TABLE 1-4
Approximate Composition of Metabolically Active Cells and Tissues[a]

Component	*E. coli*[b] (%)	Green plant (spinach, *Spinacia oleracea*)[c]	Rat liver[d] (%)
H_2O	70	93	69
Protein	15	2.3	21
Amino acids	0.4		
DNA	1		0.2
RNA	6		1.0
Nucleotides	0.4		
Carbohydrates	3	3.2	
Cellulose		0.6	
Glycogen			3.8
Lipids	2	0.3	6
Phospholipids			3.1
Neutral lipids			1.6
Sterols			0.3
Other small molecules	0.2		
Inorganic ions	1	1.5	
K^+			0.4

	Equivalents per liter in rat liver
Amino acid residues	2.1
Nucleotide units	0.03
Glycogen (glucose units)	0.22
K^+	0.1

[a] Data were not readily available for spaces left blank
[b] From J. D. Watson (1976) *Molecular Biology of the Gene*, 3rd ed., p. 69, Benjamin, New York The amounts of amino acids, nucleotides, carbohydrates, and lipids include precursors present in the cell.
[c] From B. T. Burton (1976) *Human Nutrition*, 3rd ed., McGraw-Hill, New York (p. 505)
[d] From C. Long, ed., (1961) *Biochemists' Handbook*, pp. 677–679, Van Nostrand-Reinhold, Princeton, New Jersey

Biochemistry: The Chemical Reactions of Living Cells (2nd edition, 2001), David E. Metzler

Table 1.2
Biomolecular Dimensions

The dimensions of mass* and length for biomolecules are given typically in daltons and nanometers,† respectively. One dalton (D) is the mass of one hydrogen atom, 1.67×10^{-24} g. One nanometer (nm) is 10^{-9} m, or 10 Å (angstroms).

Biomolecule	Length (long dimension, nm)	Mass: Daltons	Mass: Picograms
Water	0.3	18	
Alanine	0.5	89	
Glucose	0.7	180	
Phospholipid	3.5	750	
Ribonuclease (a small protein)	4	12,600	
Immunoglobulin G (IgG)	14	150,000	
Myosin (a large muscle protein)	160	470,000	
Ribosome (bacteria)	18	2,520,000	
Bacteriophage ϕX174 (a very small bacterial virus)	25	4,700,000	
Pyruvate dehydrogenase complex (a multienzyme complex)	60	7,000,000	
Tobacco mosaic virus (a plant virus)	300	40,000,000	6.68×10^{-5}
Mitochondrion (liver)	1,500		1.5
Escherichia coli cell	2,000		2
Chloroplast (spinach leaf)	8,000		60
Liver cell	20,000		8,000

*Molecular mass is expressed in units of daltons (D) or kilodaltons (kD) in this book; alternatively, the dimensionless term *molecular weight*, symbolized by Mr, and defined as the ratio of the mass of a molecule to 1 dalton of mass, is used.

Biochemistry 2nd edition (1999), Garrett and Grisham

Life
Water

Table 2.1
Dielectric Constants* of Some Common Solvents at 25°C

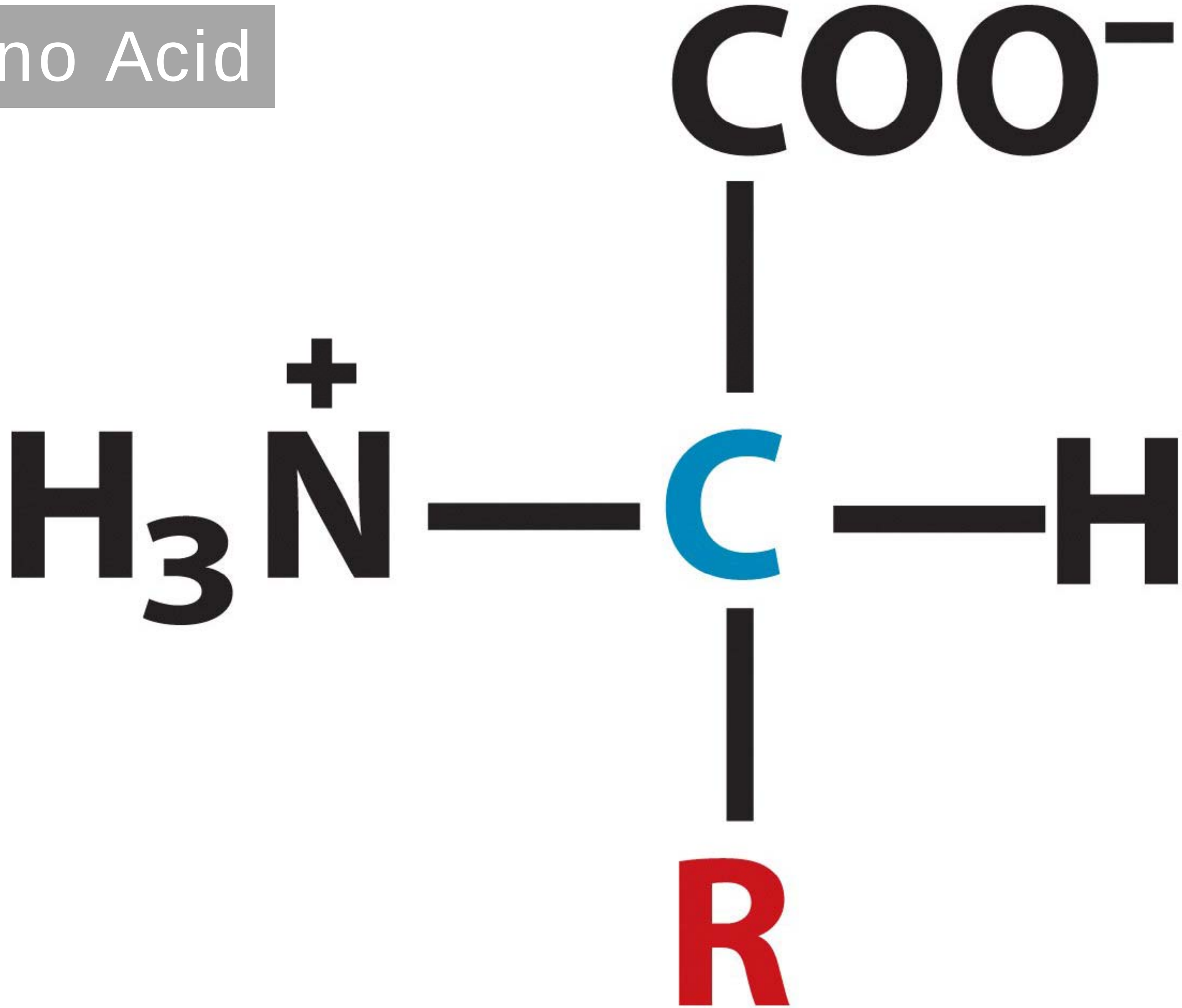
Solvent	Dielectric Constant (D)
Water	78.5
Methyl alcohol	32.6
Ethyl alcohol	24.3
Acetone	20.7
Acetic acid	6.2
Chloroform	5.0
Benzene	2.3
Hexane	1.9

*The dielectric constant is also referred to as *relative permittivity* by physical chemists.

Chapter 3

Amino acids, peptides, and proteins

Amino Acid



分類的依據

1806 Asparagine from asparagus

by Louis Nicolas Vauquelin and Pierre Jean Robiquet

1938 Threonine

by William Cumming Rose

our original mixtures. This led eventually to the isolation and identification of a new indispensable constituent, namely, α-amino-β-hydroxy-n-butyric acid.[4] This compound is widely distributed in nature, but appears to occur in greatest abundance in the blood proteins. It has been named d-threonine, inasmuch as its spatial configuration is exactly analogous to that of the sugar d-threose.[5] When threonine is added to suitable amino acid mixtures the resulting preparation is an excellent substitute for dietary proteins.

equal importance of modern technology for the advance of science, I shall close, acknowledging my obligation to these modern philosophers by quoting from one who was a contemporary of Galileo—for it was Sir Francis Bacon who said, "Nature to be commanded must first be obeyed. Knowledge is power."

THE NUTRITIVE SIGNIFICANCE OF THE AMINO ACIDS AND CERTAIN RELATED COMPOUNDS[1,2]

By Professor W. C. ROSE
UNIVERSITY OF ILLINOIS

THE relation of the amino acids to growth has been the subject of numerous investigations during the past thirty years. Until comparatively recently, however, only three of these compounds, namely, tryptophane, lysine and histidine, had been shown definitely to be indispensable components of the food. Evidence which appeared to demonstrate the essential nature of cystine was presented by Osborne and Mendel; while certain other protein components, notably the dibasic amino acids and the prolines, seemed to be dispensable.[3]

Progress in such investigations was hampered by reason of the fact that methods were not available for the quantitative removal of single protein components. It appeared that if further information was to be obtained, one must resort to the use of diets in which the proteins were replaced entirely by mixtures of highly purified amino acids. Such investigations have been under way in this laboratory since 1930.

It soon became apparent that the *known* amino acids, when incorporated in otherwise adequate diets, were incapable of supporting growth. Evidently, proteins supply something which was not present in our original mixtures. This led eventually to the isolation and identification of a new indispensable constituent, namely, α-amino-β-hydroxy-n-butyric acid.[4] This compound is widely distributed in nature, but appears to occur in greatest abundance in the blood proteins. It has been named d-threonine, inasmuch as its spatial configuration is exactly analogous to that of the sugar d-threose.[5] When threonine is added to suitable amino acid mixtures the resulting preparation is an excellent substitute for dietary proteins.

In all our investigations young albino rats from our own colony have served as the experimental animals. The diets have carried the usual components—carbohydrates, fats, inorganic salts and vitamins—and differed from the ordinary so-called "synthetic" rations only in that proteins were replaced by amino acids. Food and water were kept in the cages at all times, so that the animals ate and drank *ad libitum*. By such a procedure, the importance of the individual amino acids has been determined by omitting them from the food one or more at a time.

Data have already been presented elsewhere demonstrating the indispensable nature of phenylalanine,[6] leucine and isoleucine.[7] It has also been shown that hydroxyglutamic acid,[8] citrulline,[9] tyrosine,[6] norleucine,[7] glycine and serine[10] are non-essential. During the past eighteen months all the generally recognized amino acids present in proteins have been classified with respect to their growth importance. It is the purpose of this note to present these findings, together with an outline of the physiological behavior of certain optically isomeric amino acids and related compounds. The evidence upon which the following statements are based will be described in detail elsewhere.

Contrary to the usual belief, cystine is not an indispensable component of the food. On the other hand, methionine is indispensable. In the absence of the latter from the ration, animals rapidly lose weight and eventually die, even though an abundant amount of cystine is supplied. Of particular interest in this connection is the fact that if methionine is administered at a level which permits maintenance or slow increase in weight, the addition of cystine greatly improves the quality of the diet. Thus, cystine stimu-

[1] Aided by a grant from the Rockefeller Foundation.

[2] This paper is a summary of one presented before the joint session of the Federation of American Societies for Experimental Biology at Memphis, Tenn., April 22, 1937. The author is indebted to Drs. Madelyn Womack, S. H. Eppstein, C. E. Meyer and a number of graduate students for the actual conduct of the experiments.

[3] The earlier literature is reviewed by W. C. Rose, *Yale Jour. Biol. and Med.*, 4: 519, 1932.

[4] R. H. McCoy, C. E. Meyer and W. C. Rose, *Jour. Biol. Chem.*, 112: 283, 1935–36.

[5] C. E. Meyer and W. C. Rose, *Jour. Biol. Chem.*, 115: 721, 1936.

[6] M. Womack and W. C. Rose, *Jour. Biol. Chem.*, 107: 449, 1934.

[7] M. Womack and W. C. Rose, *Jour. Biol. Chem.*, 116: 381, 1936.

[8] W. Windus, F. L. Catherwood and W. C. Rose, *Jour. Biol. Chem.*, 94: 173, 1931.

[9] C. T. Caldwell and W. C. Rose, *Jour. Biol. Chem.*, 107: 57, 1934.

[10] R. H. McCoy and W. C. Rose, *Jour. Biol. Chem.*, 117: 581, 1937.

Science. 1937 Oct 1;86(2231):298-300.

BOX 3.2 Common Names of Amino Acids

Alanine	probably from aldehyde + "an" (for convenience) + amine (1849)
Arginine	crystallizes as a silver salt, from Latin *argentum* (silver) (1886)
Asparagine	first isolated from asparagus (1813) 1806
Aspartate	similar to asparagine (1836)
Glutamate	first identified in the plant protein gluten (1866)
Glutamine	similar to glutamate (1866)
Glycine	from the Greek *glykys* (sweet), tastes sweet (1848)
Cysteine	from the Greek *kystis* (bladder), discovered in bladder stones (1882)
Histidine	first isolated from sturgeon sperm, named for the Greek *histidin* (tissue) (1896)
Isoleucine	isomer of leucine
Leucine	from the Greek *leukos* (white), forms white crystals (1820)
Lysine	product of protein hydrolysis, from the Greek *lysis* (loosening) (1891)
Methionine	side chain is a sulfur (Greek *theion*) atom with a methyl group (1928)
Phenylalanine	alanine with a phenyl group (1883)
Proline	a corrupted form of "pyrrolidine" because it forms a pyrrolidine ring (1904)
Serine	from the Latin *sericum* (silk), serine is common in silk (1865)
Threonine	similar to the four-carbon sugar threose (1936) 1938
Tryptophan	isolated from a tryptic digest of protein + Greek *phanein* (to appear) (1890)
Tyrosine	found in cheese, from the Greek *tyros* (cheese) (1890)
Valine	derivative of valeric acid from the plant genus Valeriana (1906) 纈草

Sources: Oxford English Dictionary 2nd ed., and Leung, S.H. (2000) "Amino Acids, Aromatic Compounds, and Carboxylic Acids: How Did They Get Their Common Names?" J. Chem. Educ. 77: 48–49.

Principles of biochemistry, 4th edition (2006), Horton, Moran, Scrimgeour, Perry, Rawn

Common names are often more interesting than **systematic names**. Therefore, the derivations of the common names may make learning about the compounds more **enjoyable**.

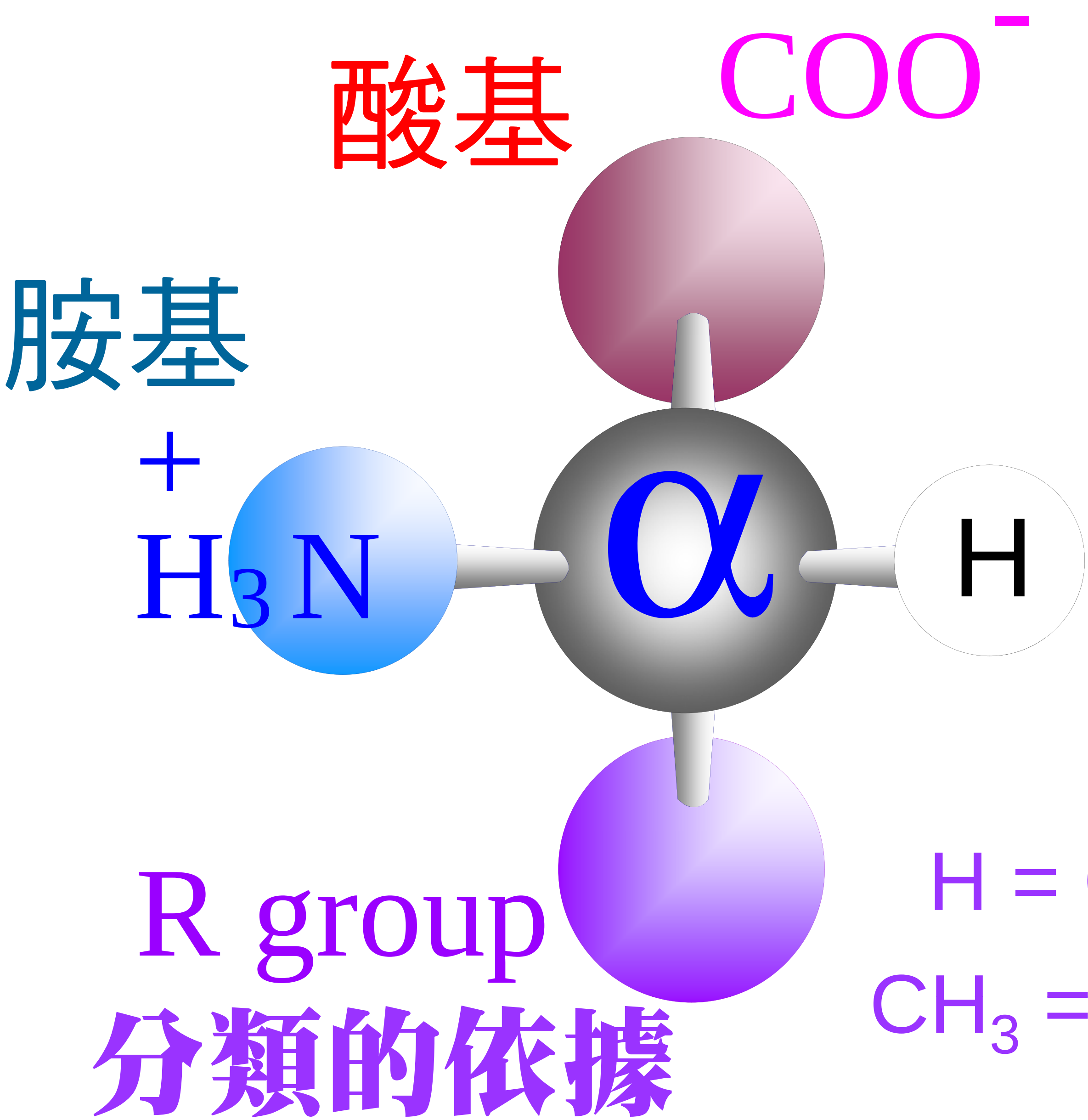
Table1. Amino Acids

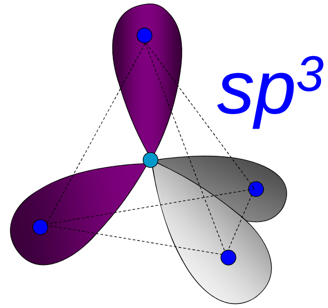
Common Name[a]	Root[b]	Notes	Systematic Name	Ref
Arginine	L *argentum*, silver	forms a well-defined silver salt	(*S*)-2-amino-5-guanidinopentanoic acid	*3*
Asparagine	*asparagus*	first found in asparagus 蘆筍, 天門冬屬	(*S*)-2-amino-3-carbamoylpropanoic acid	*4, 5*
Aspartic acid	—	related to asparagine	(*S*)-2-aminobutanedioic acid	*5*
Cysteine	—	reduction product of cystine (which see)	(*S*)-2-amino-3-mercaptopropanoic acid	*5*
Cystine	Gk *kystis*, bladder	first isolated from a bladder stone 膀胱結石	bis(2-amino-2-carboxyethyl)disulfide	*3*
Glutamic acid	*gluten* + *amino*	obtained by the hydrolysis of gluten, a protein-rich product obtained in the separation of starch from corn or wheat 麵麩	(*S*)-2-aminopentanedioic acid	*3, 6*
Glutamine	—	derived from glutamic acid (which see)	(*S*)-2-amino-4-carbamoylbutanoic acid	*6*
Glycine	Gk *glykys*, sweet	tastes sweet 甜味 白色結晶	aminoethanoic acid	*3, 4*
Histidine	Gk *histion*, tissue	— 組織	(*S*)-2-amino-3-(5-imidazolyl)propanoic acid	*6*
Isoleucine	—	isomer of leucine (which see)	(2*S*, 3*S*)-2-amino-3-methylpentanoic acid	*5*
Leucine	Gk *leukos*, white	obtained in the form of white plates 白色結晶	(*S*)-2-amino-4-methylpentanoic acid	*3*
Lysine	Gk *lysis*, loosening	discovered among the products from the hydrolysis of casein	(*S*)-2,6-diaminohexanoic acid	*3*
Methionine	*methyl* + *thio*	contains a S atom (Gk theion, sulfur) with a methyl group attached	(*S*)-2-amino-4-methylthiobutanoic acid	*6*
Proline	*pyrrolidine*	contains a pyrrolidine ring	2-pyrrolidinecarboxylic acid	*3*
Serine	L *sericum*, silk	first isolated from silk 絲	(*S*)-2-amino-3-hydroxypropanoic acid	*5*
Threonine	*threose*	spatial configuration analogous to that of D-threose, a 4-carbon sugar 蘇糖	(2*S*,3*R*)-2-amino-3-hydroxybutanoic acid	*5*
Tryptophan	*tryptic* + *phane*	obtained from the pancreatic (tryptic) digestion of proteins: *tryptic*, the adjective form of trypsin, a pancreatic digestive enzyme; phane, from Gk *phanein*, to appear	(*S*)-2-amino-3-(3-indolyl)propanoic acid	*5*
Tyrosine	Gk *tyros*, cheese	found in cheese 起司	(*S*)-2-amino-3-(4-hydroxyphenyl)propanoic acid	*3, 4*
Valine	*valeric*	carbon skeleton corresponds to isovaleric acid (3-methylbutanoic acid) 異戊酸	(*S*)-2-amino-3-methylbutanoic acid	*4*

[a]These biologically important α-amino acids are almost always called by their common names. The suffix *-ine* is a common ending for compounds containing nitrogen (amine bases). [b]L indicates Latin; Gk indicates Greek.

Amino Acids, Aromatic Compounds, and Carboxylic Acids: How Did They Get Their Common Names. Sam H. Leung J. Chem. Educ. (2000)

L-Form α-Amino Acid





H = Glycine

CH_3 = Alanine

Juang RH (2004) BCbasics

TABLE 3-1 Properties and Conventions Associated with the Common Amino Acids Found in Proteins

Amino acid	Abbreviation/ symbol		M_r	pK_a values: pK_1 (—COOH)	pK_a values: pK_2 ($—NH_3^+$)	pK_a values: pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Nonpolar, aliphatic R groups 碳鏈 (脂肪)									
Glycine	Gly	G	75	2.34	9.60		5.97	−0.4	7.2
Alanine	Ala	A	89	2.34	9.69		6.01	1.8	7.8
Proline	Pro	P	115	1.99	10.96		6.48	1.6	5.2
Valine	Val	V	117	2.32	9.62		5.97	4.2	6.6
Leucine	Leu	L	131	2.36	9.60		5.98	3.8	9.1
Isoleucine	Ile	I	131	2.36	9.68		6.02	4.5	5.3
Methionine	Met	M	149	2.28	9.21		5.74	1.9	2.3
Aromatic R groups 芳香環									
Phenylalanine	Phe	F	165	1.83	9.13		5.48	2.8	3.9
Tyrosine	Tyr	Y	181	2.20	9.11	10.07	5.66	−1.3	3.2
Tryptophan	Trp	W	204	2.38	9.39		5.89	−0.9	1.4

*A scale combining hydrophobicity and hydrophilicity of R groups; it can be used to measure the tendency of an amino acid to seek an aqueous environment (− values) or a hydrophobic environment (+ values). See Chapter 11. From Kyte, J. & Doolittle, R.F. (1982) A simple method for displaying the hydropathic character of a protein. *J. Mol. Biol.* **157,** 105–132.

†Average occurrence in more than 1,150 proteins. From Doolittle, R.F. (1989) Redundancies in protein sequences. In *Prediction of Protein Structure and the Principles of Protein Conformation* (Fasman, G.D., ed.), pp. 599–623, Plenum Press, New York.

P. 72, text

Margaret Oakley Dayhoff: One-letter code

P. 73

- **Hydropathy**: the relative hydrophobicity of each amino acid
- The larger the hydropathy, the greater the tendency of an amino acid to prefer a hydrophobic environment
- Hydropathy affects protein folding: hydrophobic side chains tend to be in the interior hydrophilic residues tend to be on the surface

Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

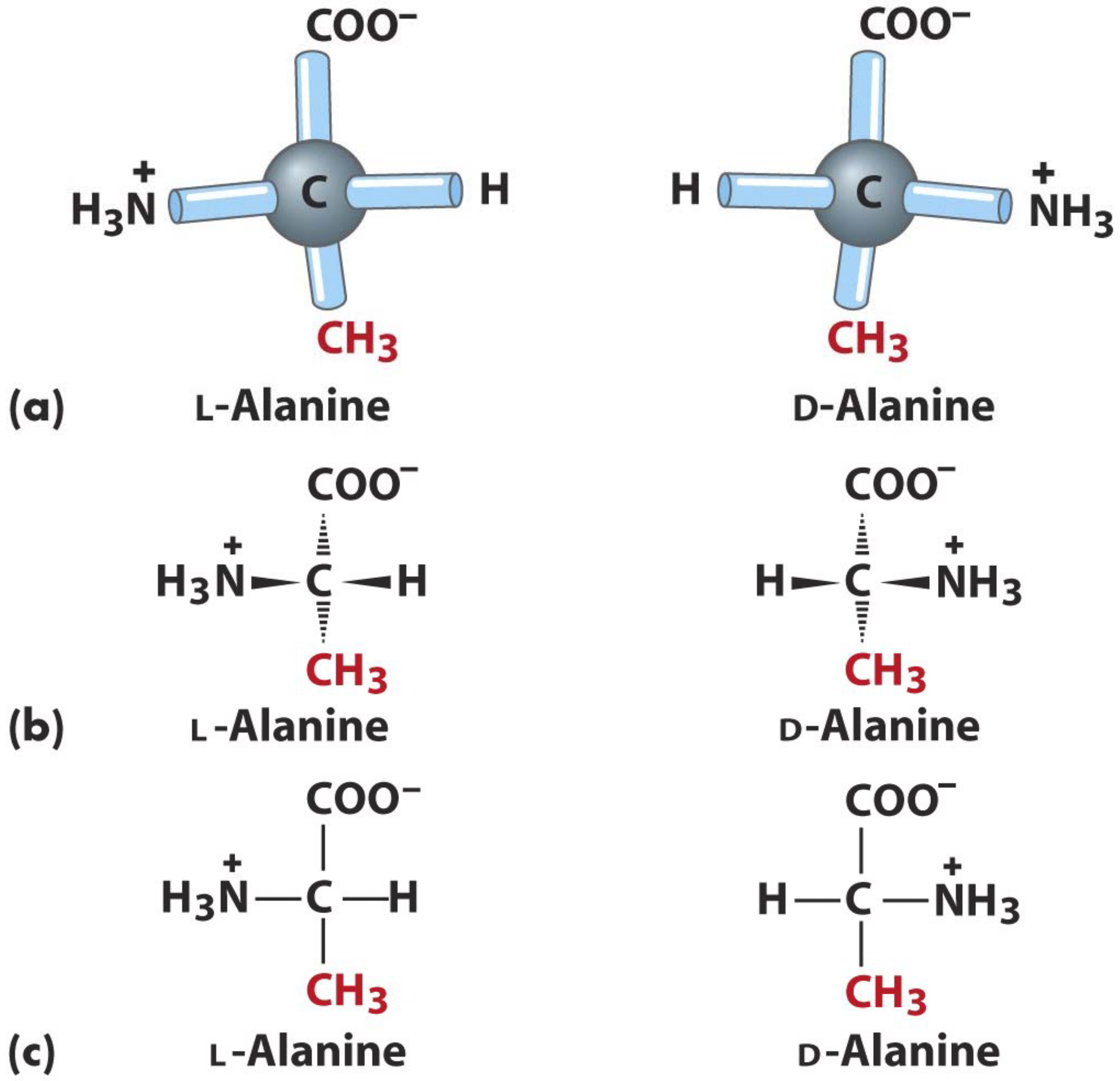
TABLE 3–1 Properties and Conventions Associated with the Common Amino Acids Found in Proteins

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_2 ($—NH_3^+$)	pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Polar, uncharged R groups 具極性 但不帶電								
Serine	Ser S	105	2.21	9.15		5.68	−0.8	6.8
Threonine	Thr T	119	2.11	9.62		5.87	−0.7	5.9
Cysteine	Cys C	121	1.96	10.28	8.18	5.07	2.5	1.9
Asparagine	Asn N	132	2.02	8.80		5.41	−3.5	4.3
Glutamine	Gln Q	146	2.17	9.13		5.65	−3.5	4.2
Positively charged R groups 帶正電								
Lysine	Lys K	146	2.18	8.95	10.53	9.74	−3.9	5.9
Histidine	His H	155	1.82	9.17	6.00	7.59	−3.2	2.3
Arginine	Arg R	174	2.17	9.04	12.48	10.76	−4.5	5.1
Negatively charged R groups 帶負電								
Aspartate	Asp D	133	1.88	9.60	3.65	2.77	−3.5	5.3
Glutamate	Glu E	147	2.19	9.67	4.25	3.22	−3.5	6.3

*A scale combining hydrophobicity and hydrophilicity of R groups; it can be used to measure the tendency of an amino acid to seek an aqueous environment (− values) or a hydrophobic environment (+ values). See Chapter 11. From Kyte, J. & Doolittle, R.F. (1982) A simple method for displaying the hydropathic character of a protein. *J. Mol. Biol.* **157,** 105–132.

†Average occurrence in more than 1,150 proteins. From Doolittle, R.F. (1989) Redundancies in protein sequences. In *Prediction of Protein Structure and the Principles of Protein Conformation* (Fasman, G.D., ed.), pp. 599–623, Plenum Press, New York.

P. 73



P. 72

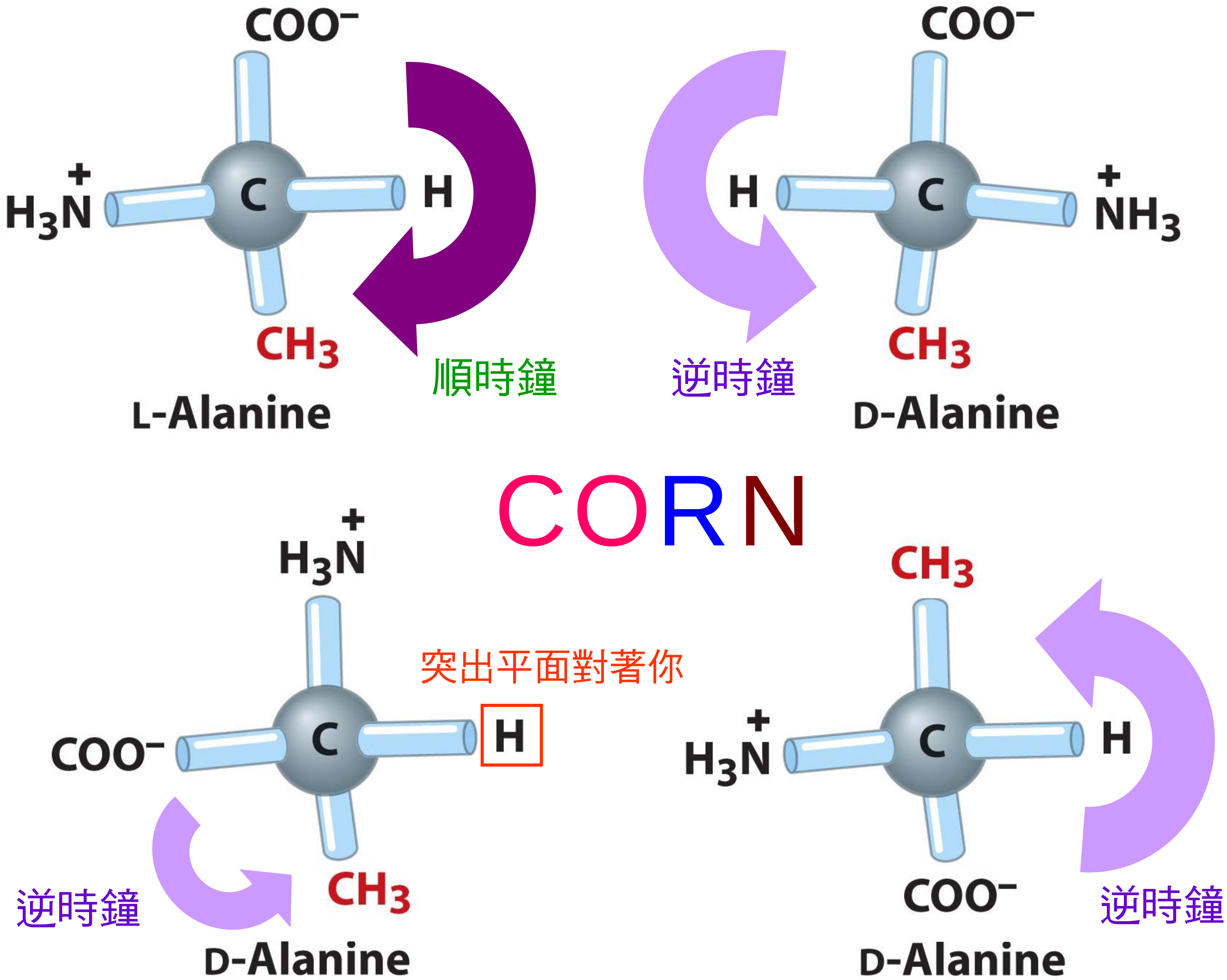
L: Levorotatory D: Dextrorotatory

Stereochemistry

- **Stereoisomers** - compounds that have the same molecular formula but differ in the arrangement of atoms in space
- **Enantiomers** - nonsuperimposable mirror images
- **Chiral carbons** - have four different groups attached

Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

P. 72



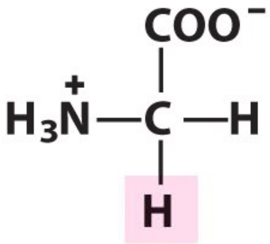
COO⁻
$H_3\overset{+}{N}$
C
H
CH_3
順時鐘
L-Alanine
COO⁻
H
C
$\overset{+}{N}H_3$
CH_3
逆時鐘
D-Alanine
CORN
$H_3\overset{+}{N}$
COO⁻
C
H
突出平面對著你
CH_3
逆時鐘
D-Alanine
CH_3
$H_3\overset{+}{N}$
C
H
COO⁻
逆時鐘
D-Alanine

Stereochemistry of amino acids

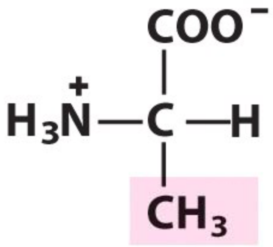
- 19 of the 20 common amino acids have a chiral α-carbon atom (Gly does not)
- Threonine and isoleucine have 2 chiral carbons each (4 possible stereoisomers each)
- Mirror image pairs of amino acids are designated L (levo) and D (dextro)
- Proteins are assembled from L-amino acids (a few D-amino acids occur in nature)

Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

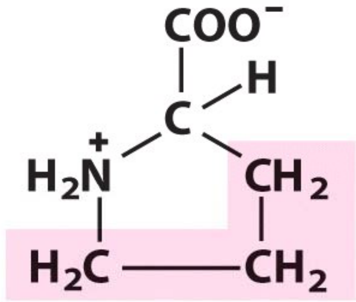
Nonpolar, aliphatic R groups



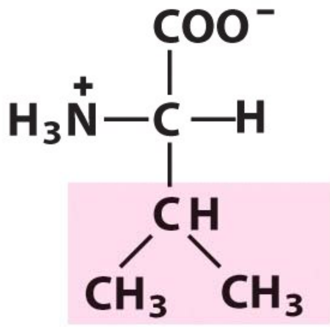
Glycine
甘胺酸



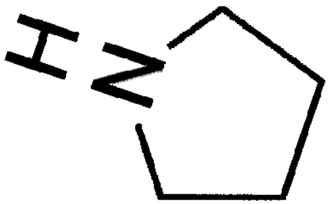
Alanine
丙胺酸



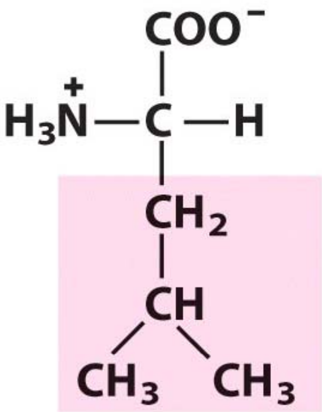
Proline
脯胺酸



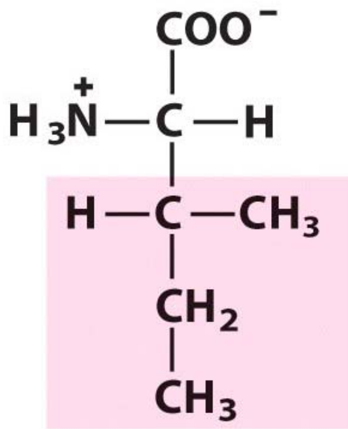
Valine
纈胺酸



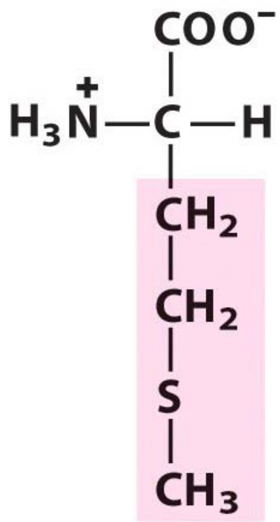
Pyrrolidine ring



Leucine
白胺酸



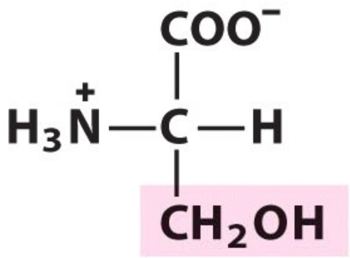
Isoleucine
異白胺酸



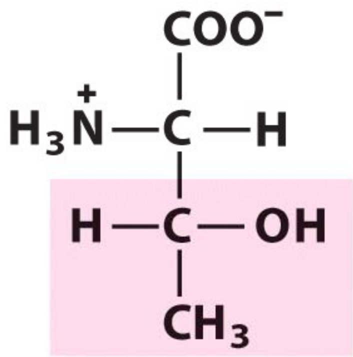
Methionine
甲硫(丁)胺酸

P. 75

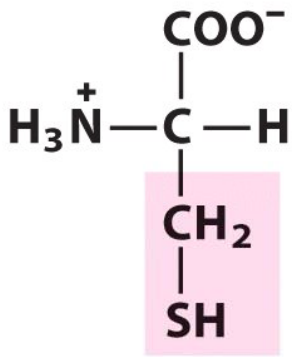
Polar, uncharged R groups



Serine
絲胺酸

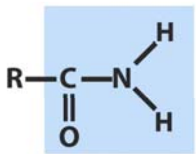


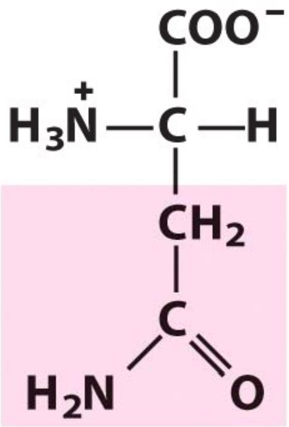
Threonine
蘇胺酸



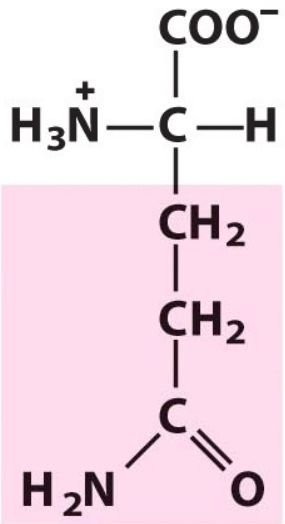
Cysteine
半胱胺酸

Amido

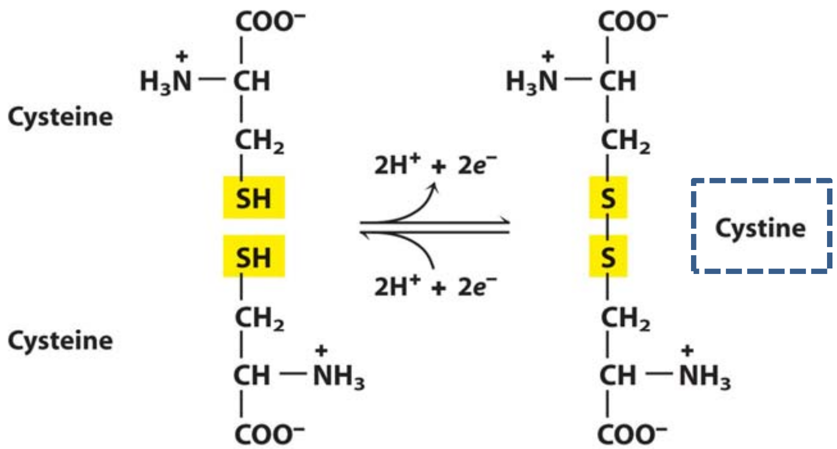




Asparagine
天門冬醯胺酸



Glutamine
麩醯胺酸

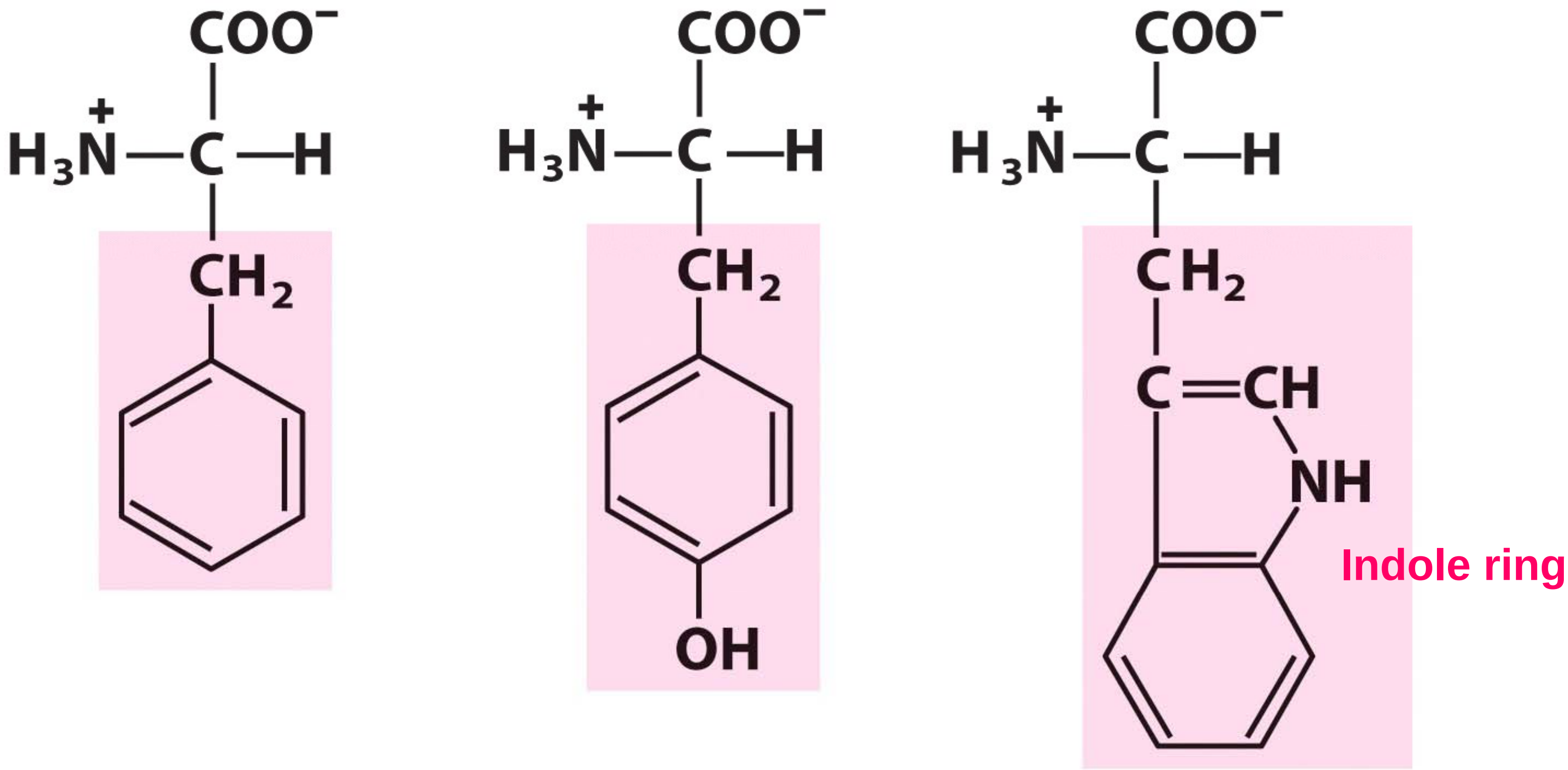


胱胺酸

P. 75

P. 77

Aromatic R groups

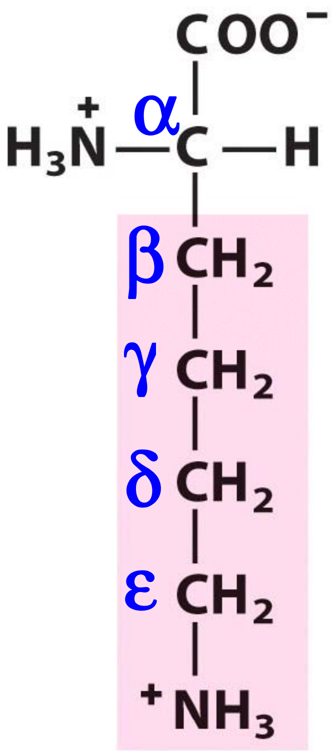


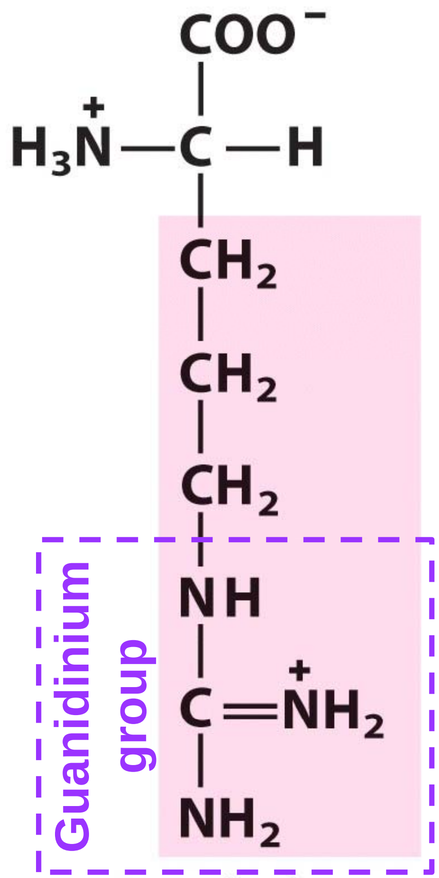
Phenylalanine 苯丙胺酸

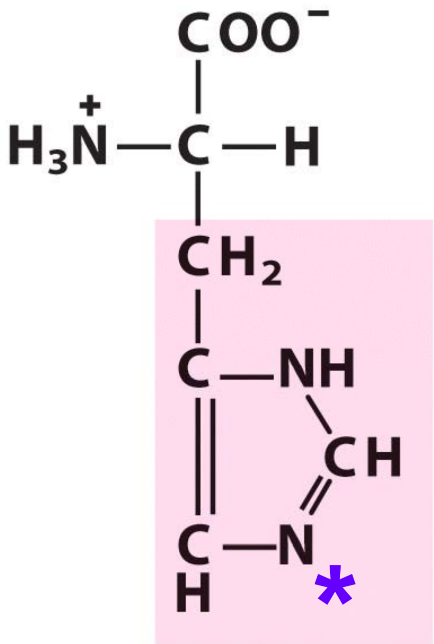
Tyrosine 酪胺酸

Tryptophan 色胺酸

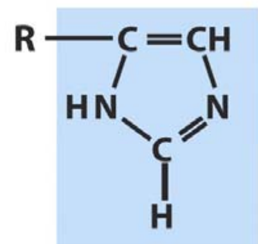
Positively charged R groups







Imidazole ring

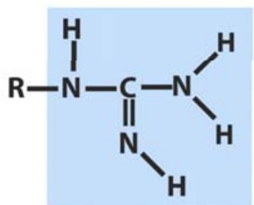


Lysine
離胺酸
賴胺酸

Arginine
精胺酸

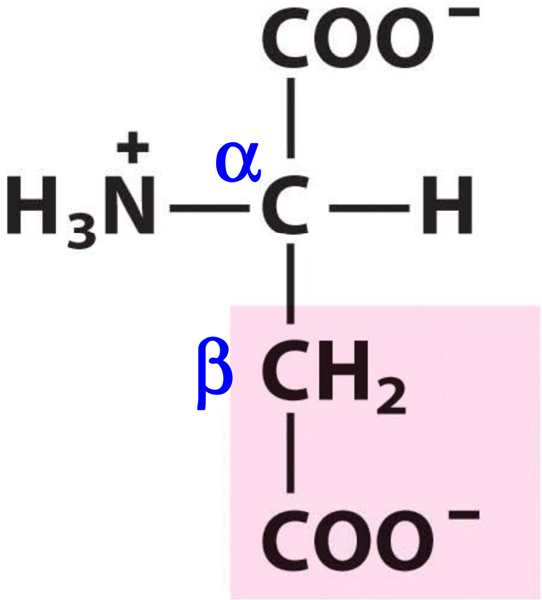
Histidine
組胺酸

Guanidino



Guanidine group

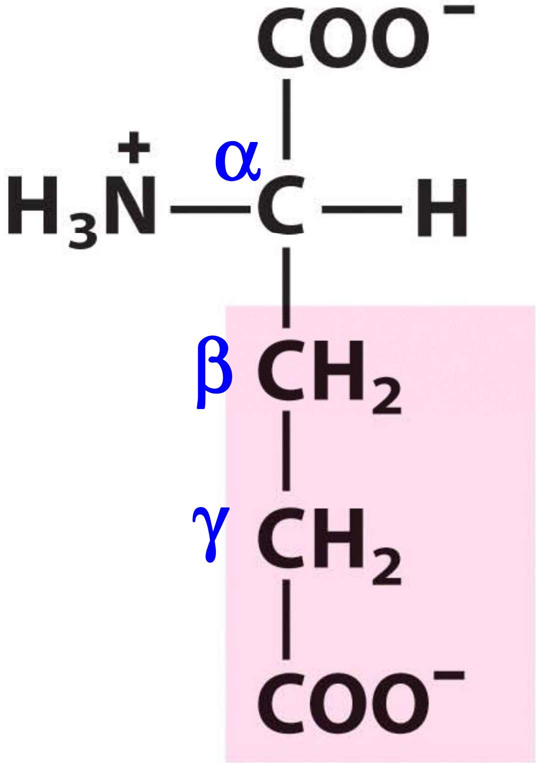
Negatively charged R groups



Aspartate

天門冬胺酸

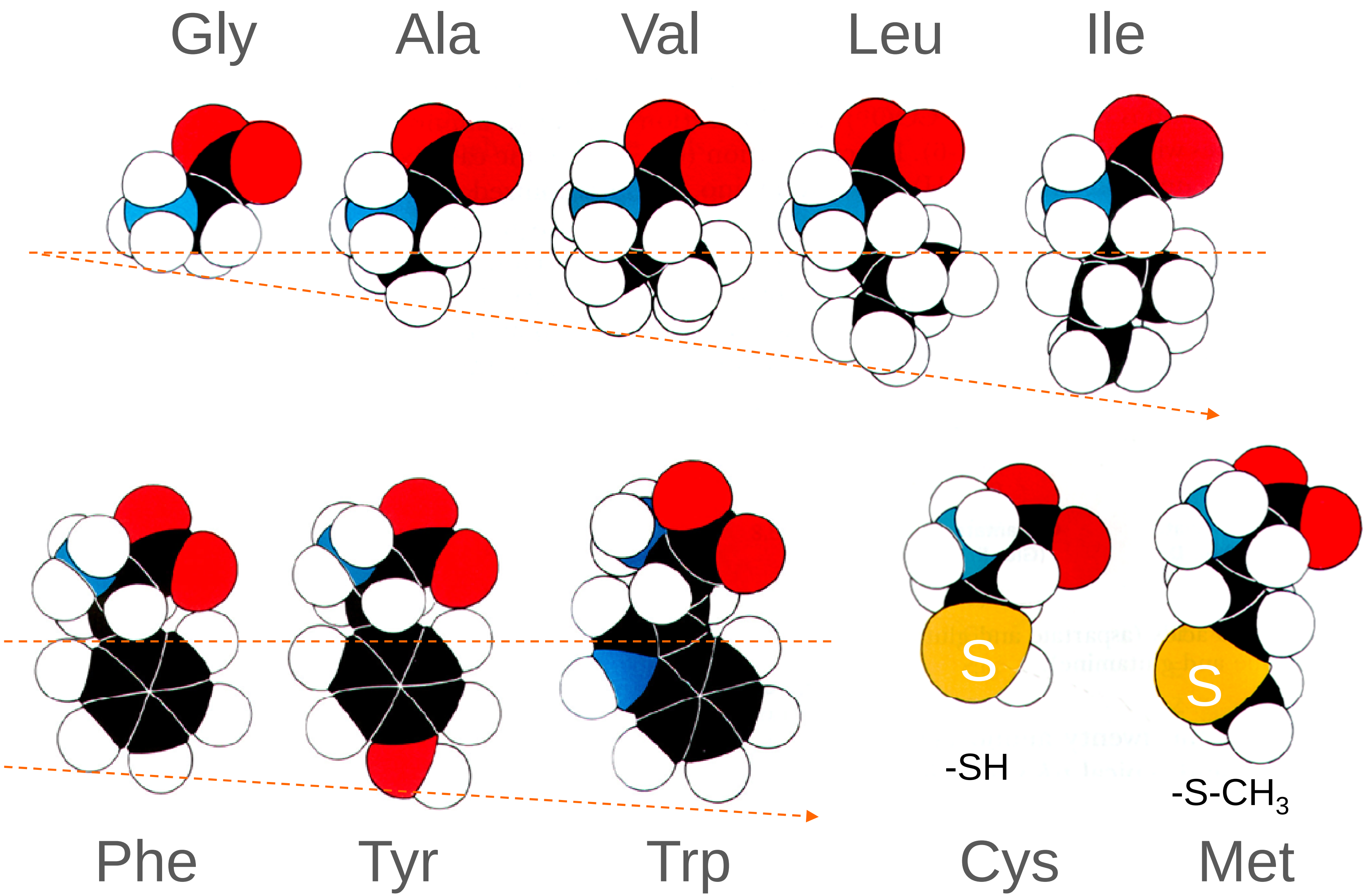
天冬胺酸



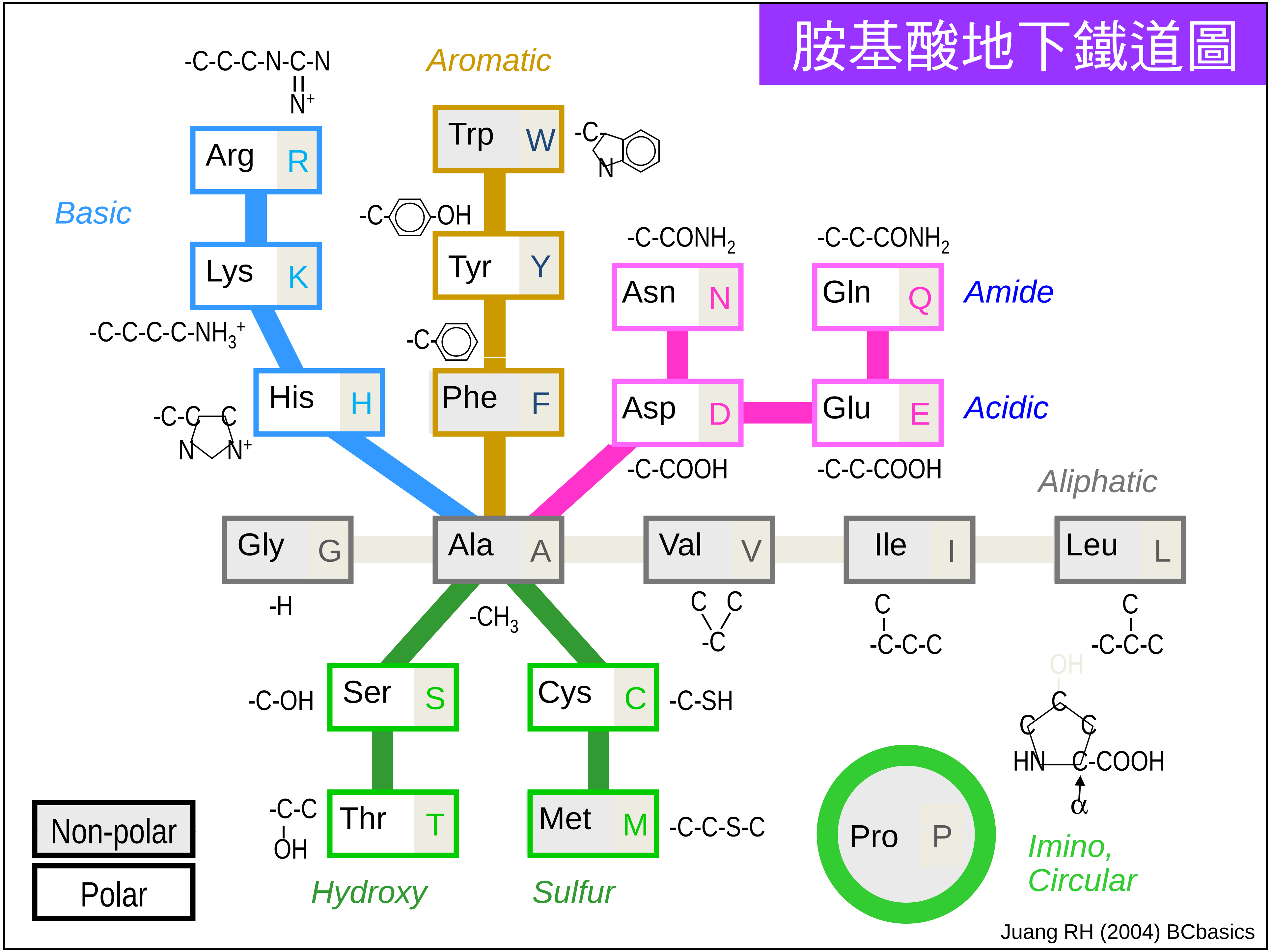
Glutamate

麩胺酸

各式胺基酸的大小樣式齊全

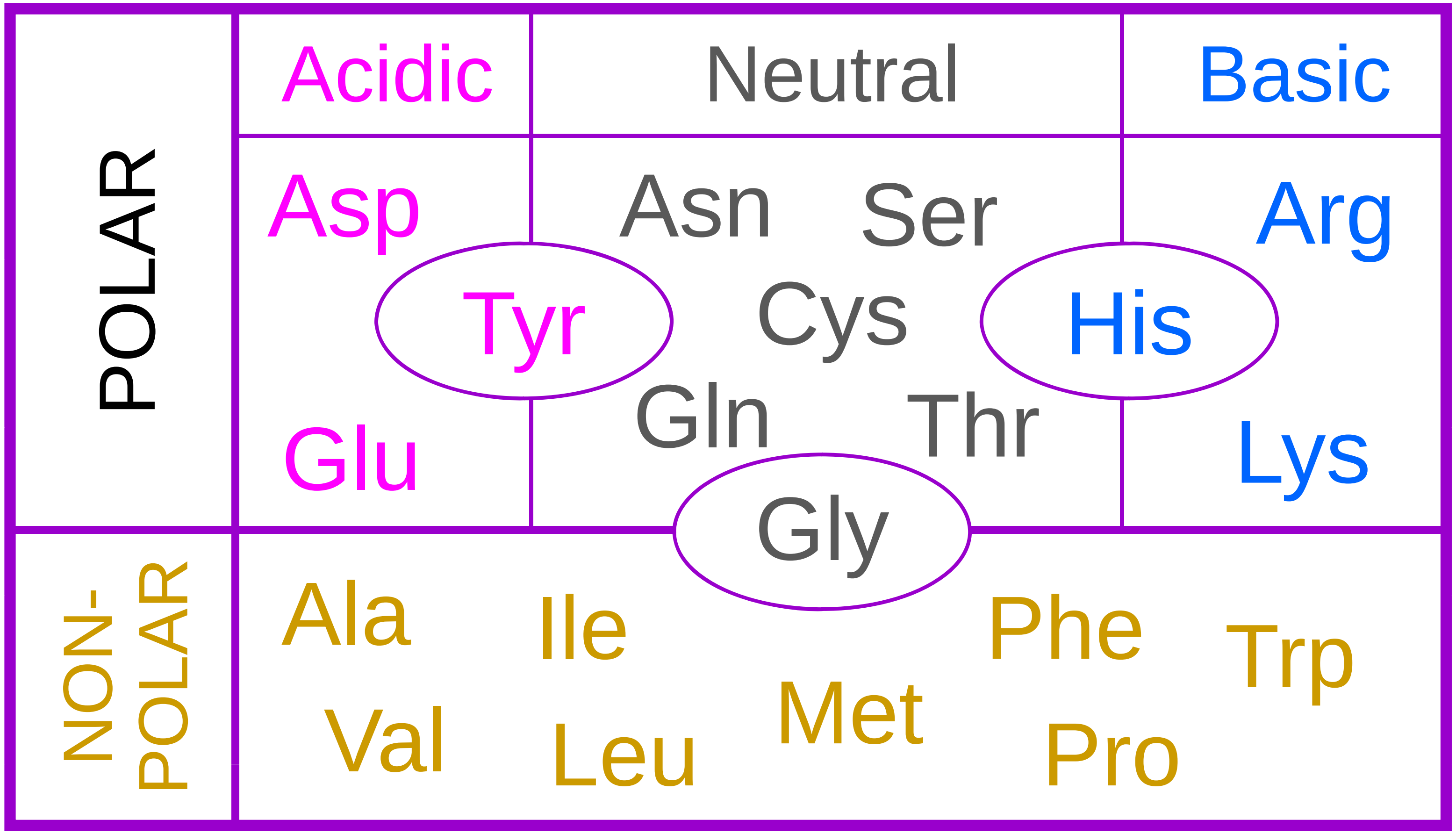


Stryer (1995) Biochemistry (4e) p.20



胺基酸地下鐵道圖
Aromatic
Basic
Amide
Acidic
Aliphatic
Hydroxy
Sulfur
Imino, Circular
Arg R
Lys K
His H
Trp W
Tyr Y
Phe F
Asn N
Gln Q
Asp D
Glu E
Gly G
Ala A
Val V
Ile I
Leu L
Ser S
Cys C
Thr T
Met M
Pro P
-C-C-C-N-C-N
N+
-C-C-C-C-NH3+
-C-C-C
N N+
-C
N
-C OH
-C
-C-CONH2
-C-C-CONH2
-C-COOH
-C-C-COOH
-H
-CH3
C C
-C
C
-C-C-C
C
-C-C-C
OH
C
C C
HN C-COOH
α
-C-OH
-C-SH
-C-C
OH
-C-C-S-C
Non-polar
Polar
Juang RH (2004) BCbasics

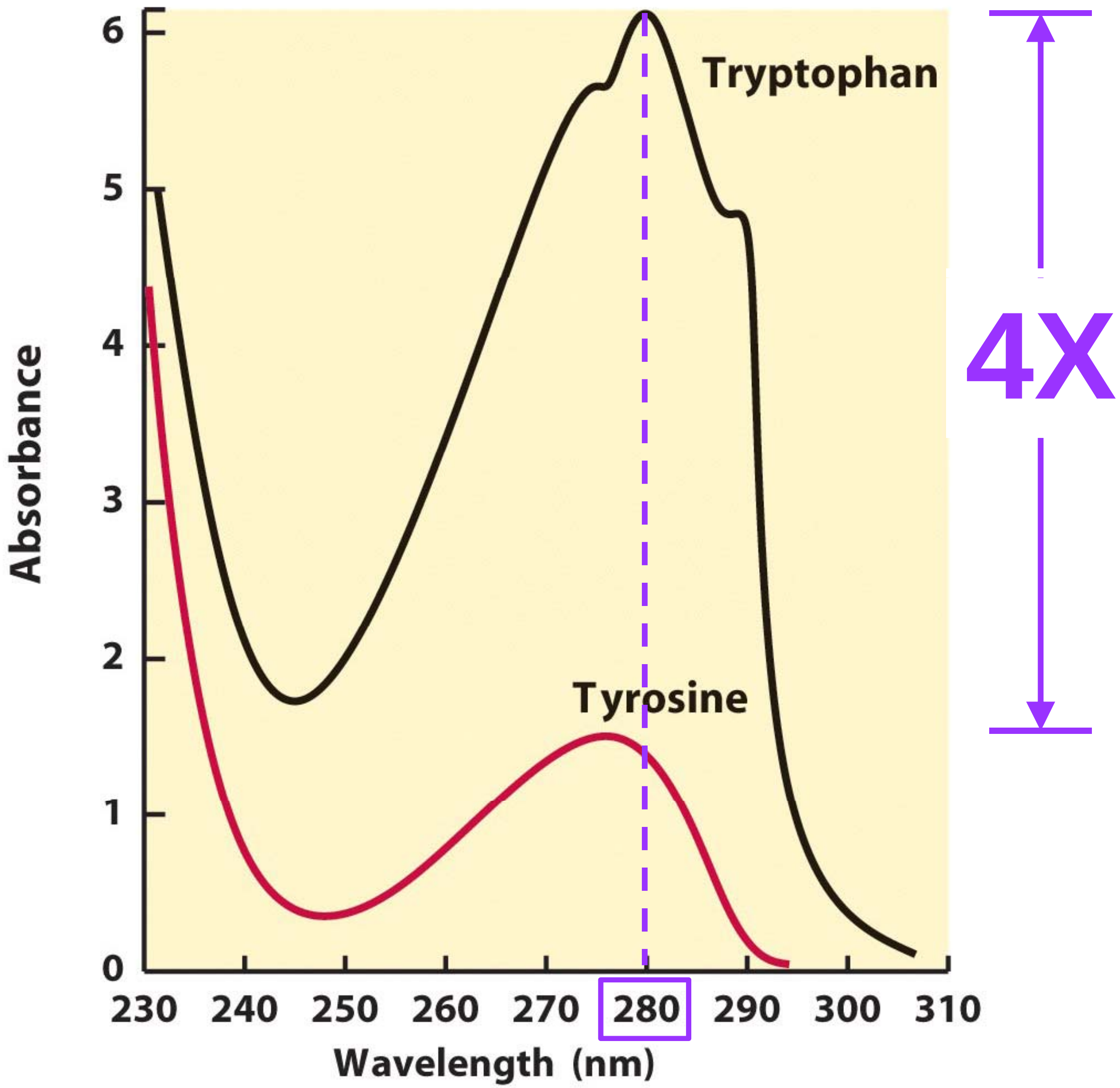
胺基酸的極性分類



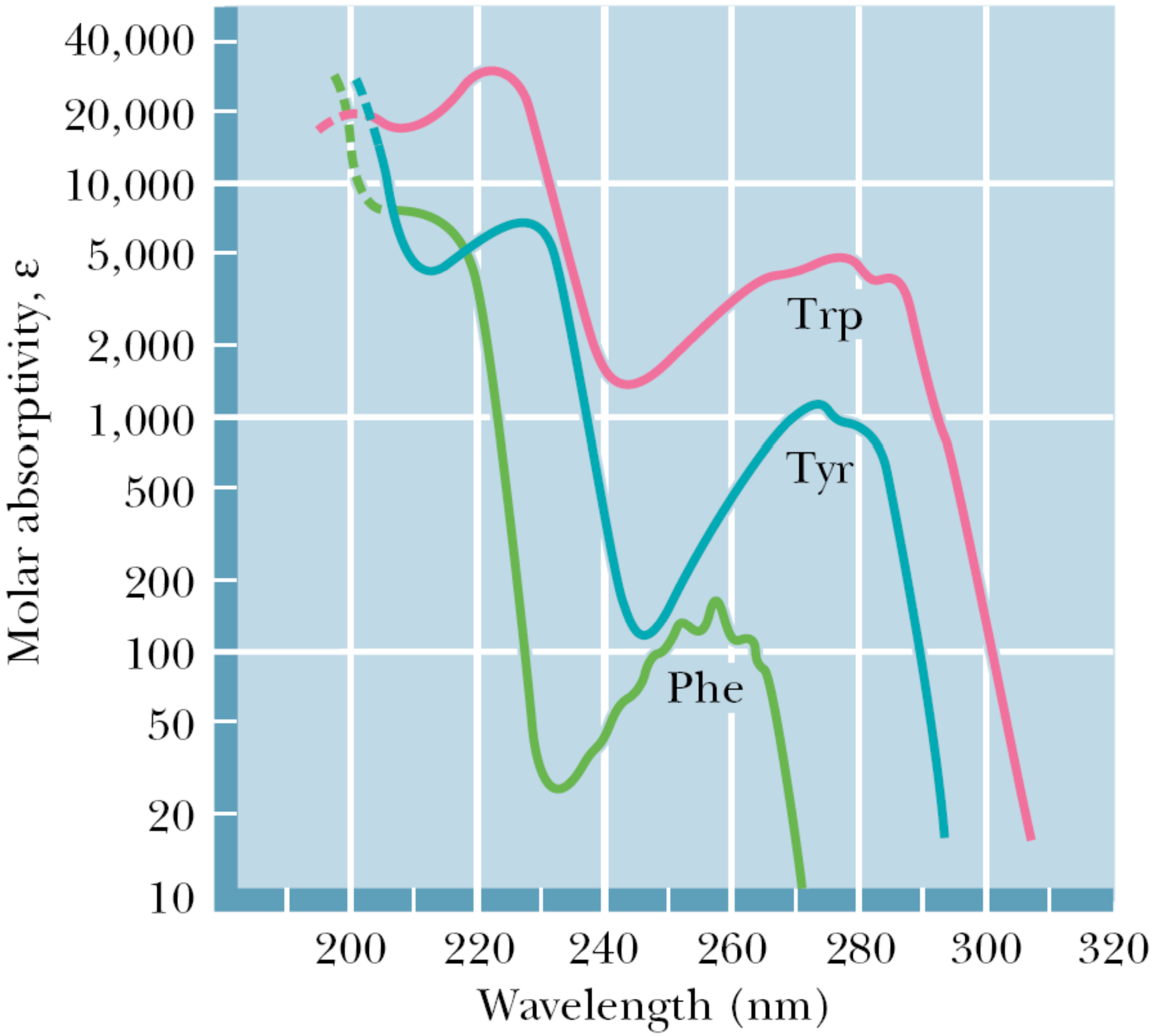
『極性或非極性，是蛋白質性質之所繫。』

Juang RH (2004) BCbasics

Absorption of UV by Trp and Tyr



1 mM, pH 6.0



The ultraviolet absorption spectra of the aromatic amino acids at pH 6.

(From Wetlaufer, D.B., 1962. Ultraviolet spectra of proteins and amino acids. Advances in Protein Chemistry 17:303–390.)

Biochemistry 2nd edition (1999), Garrett and Grisham

The Beer's Law (Beer-Lambert Law) :

$$A = \varepsilon b c$$

OD: optical density	$\mathbf{OD = \log \frac{1}{T}}$
%T: transmittance	

A_λ = the absorbance at wavelength λ

A: absorbance (no units)

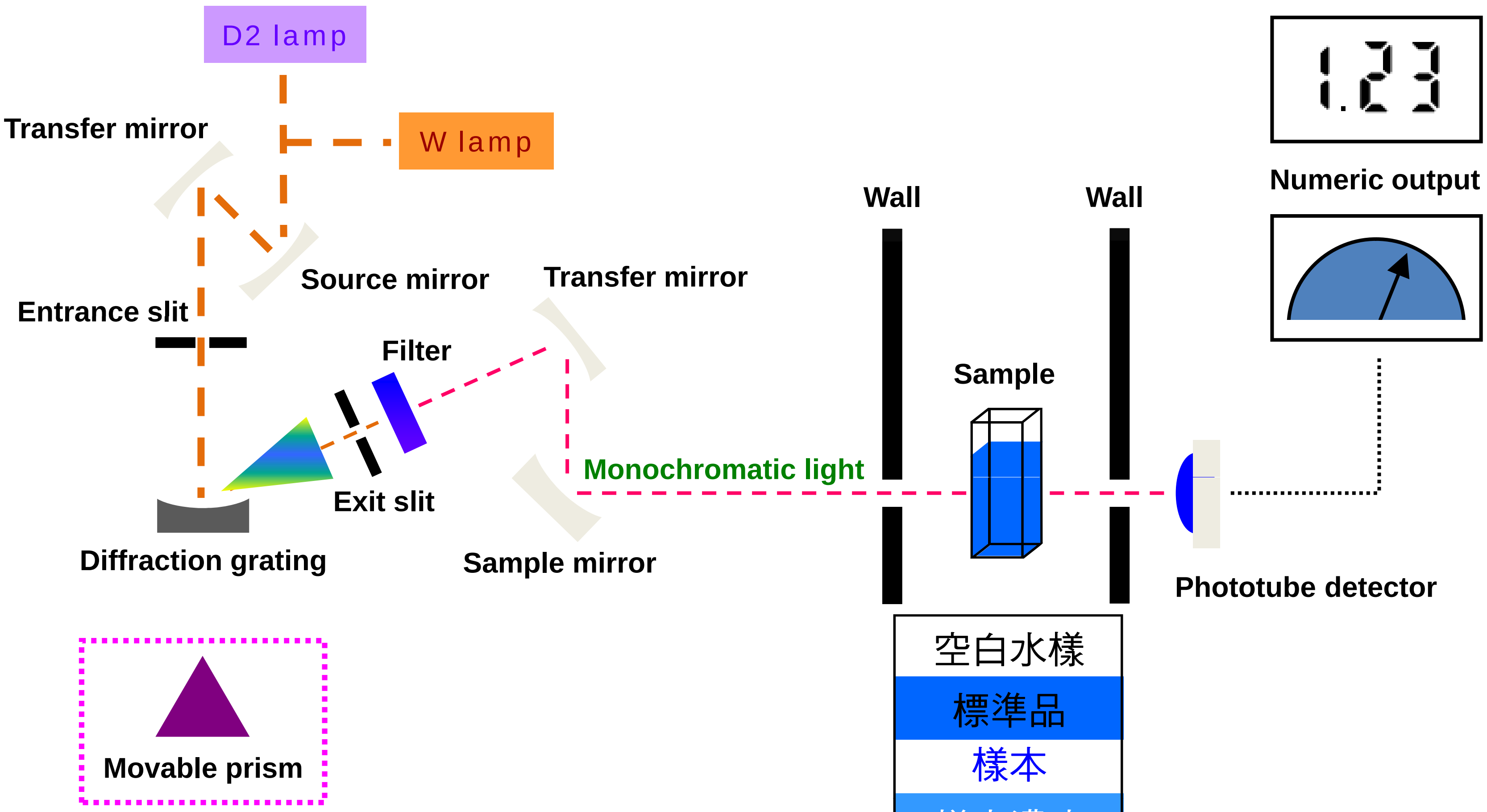
ε: molar extinction coefficient (L mol^{-1} cm^{-1})

b: the path length of the sample (cm)

c: the concentration of the sample (mol L^{-1})

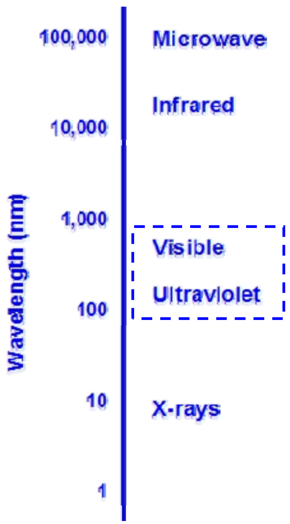
分光光度計 Spectrophotometer：

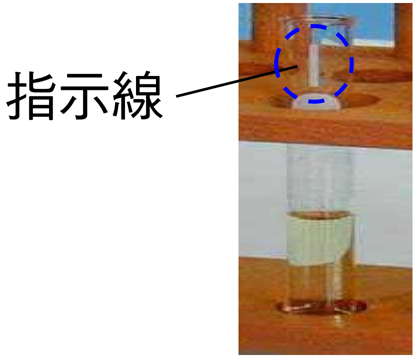
可見光或紫外光 →聚焦 →分光 →選擇波長 →單一且特定波長之光線 →樣品 →光電管 →訊號



空白水樣
標準品
樣本
樣本濃度

Cuvette (比色管)：





UV: 180~350

Visible: 340~1000

200~2500 nm

230~2500 nm

200~2500 nm

320~2500 nm

360~2500 nm

330~2500 nm

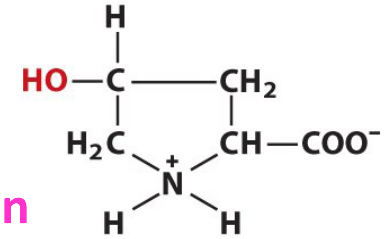
Quartz

Optical glass

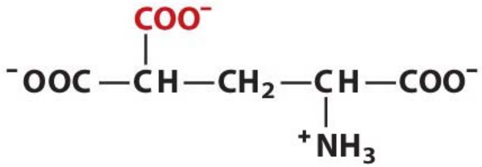
如果要測量的物質是在紫外光的範圍內，則比色管的材質要用特殊的石英玻璃，而不能用一般的玻璃或普通的塑膠材質。因為一般的玻璃或塑膠會吸收紫外光。

Uncommon amino acids

Collagen

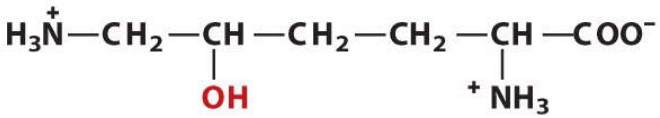


4-Hydroxyproline

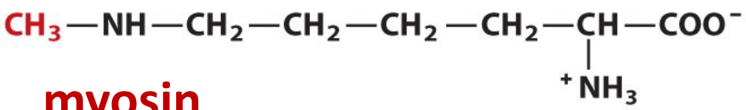


γ-Carboxyglutamate

10 glutamic acid residues on the N-terminal end of **prothrombin** are carboxylated to form **γ-carboxyglutamyl** residues. These residues are effective in the coordination of **calcium**, which is required for the **coagulation process**. The enzyme responsible for this modification, a liver microsomal **glutamyl carboxylase**, requires **vitamin K** for its activity

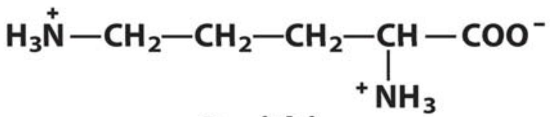


5-Hydroxylysine

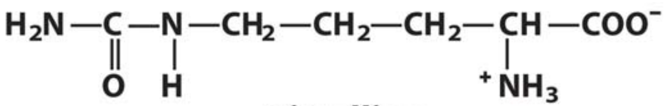


myosin

6-*N*-Methyllysine

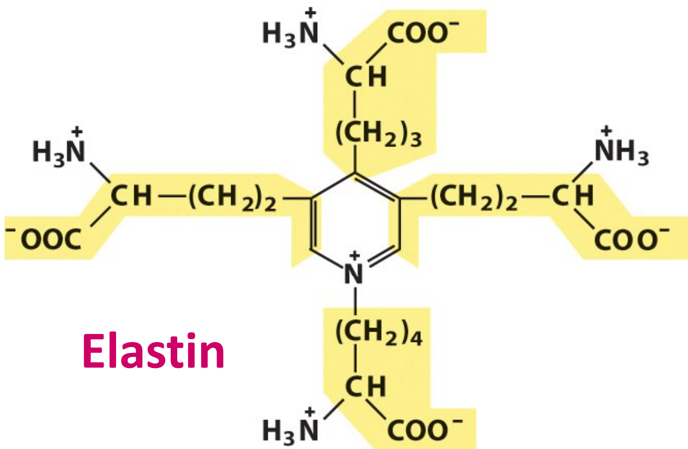


Ornithine

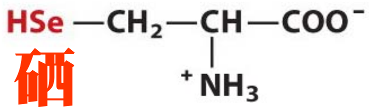


Citrulline

Elastin



Desmosine



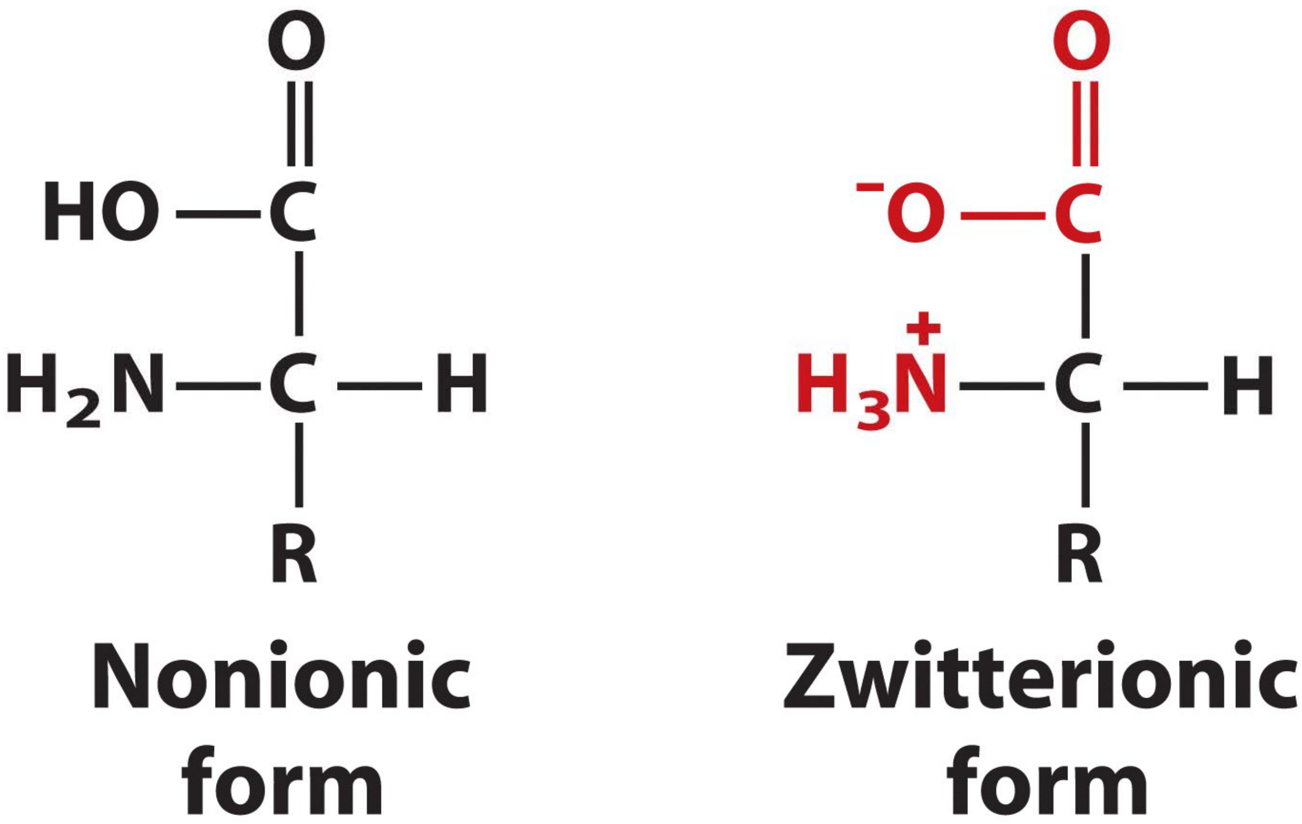
硒

Selenocysteine

The 21st amino acid

Amino acids can act as acids and bases

- Under normal cellular conditions amino acids are **zwitterions** (dipolar ions): Amino group = **$-NH_3^+$** ; **C**arboxyl group = **$-COO^-$**

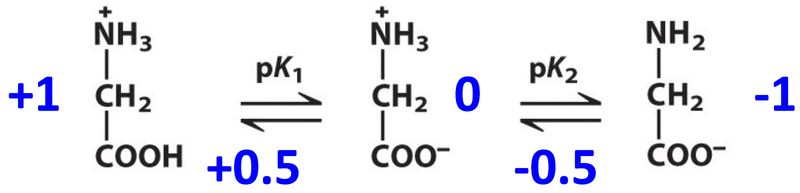


Zwitterion (German for "hybrid ion")
(帶正、負電荷的) 兩性離子

P. 79

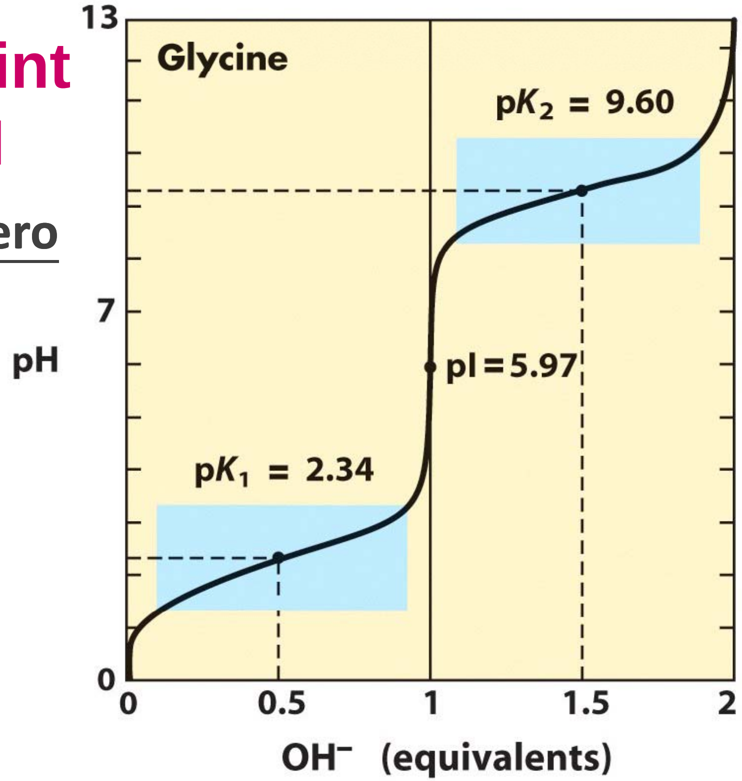
Titration of glycine

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_a values: pK_2 ($—NH_3^+$)	pK_a values: pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Glycine	Gly G	75	$\boxed{2.34}$	$\boxed{9.60}$		$\boxed{5.97}$	−0.4	7.2



pI: isoelectric point , isoelectric pH

<u>Net electric charge is zero</u>

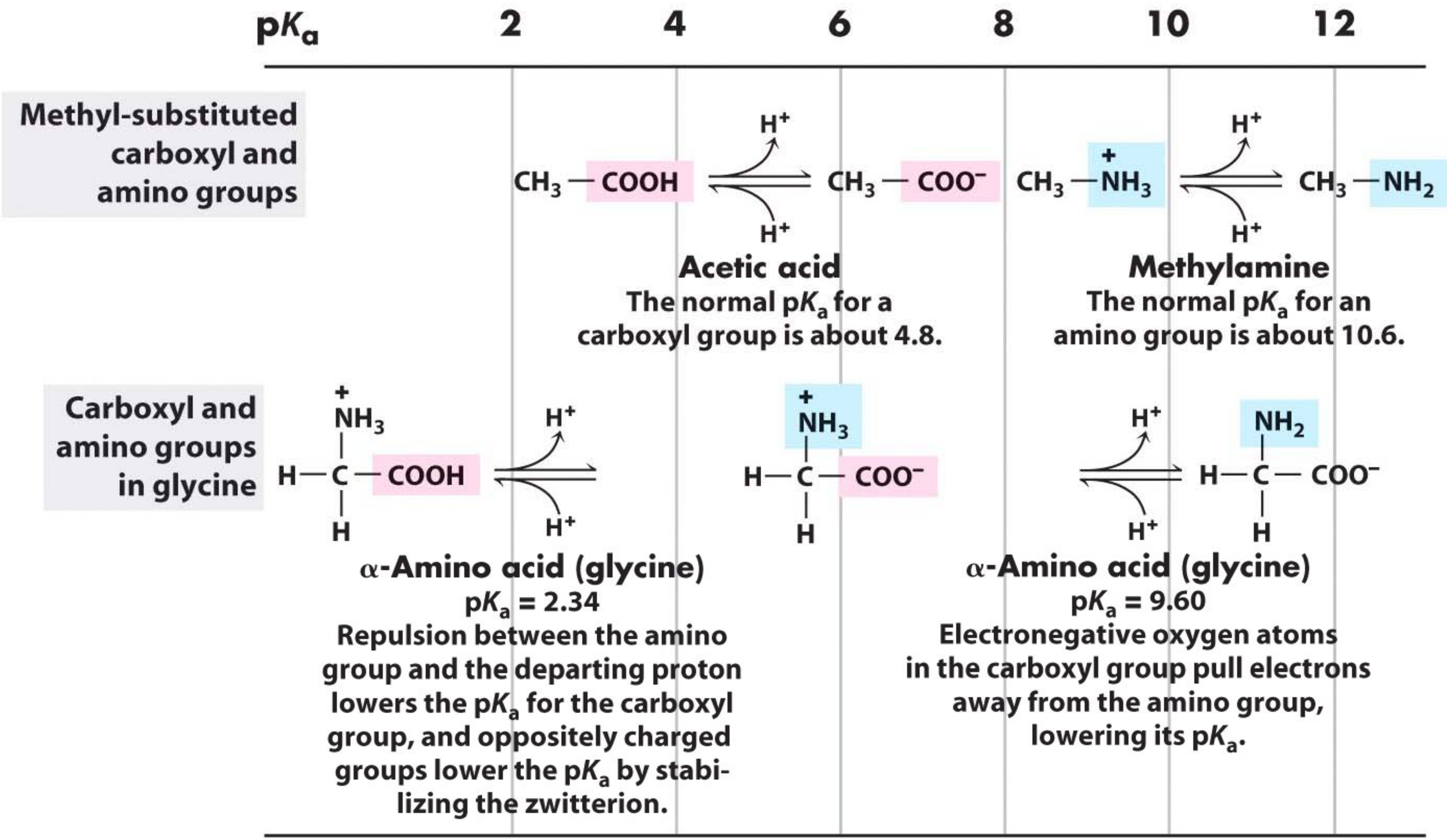


$$pI = (pK_1 + pK_2)/2$$

$$= (2.34 + 9.6)/2$$

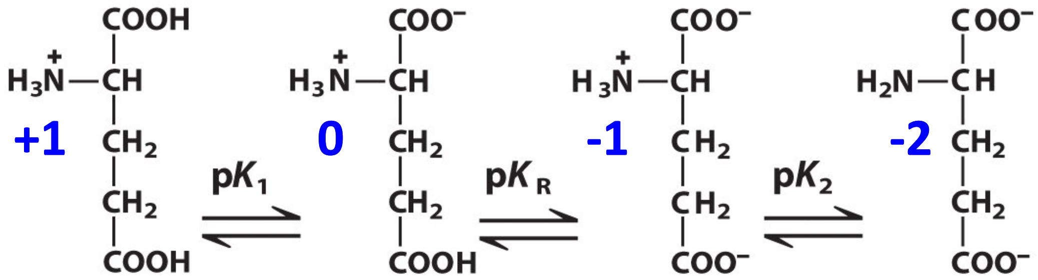
$$= 5.97$$

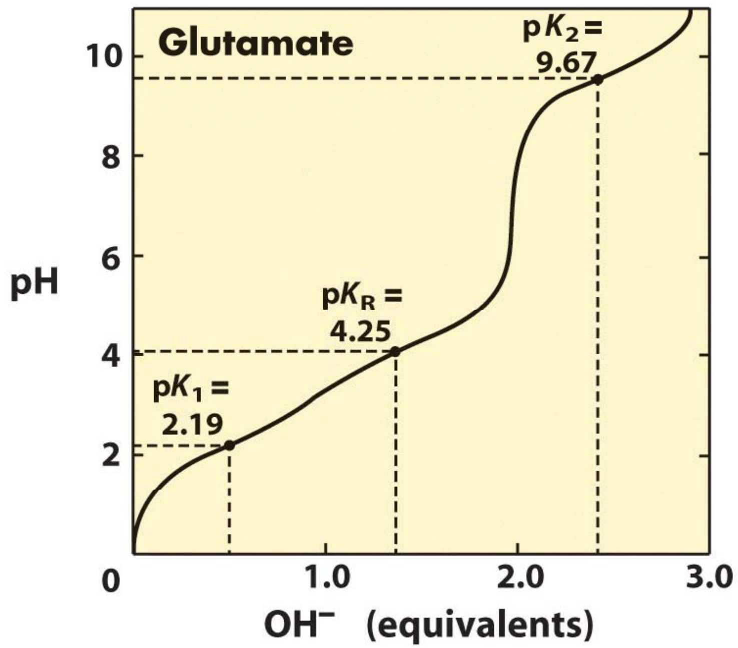
Effect of the chemical environment on pKa



Titration curve for glutamate

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_2 (—NH_3^+)	pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Glutamate	Glu E	147	2.19	9.67	4.25	3.22	−3.5	6.3





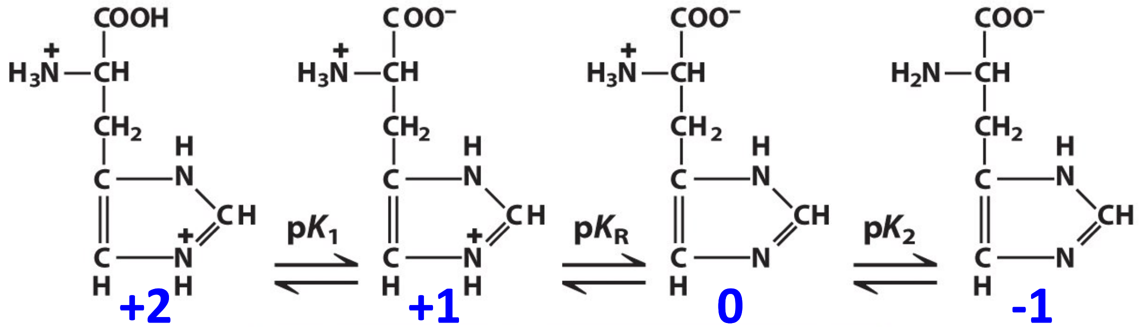
$$pI = (pK_1 + pK_R)/2$$

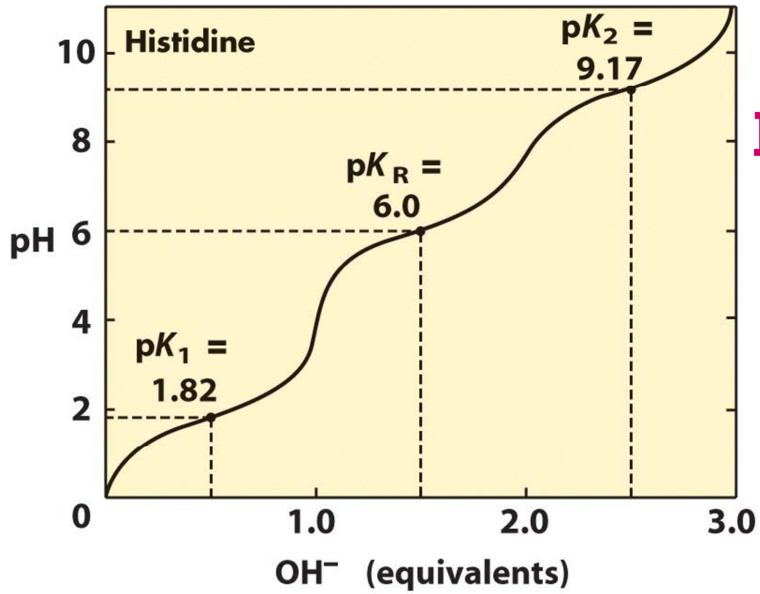
$$= (2.19 + 4.25)/2$$

$$= 3.22$$

Titration curve for histidine

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_a values: pK_2 ($—NH_3^+$)	pK_a values: pK_R (R group)	pI	Hydropathy index*	Occurrence in proteins (%)†
Histidine	His H	155	1.82	9.17	6.00	7.59	−3.2	2.3



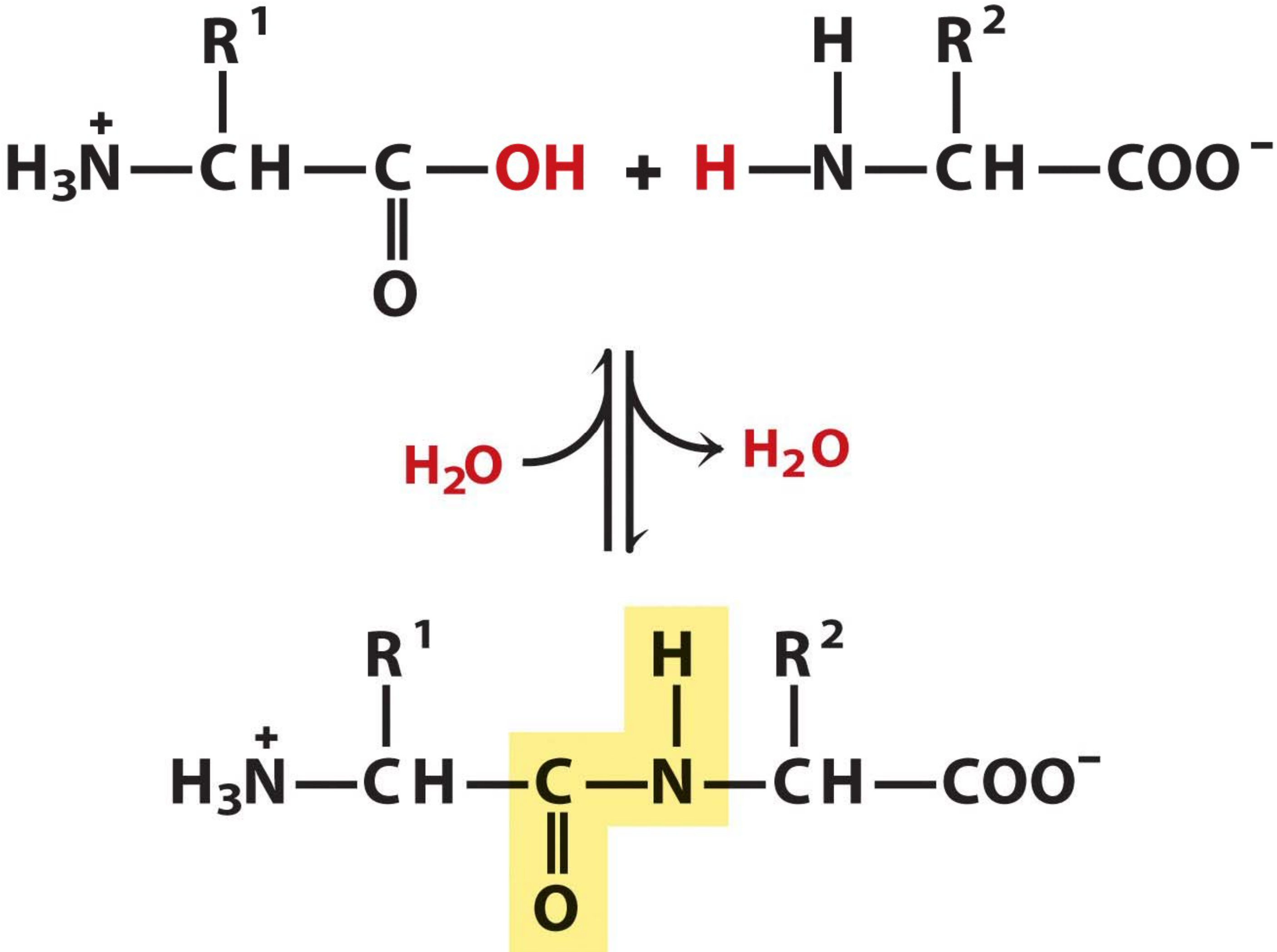


$$pI = (pK_R + pK_2)/2$$

$$= (6.00 + 9.17)/2$$

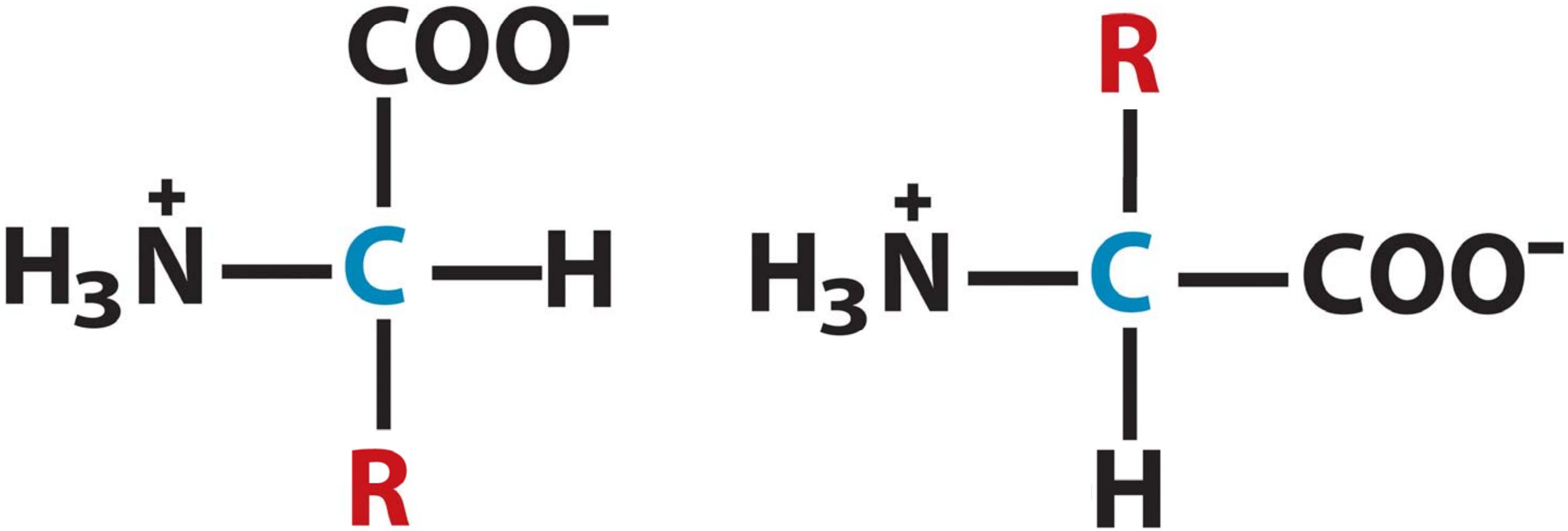
$$= 7.585$$

Formation of a peptide bond by condensation



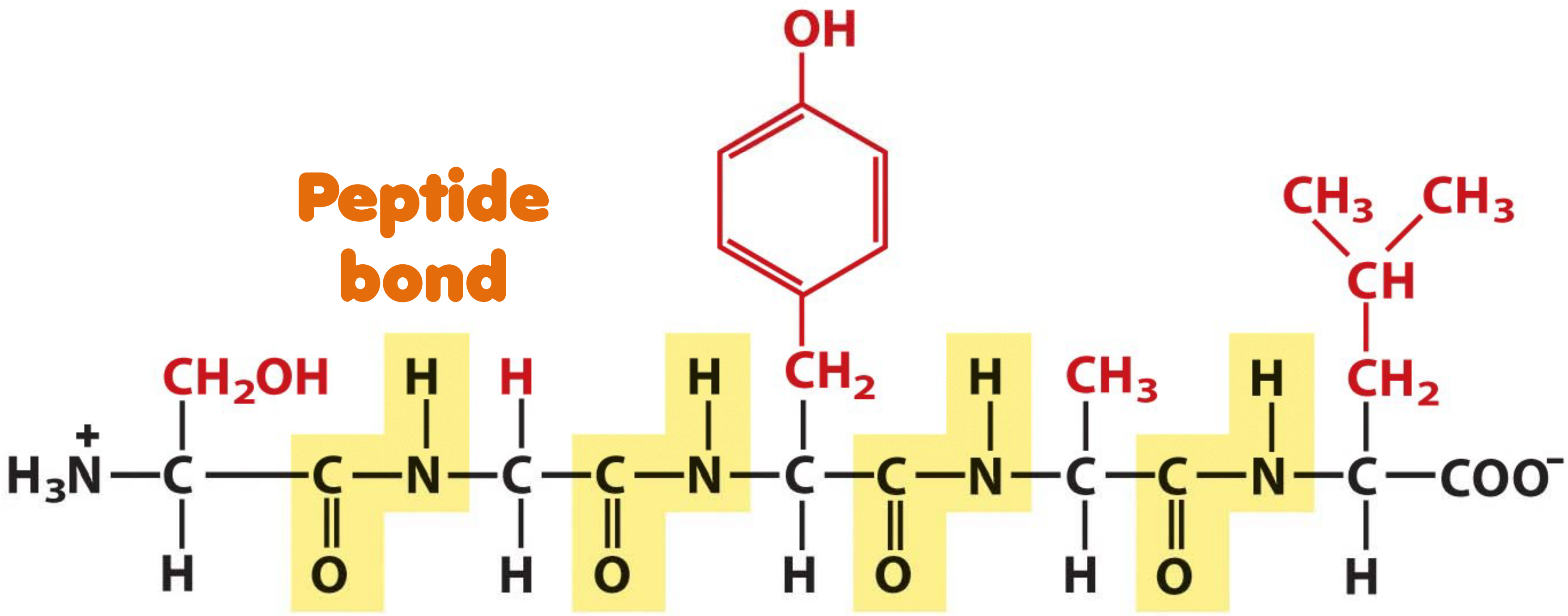
$T_{1/2}$: ~ 7 days

L-Amino Acid



Serylglycyltyrosylalanylleucine

Ser-Gly-Tyr-Ala-Leu, SGYAL

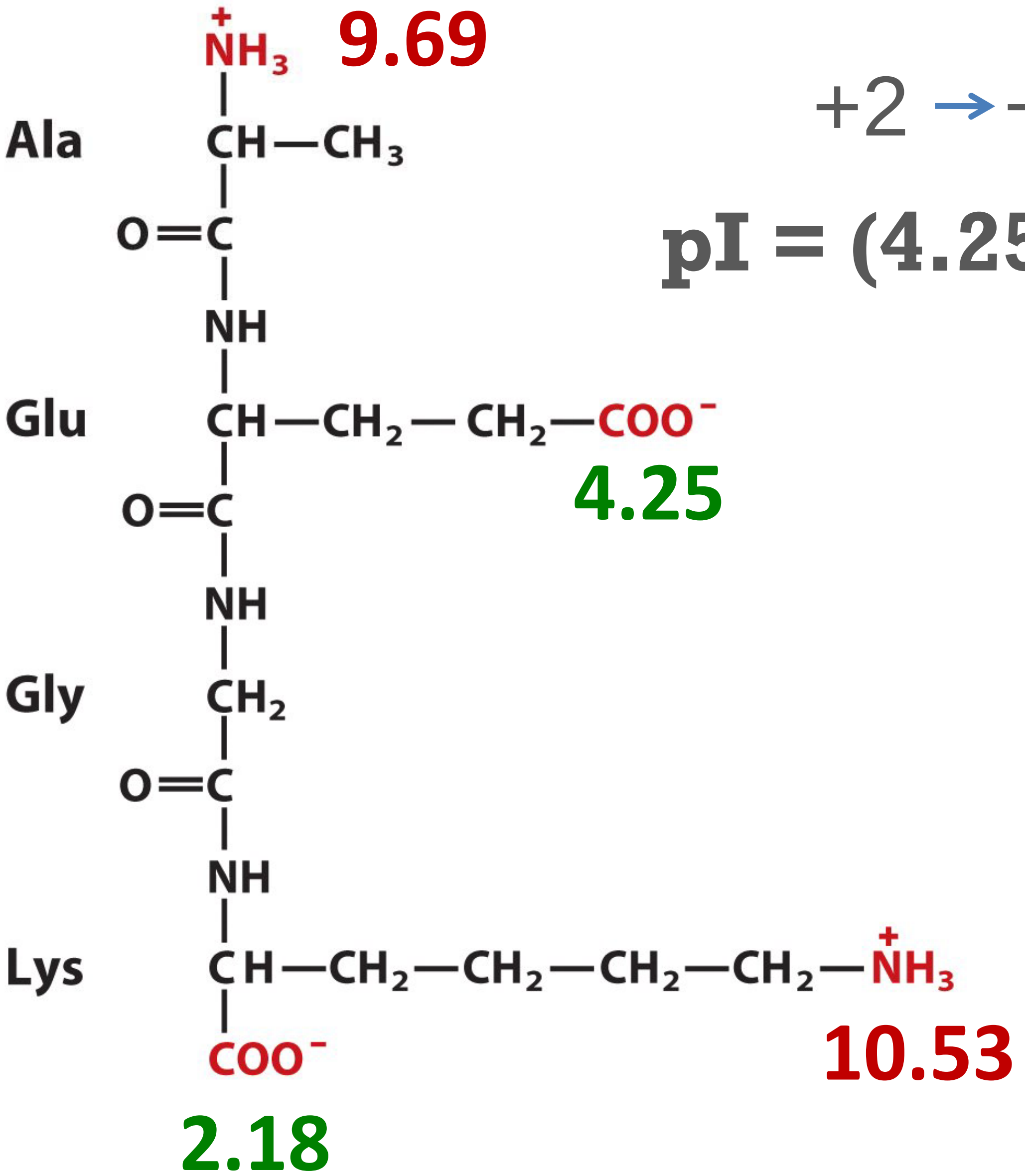


Amino-terminal end

Carboxyl-terminal end

N ——— Fischer projections ——— C

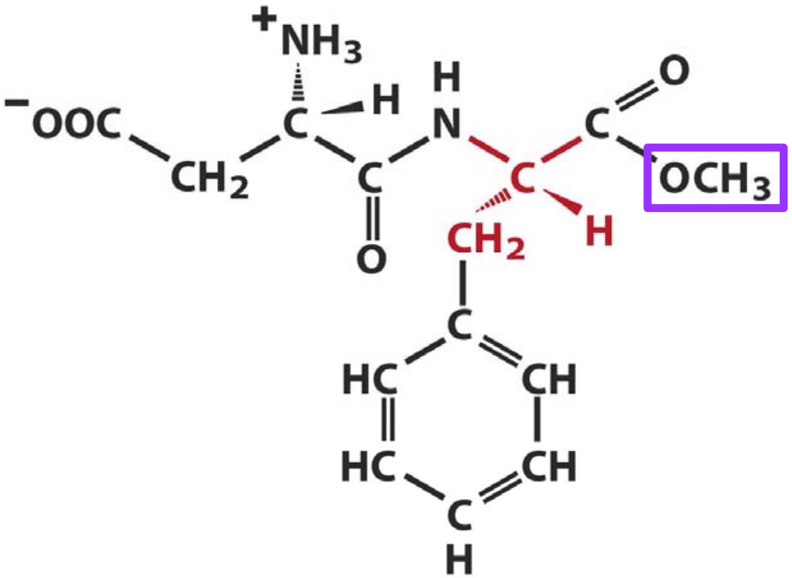
The pI of alanylglutamylglycyllysine



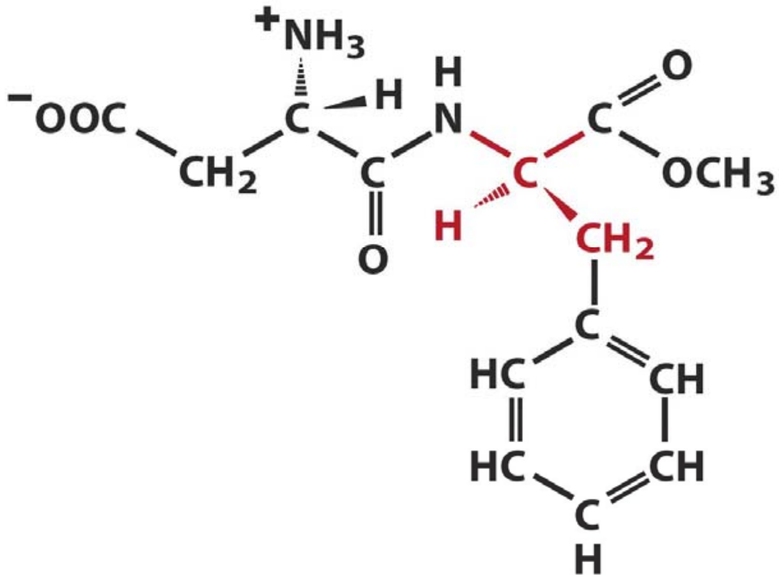
+2 → +1 → 0 → -1 → -2

pI = (4.25+9.69)/2 = 6.97

For life, a simple difference may lead to an opposite consequence



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



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

Aspartame

PKU 患者不可食用！

Asp-Phe 的甜度比蔗糖高兩百倍，阿斯巴甜則更高

TABLE 3–2 Molecular Data on Some Proteins

	Molecular weight	*Number of residues*	*Number of polypeptide chains*
Cytochrome *c* (human)	13,000	104	1
Ribonuclease A (bovine pancreas)	13,700	124	1
Lysozyme (chicken egg white)	13,930	129	1
Myoglobin (equine heart)	16,890	153	1
Chymotrypsin (bovine pancreas)	21,600	241	3
Chymotrypsinogen (bovine)	22,000	245	1
Hemoglobin (human)	64,500	574	4
Serum albumin (human)	68,500	609	1
Hexokinase (yeast)	102,000	972	2
RNA polymerase (*E. coli*)	450,000	4,158	5
Apolipoprotein B (human)	513,000	4,536	1
Glutamine synthetase (*E. coli*)	619,000	5,628	12
Titin (human)	2,993,000	26,926	1

20個胺機酸平均分子量：**138**

但是以在蛋白質中出現的比例之平均分子量：128

扣掉形成peptide bond**後少掉了一個水分子：128-18=110**

110

P. 83

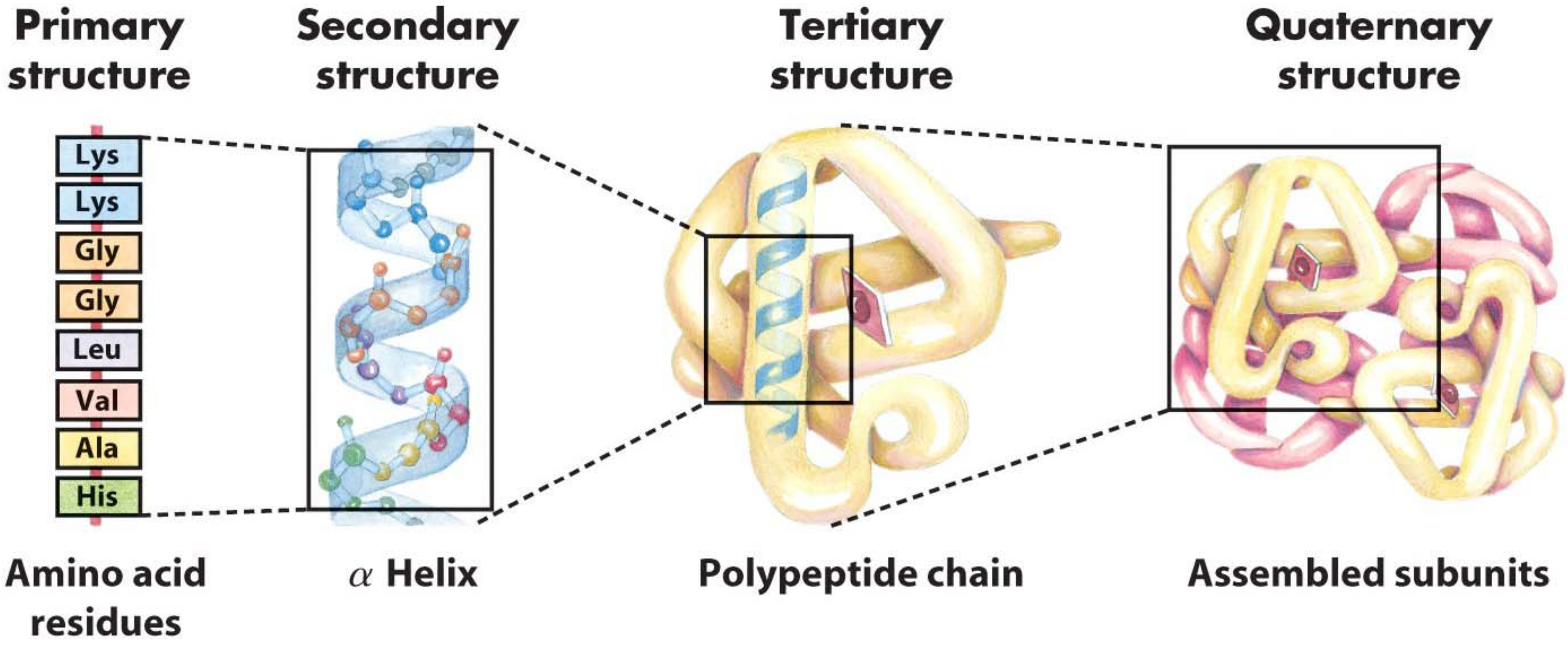
TABLE 3–3 Amino Acid Composition of Two Proteins

	*Number of residues per molecule of protein**	
Amino acid	*Bovine cytochrome* c	*Bovine chymotrypsinogen*
Ala	6	22
Arg	2	4
Asn	5	15
Asp	3	8
Cys	2	10
Gln	3	10
Glu	9	5
Gly	14	23
His	3	2
Ile	6	10
Leu	6	19
Lys	18	14
Met	2	2
Phe	4	6
Pro	4	9
Ser	1	28
Thr	8	23
Trp	1	8
Tyr	4	4
Val	3	23
Total	104	245

*In some common analyses, such as acid hydrolysis, Asp and Asn are not readily distinguished from each other and are together designated Asx (or B). Similarly, when Glu and Gln cannot be distinguished, they are together designated Glx (or Z). In addition, Trp is destroyed. Additional procedures must be employed to obtain an accurate assessment of complete amino acid content.

TABLE 3–4 Conjugated Proteins

Class	*Prosthetic group*	*Example*
Lipoproteins	Lipids	β_1-Lipoprotein of blood
Glycoproteins	Carbohydrates	Immunoglobulin G
Phosphoproteins	Phosphate groups	Casein of milk
Hemoproteins	Heme (iron porphyrin)	Hemoglobin
Flavoproteins	Flavin nucleotides	Succinate dehydrogenase
Metalloproteins	Iron	Ferritin
	Zinc	Alcohol dehydrogenase
	Calcium	Calmodulin
	Molybdenum	Dinitrogenase
	Copper	Plastocyanin


Primary structure
Secondary structure
Tertiary structure
Quaternary structure
Lys
Lys
Gly
Gly
Leu
Val
Ala
His
Amino acid residues
α Helix
Polypeptide chain
Assembled subunits

Assignment of configuration by the RS system

(a) Assign a priority to each group attached to a chiral carbon based upon atomic mass priority (1 highest, 4 lowest)

- If two atoms are identical, move to the next atoms
- For double or triple bonds, count atom once for each bond (-CHO higher priority than $-CH_2OH$)
- Priorities (low to high): -H, $-CH_3$, $-C_6H_5$, $-CH_2OH$, -CHO, -COOH, $-NH_2$, -NHR, -OH, -OR, -SH

Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

RS system

proposed in 1956 by Robert Cahn, Sir Christopher Ingold, and Vladimir Prelog

(b) Orient the molecule with priority 4 pointing away (behind the chiral carbon). Trace path from highest priority to lowest priority (1, 2, 3, 4)

(c) Clockwise path: absolute configuration **R**

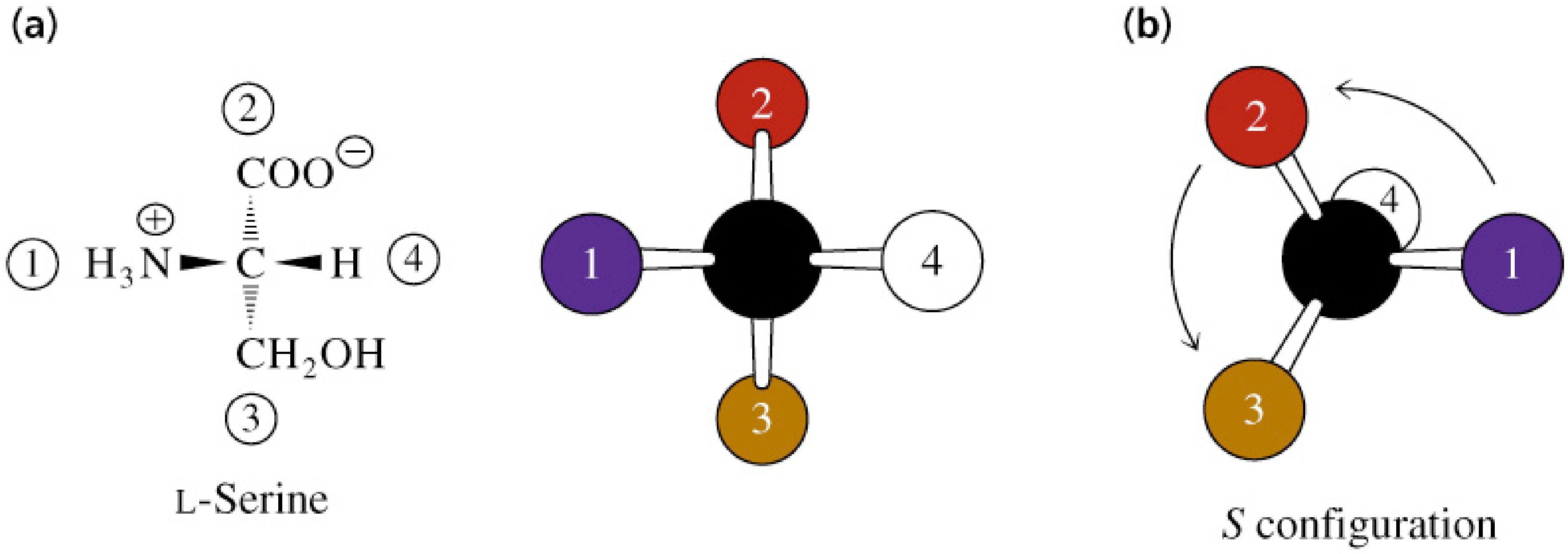
Counterclockwise path: absolute configuration **S**

NOTE: **All of the 19 common chiral L-amino acids except cysteine have the S configuration**.

Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

Assignment of RS configuration

proposed in 1956 by Robert Cahn, Sir Christopher Ingold, and Vladimir Prelog



Principles of biochemistry, 3rd edition, Horton, Moran, Ochs , Rawn, Scrimgeour

Table 4.2

Specific Rotations for Some Amino Acids

Amino Acid	Specific Rotation $[\alpha]_D^{25}$, Degrees
L-Alanine	+1.8
L-Arginine	+12.5
L-Aspartic acid	+5.0
L-Glutamic acid	+12.0
L-Histidine	−38.5
L-Isoleucine	+12.4
L-Leucine	−11.0
L-Lysine	+13.5
L-Methionine	−10.0
L-Phenylalanine	−34.5
L-Proline	−86.2
L-Serine	−7.5
L-Threonine	−28.5
L-Tryptophan	−33.7
L-Valine	+5.6

The direction of optical rotation can be specified in the name by using a (+) for dextrorotatory compounds and a (-) for levorotatory compounds, as in L(+)-arginine

Biochemistry 2nd edition (1999), Garrett and Grisham