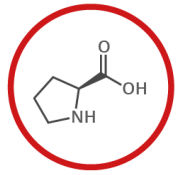
GLYCINE (G)
Gly
GGT, GGC, GGA, GGG



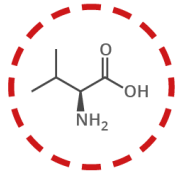
ISOLEUCINE (I)
Ile
ATT, ATC, ATA



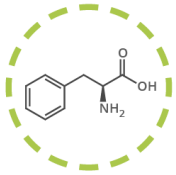
LEUCINE (L)
Leu
CTT, CTC, CTA, CTG, TTA, TTG



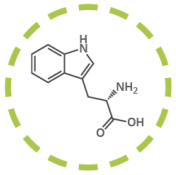
PROLINE (P)
Pro
CCT, CCC, CCA, CCG



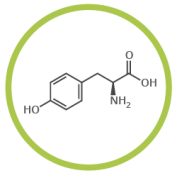
VALINE (V)
Val
GTT, GTC, GTA, GTG



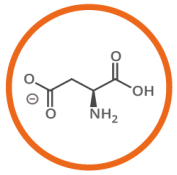
PHENYLALANINE (F)
Phe
TTT, TTC



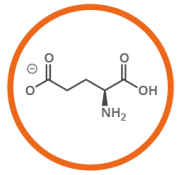
TRYPTOPHAN (W)
Trp
TGG



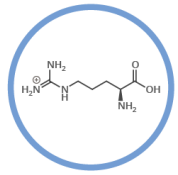
TYROSINE (Y)
Tyr
TAT, TAC



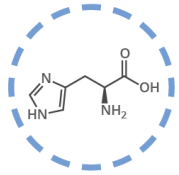
ASPARTIC ACID (D)
Asp
GAT, GAC



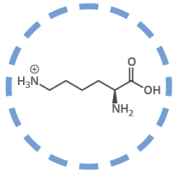
GLUTAMIC ACID (E)
Glu
GAA, GAG



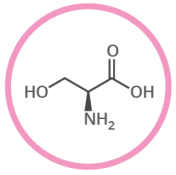
ARGININE (R)
Arg
CGT, CGC, CGA, CGG, AGA, AGG



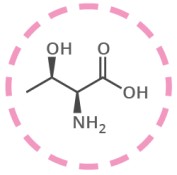
HISTIDINE (H)
His
CAT, CAC



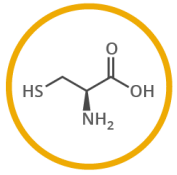
LYSINE (K)
Lys
AAA, AAG



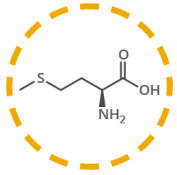
SERINE (S)
Ser
TCT, TCC, TCA, TCG, AGT, AGC



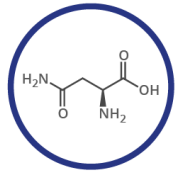
THREONINE (T)
Thr
ACT, ACC, ACA, ACG



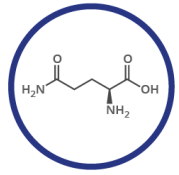
CYSTEINE (C)
Cys
TGT, TGC



METHIONINE (M)
Met
ATG



ASPARAGINE (N)
Asn
AAT, AAC



GLUTAMINE (Q)
Gln
CAA, CAG

Note: This chart only shows those amino acids for which the human genetic code directly codes for. Selenocysteine is often referred to as the 21st amino acid, but is encoded in a special manner. In some cases, distinguishing between asparagine/aspartic acid and glutamine/glutamic acid is difficult. In these cases, the codes asx (B) and glx (Z) are respectively used.

TABLE 7.1 THE 20 AMINO ACIDS FOUND IN PROTEINS

Amino acid	Abbreviation	
	Three-letter	One-letter
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartic acid	Asp	D
Cysteine	Cys	C
Glutamic acid	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

Table 7.1 Introduction to Genetics (© Garland Science 2012)

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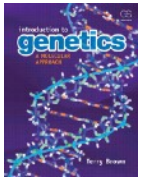


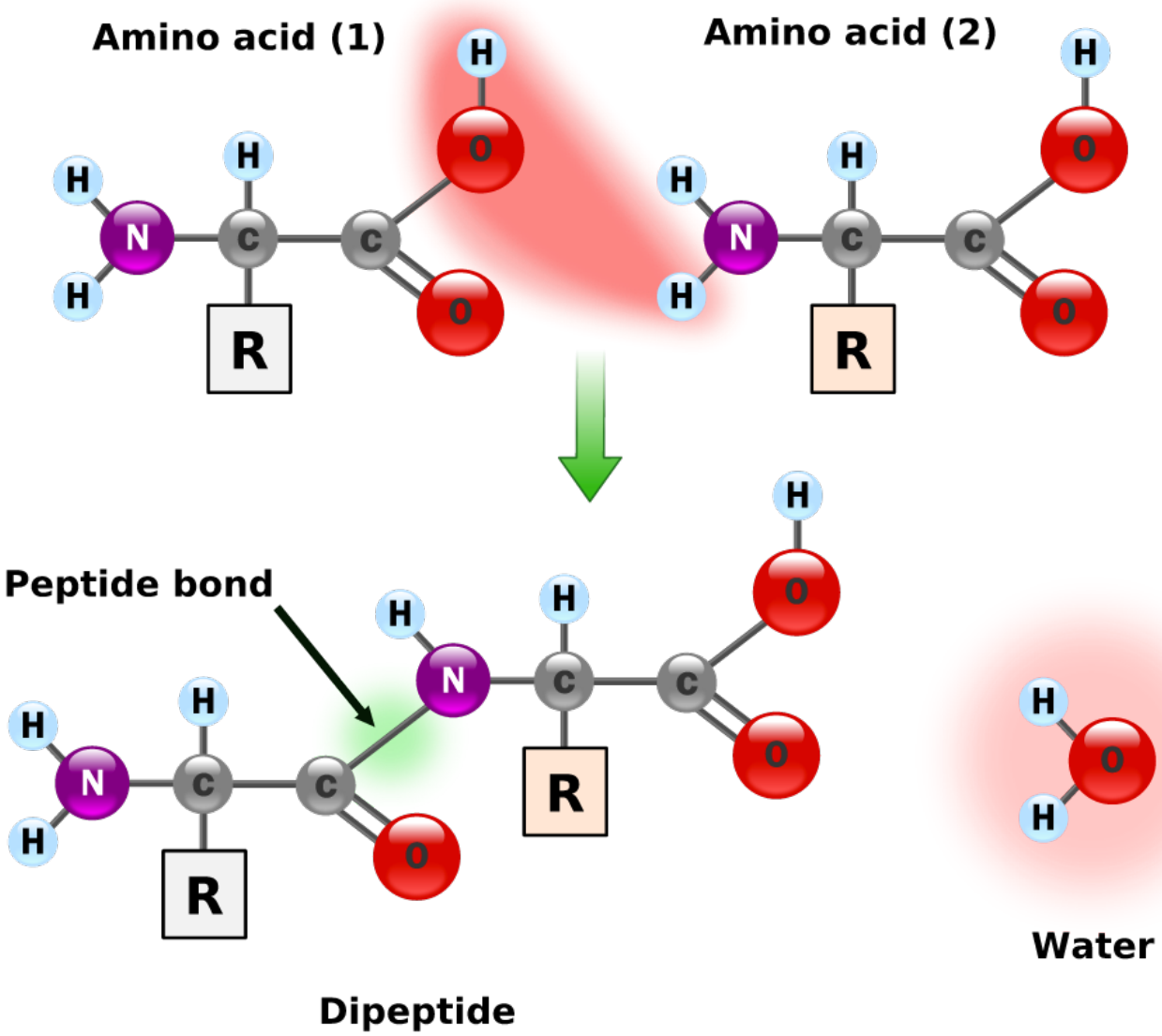
Peptide bond

- Nucleotides are linked together via a phosphodiester bond.
- Amino acids are joined together by a **peptide bond.**
- The direction of formation of a polynucleotide chain is **5’ → 3’**.
- Synthesis of a polypeptide chain is in the direction of **N → C**.

Peptide bond

- DNA has a 5’ end and 3’ end.
- The resulting polypeptide will have a free **amino group** at the **N terminus** and a free **carboxyl group** at the **C terminus**.
- A condensation reaction (dehydration) takes place between the carboxyl group of one amino acid and the amino group of the other forming the peptide bond and releasing a molecule of water.

Peptide bond



Peptide bonds

- Bonds linking a series of amino acids
- Formed by condensation between the carboxyl group of one amino acid and the amino group of a second amino acid
- The two ends of the polypeptide are chemically distinct
  - One has a free amino group and is called the **amino**, **NH2** or **N terminus**
  - The other has a free carboxyl group and is called the **carboxyl**, **COOH**, or **C terminus**.
- The direction of the polypeptide can therefore be expressed as either:
  - N $\longrightarrow$ C
  - C $\longrightarrow$ N

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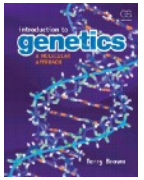

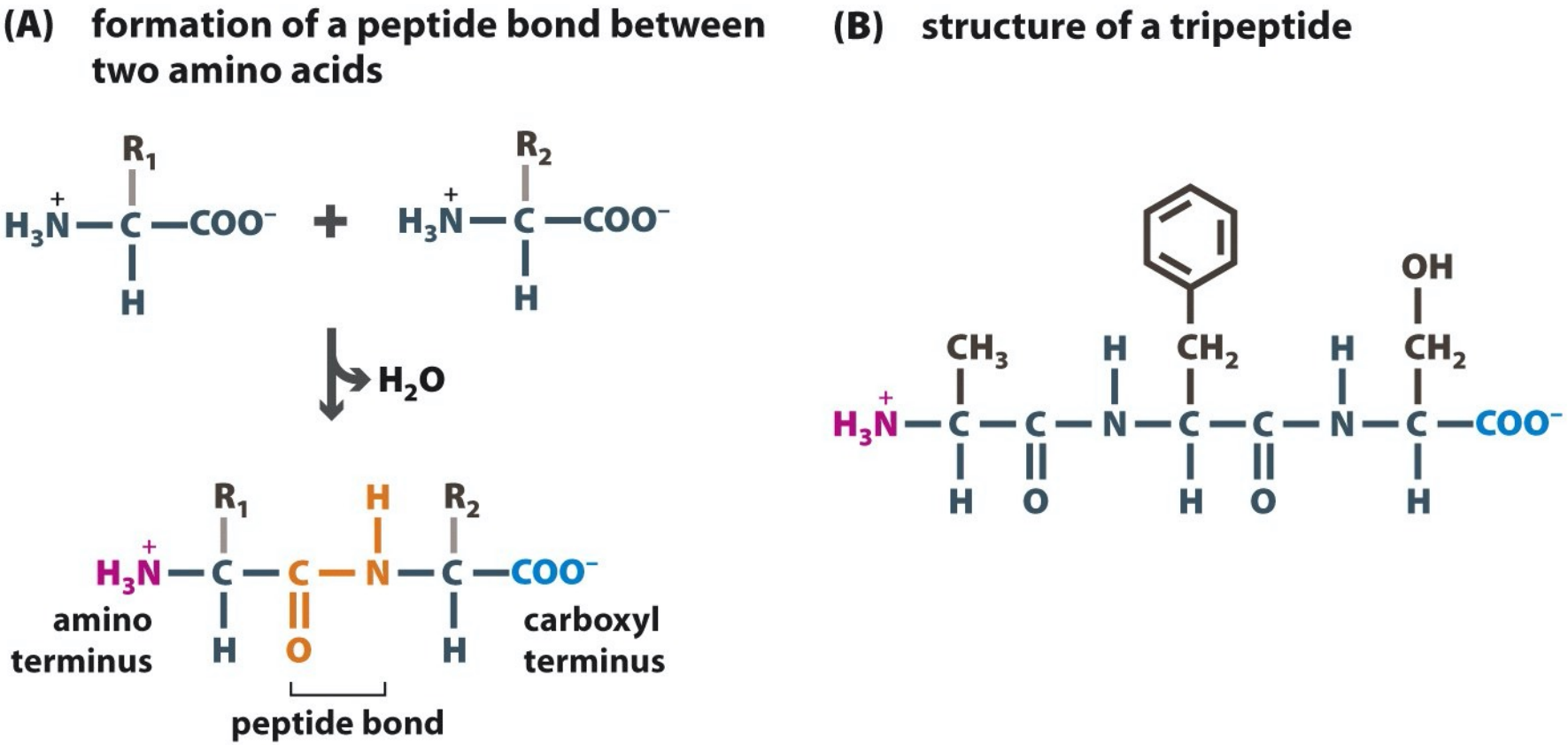

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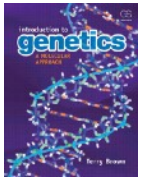

Figure. Amino acids are linked together by peptide bonds.

structure of a tripeptide

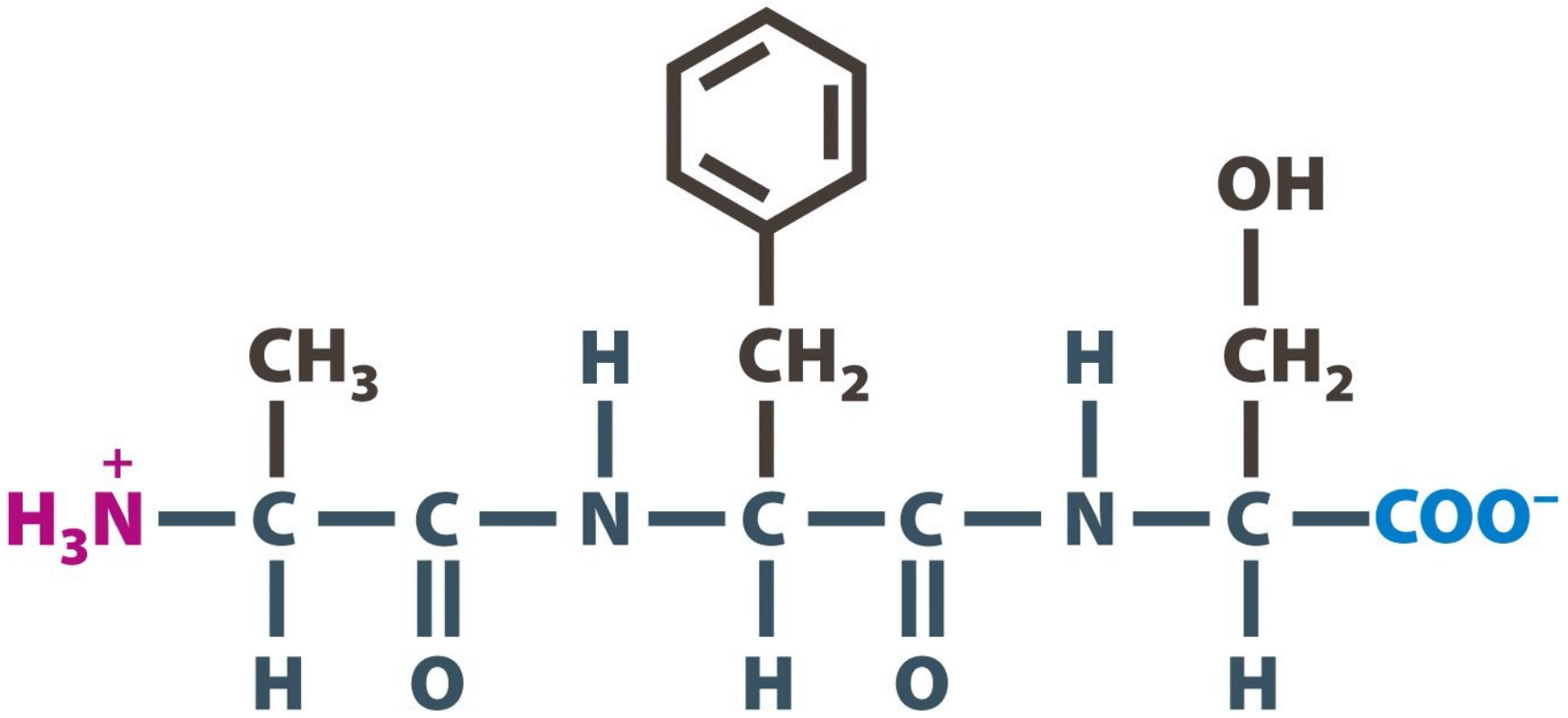

Figure 7.5b Introduction to Genetics (© Garland Science 2012)

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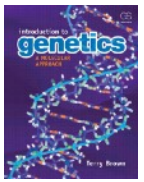
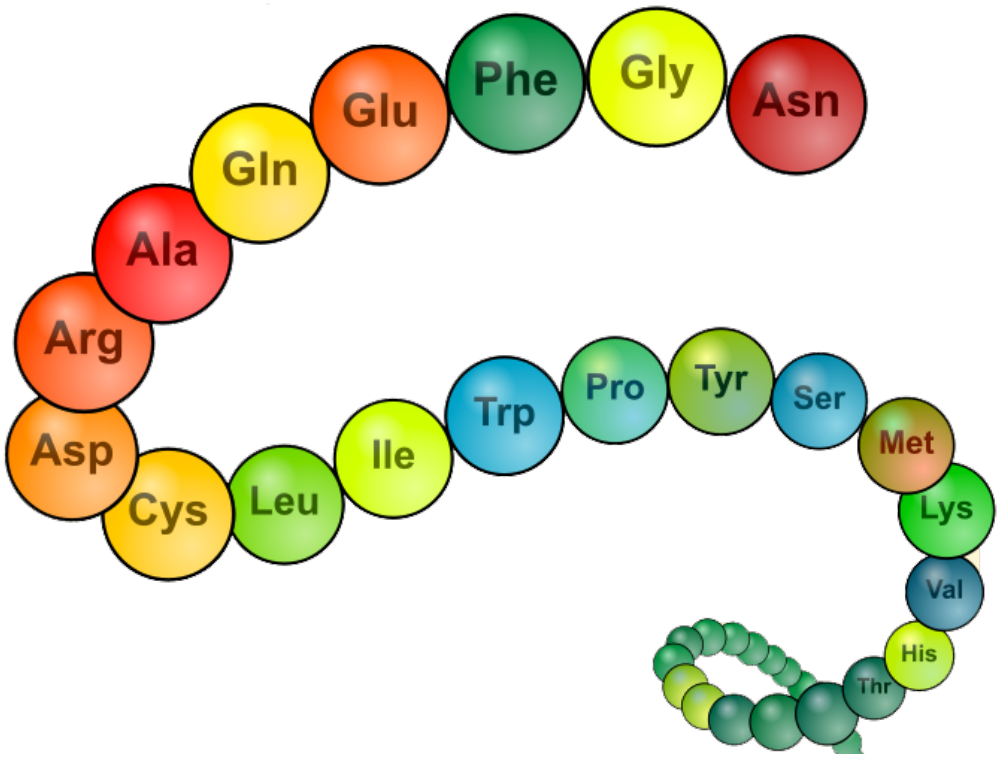


Protein organization

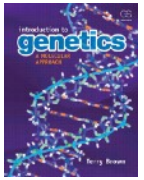
Primary structure of proteins (1°):

Simple linear polypeptide chain of amino acids



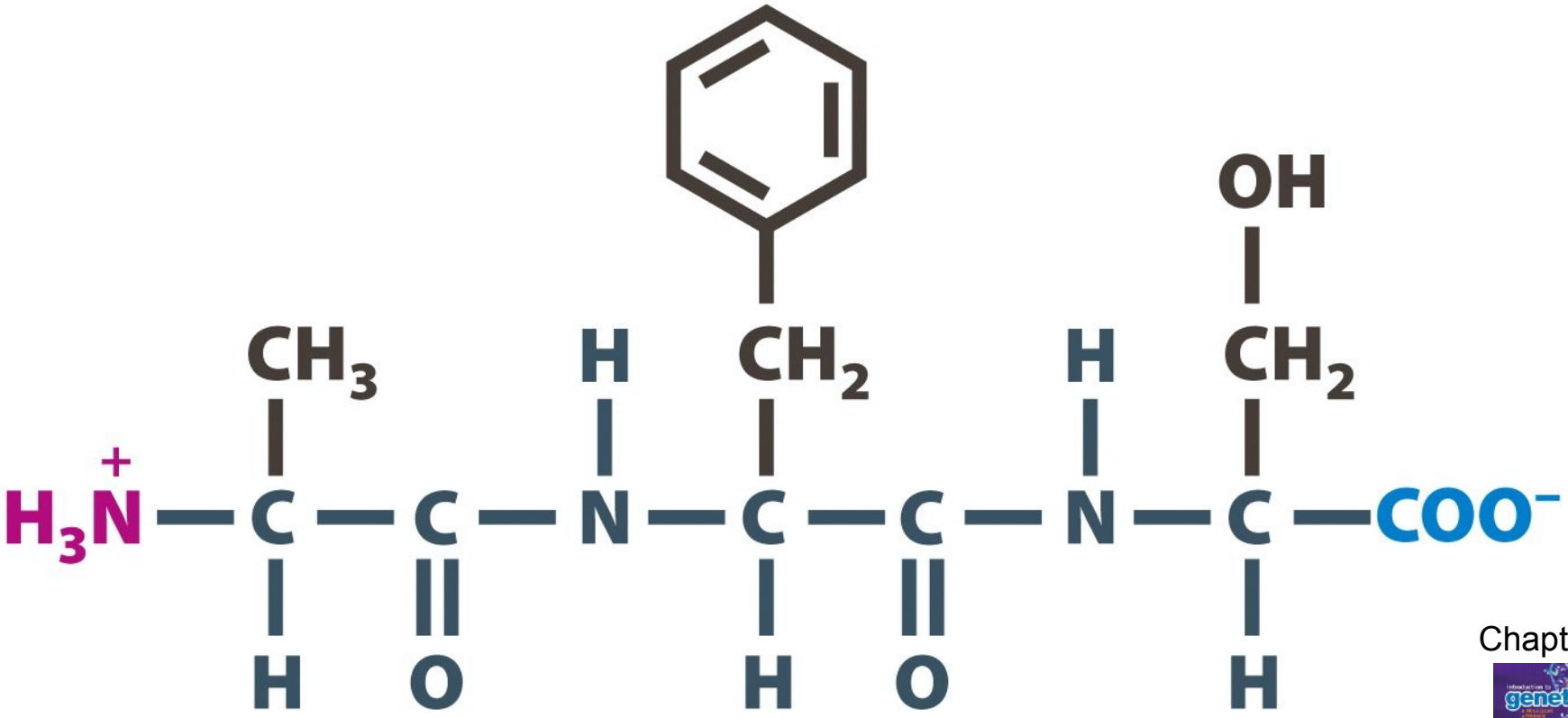
Protein Structure

- Proteins have four distinct levels of structure.
  - **Primary structure**
  - **Secondary structure**
  - **Tertiary structure**
  - **Quaternary structure**



Primary Structure

- The linear sequence of amino acids



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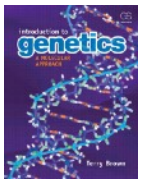


Protein organization

Secondary structure of proteins (2°):

Folding and twisting of the primary structure by the interaction (Hydrogen bonding) between amino acids to form **α helix** and **β sheets**.

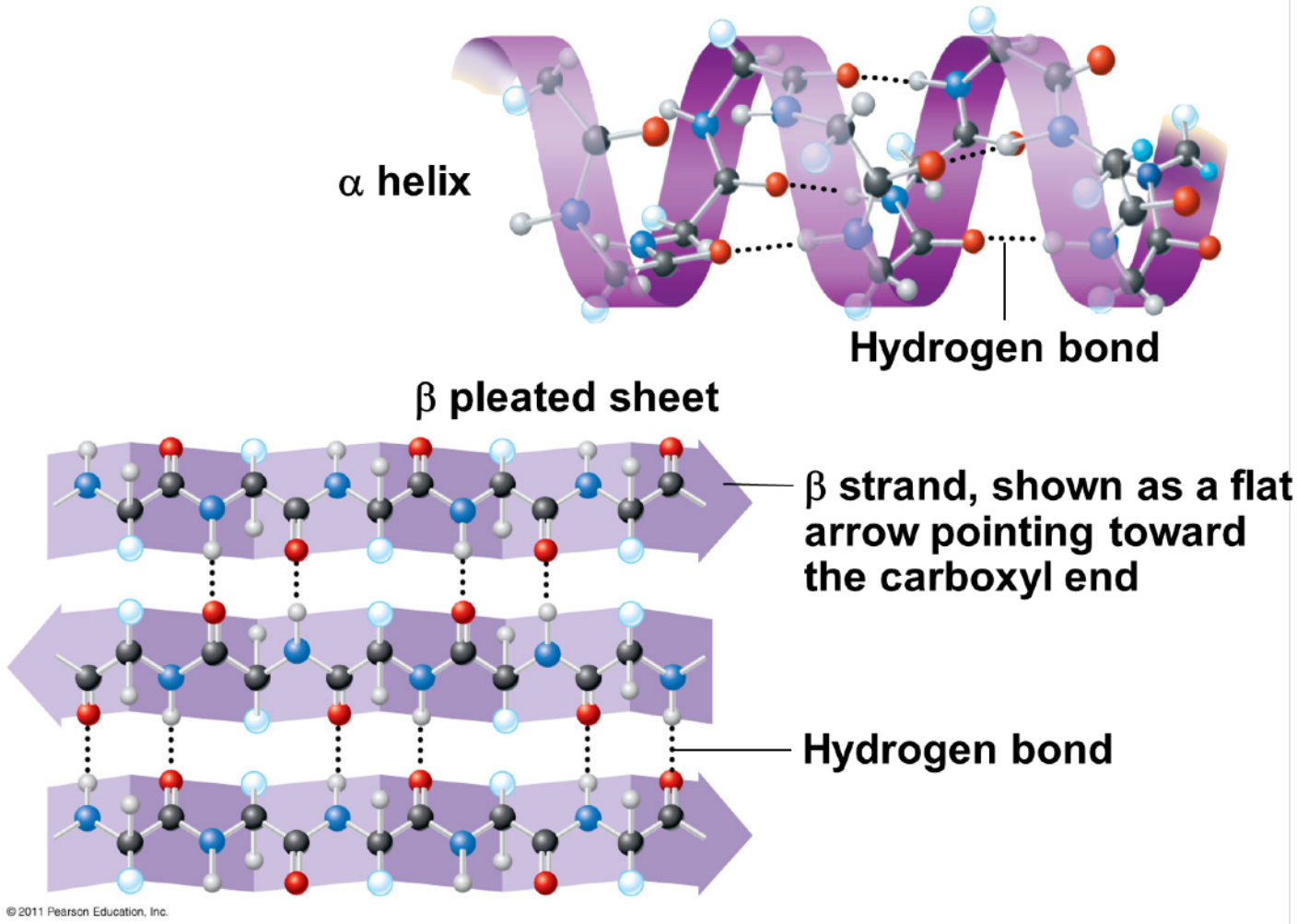
Protein organization

- **Alpha (α) helix:**
  - Helical coil due to the interactions between the amino and carboxyl groups.

- **Beta (β) sheets:**
  - Polypeptide chains fold in a zigzag way.
  - Parallel regions are linked by hydrogen bonds.

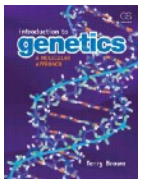
Protein organization

Secondary structure of proteins (2°):



Secondary Structure

- Refers to the different conformations that can be taken up by the polypeptide.
- Two main types:
  - α **helix**
  - β **sheet**
- Stabilized mainly by hydrogen bonds that form between different amino acids in the polypeptide.



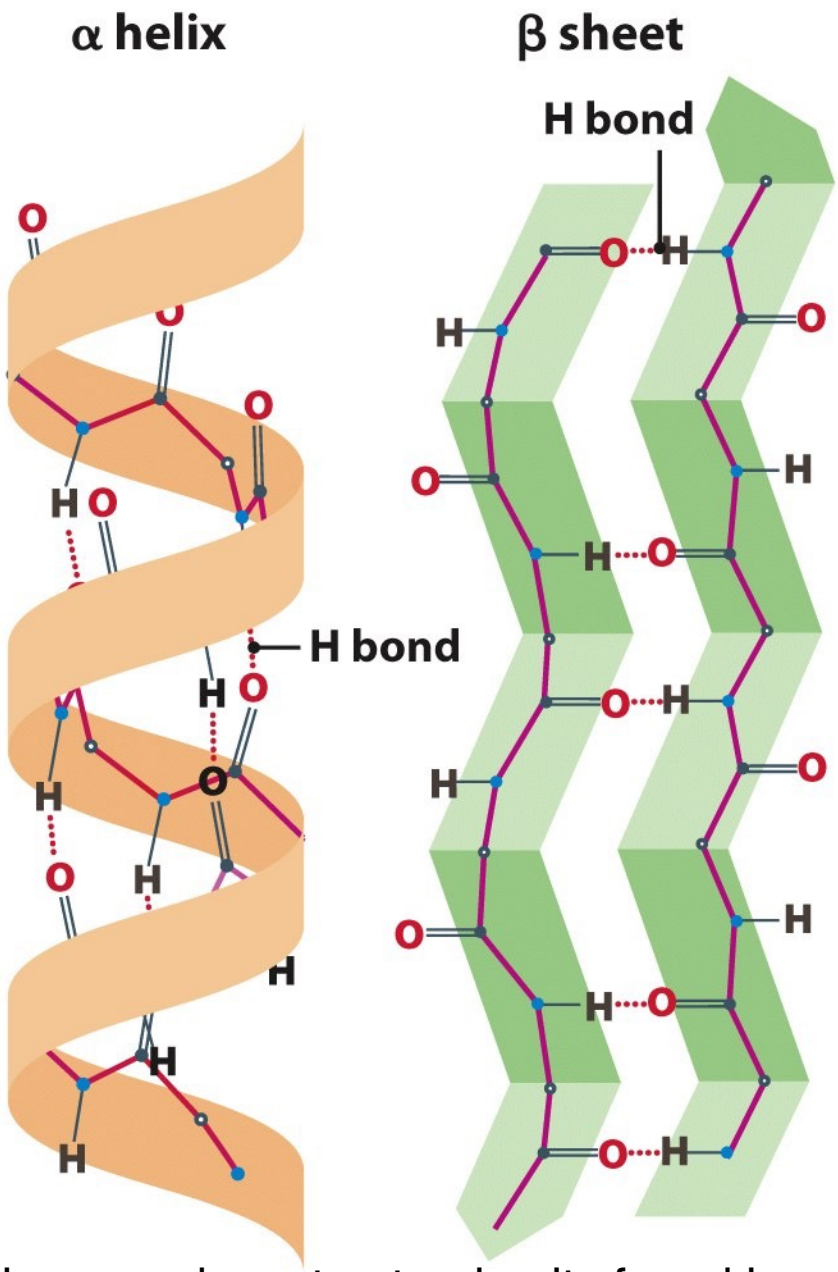
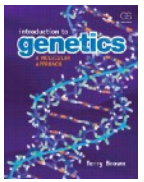


Figure. The two main secondary structural units found in proteins.

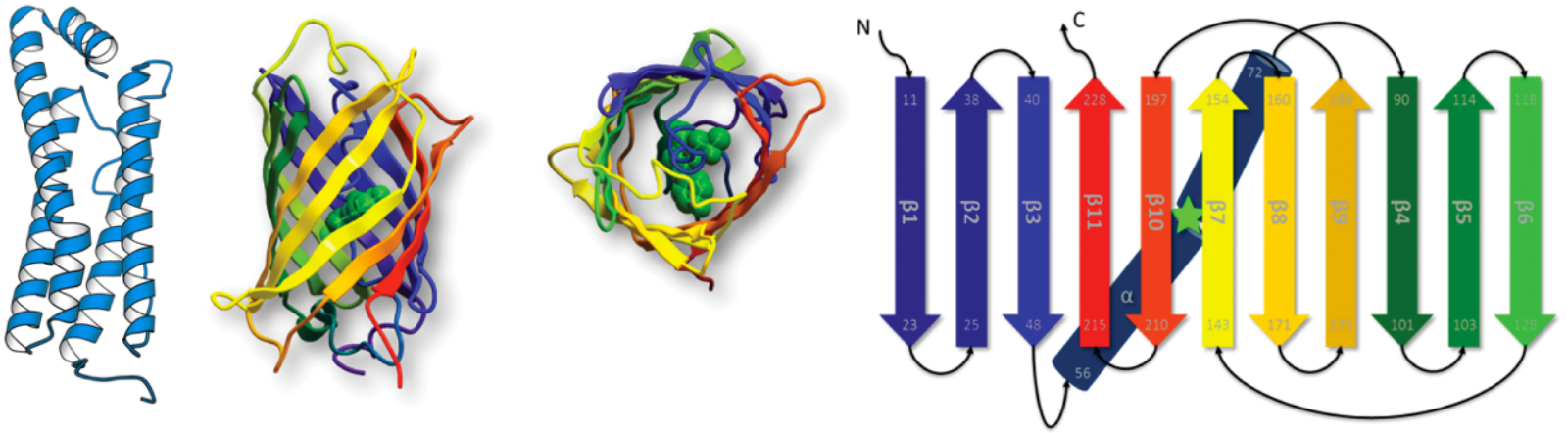


Protein organization

Tertiary structure of proteins (3°):

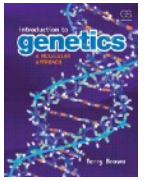
- Three dimensional shape of the protein (**conformation**).

- You can think of this as a combination of secondary structures (α helices and β sheets) put together by bonds and interactions to form the three dimensional shape.



Tertiary Structure

- Results from folding of the secondary structural components of the polypeptide into a three-dimensional configuration
- stabilized by various chemical forces, notably :
  - Hydrogen bonding between individual amino acids
  - Electrostatic interactions between the R groups of charged amino acids
  - Hydrophobic forces



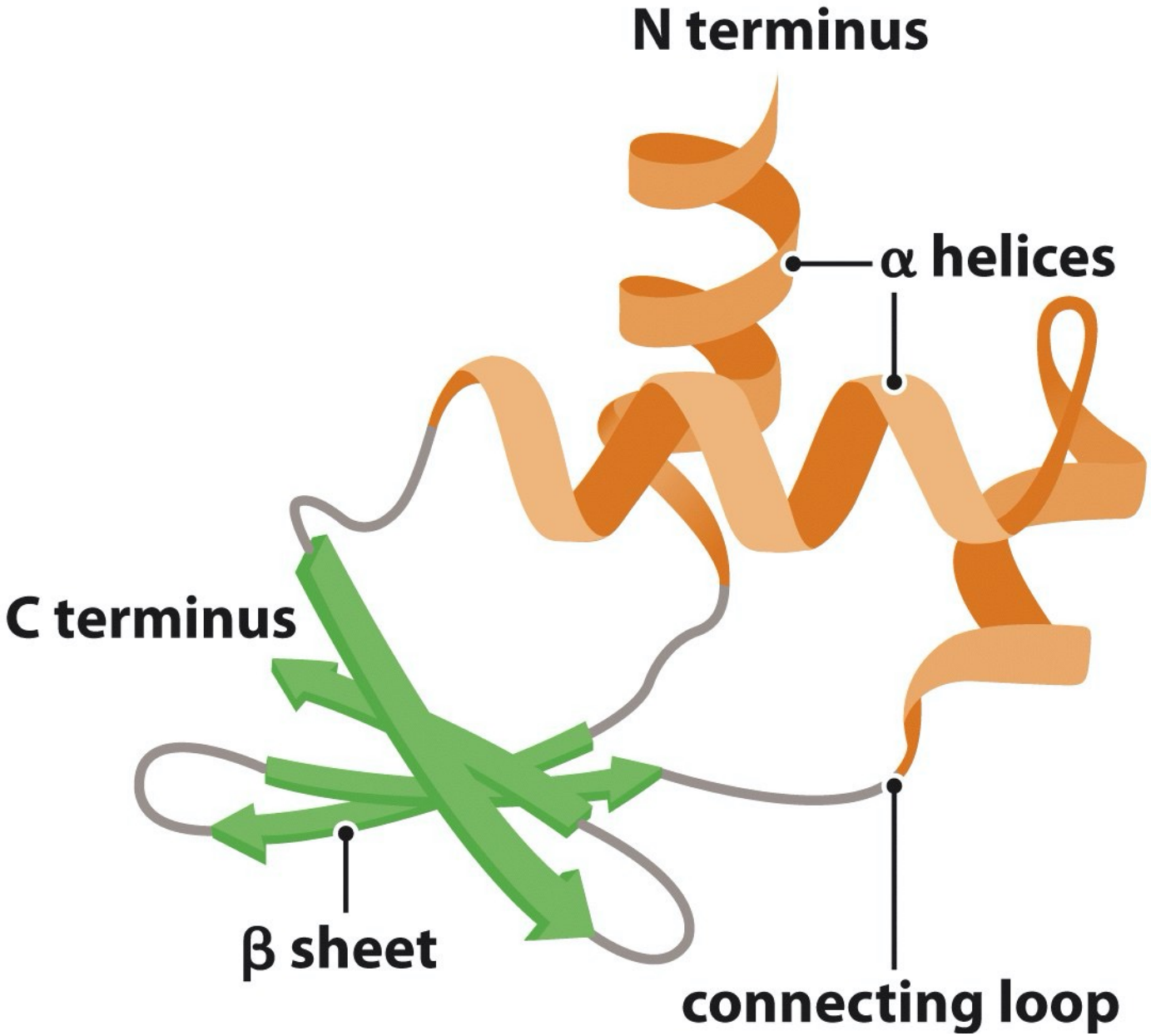
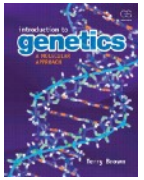
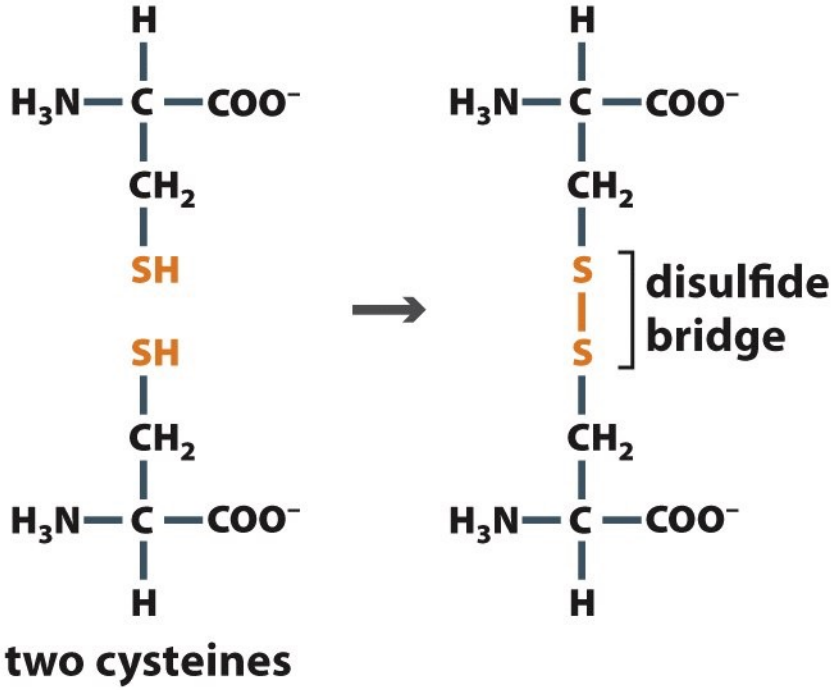


Figure. The tertiary structure of a protein



- There may also be covalent linkages
- Called **disulfide bridges** between cysteine amino acids at various places in the polypeptide



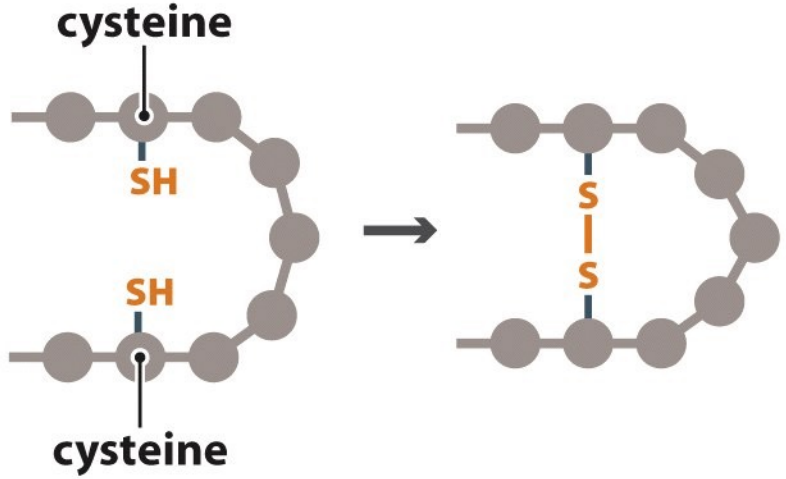


Figure 7.8 Introduction to Genetics (© Garland Science 2012)

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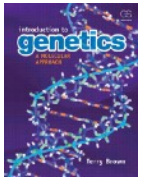


Protein organization

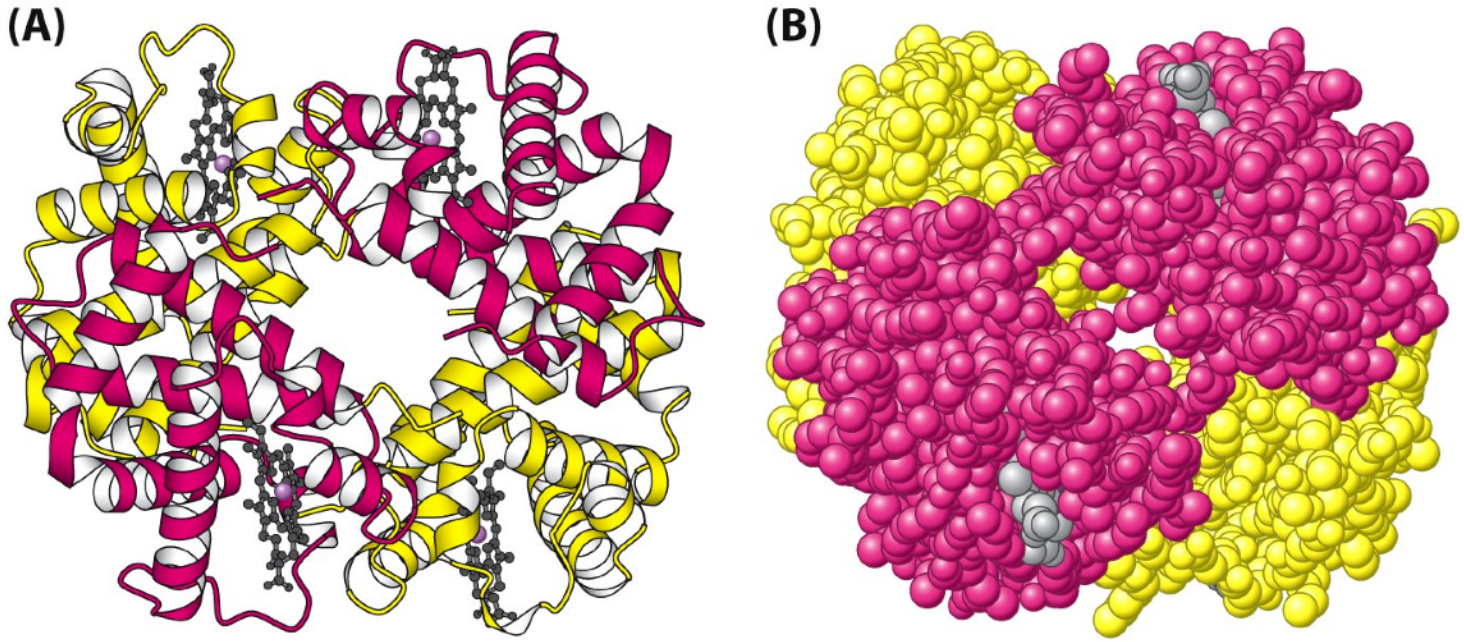
Quaternary structure of proteins (4°):

Many 3° structures (subunits) coming together to make a multi-subunit protein complex.

- **Multimeric** = many subunits
- **Heteromeric** = different subunits.

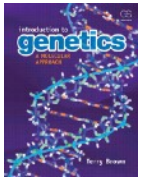
Protein organization

- Good example is **hemoglobin**.
- What is the function of hemoglobin?
- Is it a heteromeric protein or homomeric?

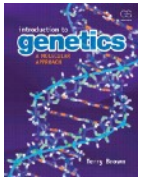


Quaternary Structure

- Involves the association of two or more polypeptides
- Each folded into its tertiary structure, into a multisubunit protein
- Not all proteins form quaternary structures, but it is a feature of many proteins with complex functions



- Quaternary structures are held together by:
  - Disulfide bridges between the different polypeptides, resulting in stable multisubunit proteins
  - Hydrogen bonding and hydrophobic effects, which means that



- The protein coats of tobacco mosaic virus is made up of 2130 identical protein subunits

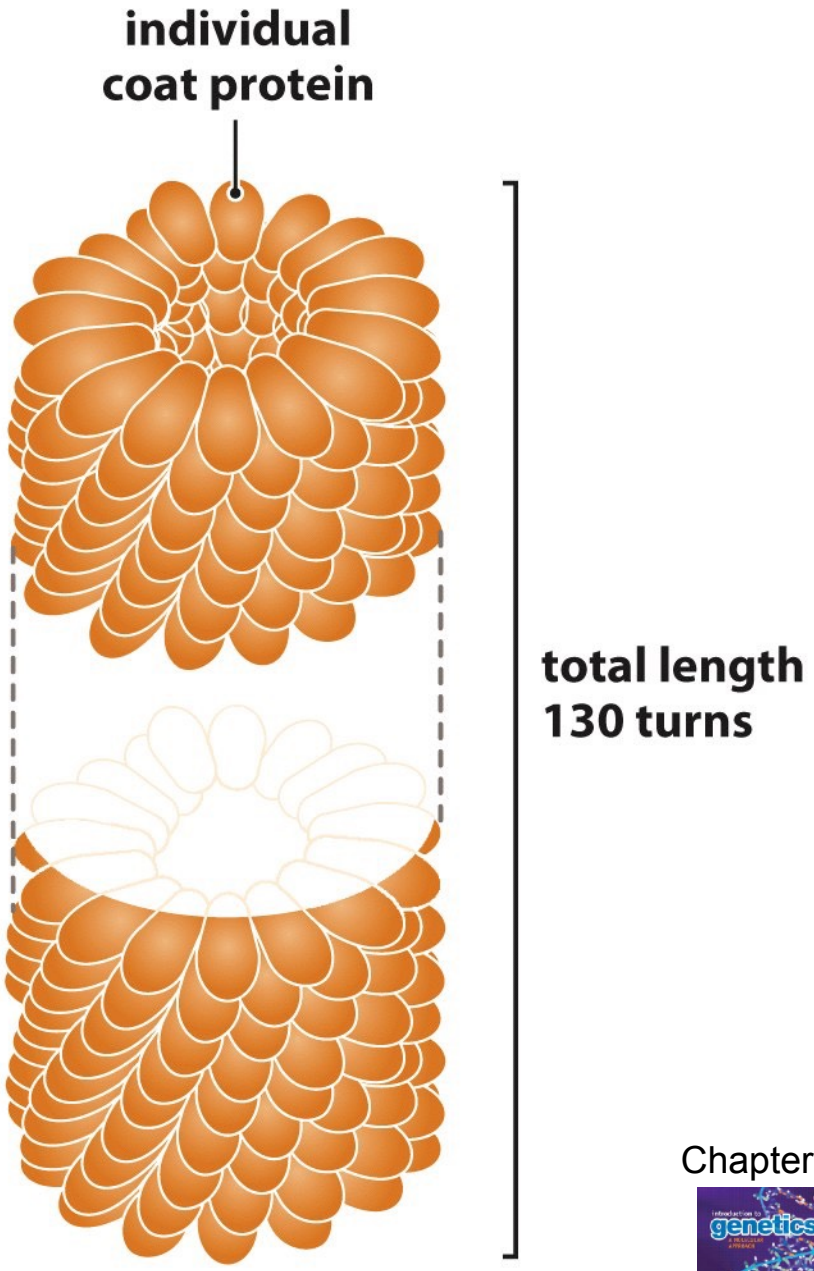
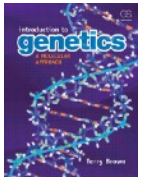
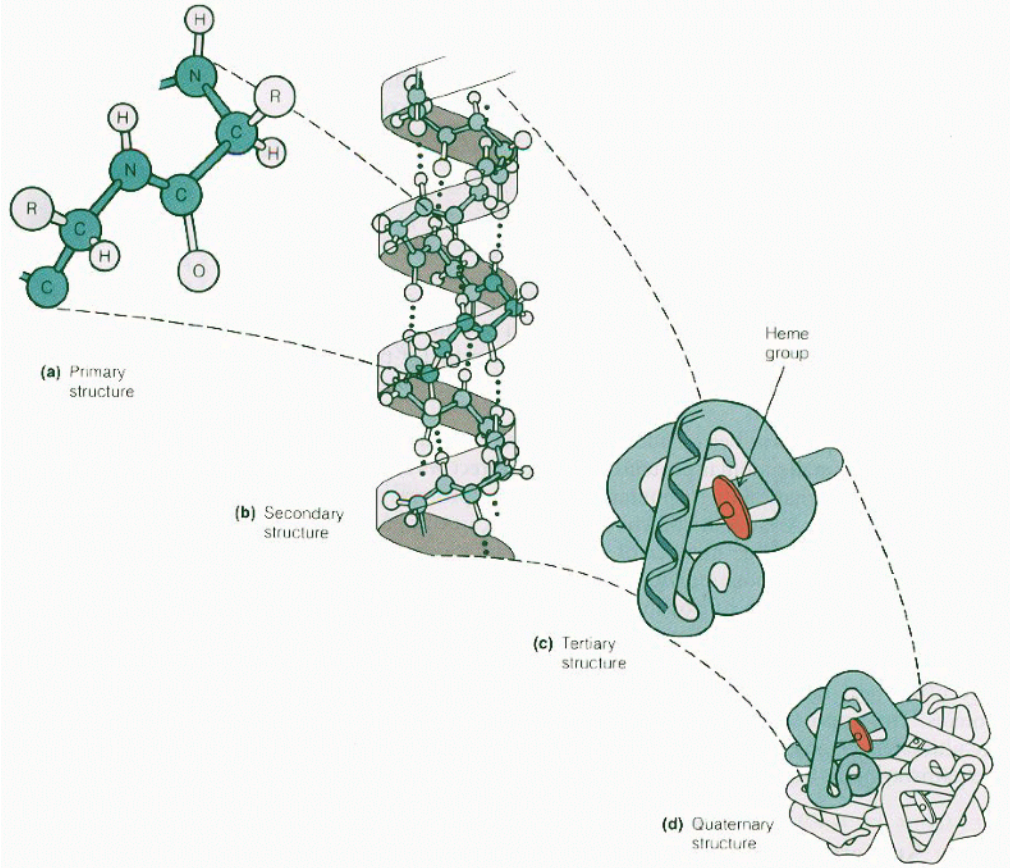


Figure 7.9 Introduction to Genetics (© Garland Science 2012)



Protein organization

The amino acid sequence of a protein is **NOT** sufficient to tell how it is going to fold! (can use predictions)



Stuff to know

Ribosome binding assay

Peptide bond

Primary structure

Basic amino acids

C terminus

N terminus

Gene expression

N - C

Nonpolar amino acids

α helix

Polar amino acids

Amino acids

Hydrogen bonds

R group

Condensation reaction

β sheets

Acidic amino acids

Tertiary structure

Amino group

Carboxyl group

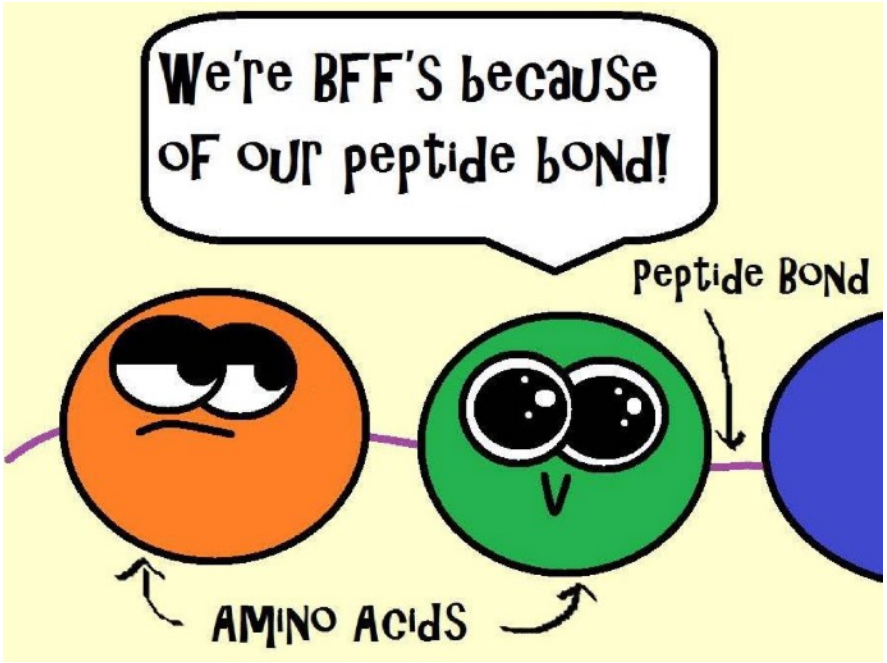
Secondary structure

Quaternary structure

Expectations

- You know the product of translation and gene expression.
- You know the chemical composition of proteins and how they are made.
- You know the protein organization.

For fun


We're BFF'S because of our peptide bond!
Peptide Bond
AMINO Acids