# CORSO INTEGRATO: BIOCHIMICA

## Organizzazione del corso:

| Modulo | CFU | ore | Collocazione | Docente |
|---|---|---|---|---|
| Biochimica I | 8 | 64 | Anno I - Sem 2 | F.Sinigaglia |
| Biochimica II | 7 | 56 | Anno II- Sem 1 | F.Sinigaglia |
| Biol. Molecolare | 2 | 24 | Anno II- Sem 1 | A.Graziani |

**Sedi del Corso: Caserma Perrone-Aula 104**
**V.le Ferrucci 33 Aula Pt 3-1 (Ist. Salesiani) dal 5/03**

**Testi consigliati:**

**-Nelson, Cox,PRINCIPI DI BIOCHIMICA di LEHNINGER Zanichelli -Va Edizione**
**-C.K.Mathews, K.E.Van Holde BIOCHIMICA Ambrosiana-Milano**
**-L. Stryer BIOCHIMICA Casa editrice:Zanichelli – Via Edizione**
**-Voet D., Voet J.G, Pratt. C.W. FONDAMENTI DI BIOCHIMICA Zanichelli**

# Quando e come comunicare con i Docenti del C.I.?

-Al termine di ciascuna lezione
-per appuntamento
-e-mail: fabiola.sinigaglia@med.unipmn.it
andrea.graziani@med.unipmn.it

# Quando e Come si svolgera' l'esame del Corso integrato?

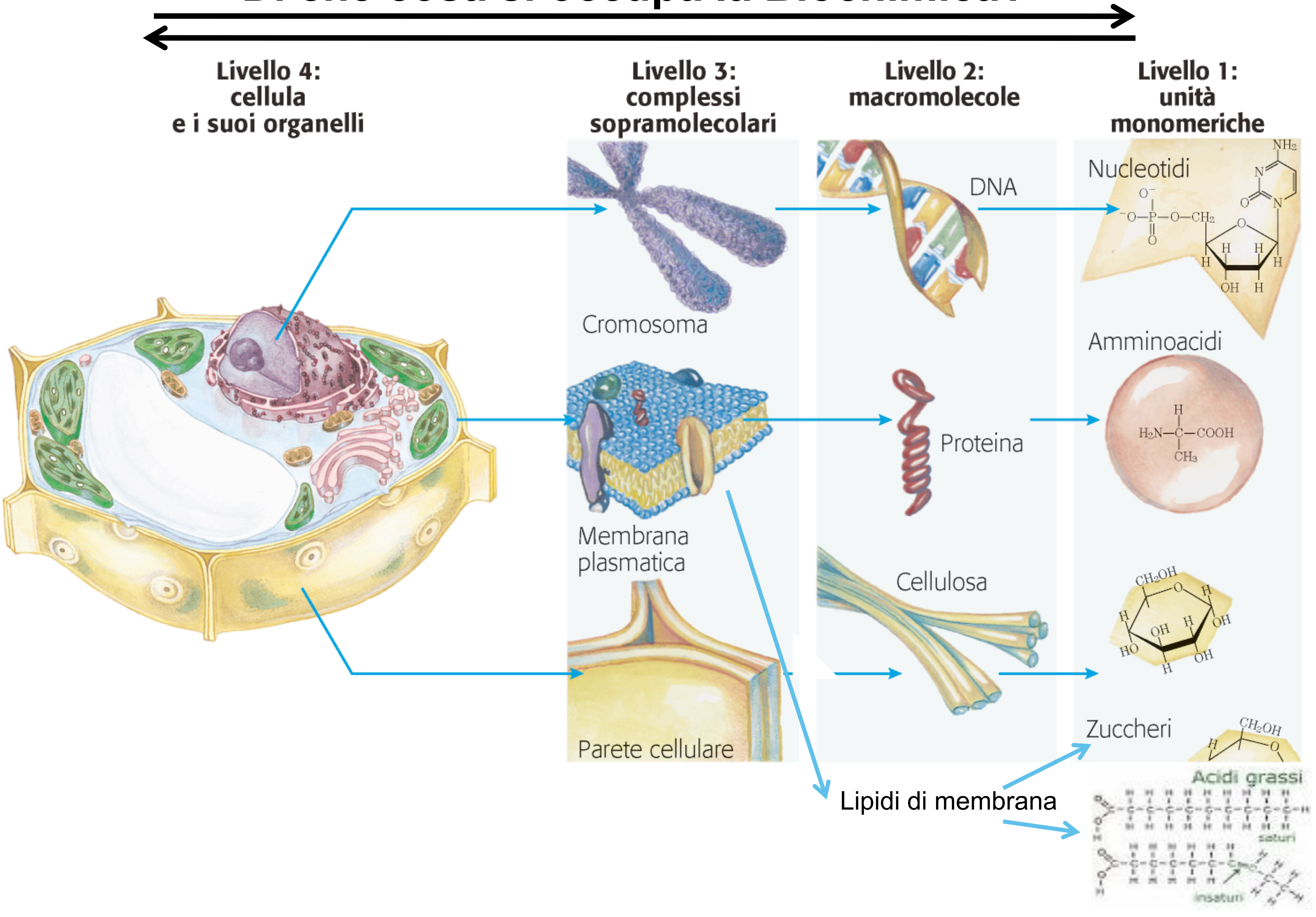
L'esame relativo all'INTERO CORSO INTEGRATO potra' essere sostenuto al termine dell'intero corso, ovvero alla fine del primo semestre del secondo anno.

L'esame si compone di 2 diverse prove:

- prova scritta
- prova orale (limitata agli studenti con voto non inferiore a 18/30 nella prova scritta)

N.B. Al termine del primo modulo di Corso verranno svolte 2 prove scritte di autovalutazione (mese di giugno e settembre) sui contenuti della prima prima parte del Corso. Tali prove saranno facoltative.

# Di che cosa si occupa la Biochimica?



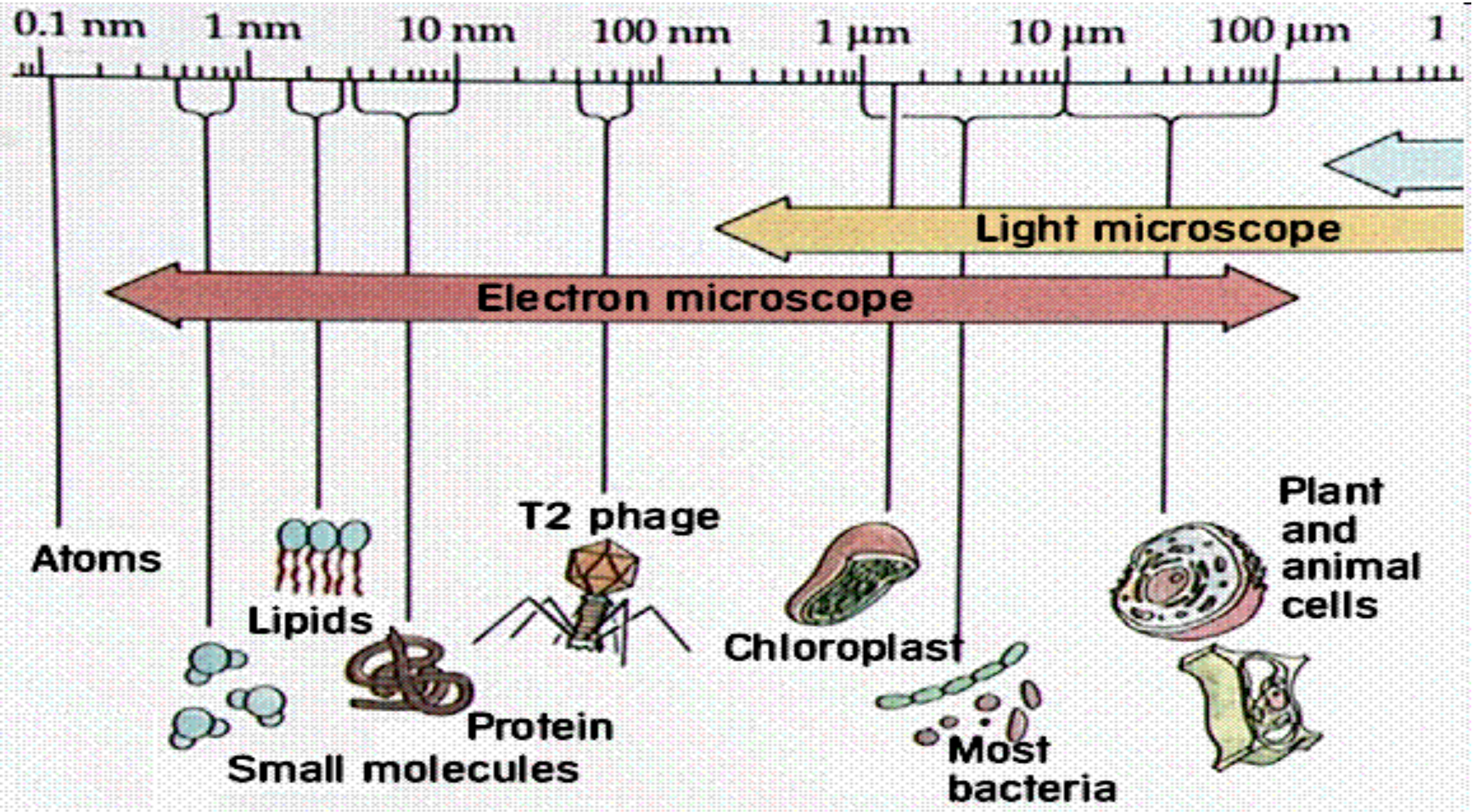
**Livello 4:**
**cellula**
**e i suoi organelli**

**Livello 3:**
**complessi**
**sopramolecolari**

**Livello 2:**
**macromolecole**

**Livello 1:**
**unità**
**monomeriche**

Cromosoma
Membrana plasmatica
Parete cellulare
DNA
Proteina
Cellulosa
Nucleotidi
Amminoacidi
Zuccheri
Acidi grassi
saturi
insaturi
Lipidi di membrana


0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1
Light microscope
Electron microscope
Atoms
Lipids
Small molecules
Protein
T2 phage
Chloroplast
Most bacteria
Plant and animal cells

# MACROMOLECOLE

-PROTEINE
-ACIDI NUCLEICI
-LIPIDI
-POLISACCARDI

# LIPIDI

# Tipi di lipidi

Acidi grassi
Saturi
insaturi

Gliceridi
Neutri
fosfolipidi

Lipidi complessi
Lipoproteine
Glicolipidi

Non gliceridi
Sfingolipidi
Steroidi
Cere
terpeni

# Funzione dei lipidi

Struttura della membrana cellulare
Creare una barriera
Controllare il flusso di materiale

Immagazzinamento di “energia”
Grasso

Ormoni. Comunicazione tra cellule
Vitamine.
Regolazione processi biologici

# ACIDI GRASSI

## NOMENCLATURA

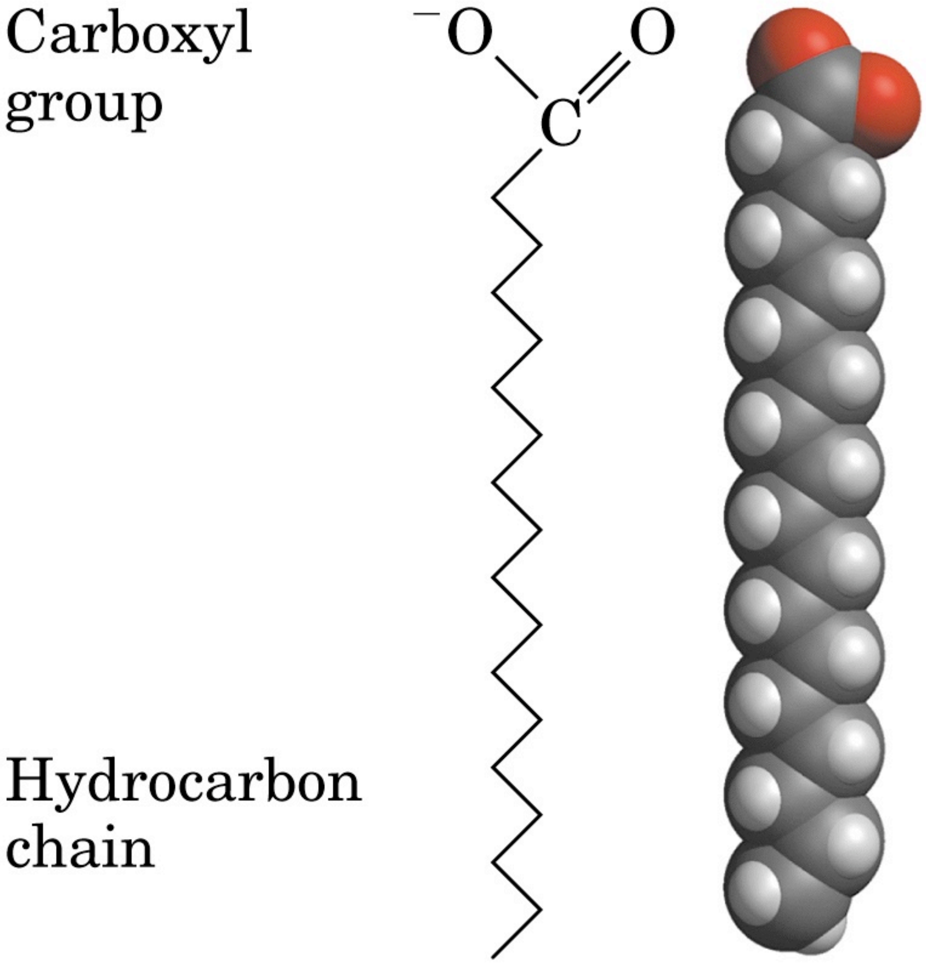
**Desinenza – OICO**

**Acido STERICO (C18) → acido OTTADECANOICO**

**Acido PALMITICO (C16) → acido ESADECANOICO**

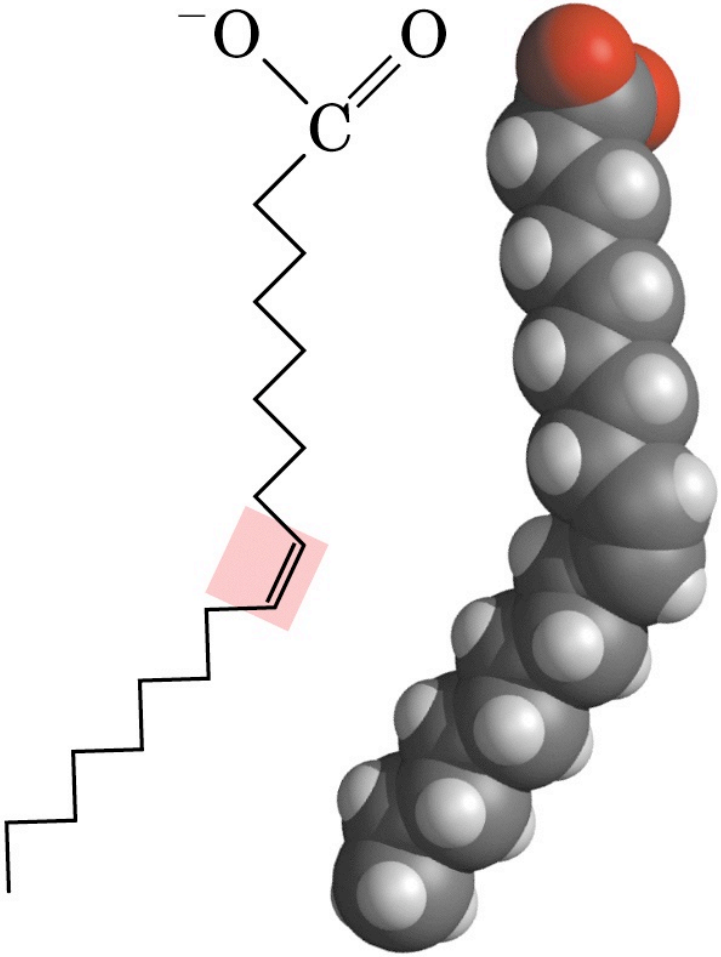
# ACIDI GRASSI

## SATURI


Carboxyl group
$^{-}O$
O
C
Hydrocarbon chain

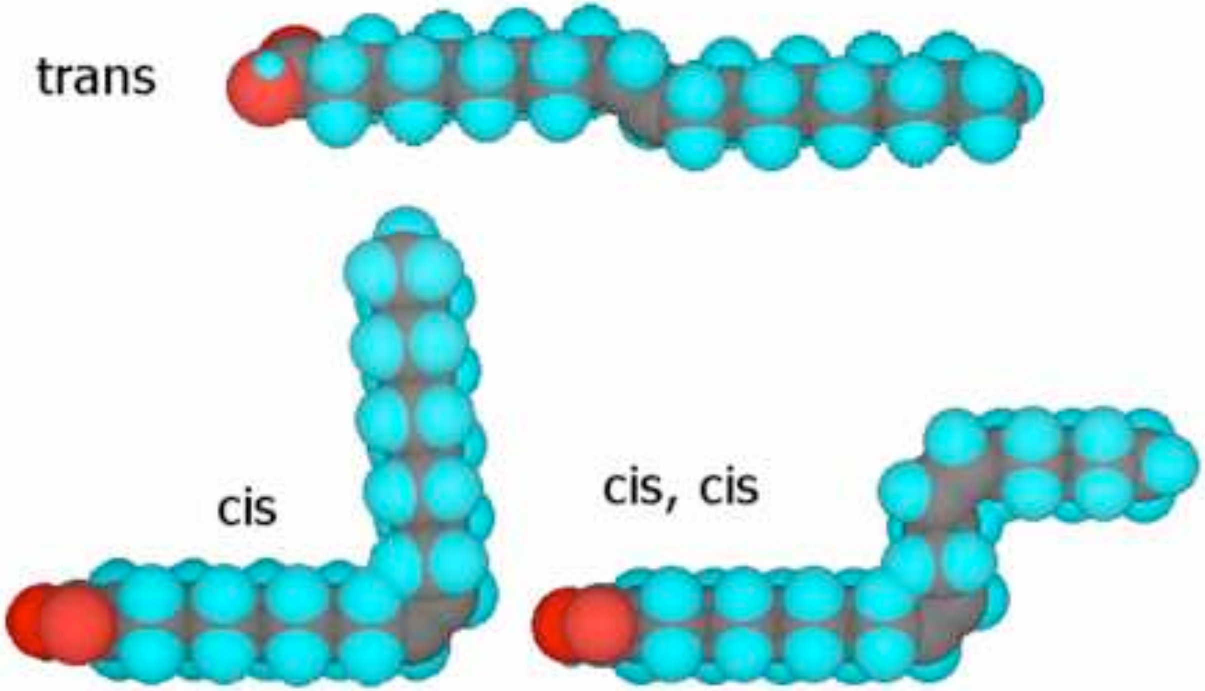
**(a)**

## INSATURI

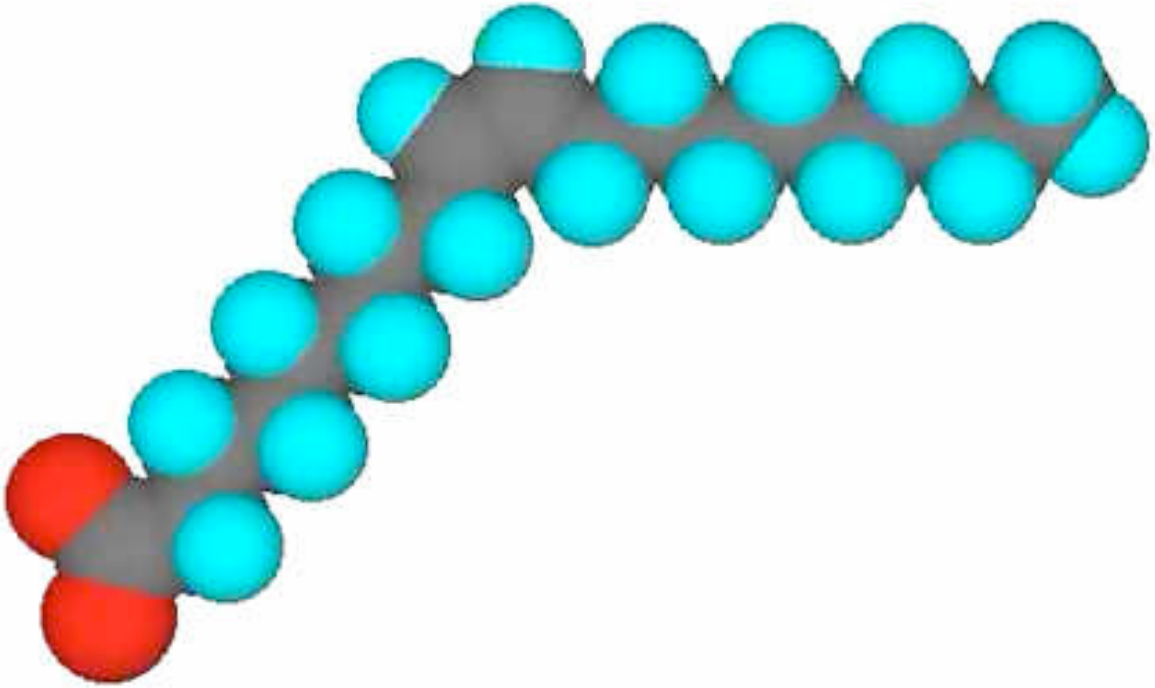


**(b)**

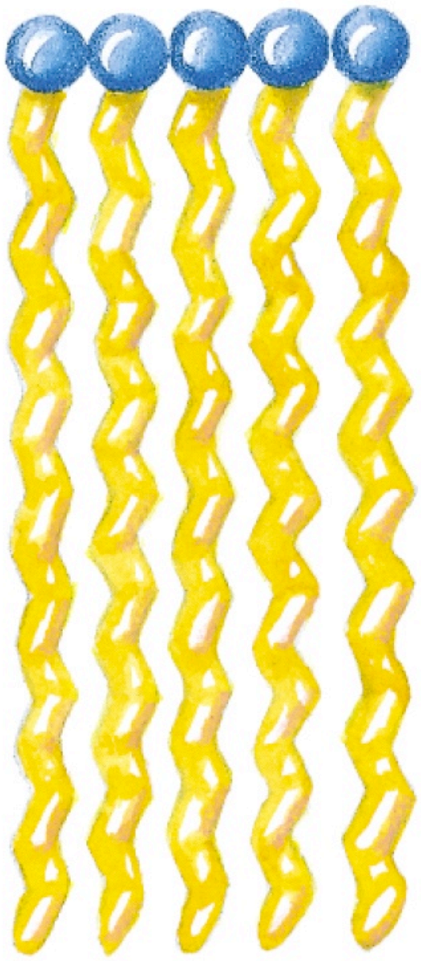
# Grassi insaturi


trans
cis
cis, cis

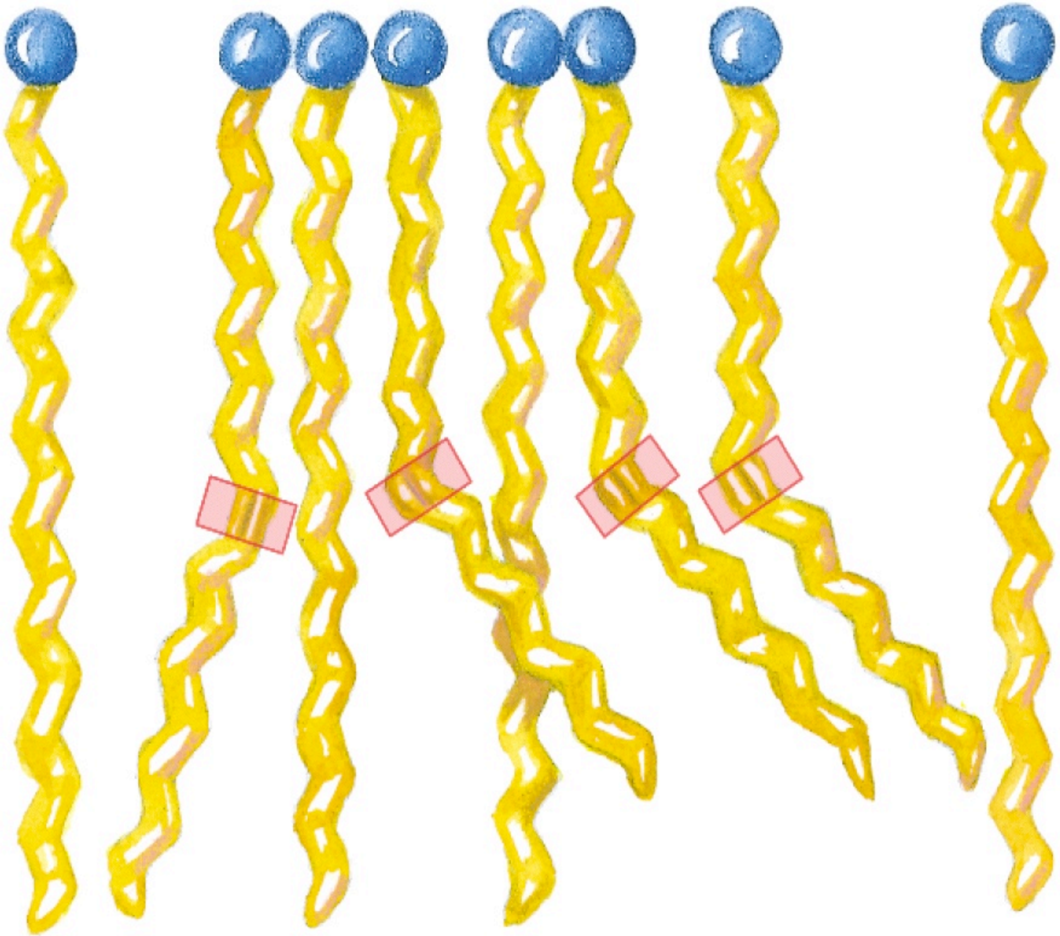
# Oleic acid



# ORGANIZZAZIONE DI ACIDI GRASSI IN AMBIENTE ACQUOSO



Saturated fatty acids



Mixture of saturated and unsaturated fatty acids

# Some common fatty acids

| Common | IUPAC Name | MP | Formula |
|---|---|---|---|
| Lauric | n-dodecanoic | 44 | $C_{11}H_{23}COOH$ |
| Palmitic | n-hexadecanoic | 63 | $C_{15}H_{31}COOH$ |
| Stearic | n-octadecanoic | 70 | $C_{17}H_{35}COOH$ |
| Palmitoleic | cis-9-hexadecenoic | 0 | $C_{15}H_{29}COOH$ |
| Oleic | cis-9-octadecenoic | 16 | $C_{17}H_{33}COOH$ |
| Linoleic | cis,cis,9,12-octadecadienoic | 5 | $C_{17}H_{31}COOH$ |

Presence of double bonds reduces melting point.

table 11–1

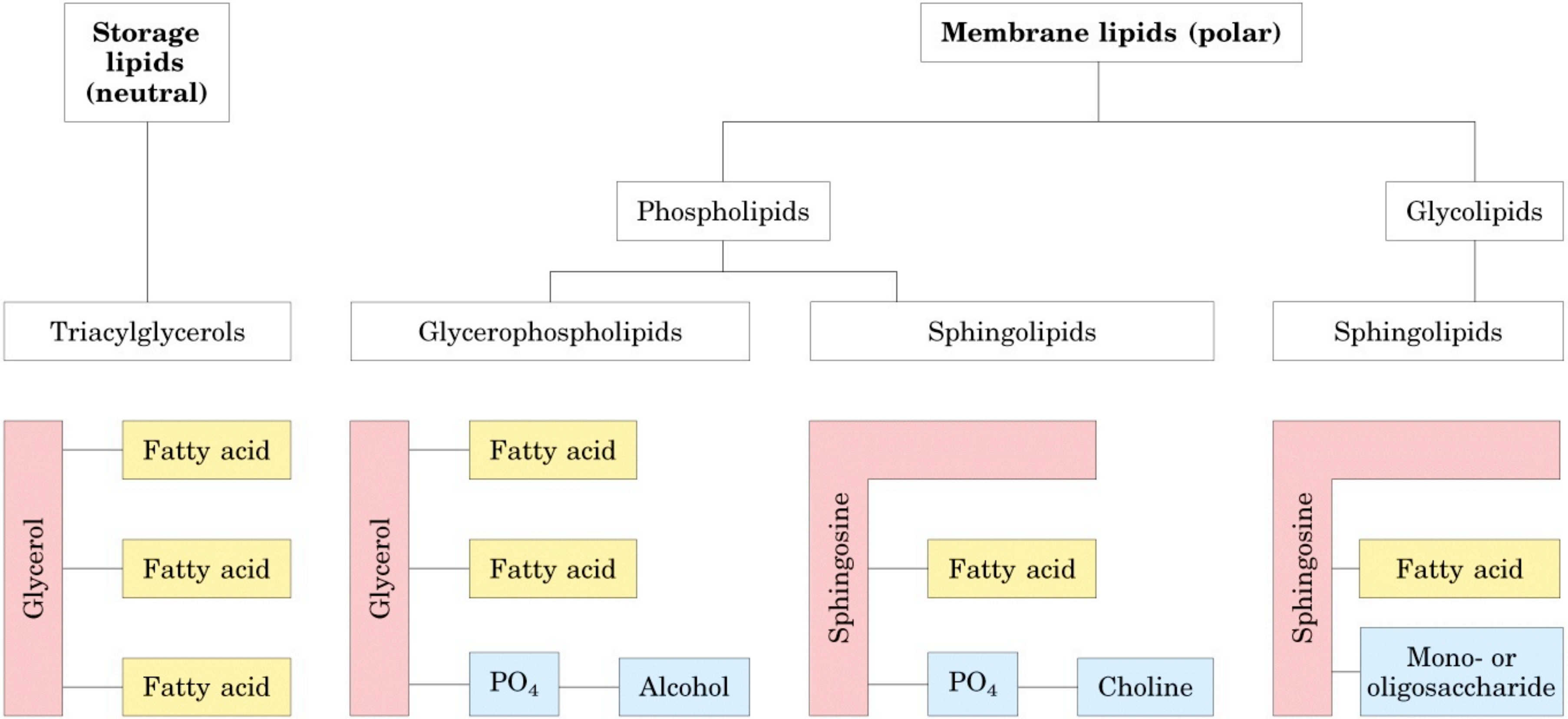
## Some Naturally Occurring Fatty Acids

| Carbon skeleton | Structure[*] | Systematic name[†] | Common name (derivation) | Melting point (°C) | Solubility at 30 °C (mg/g solvent) | |
|---|---|---|---|---|---|---|
| | | | | | Water | Benzene |
| 12:0 | $CH_3(CH_2)_{10}COOH$ | *n*-Dodecanoic acid | Lauric acid (Latin *laurus*, "laurel plant") | 44.2 | 0.063 | 2,600 |
| 14:0 | $CH_3(CH_2)_{12}COOH$ | *n*-Tetradecanoic acid | Myristic acid (Latin *Myristica*, nutmeg genus) | 53.9 | 0.024 | 874 |
| 16:0 | $CH_3(CH_2)_{14}COOH$ | *n*-Hexadecanoic acid | Palmitic acid (Latin *palma*, "palm tree") | 63.1 | 0.0083 | 348 |
| 18:0 | $CH_3(CH_2)_{16}COOH$ | *n*-Octadecanoic acid | Stearic acid (Greek *stear*, "hard fat") | 69.6 | 0.0034 | 124 |
| 20:0 | $CH_3(CH_2)_{18}COOH$ | *n*-Eicosanoic acid | Arachidic acid (Latin *Arachis*, legume genus) | 76.5 | | |
| 24:0 | $CH_3(CH_2)_{22}COOH$ | *n*-Tetracosanoic acid | Lignoceric acid (Latin *lignum*, "wood" + *cera*, "wax") | 86.0 | | |
| 16:1($\Delta^{9}$) | $CH_3(CH_2)_5CH{=}CH(CH_2)_7COOH$ | *cis*-9-Hexadecenoic acid | Palmitoleic acid | −0.5 | | |
| 18:1($\Delta^{9}$) | $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ | *cis*-9-Octadecenoic acid | Oleic acid (Latin *oleum*, "oil") | 13.4 | | |
| 18:2($\Delta^{9,12}$) | $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ | *cis*-,*cis*-9,12-Octadecadienoic acid | Linoleic acid (Greek *linon*, "flax") | −5 | | |
| 18:3($\Delta^{9,12,15}$) | $CH_3CH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ | *cis*-,*cis*-,*cis*-9,12,15-Octadecatrienoic acid | α-Linolenic acid | −11 | | |
| 20:4($\Delta^{5,8,11,14}$) | $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH{=}CH(CH_2)_3COOH$ | *cis*-,*cis*-,*cis*-,*cis*-5,8,11,14-Icosatetraenoic acid | Arachidonic acid | −49.5 | | |

[*] All acids are shown in their nonionized form. At pH 7, all free fatty acids have an ionized carboxylate. Note that numbering of carbon atoms begins at the carboxyl carbon.

[†] The prefix *n*- indicates the "normal" unbranched structure. For instance, "dodecanoic" simply indicates 12 carbon atoms, which could

# Lipidi semplici e complessi



**Storage lipids (neutral)**

**Membrane lipids (polar)**

Phospholipids

Glycolipids

Triacylglycerols

Glycerophospholipids

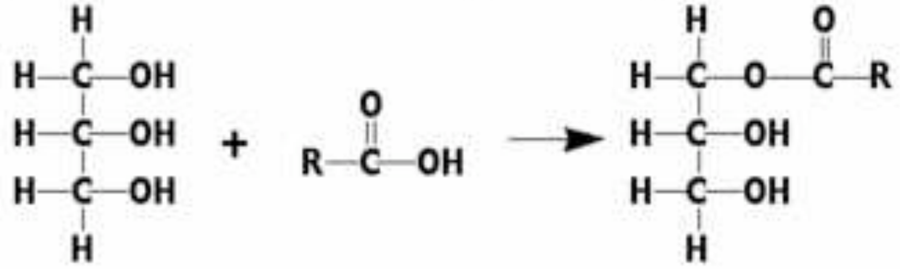
Sphingolipids

Sphingolipids

Glycerol
Fatty acid
Fatty acid
Fatty acid
Glycerol
Fatty acid
Fatty acid
$PO_4$
Alcohol
Sphingosine
Fatty acid
$PO_4$
Choline
Sphingosine
Fatty acid
Mono- or oligosaccharide

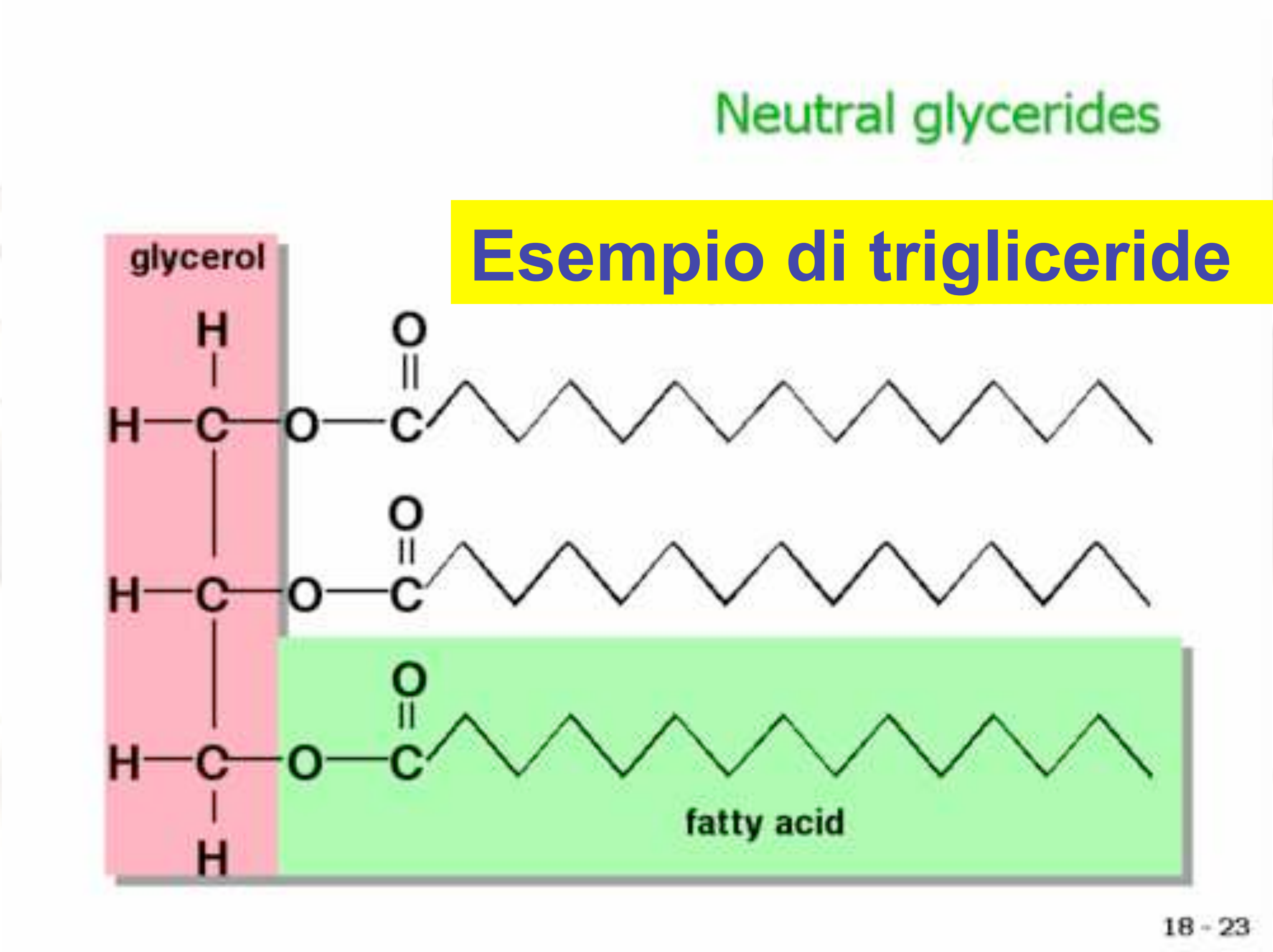
# Gliceridi neutri

**Gliceridi:**
**esteri del glicerolo**



**Mono, di e trigliceridi**

# Esempio di trigliceride

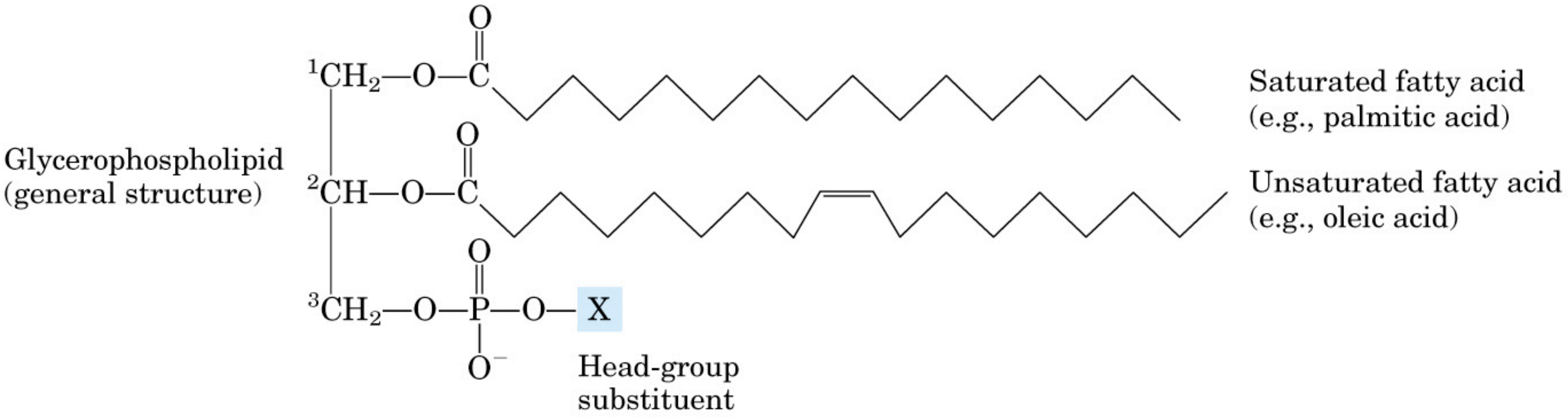


Neutral glycerides

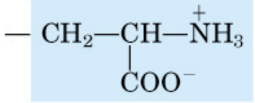
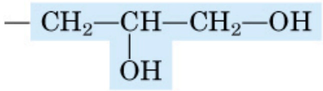
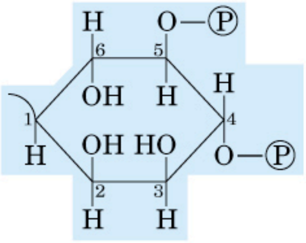
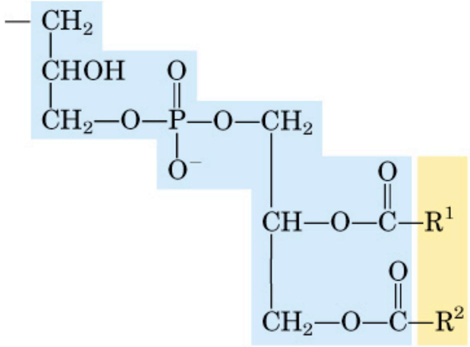
glycerol
H
H—C—O—C
O
H—C—O—C
O
H—C—O—C
O
H
fatty acid

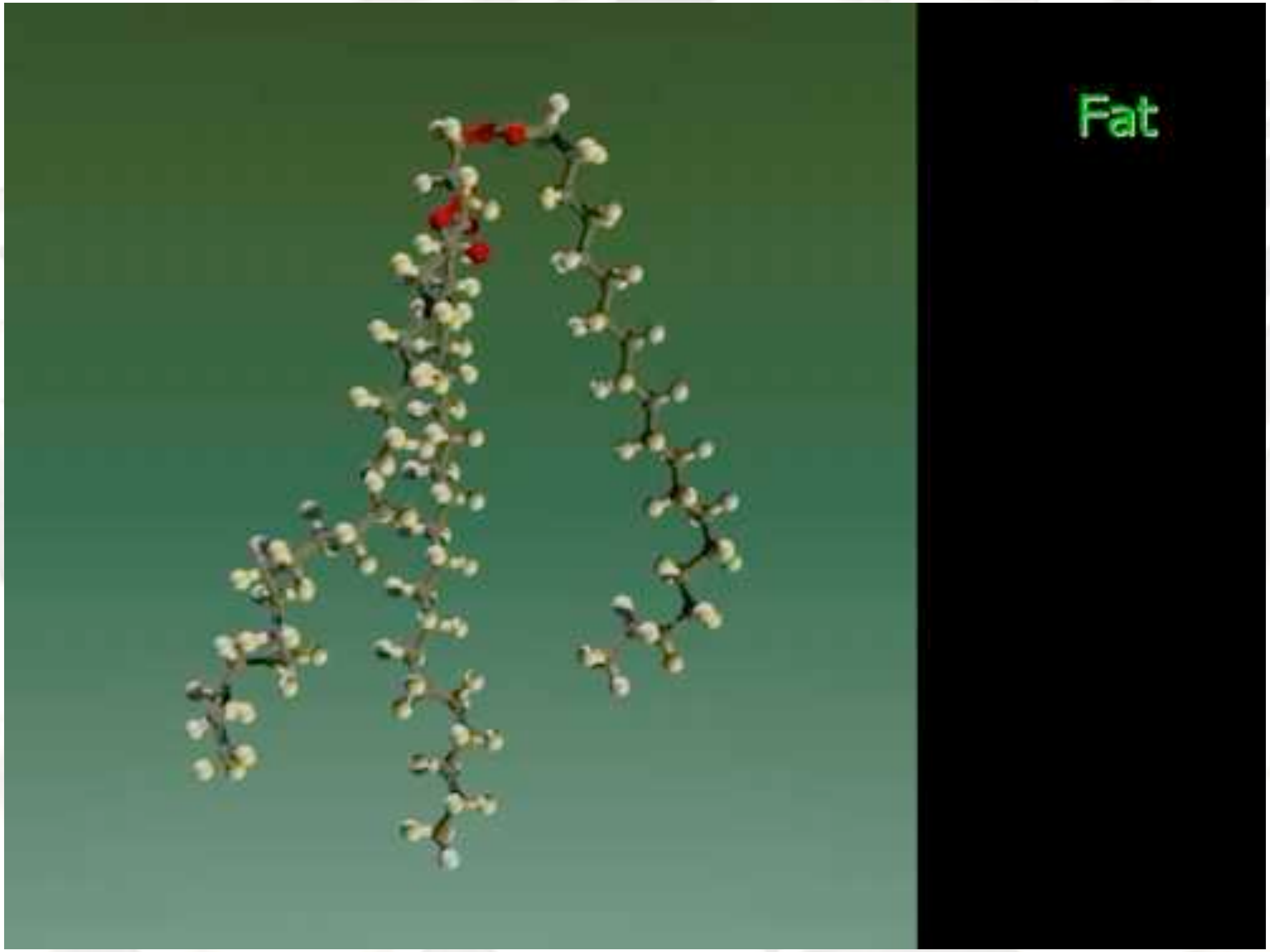
18 - 23

# GLICEROFOSFOLIPIDE


Glycerophospholipid
(general structure)
1
CH2—O—C
O
2
CH—O—C
O
3
CH2—O—P—O—
O
O−
X
Head-group substituent
Saturated fatty acid (e.g., palmitic acid)
Unsaturated fatty acid (e.g., oleic acid)

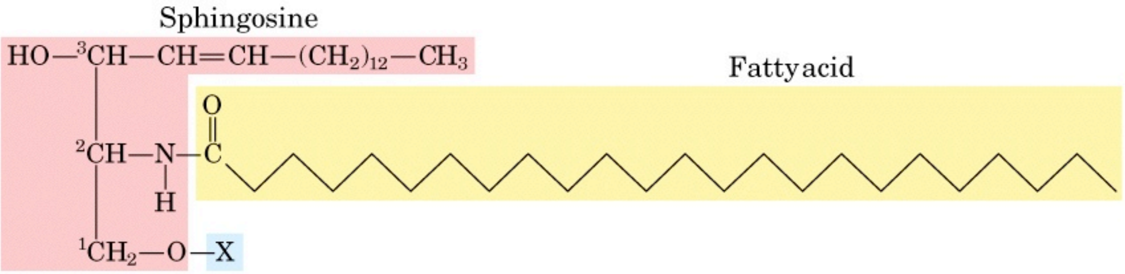
# GLICEROFOSFOLIPIDI DI MEMBRANA

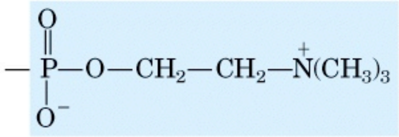
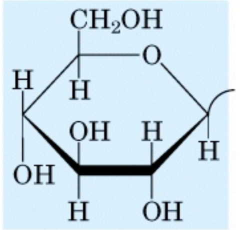
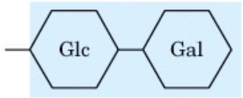
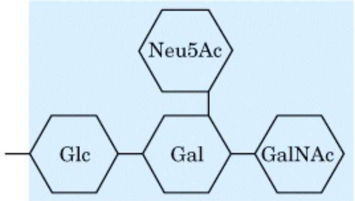
| Name of glycerophospholipid | Name of X | Formula of X | Net charge (at pH 7) |
|---|---|---|---|
| Phosphatidic acid | — | $-H$ | −1 |
| Phosphatidylethanolamine | Ethanolamine | $-CH_2-CH_2-\overset{+}{N}H_3$ | 0 |
| Phosphatidylcholine | Choline | $-CH_2-CH_2-\overset{+}{N}(CH_3)_3$ | 0 |
| Phosphatidylserine | Serine |  $-CH_2-\underset{COO^-}{CH}-\overset{+}{N}H_3$ | −1 |
| Phosphatidylglycerol | Glycerol |  $-CH_2-\underset{OH}{CH}-CH_2-OH$ | −1 |
| Phosphatidylinositol 4,5-bisphosphate | *myo*-Inositol 4,5-bisphosphate |  | −4 |
| Cardiolipin | Phosphatidyl-glycerol |  | −2 |


Fat

# SFINGOLIPIDI

Sphingolipid (general structure)


Sphingosine
HO—³CH—CH=CH—(CH₂)₁₂—CH₃
²CH—N—C
O
H
¹CH₂—O—X
Fatty acid

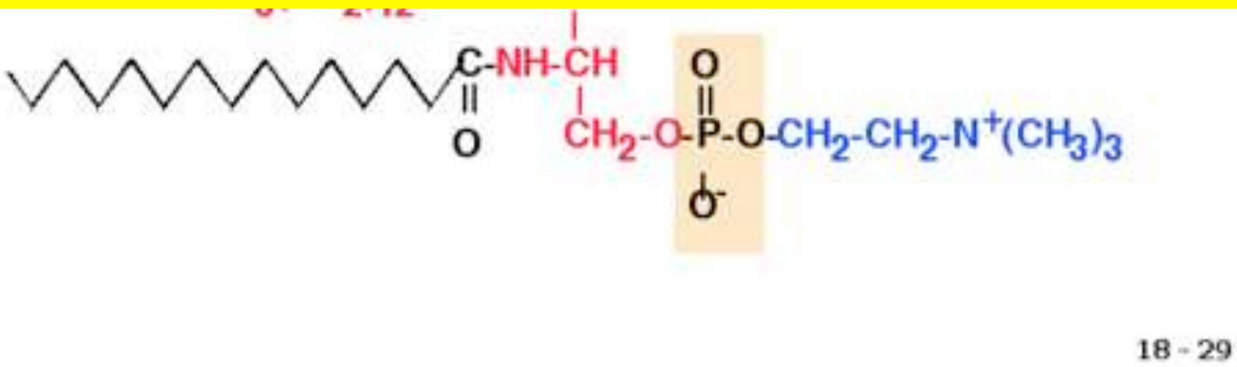
| Name of sphingolipid | Name of X | Formula of X |
|---|---|---|
| Ceramide | — | —H |
| Sphingomyelin | Phosphocholine |  $-\overset{\overset{O}{\parallel}}{\underset{\underset{O^-}{\vert}}{P}}-O-CH_2-CH_2-\overset{+}{N}(CH_3)_3$ |
| Neutral glycolipids<br>Glucosylcerebroside | Glucose |   CH₂OH<br>O<br>H<br>H<br>OH<br>H<br>H<br>OH<br>H<br>OH |
| Lactosylceramide<br>(a globoside) | Di-, tri-, or tetrasaccharide |  |
| Ganglioside GM2 | Complex oligosaccharide |   Neu5Ac<br>Glc<br>Gal<br>GalNAc |

**Sfingolipidi**

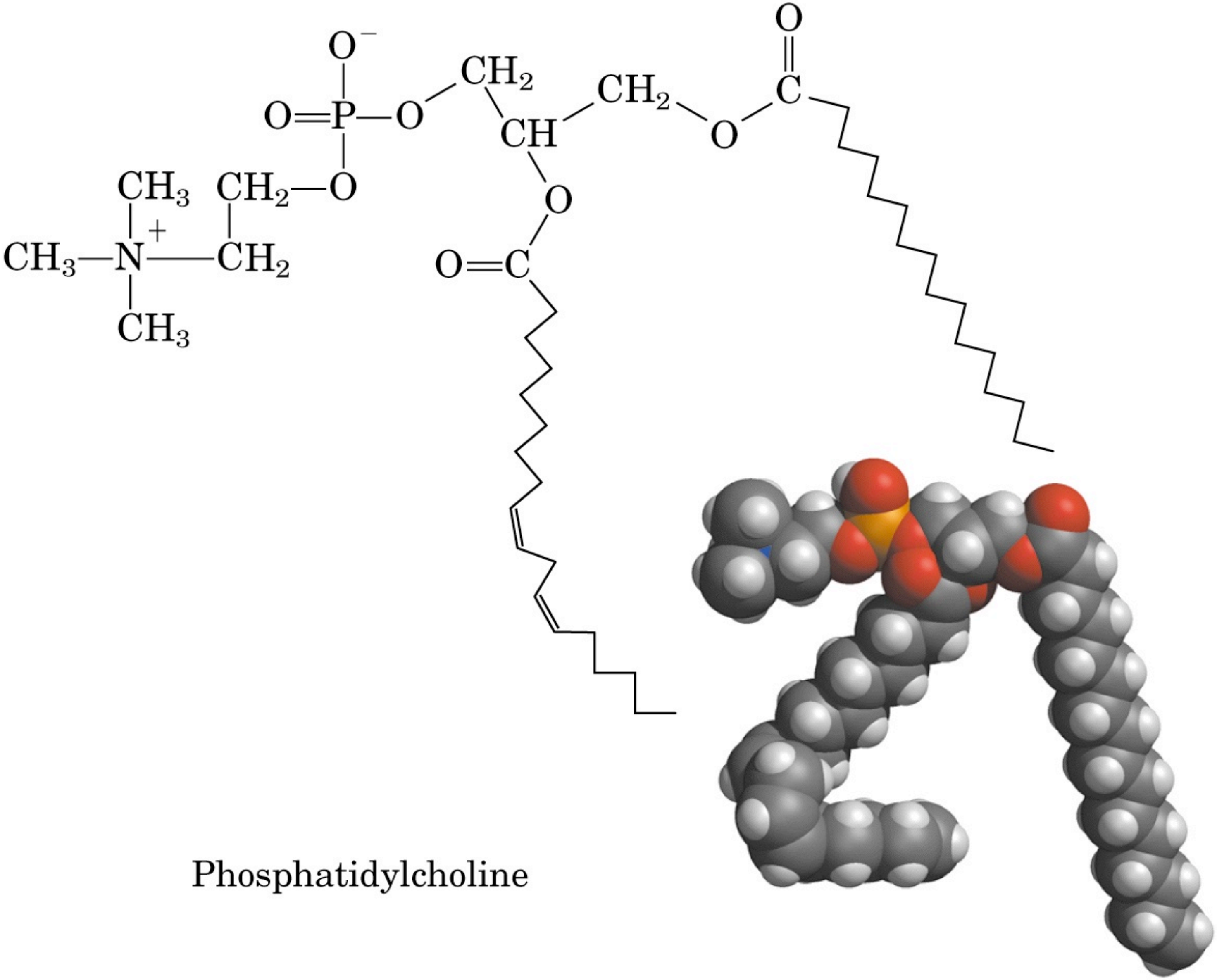
**Asenti nei grassi di deposito.**

**Sono abbondanti nel tessuto nervoso (Guaina mielinica)**

**Circa il 25% dei lipidi negli esseri umani è costituito da sfingolipidi**

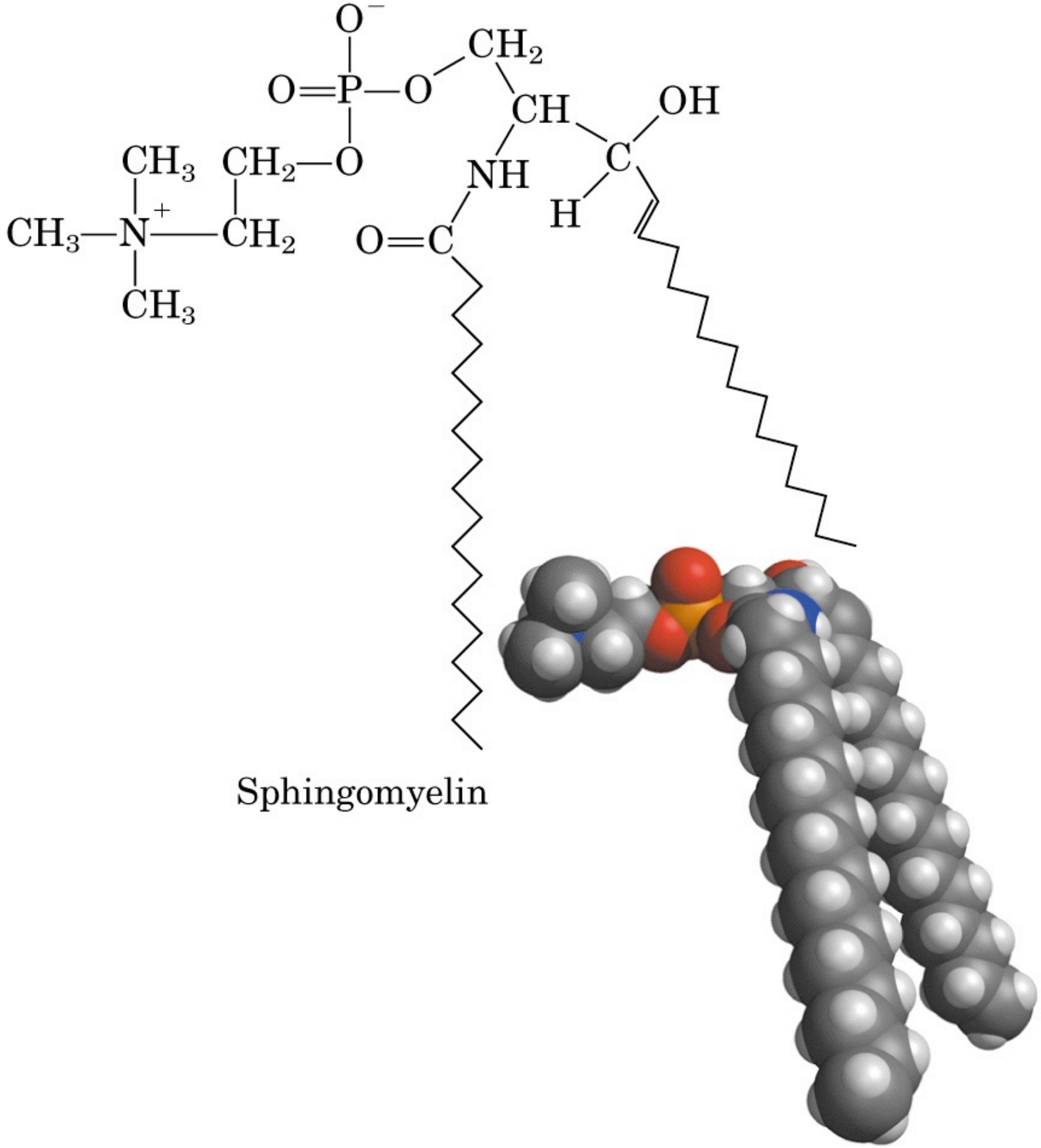

C-NH-CH
O
CH2-O-P-O-CH2-CH2-N+(CH3)3
O
O-
18 - 29

# FOSFATIDILCOLINA


O⁻
O=P—O
CH₂
CH
CH₂
O
C
O
CH₃
CH₂—O
CH₃—N⁺—CH₂
CH₃
O
O=C

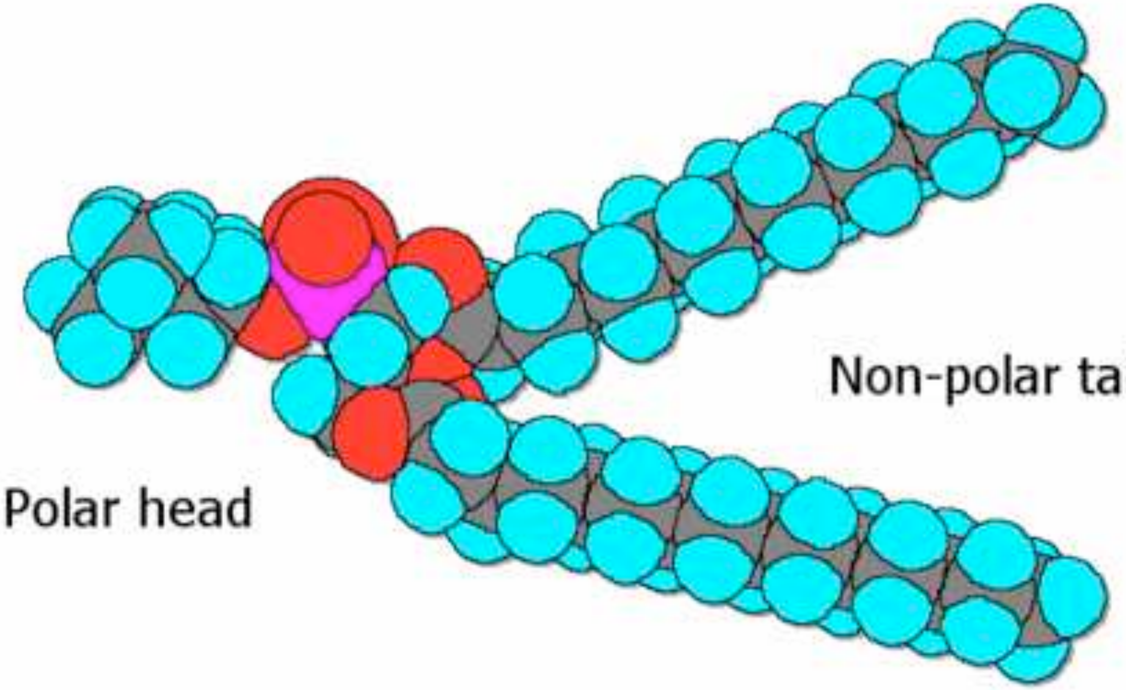
Phosphatidylcholine

# SFINGOMIELINA



Sphingomyelin

# Lecithin



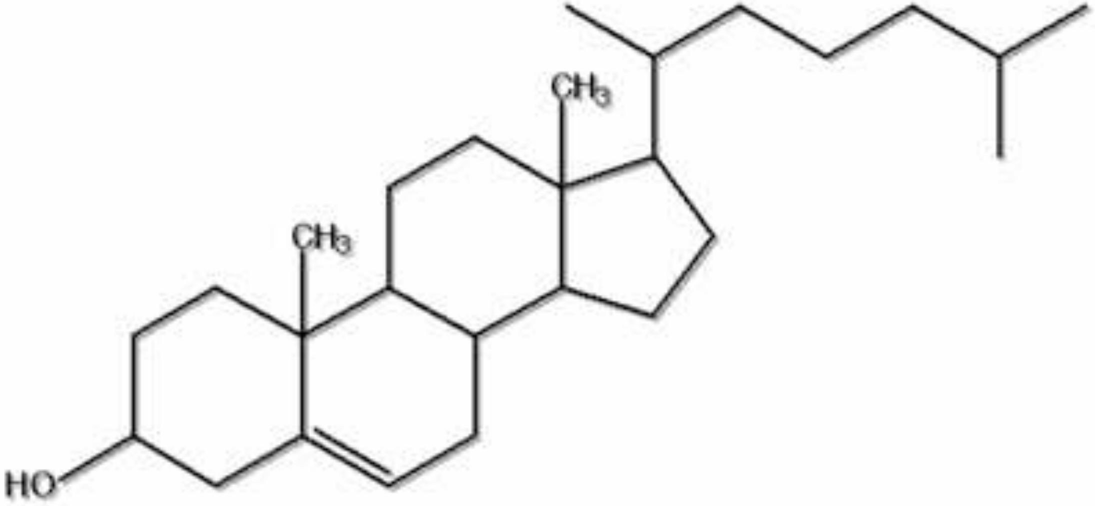
Non-polar tail

Polar head

# Colesterolo
# Costituente principale delle membrane lipidiche

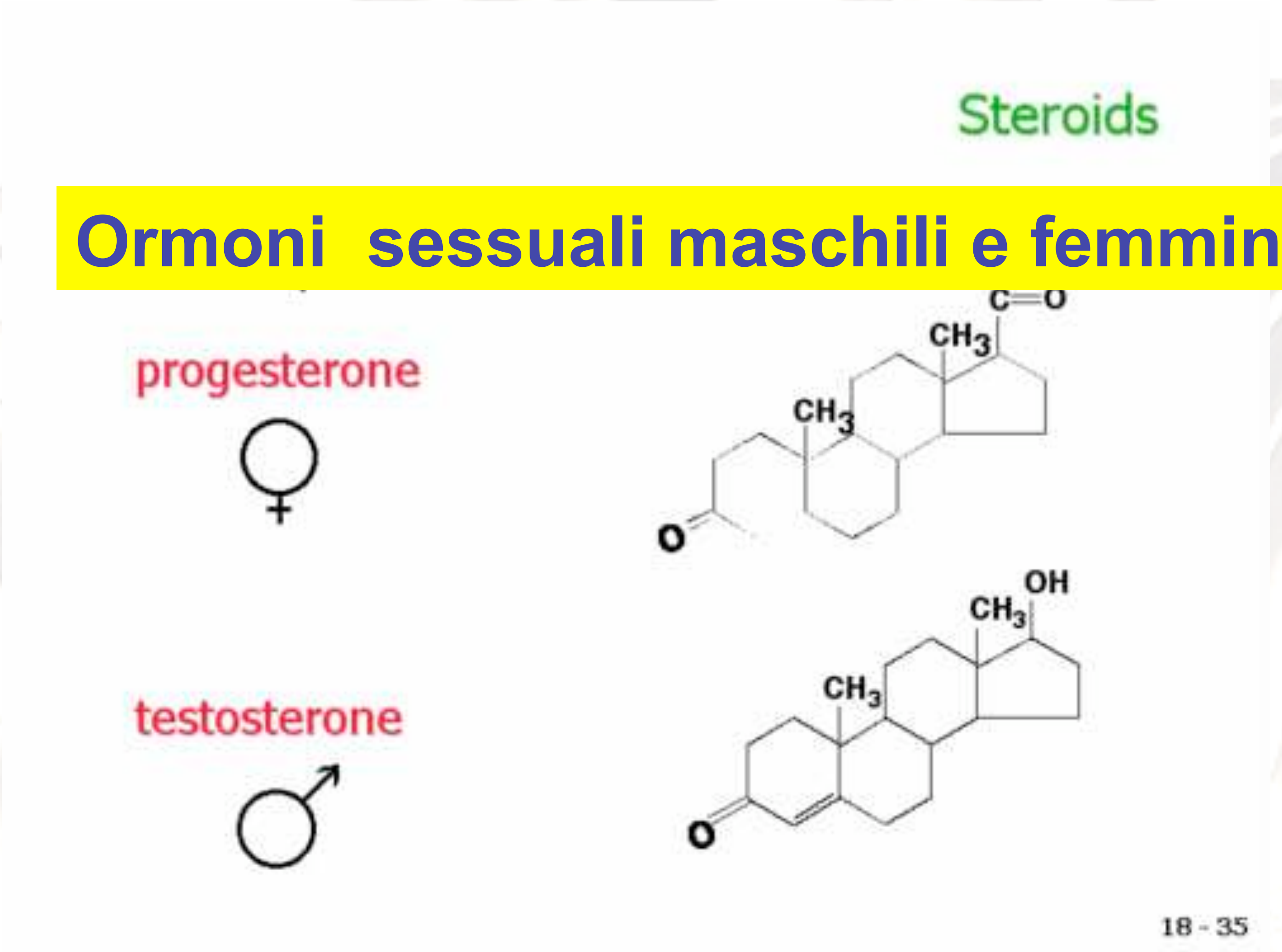
Steroids

Principal membrane lipid for fluidity.



18 - 32

# Ormoni sessuali maschili e femminili.



Steroids

progesterone

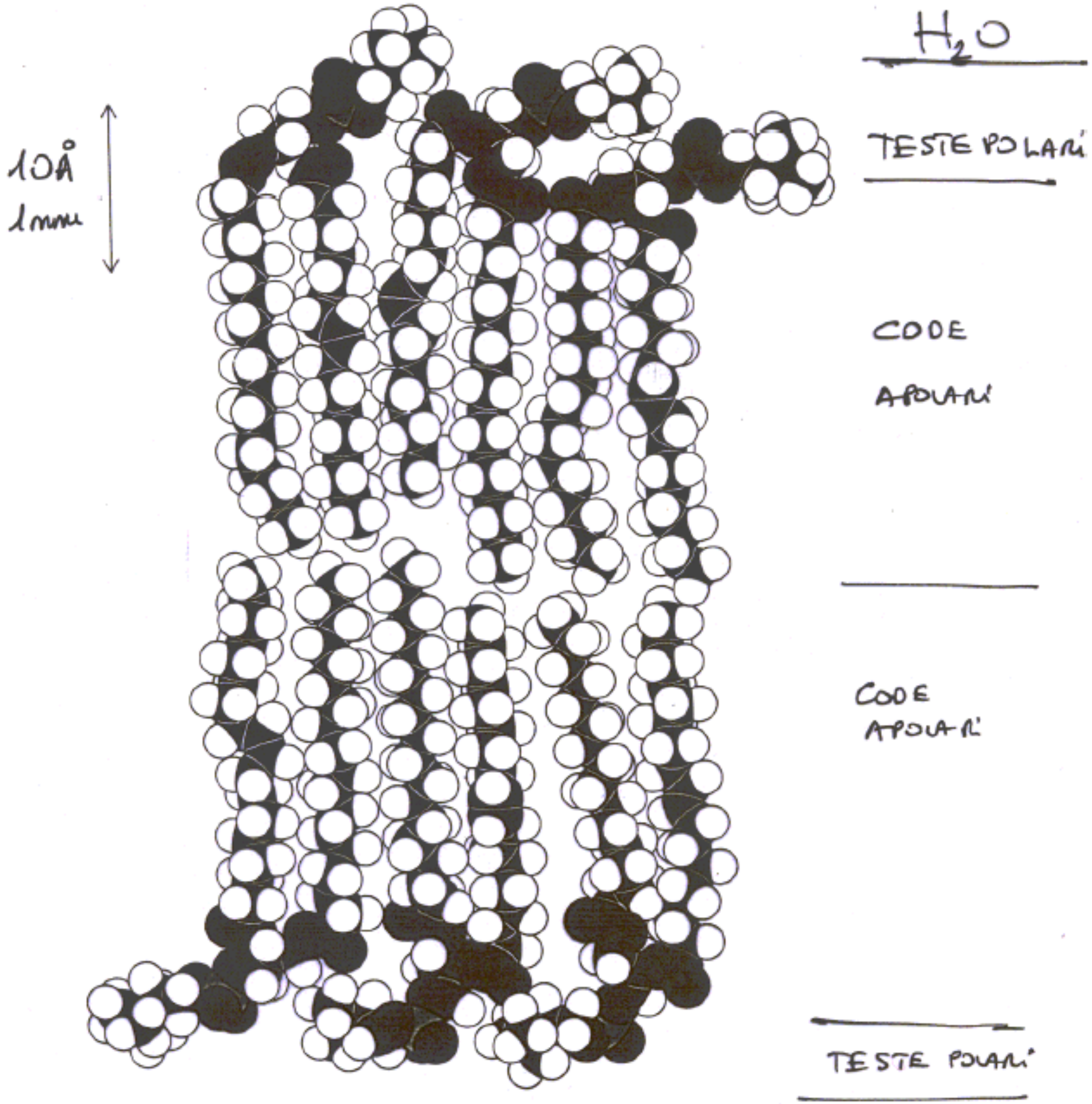
♀

testosterone

♂

18 - 35

C=O
CH3
CH3
O
OH
CH3
CH3
O


10Å
1mm
$H_2O$
TESTE POLARI
CODE
APOLARI
CODE
APOLARI
TESTE POLARI

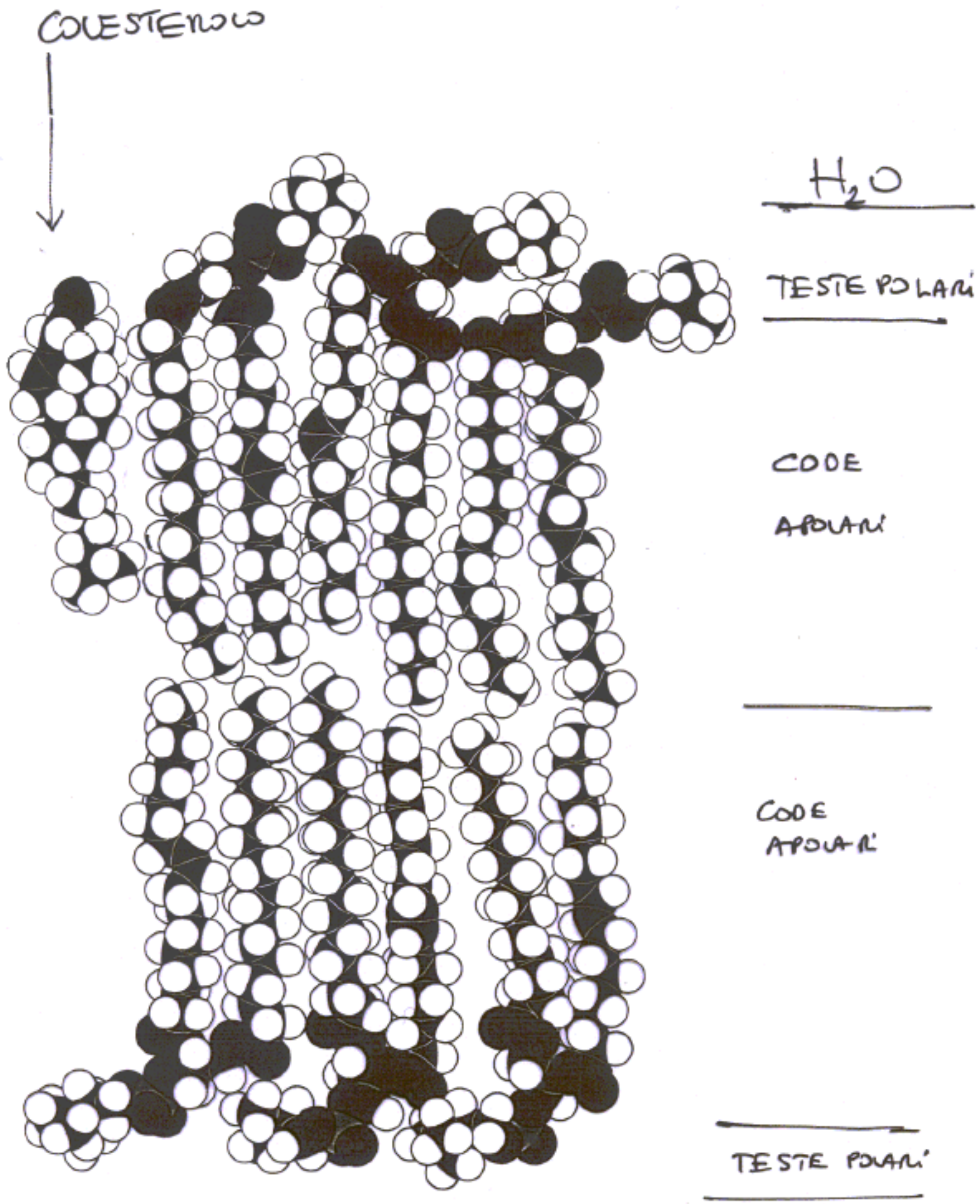
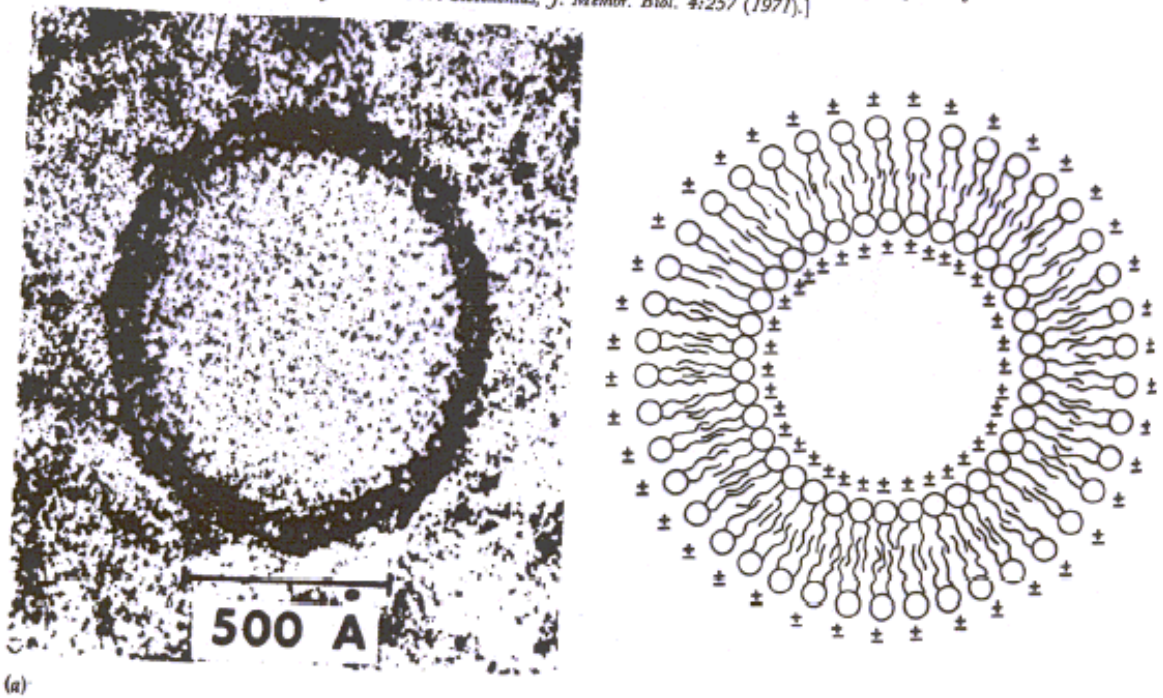
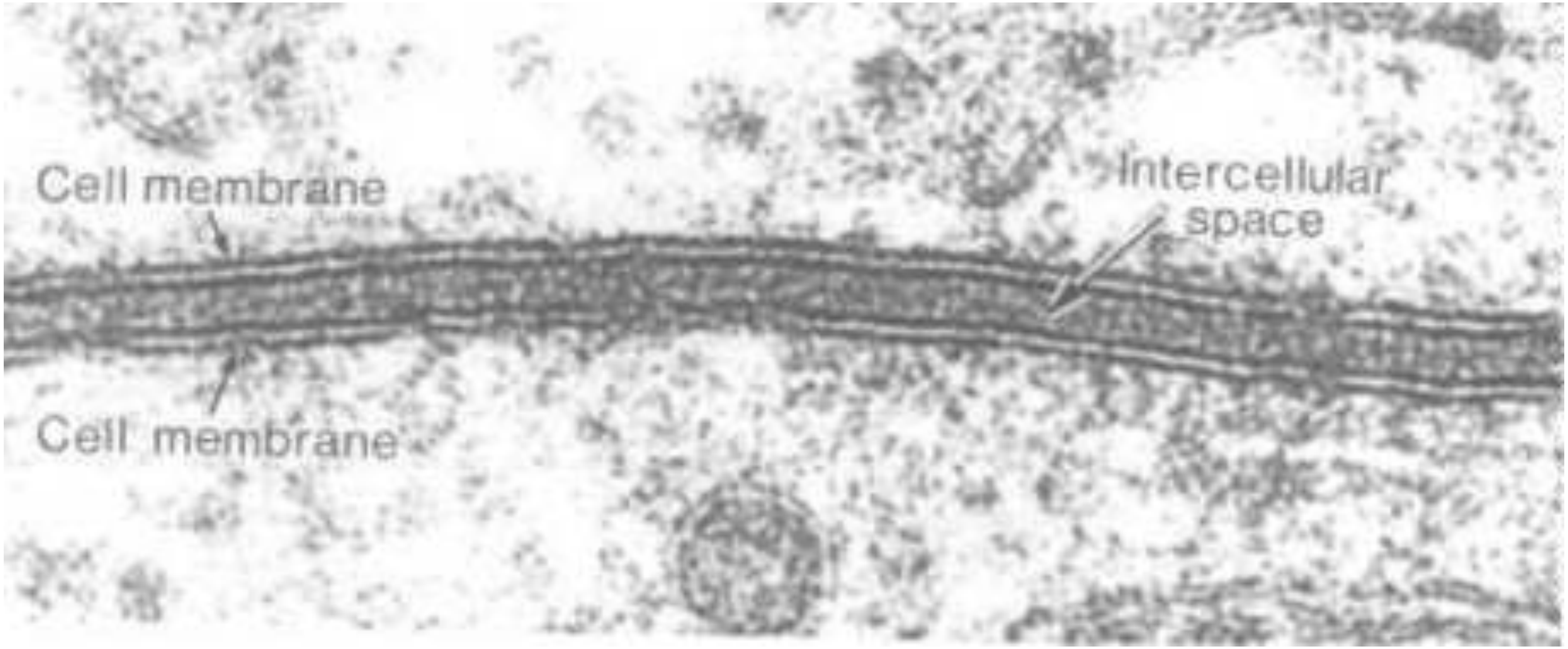

COLESTEROLO
$H_2O$
TESTE POLARI
CODE
APOLARI
CODE
APOLARI
TESTE POLARI

**Figure 7.3** (*a*) Electron micrograph of a thin section of a phosphoglyceride vesicle isolated from an ultrasonicated lipid vesicle from a phosphoglyceride mixture derived from soybeans. The vesicles were negatively stained after fixation in osmium tetroxide. The thickness of the lipid wall of the vesicle is 45 ± 5 Å. (*b*) Diagrammatic representation of a phosphoglyceride bilayer found in vesicles of the type shown in part *a*. The dimensions of the individual lipid are not on the same scale as actually observed in part *a*. The head groups and tails are designated as (○) and (∽), respectively. It should be emphasized that vesicles of this type are spherical or ellipsoidal in three dimensions and contain solvent inside as well as outside. [*Part a from V. K. Miyamoto and W. Stoeckenius, J. Membr. Biol. 4:257 (1971).*]

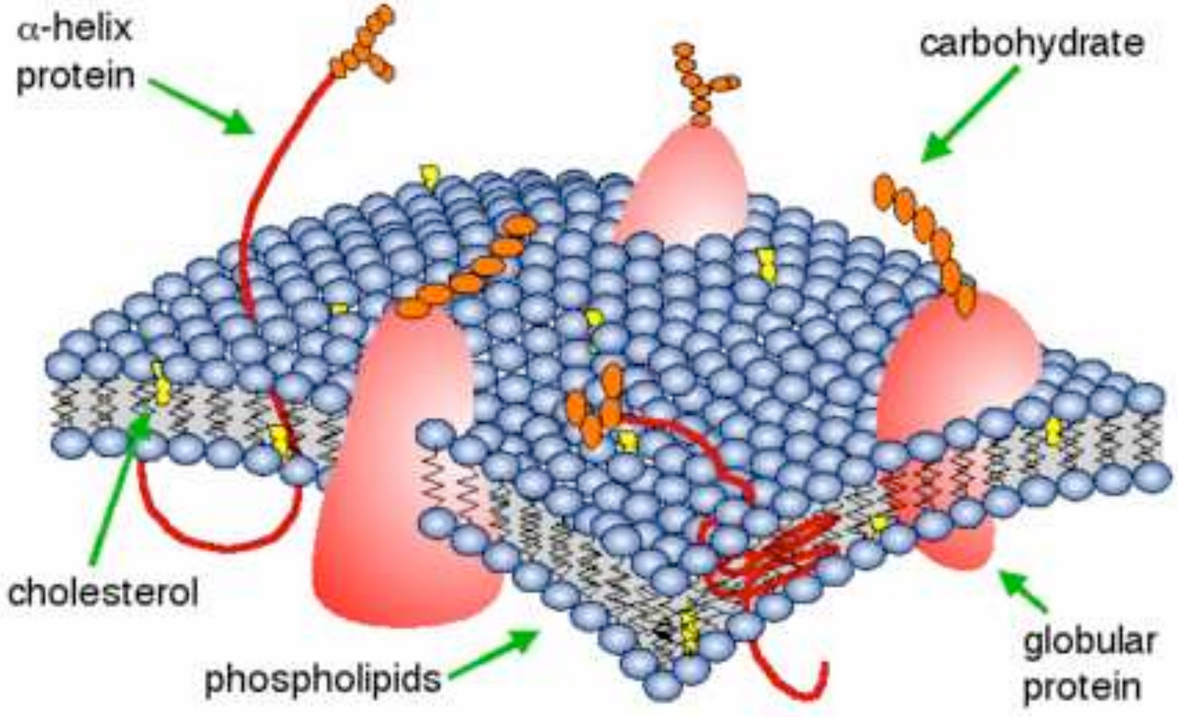


(*a*)

(*b*)

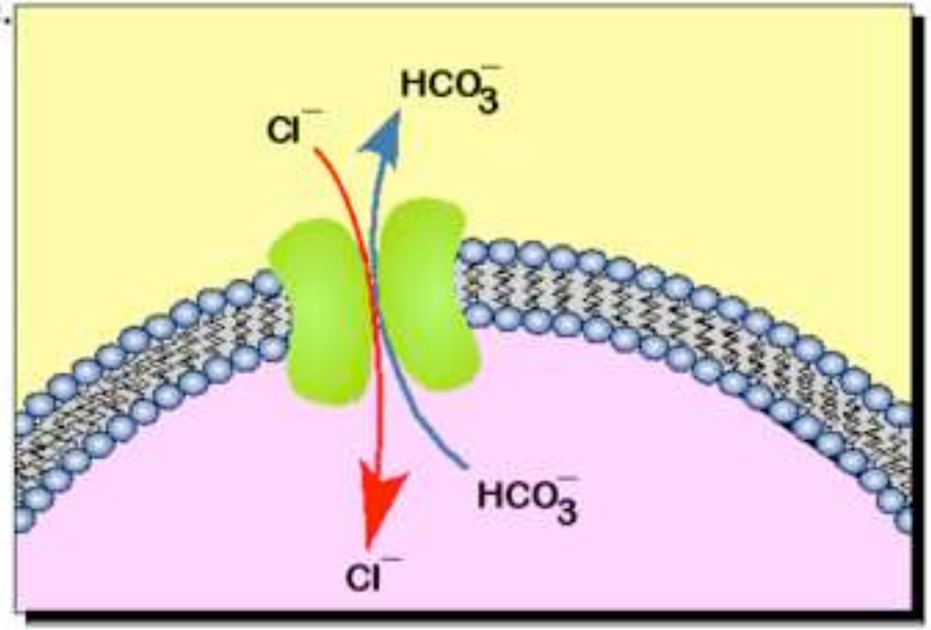

Cell membrane
Intercellular space
Cell membrane

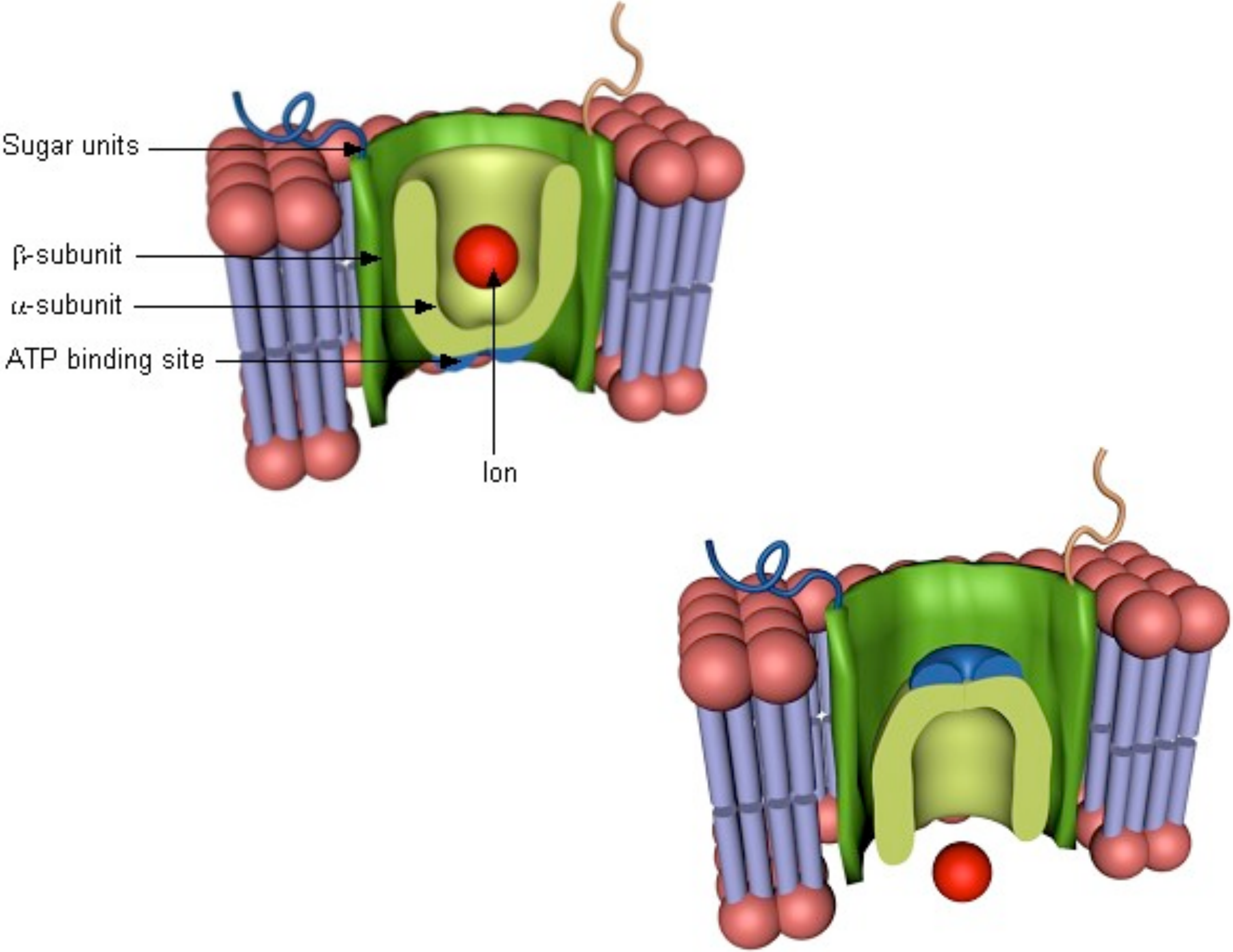
# Mosaic structure of membranes

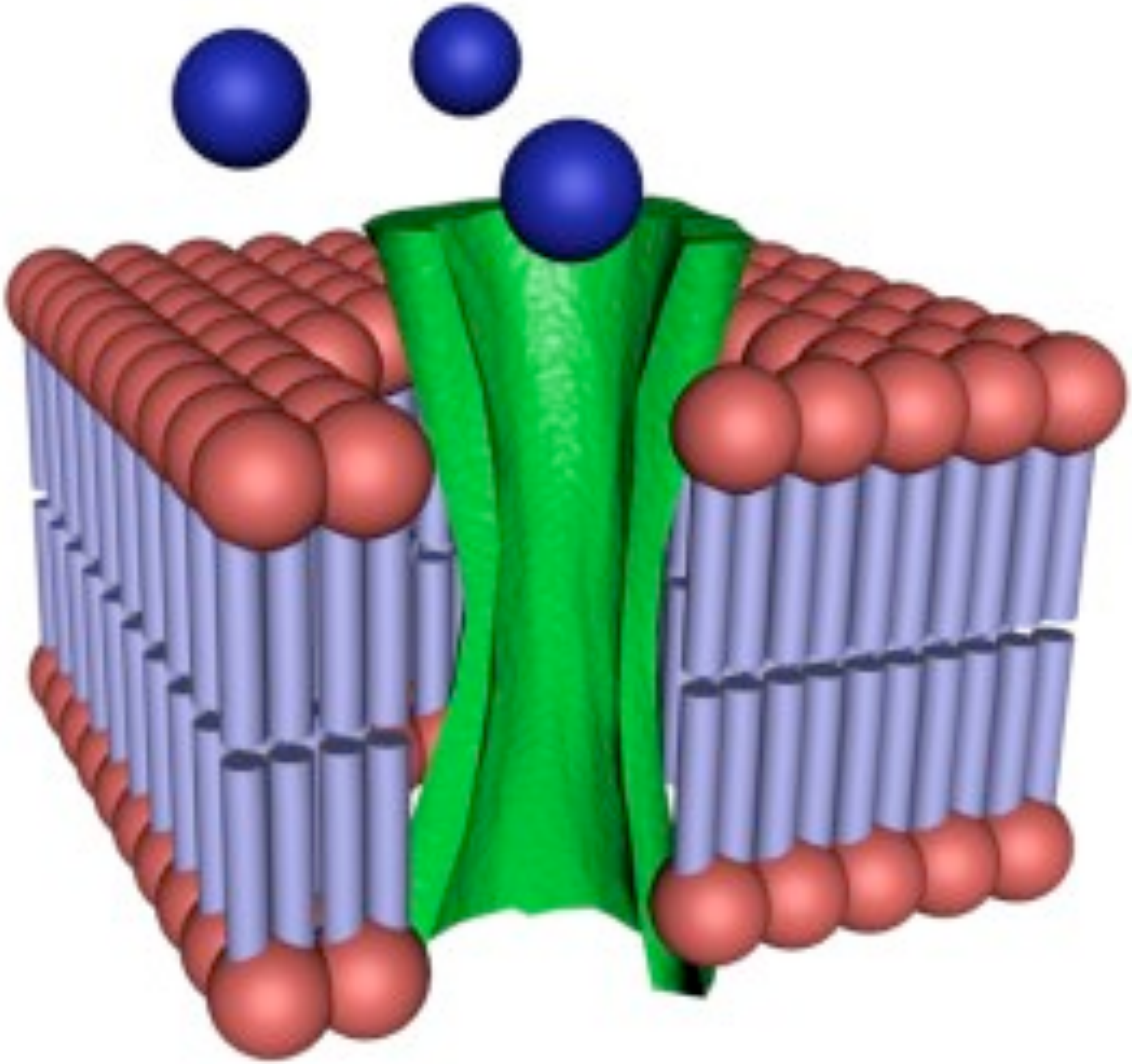

α-helix protein
carbohydrate
cholesterol
phospholipids
globular protein

# Facilitated diffusion

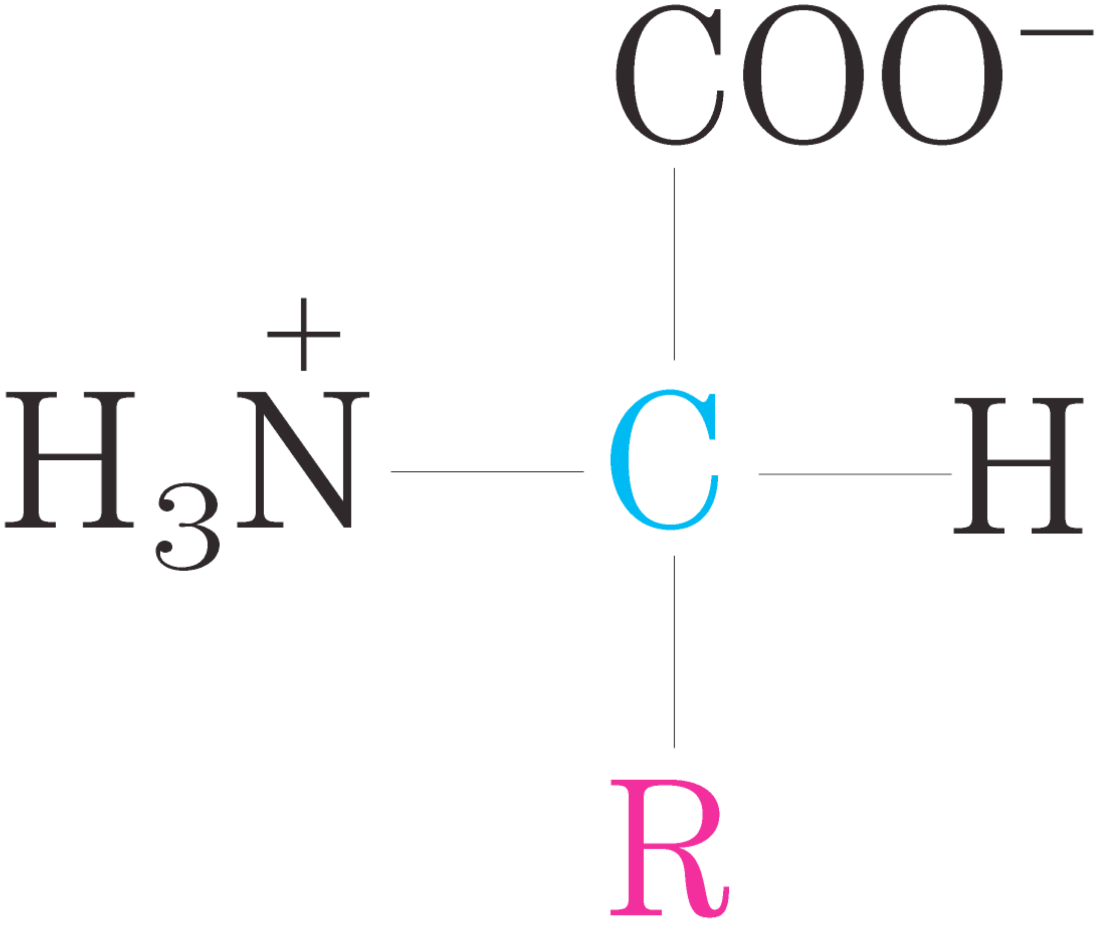
Permeases - Specific protein transports materials across a membrane.


$HCO_3^-$
$Cl^-$
$HCO_3^-$
$Cl^-$

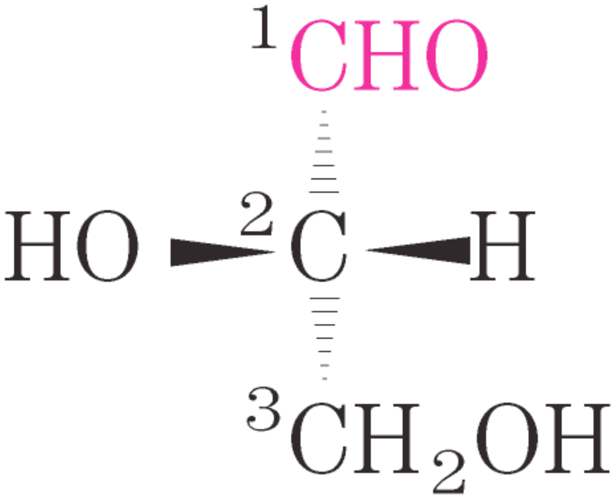

Sugar units
β-subunit
α-subunit
ATP binding site
Ion



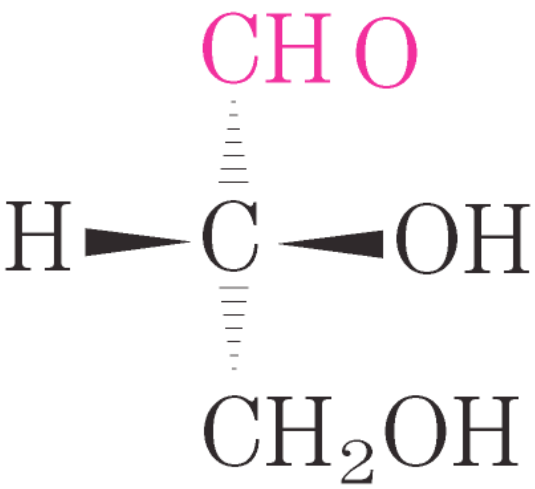
# PROTEINE



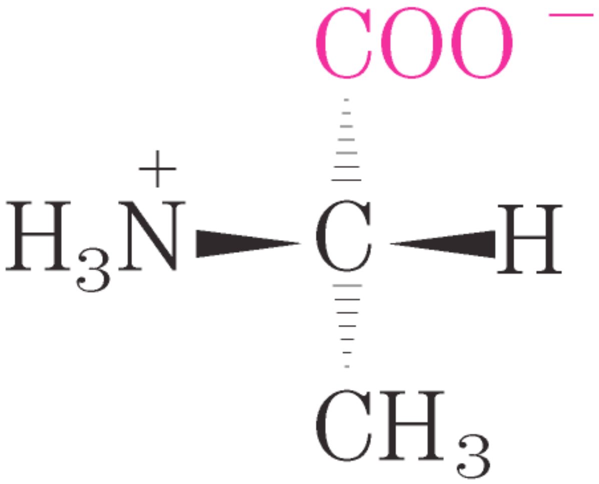
$$\begin{array}{ccc} & \mathrm{COO^-} & \\ & | & \\ \mathrm{H_3\overset{+}{N}} - & \mathrm{C} & - \mathrm{H} \\ & | & \\ & \mathrm{R} & \end{array}$$


1
CHO
HO
2
C
H
3
CH2OH

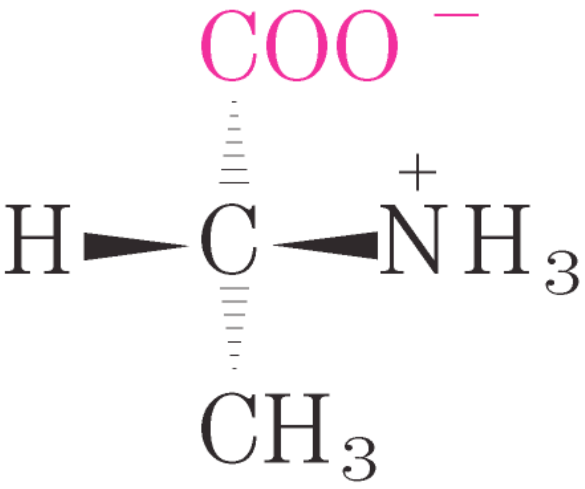
L-Gliceraldeide


CHO
H
C
OH
CH2OH

D-Gliceraldeide

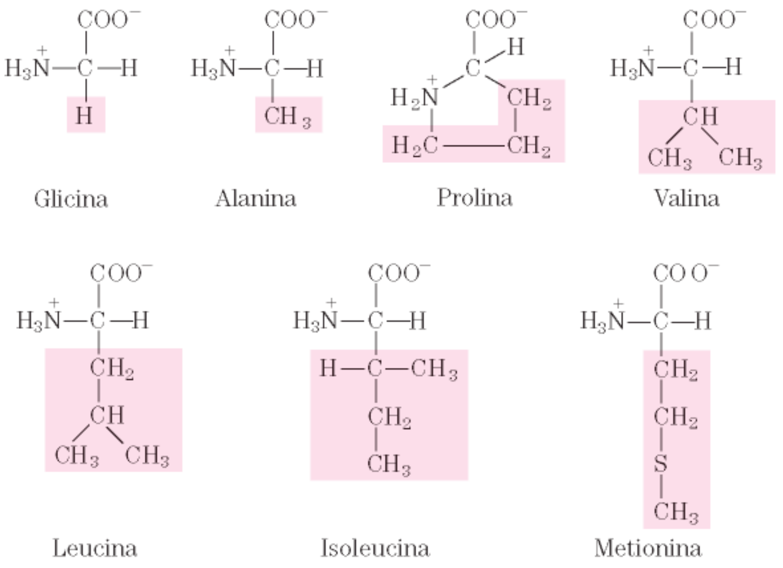

COO−
H3N+
C
H
CH3

L-Alanina

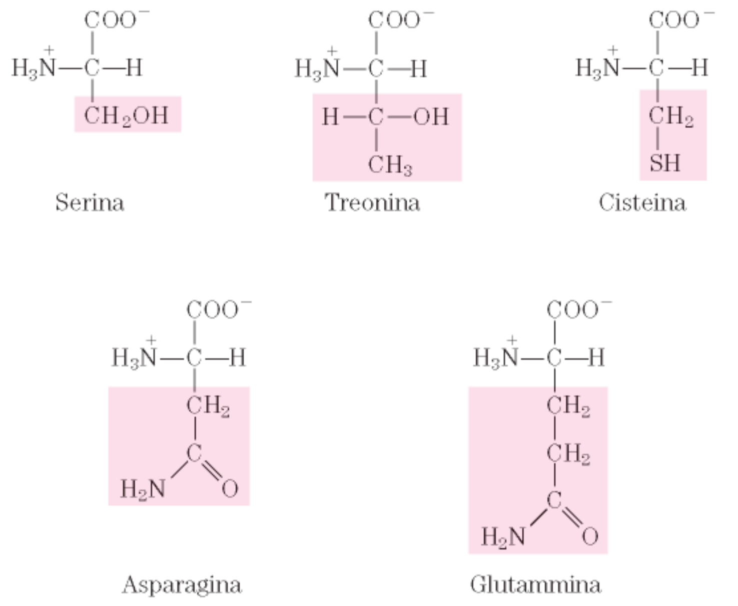

COO−
H
C
N+H3
CH3

D-Alanina

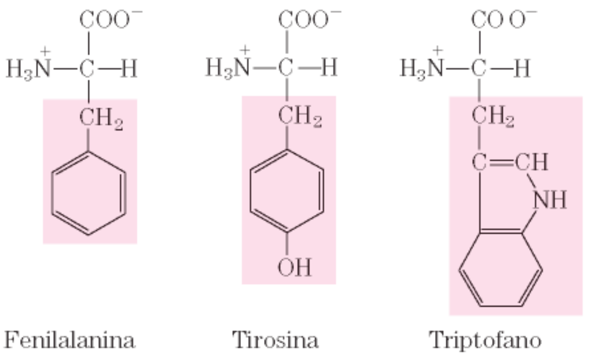
### Gruppi R alifatici, non polari


Glicina
Alanina
Prolina
Valina
Leucina
Isoleucina
Metionina

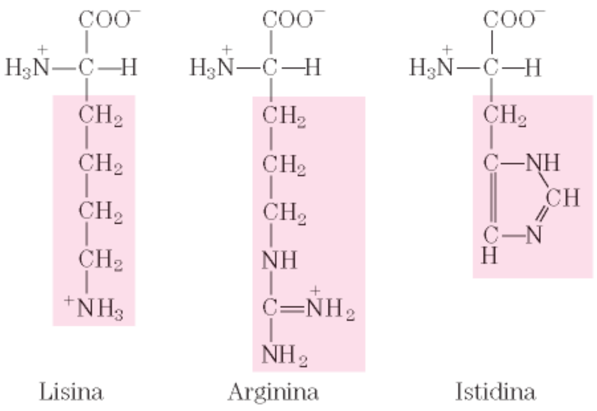
### Gruppi R polari, non carichi


Serina
Treonina
Cisteina
Asparagina
Glutammina

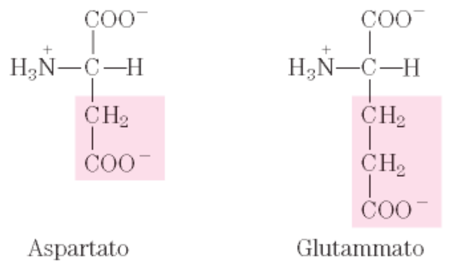
### Gruppi R aromatici


Fenilalanina
Tirosina
Triptofano

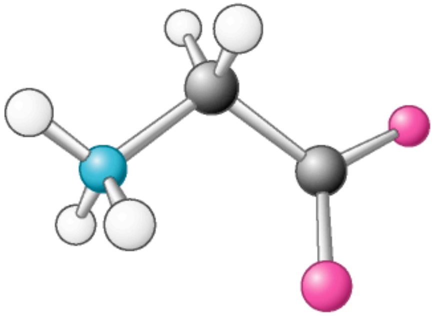
### Gruppi R carichi positivamente

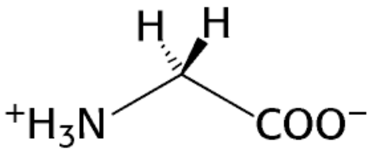

Lisina
Arginina
Istidina

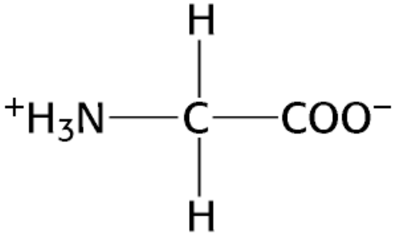
### Gruppi R carichi negativamente


Aspartato
Glutammato

**Glicina**
**(Gly, G)**



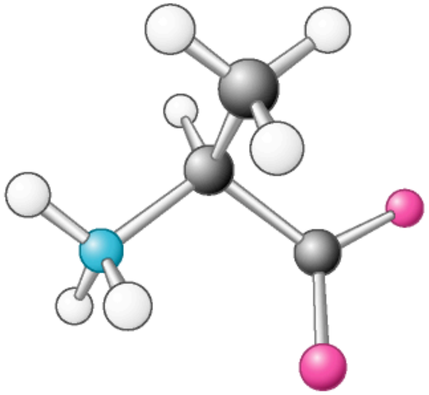


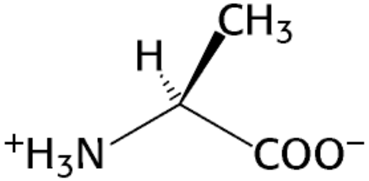


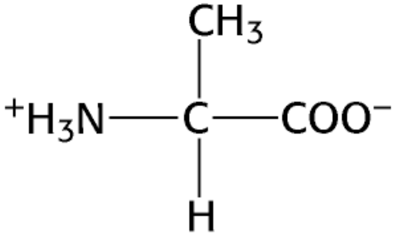
$${}^{+}\mathrm{H_3N}-\underset{\mathrm{H}}{\overset{\mathrm{H}}{\mathrm{C}}}-\mathrm{COO^-}$$

**Glicina**
**(Gly, G)**

**Alanina**
**(Ala, A)**



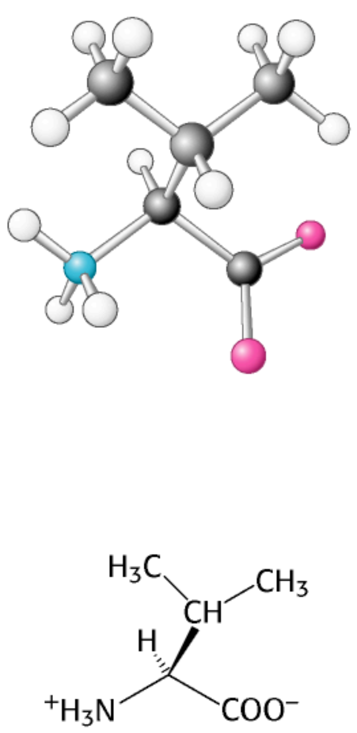

$CH_3$
H
$^{+}H_3N$
$COO^-$

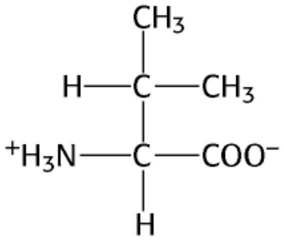


$${}^{+}\mathrm{H_3N}-\underset{\mathrm{H}}{\overset{\mathrm{CH_3}}{\mathrm{C}}}-\mathrm{COO^-}$$

**Alanina**
**(Ala, A)**

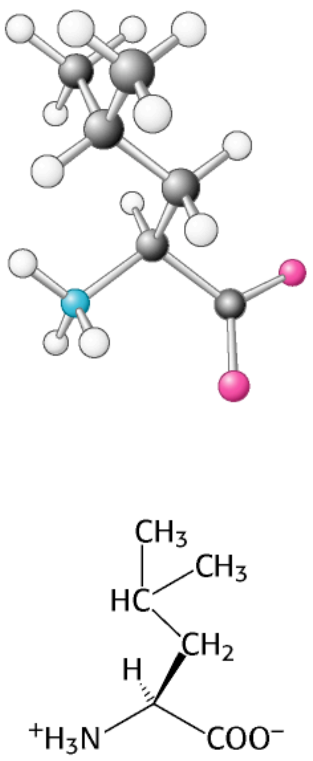
**Valina**
**(Val, V)**

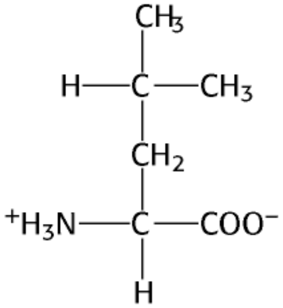




**Valina**
**(Val, V)**

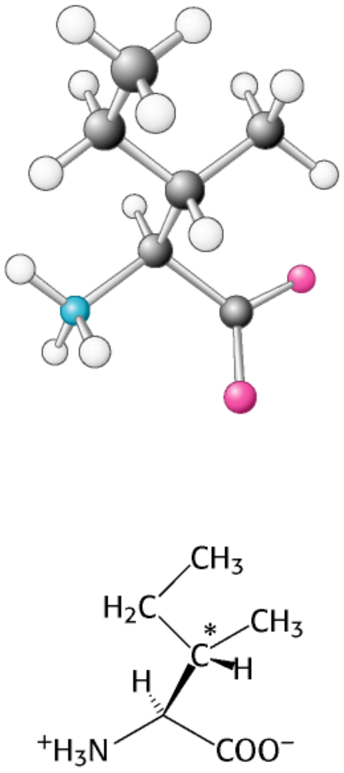
**Leucina**
**(Leu, L)**

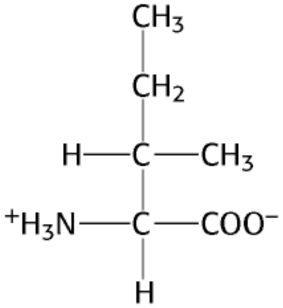




**Leucina**
**(Leu, L)**

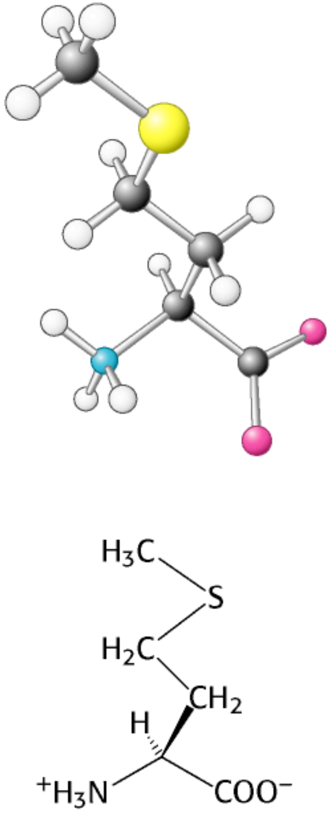
**Isoleucina**
**(Ile, I)**

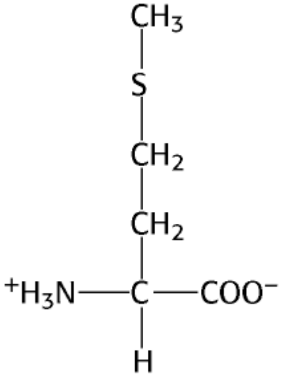




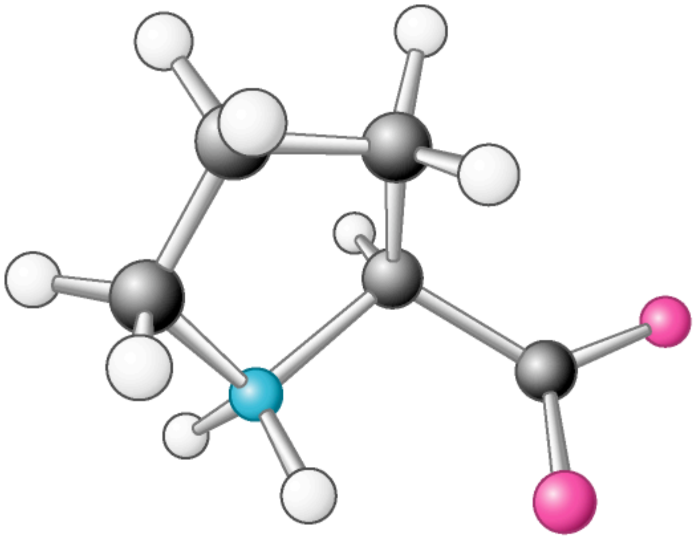
**Isoleucina**
**(Ile, I)**

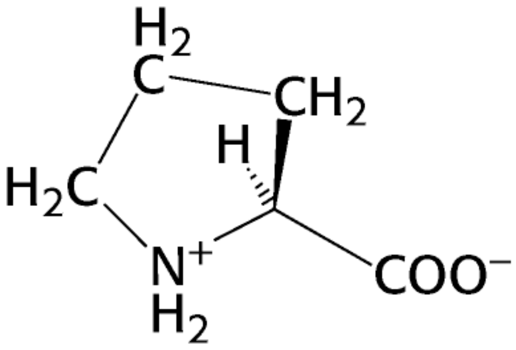
**Metionina**
**(Met, M)**





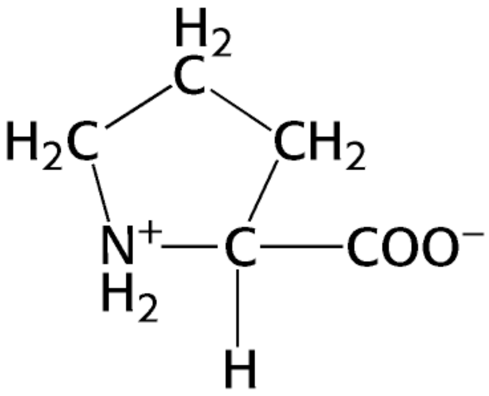
**Metionina**
**(Met, M)**





$H_2$
C
$CH_2$
H
$H_2C$
$N^+$
$H_2$
$COO^-$

**Prolina**
**(Pro, P)**

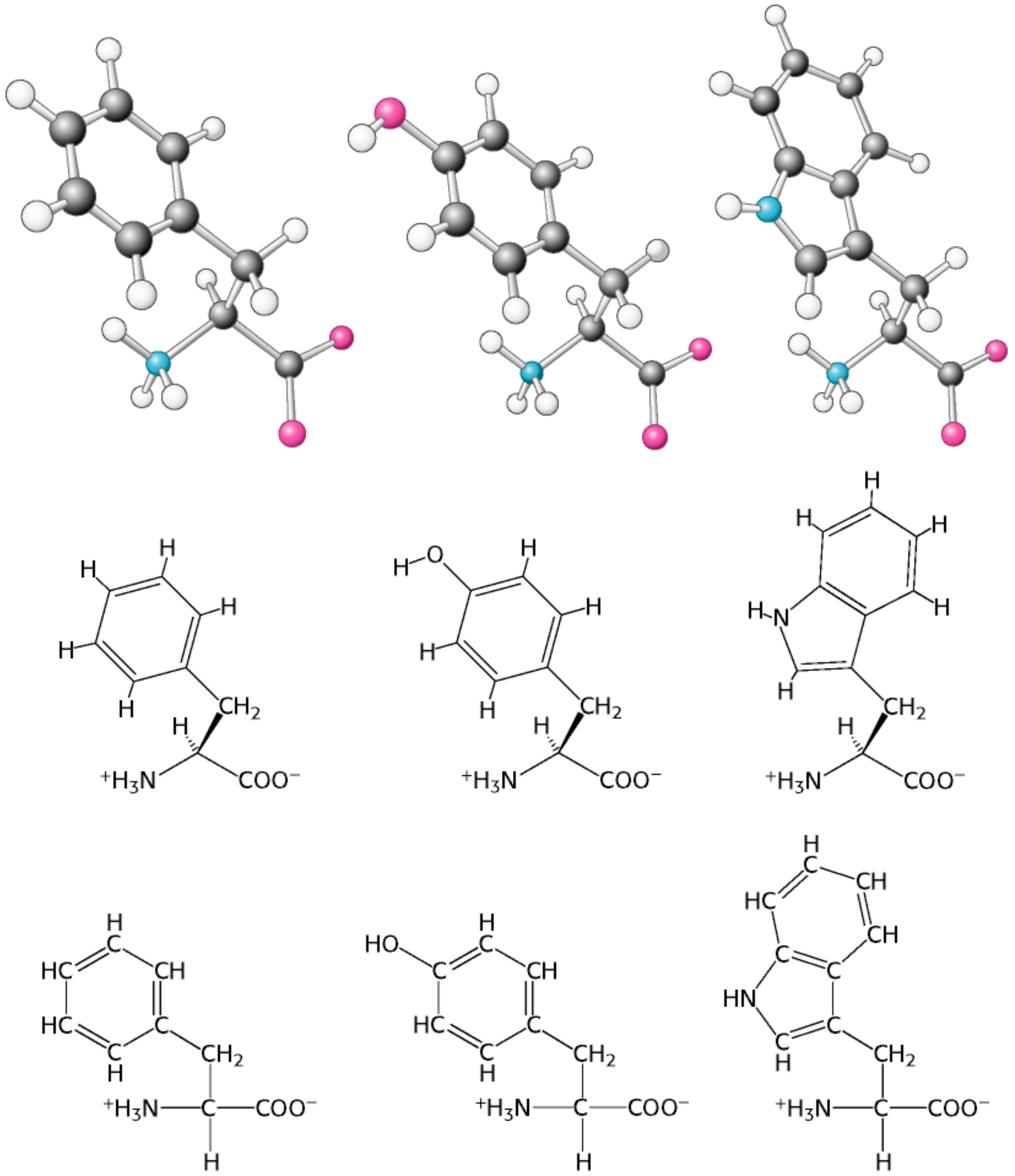


$H_2$
C
$H_2C$
$CH_2$
$N^+$
$H_2$
C
$COO^-$
H

**Fenilalanina**
**(Phe, F)**

**Tirosina**
**(Tyr, Y)**

**Triptofano**
**(Trp, W)**

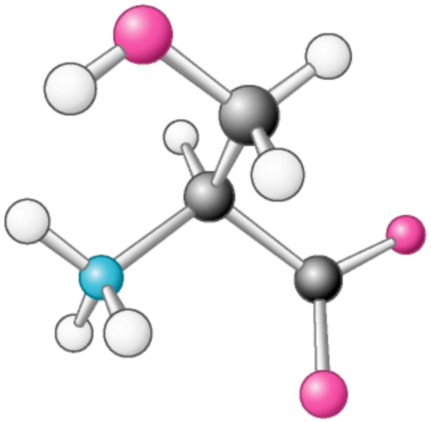


**Fenilalanina**
**(Phe, F)**

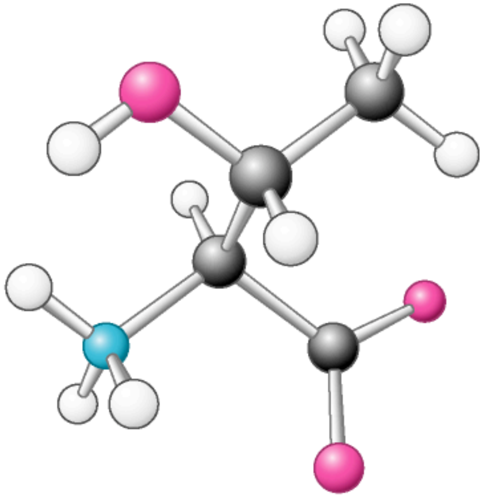
**Tirosina**
**(Tyr, Y)**

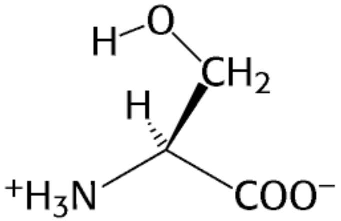
**Triptofano**
**(Trp, W)**

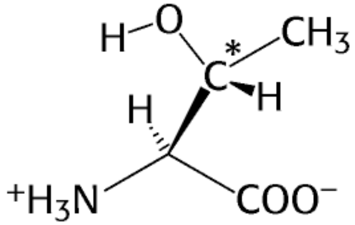
**Serina**
**(Ser, S)**

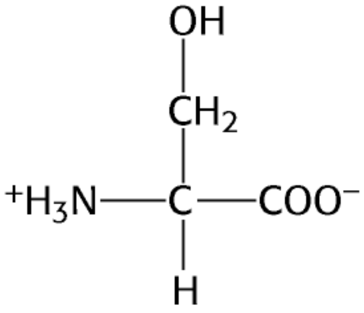


**Treonina**
**(Thr, T)**

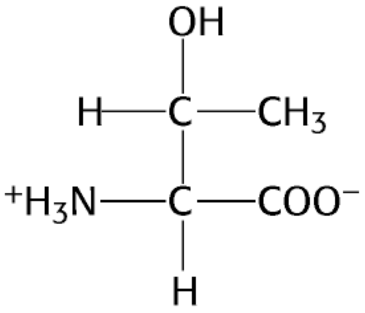



H
O
CH2
H
+H3N
COO−


H
O
*
CH3
C
H
H
+H3N
COO−


OH
CH2
+H3N
C
COO−
H

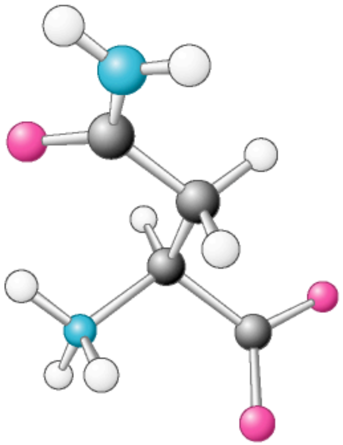
**Serina**
**(Ser, S)**

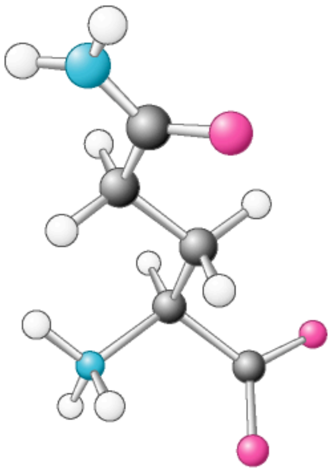

OH
H
C
CH3
+H3N
C
COO−
H

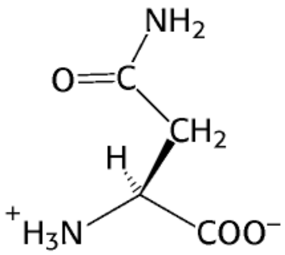
**Treonina**
**(Thr, T)**

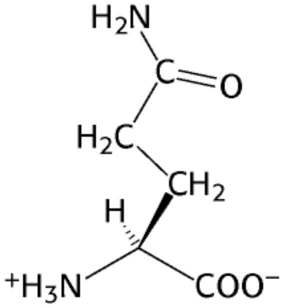
**Asparagina**
**(Asn, N)**

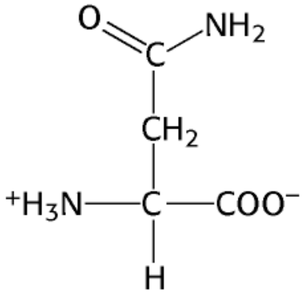
**Glutammina**
**(Gln, Q)**

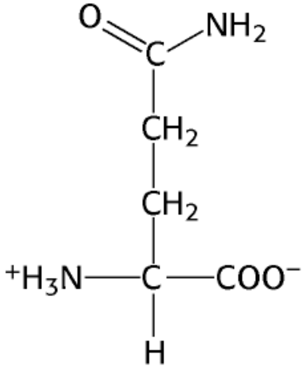





NH2
O
C
CH2
H
+H3N
COO−

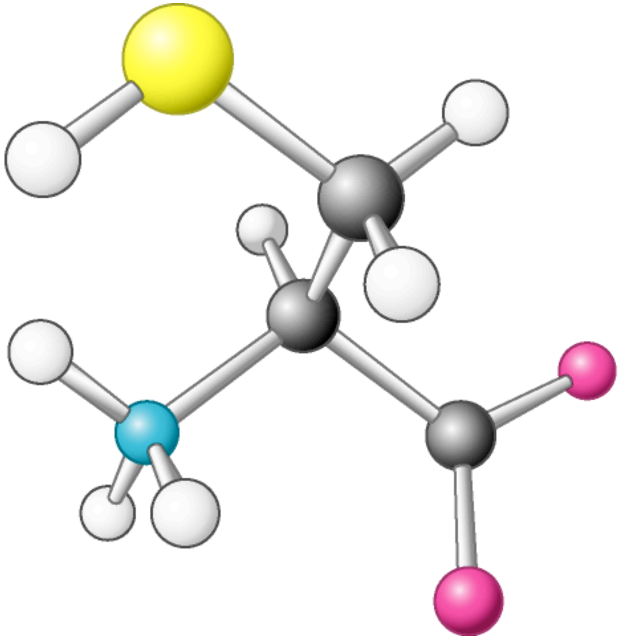

H2N
C
O
H2C
CH2
H
+H3N
COO−

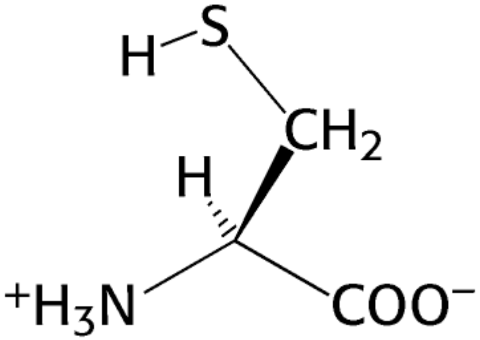

O
NH2
C
CH2
+H3N
C
COO−
H


O
NH2
C
CH2
CH2
+H3N
C
COO−
H

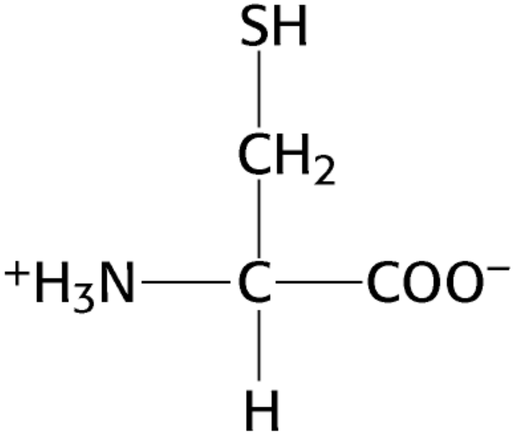
**Asparagina**
**(Asn, N)**

**Glutammina**
**(Gln, Q)**



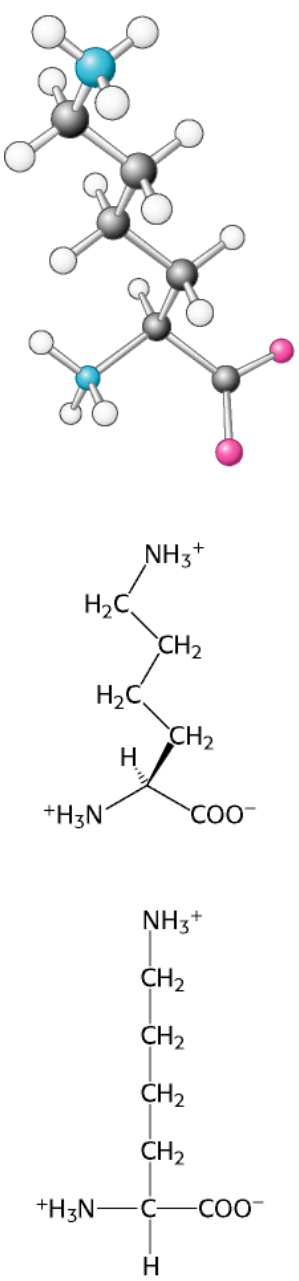

H
S
CH2
H
+H3N
COO−

**Cisteina**
**(Cys, C)**



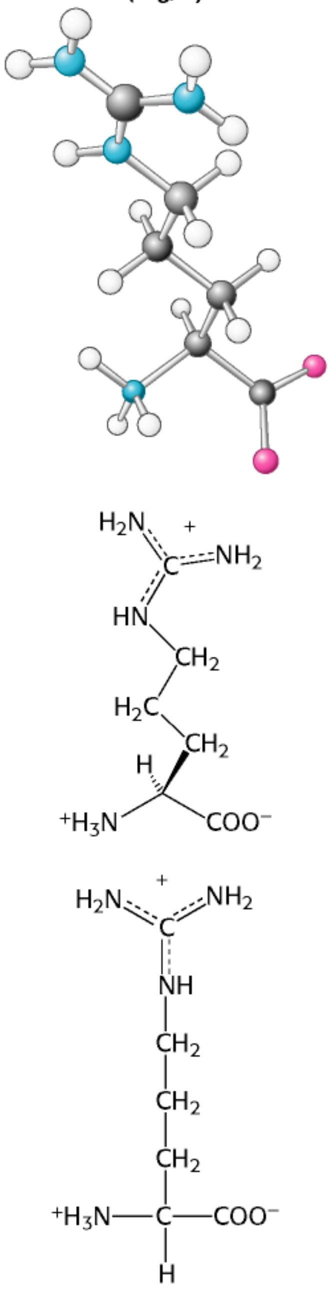
$$\begin{array}{c} \mathrm{SH} \\ | \\ \mathrm{CH_2} \\ | \\ {}^{+}\mathrm{H_3N}\!-\!\mathrm{C}\!-\!\mathrm{COO^-} \\ | \\ \mathrm{H} \end{array}$$

**Lisina**
**(Lys, K)**



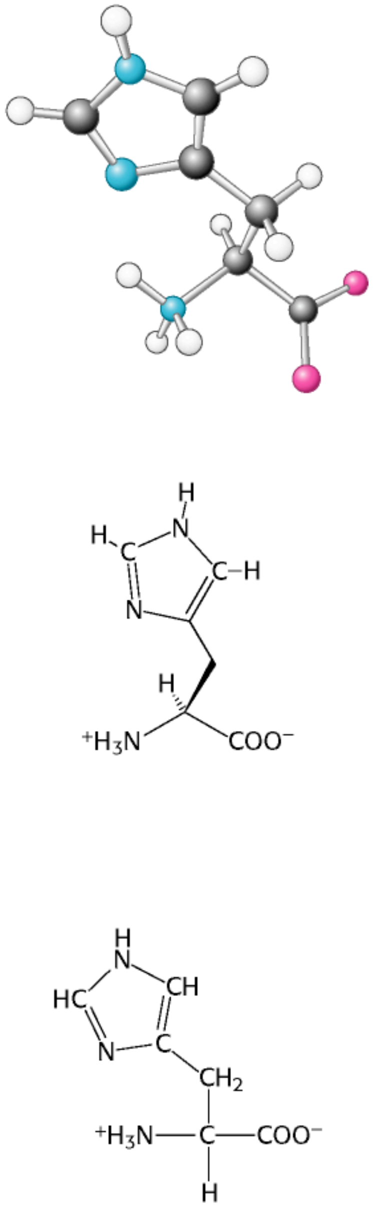
**Lisina**
**(Lys, K)**

**Arginina**
**(Arg, R)**

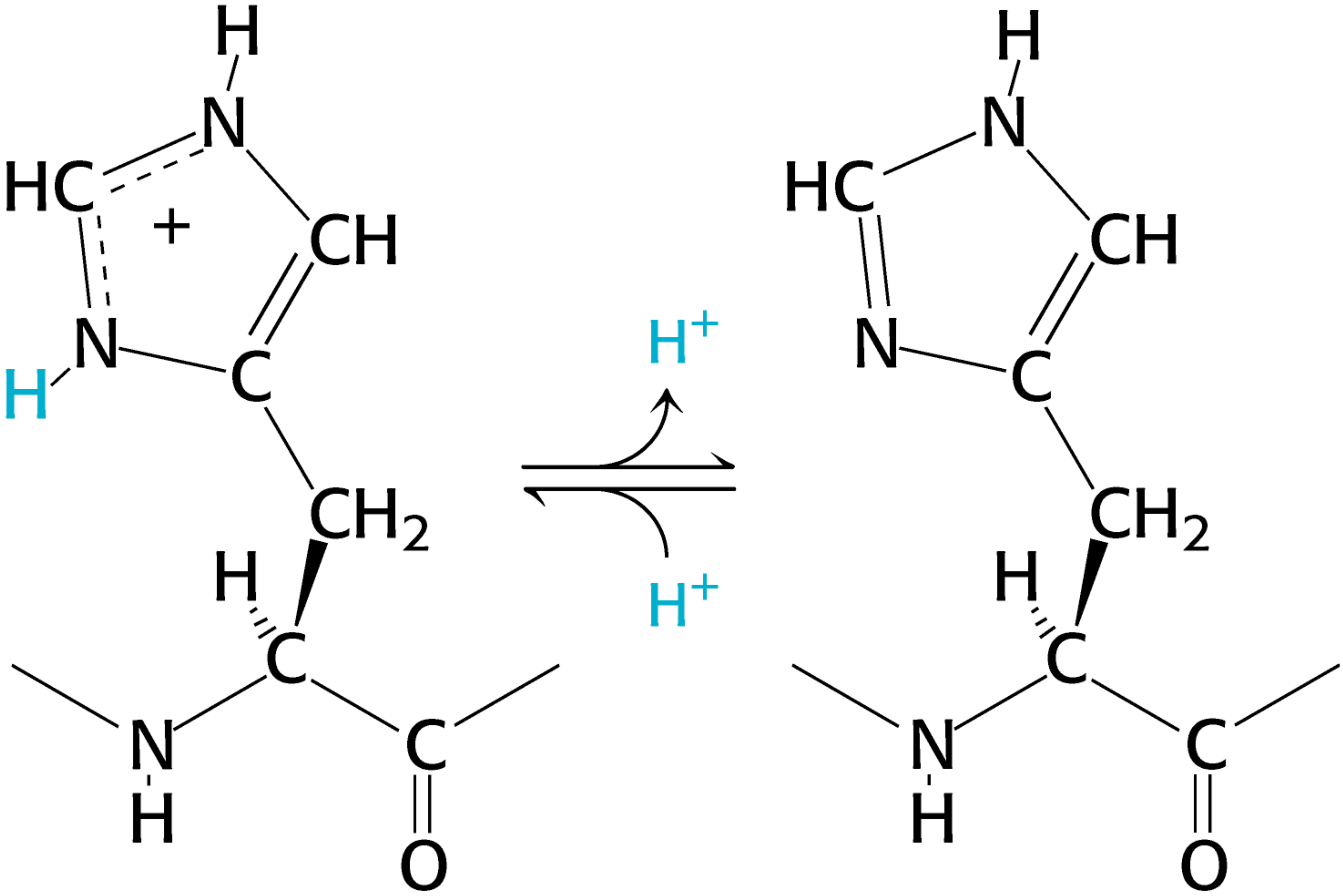


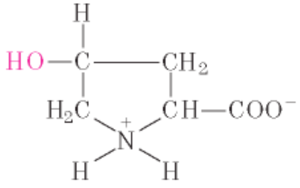
**Arginina**
**(Arg, R)**

**Istidina**
**(His, H)**



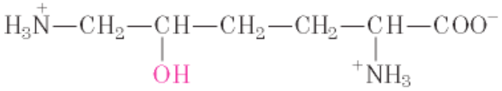
**Istidina**
**(His, H)**


H
N
HC
+
CH
N
H
C
CH2
H
C
N
H
C
O
H+
H+
H
N
HC
CH
N
C
CH2
H
C
N
H
C
O



4-Idrossiprolina

Idrossiprolina

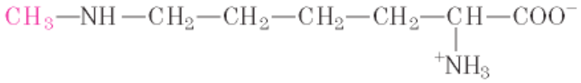


$$H_3\overset{+}{N}-CH_2-\underset{\underset{OH}{|}}{CH}-CH_2-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

5-Idrossilisina

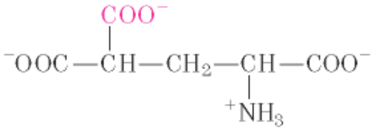
Idrossilisina

Metil-lisina



$$CH_3-NH-CH_2-CH_2-CH_2-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

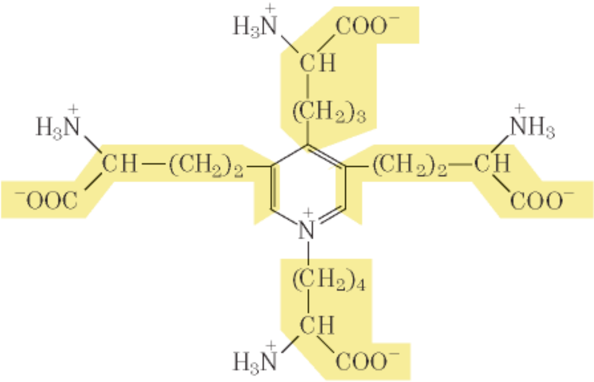
6-*N*-Metillisina



$$^-OOC-\overset{\overset{COO^-}{|}}{CH}-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

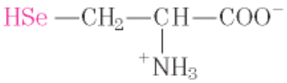
γ-Carbossiglutammato

Ac. **gamma**-carbossiglutammico



Desmosina

Desmosina



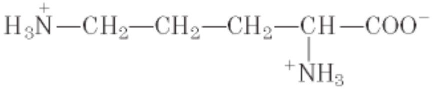
$$HSe-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

Selenocisteina

(a)

Selenocisteina

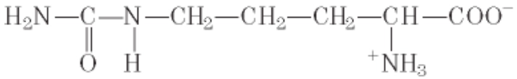
(b)



$$H_3\overset{+}{N}-CH_2-CH_2-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

Ornitina

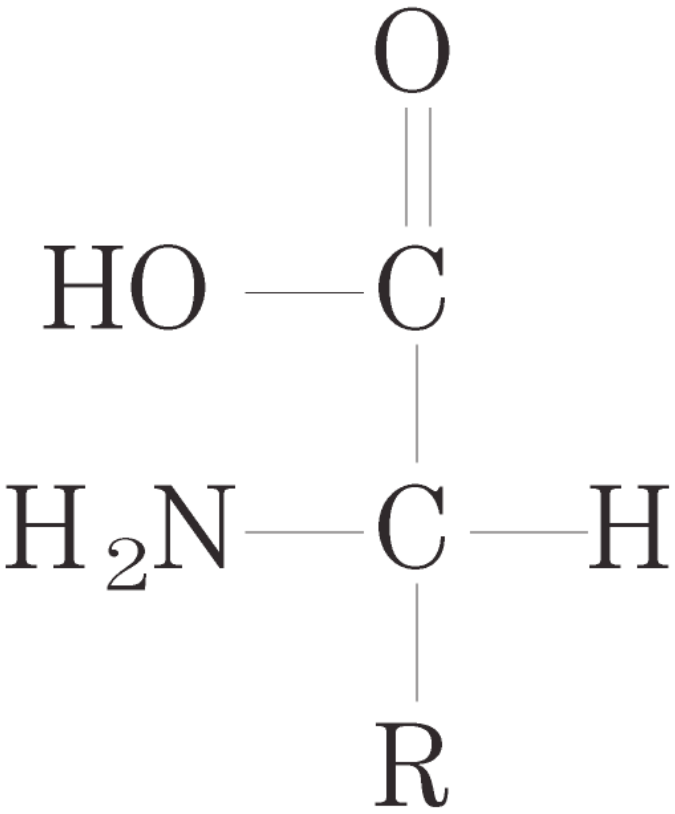
Ornitina



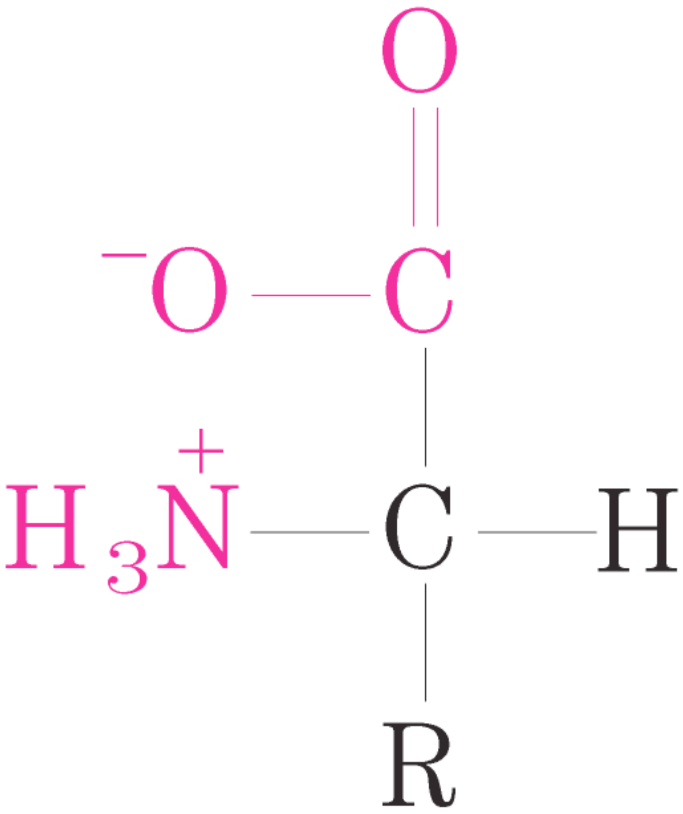
$$H_2N-\underset{\underset{O}{\|}}{C}-\underset{\underset{H}{|}}{N}-CH_2-CH_2-CH_2-\underset{\underset{^+NH_3}{|}}{CH}-COO^-$$

Citrullina

Citrullina



Forma
non ionica



Forma
zwitterionica
(Anfoionica)

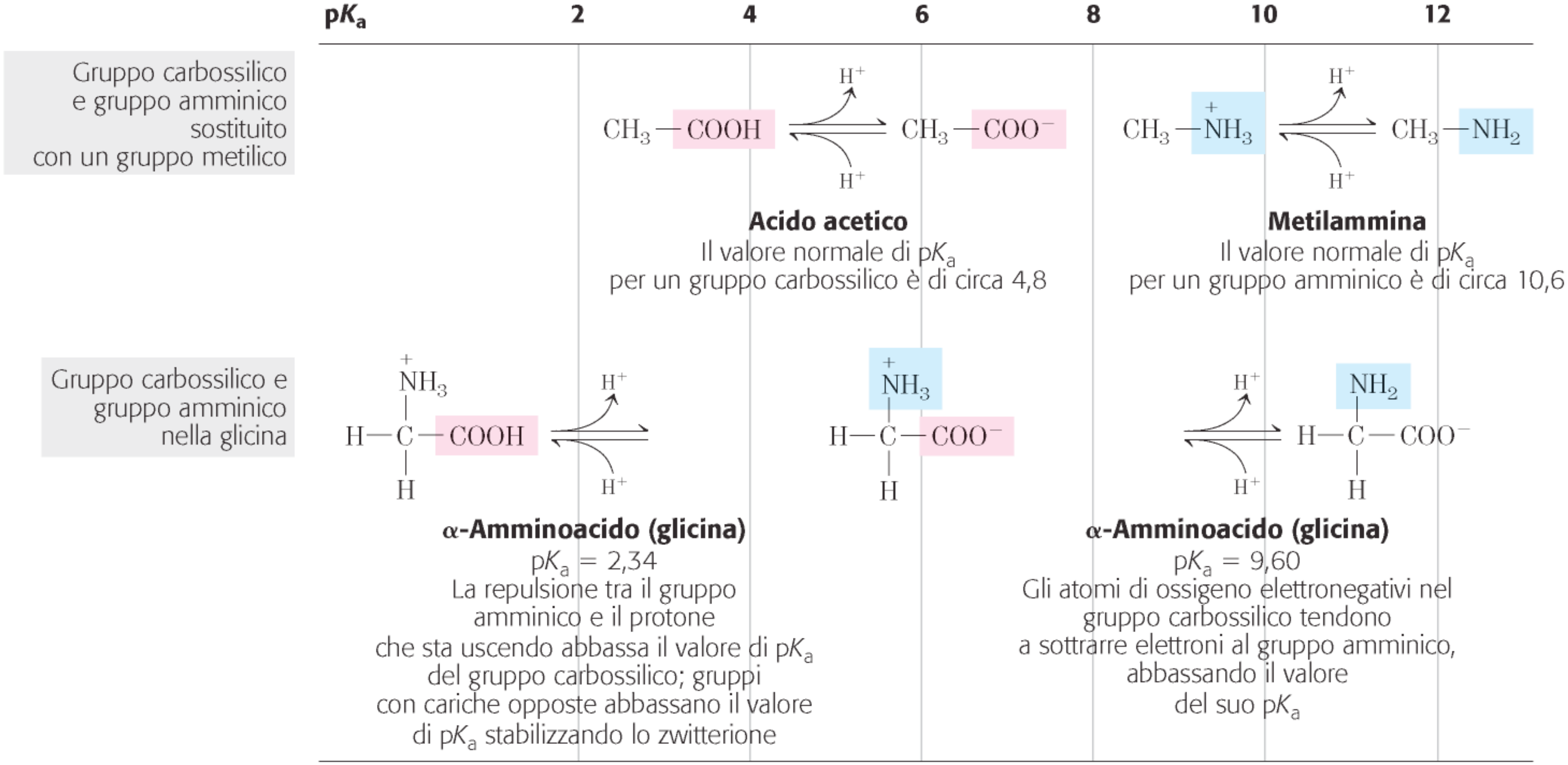
# Cose’ il punto isoelettrico di un amminoacido?

Il **punto isoelettrico (pI) è il valore di pH al quale una molecola non reca alcuna carica elettrica netta**

**Il pI di un anfoione e’ uguale ad ½ della somma algebrica dei valori di pKa dei gruppi ionizzabili.**

**Per un amminoacido avente un solo gruppo amminico ed un solo gruppo carbossilico il valore di pI e’ calcolable dalla seguente espressione:**

$$pI = \frac{pK_{COOH} + pK_{NH_3^+}}{2}$$

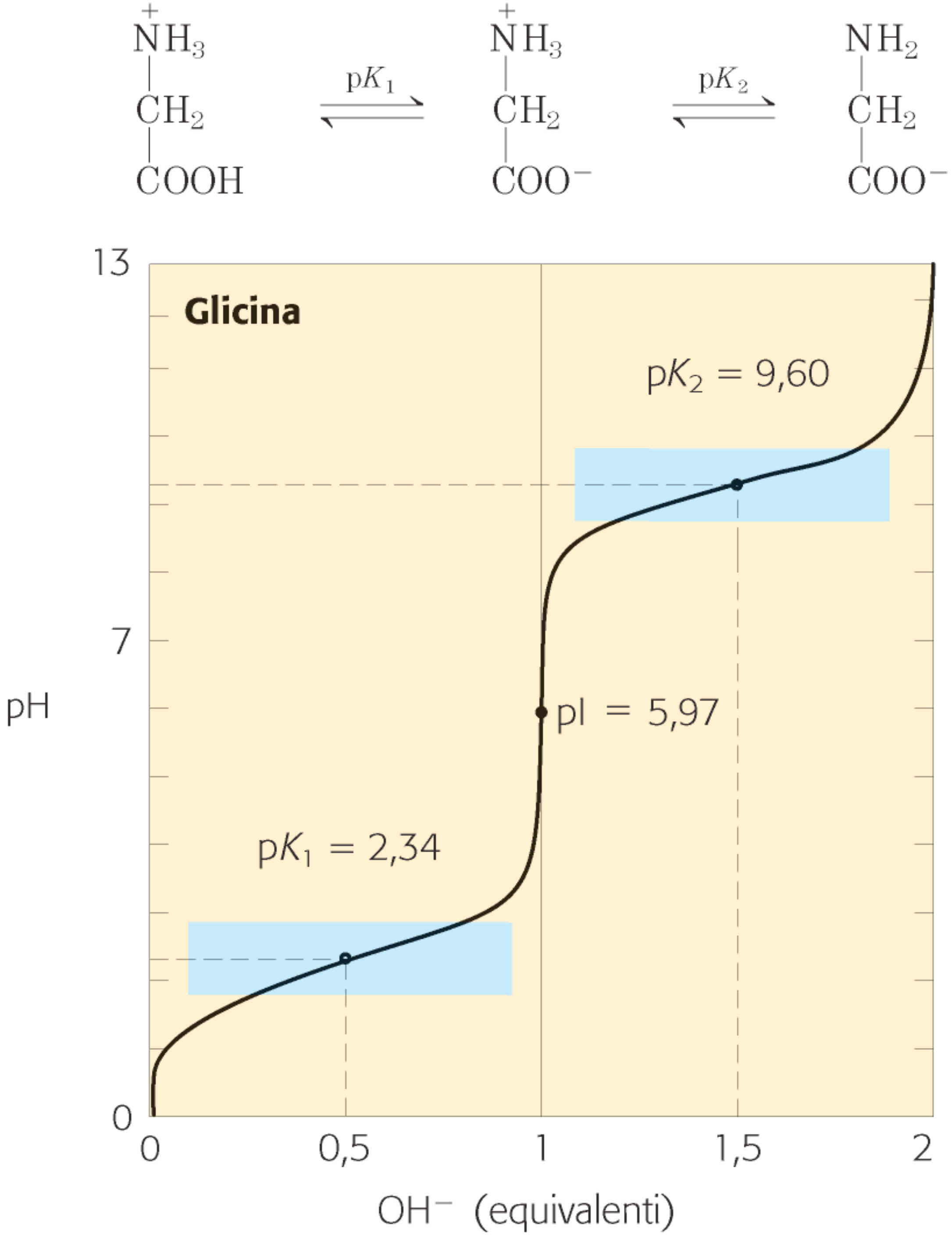

pKa
2
4
6
8
10
12
Gruppo carbossilico e gruppo amminico sostituito con un gruppo metilico
Gruppo carbossilico e gruppo amminico nella glicina
CH3—COOH
CH3—COO−
H+
CH3—NH3+
CH3—NH2
NH3+
H—C—COOH
H
H—C—COO−
NH2

**Acido acetico**
Il valore normale di $pK_a$
per un gruppo carbossilico è di circa 4,8

**Metilammina**
Il valore normale di $pK_a$
per un gruppo amminico è di circa 10,6

**α-Amminoacido (glicina)**
$pK_a = 2{,}34$
La repulsione tra il gruppo
amminico e il protone
che sta uscendo abbassa il valore di $pK_a$
del gruppo carbossilico; gruppi
con cariche opposte abbassano il valore
di $pK_a$ stabilizzando lo zwitterione

**α-Amminoacido (glicina)**
$pK_a = 9{,}60$
Gli atomi di ossigeno elettronegativi nel
gruppo carbossilico tendono
a sottrarre elettroni al gruppo amminico,
abbassando il valore
del suo $pK_a$



$\overset{+}{N}H_3-CH_2-COOH \underset{}{\xrightarrow{pK_1}} \overset{+}{N}H_3-CH_2-COO^- \xrightarrow{pK_2} NH_2-CH_2-COO^-$
Glicina
pK₂ = 9,60
pI = 5,97
pK₁ = 2,34
pH
13
7
0
0
0,5
1
1,5
2
OH⁻ (equivalenti)

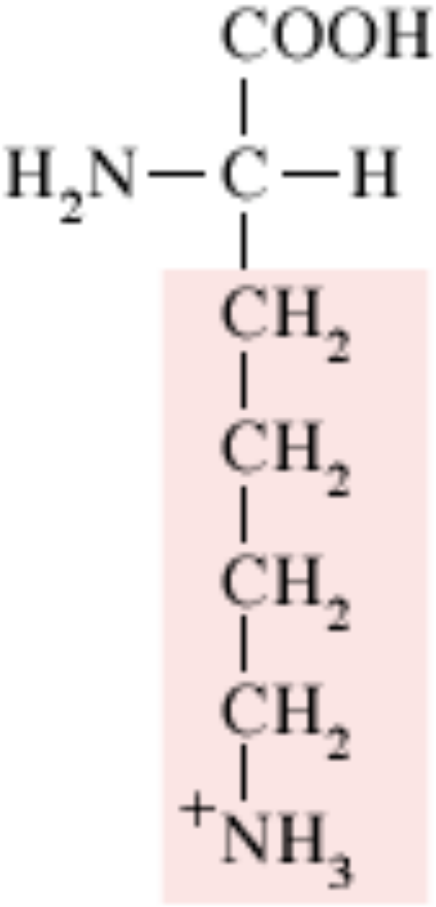
# CALCOLO DEL PUNTO ISOELETTRICO DI AMMINOACIDI ACIDI O BASICI

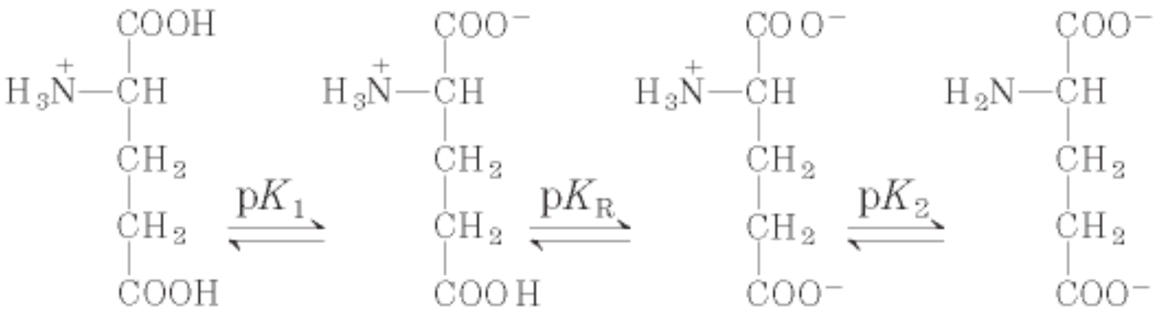
Per quanto riguarda gli amminoacidi con un gruppo ionizzabile nella catena laterale, per esempio la lisina o l’aspartato, si utilizza la stessa formula utilizzata per gli anfoioni.
Operativamente e’ necessario considerare unicamente i pKa dei gruppi maggiormente rappresentati:

Es:
- per lisina si considerano unicamente i pKa dei due gruppi amminici
- per glutammato si considerano unicamente i pKa dei due gruppi carbossilici.

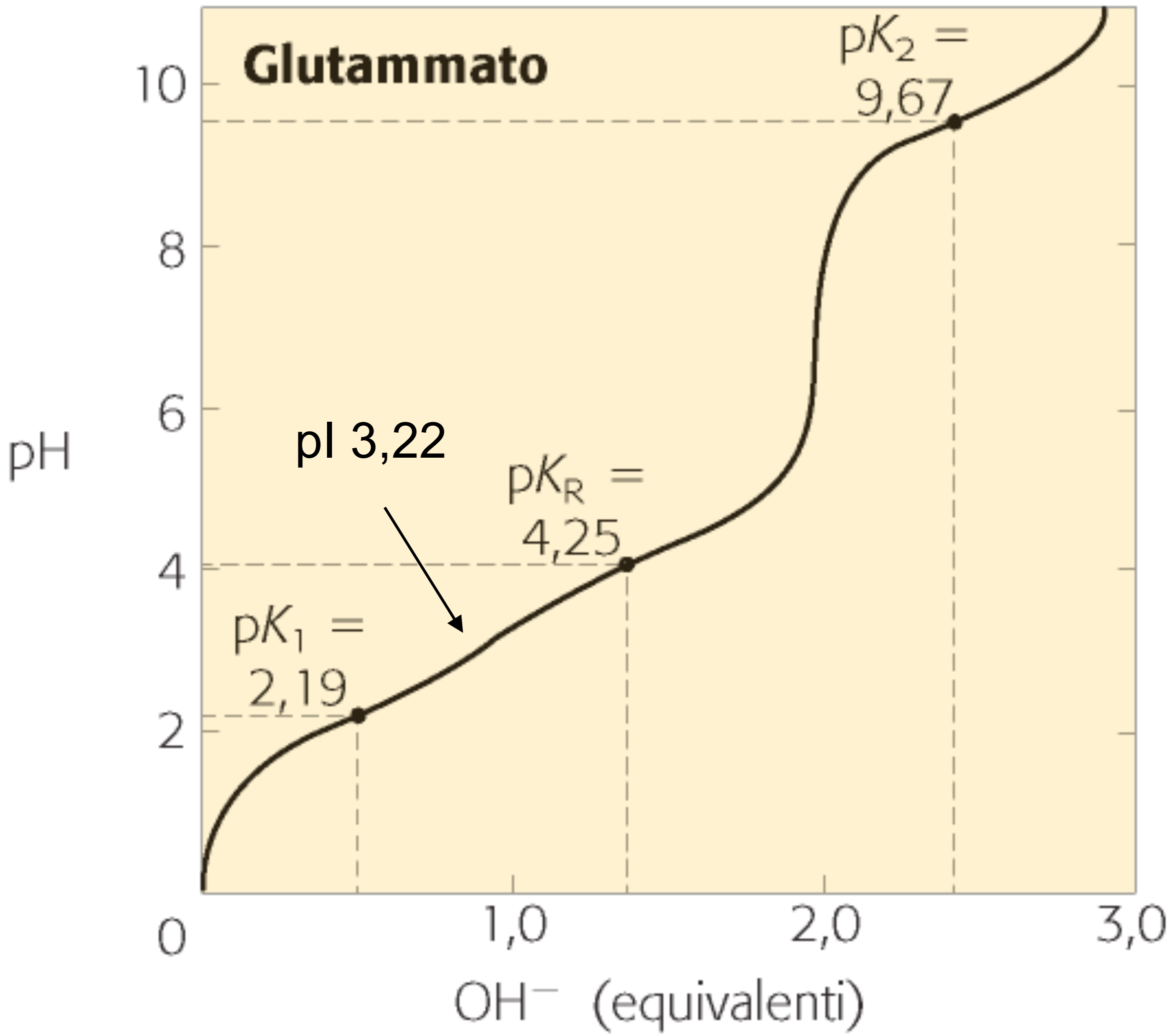
**LISINA** presenta tre pKa:
l'α-Carbossile 2,16;
l'α-ammino gruppo 9,06
l'ε-ammino gruppo 10,54.
Il calcolo del pI prende in considerazione solamente i pKa dei due gruppi amminici, per cui:

$$pI = \frac{9,06 + 10,54}{2} = 9,80$$


COOH
$H_2N-C-H$
$CH_2$
$CH_2$
$CH_2$
$CH_2$
$^+NH_3$



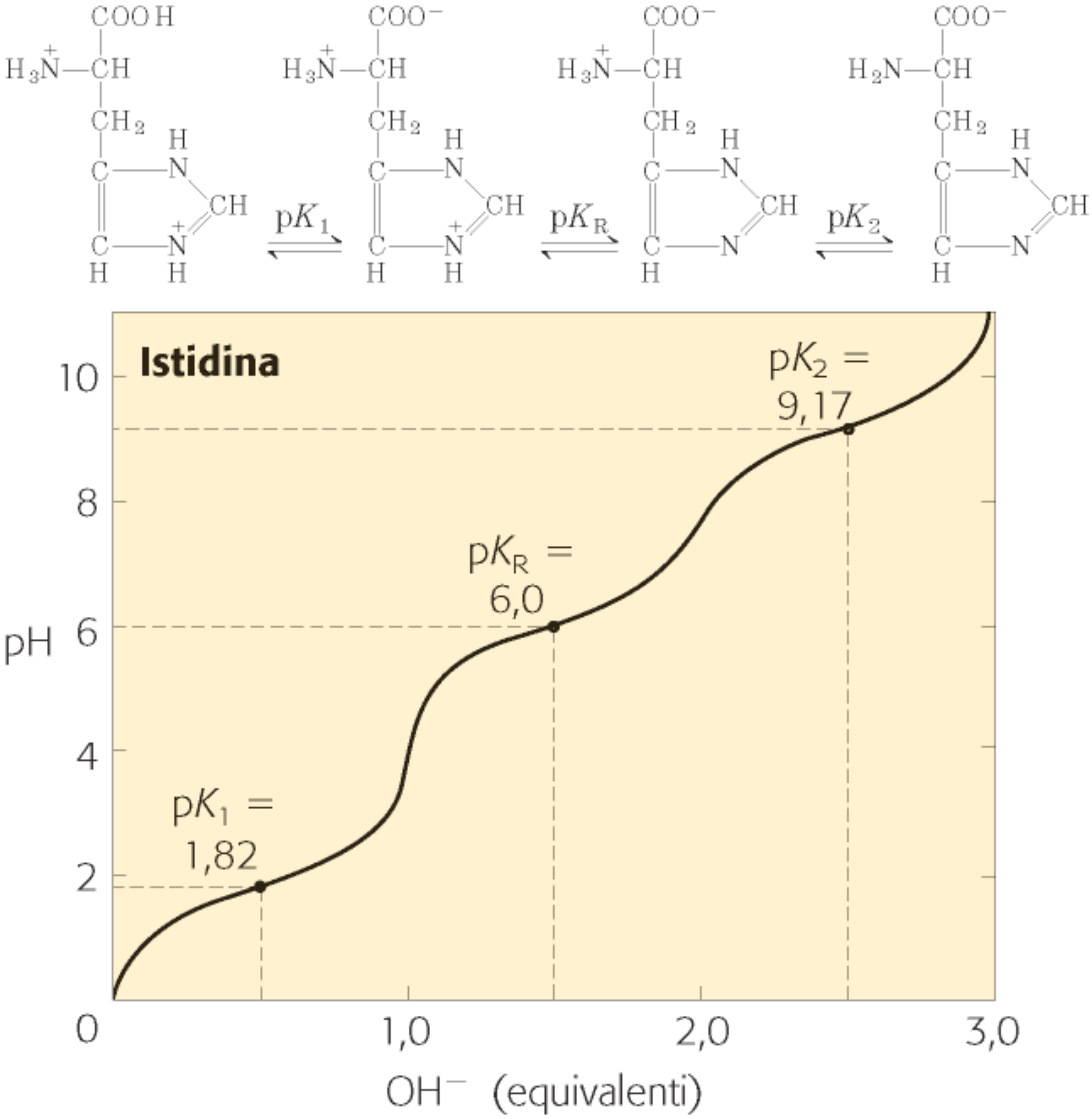
pK1
pKR
pK2



Glutammato
pK2 = 9,67
pI 3,22
pKR = 4,25
pK1 = 2,19
pH
10
8
6
4
2
0
1,0
2,0
3,0
OH⁻ (equivalenti)

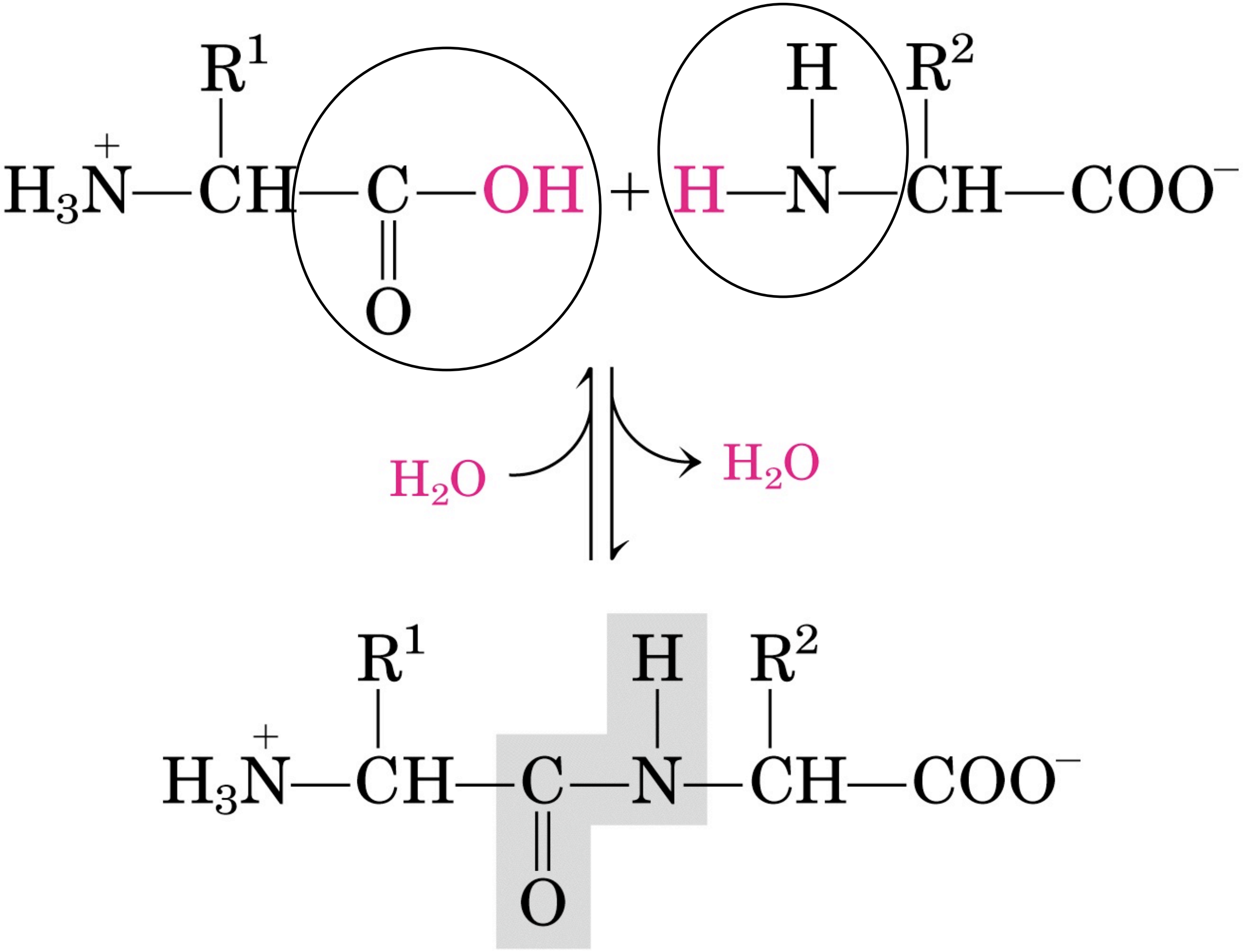
(a)

**PI ?**

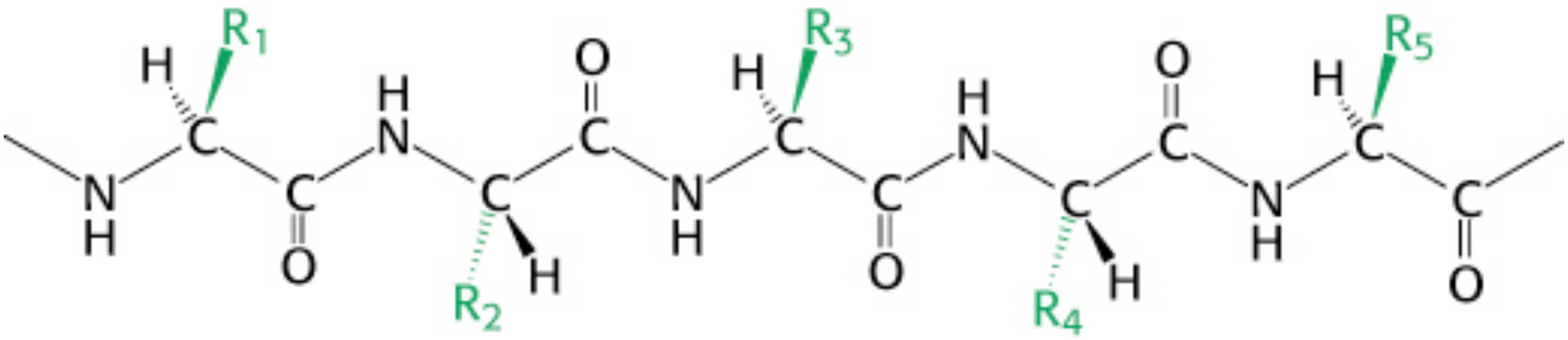

COOH
$H_3\overset{+}{N}$—CH
$CH_2$
$pK_1$
COO⁻
$pK_R$
$H_2N$—CH
$pK_2$
Istidina
$pK_2$ = 9,17
$pK_R$ = 6,0
$pK_1$ = 1,82
pH
10
8
6
4
2
0
1,0
2,0
3,0
OH⁻ (equivalenti)

b)

# Formazione del legame peptidico

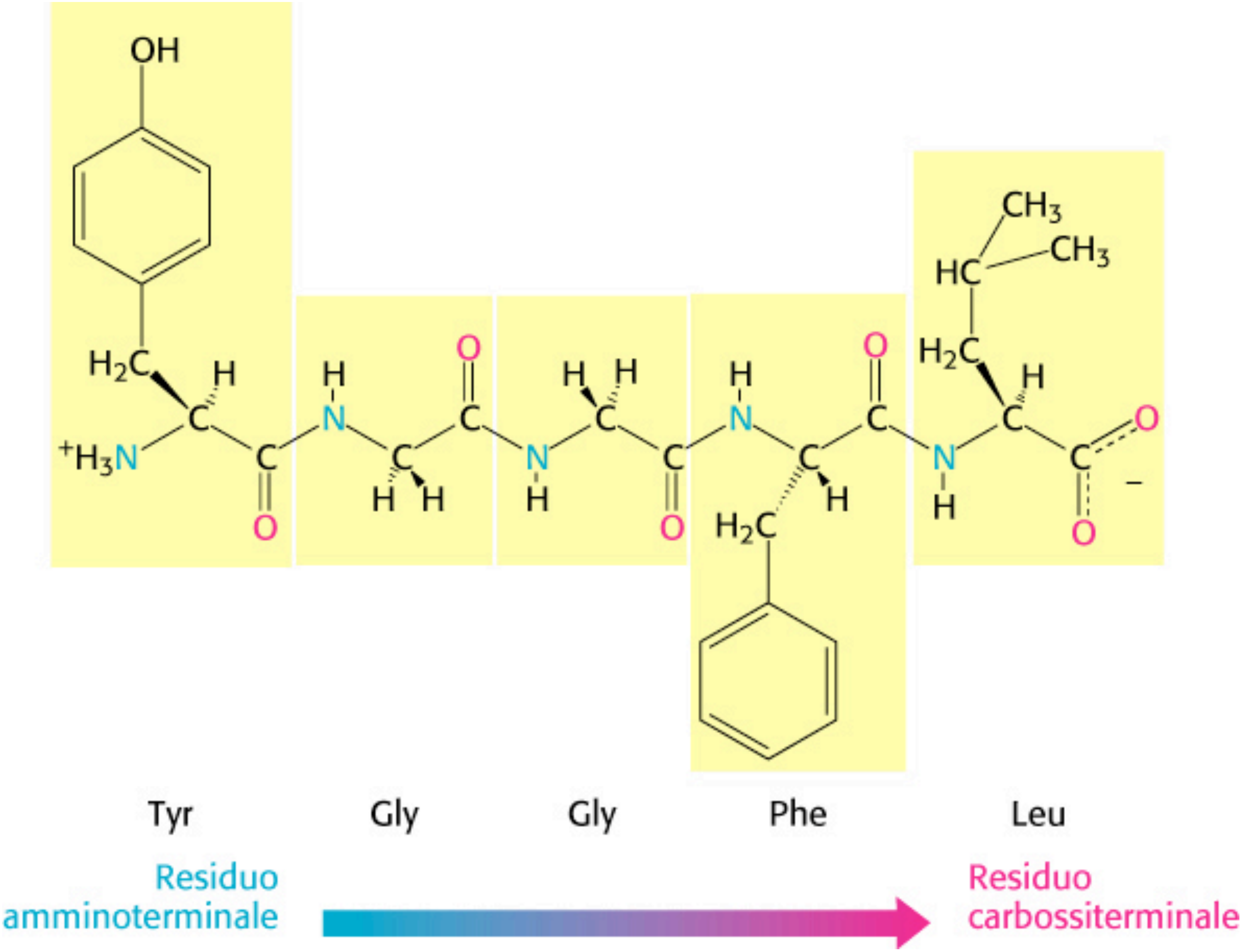

R1
R2
H
H3N+—CH—C—OH + H—N—CH—COO−
O
H2O
H2O
R1
H
R2
H3N+—CH—C—N—CH—COO−
O

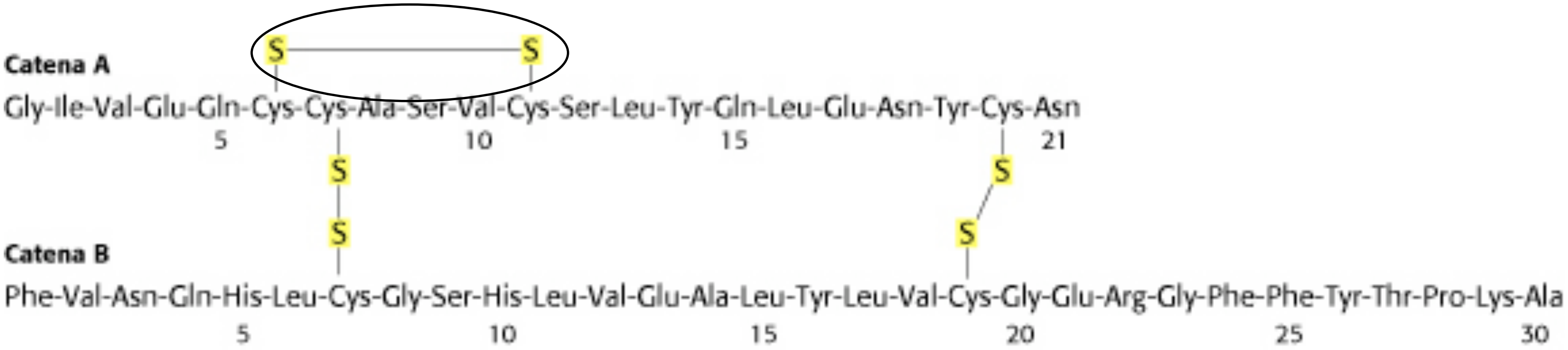
**Legame carbammidico**


R1
R2
R3
R4
R5
H
N
C
O

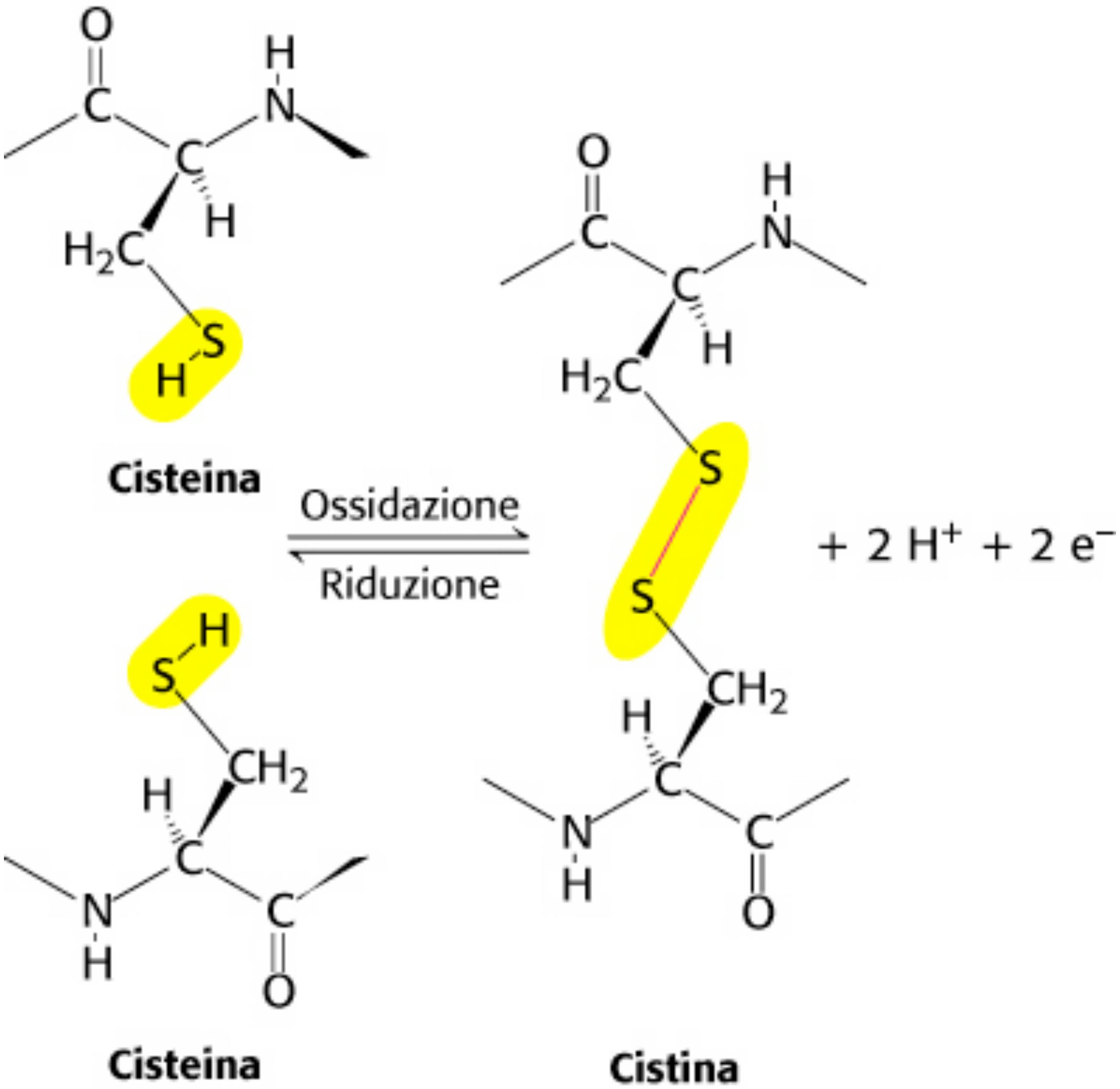
Una catena polipeptidica è costitutita da una catena principale (scheletro covalente) con struttura ripetitiva (in nero) e da catene variabili (in verde)

# Le sequenze amminoacidiche hanno una direzionalità ben precisa

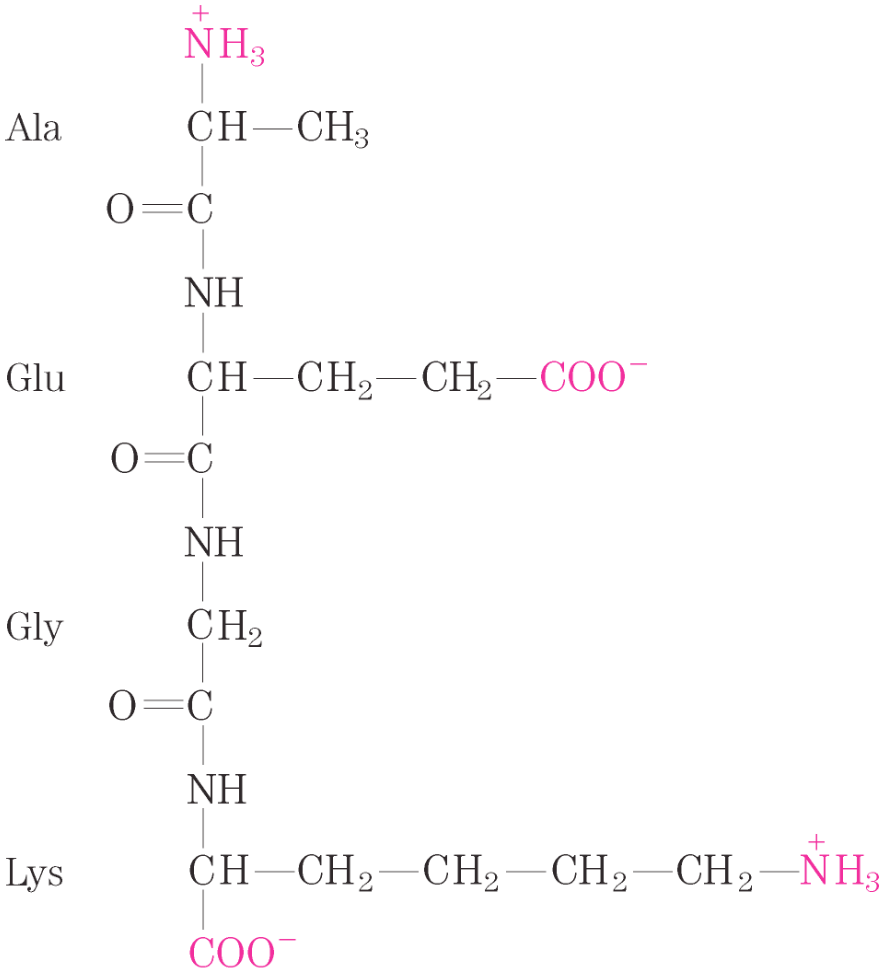

OH
H2C
H
+H3N
C
C
O
H
N
C
H
H
O
C
H
H
N
H
C
O
H
N
C
H
H2C
O
C
CH3
CH3
HC
H2C
H
N
H
C
C
O
O
–
Tyr
Gly
Gly
Phe
Leu
Residuo amminoterminale
Residuo carbossiterminale


Catena A
Gly-Ile-Val-Glu-Gln-Cys-Cys-Ala-Ser-Val-Cys-Ser-Leu-Tyr-Gln-Leu-Glu-Asn-Tyr-Cys-Asn
5
10
15
21
S
S
S
S
S
S
Catena B
Phe-Val-Asn-Gln-His-Leu-Cys-Gly-Ser-His-Leu-Val-Glu-Ala-Leu-Tyr-Leu-Val-Cys-Gly-Glu-Arg-Gly-Phe-Phe-Tyr-Thr-Pro-Lys-Ala
5
10
15
20
25
30

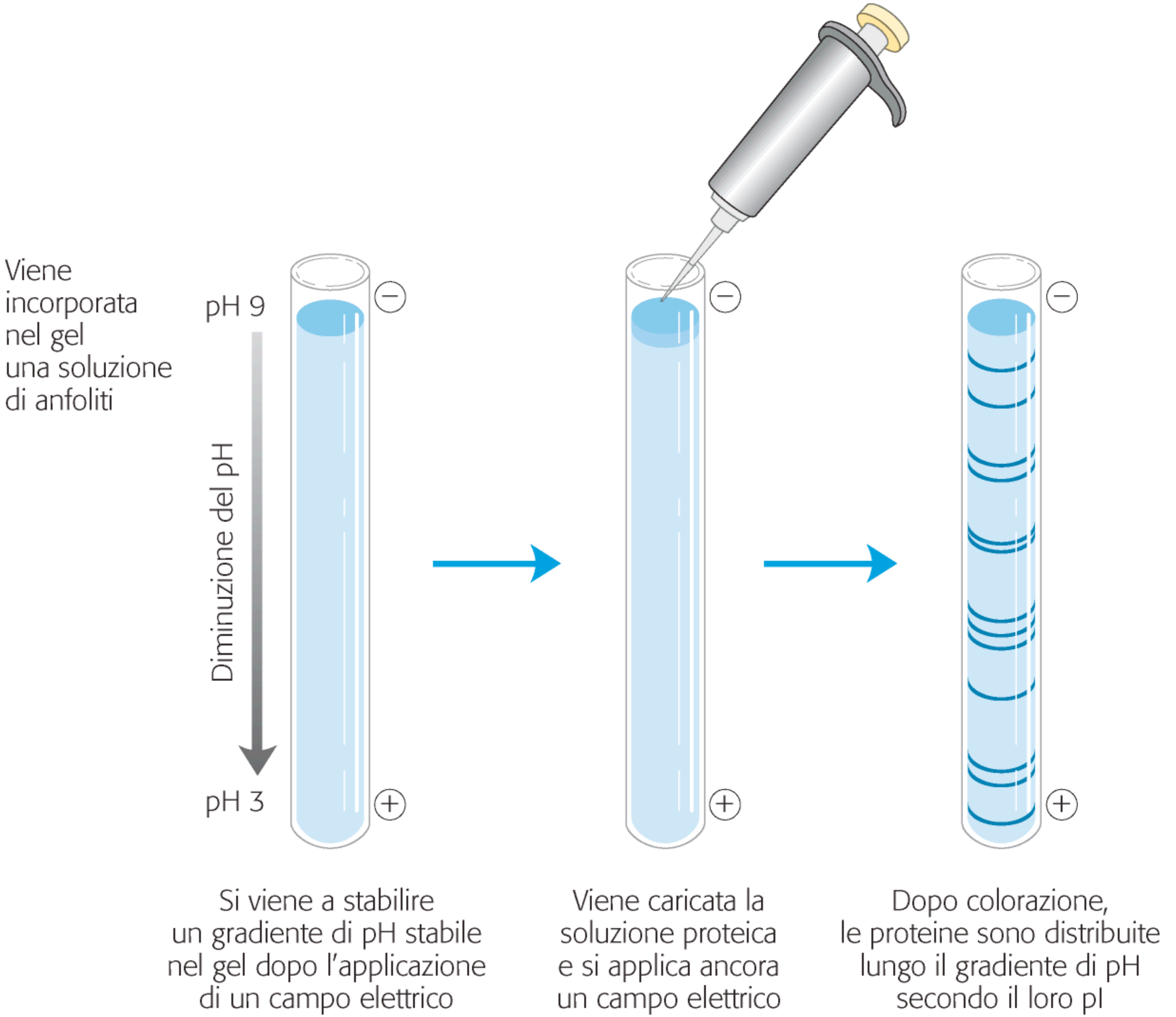
**Prima sequenza di una proteina (l'insulina) ad opera di Sanger**

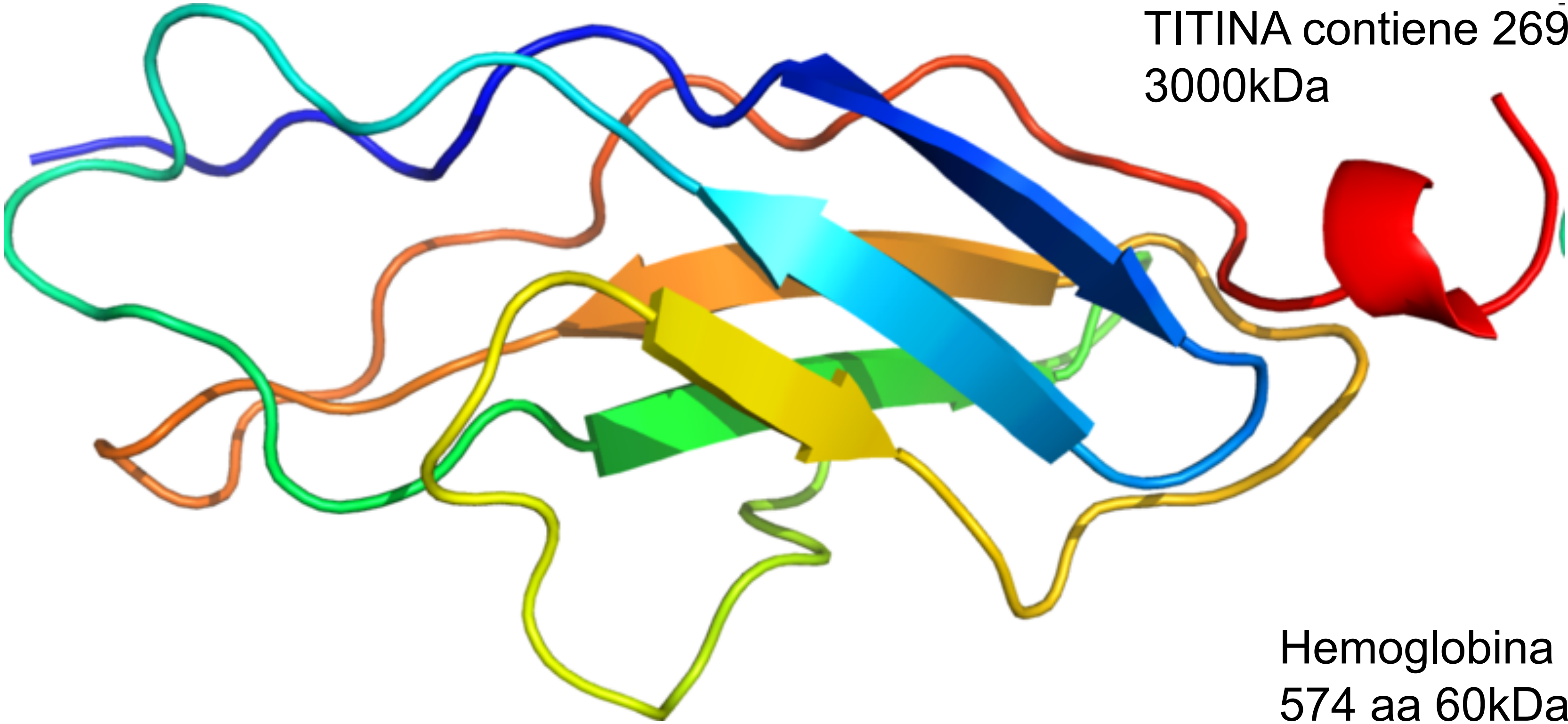

Cisteina
Ossidazione
Riduzione
$+ 2 H^+ + 2 e^-$
Cisteina
Cistina

# COME GLI AMMINOACIDI ANCHE I POLIPEPTIDI HANNO UN pI



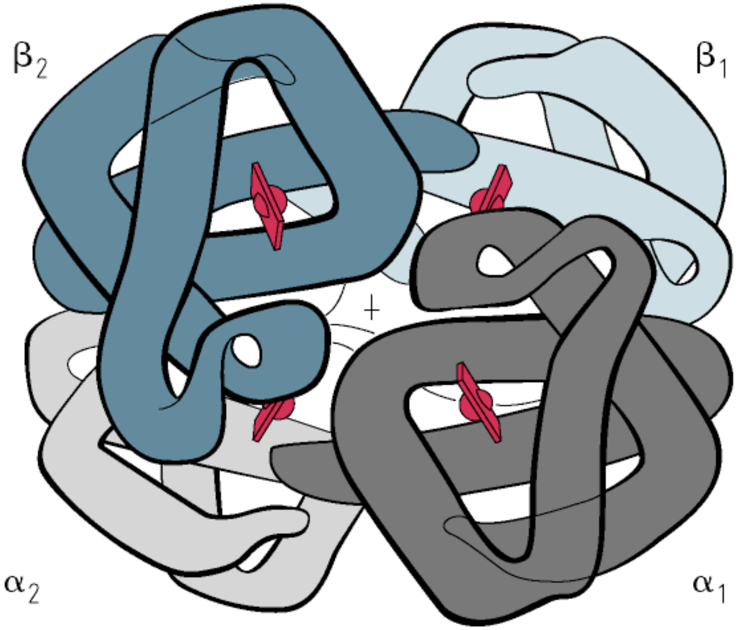
Ala
Glu
Gly
Lys


Viene incorporata nel gel una soluzione di anfoliti
pH 9
Diminuzione del pH
pH 3
−
+
−
+
−
+
Si viene a stabilire un gradiente di pH stabile nel gel dopo l'applicazione di un campo elettrico
Viene caricata la soluzione proteica e si applica ancora un campo elettrico
Dopo colorazione, le proteine sono distribuite lungo il gradiente di pH secondo il loro pI



TITINA contiene 26926 aa
3000kDa

Hemoglobina 4 catene
574 aa 60kDa


$\beta_2$
$\beta_1$
$\alpha_2$
$\alpha_1$

### **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 |

# ALCUNE PROTEINE CONTENGONO GRUPPI CHIMICI DIVERSI DAGLI AMMINOACIDI

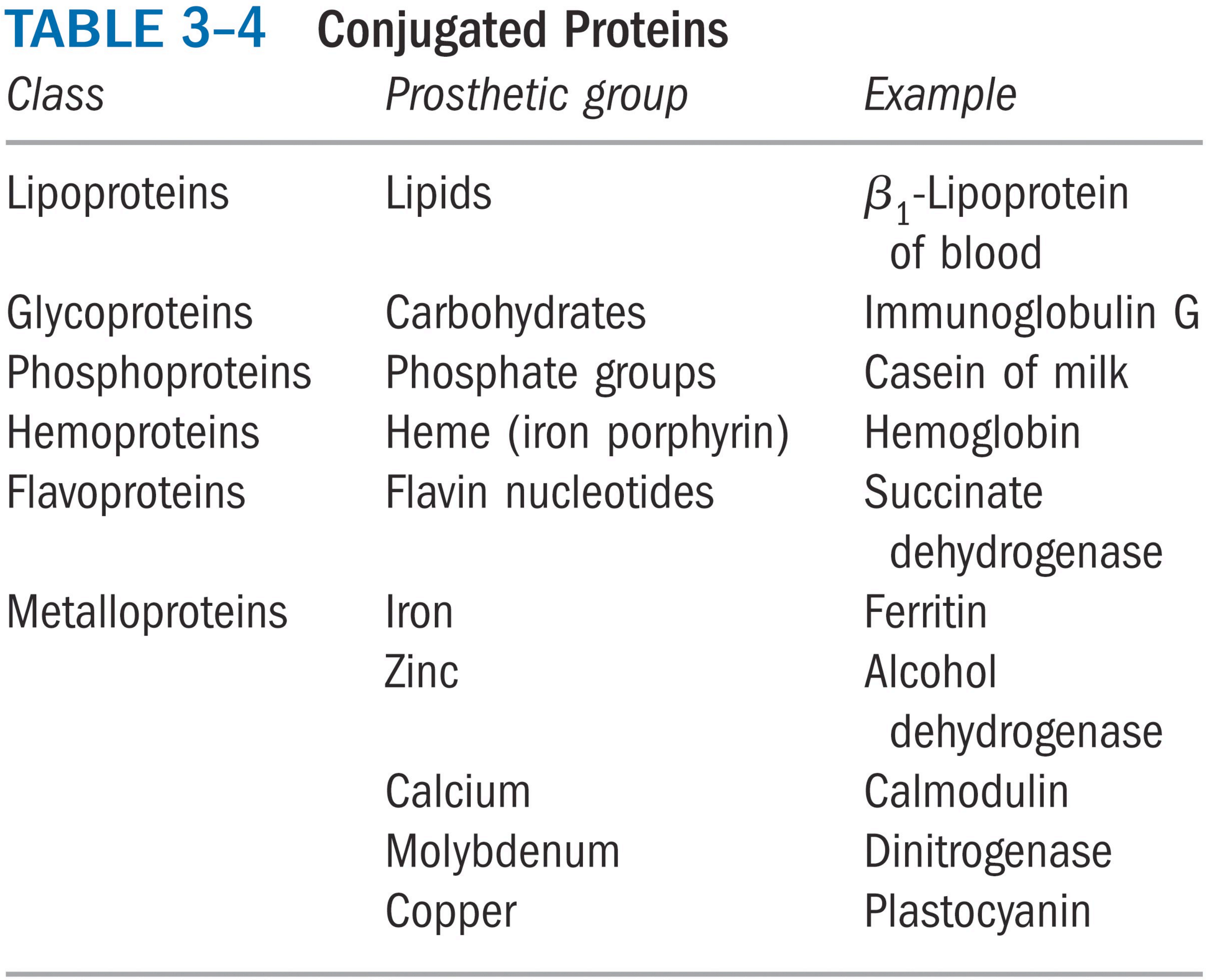
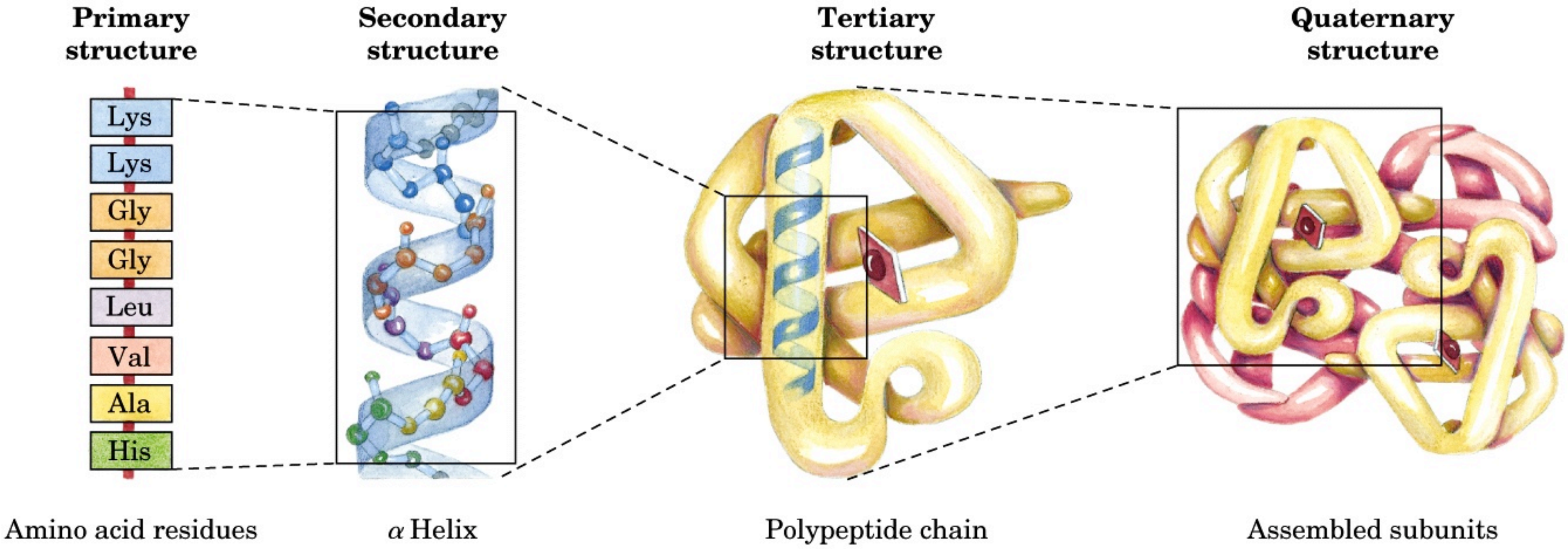


**TABLE 3–4 Conjugated Proteins**

| *Class* | *Prosthetic group* | *Example* |
|---|---|---|
| Lipoproteins | Lipids | $\beta_1$-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 |

# La sequenza amminoacidica di una proteina ne determina la struttura secondaria, terziaria e quaternaria


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

**La struttura secondaria:**

**- le catene polipetidiche si possono ripiegare in strutture regolari come l'alfa-elica e foglietto beta**