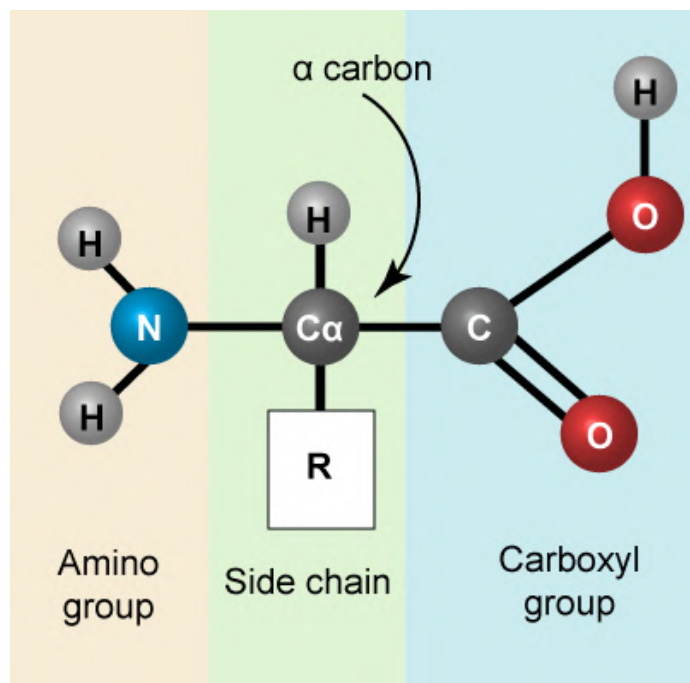


B1.2

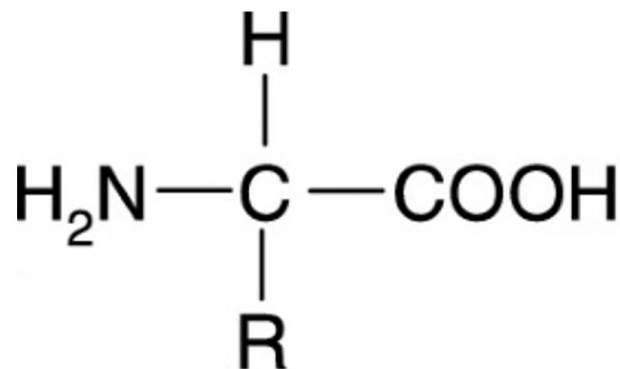
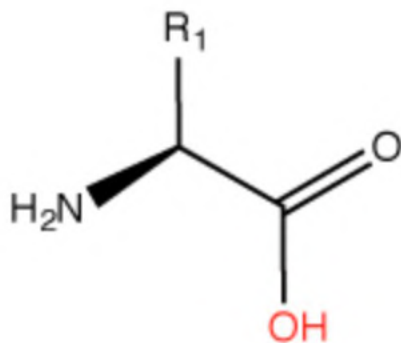
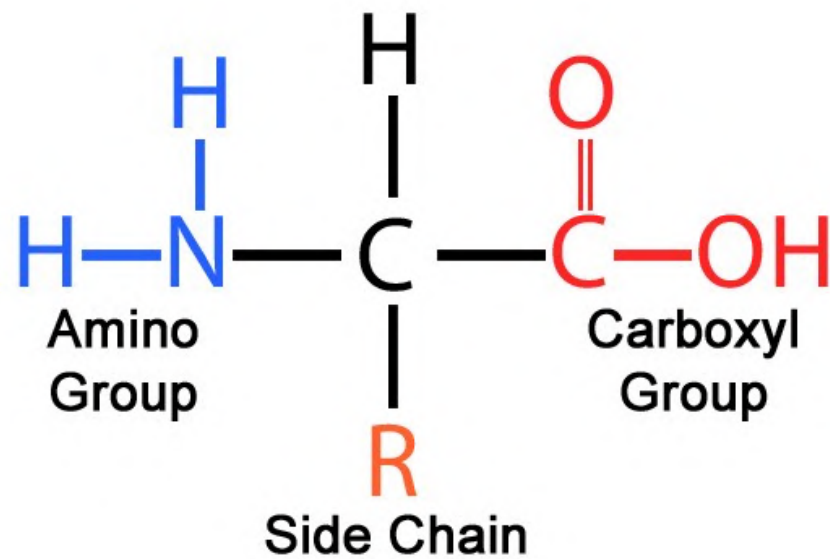
Proteins

What is the relationship between amino acid sequence and diversity in form and function of proteins?
How are protein molecules affected by their chemical and physical environments?

Amino acid structure



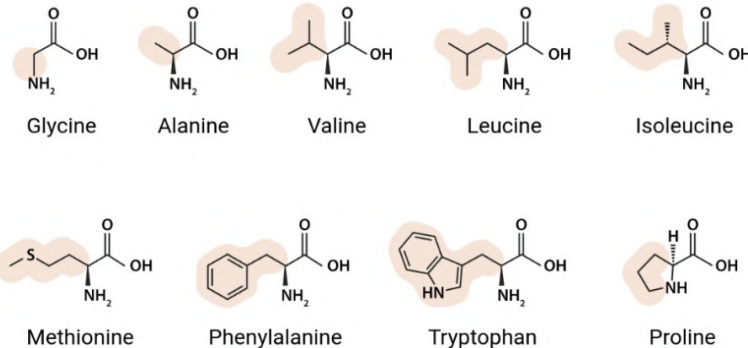
[Libre Texts](#)



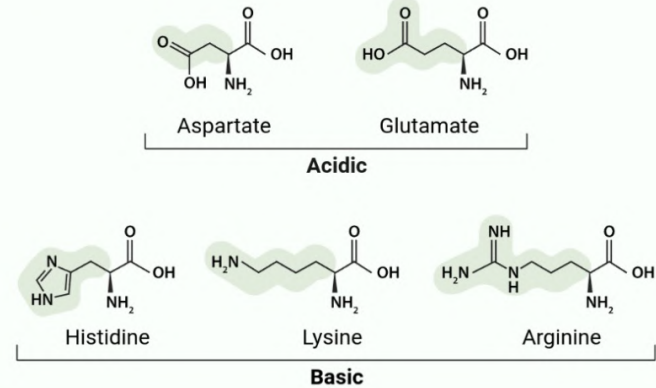
Amino acid R groups

R- groups give each amino acid unique properties

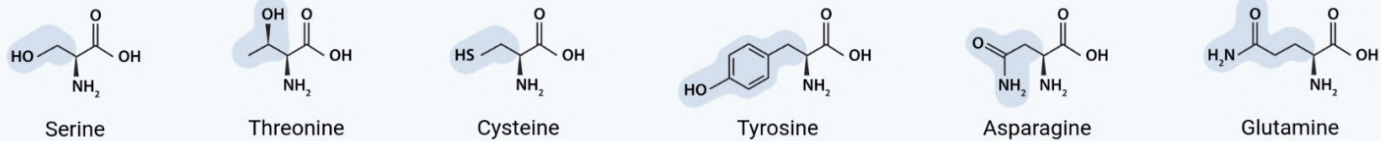
Non-polar side chains hydrophobic



Electrically charged side chains hydrophilic

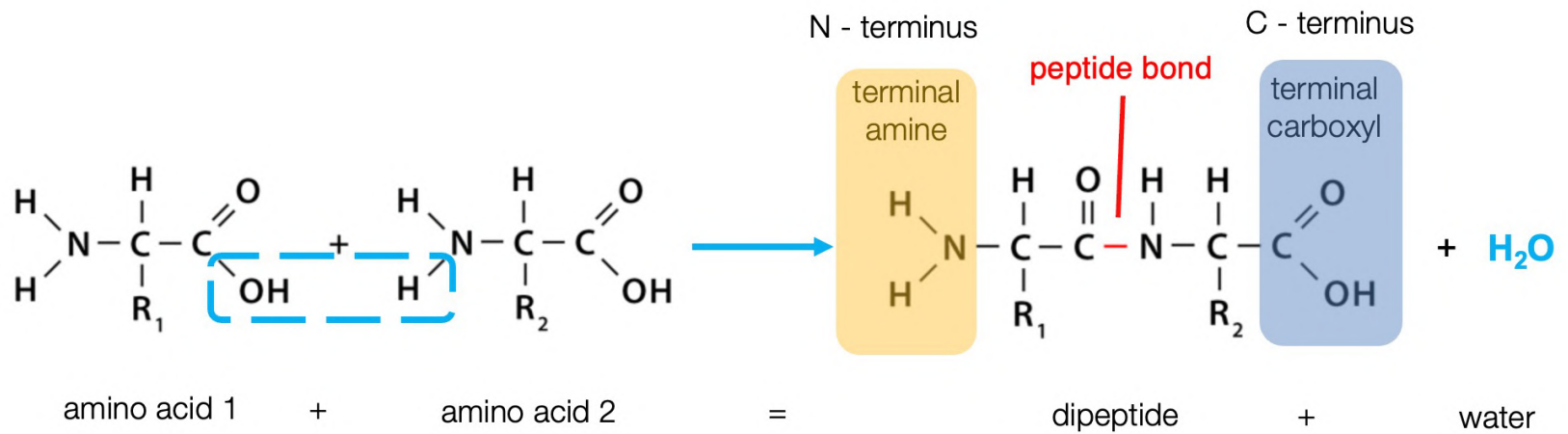


Polar side chains hydrophilic

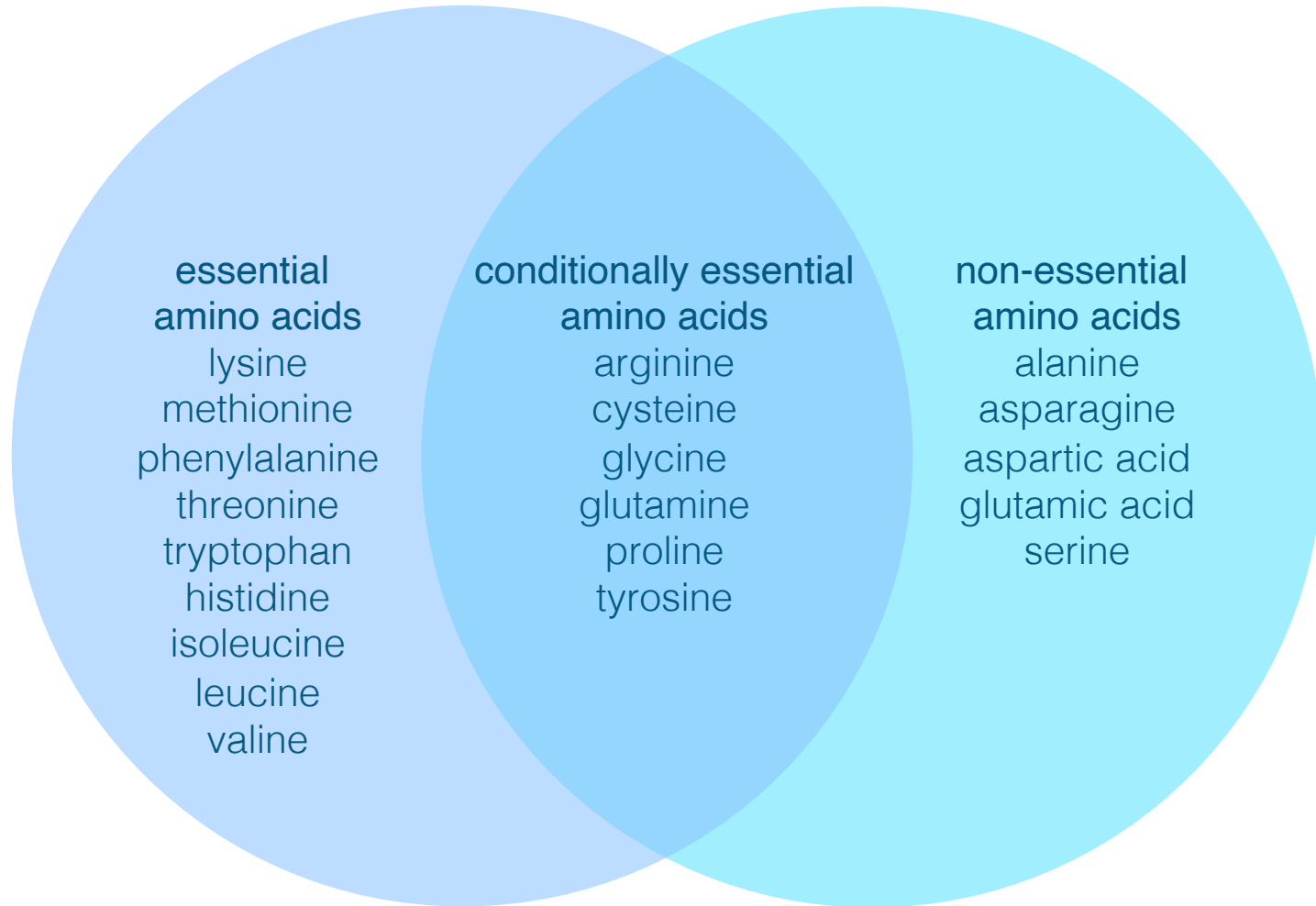


[Sally Kim](#)

Condensation reactions form dipeptides



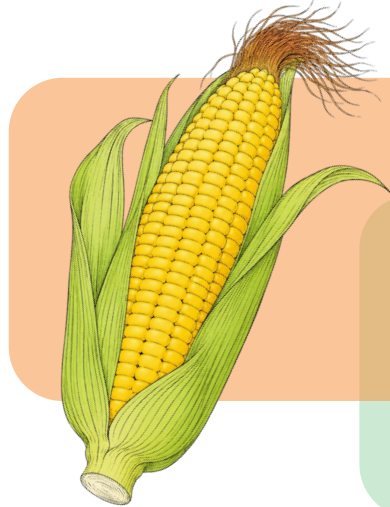
Essential amino acids



Conditionally essential amino acids only become essential during rapid growth/repair, pregnancy or illness. During these times our bodies may not produce enough.

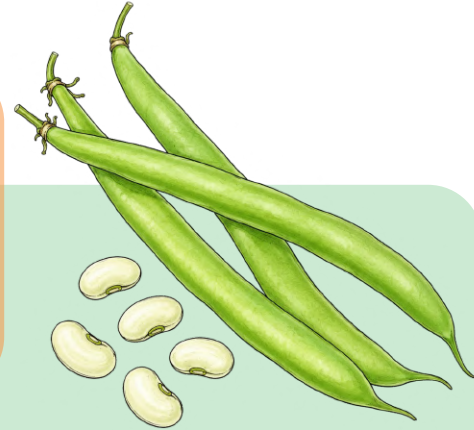
Essential amino acids

corn and grains



tryptophan
methionine
valine
threonine
phenylalanine
leucine
isoleucine
lysine

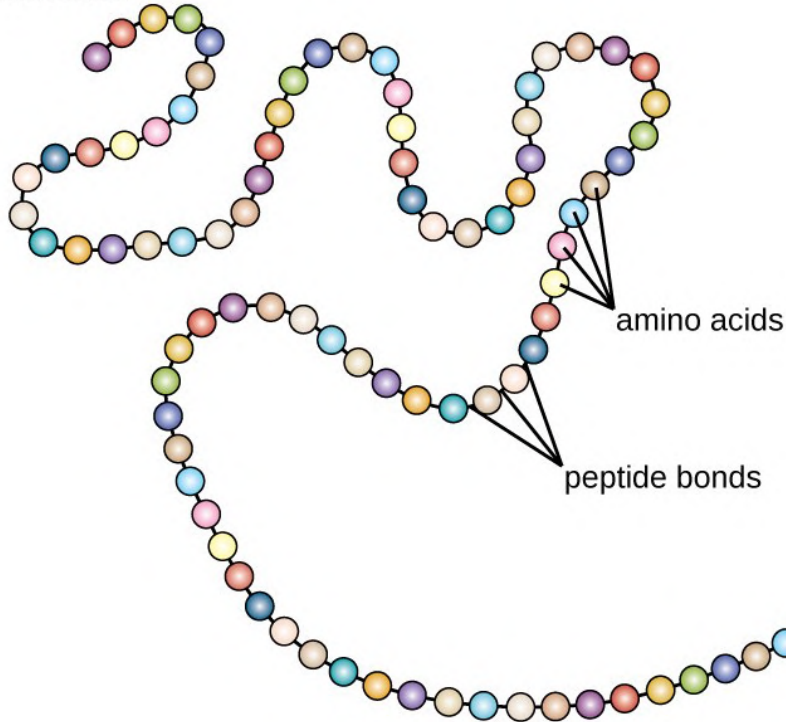
beans and legumes



biocode.co CC-BY

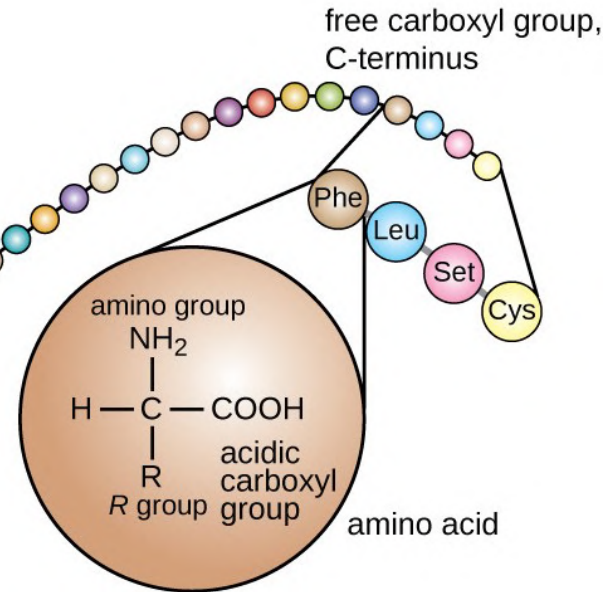
Polypeptide chain variation

free amino group,
N-terminus



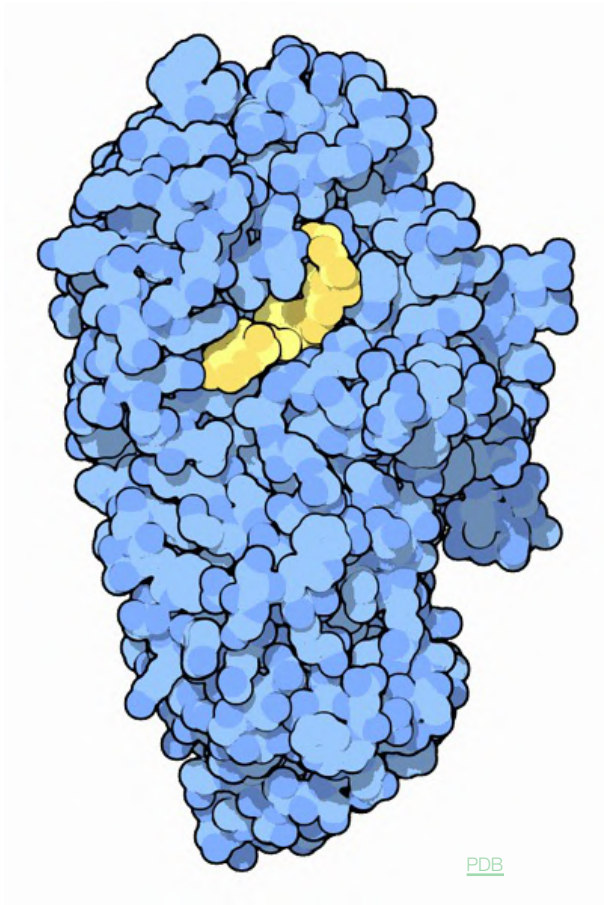
The primary protein structure is the chain of amino acids that makes up the protein.

free carboxyl group,
C-terminus

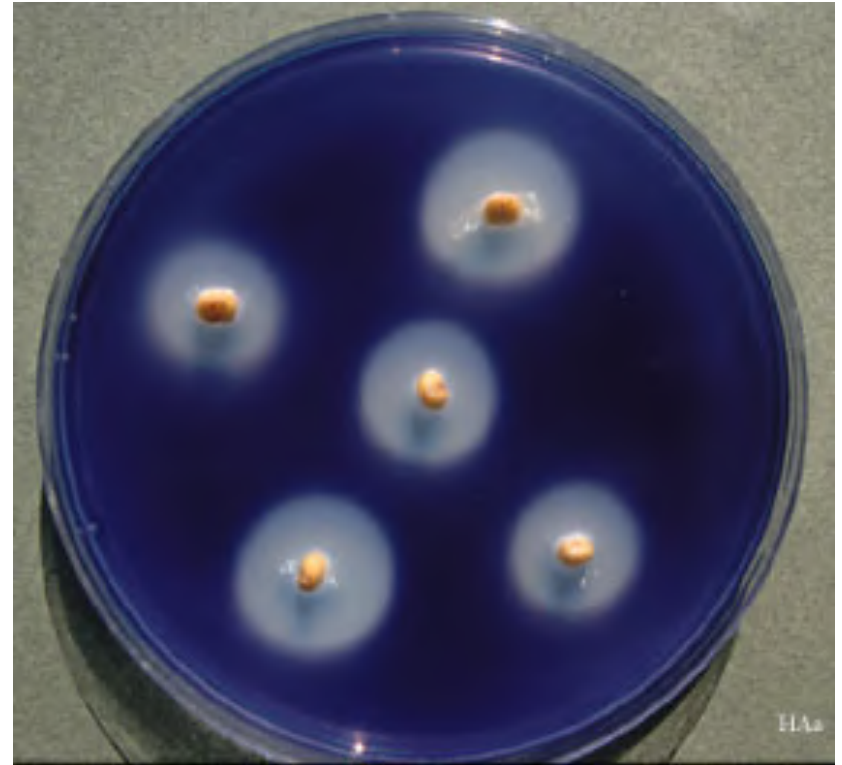


WOU

Amylase enzyme an example of a polypeptide

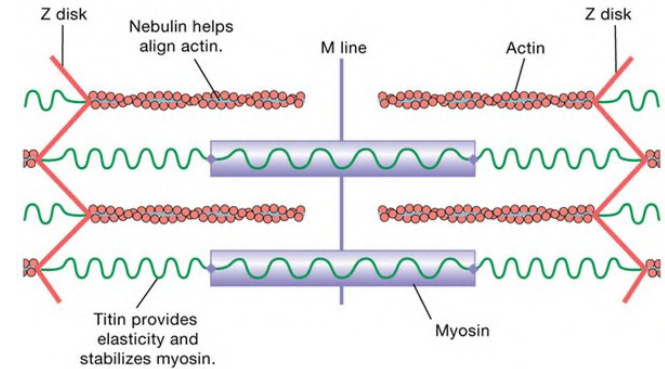
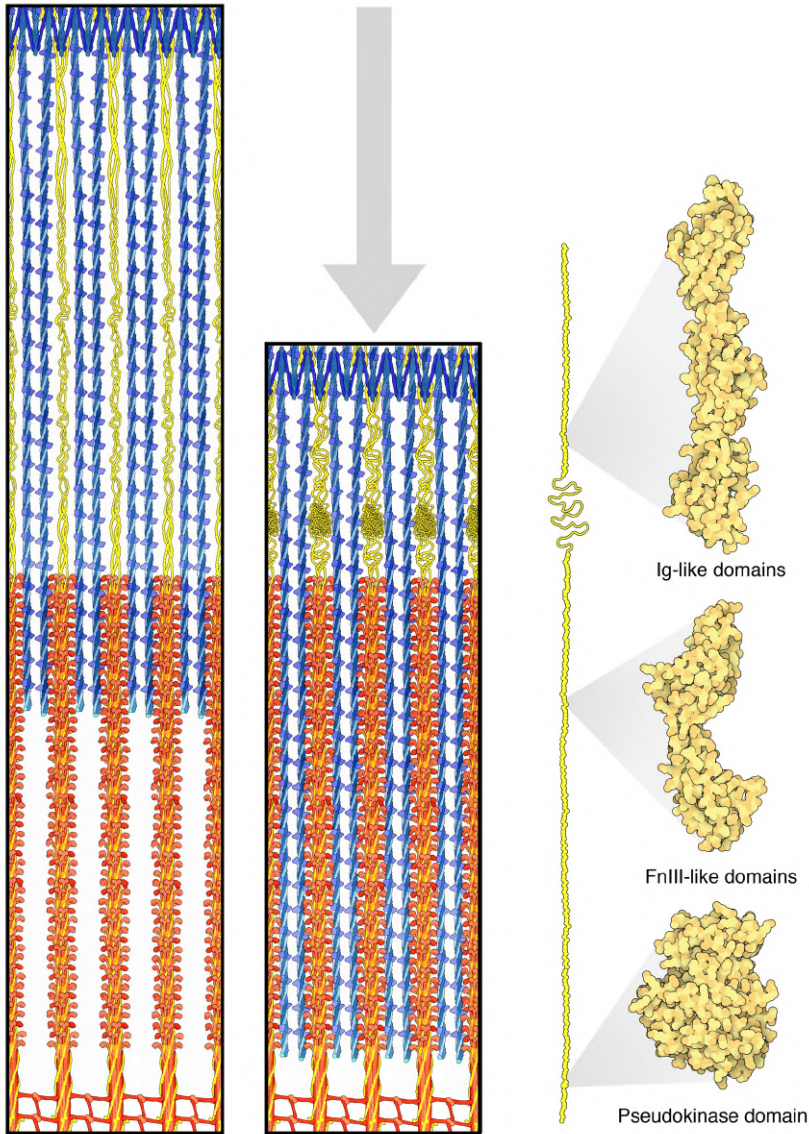


Alpha amylase
with a short chain
of sugars in
yellow.



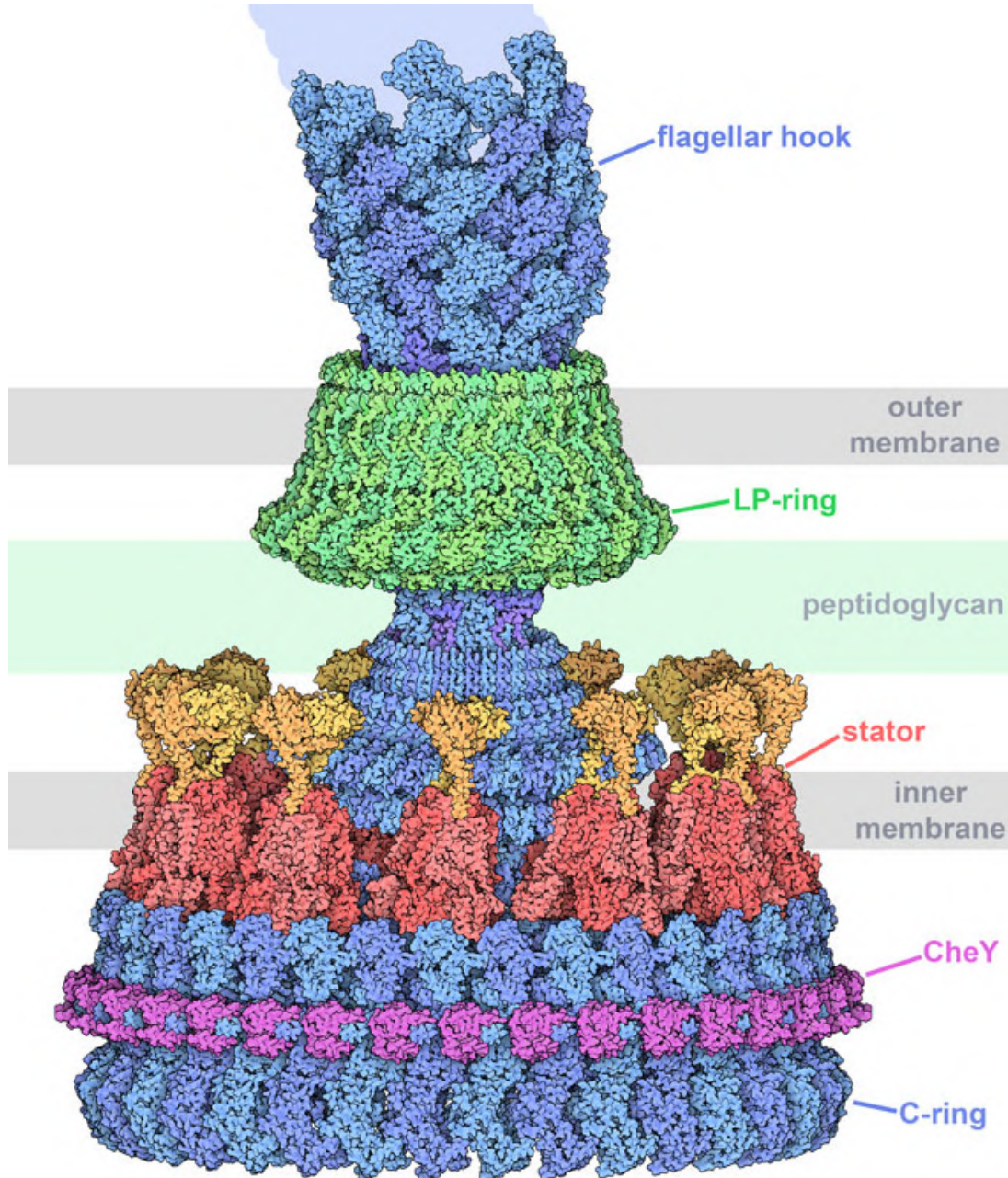
Iodine-starch agar
germination investigation
with clear halos formed by amylase
diffusing out from the seeds.

Titan an example of a polypeptide



- titan
- the largest human protein
 - an elastic band in muscle (shaded yellow)

Optional Extra (not required for the IB exam)



Flagellar motors have fascinated biologists for decades.

They are huge molecular assemblies composed of about 20 types of proteins, which together form rotary motors.

These motors are strong enough to turn long corkscrew-shaped flagella many times the length of the cell.

The *Salmonella* motor shown here turns at a speed of about 18,000 revolutions per minute. Other bacteria have motors that spin even faster.

Is it an irreducibly complex structure?

"If it could be demonstrated that any complex organ existed which could not possibly have been formed by

numerous, successive, slight modifications, my theory would absolutely break down."

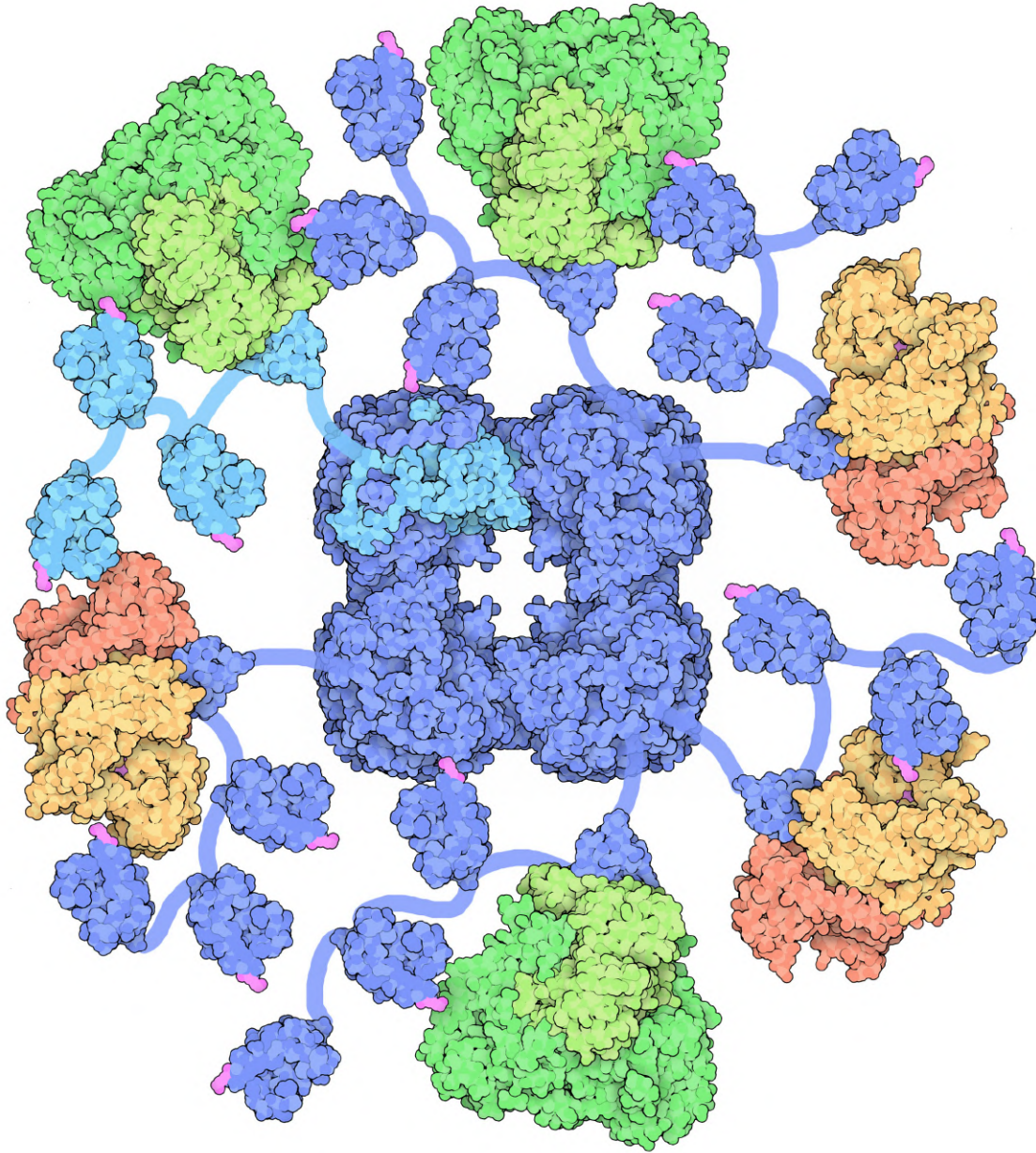
--Charles Darwin, Origin of Species

PDB Molecule of the Month

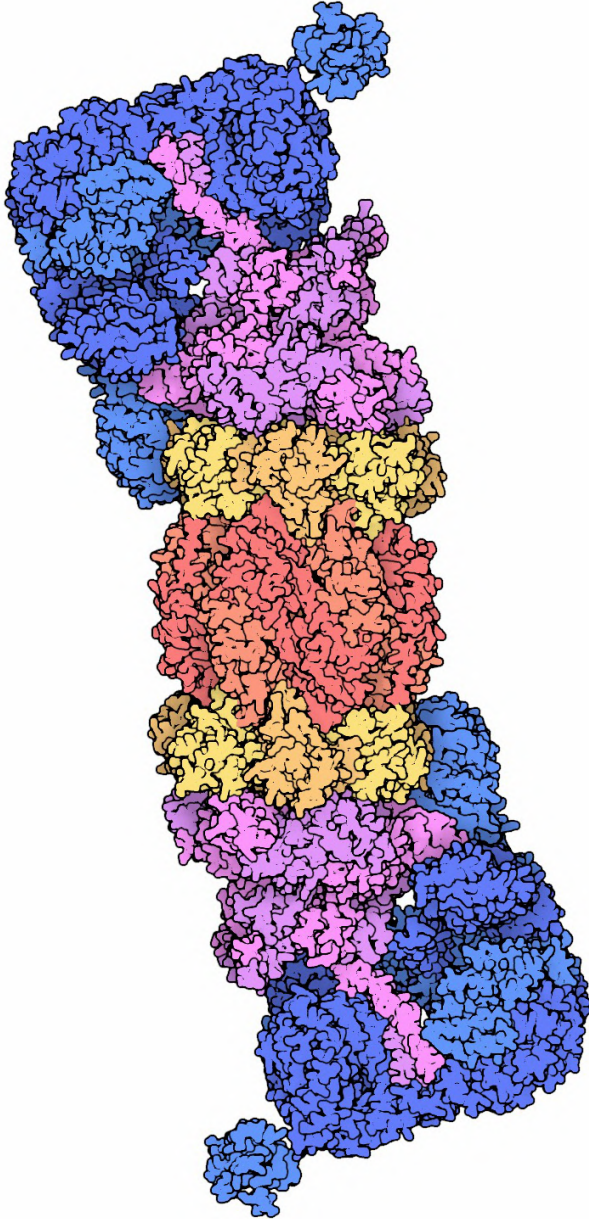
Optional Extra (not required for the IB exam)

pyruvate dehydrogenase complex

[animation](#)



Optional Extra (not required for the IB exam)

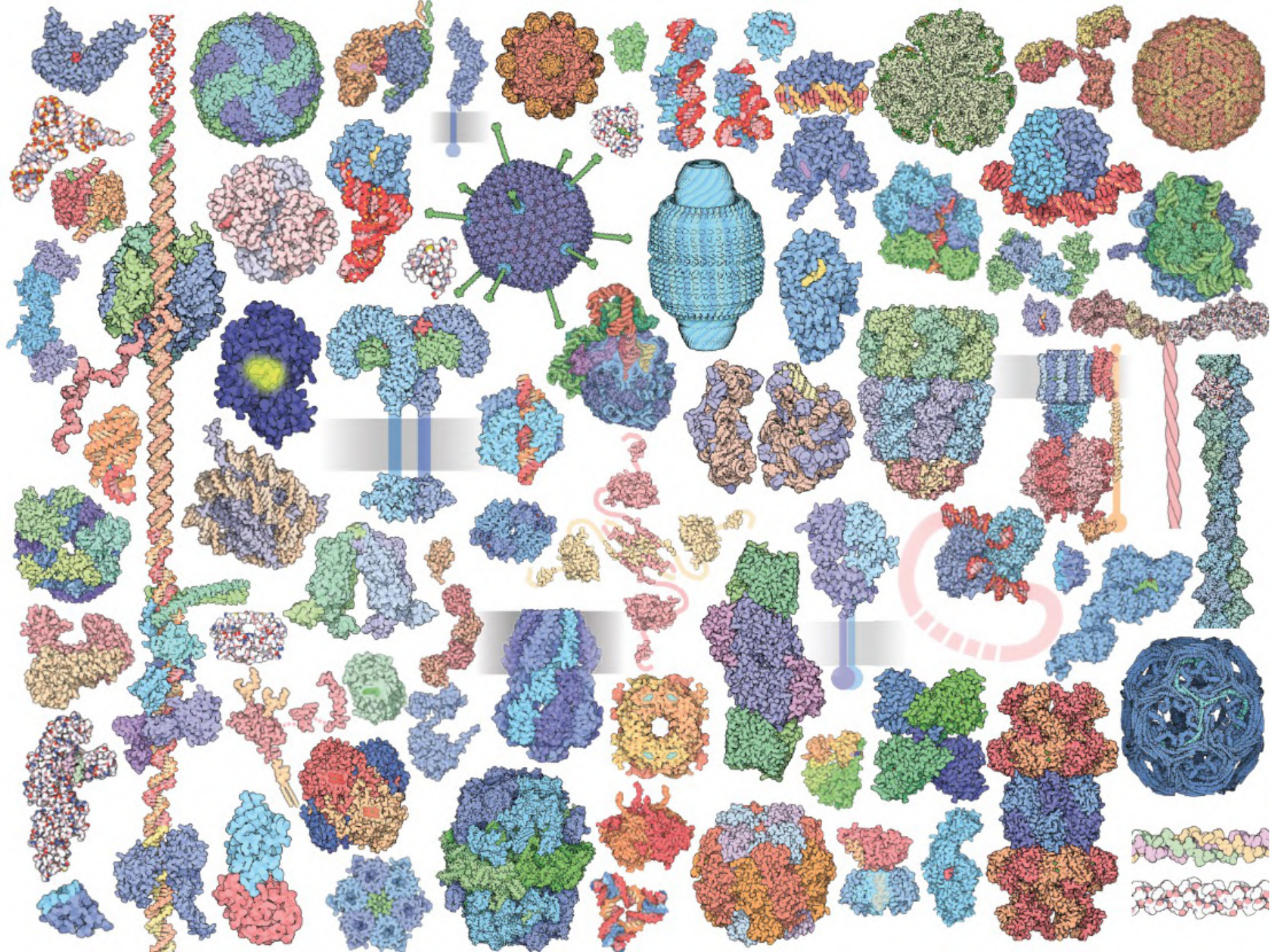


Proteasome - recycler of proteins

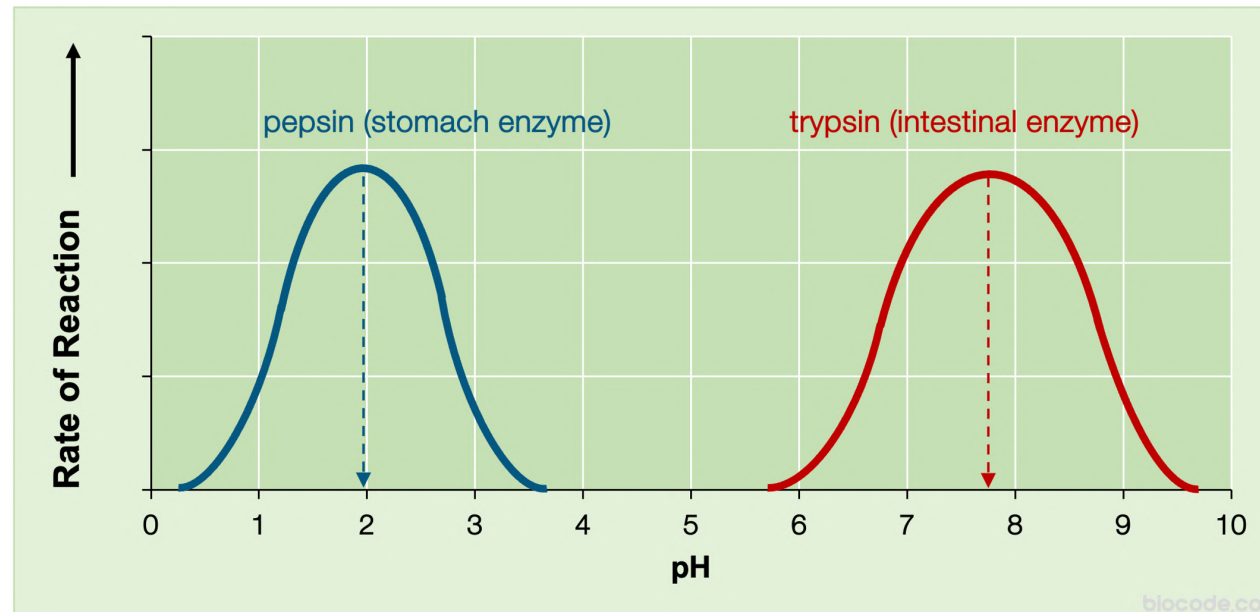
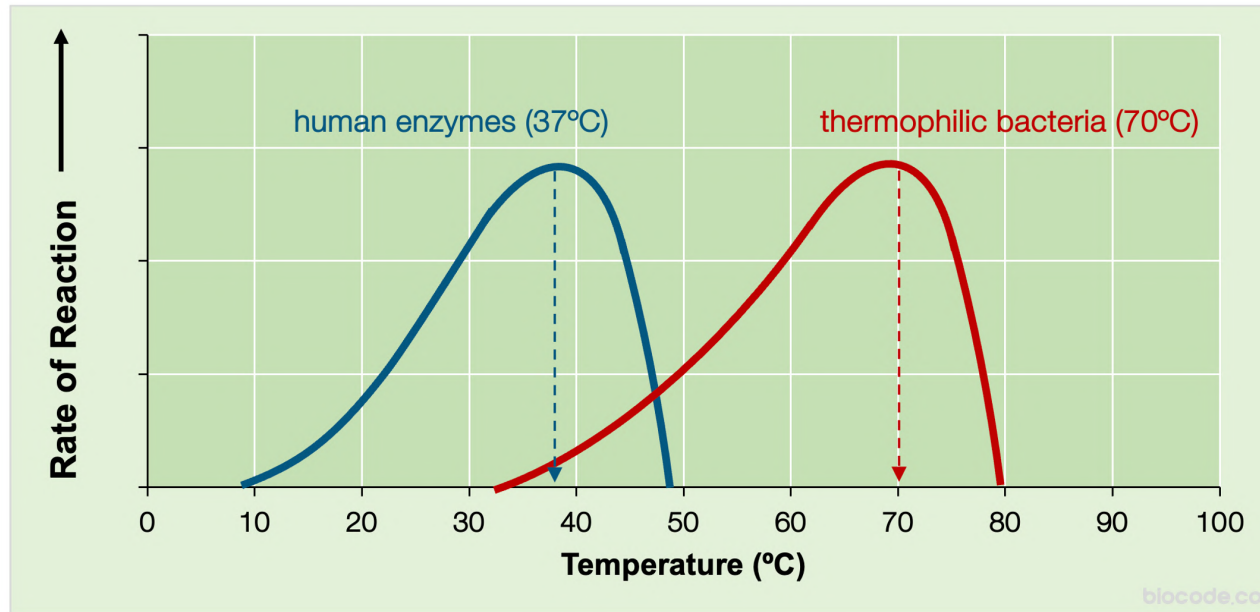
Proteins need to be destroyed for many reasons: they may be damaged, or they may be part of an invading virus, or they simply may not be needed any more. Proteasomes provide a controlled method for breaking down proteins safely within the environment of the cell. They chop obsolete or damaged proteins into small pieces, about 2 to 25 amino acids in length.

[animation](#)

Nature, in order to carry out the marvelous operations in animals and plants, has been pleased to construct their organized bodies with a very large number of machines.... Machines will be eventually found not only unknown to us but also unimaginable by our mind.
Marcello Malpighi, 1697

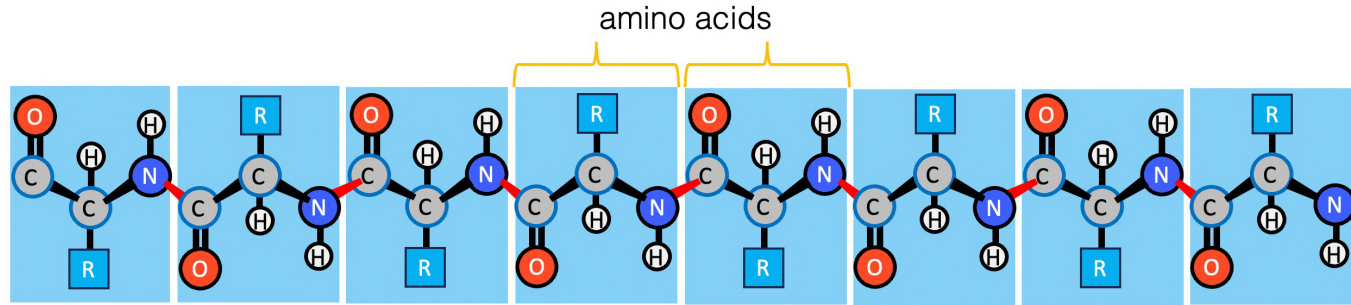


Effect of pH and Temperature

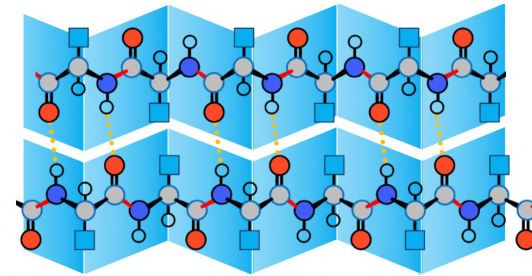
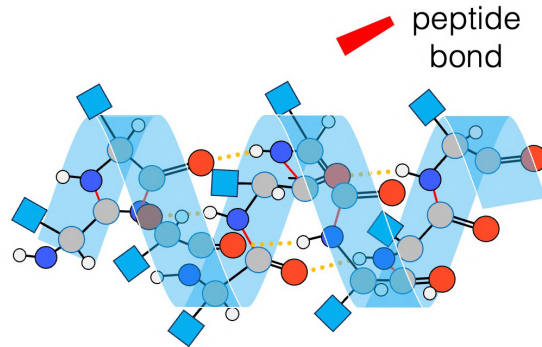


Proteins have four levels of structure

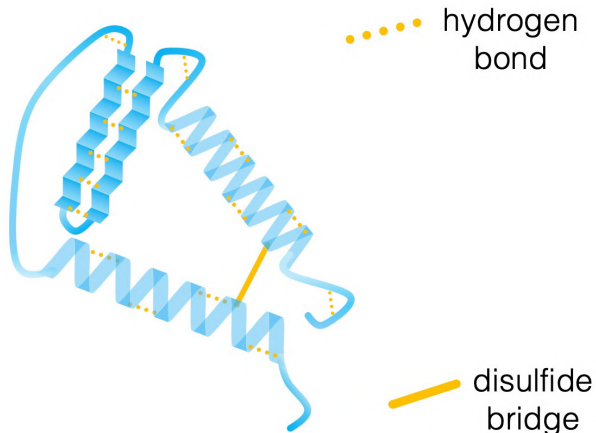
**primary
structure**
polypeptide



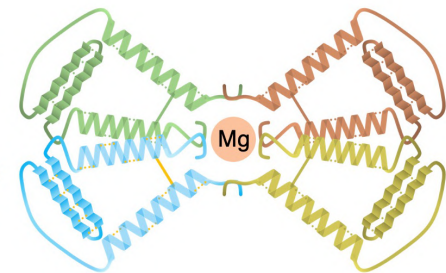
**secondary
structure**
 α helix
 β sheet



**tertiary
structure**
fully folded
polypeptide



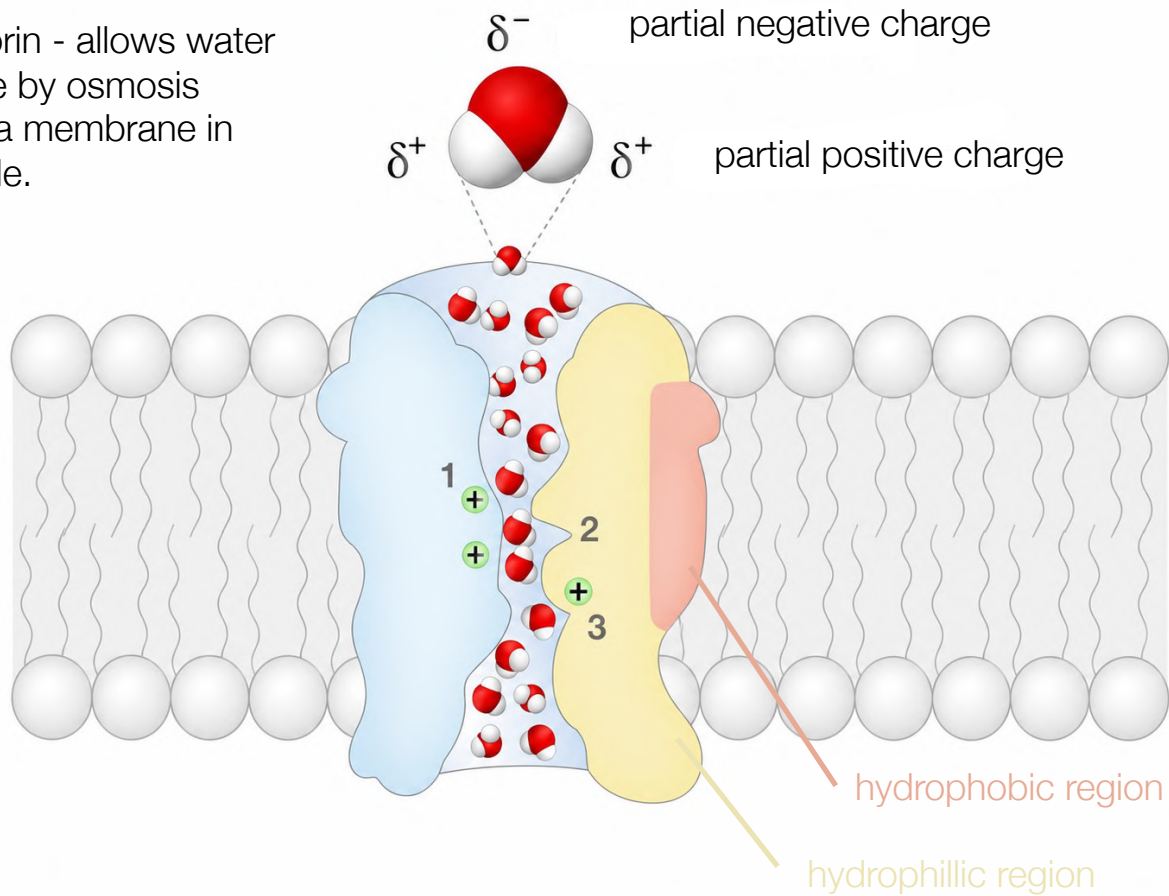
**quaternary
structure**
larger protein with
two or more
polypeptide
subunits, may have
non-protein
molecules



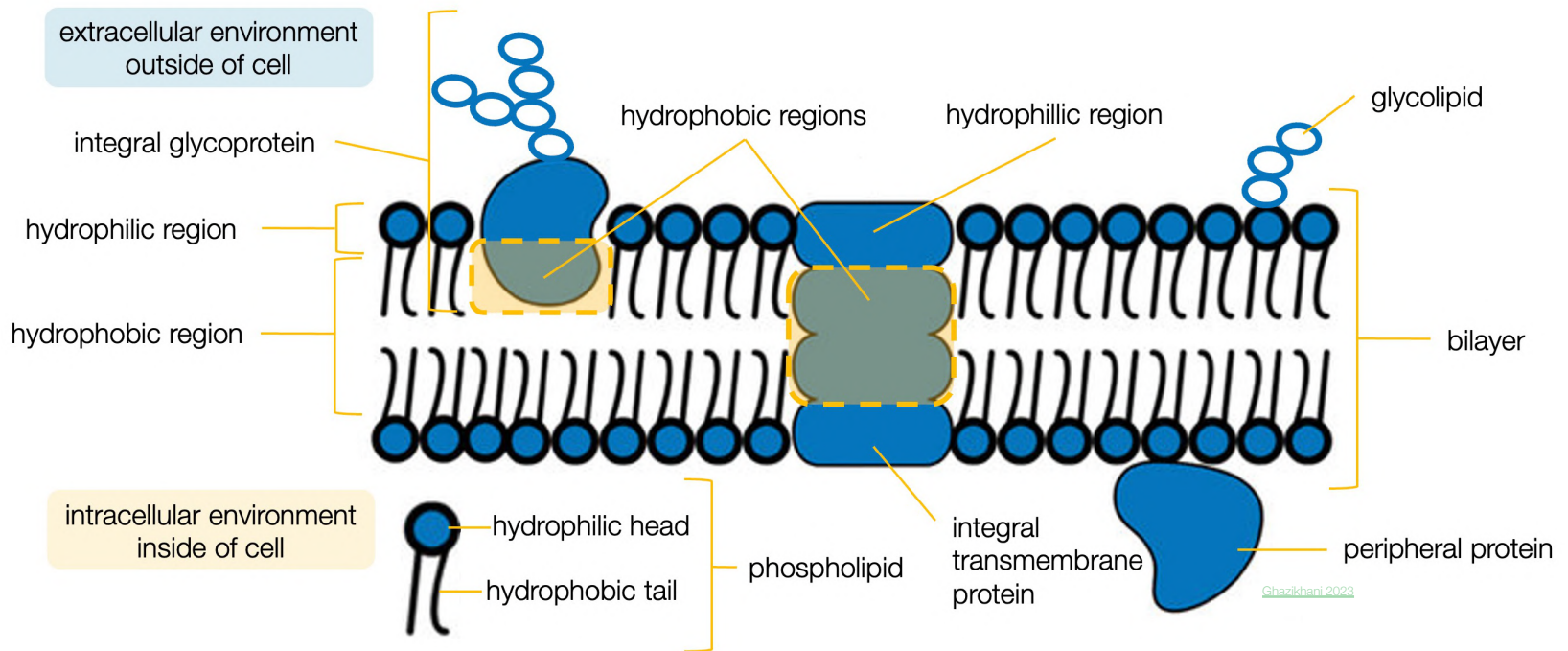
biocode.co

Effect of polar and non-polar amino acids on protein structure

Aquaporin - allows water to move by osmosis across a membrane in single file.



Effect of polar and non-polar amino acids on protein structure

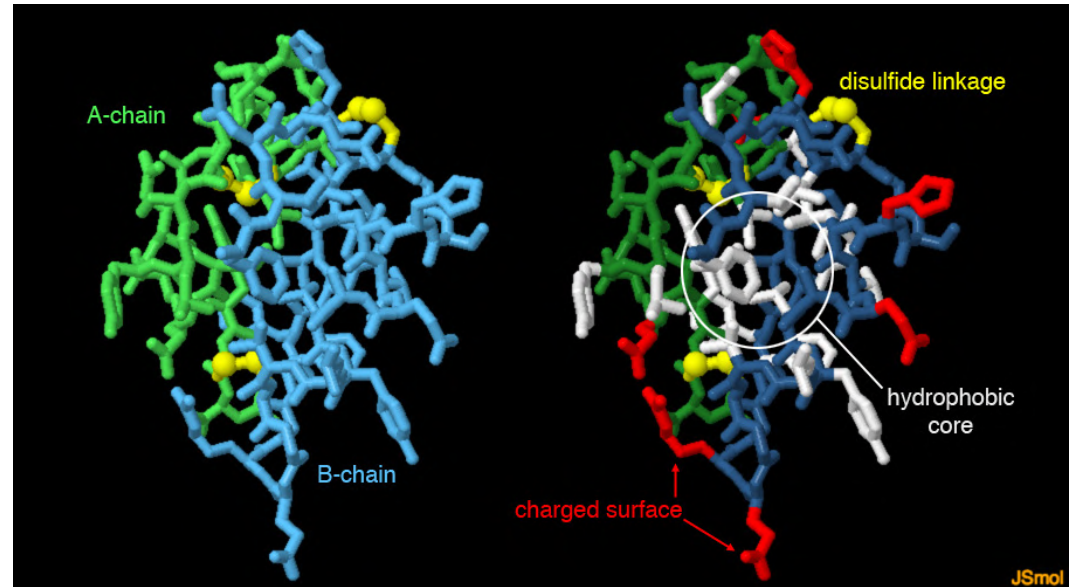


[animation](#)

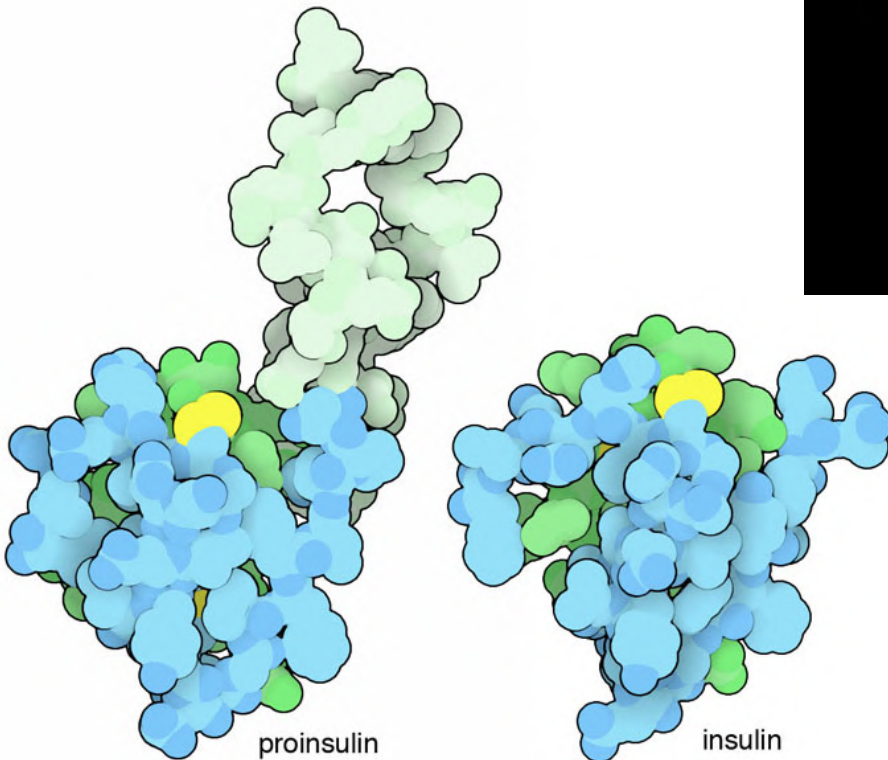
Example of a non-conjugated protein

insulin

Insulin is a globular protein with a hydrophobic core.

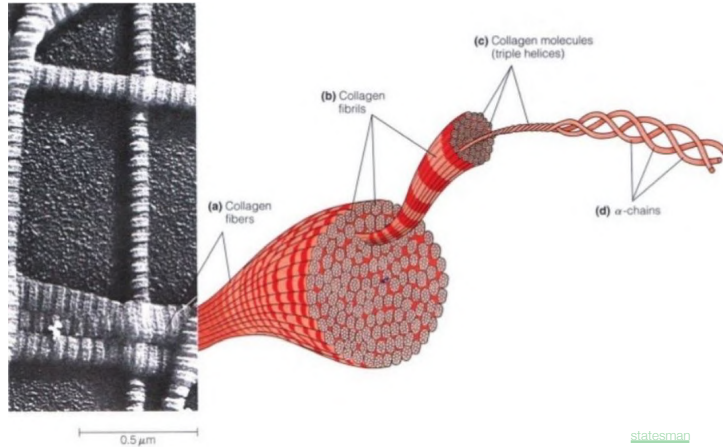


[PDB](#)

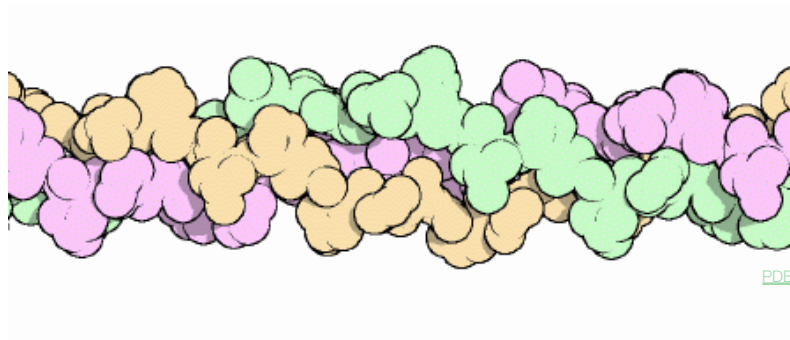


Example of a non-conjugated protein

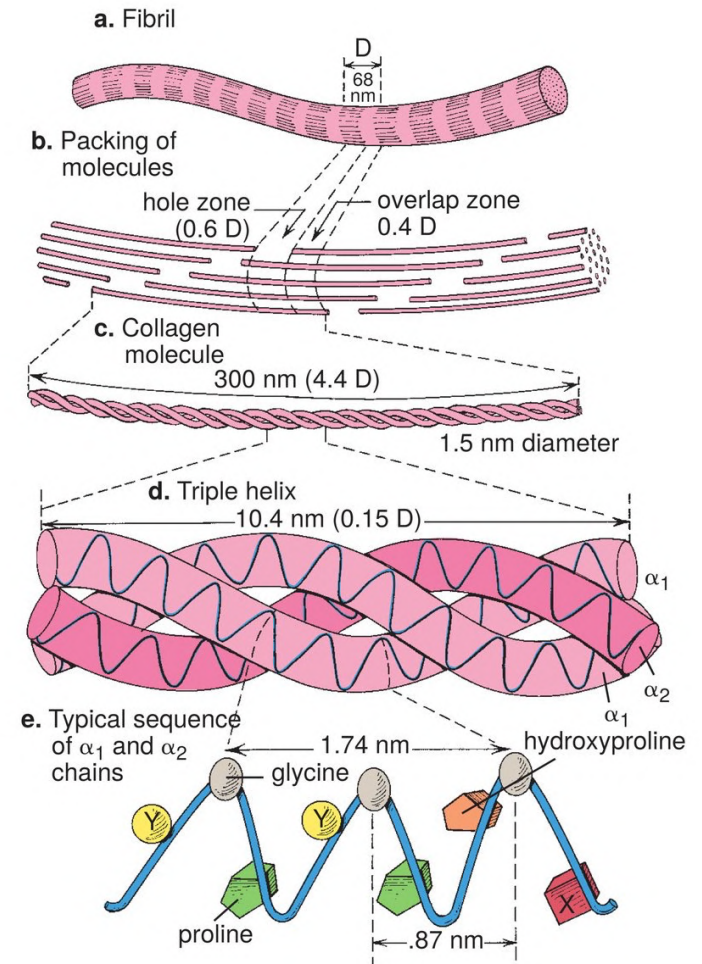
collagen



statesman



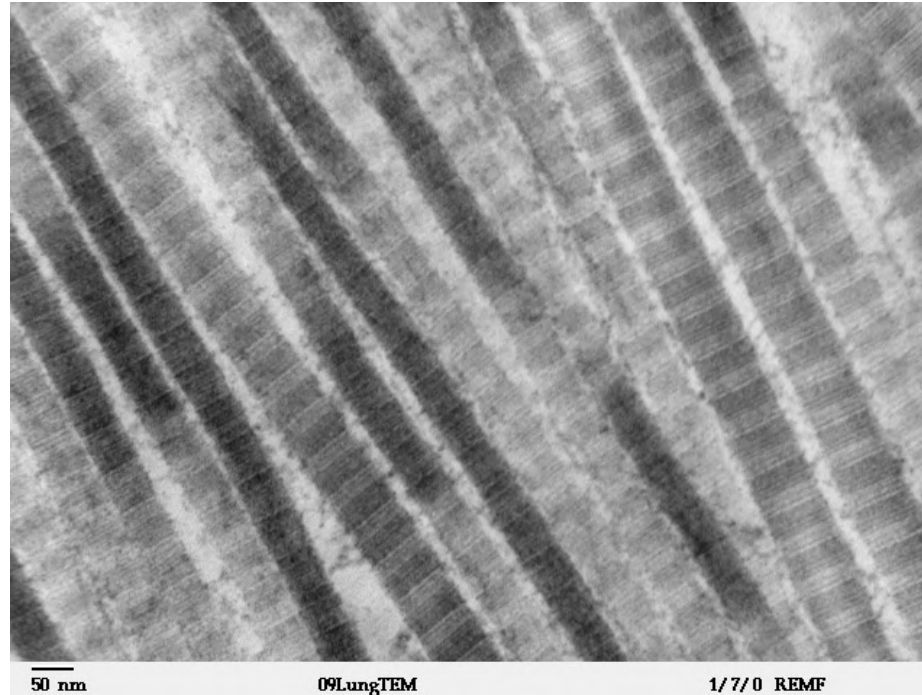
PDB



Guellitkin 2016

Example of a non-conjugated protein

collagen

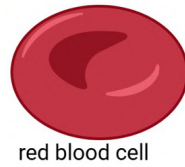


[public domain](#)

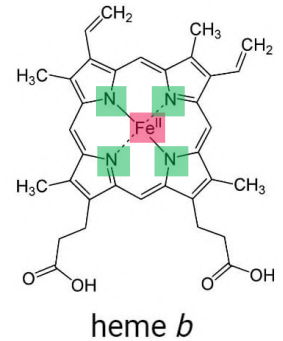
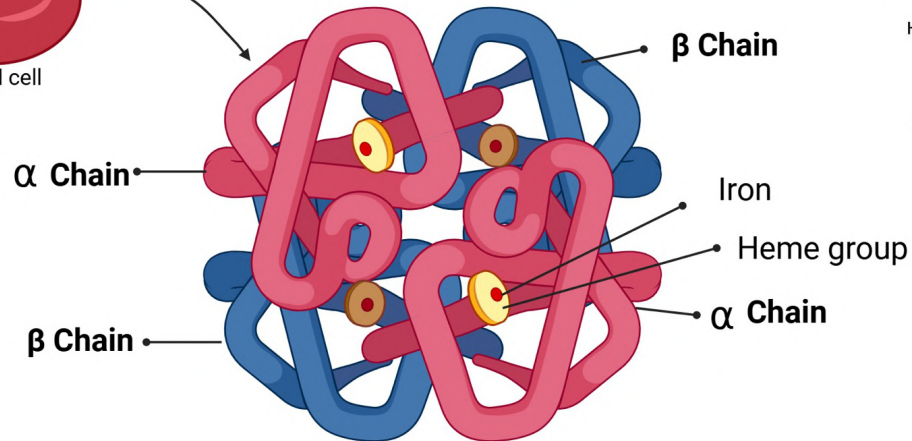
Transmission electron microscope image of a thin section cut through an area of mammalian lung tissue. The high magnification image of connective tissue area shows fibers of Collagen Type I

Example of a conjugated protein

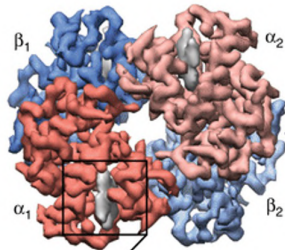
hemoglobin



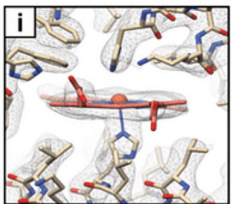
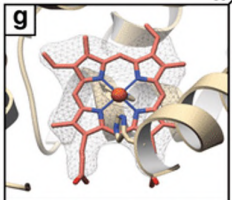
red blood cell



heme b

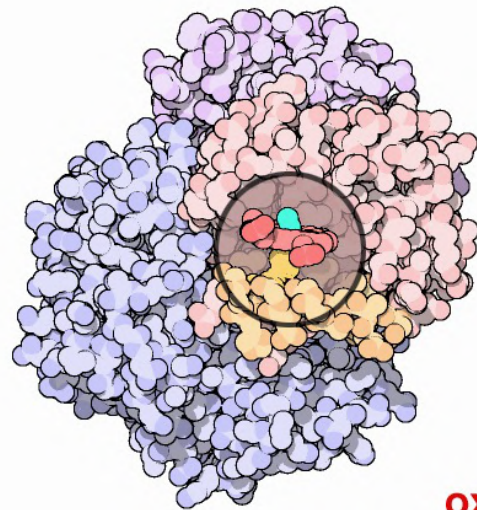


90°



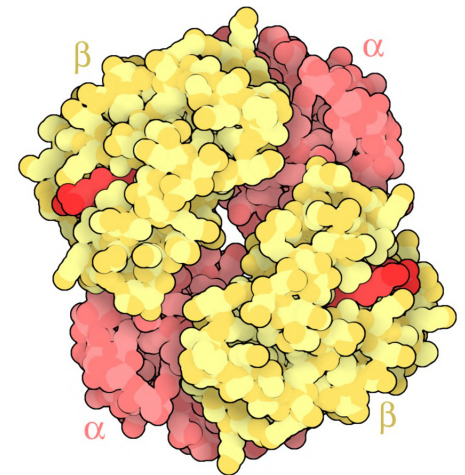
Adapted from Herzik et al 2019

Cryo-EM image of hemoglobin
(g,i) haeme groups



oxy

[animation of conformational change](#) during oxygen binding



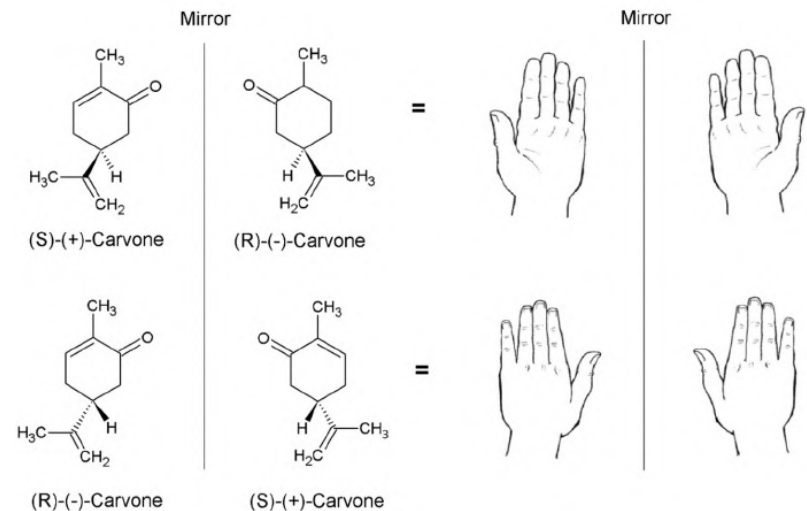
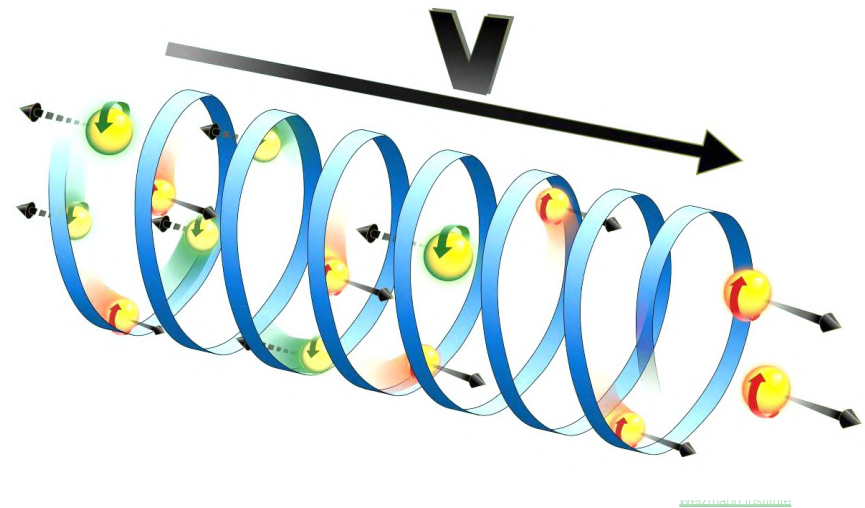
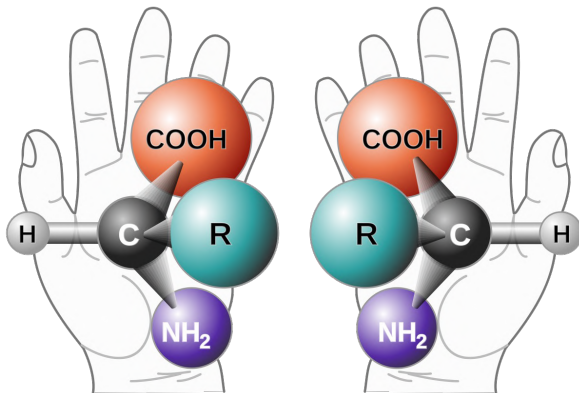
PDB

Optional Extension (not required for IB exams)

Molecules show chirality or handedness. They have the same formula but are a mirror image of each other. Amino acids in cells are all left-handed. It allows for chiral spin of electrons for efficient metabolic reactions that release less heat. For example, the human brain performs many calculations per second continuously like a supercomputer on just 20W of energy.

How did chirality in biological systems gradually evolve? Tantalising evidence suggests molecules *may* have aligned all one way on rock that was magnetic. In the lab using magnets it was found that short RNA molecules sorted into a right-handed form with a purity of 60% that led to crystal growth with molecules only of one handedness.

One concern is that the applied magnetic field was some 6500 times stronger than Earth's own field, cautions Noémie Globus, a physicist at the University of California, Santa Cruz, whose own work supports cosmic rays as the source of life's chiral bias. "It requires conditions that are quite unrealistic," she says. [Science](#)



Chiral Carvone (1)

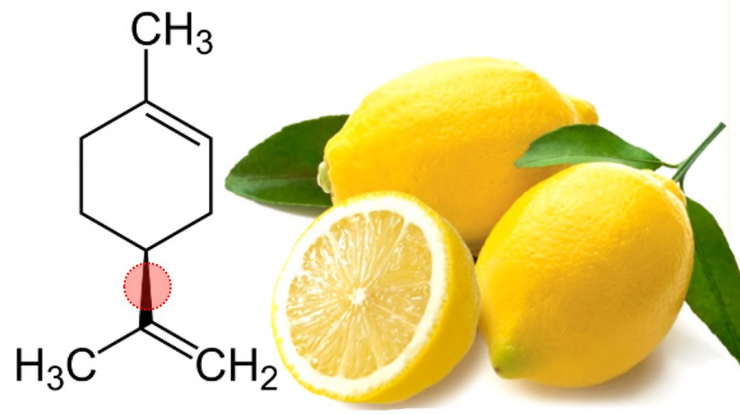
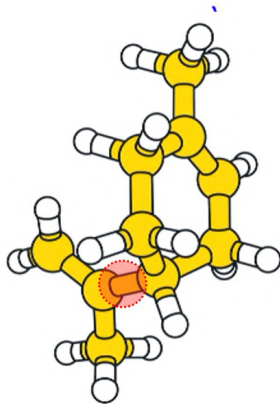
Chiral = Hands

amino acids in living things are all left-handed

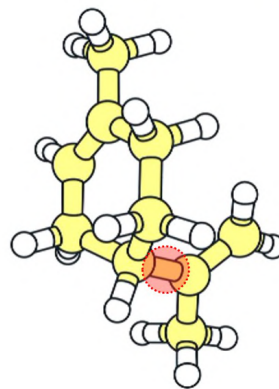
Optional Extension (not required for IB exams)



(+)- limonene
orange
smell



(-)- limonene
lemon
smell



Optional Extension (not required for IB exams)

Proteins denature when an organism dies due to changes in pH, temperature and chemical reactions.

However, proteins have been discovered in dinosaur bone dated to 65 million years old.

This seems to defy our scientific understanding of protein decay.

Even collagen the toughest protein is completely degraded by 4 million years under ideal conditions.

The kinetic energy of particles eventually over millions of years would pull a protein apart.

Yet, scientists have discovered: collagen, tropomyosin, actin, histones, tubulin and myosin proteins in blood vessels removed from carefully dissolved dinosaur bones that were over 80 million years old.

These findings do not support the hypothesis that dinosaurs are millions of years old.

*“That leaves us with two alternatives for interpretation:
either the dinosaurs aren’t as old as we think they are,
or maybe we don’t know exactly how these things get preserved.”
Mary Schweitzer*

Biochemists seek to explain the presence of protein and suggest preservation methods such as by:

- o iron from hemoglobin in the bone causing stable crosslinks in the polypeptides
 - ostrich protein soaked in lysed blood cells lasted 2 years when stored at a set temperature - but real dinosaur bones are scattered and not soaked in blood or kept cool
- o iron from acidic ground water but the low pH would degrade the protein
- o crusty brown oxidation end products can cause crosslinking and make the bone waterproof
 - however, many dinosaur bones are not brown and the protein is soft and stretchy

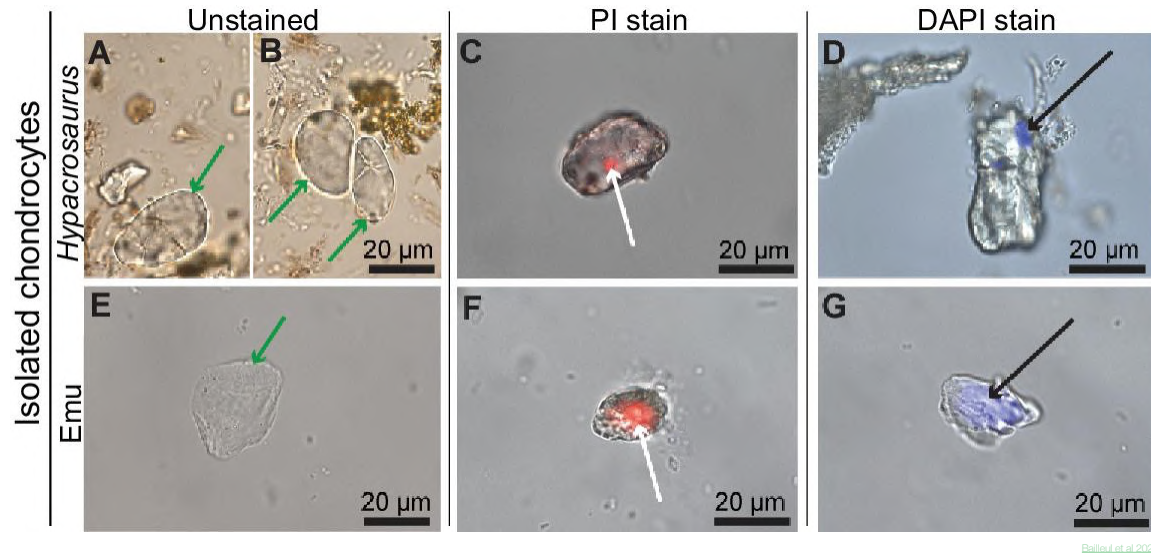
There is another challenge to keep in mind.

All fossil bones *absorb* ground radiation and after millions of years the radiation would have destroyed all biomolecules even if iron or other substances are present.

More incredible discoveries are being made including bone *cells*, elastic tissue and blood vessels in a *Triceratops* [horn](#). Many discoveries are waiting to be made.

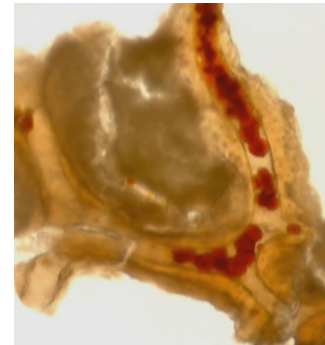


Optional Extension (not required for IB exams)



Chondrocyte cells are found in cartilage tissue.

Chondrocytes from an *Hypacrosaurus* dinosaur bone and an Emu are used for a comparison to show their positive response to two DNA stains.



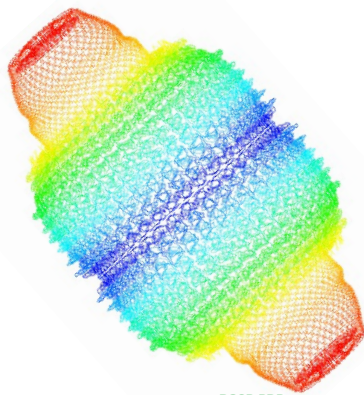
Dr. Mary Schweitzer Presentation NC Museum of Natural Sciences

Blood vessel taken from a *T. rex* fossilized bone 66 million years old.

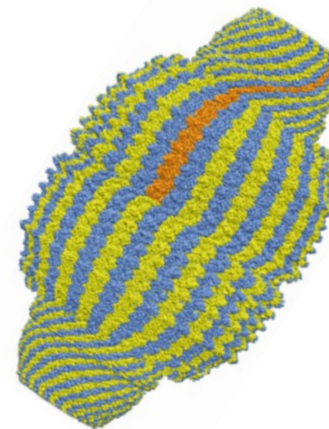


Amalino 2016

Osteocyte (bone cell) taken from a *Triceratops* horn. Scale bar is 5 μm.



RCSB PDB

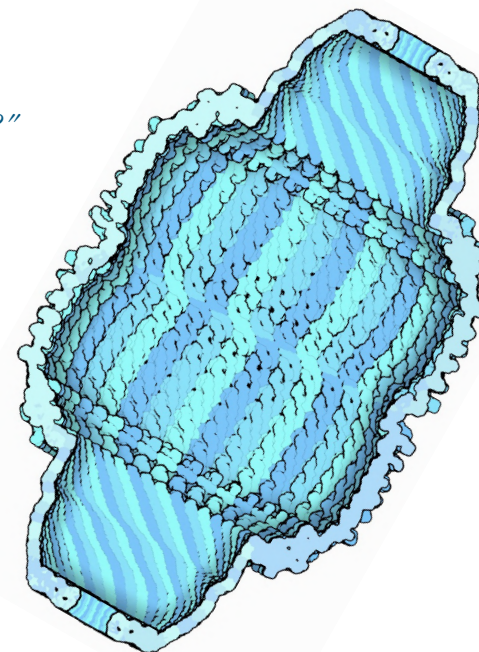
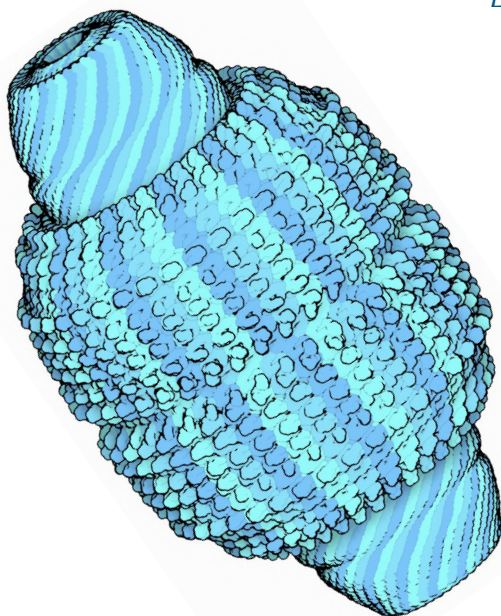


RCSB PDB

Tirocinium

William Cowper

*Thus form'd, thus placed, intelligent, and taught,
Look where he will, the wonders God has wrought,
The wildest scorner of his Maker's laws
Finds in a sober moment time to pause,
To press the important question on his heart,
"Why form'd at all, and wherefore as thou art?"*



RCSB PDB

