

Protein structure and function

Amino acids



Structure of amino acids

- Proteins are **diverse in function** but **share common structural feature of being linear polymers of α -amino acids (20 aa in nature)**
← متنوعة
↳ common structure for protein
- Amino acids are **very small biomolecules** with an average molecular weight of about **135 daltons**.
↳ mean amino acid *↳ average molecular weight for amino acid*
- Each **a.a.** has a **carboxyl group**, an **amino group** (**except proline**) and **distinctive side chain** *↳ component for any amino acid* *↳ isn't contain on amino group*
← حالة الطبيعية التي يوجد عليها الحمض الأميني
← سلسلة جانبية مميزة
(متبادل وينفس الوقت في شحنة -,+)
- They exist naturally in a **zwitterion** state where the **carboxylic acid moiety is ionized** and **the basic amino group is protonated**
↳ (-) *↳ when pH=7* *↳ (+)*
- In amino acids, **COOH has a pKa (about 2) lower** than that of **normal carboxylic group (4-5)** due to the **presence of nitrogen which acts as electron withdrawing group** *↳ why?!*
← خاصية الإلكترونات

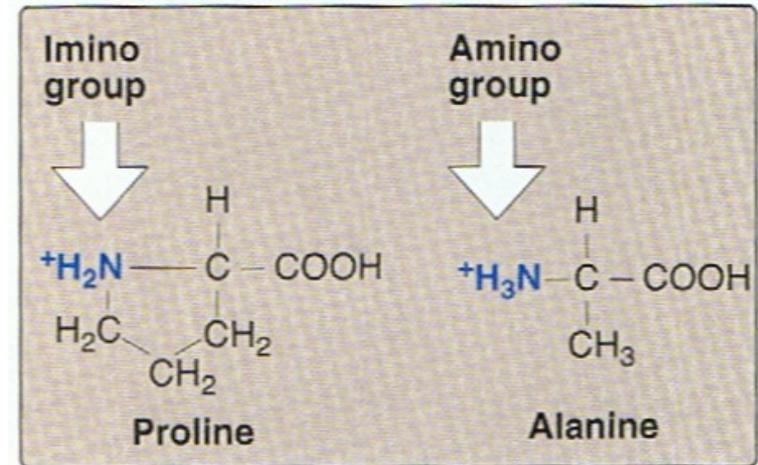
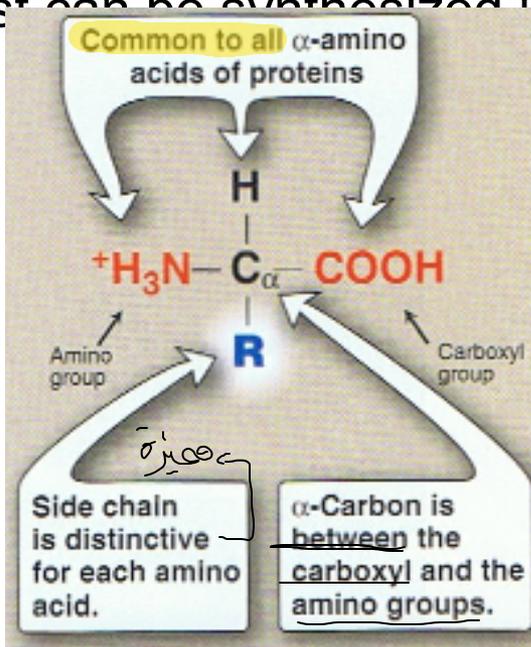
Structure of amino acids

□ They are **classified as α , β , γ , etc.** amino acids **according to the carbon that bears the nitrogen.**

□ Amino acids are divided into: **essential** and **non-essential**

The essential are Ile, Leu, Lys, Met, Phe, Thr, Trp, His and Val. while the rest can be synthesized in our bodies \Rightarrow the number for these amino acid is nine

Handwritten notes in Arabic:
 Ile \rightarrow إيزوليوسين, Leu \rightarrow ليوسين, Lys \rightarrow كليسين, Met \rightarrow ميثيونين
 Phe \rightarrow فينيل الأنيث, Thr \rightarrow ثريونين, Trp \rightarrow تريبتوفان, His \rightarrow هيسستين
 Val \rightarrow فالين
 ← الأساسية ← غير الأساسية



← هيسٽيرين، الاليسين، اثيريونين
is polar

1. Nonpolar amino acids

alanin + glycine + proline is not essential amino acid.

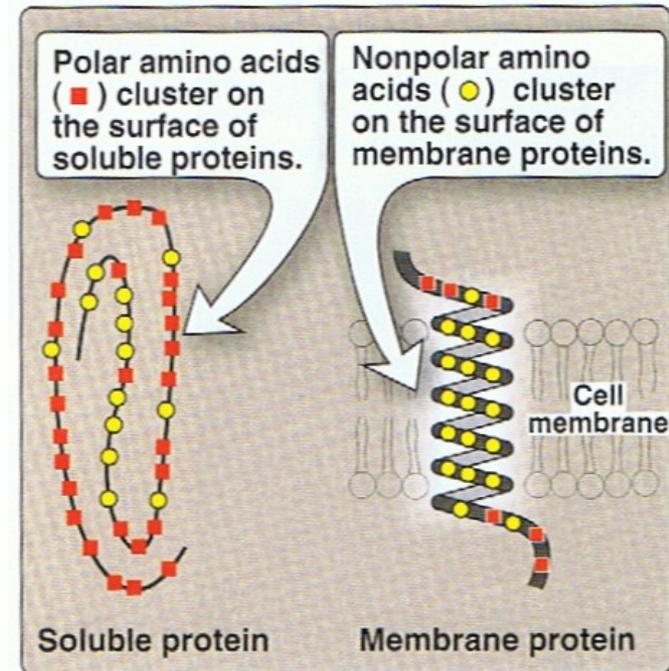
- **Include:** Alanine, Glycine, **Isoleucine**, **Leucine**, **Methionine**, **Phenylalanine**, Proline, **Tryptophan**, **Valine**

← ليس يشارك بالتفاعلات الكارهة للماء

- Nonpolar amino acids **share only in hydrophobic interaction** (**No hydrogen or ionic bonds**) which **stabilize the protein structure**

↳ importance for this share importance for non-polar amino acid?!

- **Determine the three dimensional shape and their location in the cell.**



- **Proline** contains **imino** so it interrupts the α -helices in globular proteins and contributes to the formation of fibrous proteins.

NH-

← يعيق

← القطبي

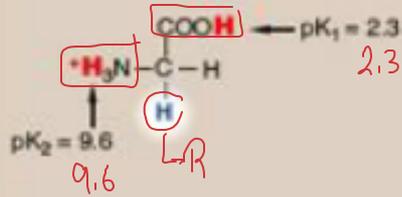
← الحارونات

to the formation of fibrous protein.

Nonpolar amino acids. 1

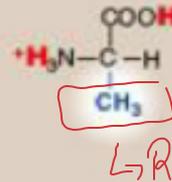
↳ is nine

NONPOLAR SIDE CHAINS

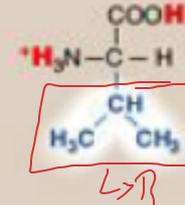


Glycine

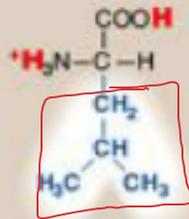
↳ simplest amino acid



Alanine

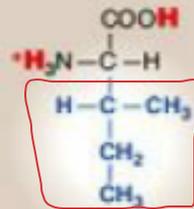


Valine

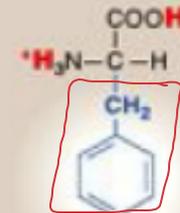


Leucine

↳ نفس العدد
الفرق بالترتيب فقط

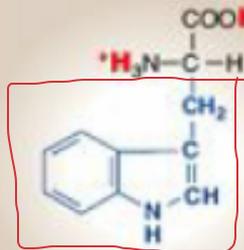


Isoleucine



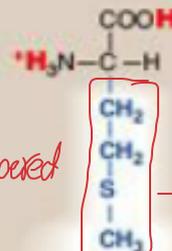
Phenylalanine

benzene



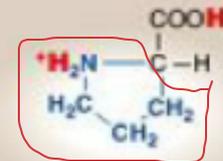
Tryptophan

↳ benzene + five-membered ring + methyl



Methionine

↳ 3 carbon + sulfur



Proline → not contain amino acid → contain imine

Uncharged polar amino acids. 2

↳ is six amino acid and all not essential amino acid except threonine

□ **Include:** Asparagine, Glutamine, Serine, **Threonine**, Tyrosine and Cysteine → two T, two S, one A, one G ↳ only essential amino acid

□ **form hydrogen bond** with other polar aa → polar amino acid

(تفاعلات هيدروجينية)

□ **Present outside of the proteins** that **function in aqueous environment** and in **interior of membrane associated proteins.**

↳ داخل البروتينات المرتبطة بالأغشية

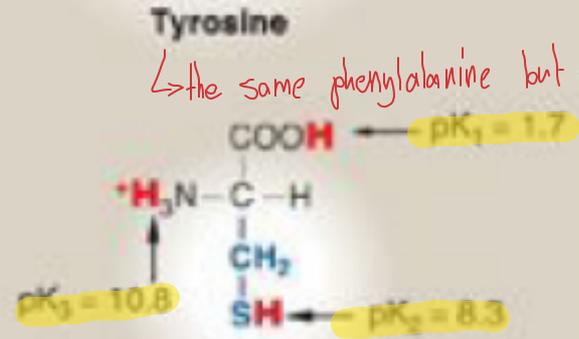
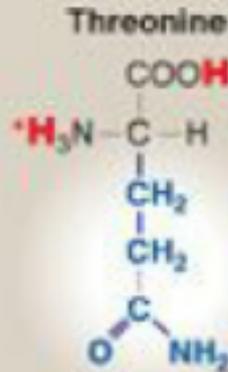
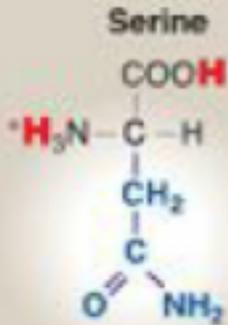
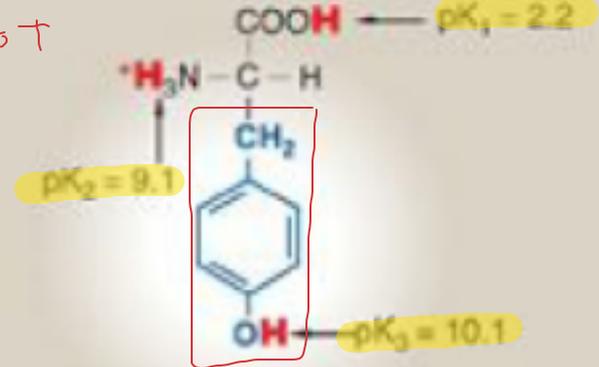
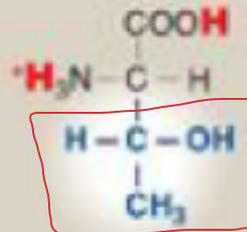
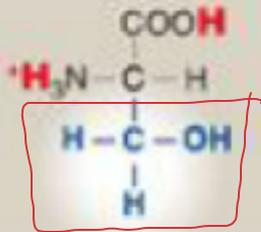
□ Cysteine has sulfhydryl group which can be oxidized to form a **dimer, Cystine (C-S-S-C)** → that help stabilized protein structure

↳ is composed after oxidized sulfur group in Cysteine

Uncharged polar amino acids. 2

UNCHARGED POLAR SIDE CHAINS

the first three amino acid contain (OH-) group \rightarrow S and two T



Asparagine

Glutamine

Cysteine

A and G contain NH_2 group

\rightarrow sulfur group

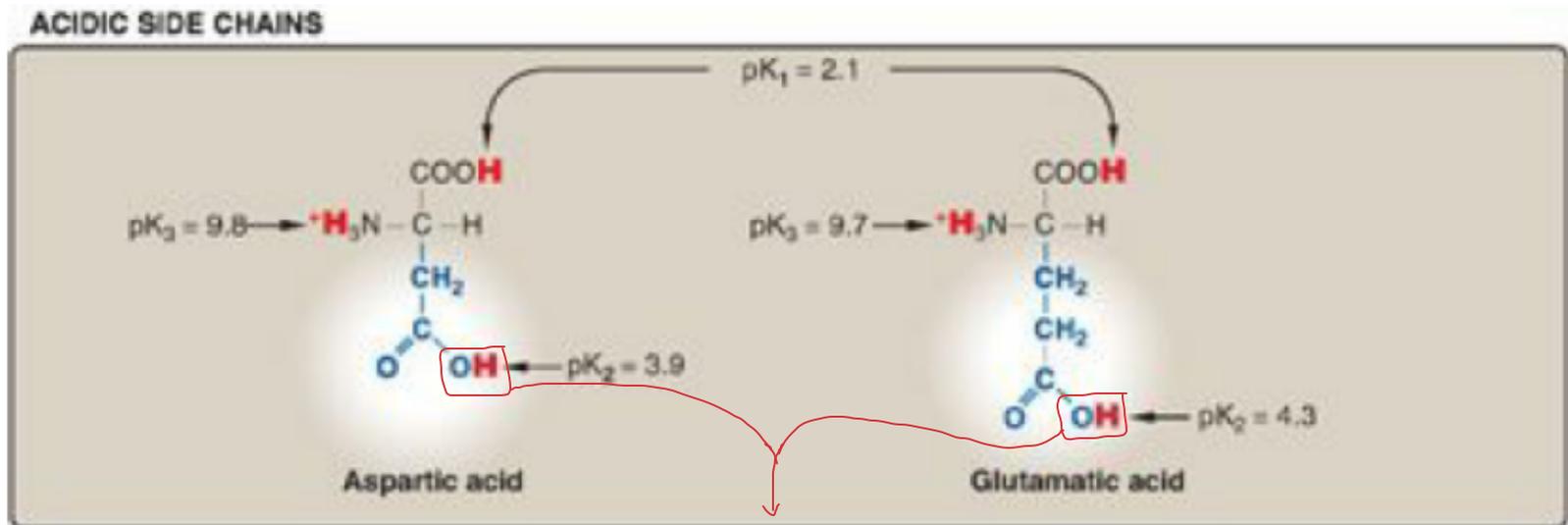
Acidic amino acids. 3

□ **Include:** aspartic acid, Glutamic acid

↳ in above (uncharged polar) Asparagine and glutamine contain (NH₂) group

□ The side chain dissociate to COO⁻ at physiological pH

↳ تتفكك



at the same for asparagine and glutamine but differ replacement (NH₂) group in (OH) group

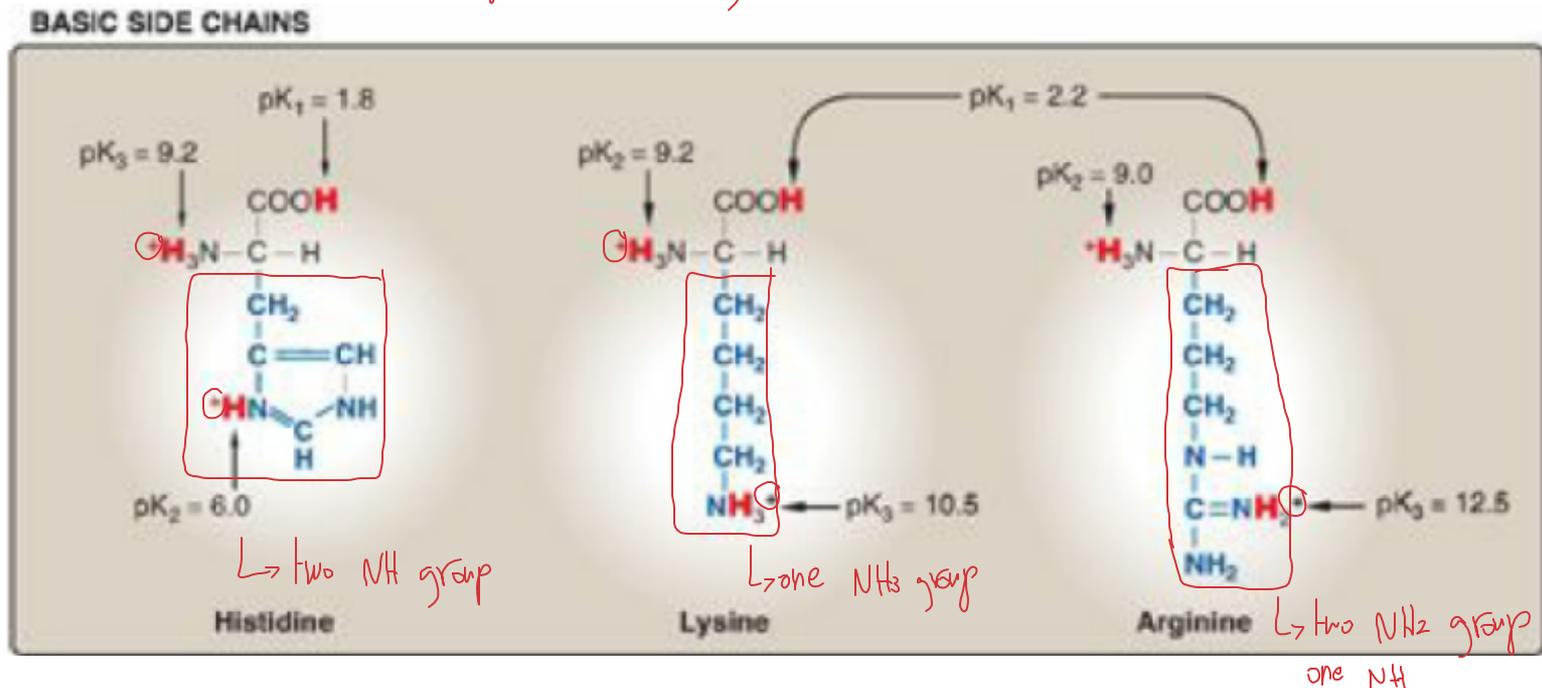
Basic amino acids. 4

↳ HLA → 8p

□ Include **Histidine**, **Lysine** and **Arginine** → they all contain (NH₂) group

↳ these are essential amino acid

□ Side chain is protonated and generally has a positive charge at physiological pH. ↳ positive charge



Abbreviations for the 20 Amino Acids

→ nine are essential
→ eleven are not essential

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

phenylalanine
L-serine
glycine
four A

near from
A
ABCD

(F...)

X X X
W
L

Abbreviations and symbols of amino acids

1 Unique first letter:

Cysteine	=	Cys	=	C
Histidine	=	His	=	H
Isoleucine	=	Ile	=	I
Methionine	=	Met	=	M
Serine	=	Ser	=	S
Valine	=	Val	=	V

2 Most commonly occurring amino acids have priority:

Alanine	=	Ala	=	A
Glycine	=	Gly	=	G
Leucine	=	Leu	=	L
Proline	=	Pro	=	P
Threonine	=	Thr	=	T

3 Similar sounding names:

Arginine	=	Arg	=	R	("aRginine")
Asparagine	=	Asn	=	N	(contains N)
Aspartate	=	Asp	=	D	("asparDic")
Glutamate	=	Glu	=	E	("glutEmate")
Glutamine	=	Gln	=	Q	("Q-tamine")
Phenylalanine	=	Phe	=	F	("Fenylalanine")
Tyrosine	=	Tyr	=	Y	("tYrosine")
Tryptophan	=	Trp	=	W	(double ring in the molecule)

4 Letter close to initial letter:

Aspartate or asparagine	=	Asx	=	B	(near A)
Glutamate or glutamine	=	Glx	=	Z	
Lysine	=	Lys	=	K	(near L)
Undetermined amino acid	=		=	X	



A GUIDE TO THE TWENTY COMMON AMINO ACIDS

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

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

Chemical Structure
single letter code

NAME **A**
three letter code
DNA codons

ALANINE **A**
Ala
GCT, GCC, GCA, GCG

GLYCINE **G**
Gly
GGT, GGC, GGA, GGG

ISOLEUCINE **I**
Ile
ATT, ATC, ATA

LEUCINE **L**
Leu
CTT, CTC, CTA, CTG, TTA, TTG

PROLINE **P**
Pro
CCT, CCC, CCA, CCG

VALINE **V**
Val
GTT, GTC, GTA, GTG

PHENYLALANINE **F**
Phe
TTT, TTC

TRYPTOPHAN **W**
Trp
TGG

TYROSINE **Y**
Tyr
TAT, TAC

ASPARTIC ACID **D**
Asp
GAT, GAC

GLUTAMIC ACID **E**
Glu
GAA, GAG

ARGININE **R**
Arg
CGT, CGC, CGA, CGG, AGA, AGG

HISTIDINE **H**
His
CAT, CAC

LYSINE **K**
Lys
AAA, AAG

SERINE **S**
Ser
TCT, TCC, TCA, TCG, AGT, ACC

THREONINE **T**
Thr
ACT, ACC, ACA, ACC

CYSTEINE **C**
Cys
TGT, TGC

METHIONINE **M**
Met
ATG

ASPARAGINE **N**
Asn
AAT, AAC

GLUTAMINE **Q**
Gln
CAA, CAG

YouTube

You can use YouTube to help you memorize AA-whatever video suits you



easy way to memorize amino acids

The video displays four handwritten chemical structures of amino acids:

- Leucine:** $\begin{array}{c} \text{CH}_2 \\ | \\ \text{CH} - \text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$
- Threonine:** $\begin{array}{c} \text{H}_3\text{N}^+ - \text{CH} - \text{COO}^- \\ | \\ \text{CH} - \text{CH}_3 \\ | \\ \text{OH} \end{array}$
- Cysteine:** $\begin{array}{c} \text{H}_3\text{N}^+ - \text{CH} - \text{COO}^- \\ | \\ \text{CH}_2 \\ | \\ \text{SH} \end{array}$
- Methionine:** $\begin{array}{c} \text{H}_3\text{N}^+ - \text{CH} - \text{COO}^- \\ | \\ \text{CH}_2 \\ | \\ \text{CH}_2 \\ | \\ \text{S} - \text{CH}_3 \end{array}$

Trick to draw & memorize 20 Amino acid structures from Biomolecules class 12 chemistry by Komali mam

11,117 views • 11 Oct 2020

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Optical properties of amino acids

(الخواص البصرية للأحماض الأمينية)

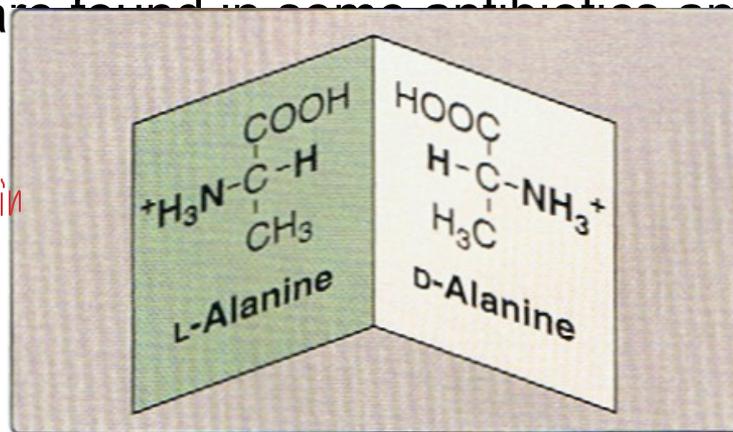
□ With the exception of glycine, the α -carbon of all aa's is optically active (chiral) → كيرالية (غير متناظرة)

□ a.a. Exist in two forms, L and D, which are mirror images → صورتان متطابقتان مرآتياً

□ All amino acids found in proteins are of the L-configuration → له التكوين (L)

□ D- amino acids are found in some antibiotics and in bacterial cell walls

→ found in some antibiotic and in bacterial cell wall.



Optical properties of amino acids

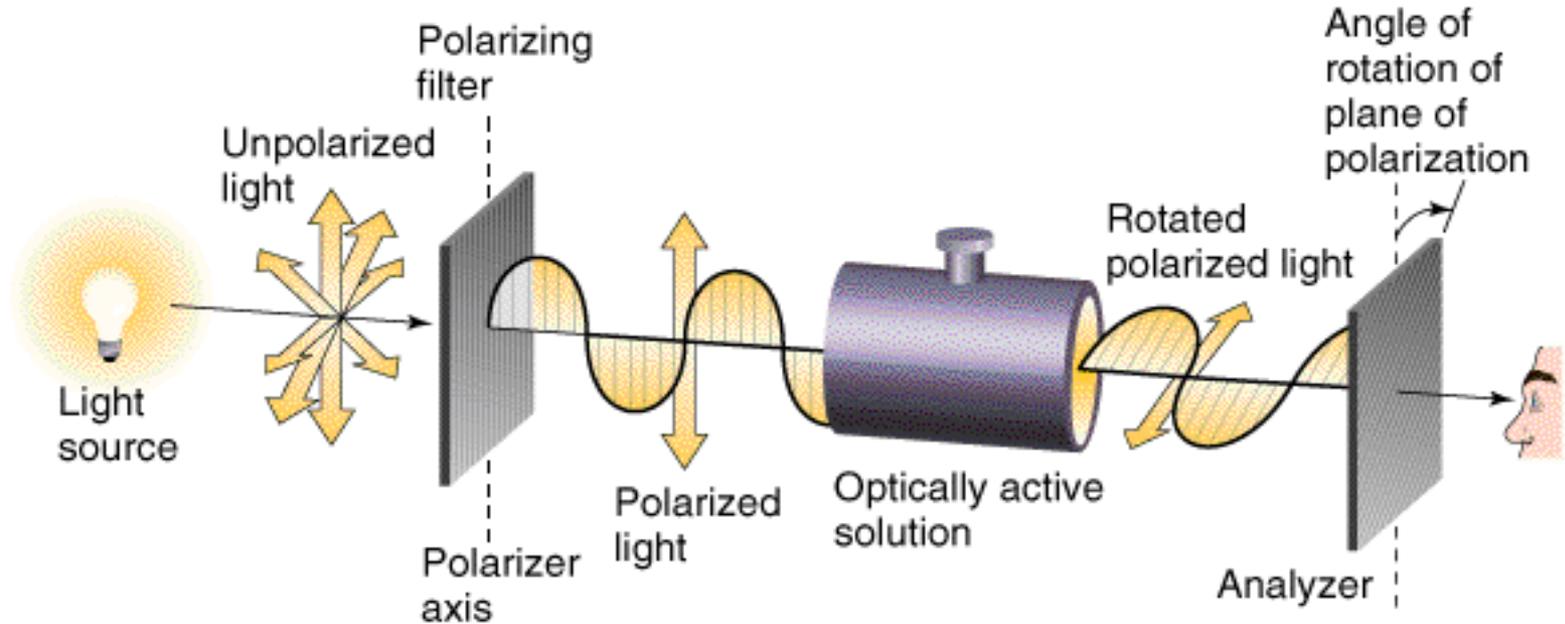
التوضيح:

توضح الصورة كيف تؤثر الأحماض الأمينية على الضوء المستقطب نتيجة لخواصها البصرية. تتبع العملية الخطوات التالية:

1. مصدر الضوء: يصدر ضوء غير مستقطب، أي أن موجاته تنتشر في جميع الاتجاهات.
2. مرشح الاستقطاب (Polarizing filter): يقوم بترشيح الضوء بحيث يسمح فقط للموجات المهتزة في اتجاه معين بالمرور، مكوناً ضوءاً مستقطباً خطياً.
3. المحلول الفعال بصرياً (Optically active solution): يحتوي على الأحماض الأمينية القادرة على تدوير مستوى استقطاب الضوء.
4. دوران الضوء المستقطب: عند مرور الضوء المستقطب عبر المحلول، يتم تدوير مستوى استقطابه بزاوية معينة نتيجة للتفاعل مع الجزيئات الفعالة بصرياً.
5. المحلل (Analyzer): يتم استخدامه لقياس مقدار التغير في مستوى استقطاب الضوء بعد مروره في المحلول.

التطبيق العملي

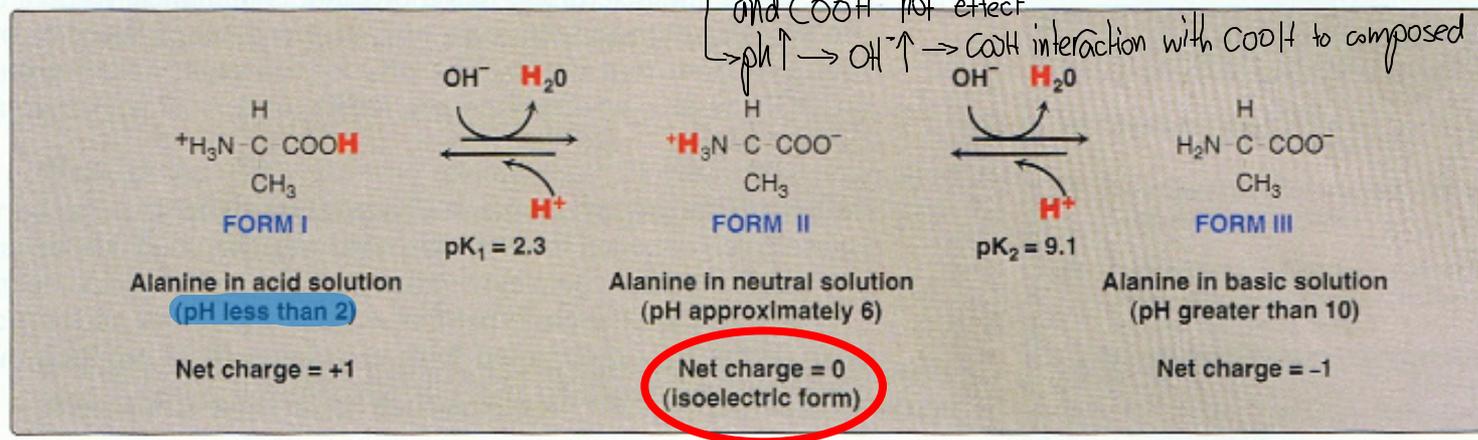
يتم استخدام هذه الخاصية في الكيمياء التحليلية لتمييز المركبات المتشابهة بصرياً (المتصاوغات الضوئية) ومعرفة تركيبها، حيث تدور بعض الأحماض الأمينية مستوى استقطاب الضوء إلى اليمين (+) والبعض الآخر إلى اليسار (-).



Acidic and basic properties of amino acids

الحضائص الحمضية والقاعدية الأحماس الأيونية

□ Amino acids can act as buffers



Handwritten notes explaining the buffer regions:

- $pH \downarrow \rightarrow H^+ \uparrow \rightarrow NH_2$ interaction with H^+ to composed NH_3^+ and $COOH$ not effect.
- $pH \uparrow \rightarrow OH^- \uparrow \rightarrow COOH$ interaction with $COOH$ to composed $COO^- \rightarrow NH_2$ not effect.

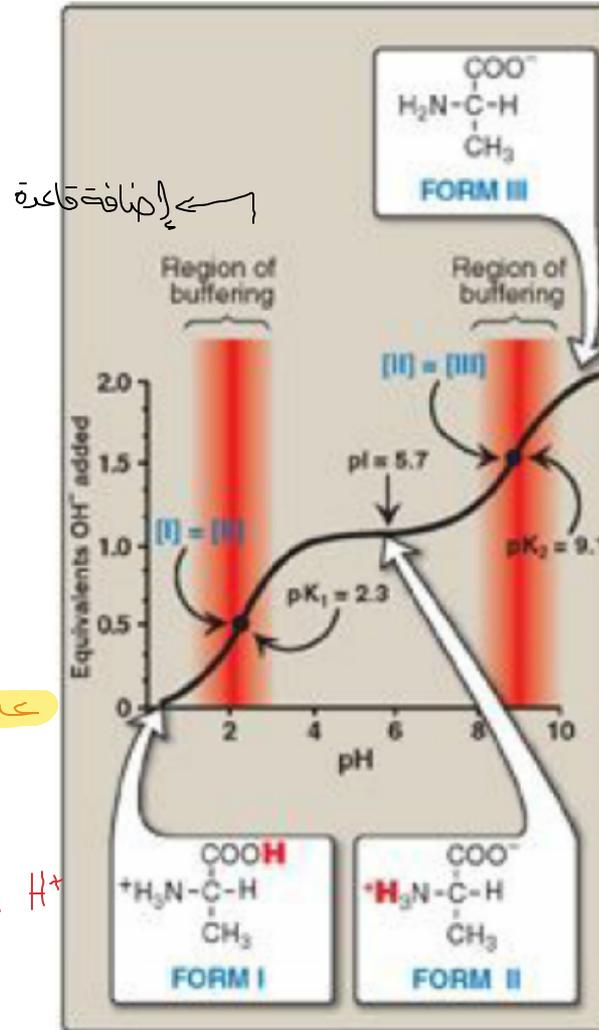
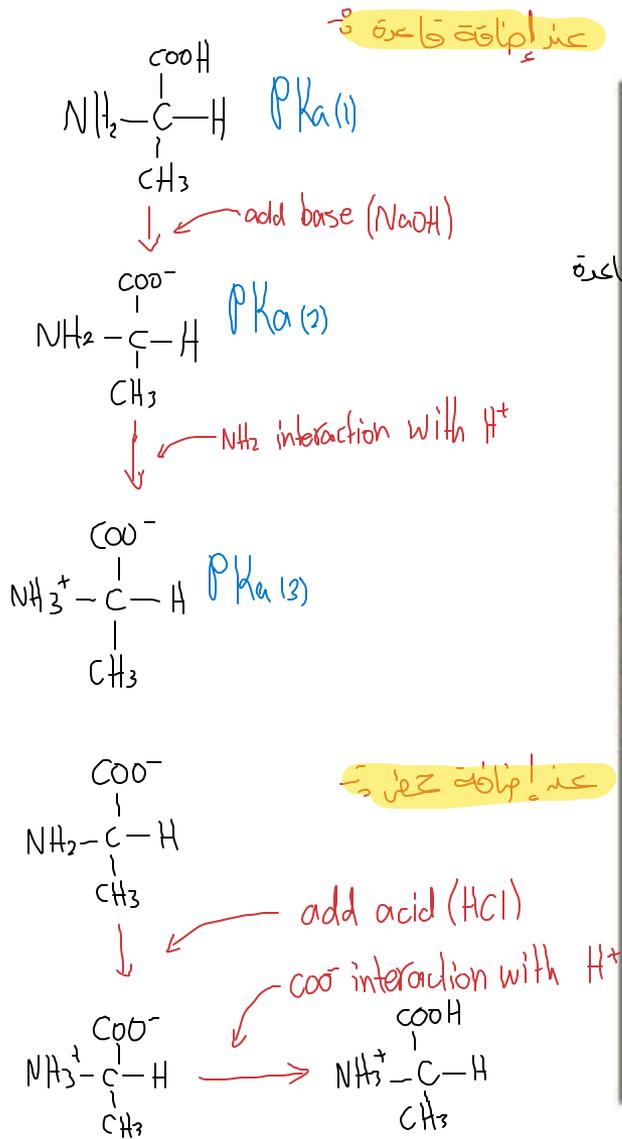
□ The quantitative relationship is described by Henderson-Hasselbalch equation:

$$pH = pK_1 + \log \frac{[II]}{[I]}$$

توضح العلاقة الكمية بين pH, pKa والنسبة بين الشكل الحمضي والقاعدي

10 : 1
basic (COO⁻, NH₂) : acid (COOH, NH₃⁺)

Titration curve for alanine



Isoelectric point (pI)

النقطة المتعادلة كهربائياً

- At Its Isoelectric pH (pI), an **Amino Acid Bears No Net Charge**
يكون حافى شحنة يعني عدد الشحنات الموجبة يساوي عدد الشحنات السالبة

- The isoelectric pH is calculated as the pH midway between pKa values on either side of the isoelectric species.
→ average
→ average between pKa(NH₃⁺) and pKa(COOH)

- Example:** alanine has only two dissociating groups, pKa (R-COOH) is 2.35 and pKa (R-NH₃⁺) is 9.69. The isoelectric pH (pI) of alanine is

$$pI = (pKa_1 + pKa_2)/2 = 6.02 = \frac{2.35 + 9.69}{2} = \frac{12.04}{2} = 6.02$$

- For polyfunctional acids, pI is also the pH midway between the pKa values on either side of the isoionic species. For example, the pI for aspartic acid is

$$pI = (pKa_1 + pKa_2)/2 \\ (2.09 + 3.96)/2 = 3.02$$

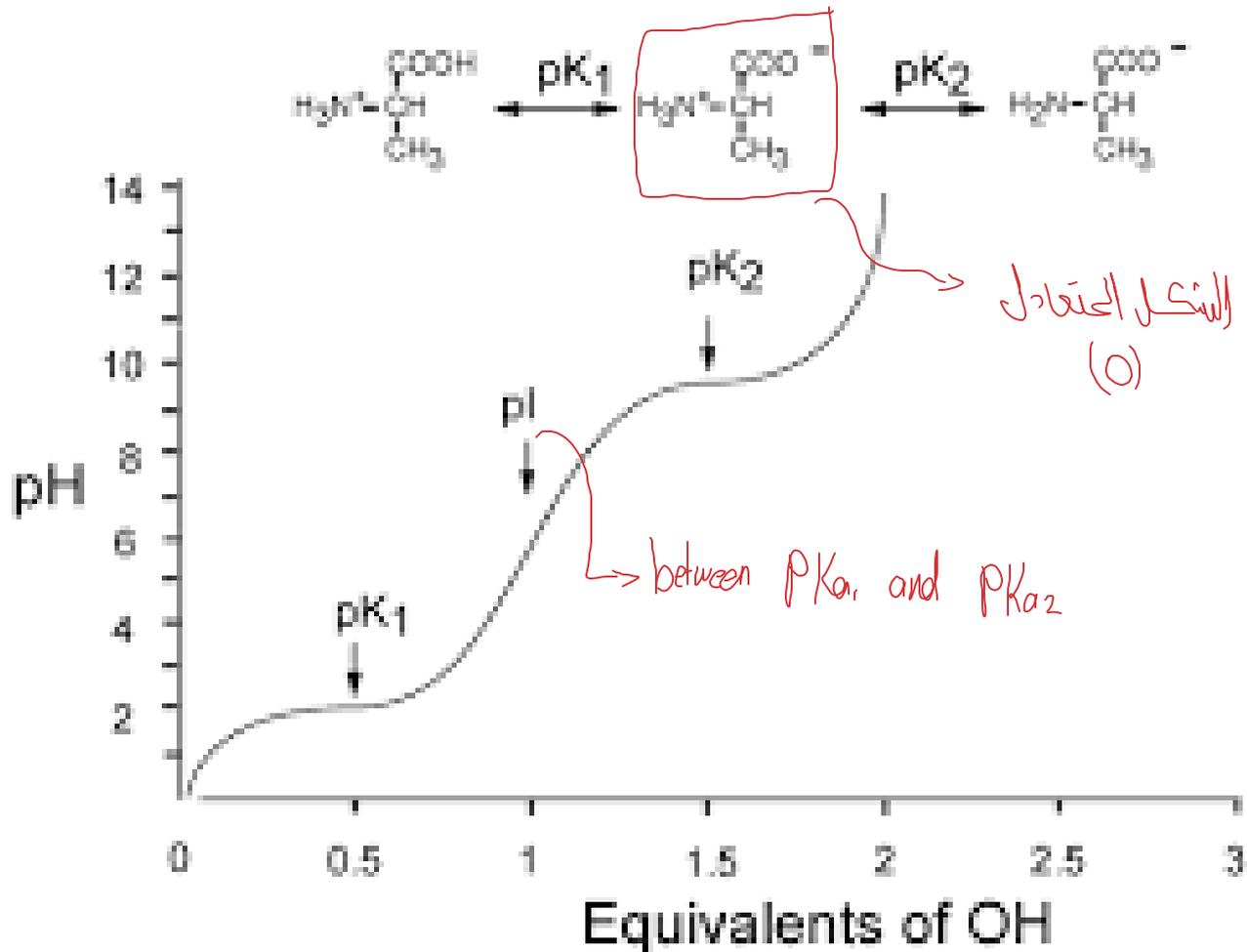
three pKa: pKa(COOH)₁ = 2.09, pKa(COOH)₂ = 3.96

pKa(NH₃⁺) = 9.82 × →

لأن عند pKa₃ يبدأ NH₃⁺ بالتحول إلى NH₂ يعني يعتبر المركب إلى شحنة سالبة يعني مثل متعادل

والاستجابة بالـ

Diprotic amino acids



Tripotric amino acid-titration curve

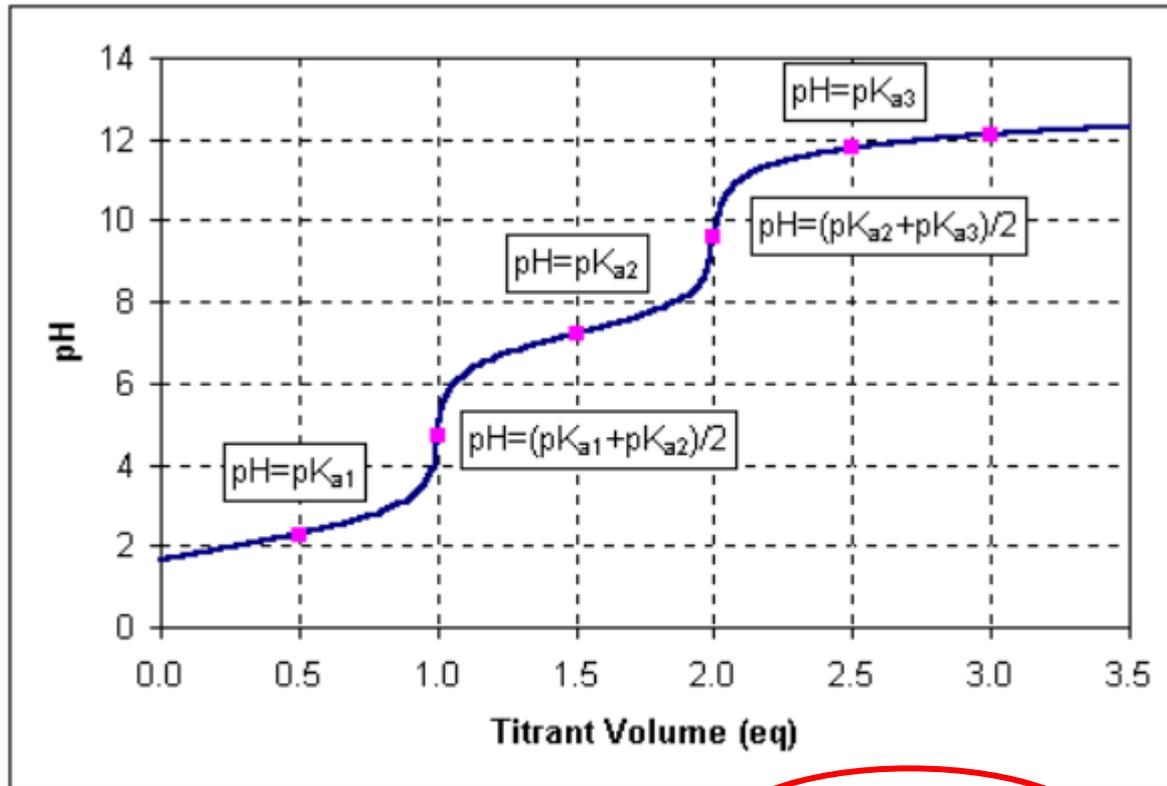
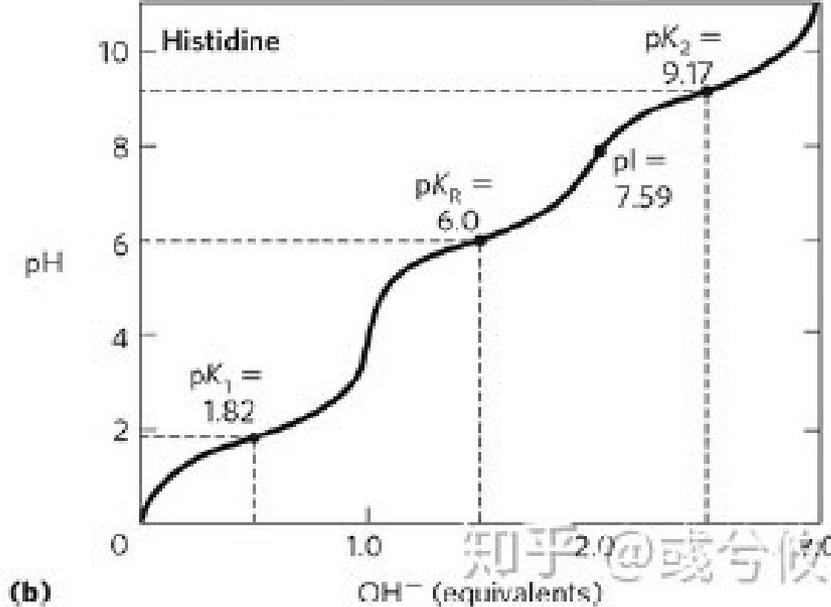
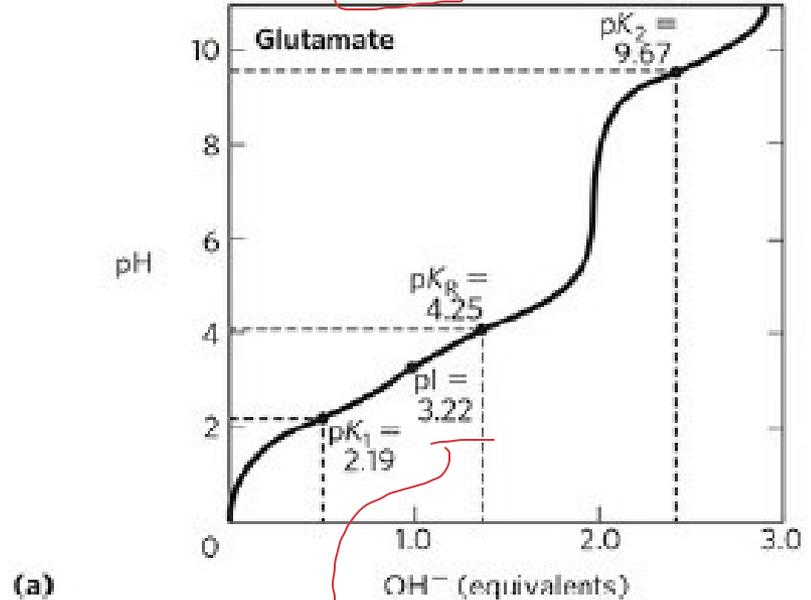
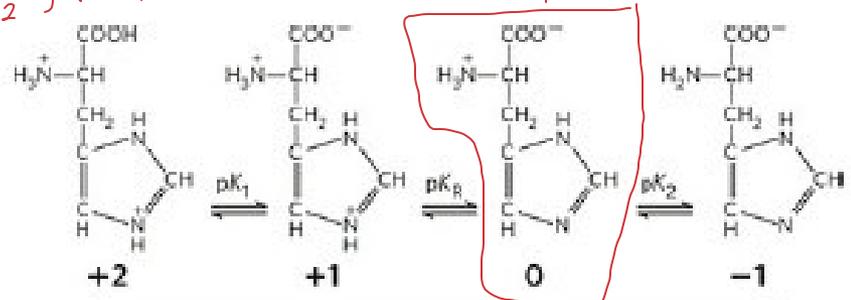
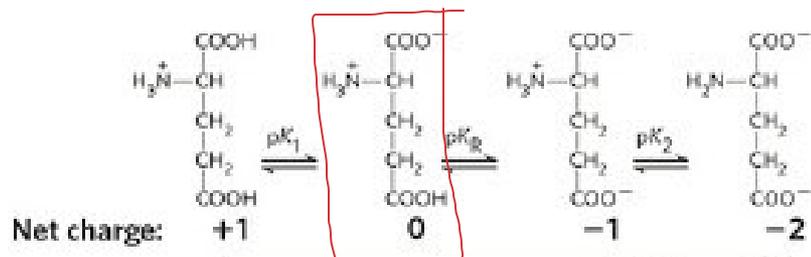


Figure 1.2. Titration curve for a triprotic amino acid

Triprotic amino acid-titration curve

السائل المتبادل بين pK_{a1} و pK_{a2} ←

السائل المتبادل بين pK_{a2} و pK_{aR} ←



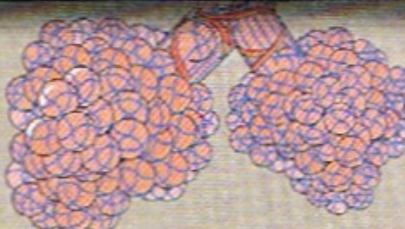
$$\frac{2.19 + 4.25}{2} = \frac{6.44}{2} = 3.22$$

Application on buffer effect

تطبيق على تأثير العازل

A BICARBONATE AS A BUFFER

- $\text{pH} = \text{pK} + \log \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$
- An increase in bicarbonate ion causes the pH to rise. (pH ↑) ← السداد الزيادة
- Pulmonary obstruction causes an increase in carbon dioxide and causes the pH to fall. (pH ↓)



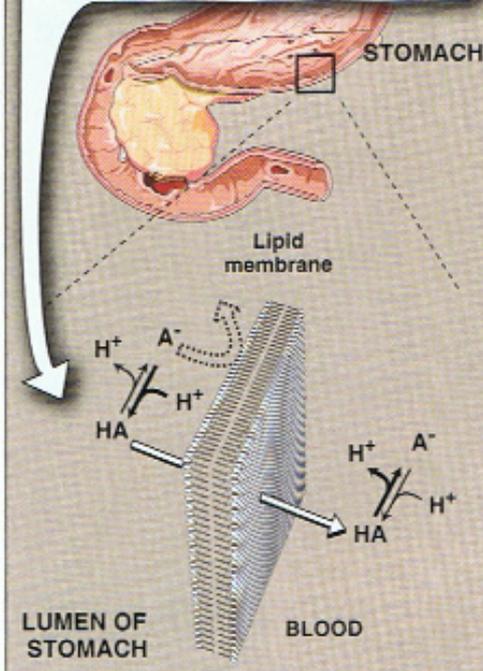
LUNG ALVEOLI

$$\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$$

B DRUG ABSORPTION

افتصاص الدواء

- $\text{pH} = \text{pK} + \log \frac{[\text{Drug}^-]}{[\text{Drug-H}]}$
- At the pH of the stomach (1.5), a drug like aspirin (weak acid, pK = 3.5) will be largely protonated (COOH) and, thus, uncharged.
- Uncharged drugs generally cross membranes more rapidly than charged molecules.



STOMACH

Lipid membrane

LUMEN OF STOMACH

BLOOD

Biological importance of proteins

1. Proteins are essential component of membranes.
2. Plasma membrane proteins regulate the transfer of various substances across the cell membrane or act as receptors.
3. All enzymes are protein in nature.
4. All antibodies (immunoglobulins) are protein in nature, play an important role in the bodies' defensive mechanisms.
5. Some hormones are proteins in nature e.g. insulin, glucagon, and growth hormone.
6. Hemoglobin carries oxygen in the blood and myoglobin stores O_2 in muscles. Both are proteins in nature.

Biological importance of proteins

7. Some proteins are protective e.g. keratins make the skin resistant to chemicals. Others have supportive functions e.g. collagen and elastin.
8. Amino acids are converted to other substances of great physiologic importance e.g. creatine, heme, histamine, serotonin, purines and pyrimidines. $\rightarrow 2h, 2p, 1s, 1k$
9. Actin and myosin are contractile proteins found in muscle cells and are responsible for muscular contraction.
10. Plasma proteins can carry: lipids forming lipoprotein complexes; hormones (e.g. thyroid and steroid hormones) and minerals (e.g. calcium and copper).

Structure of proteins

□ The are four levels of protein structures:

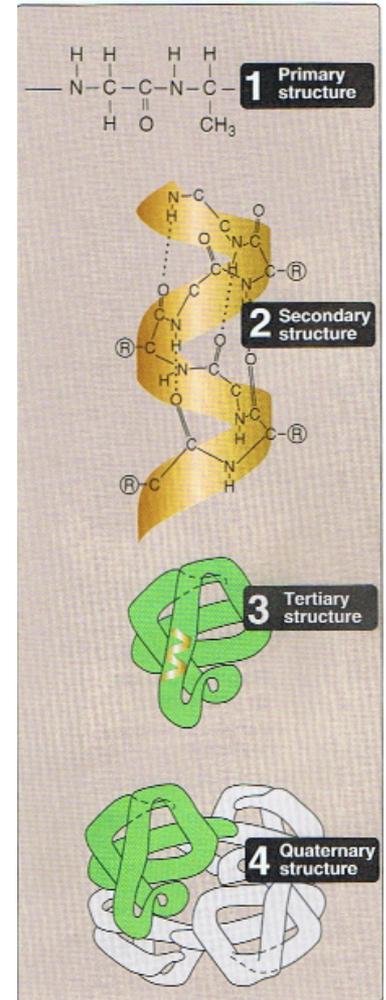
1. **Primary structure**: the **amino acid sequence** of proteins.
2. **Secondary structure**: **α -helices** and **β -sheets**.
3. **Tertiary structure**: the **three dimensional structure** of protein
4. **Quaternary structure**: **arrangement of polypeptide subunits**

الوحدات الفرعية للبروتين
↓
↓

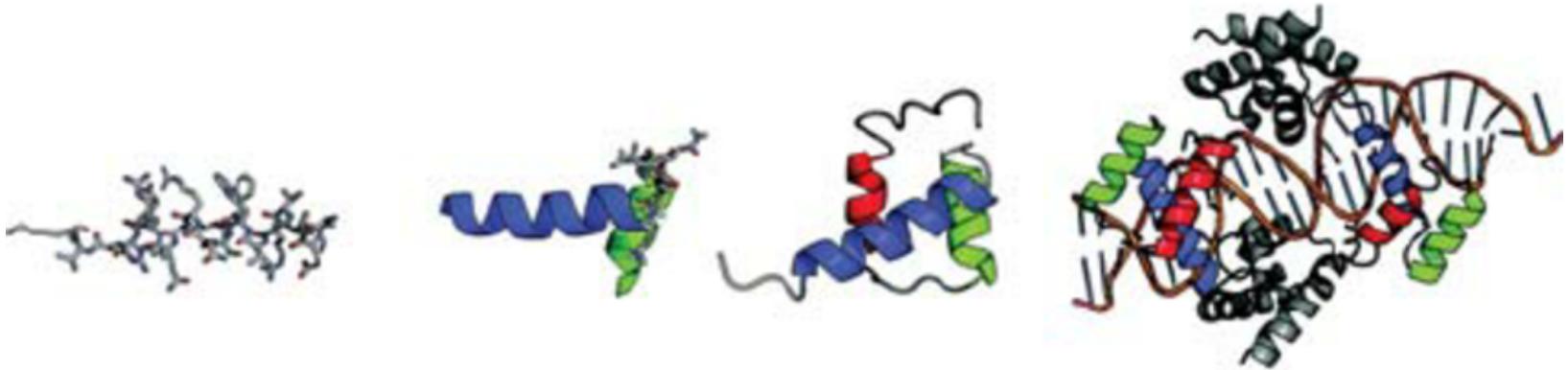
□ The folding of the protein ranges from simple combinations of α -helices and β -sheets forming small motifs to the complex folding of polypeptide domains of multifunctional proteins.

تركيبات
←
← أشكال مختلفة

سلسلة
←



Motifs and Domains



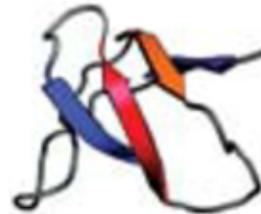
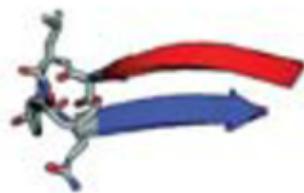
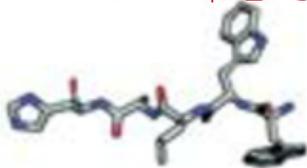
Secondary structure

Motif

Domain

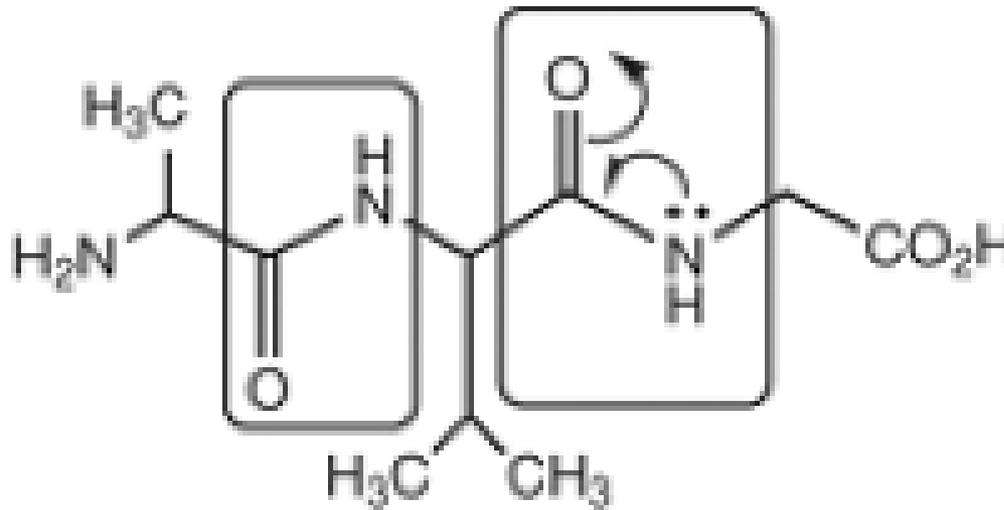
Quaternary/tertiary structure

١- مستقل هيكلياً وظيفياً
 وقد يتكون من عدة (motifs).
 ٢- تركيب محدد من الين الثانوية يتكرر في
 العديد من البروتينات (ليس تركيب مستقل)



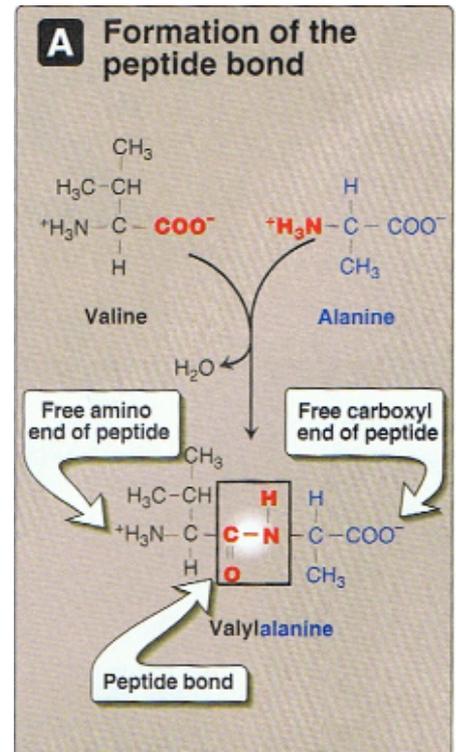
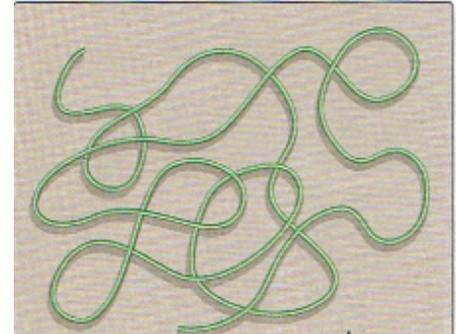
Classification of proteins

- **Oligopeptides:** Peptides with fewer than 15 residues e.g., gonadotropin-releasing hormone [GnRH] contains 10 residues
- **Polypeptides:** Peptides consisting of 15 to 50 residues e.g., adrenocorticotropin hormone consists of 39 residues.
- **Protein:** polypeptide that contains more than 50 amino acid residues e.g., parathyroid hormone contains 84 residues



Primary structure. 1

- The amino acid sequence of proteins
 تسلسل الأحماض الأمينية في البروتينات
 ← ظل/عيب
- Genetic diseases occurs due to defect in the amino acid sequence leading to improper folding and impairment of function.
 ← في خاطئ
 ← ظل
- In proteins, amino acids are joined covalently by peptide bonds, which are amide linkages between the α-carboxyl group of one amino acid, and the α-amino group of another.
- The peptide bond of the protein can be hydrolyzed by prolonged exposure to acid or base at high temperature or enzymatically.
 ← التحلل الإنزيمي
 ← التحلل عن طريق الحرارة العالية
 ← التحلل عن طريق الحمض/القاعدة

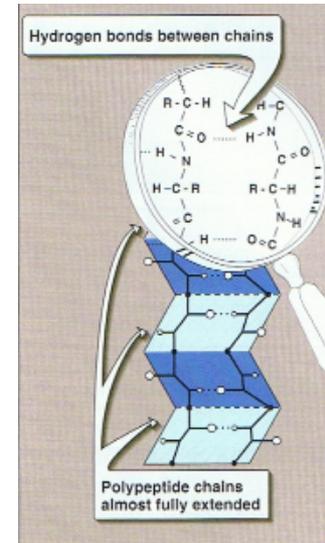
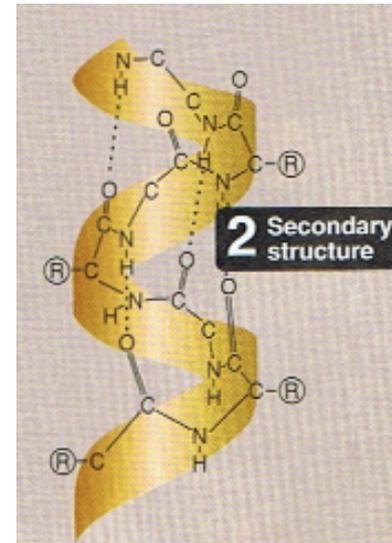


2. Secondary structure

□ The secondary structure of protein is **stabilized by hydrogen bonding**

□ **Folding of the protein to:**

1. **α -helix:**

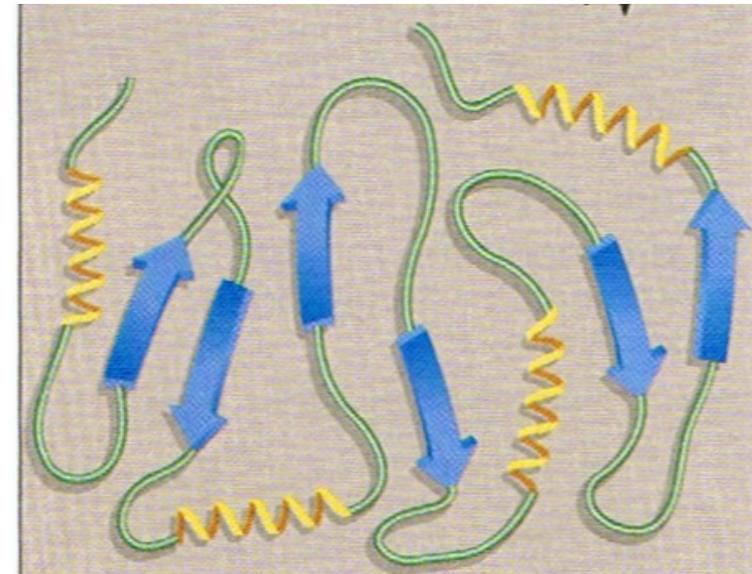


2. **β -pleated sheats:** can be parallel or antiparallel

للموازية

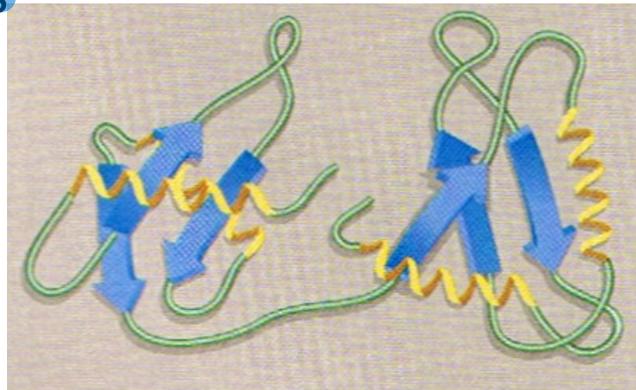
للمعاكسة للاتجاه
المنحنيات

3. **β -turns:** usually at the surface of the protein, **contains usually proline** which causes a kink the structure in addition to glycine.



3. Tertiary structure

- The tertiary structure is the **three dimensional structure of proteins (folding of the domains)** *→ in slide 26*
- **The protein tends to fold correctly with a low energy state.** *(more stable state)*
- **Interactions stabilizing the tertiary structure:** *(الروابط التي تثبت التركيب الثلاثي)*
 1. **Disulfide bond:** in presence of Cysteine which forms a covalent bond (-S-S-)
 2. **Hydrophobic interactions** *تفاعلات كارهة للماء*
 3. **Hydrogen bonding**
 4. **Ionic interactions**



Quaternary structure. 4

← يتكون من وحدة فرعية واحدة

- The polypeptide can be one domain (monomer), dimer, trimer depends on the number of subunits.

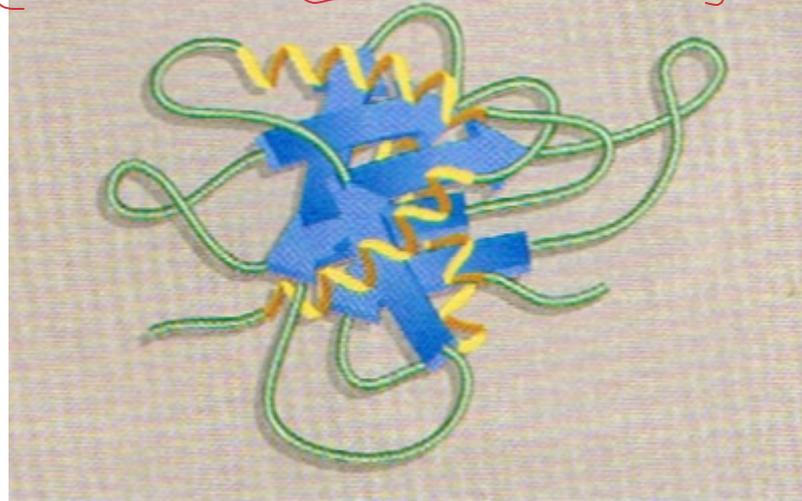
← يتكون من وحدتين فرعيتين

← الوحدات الفرعية

← يتكون من ثلاث وحدات فرعية

- A specialized group of proteins (called chaperones) are required for the proper folding of the protein.

← بروتينات تساعد في الطي الصحيح للبروتينات أثناء التصنيع داخل الخلية



Denaturation of the proteins

لـ تحلل البروتينات

لـ فتح البروتينات

□ **Unfolding of protein: occurs due to different factors:**

□ **Urea** → يعمل على إضعاف الروابط الهيدروجينية ويؤدي إلى فقد الشكل

□ **Extreme pH and temperature** → يؤثر على الروابط الأيونية

□ **Organic solvents** → تدمير الروابط الظاهرة للماء

□ Leads to loss of secondary and tertiary structure and hence, loss of function.

وبالتالي

بعد إعادة الضم

□ Most of proteins can't refold upon removal of the denaturant (**irreversible denaturation**)

لـ يحدث بشكل خاص عند تدمير الروابط التساهمية
لـ العامل المسبب للتحلل

Diseases related to denaturation of proteins

← الأمراض المرتبطة بتغيير بنية البروتينات

□ Alzheimer disease:

Normal proteins, after abnormal chemical processing, take on a unique conformational state that leads to the formation of neurotoxic amyloid protein assemblies consisting of β -pleated sheets.

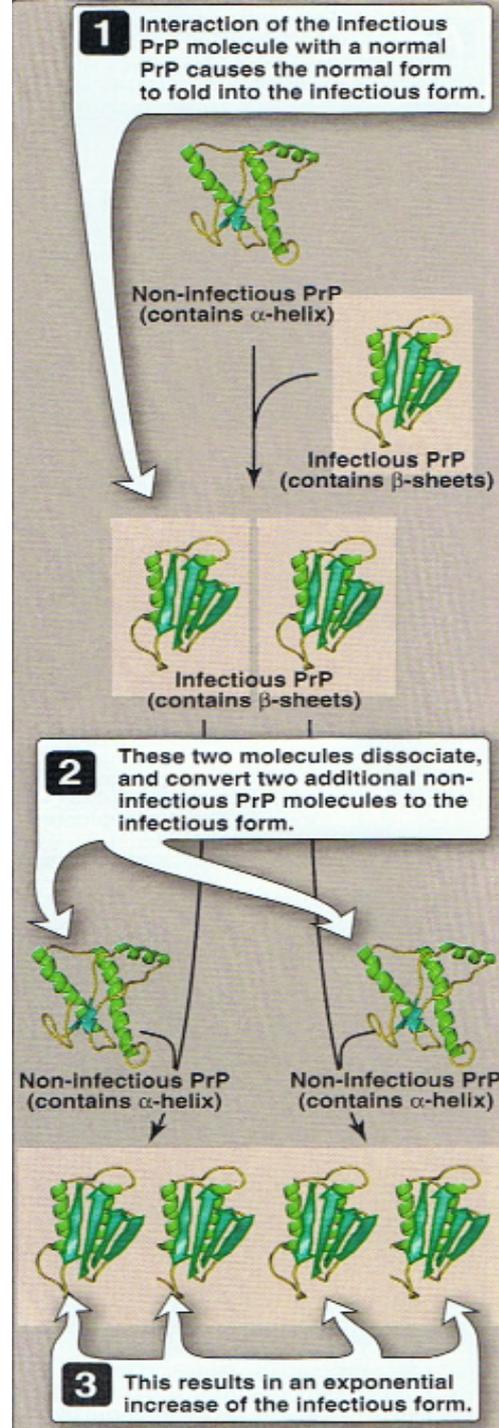
← في عنا أجليود بروتين في الدماغ يصير فيه خلل ← تغيير شكل هذا البروتين (يشكل تجمعات تكون من ليهجات β -pleated تسمح ساعة الخلايا العصبية نسب موت هذه الخلايا) هذا ليسب فقدان الذاكرة واختلال الأداء العقلي.

□ In Transmissible Spongiform Encephalopathy 5

(Mad cow disease): التهاب الدماغ الاسفنجي القابل للانتقال (عرفن جنون البقر)

The infective agent is an altered version of a normal prion protein that acts as a "template" for converting normal protein to the pathogenic conformation.

← يتعرفن بروتين البريون إلى تغيير يصير غير طبيعي ← تحويل البروتينات الطبيعية إلى بروتينات غير طبيعية تؤدي إلى تدمير الخلايا العصبية



Biosynthesis of protein

التركيب الجيني للبروتين

مشفرة

- The information that tells a cell how to build the proteins it needs to survive is coded in the structure of the DNA in the nucleus of that cell. (البقاء على قيد الحياة) →

number for codon = $4^3 = 64$ codon

- Because there are only four nucleotides and there are 20 amino acids that must be coded. the nucleotides are grouped in threes, however, there are 64 possible triplets, or codons

لإحداث الكودون عبارة عن ثلاث نيوكليوتيدات.

- DNA only stores the genetic information, while RNA is responsible of its translation to protein

- ① أدينين A
- ② جوانين G
- ③ سيتوزين C
- ④ ثايمين T

ملاحظة:

عند نسخ RNA تكون:

$A \Rightarrow U$, $T \rightarrow A$

$C \Rightarrow G$

- ① أدينين A
- ② جوانين G
- ③ سيتوزين C
- ④ يوراسيل بدلاً من ثايمين U

Biosynthesis of protein

النسخ ← **Transcription. 1**

- Before the information in DNA can be decoded, a small portion of the DNA double helix must be uncoiled.
- A strand of RNA is then synthesized that is a complementary copy of one strand of the DNA **using RNA polymerase**.
- RNA uses U where T would be found in DNA and base pairing occurs between two chains that run in *opposite directions*. The RNA complement of this DNA should therefore be written as follows.

□ 3' T-A-C-A-A-G-C-A-G-T-T-G-G-T-C-G-T-G... 5' DNA

5' A-U-G-U-U-C-G-U-C-A-A-C-C-A-G-C-A-C 3'

□ 5' A-U-G-U-U-C-G-U-C-A-A-C-C-A-G-C-A-C... 3' mRNA

- Since this RNA strand contains the message that was coded in the DNA, **it is called messenger RNA, or mRNA**.

From slid 35: 3' U-A-C-A-A-G-C-A-G-U-U-G-G-U-C-G-U-G 5'

Biosynthesis of protein

← الترجمة Translation. 2

- The messenger RNA now binds to a ribosome, where the message is translated into a sequence of amino acids.
- The amino acids that are incorporated into the protein being synthesized are carried by relatively small RNA molecules known as transfer RNA, or tRNA.
- There are at least 60 tRNAs, which differ slightly in their structures, in each cell. At one end of each tRNA is a specific sequence of three nucleotides that can bind to the messenger RNA. At the other end is a specific amino acid.
- each three-nucleotide segment of the messenger RNA molecule codes for the incorporation of a particular amino acid.

← تصغيرها

تصغيرها

← تسلسل خاص

← لترسفر

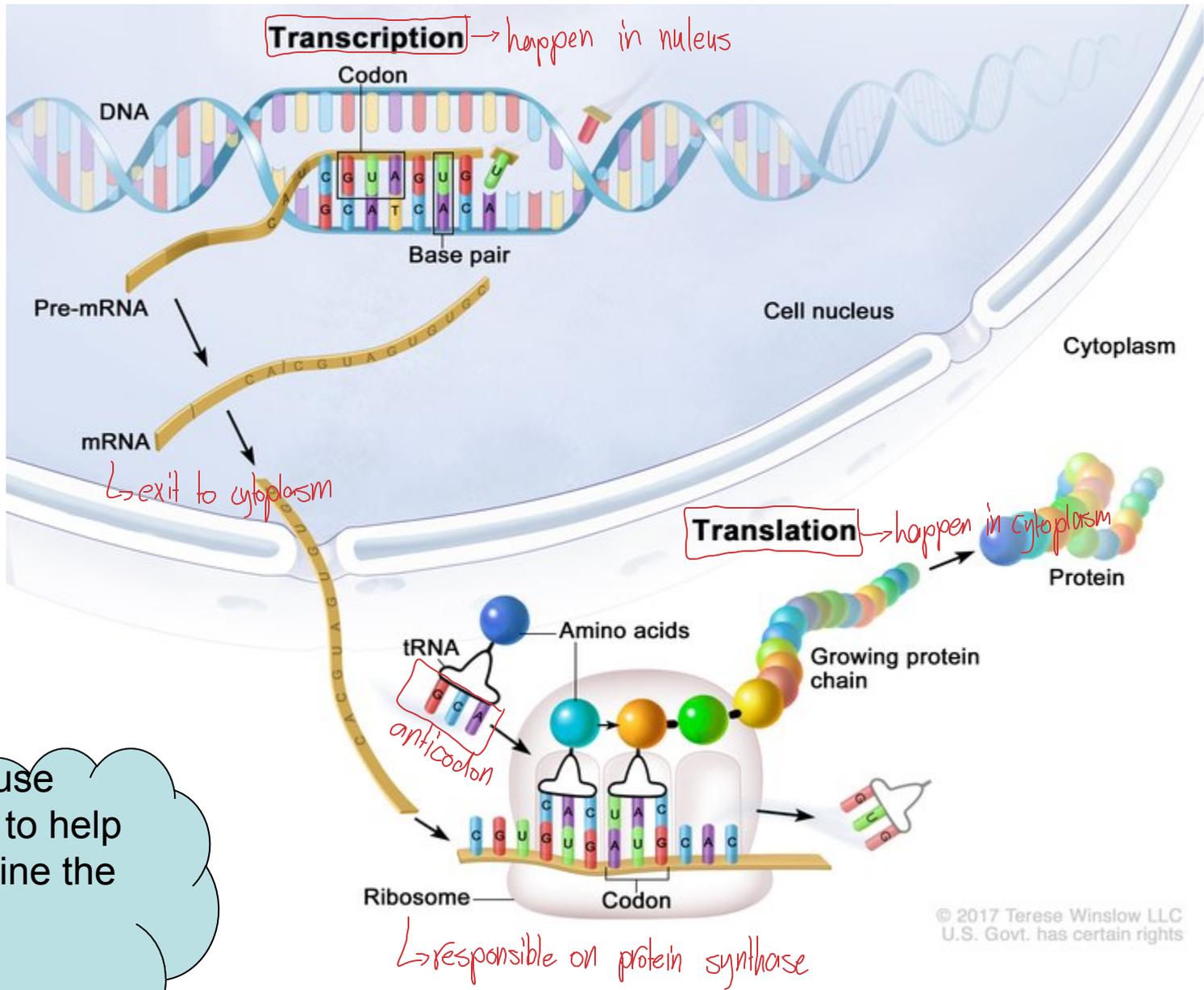
← مضمون الكلام كل ثلاث نيوكليو تيدات
 لترسفر كودون وكل كودون يمثل حمض اأيني
 (ممكن أن يكون لكل حمض اأيني أكثر من كودون)

Codons

		Second letter				
		U	C	A	G	
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G
	A	AUU } AUC } Ile AUA } AUG Met	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G

ثلاث كودونات وقف

كودون البدء



You can use YouTube to help you imagine the process

Biosynthesis of protein



Translation. 2

- The signal to start making a polypeptide chain in simple, prokaryotic cells is the triplet **AUG**, which codes for the amino acid **methionine (Met)**. The synthesis of every protein in these cells therefore starts with a Met residue at the N-terminal end of the polypeptide chain. After the tRNA that carries Met binds to the start signal on the messenger RNA, a tRNA carrying the second amino acid binds to the next codon. A **dipeptide** is synthesized when the Met residue is transferred from the first tRNA to the amino acid on the second tRNA.
- The mRNA now moves through the ribosome, and a tRNA carrying the third amino acid (Val) binds to the next codon. The dipeptide is then transferred to the amino acid on this third tRNA to form a **tripeptide**.
- This sequence of steps continues until one of three codons is encountered: **UAA, UGA, or UAG**. These codons give the signal for terminating the synthesis of the polypeptide chain, and the chain is cleaved from the last tRNA residue

Biosynthesis of protein

Translation. 2

- The sequence of DNA described in this section would produce the following sequence of amino acids.

Met-Phe-Val-Asn-Gln-His-...

- This polypeptide is not necessarily an active protein. All proteins in prokaryotic cells start with Met when synthesized, but not all proteins have Met first in their active form.

- It is often necessary to clip off this Met after the polypeptide has been synthesized to give a protein with a different N-terminal amino acid

←

↳ why?!

Biosynthesis of protein

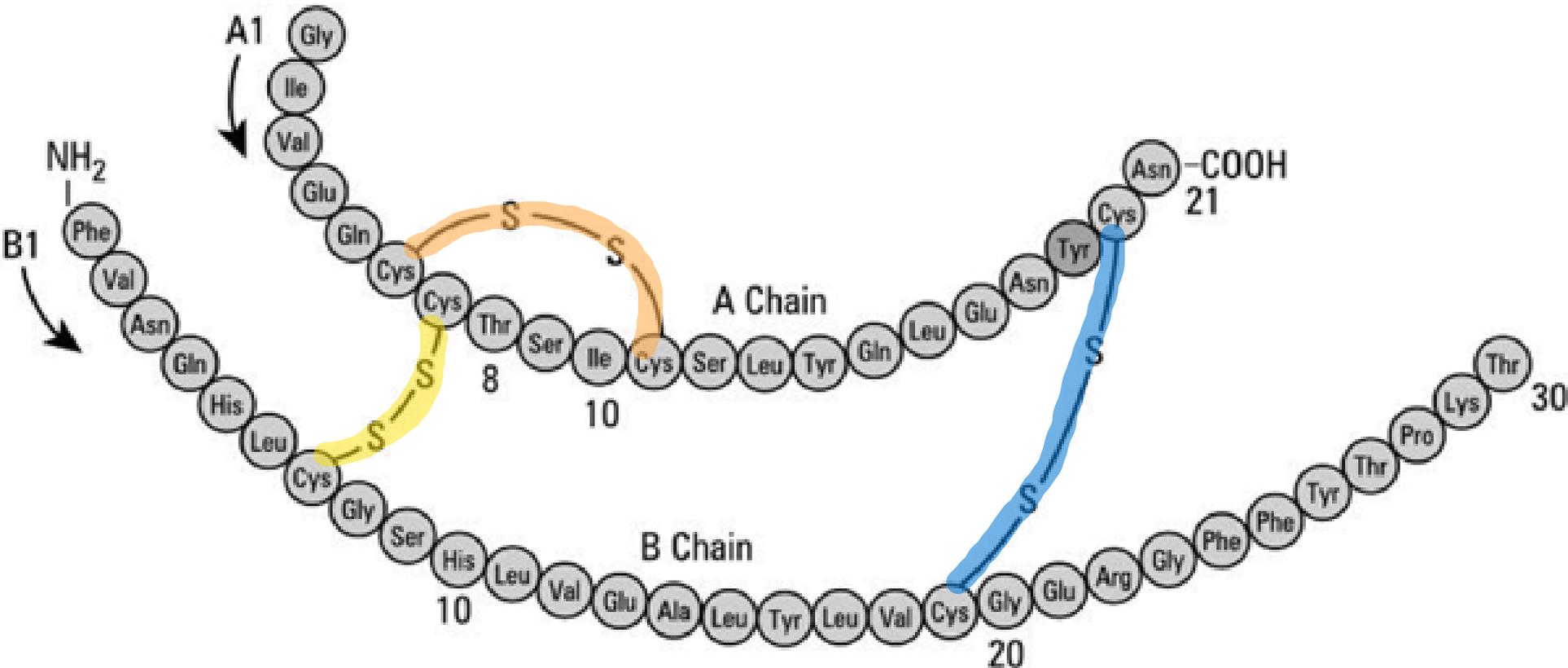
Post-translational modification. 3

← التعديلات ما بعد الترجمة

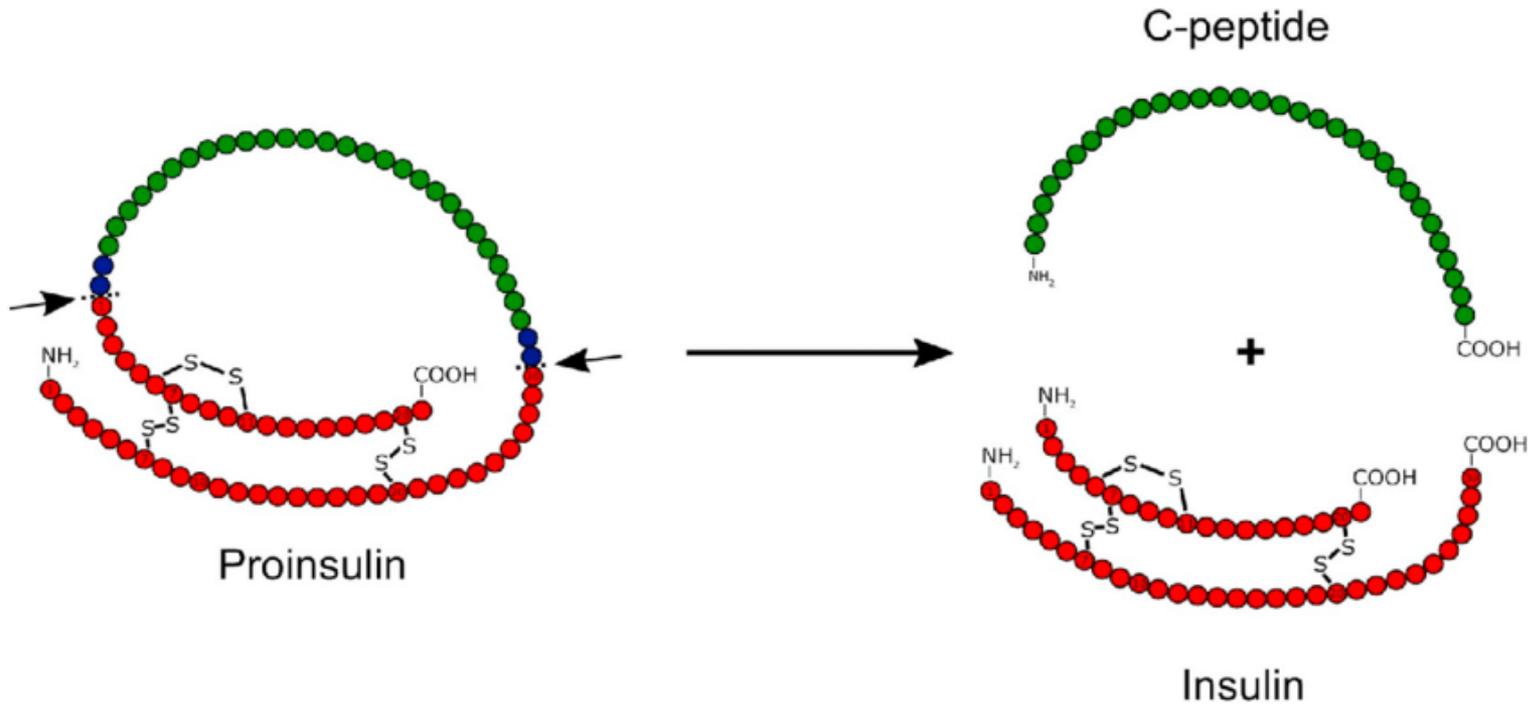
- Modifications to the polypeptide often have to be made before an active protein is formed
- **Example:**
 - Insulin consists of two polypeptide chains connected by disulfide linkages. In theory, it would be possible to make these chains one at a time and then try to assemble them to make the final protein
← لتجميعها
 - The polypeptide chain that is synthesized contains a total of 81 amino acids.
 - All of the disulfide bonds that will be present in insulin are present in this chain. The protein is made when a sequence of 30 amino acids is clipped out of the middle of this polypeptide chain

Primary structure of human insulin

Chains A and B, including the interchain disulfide bonds **A7-B7** and **A20-B19** and intrachain disulfide bond **A6-A11**



Insulin



Tertiary and quaternary structure of insulin

