Hogeschool van Arnhem en Nijmegen
HAN University of Applied Sciences

Course bi5b chemistry: Chapter 18
Amino acids and proteins



HAN www.han.nl

Reference

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Fundamentals of General, Organic, and Biological

Chemistry

Seventh Edition

John McMurry
Cornell University

David S. Ballantine
Northern Illinois University

Carl A. Hoeger
University of California, San Diego

Virginia E. Peterson
University of Missouri, Columbia

PEARSON

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Studiewijzer

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- 18.5
  - je kent de begrippen chiraal en a-chiraal
- 18.6
  - je kan uitleggen wat chirale moleculen zijn
  - je kan uitleggen waar in een molecuul chirale C-atomen zitten
  - je weet wat enantiomeren zijn
  - je weet wat optische isomeren zijn
  - je weet wat stereo-isomeren zijn

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(Reference: Chapter18 from McMurry et al.)

Studiewijzer

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- 18.7
  - je kan uitleggen wat de primaire structuur van een eiwit is
- 18.8
  - je weet welke interacties in eiwitten de ruimtelijke structuur bepalen
    - waterstofbruggen
    - ion-interacties (zoutbruggen)
    - hydrofobe interacties
    - zwavelbruggen

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(Reference: Chapter18 from McMurry et al.)

18.5 “Handedness”

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- **Voorwerpen die elkaars spiegelbeeld zijn maar NIET met elkaar “tot dekking”te brengen zijn.**
  - **linker en rechter hand, schoen, handschoen**

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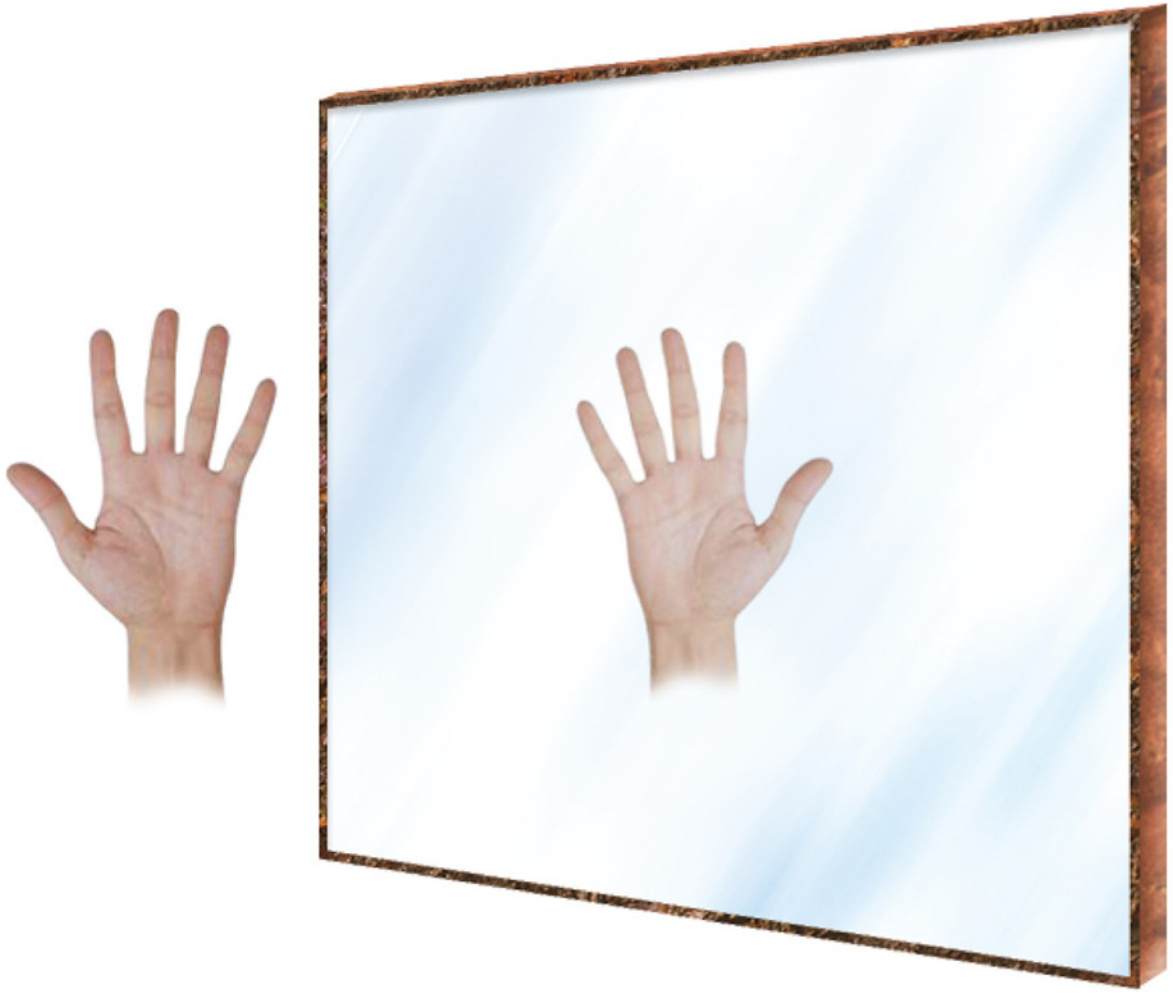
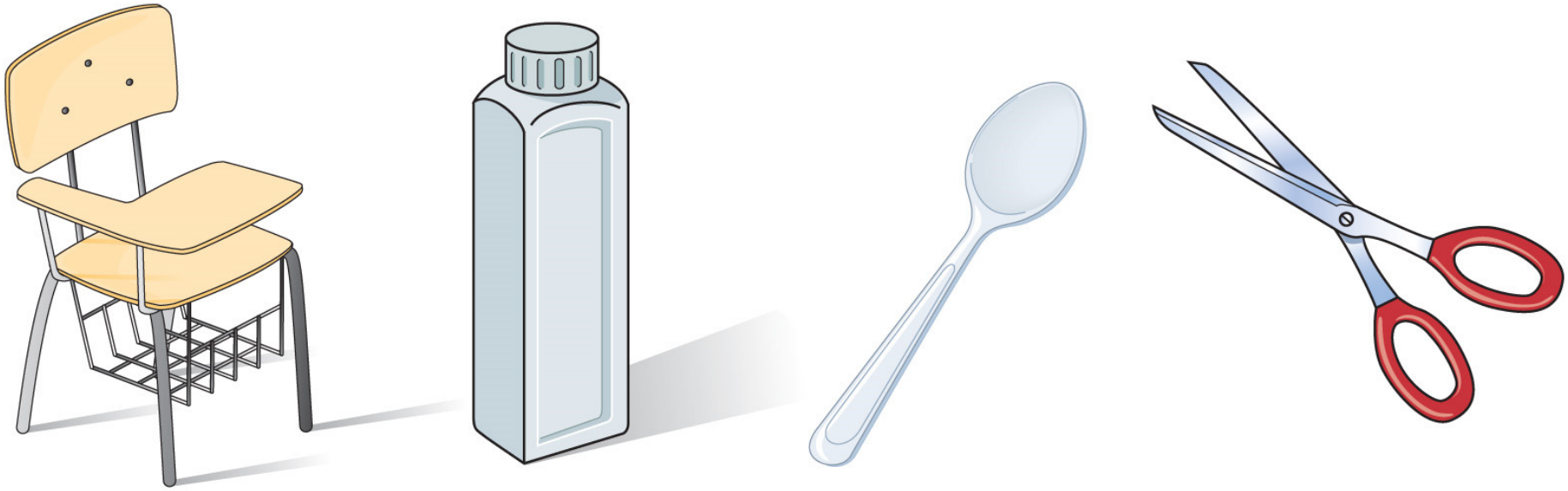
18.5 Een CHIRAAL voorwerp



18.5 Een ACHIRAAL voorwerp

18.5 Welke zijn chiraal ?



(a) (b) (c) (d)

18.9 Chiral: (a), (b), and (d)

18.6 (A)chirale moleculen

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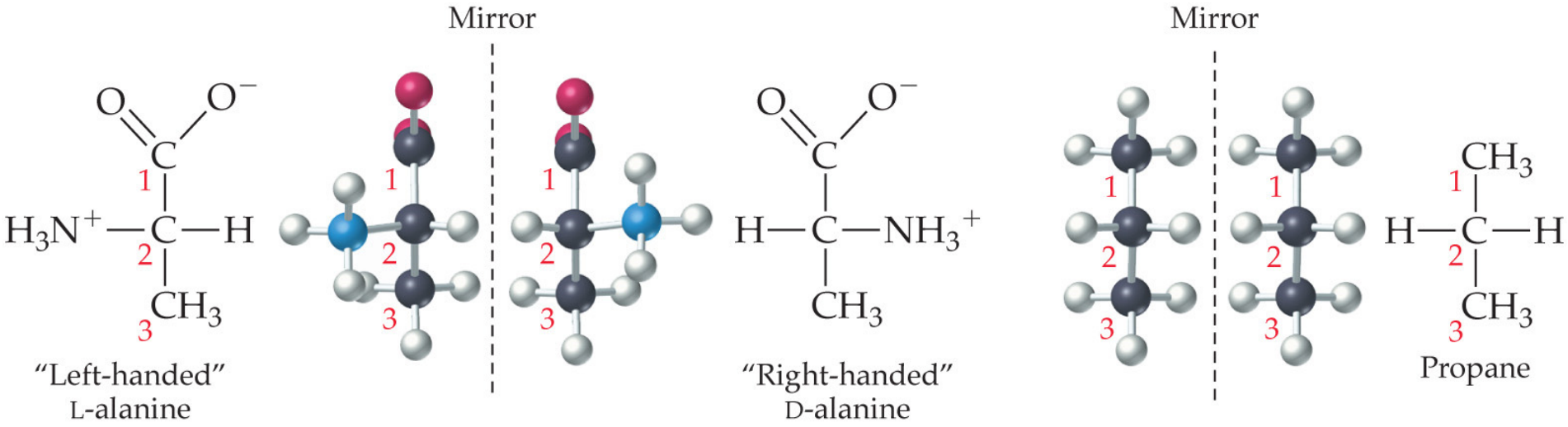
Alanine, a chiral molecule

Propane, an achiral molecule



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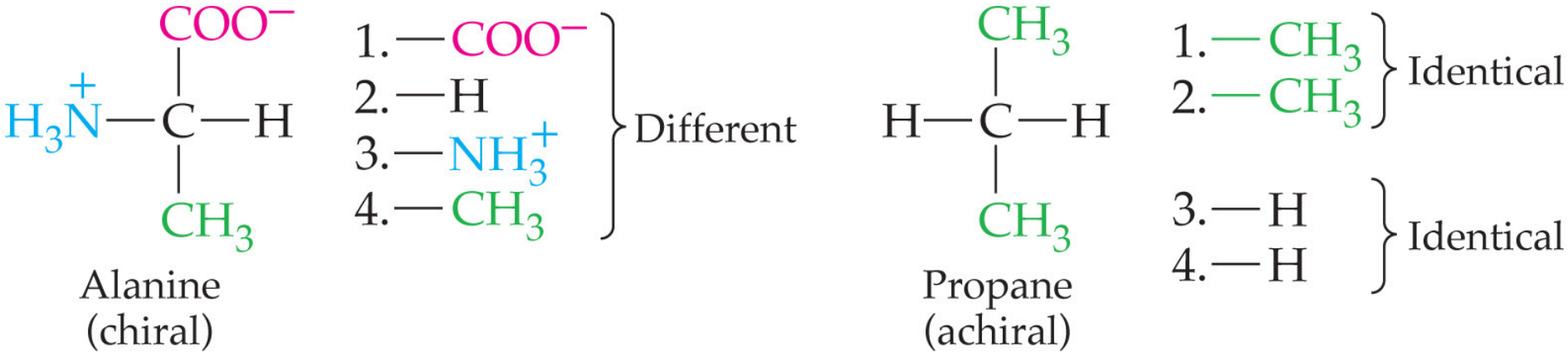
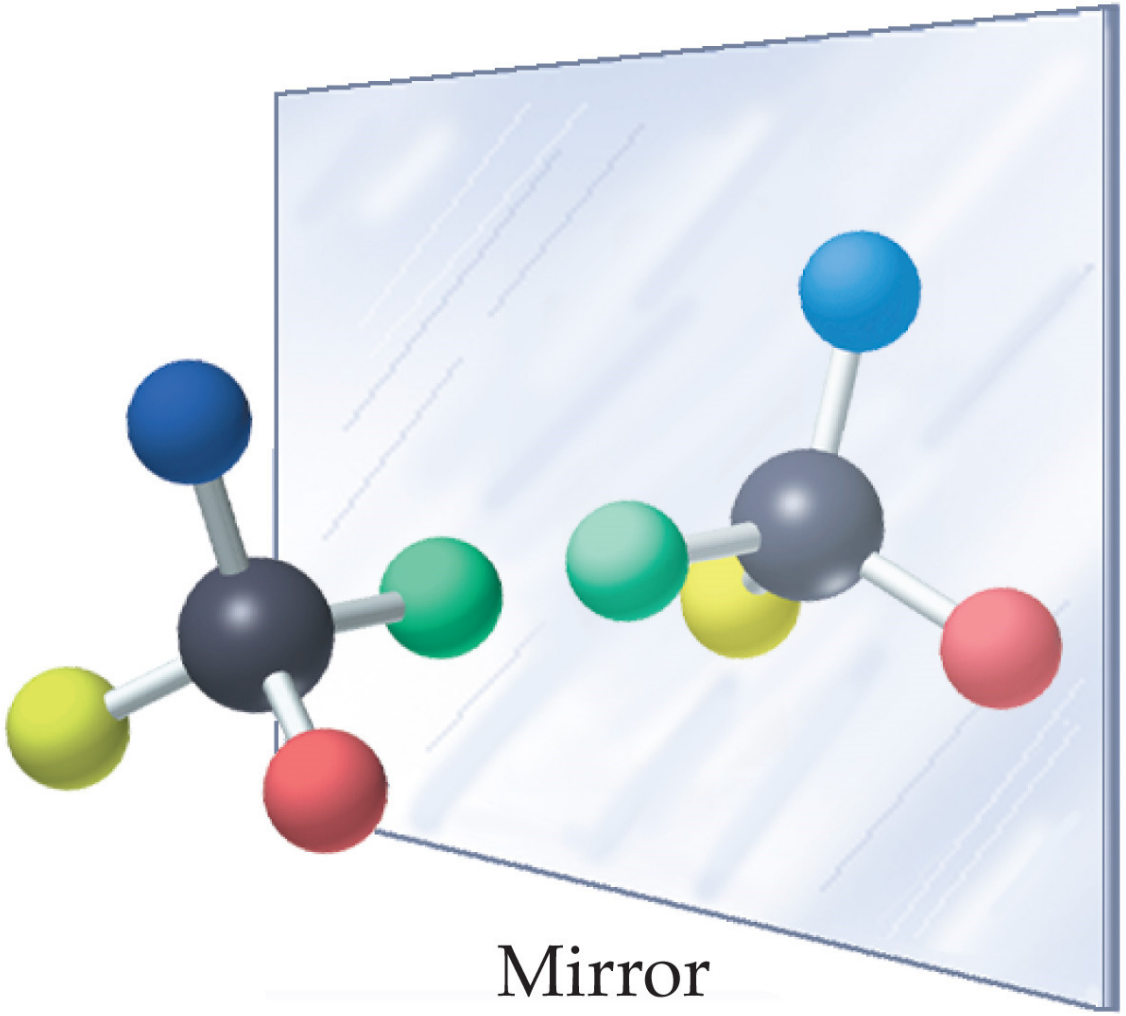
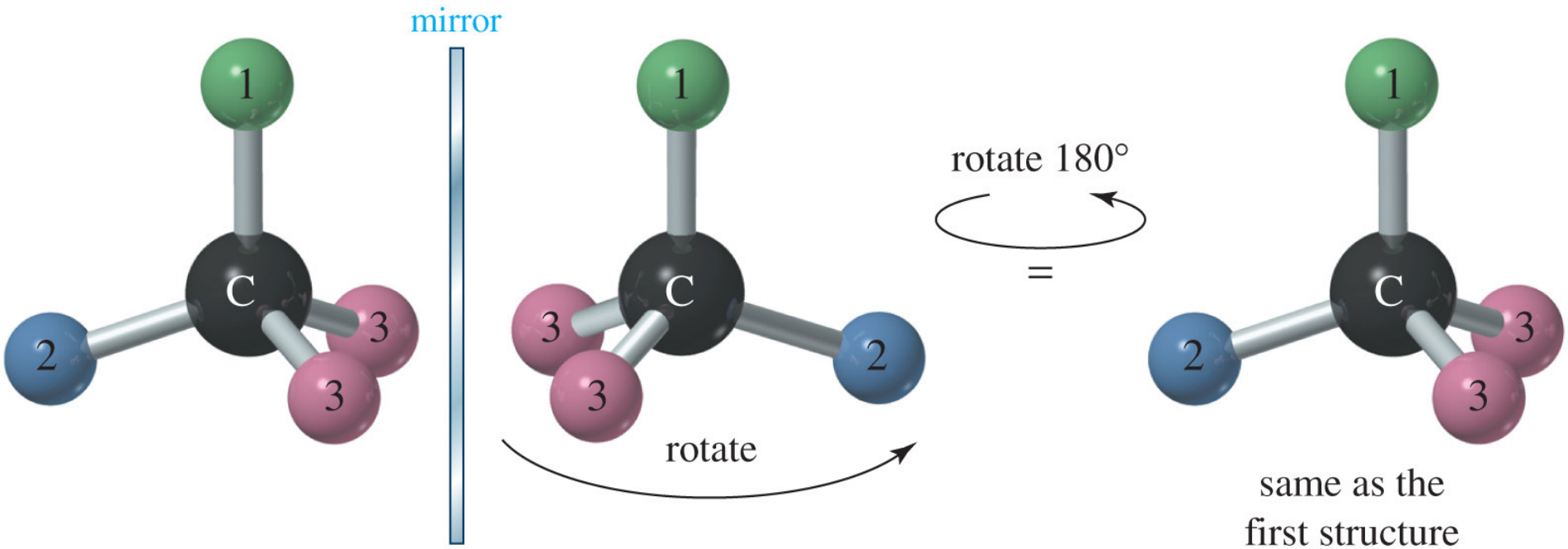
18.6 Vier verschillende groepen



18.6 Mirror

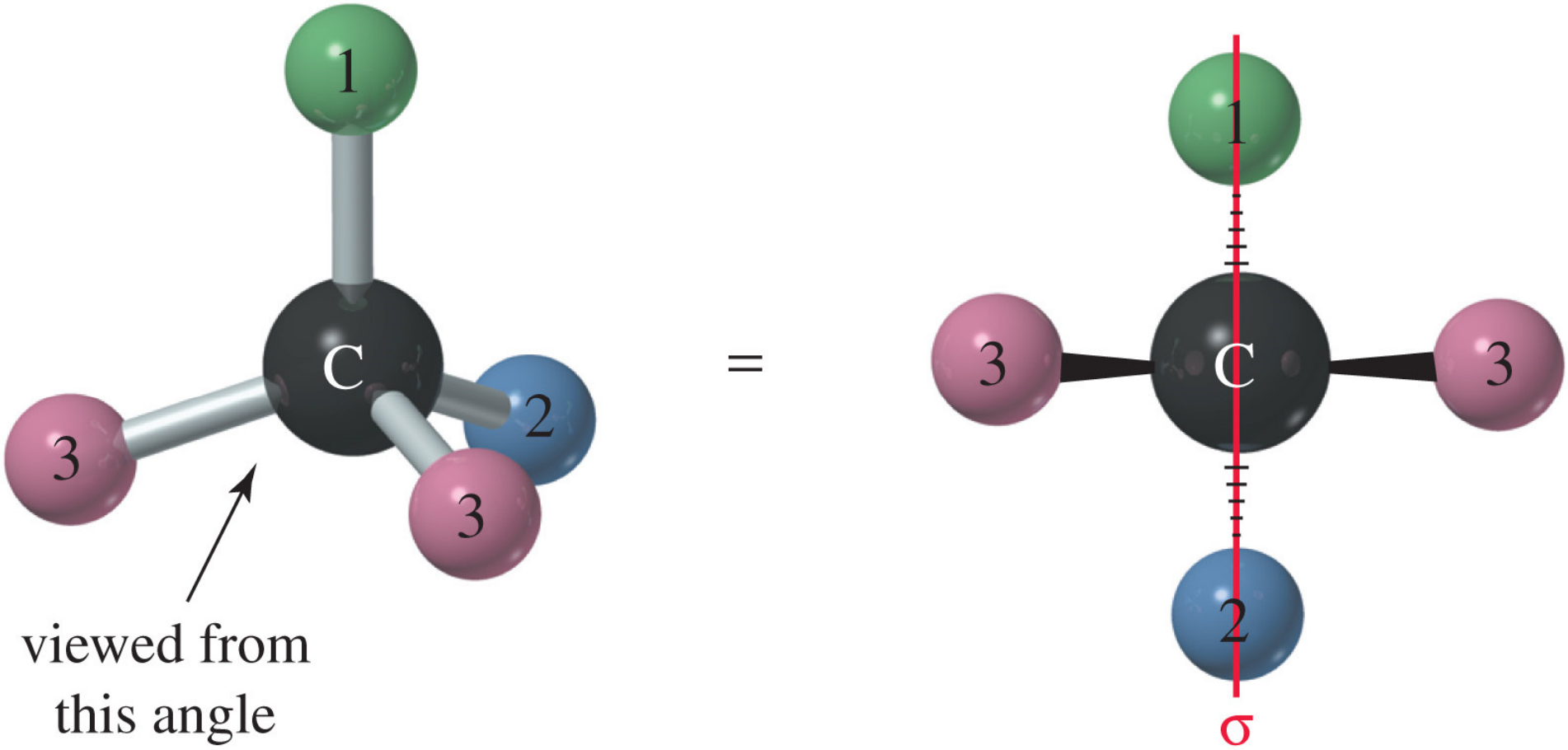


18.6 Achiraal



Na spiegelen zijn deze moleculen **WEL** over elkaar heen te leggen. Ze zijn dus **NIET** chiraal, oftewel achiral.

18.6 Symmetrievlak: achiraal



18.6 Welke aminozuren zijn chiraal?

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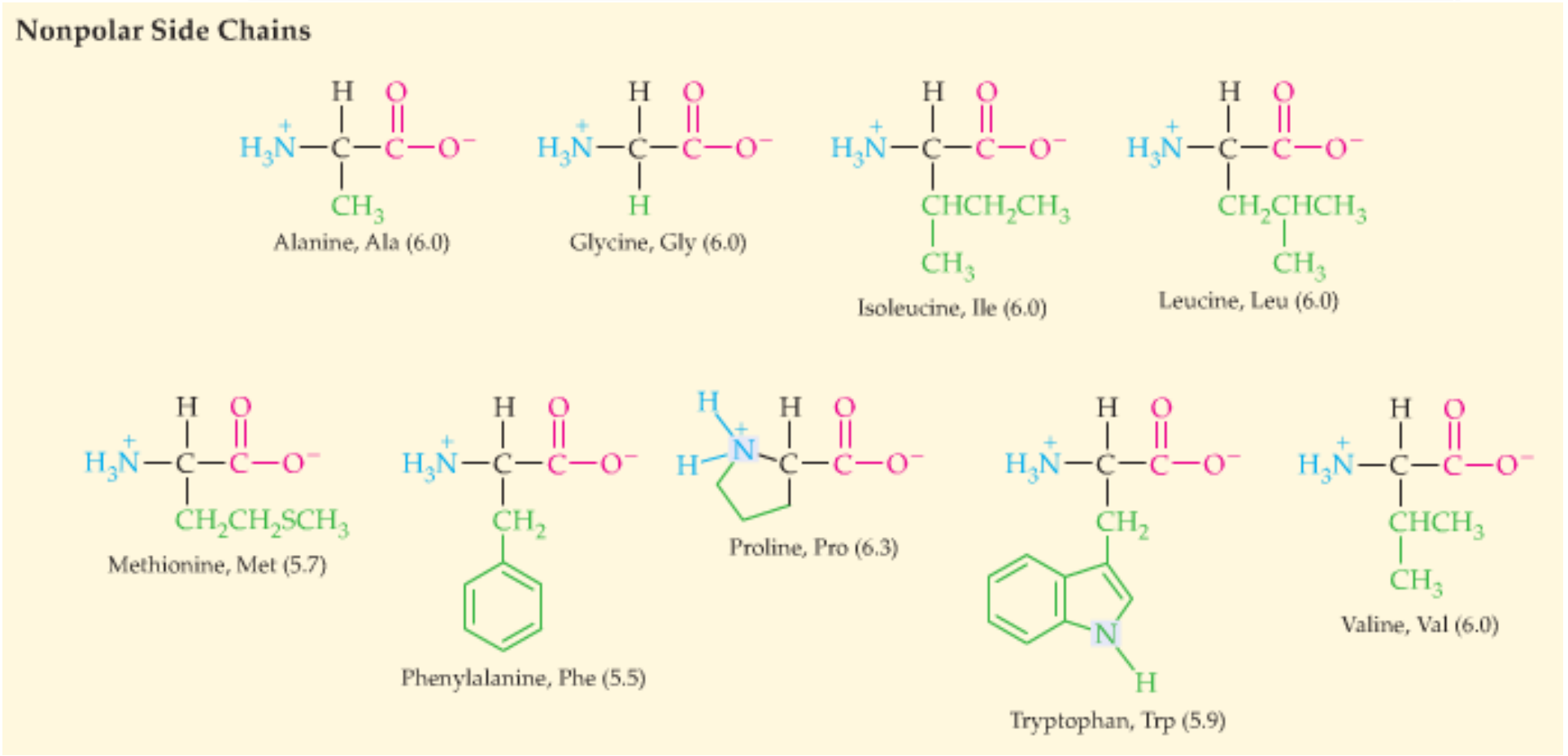

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(Reference: Chapter18 from McMurry et al.)

18.6 Stereo-isomeren

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- **Moleculen met dezelfde molecuul- en structuurformule maar de ruimtelijke rangschikking van de atomen verschilt.**
  - **diastereomeren**
    - **géén spiegelbeeld en nìet met elkaar tot dekking te brengen**
    - **b.v. cis-trans-isomeren**
  - **enantiomeren**
    - **wèl spiegelbeeld en nìet met elkaar tot dekking te brengen**

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(Reference: Chapter18 from McMurry et al.)

18.6 Cis-trans isomeren

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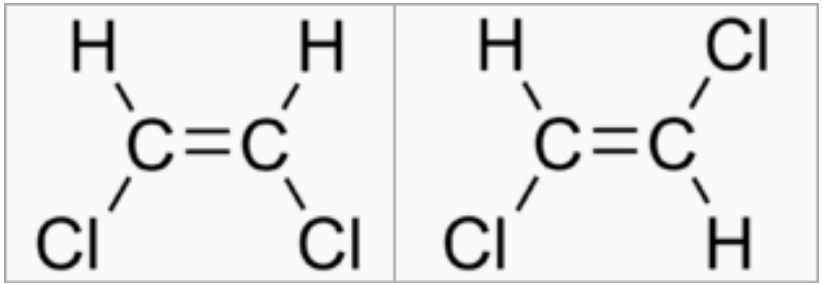
De woordelementen *cis* en *trans* komen uit het Latijn, waarin *cis* betekent 'aan dezelfde kant' en *trans* 'aan de andere kant' of 'eroverheen‘.



cis-1,2-dichlooretheen of *Z*-1,2-dichlooretheen	*trans*-1,2-dichlooretheen of *E*-1,2-dichlooretheen

E: Entgegen - tegengesteld

Z-configuratie (*zusammen*): de twee atomen met het hoogste atoomnummer zitten aan dezelfde zijde van de dubbele binding.

(Reference: https://nl.wikipedia.org/wiki/Cis-trans-isomerie

18.6 Enantimeren = optische isomeren

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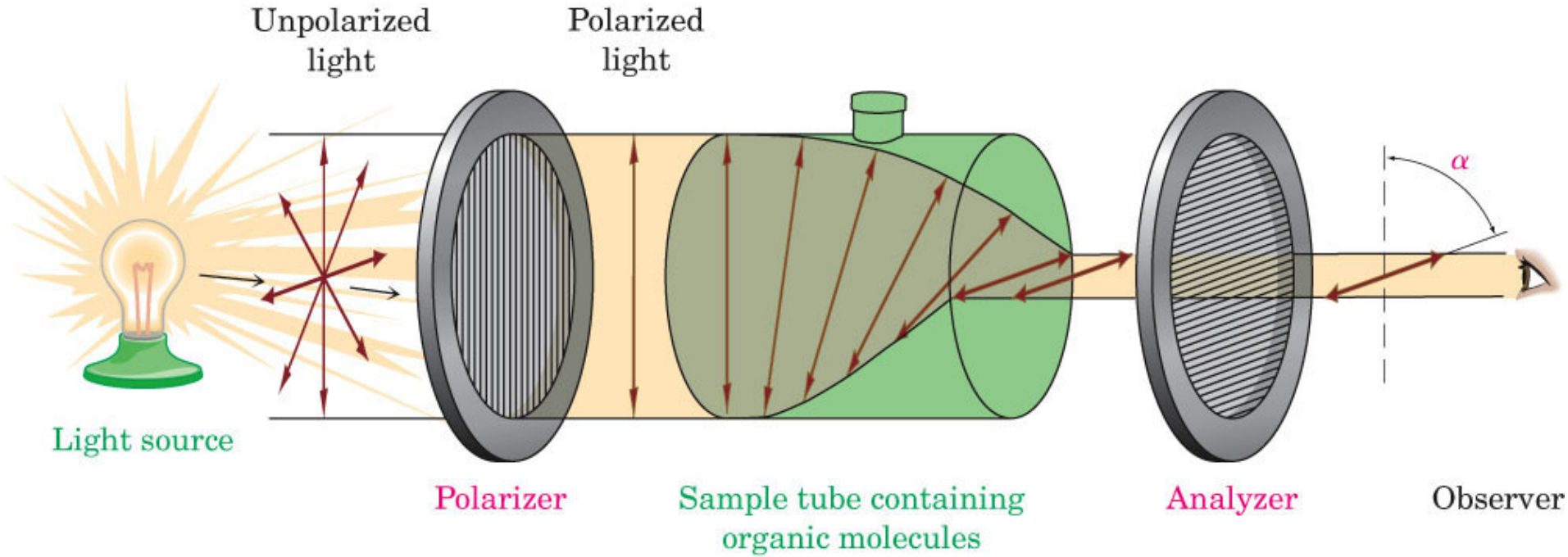
- **optische activiteit**



Specific rotation (using sodium D line)

Observed rotation (degrees)

$$[\alpha]_D = \frac{\alpha}{(c)\,(l)}$$

Concentration (g/mL)

Length of sample tube (dm)

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18.6 Biologische (in)activiteit

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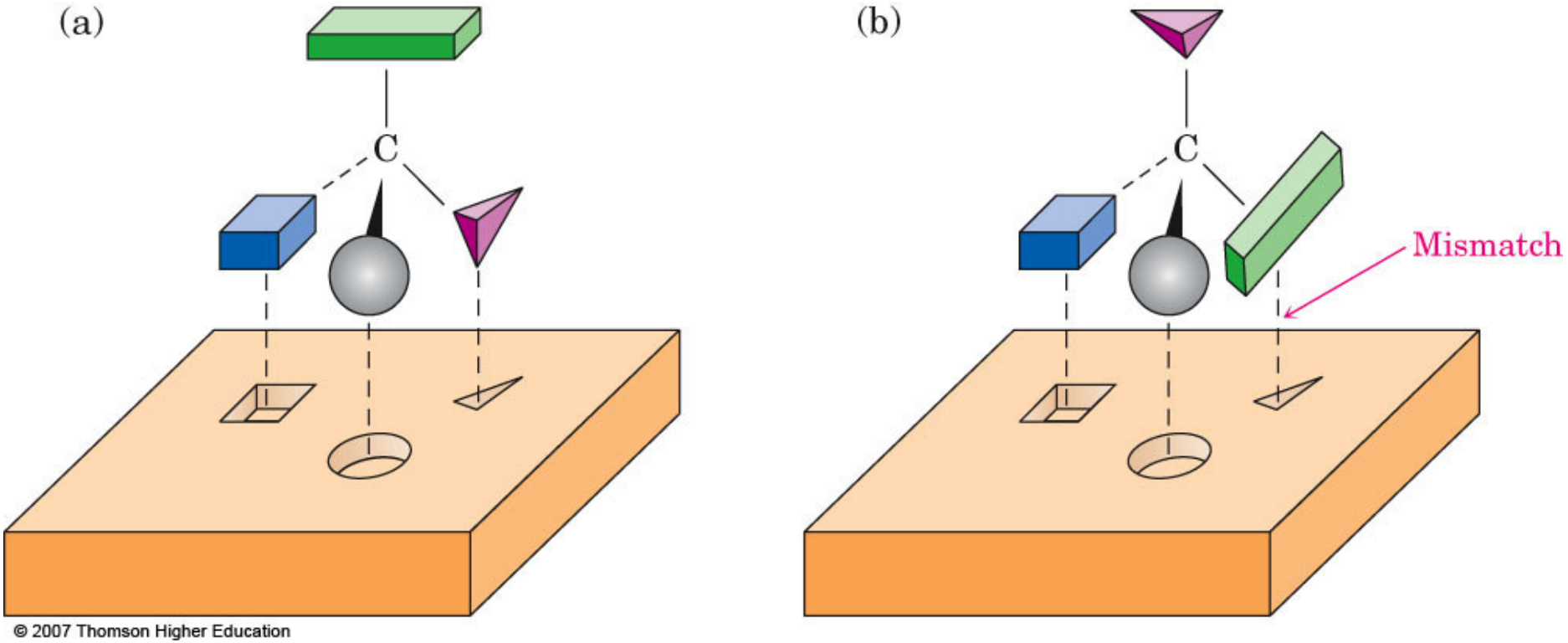

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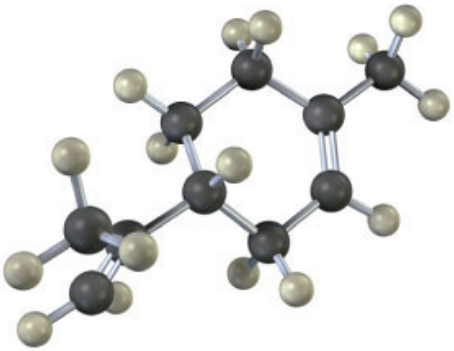
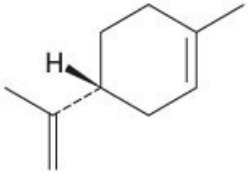
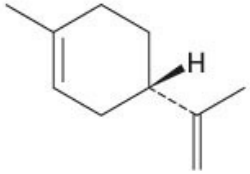
18.6 Nutteloze feitjes …

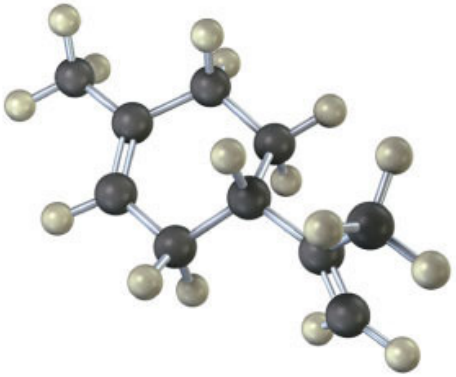


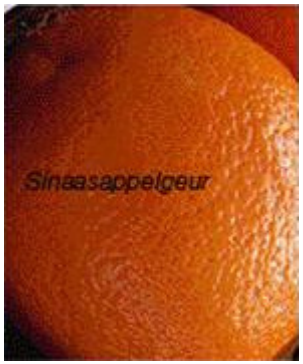


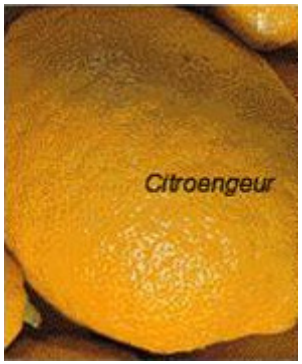
(+)-Limonene
(in oranges)



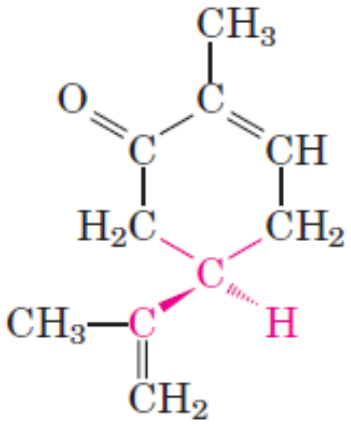
(−)-Limonene
(in lemons)



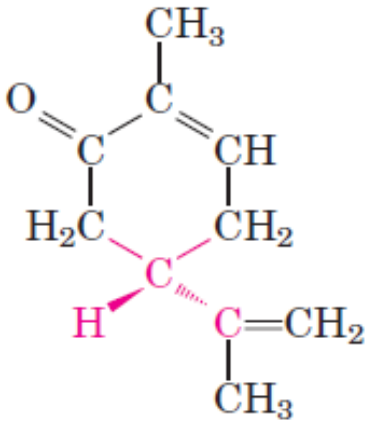




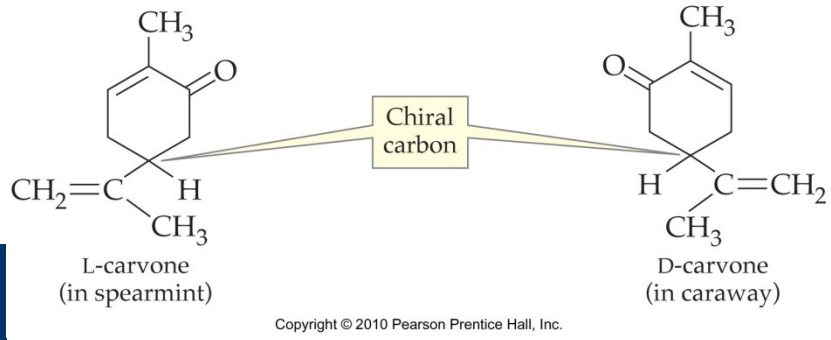
18.6 Nutteloze feitjes …



(*R*)-Carvone
(spearmint)



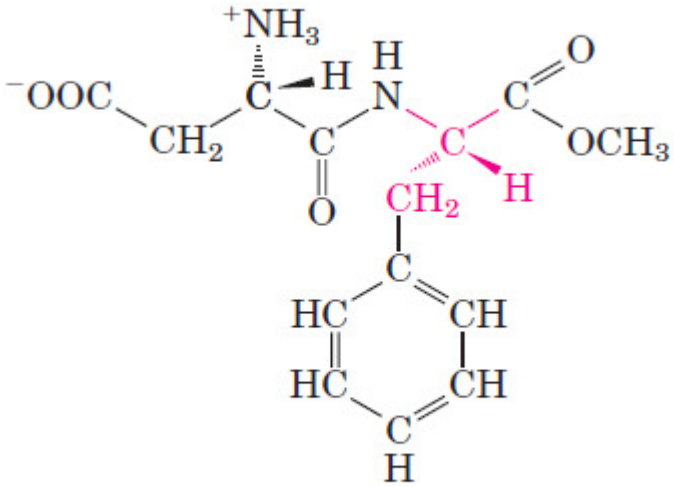
(*S*)-Carvone
(caraway)



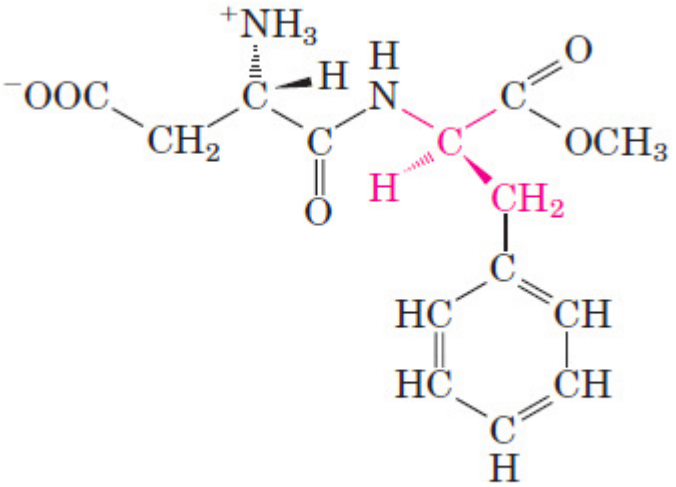
L-carvone
(in spearmint)

D-carvone
(in caraway)

18.6 Nutteloze feitjes …



L-Aspartyl-L-phenylalanine methyl ester
(aspartame) (sweet)

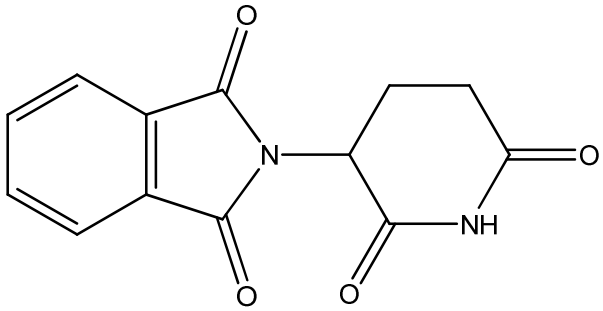


L-Aspartyl-D-phenylalanine methyl ester
(bitter)

18.6 Nutteloze feitjes …

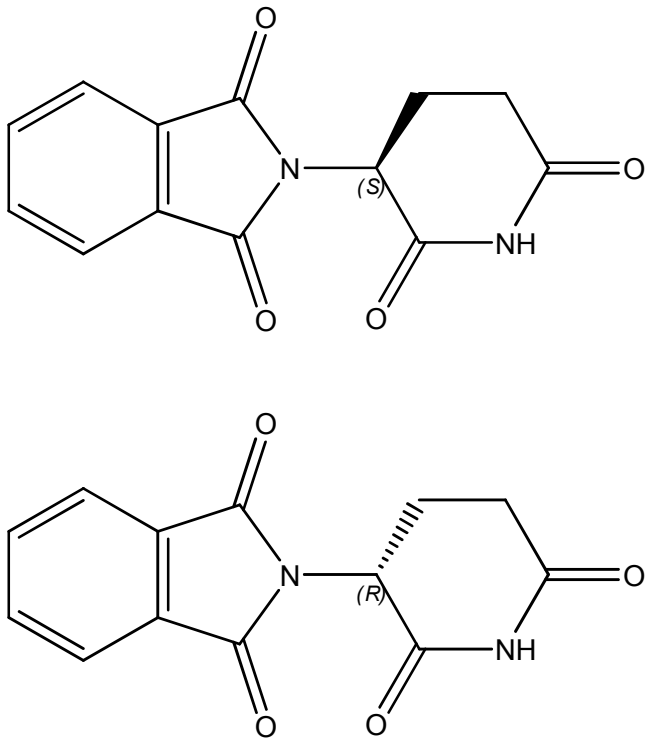
Thalidomide

“softenon”

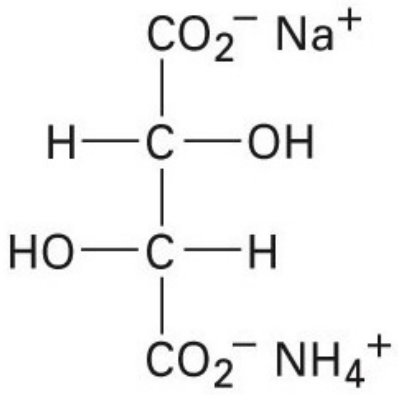


18.6 Nutteloze feitjes …

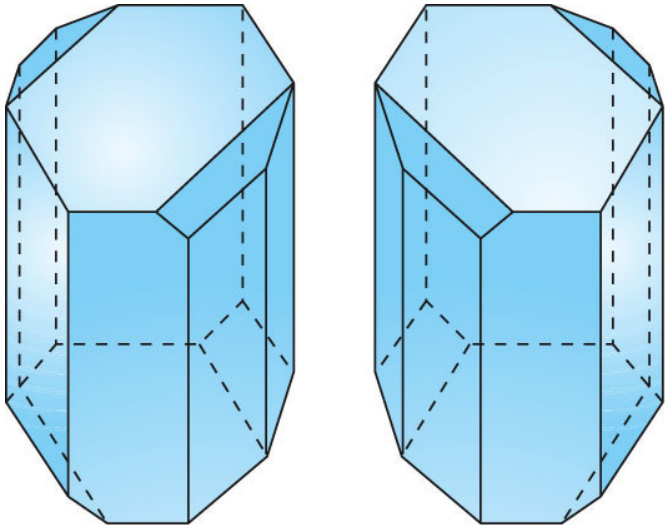
- **Slaapmiddel en middel tegen ‘ochtendmisselijkheid’**



18.6 Nutteloze feitjes …



Sodium ammonium tartrate



18.6 Problems

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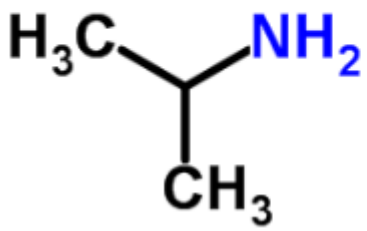
PROBLEM 18.11

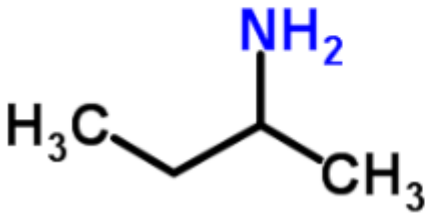
2-Aminopropane is an achiral molecule, but 2-aminobutane is chiral. Explain.



2-Aminopropane

Molecular Formula	C_3H_9N
Average mass	59.110 Da
Monoisotopic mass	59.073498 Da
ChemSpider ID	6123

http://www.chemspider.com/Chemical-Structure.6123.html



(±)-sec-Butylamine

Molecular Formula	$C_4H_{11}N$
Average mass	73.137 Da
Monoisotopic mass	73.089149 Da
ChemSpider ID	23255

http://www.chemspider.com/Chemical-Structure.23255.html

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18.6 Problems

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PROBLEM 18.12

Which of the following molecules are chiral?

(a) 3-Chloropentane

(b) 2-Chloropentane

(c) $CH_3CHCH_2CHCH_2CH_3$ (with CH_3 branches on the 2nd and 4th carbons)

PROBLEM 18.13

Two of the 20 common amino acids have two chiral carbon atoms in their structures. Identify these amino acids and their chiral carbon atoms.

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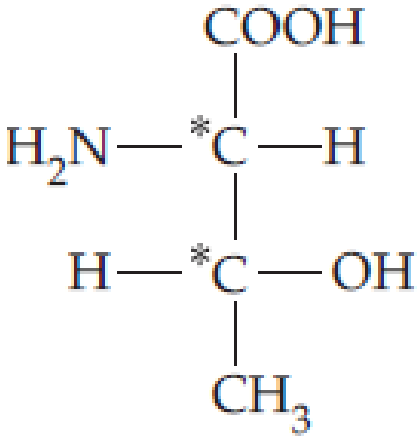
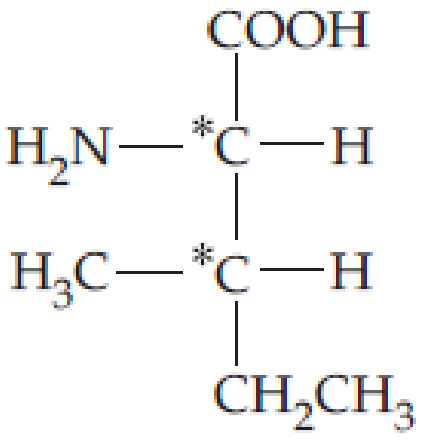
18.6 Problem 18.3



Threonine



Isoleucine

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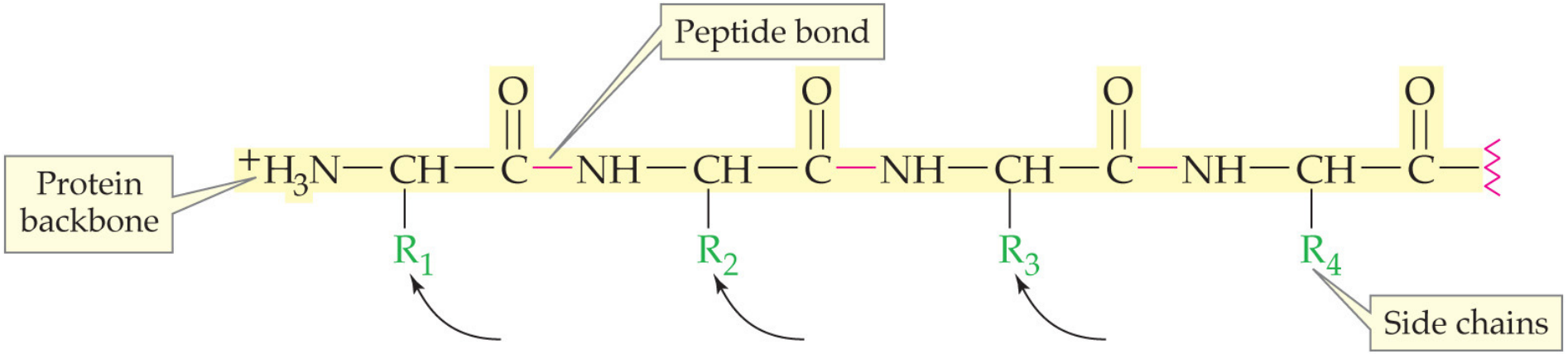
18.7 Primaire structuur

- **De volgorde waarin de aminozuren gekoppeld zijn.**



De peptideband is VLAK

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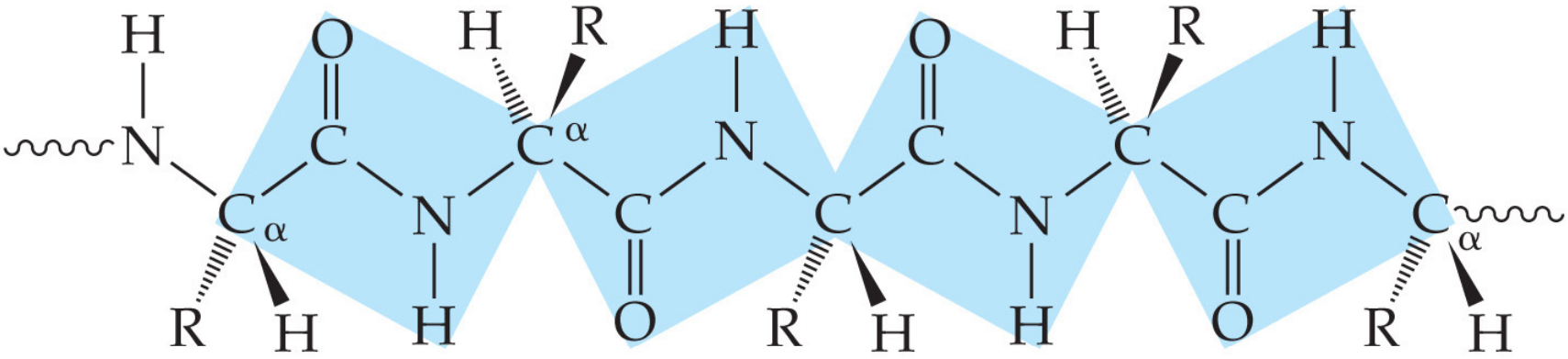
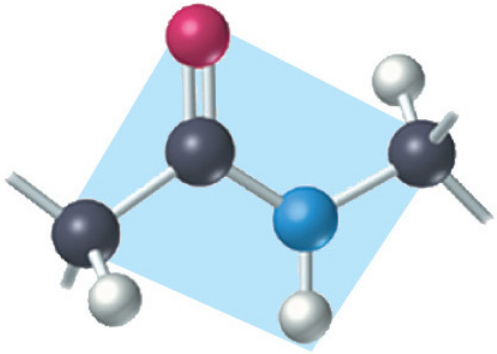
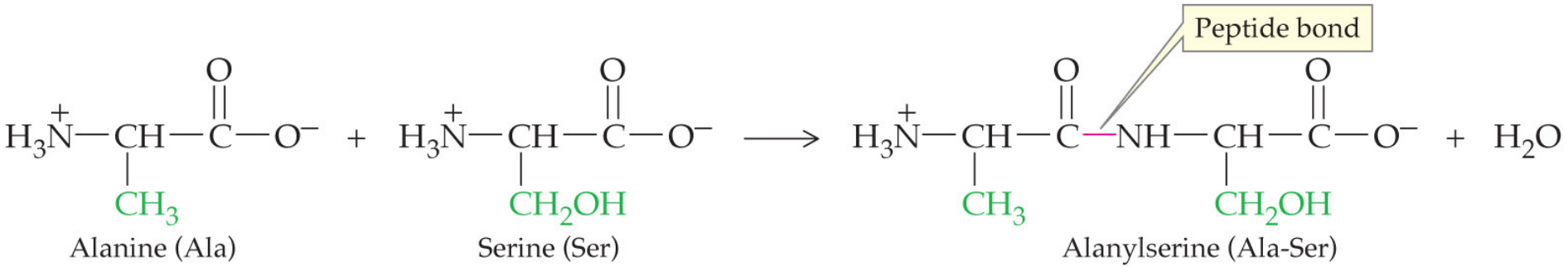
Planar units along a protein chain

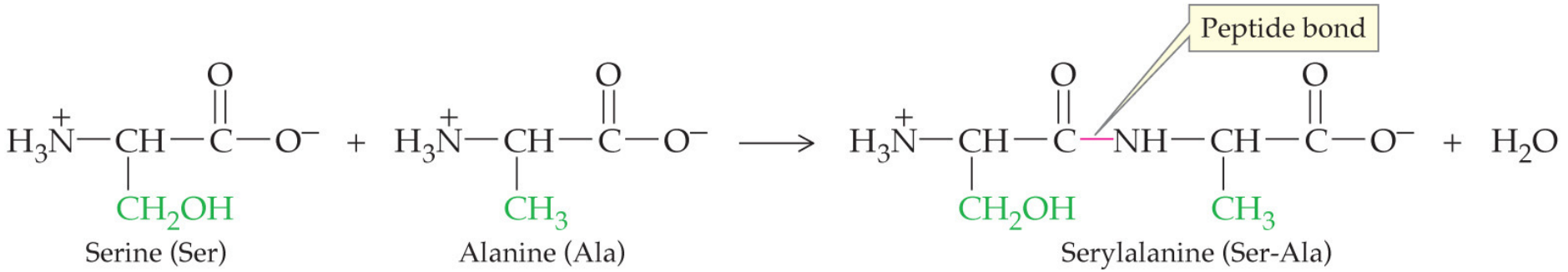


One planar unit

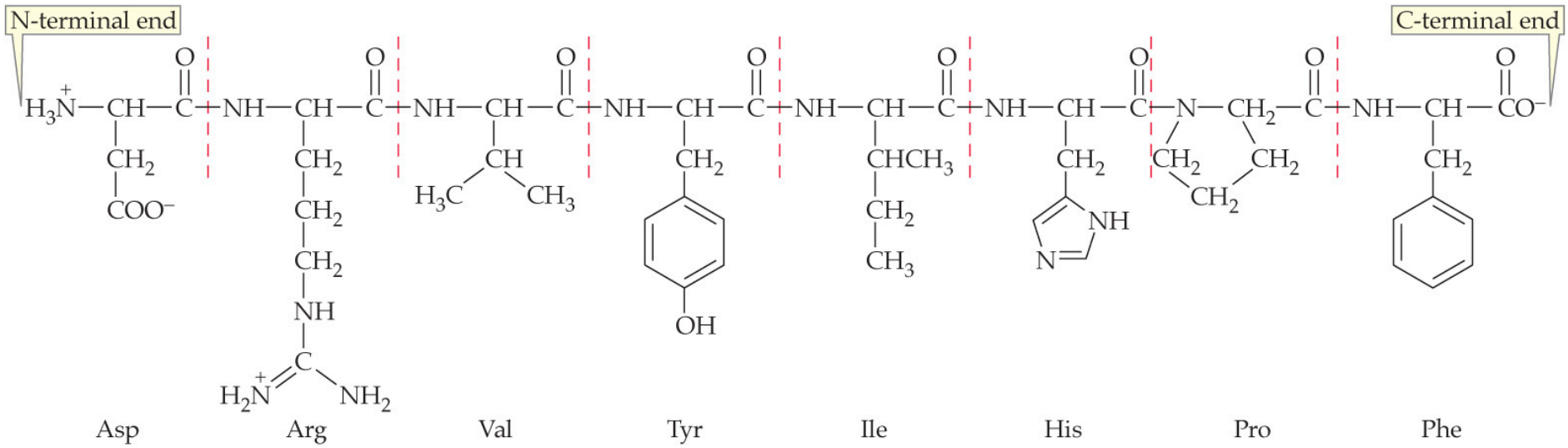


Vorming peptide-binding

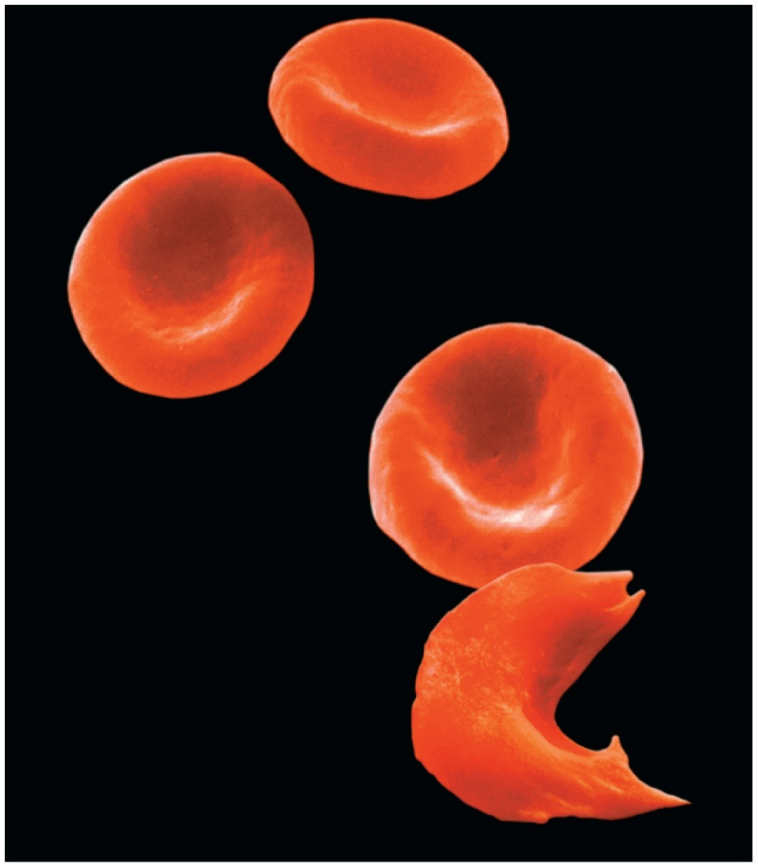




N- en C-terminaal



Foutje in de primaire structuur



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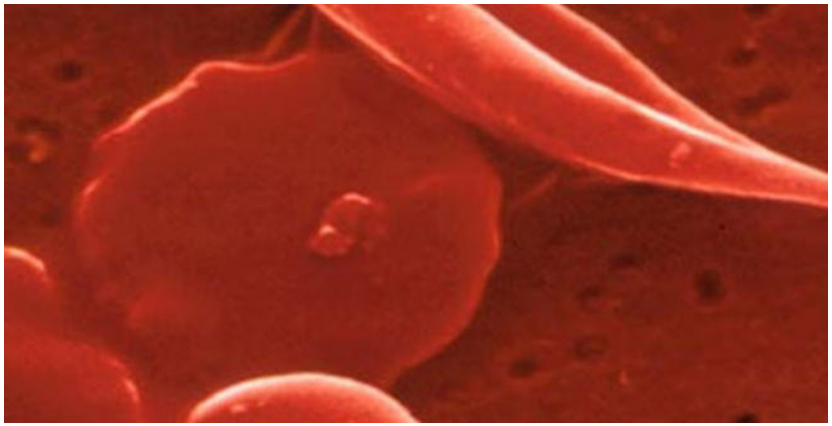

Sickle cell disease is a hereditary disease caused by a genetic difference that replaces one amino acid (glutamate, Glu) in each of two polypeptide chains of the hemoglobin molecule with another (valine, Val).

Worked example 18.4

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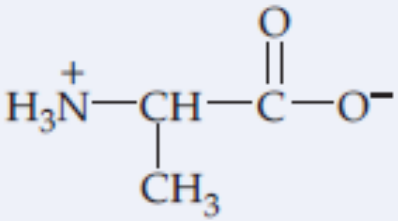
Draw the structure of the dipeptide Ala-Gly.

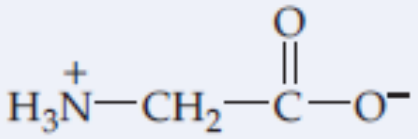
ANALYSIS You need the names and structures of the two amino acids. Since alanine is named first, it is amino-terminal and glycine is carboxyl-terminal. Ala-Gly must have a peptide bond between the alanine —COO^- and the glycine —NH_3^+.

SOLUTION

The structures of alanine and glycine, and the structure of the Ala-Gly dipeptide are



Alanine (Ala)



Glycine (Gly)

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(Reference: Chapter18 from McMurry et al.)

Worked example 18.4

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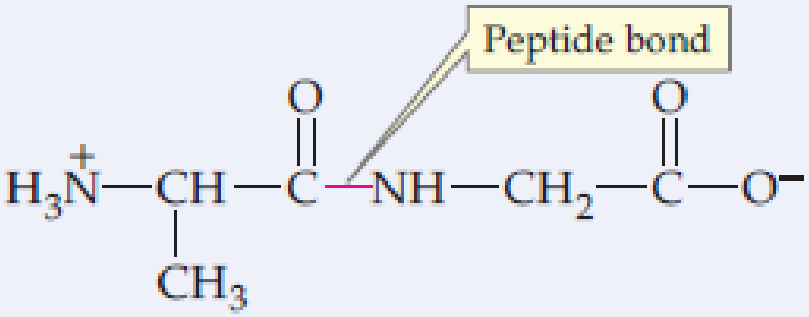
Draw the structure of the dipeptide Ala-Gly.



Ala-Gly

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(Reference: Chapter18 from McMurry et al.)

Problem 18.15

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PROBLEM 18.15

(a) Use the three-letter shorthand notations to name all the isomeric tripeptides that can be made from serine, tyrosine, and glycine.

(b) Draw the complete structure of the tripeptides that have glycine as the amino-terminal amino acid.

Gly–Ser–Tyr	Tyr–Ser–Gly	Ser–Tyr–Gly
Gly–Tyr–Ser	Tyr–Gly–Ser	Ser–Gly–Tyr

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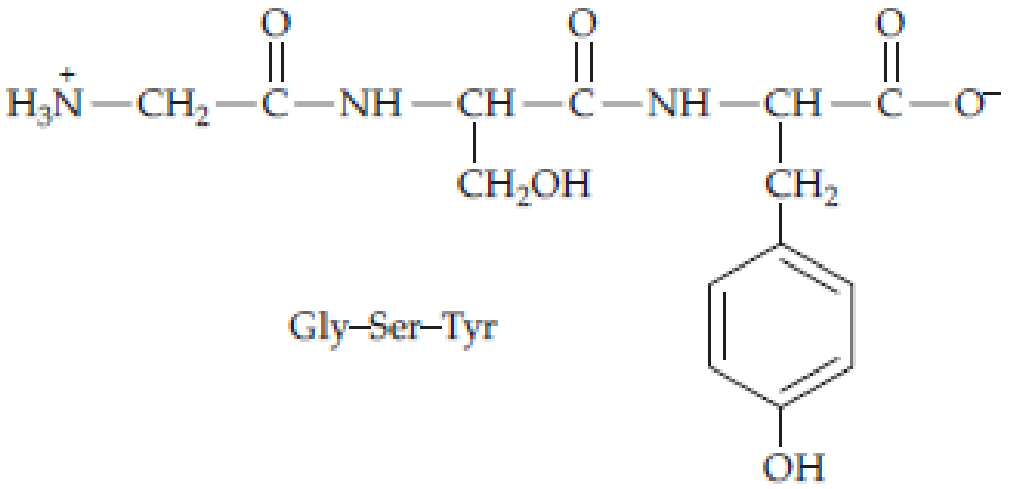
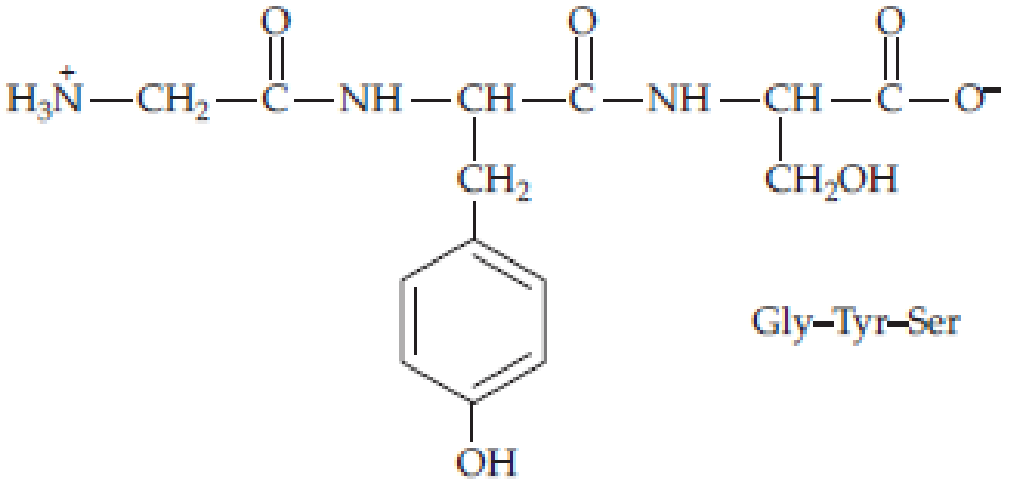
(Reference: Chapter18 from McMurry et al.)

Problem 18.15



Gly–Ser–Tyr



Gly–Tyr–Ser

(Reference: Chapter18 from McMurry et al.)

Problem 18.16

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Using three-letter abbreviations, show the six tripeptides that contain leucine, tryptophan, and serine.

Leu–Trp–Ser	Trp–Leu–Ser	Ser–Trp–Leu
Leu–Ser–Trp	Trp–Ser–Leu	Ser–Leu–Trp

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(Reference: Chapter18 from McMurry et al.)

Problem 18.17

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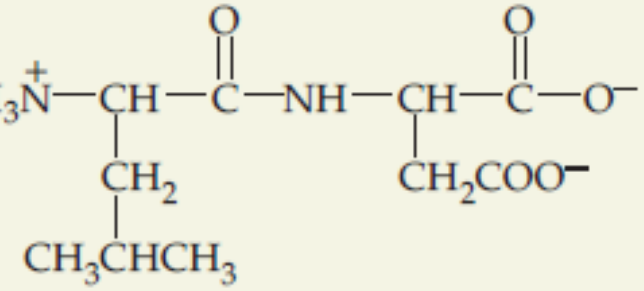
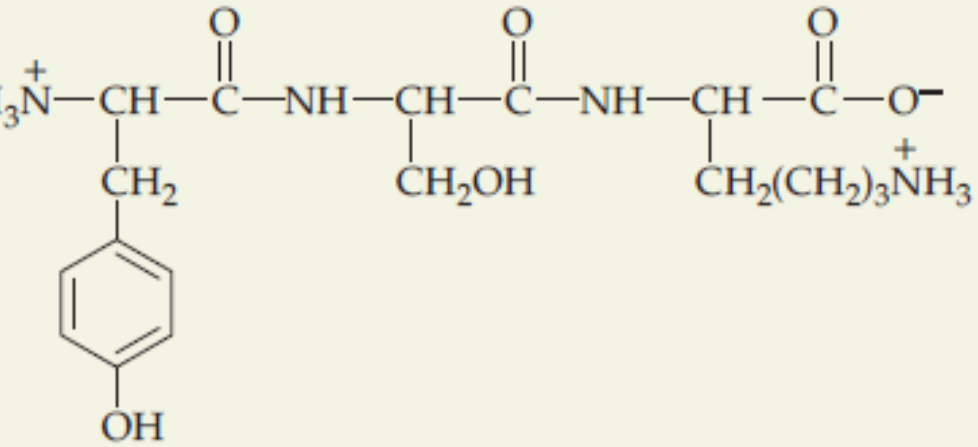
Identify the amino acids in the following dipeptide and tripeptide, and write the abbreviated forms of the peptide names.

(a)



(b)



(a) Leu–Asp (b) Tyr–Ser–Lys

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Problem 18.18

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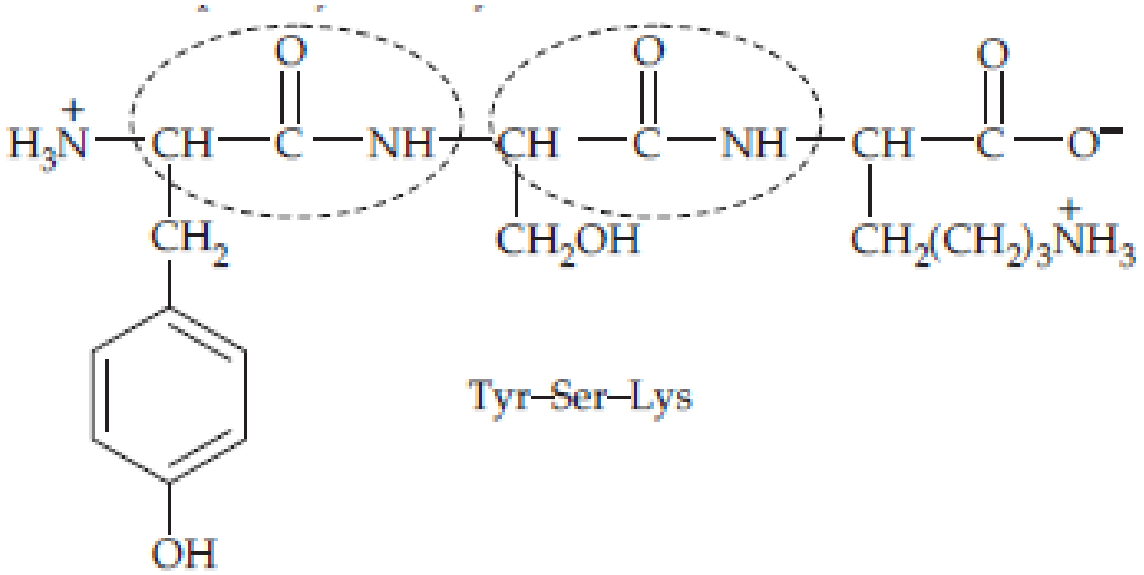
Copy the structure of the tripeptide in Problem 18.17b and circle the two planar regions along the backbone.



Tyr–Ser–Lys

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KEY CONCEPT PROBLEM 18.19

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Endoproteases are enzymes that hydrolyze proteins at specific points within their sequences. Chymotrypsin is an endoprotease that cuts on the C-terminal side of aromatic amino acids. In Table 18.3 identify the three amino acids that have aromatic side chains. Now determine the number of fragments that

result when chymotrypsin reacts with vasopressin, which has the structure

Asp-Tyr-Phe-Glu-Asn-Cys-Pro-Lys-Gly

and then write out the sequences of these fragments using the standard three-letter designator for each amino acid.

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(Reference: Chapter18 from McMurry et al.)

18.3 Apolaire zijketens

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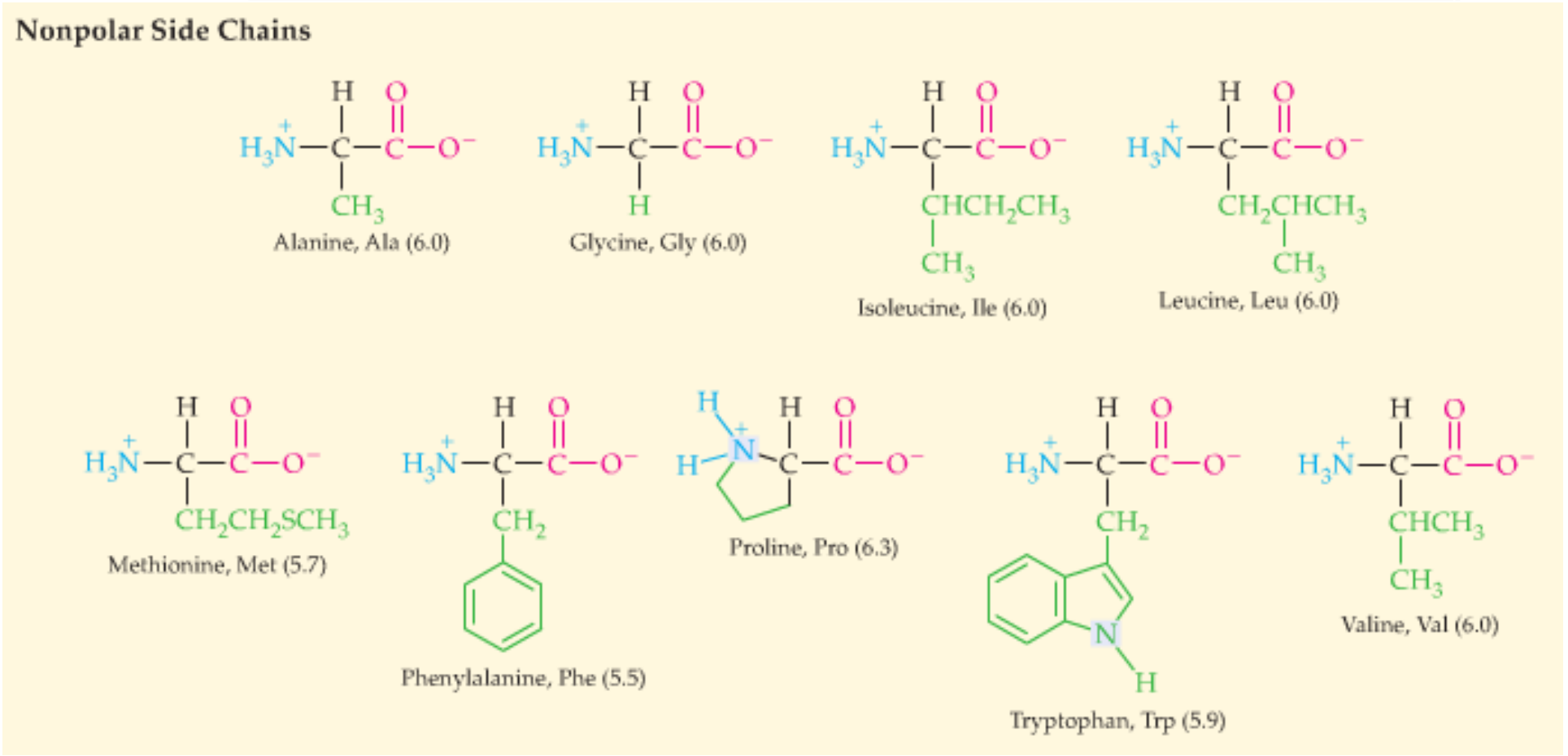

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(Reference: Chapter18 from McMurry et al.)

18.3 Polaire, neutrale zijketens

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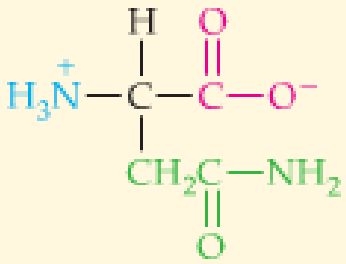
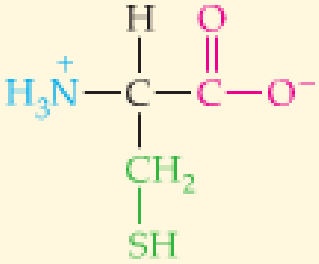
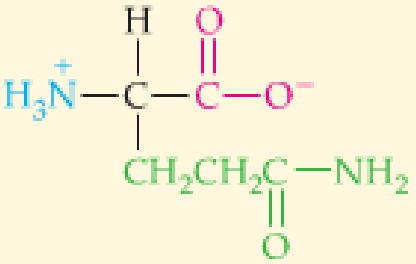
Polar, Neutral Side Chains



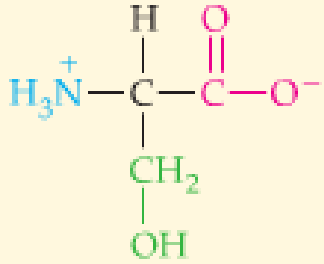
Asparagine, Asn (5.4)



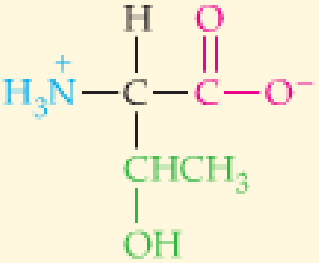
Cysteine, Cys (5.0)



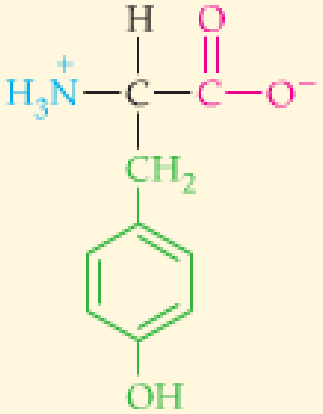
Glutamine, Gln (5.7)



Serine, Ser (5.7)



Threonine, Thr (5.6)



Tyrosine, Tyr (5.7)

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(Reference: Chapter18 from McMurry et al.)

18.3 Zure en basische zijketens

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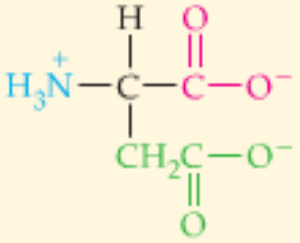
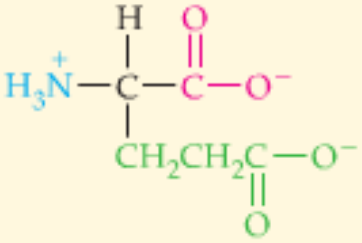
Acidic Side Chains

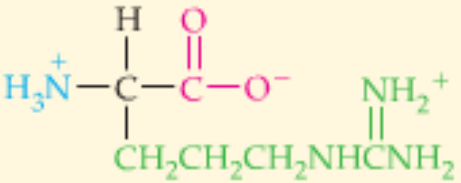


Aspartic acid, Asp (3.0)
(Aspartate)

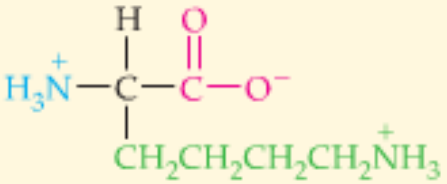


Glutamic acid, Glu (3.2)
(Glutamate)

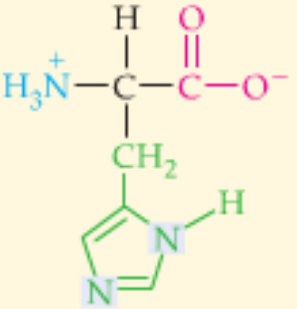
Basic Side Chains



Arginine, Arg (10.8)



Lysine, Lys (9.7)



Histidine, His (7.6)

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(Reference: Chapter18 from McMurry et al.)

KEY CONCEPT PROBLEM 18.19

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Endoproteases are enzymes that hydrolyze proteins at specific points within their sequences. Chymotrypsin is an endoprotease that cuts on the C-terminal side of aromatic amino acids. In Table 18.3 identify the three amino acids that have aromatic side chains. Now determine the number of fragments that

Tyr, Trp, Phe

result when chymotrypsin reacts with vasopressin, which has the structure

Asp-Tyr-Phe-Glu-Asn-Cys-Pro-Lys-Gly

and then write out the sequences of these fragments using the standard three-letter designator for each amino acid.

Asp–Tyr + Phe + Glu–Asn–Cys–Pro–Lys–Gly

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(Reference: Chapter18 from McMurry et al.)

18.8 Interacties in eiwitten

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- waterstofbruggen
- ion-interacties (zoutbruggen)
- hydrofobe interacties
- zwavelbruggen

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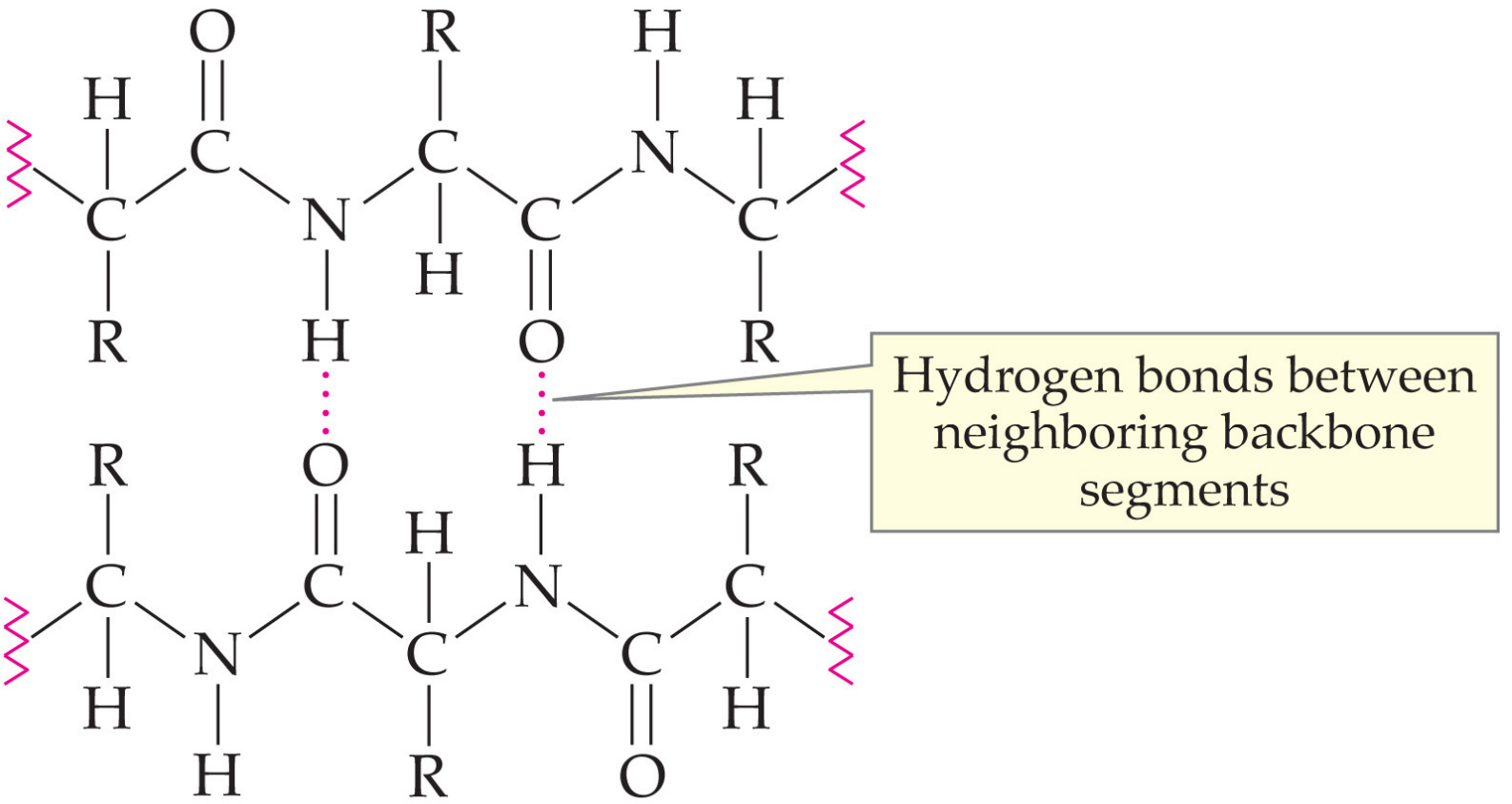
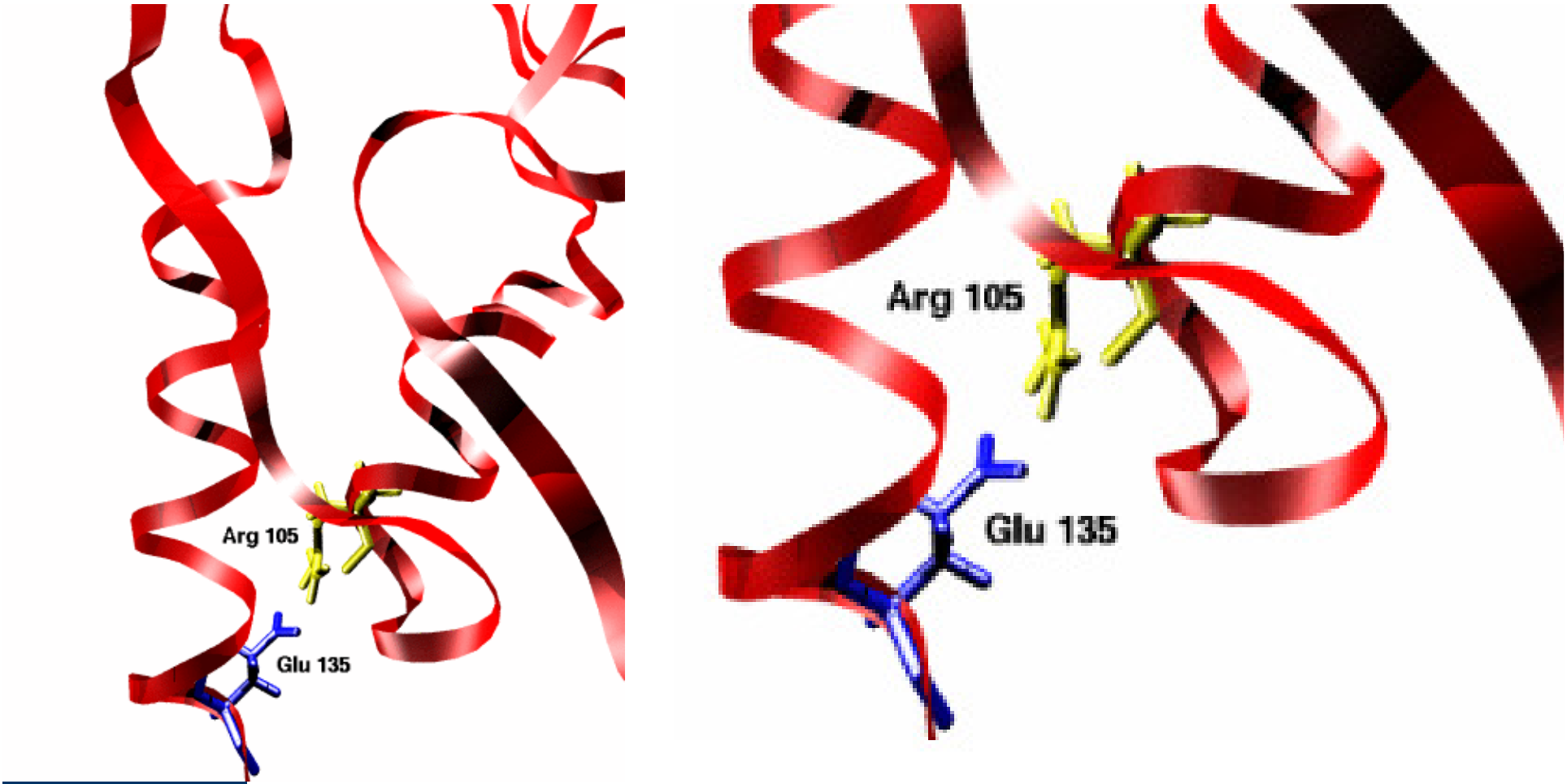
(Reference: Chapter18 from McMurry et al.)

Waterstofbruggen



(Reference: Chapter18 from McMurry et al.)

Zoutbruggen



(Reference: Chapter18 from McMurry et al.)

Zoutbrug vs waterstofbrug

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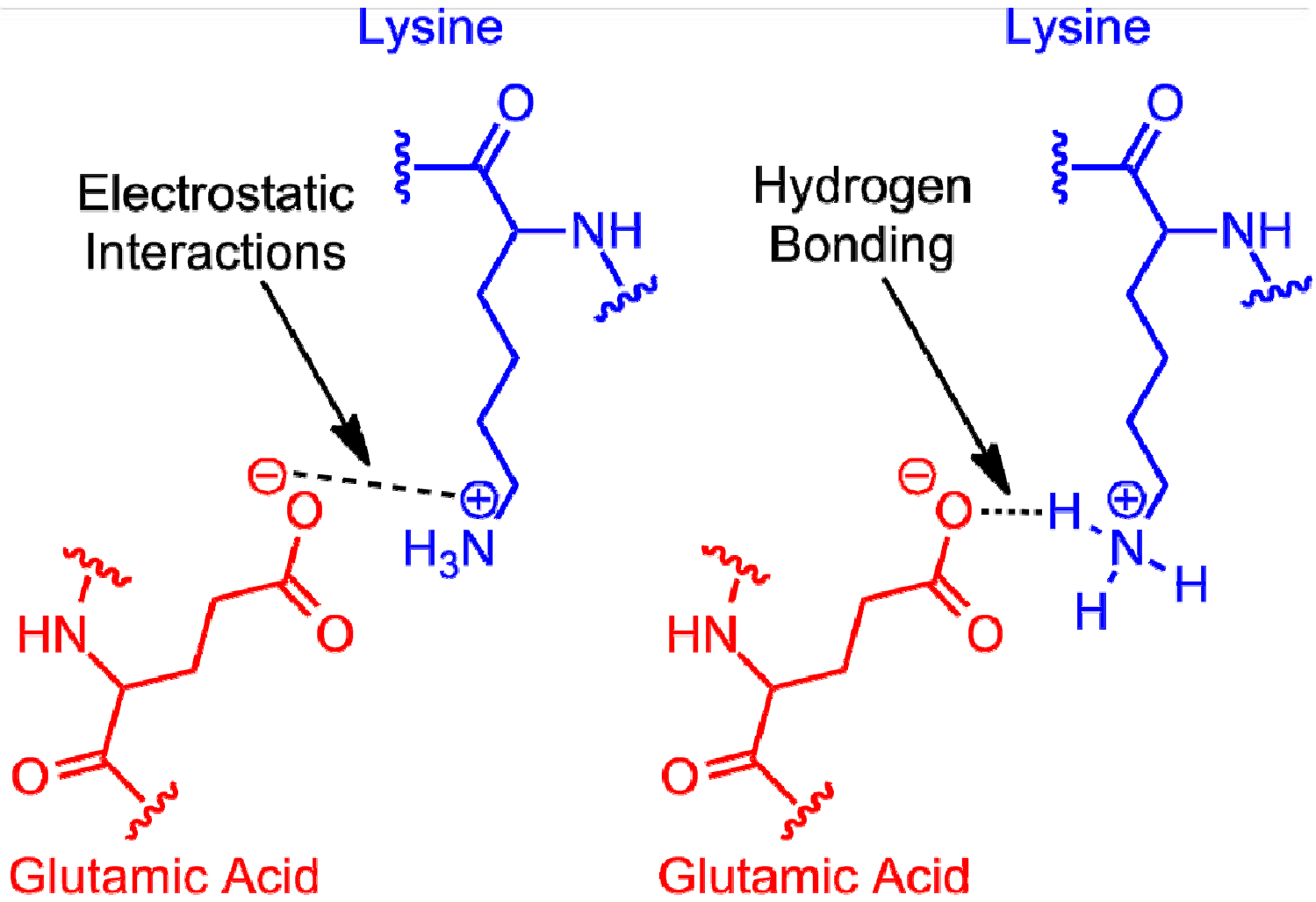

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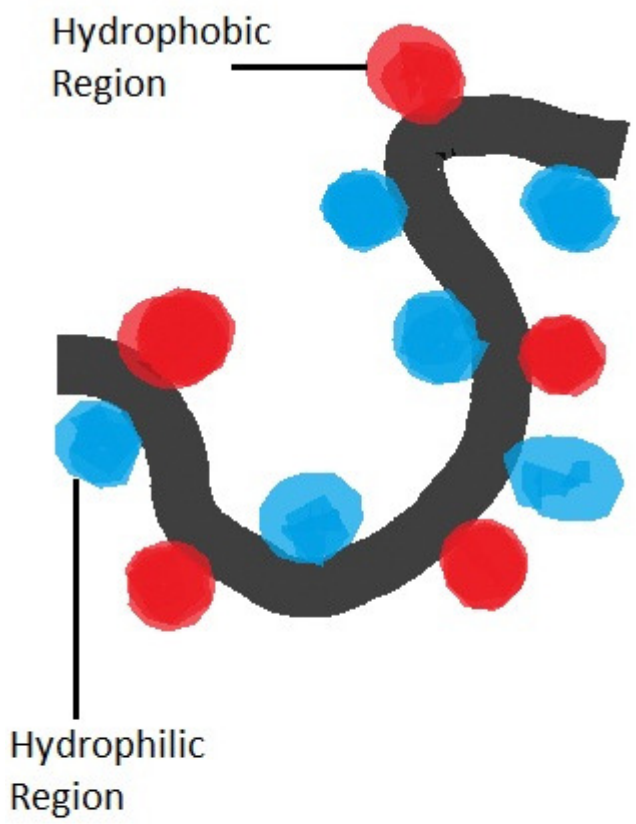
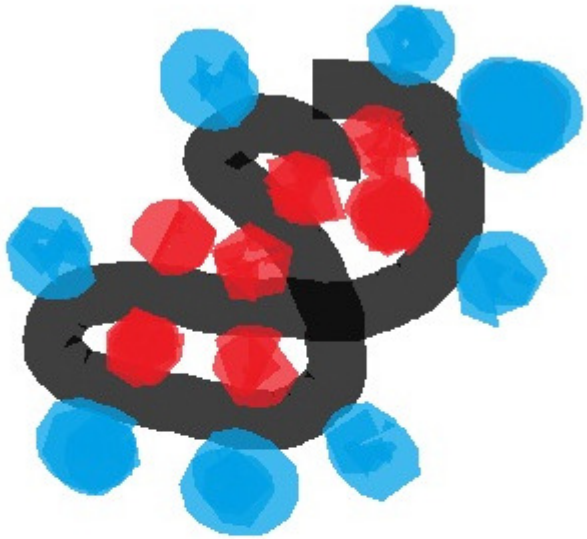
a **salt bridge** is a combination of two noncovalent interactions: **hydrogen bonding** and **electrostatic interactions**.

(Reference: https://en.wikipedia.org/wiki/Salt_bridge_(protein_and_supramolecular)

Hydrofobe interacties



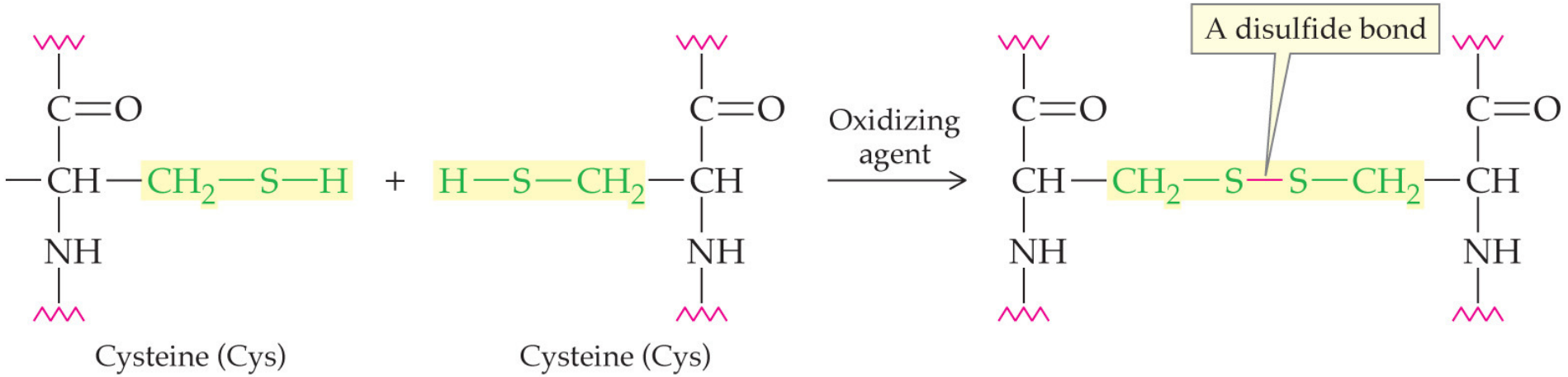


Isolated Protein

Protein in aqueous solution

(Reference: Chapter18 from McMurry et al.)

Zwavelbruggen



$$2\ RSH \rightleftharpoons RS\text{–}SR + 2\ H^+ + 2\ e^-$$

Zwavelbruggen

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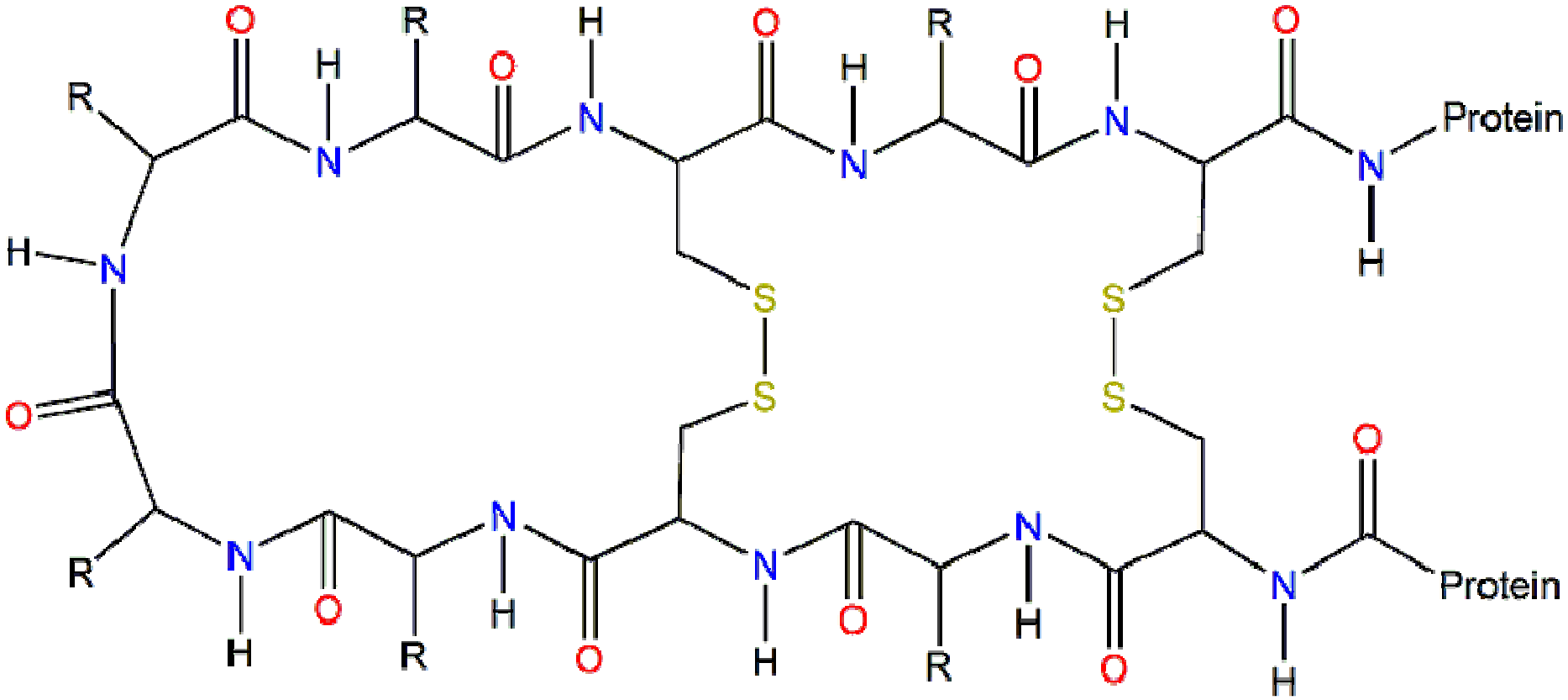

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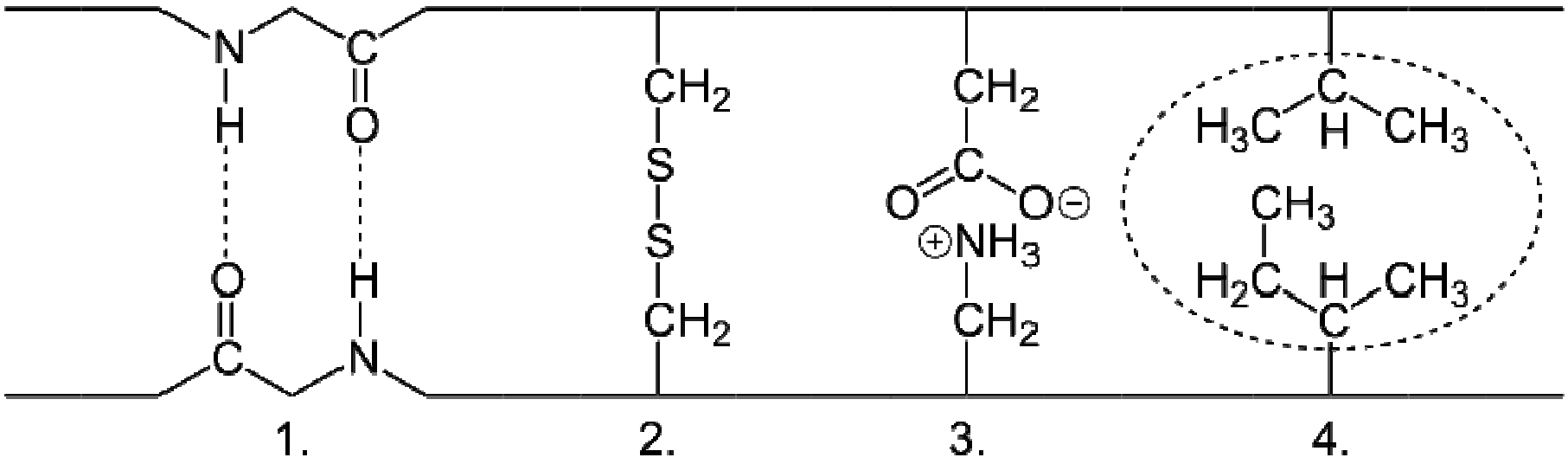
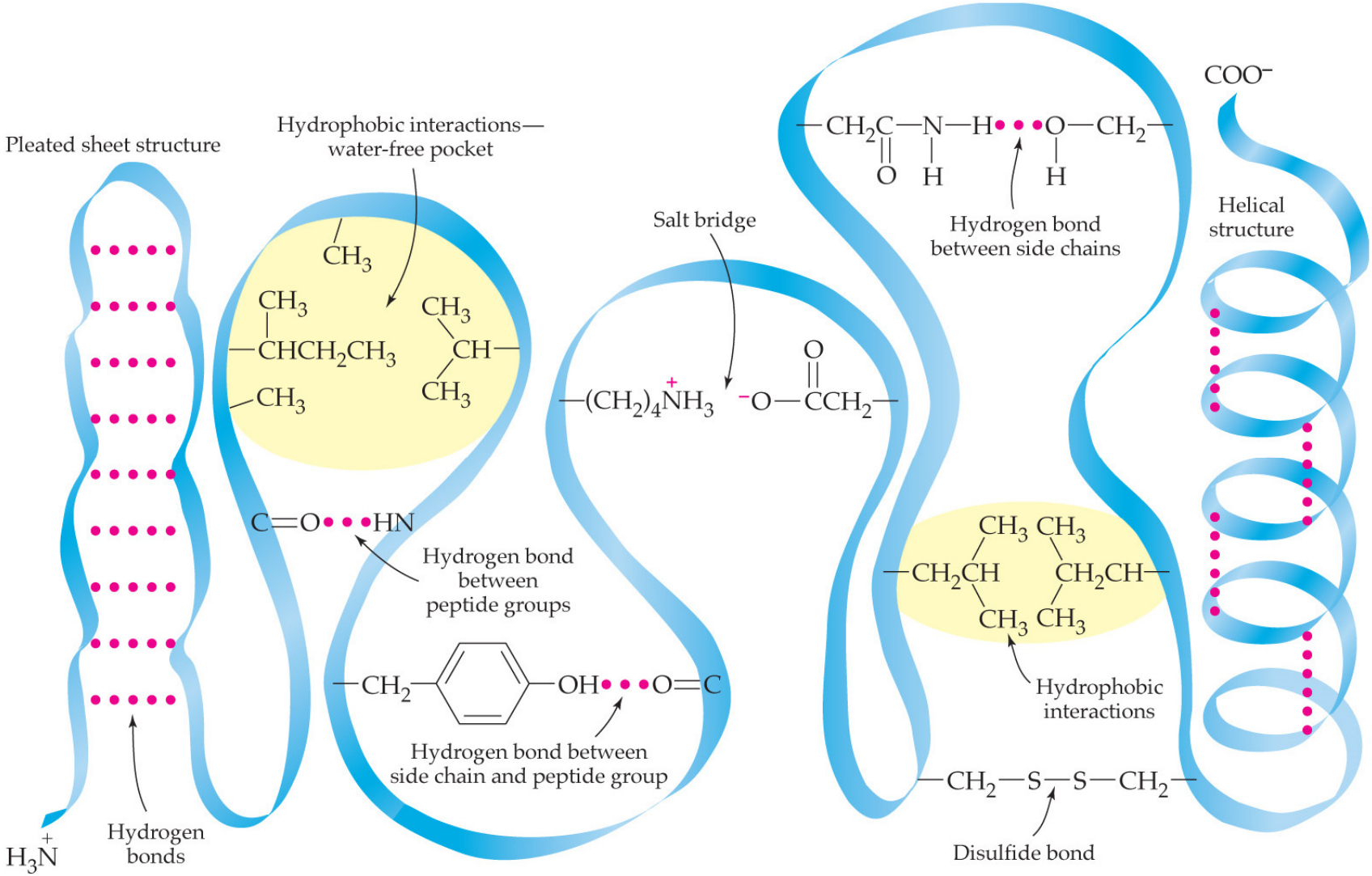
(Reference: Chapter18 from McMurry et al.)

Interacties in eiwit



(Reference: Chapter18 from McMurry et al.)

Interacties in eiwit



Interacties in eiwit

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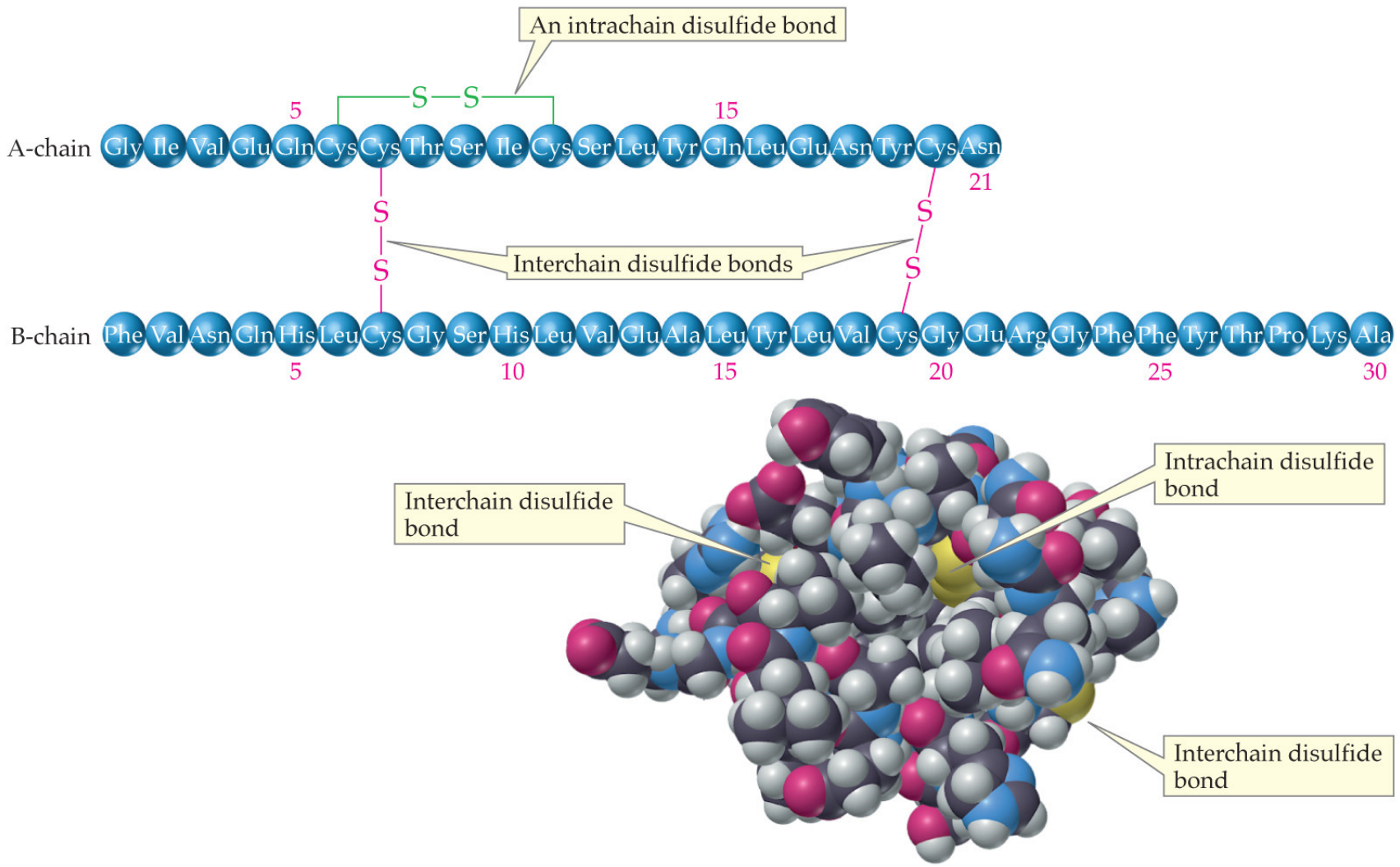
Structure of insulin



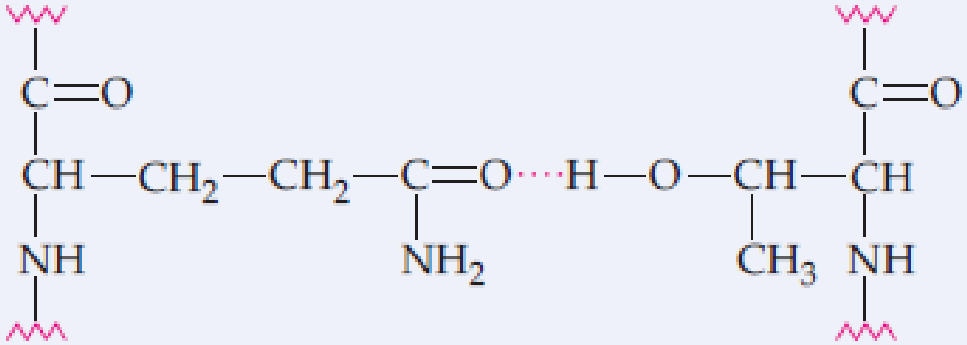
(Reference: Chapter18 from McMurry et al.)

Worked example 18.5

What type of noncovalent interaction occurs between the threonine and glutamine side chains? Draw the structures of these amino acids to show the interaction.

ANALYSIS The side chains of threonine and glutamine contain an amide group and a hydroxyl group, respectively. These groups do not form salt bridges because they do not ionize. They are polar and therefore not hydrophobic. They form a hydrogen bond between the oxygen of the amide carbonyl group and the hydrogen of the hydroxyl group.

The noncovalent, hydrogen bond interaction between threonine and glutamine is as follows:



(Reference: Chapter18 from McMurry et al.)

Problem 18.20

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Look at Table 18.3 and identify the type of noncovalent interaction expected between the side chains of the following pairs of amino acids:

(a) Glutamine and tyrosine
(b) Leucine and proline
(c) Aspartate and arginine
(d) Isoleucine and phenylalanine

(a) hydrogen bond **(b)** hydrophobic interaction **(c)** salt bridge **(d)** hydrophobic interaction

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(Reference: Chapter18 from McMurry et al.)