भारतीय सांकेतिक विज्ञान संस्थ हैदराबाद
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Introduction of Bio-nanotechnolgy

BT1110

Lecture 2 : Biological self-assembly

Himanshu Joshi 2 November 2023

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Course contents

- Introduction to nanotechnology and bionanotechnology,
- **Biological self-assembly**
- Biologically inspired nanostructures - introduction to biomimetics
- Nucleic acid nanotechnology
- DNA origami
- Protein engineering
- Lipid nanotechnology
- Chirality in biological systems
- Interaction of nanomaterials with biological systems
- Virology: viruses and vaccines

Self-assembly

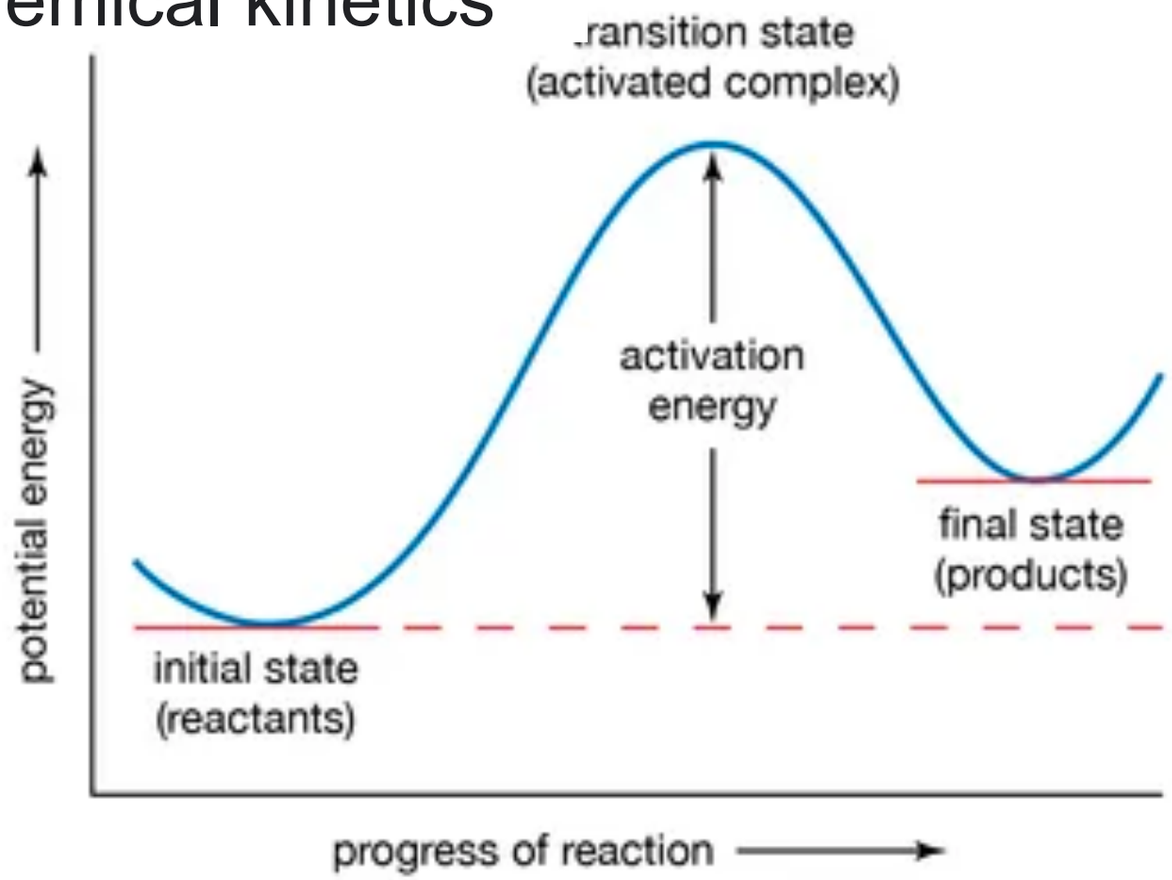
- A process in which molecules (or parts of molecules) spontaneously form ordered aggregates and involves no human intervention.

- One of the most wondrous aspects of life is that all living organisms are formed through self assembly, a fundamental biological design process by which an organized structure seemingly builds itself from a disordered collection of smaller parts.

- Cause : Thermodynamics and chemical kinetics*

Thermodynamics is the study of the relations between heat, work, temperature, and energy

Kinetics is the branch of physical chemistry that is concerned with understanding the rates of chemical reactions



Matter/Chemical and Energy

What is “matter”

Anything that has mass and occupies space is matter. Matter consists of particles. The particles may be molecules, atoms, or subatomic bits, such as protons, electrons, or leptons. So, basically anything you can taste, smell, or hold consists of matter and is therefore chemical.

What is not matter

Energy, Heat, Light, Thoughts, Forces

Reference
https://www.thoughtco.com/

Forces governing the self-assembly of biological matter

Gravitational forces

Weak nuclear Forces

Strong nuclear Forces

Electromagnetic forces 

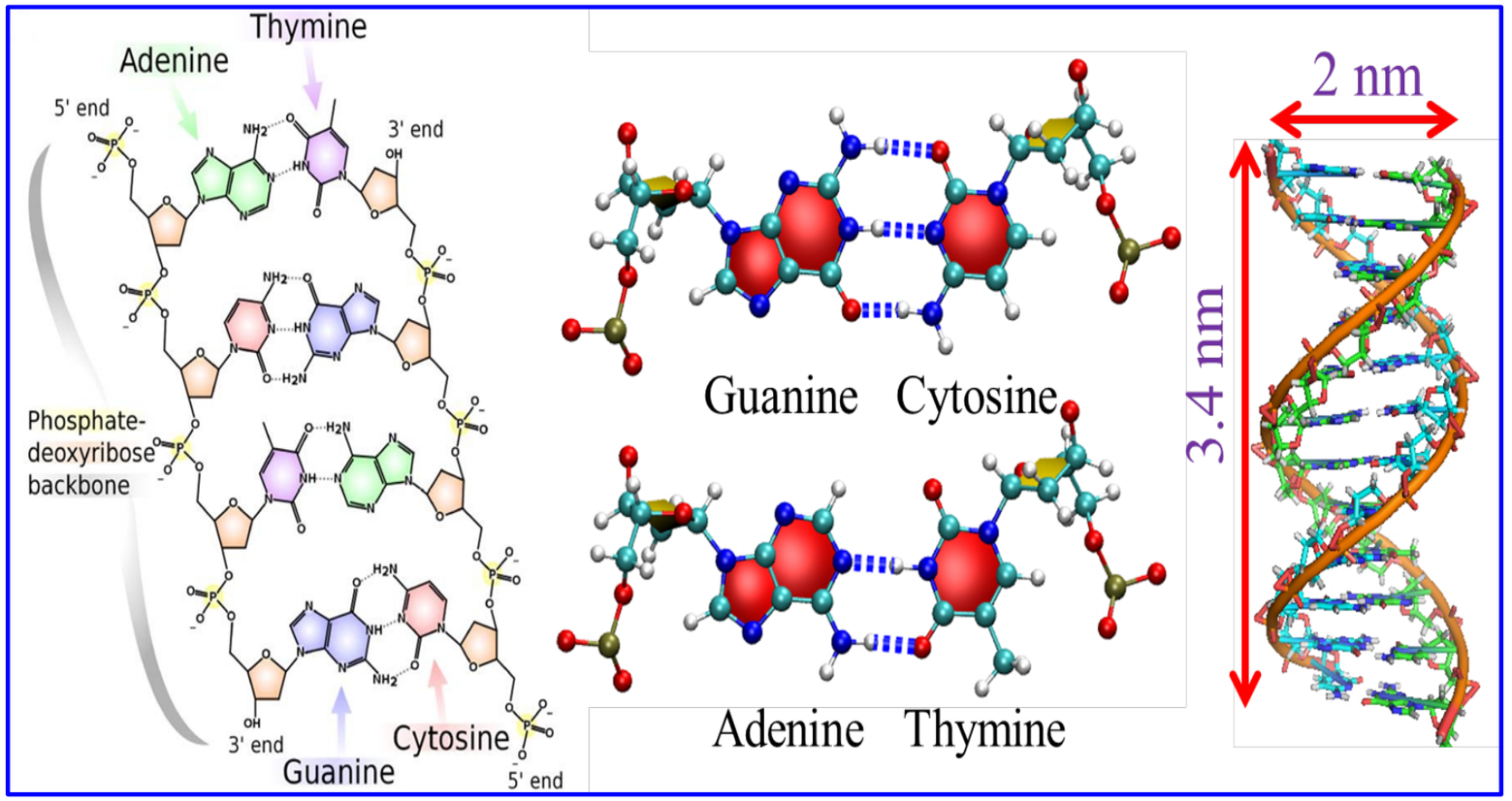
Type of Force	Example	Rupture Force
Breaking of a covalent bond	C-C	≡1600 pN
Breaking of a noncovalent bond.	Biotin/streptavidin	≡160 pN
Breaking of a weak bond.	Hydrogen bond	≡4 pN
Langevin force	on E-coli	0.01 pN (1s)
Stretching dsDNA	to 50% relative extension	0.1 pN
Developped by a molecular motor	Kinesin walking on microtubule	5 pN (max)

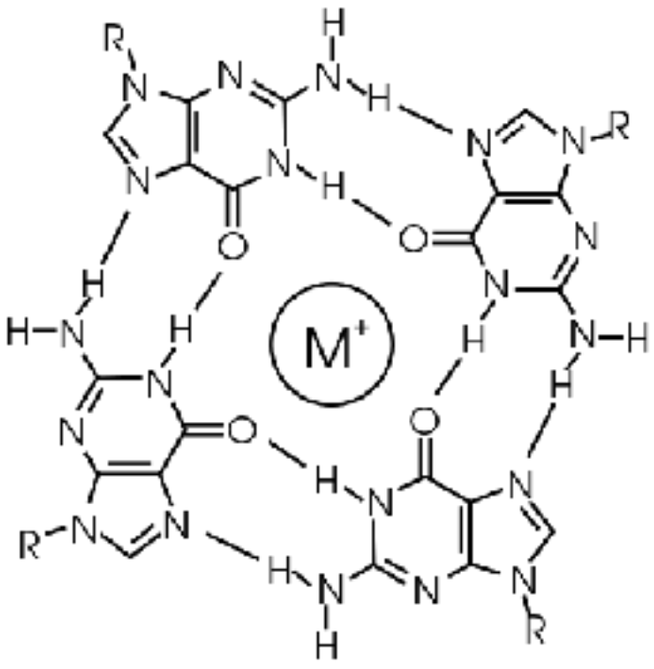
Thermal energy 2.479 kJ/mol

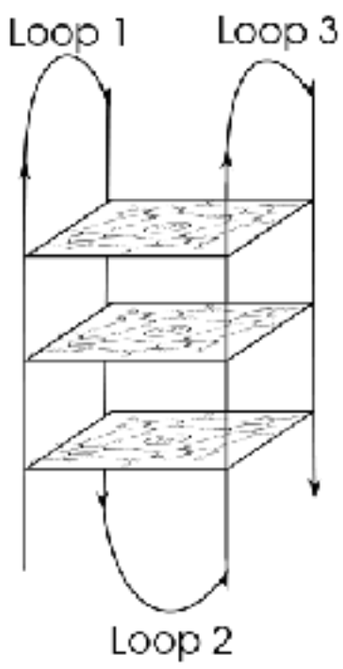
Weak electrostatic energy ≅ 0.4 to 4 KJ/mol

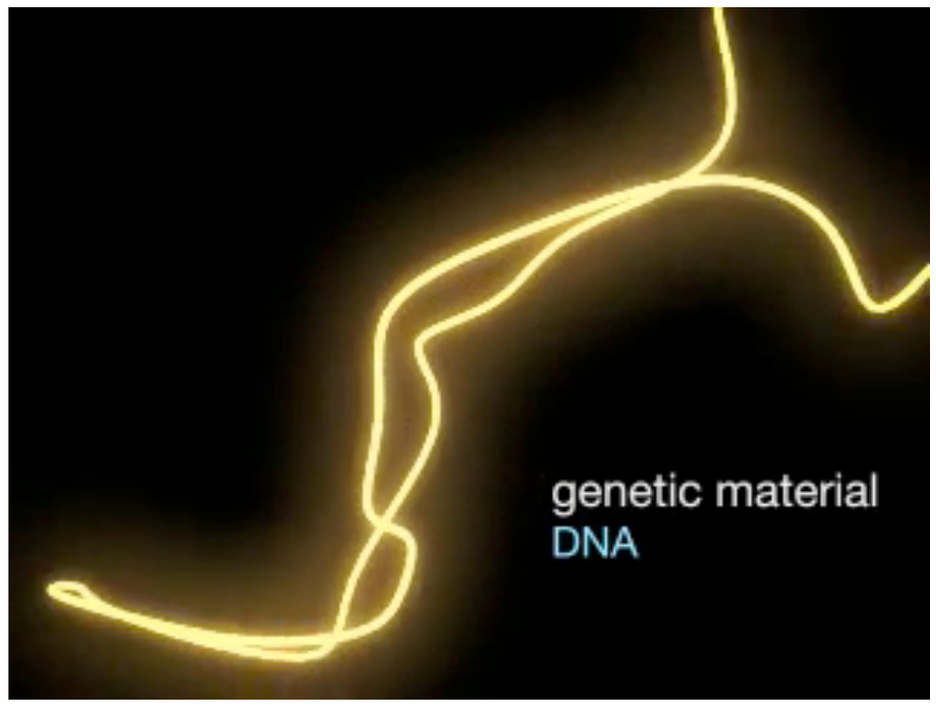
Source
http://www.picotwist.com/

DNA molecules
Primary, secondary, tertiary and Quaternary





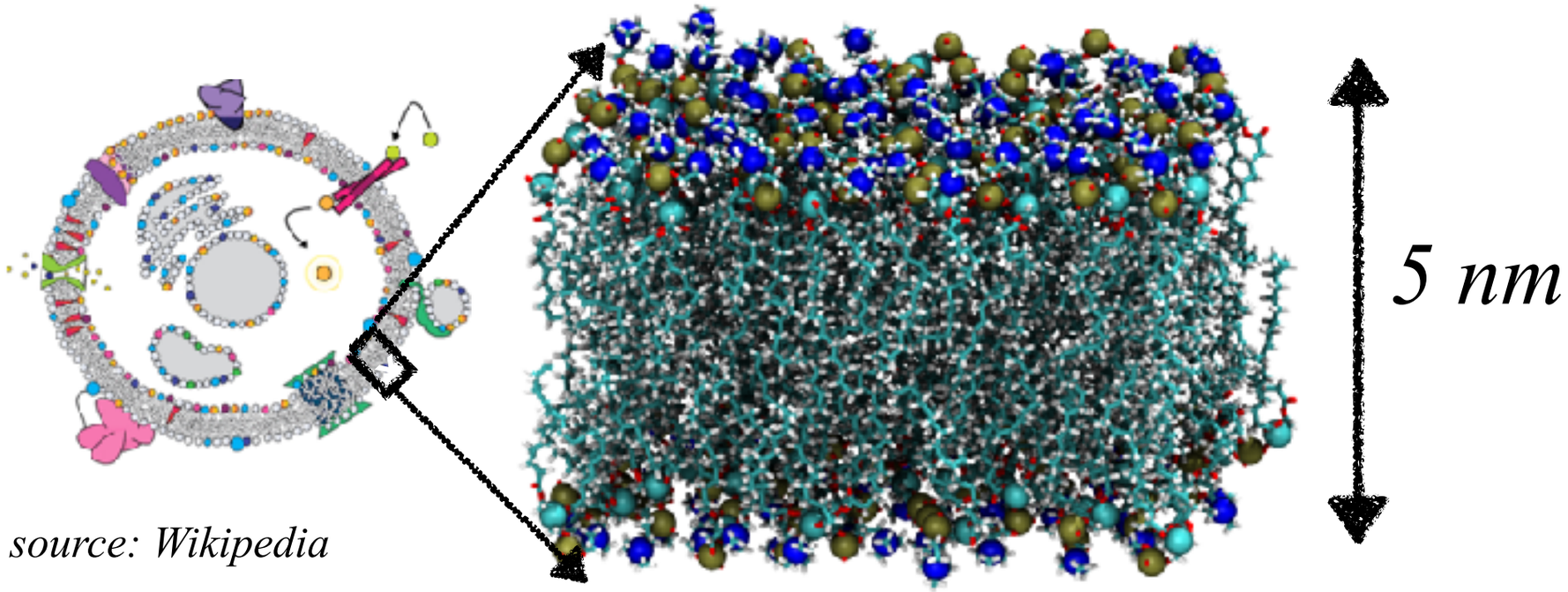




G Qudruplexes

DNA origami

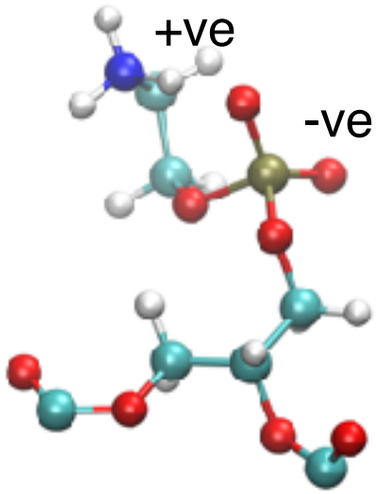
Structure of phospholipid bilayer membranes



source: Wikipedia

1-**P**almitoyl-2-**o**leoyl

Phosphatidyl**e**thanolamine



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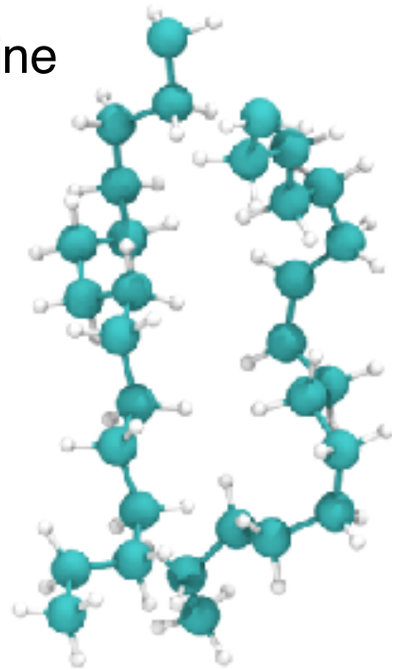

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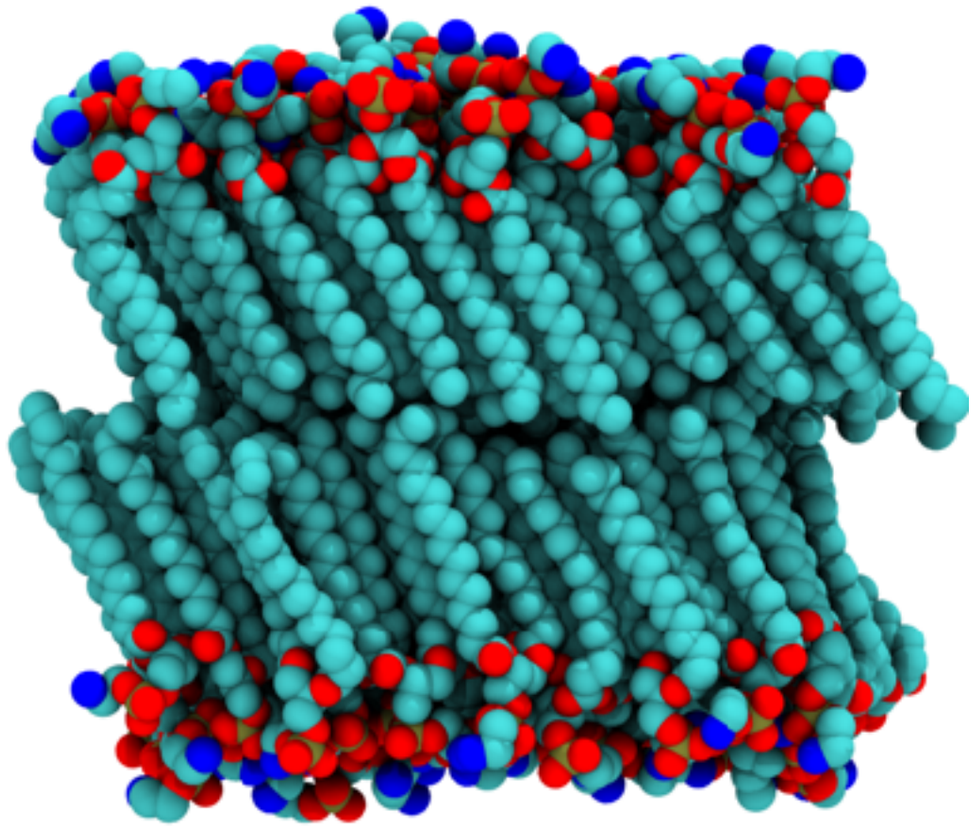
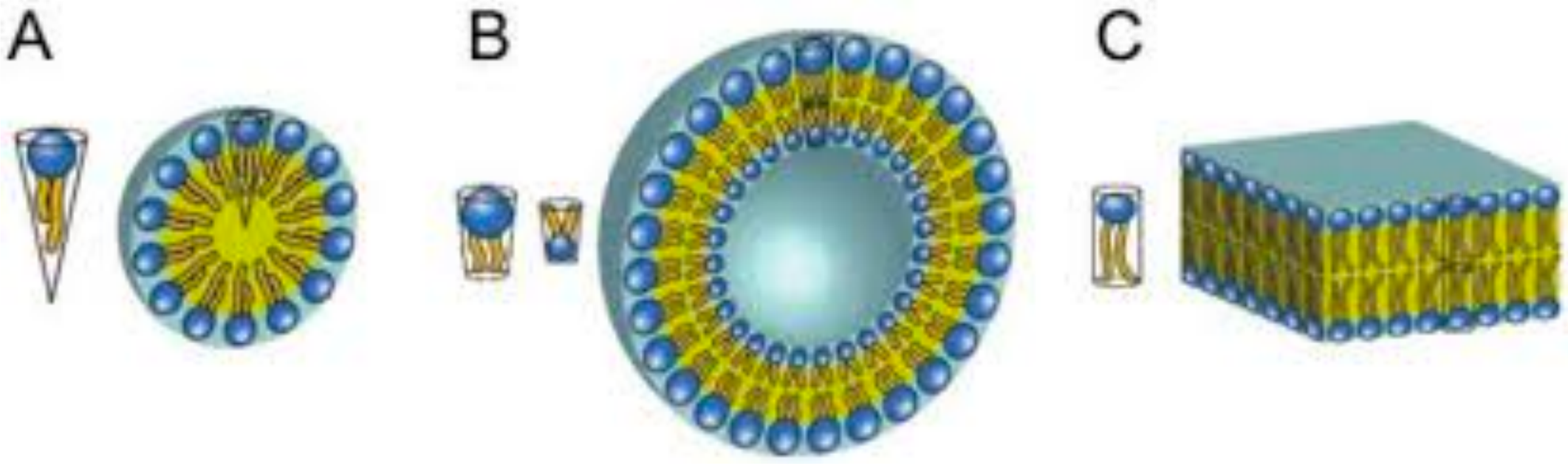
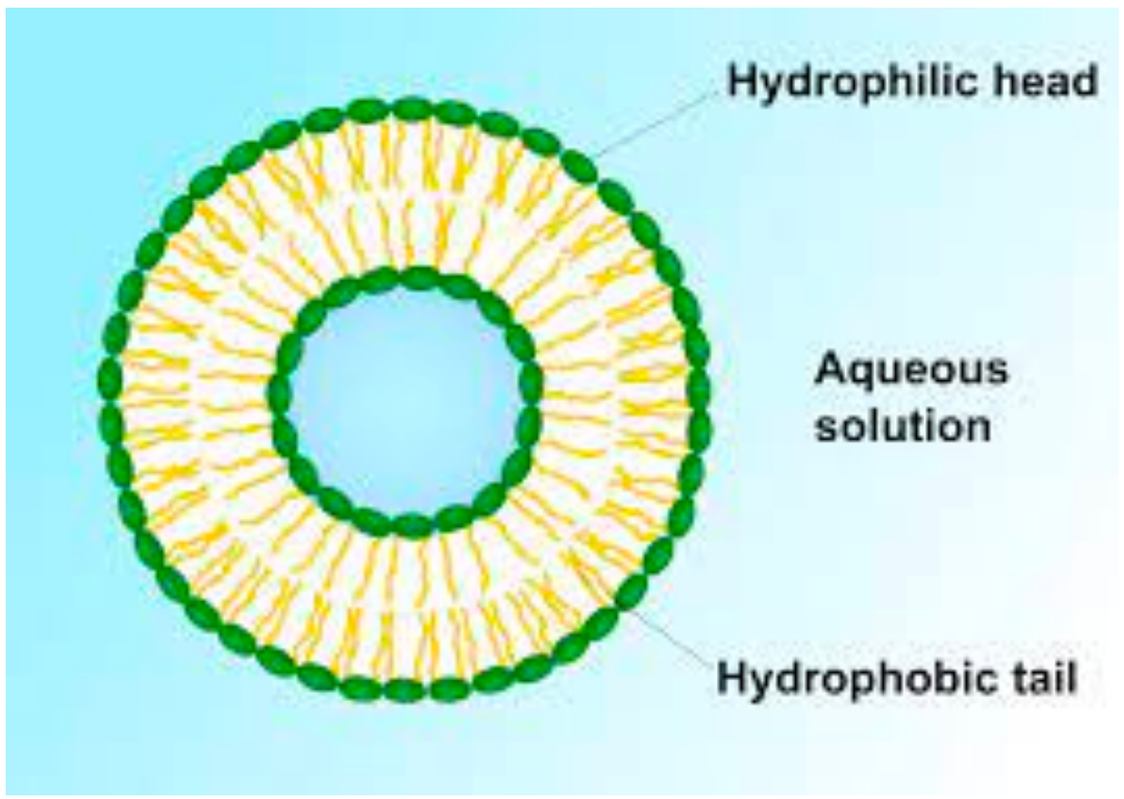
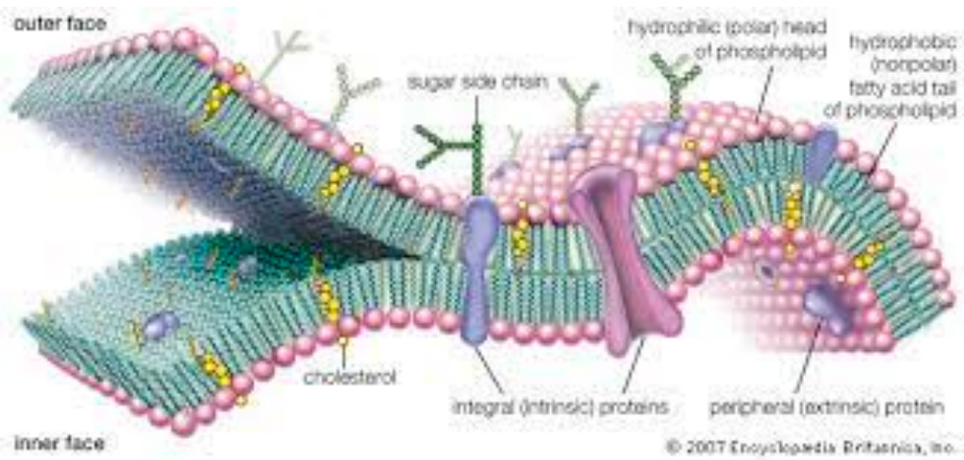


Various structure obtained by the self assembly of lipid membranes

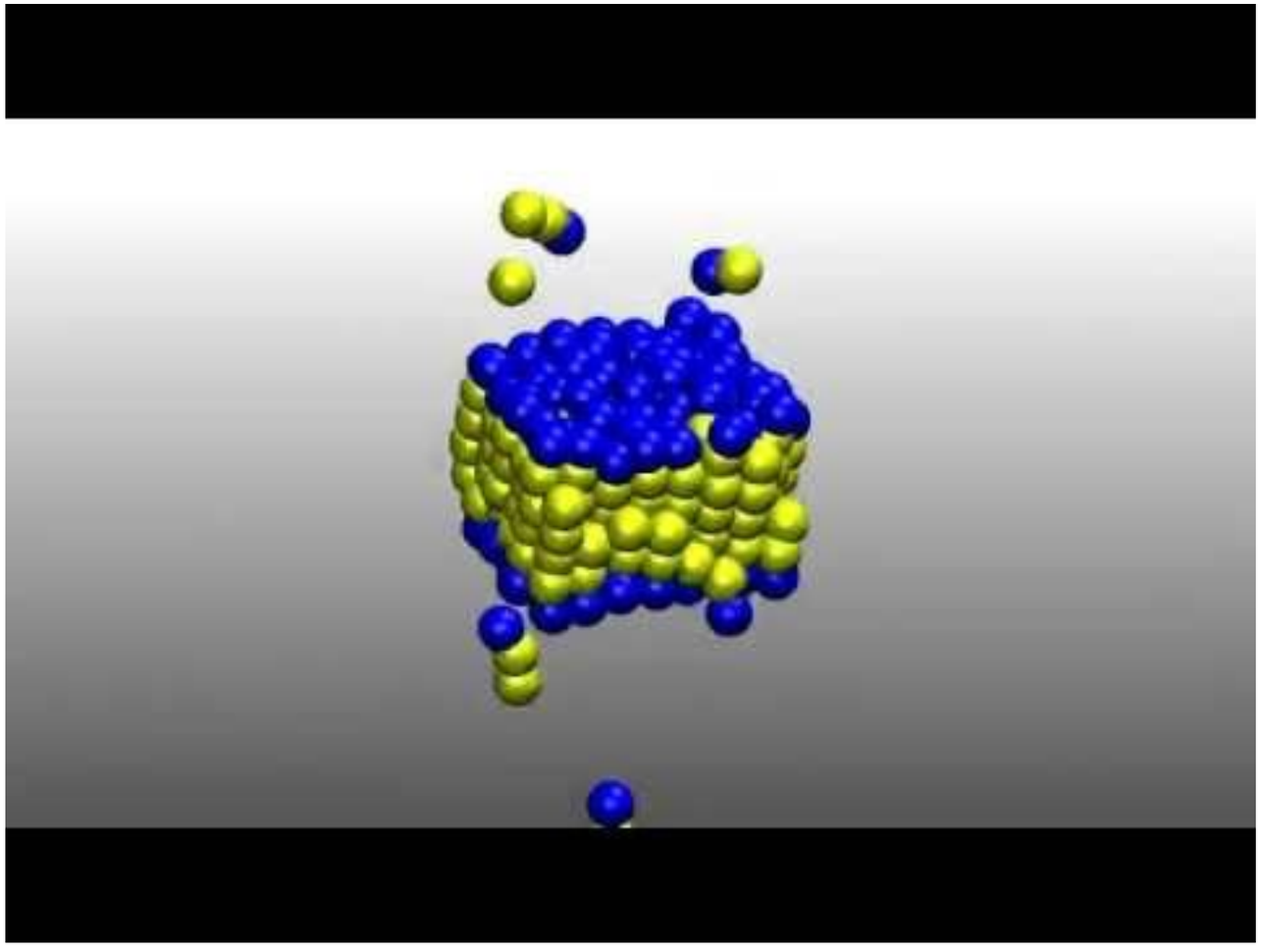


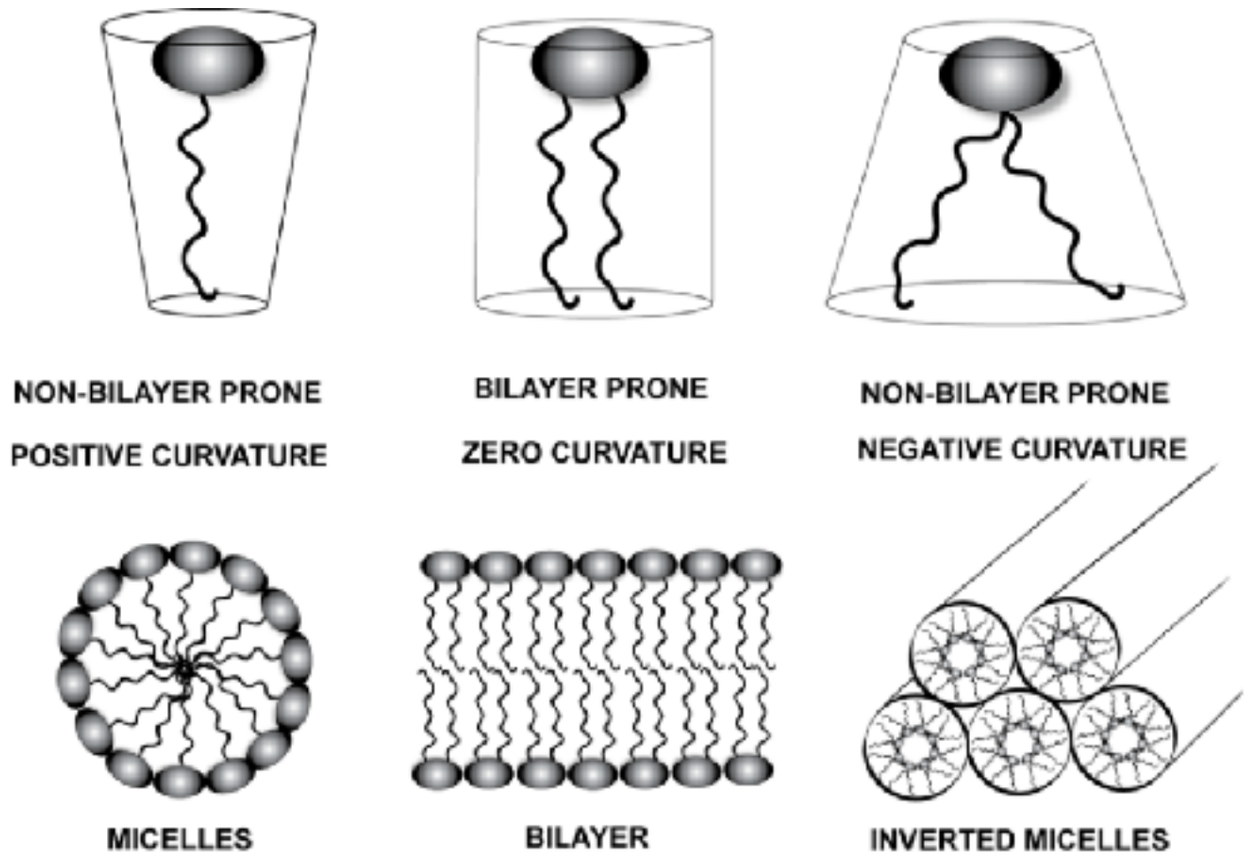




Source: Wikipedia

Various structure obtained by the self assembly of lipid membranes



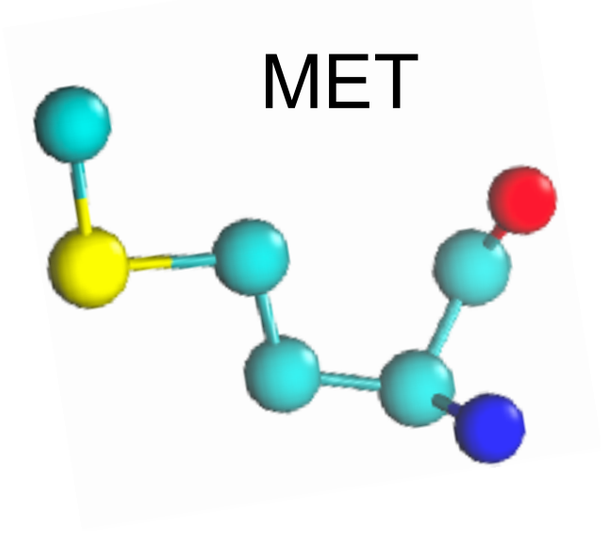


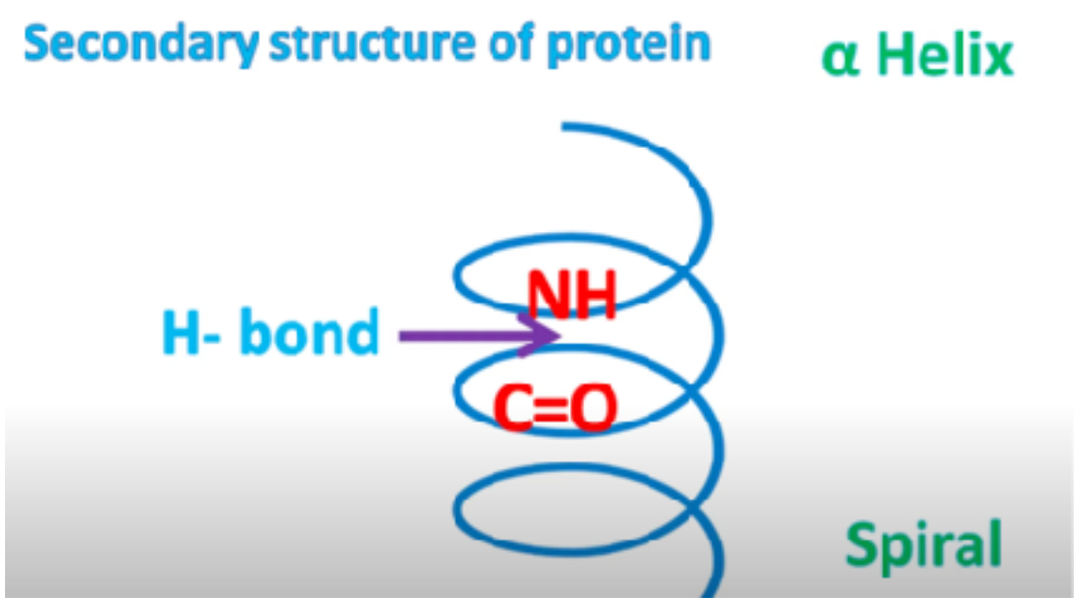
Reference
Thesis: Candan Ariöz

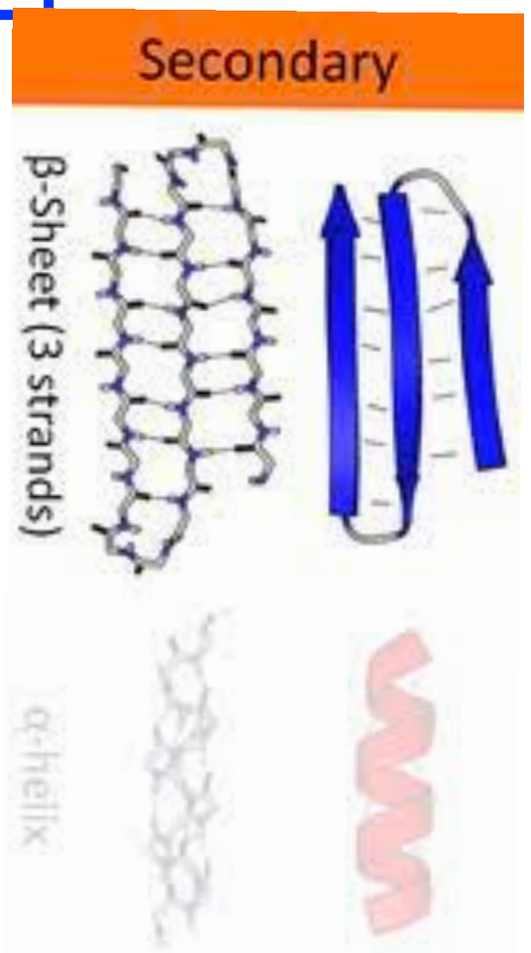
Proteins

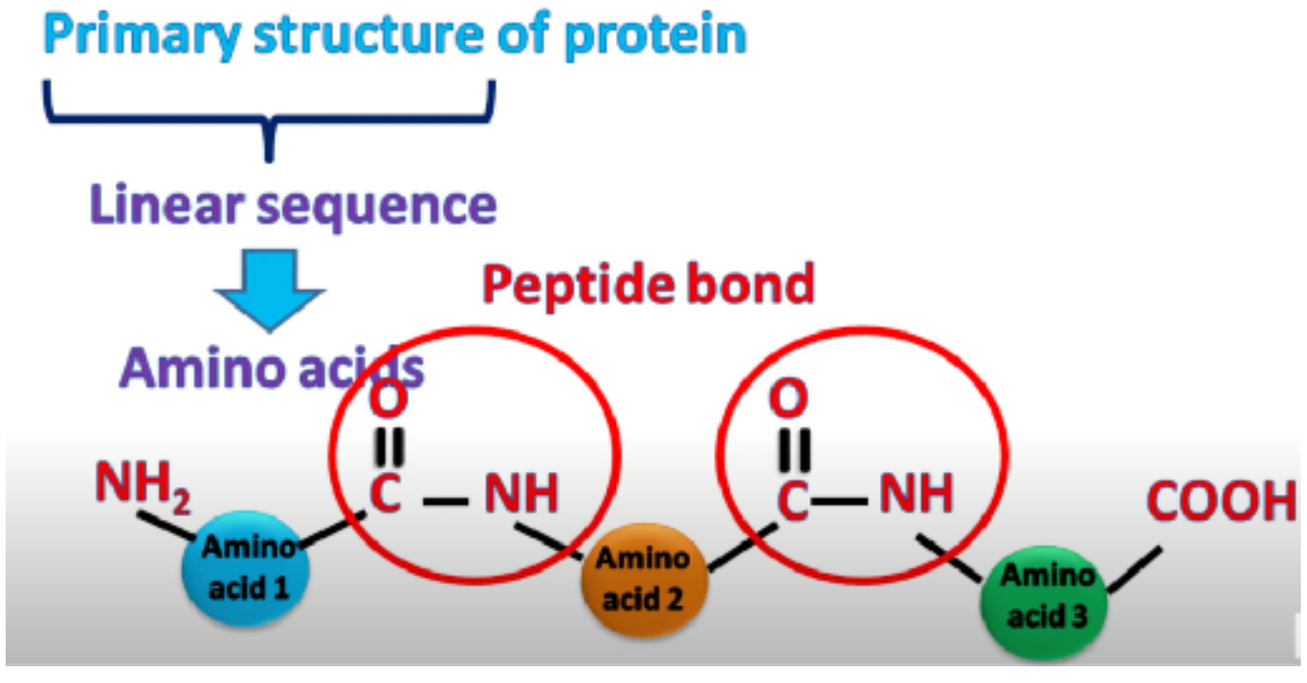
Primary, secondary, tertiary and Quaternary

Roughly 500 amino acids have been identified in nature, but just 20 amino acids make up the proteins found in the human body





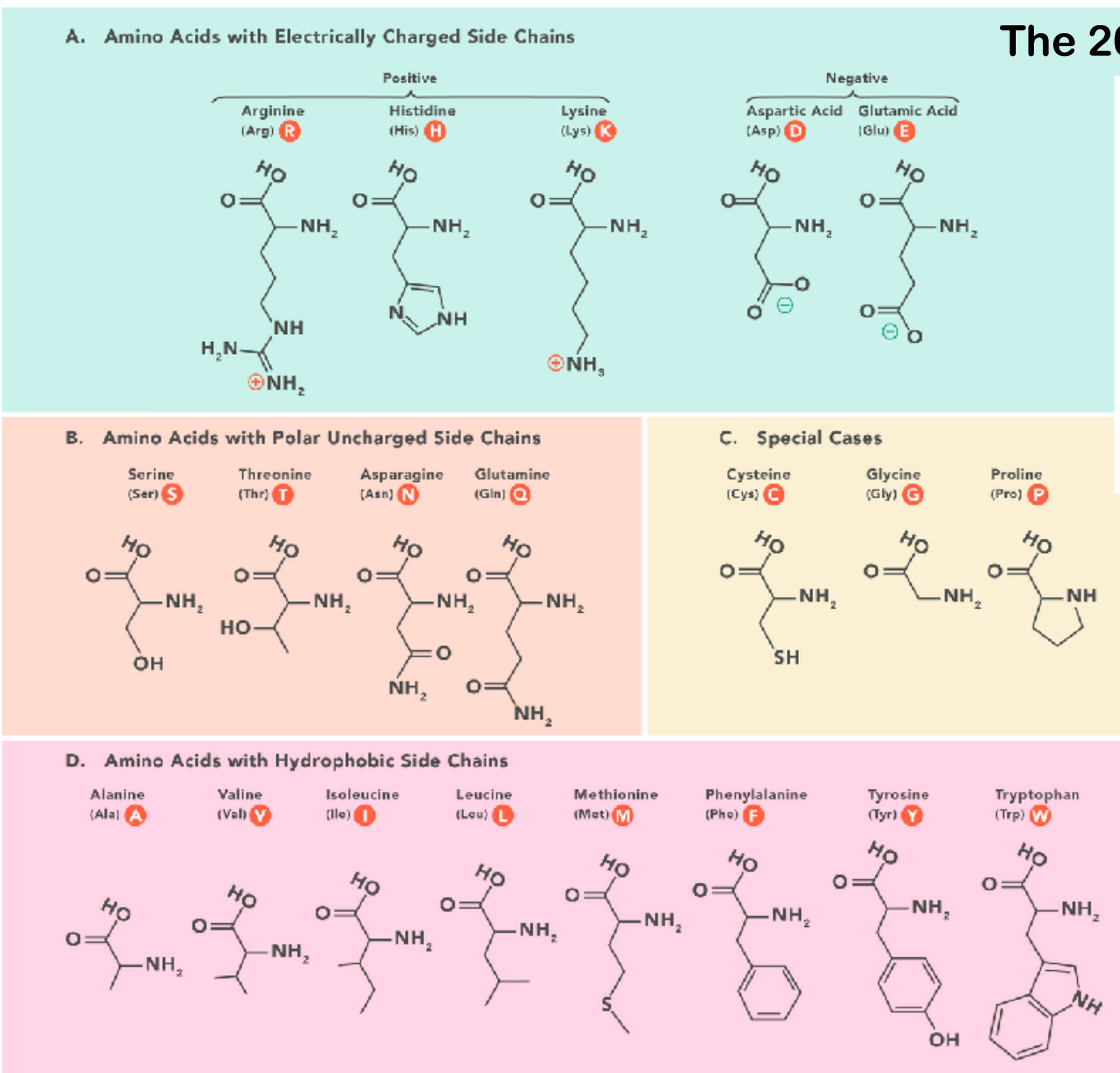




The primary structure of the protein can be obtained by sequencing the gene that encodes the protein or by sequencing the protein itself

The 20 Amino acids

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



Tertiary structure of protein

Arrangement of protein in 3D space

Tertiary

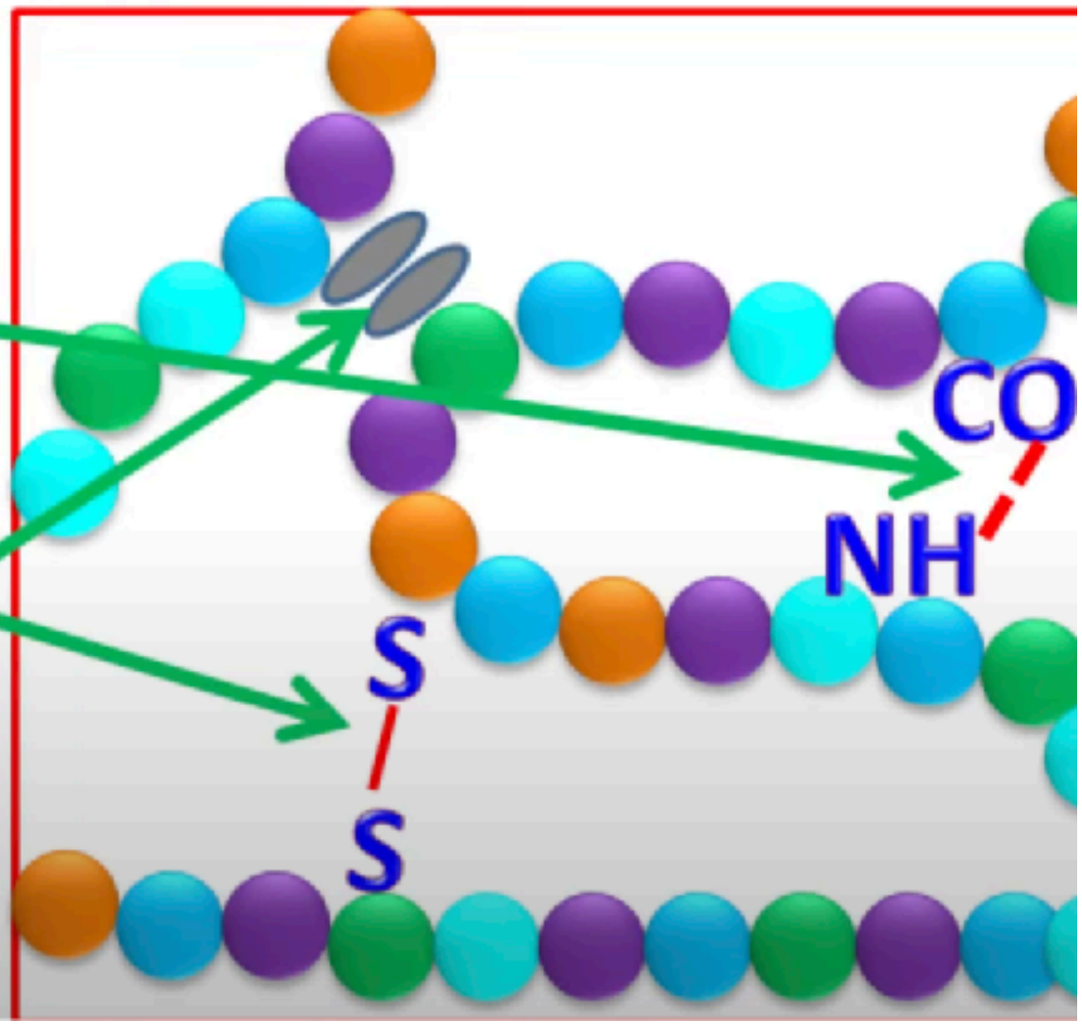
Bonds

Hydrogen bond

Disulphide bond

Hydrophobic interaction

Ionic bond



Reference
https://youtu.be/PPJ7C3hcnPw

Structure of Proteins

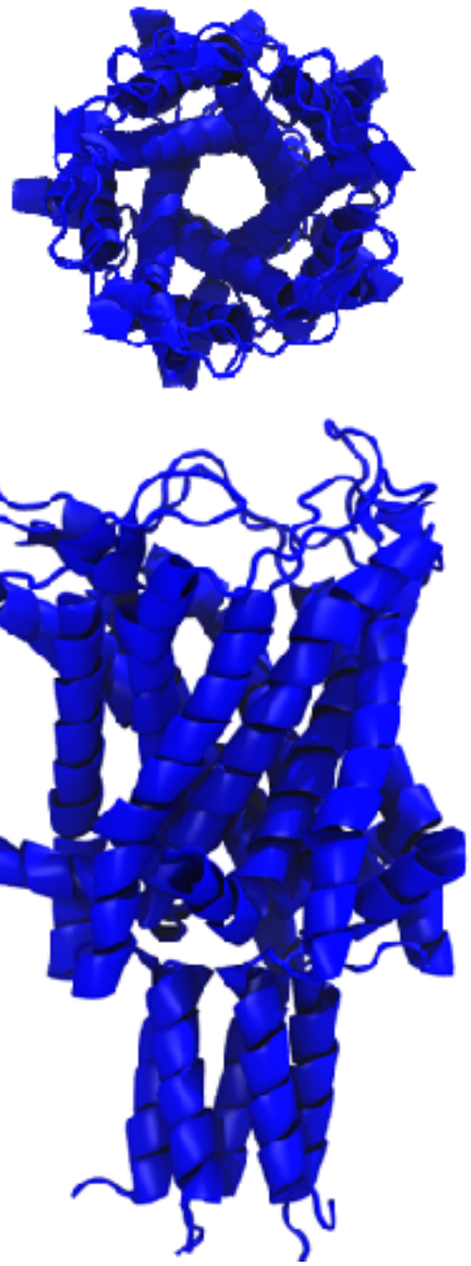
Primary

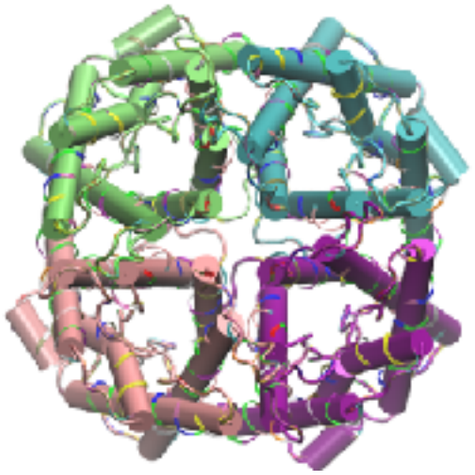
α Helix

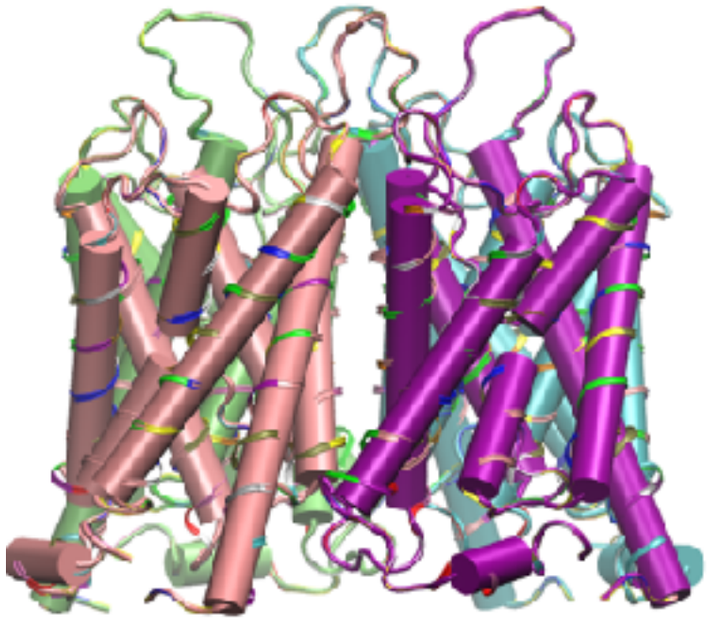
β sheet

Tertiary

Quaternary



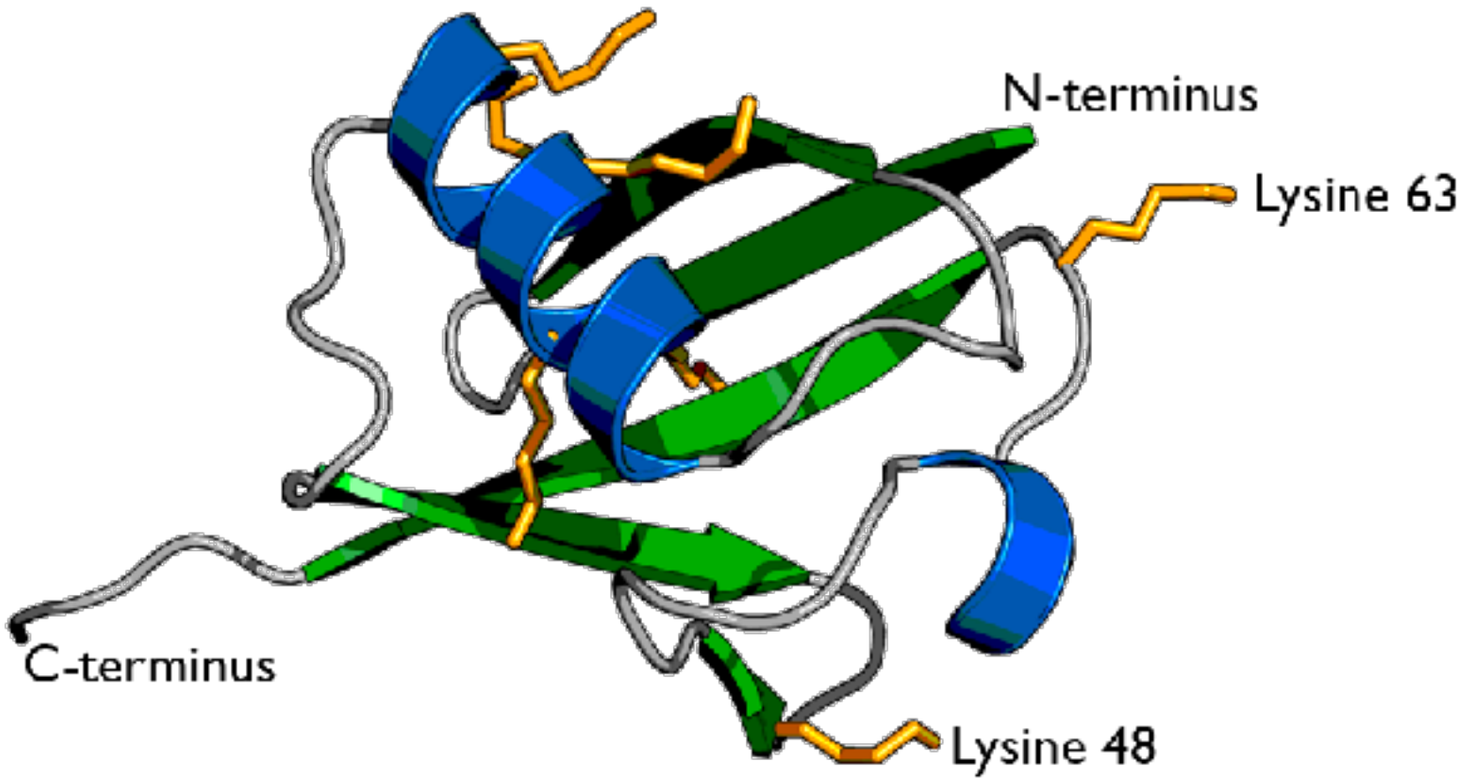




Proteins

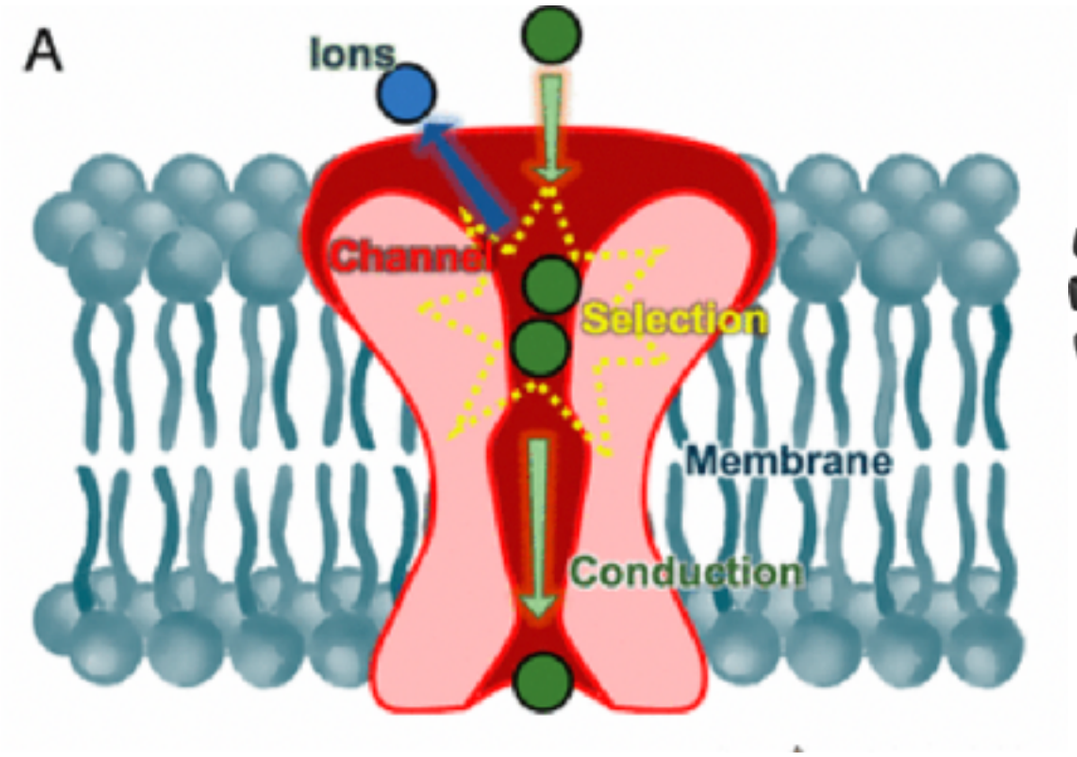
<u>Ubiquitin</u>
76 amino acids
8.5 KDalton

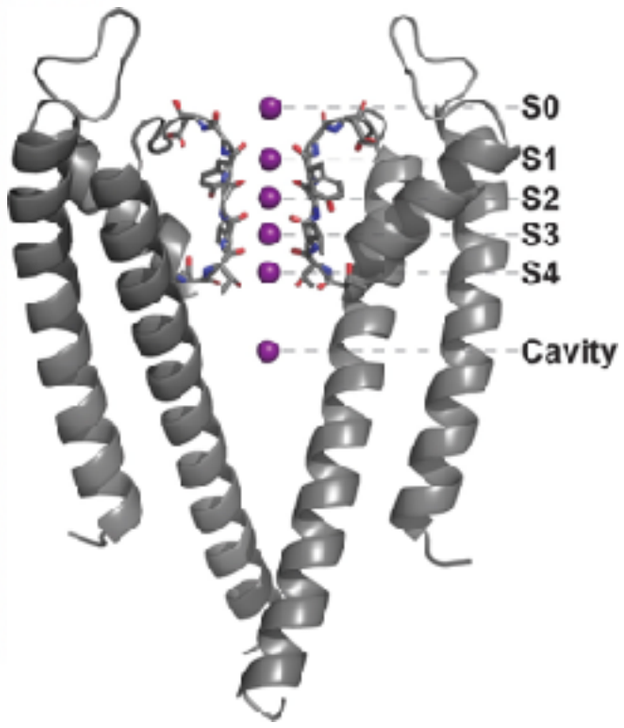
dalton or unified atomic mass unit = molar mass of C/12 =1.66 x 10^{-27} kg



- regulating the survival and death of cancer cells
- its relationship to stress
- its role at mitochondria and its disease implications

Protein channels in membrane and biomimetics





Chem. Rev. 2019, 119, 13, 7737–7832

Protein channels regulates some key functions at cellular level like

- Propagation of nerve impulses
- Enabling vital functions like heartbeat
- Brain activity
- Muscle contraction etc

The minimalistic/reductionist and simple approach of nature

- Using only 20 amino acids to create all protein
- Only 5 types of nucleotide bases to all DNA/RNA
- Only handful of lipids and carbohydrates