Metabolism of Biomolecules

NOTEWORTHY SCIENCE
MARIER

Learning Outcomes

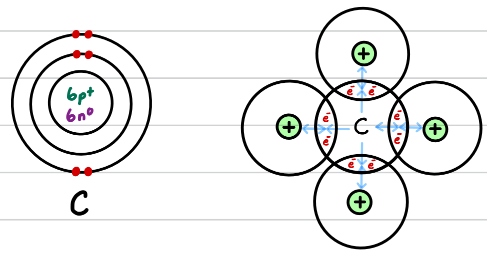
- *4.1.1* – **List** the chemical elements that make up: carbohydrates, fats and proteins
- *4.1.2* – **State** that large molecules are made from smaller molecules, limited to:
  a) Starch, glycogen and cellulose from glucose
  b) Proteins from amino acids
  c) Fats and Oils from fatty acids and glycerol
- *4.1.4* – **Describe** the structure of a DNA molecule:
  a) Two strands coiled together to form a double helix
  b) Each strand contains chemicals called bases
  c) Bonds between pairs of bases hold the strands together
  d) The bases always pair up in the same way: A with T, and C with G
- *5.1.1* – **Describe** a catalyst as a substance that increases the rate of a chemical reaction and is not changed by the reaction
- *5.1.2* – **Describe** enzymes as proteins that are involved in all metabolic reactions, where they function as biological catalysts
- *5.1.3* – **Describe** why enzymes are important in all living organisms in terms of a reaction rate necessary to sustain life
- *5.1.4* – **Describe** enzyme action with reference to the shape of the active site of an enzyme being complementary to its substrate and the formation of products
- *5.1.6* – **Explain** enzyme action with reference to: active site, enzyme-substrate complex, substrate and product
- *5.1.7* – **Explain** the specificity of enzymes in terms of the complementary shape and fit of the active site with the substrate
- *5.1.8* – **Explain** the effect of changes in temperature on enzyme activity in terms of kinetic energy, shape and fit, frequency of effective collisions and denaturation
- *5.1.9* – **Explain** the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation
- *7.1.2* – **State** the principal dietary sources and **Describe** the importance of:
  a) carbohydrates
  b) fats and oils
  c) proteins

Biomolecules

Biomolecules: molecules found in living organisms which are essential to living processes

All biomolecules contains the element carbon, this is why life is said to be "carbon-based" → why does carbon provide so much variety?

- ↳ Carbon contains 4 valence electrons, allowing it to form 4 covalent bonds with other atoms
- ↳ covalent bonds can be single (·Ċ−A), double (·C=A), or triple (·C≡A)
- ↳ carbon forms bonds with itself and with other atoms
- ↳ molecules can be linear, cyclical, branched and thousands of atoms large, creating endless combinations



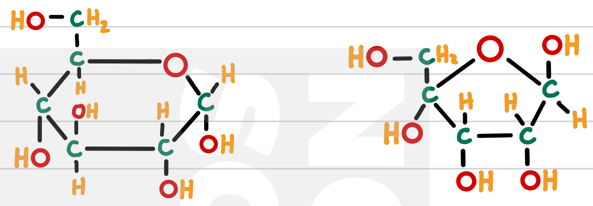
Biomolecules fall into 4 major groups: ① carbohydrates (sugars) ② lipids (fats) ③ proteins ④ nucleic acids

↳ these exist as simple single units, **monomers**, and can combine together to form larger more complex **polymers**

CARBOHYDRATES

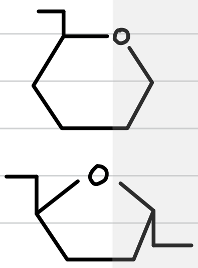
Composition: all carbohydrates contain carbon, hydrogen, and oxygen only

Structure: most carbohydrates form ring-like structures

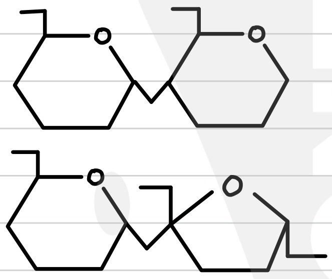


↳ Monomer: **monosaccharide** ⟷ dimer: **disaccharide** ⟷ polymer: **polysaccharide**

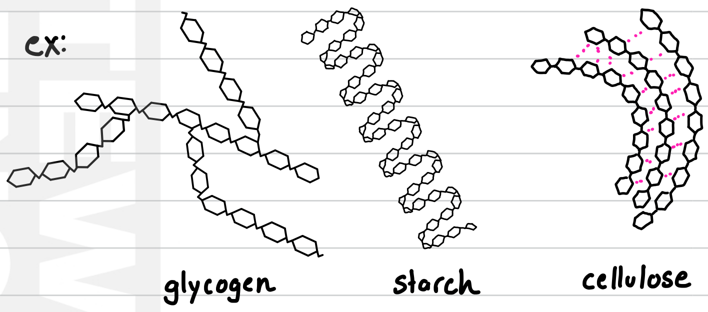
ex: glucose, galactose, fructose



ex: maltose, lactose, sucrose



ex:



properties: mono and disaccharides are polar and are freely soluble in water
↳ useful for transport in organisms

glycogen + starch can be easily formed and broken ↓ short-term energy storage

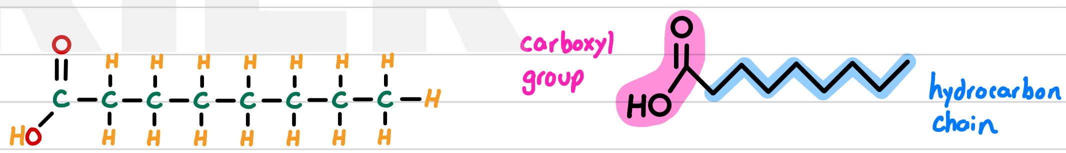
cellulose has very high tensile strength ↓ forms plant cell walls

function/uses: broken down during respiration for energy (most daily energy comes from carbs)

Sources:

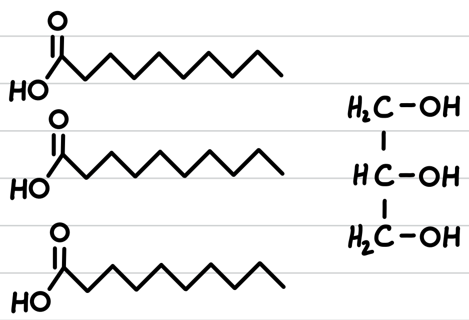
LIPIDS

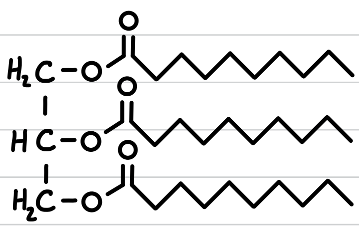
Composition: all lipids contain carbon, hydrogen, and oxygen only



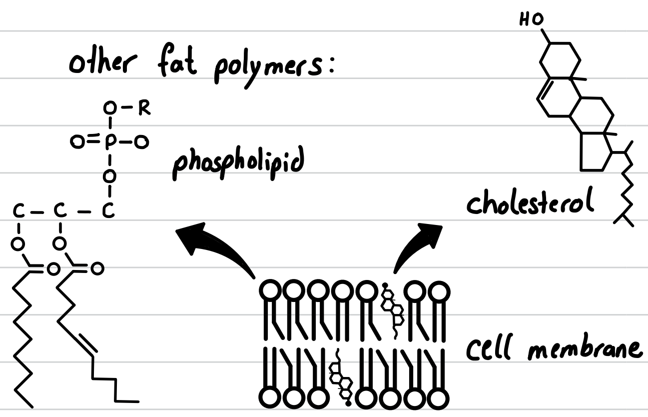
Structure: most contain fatty acids (which are bound to other groups)

↳ Monomer: **fatty acids** (3) + **glycerol** ⟷ polymer: **triglyceride**



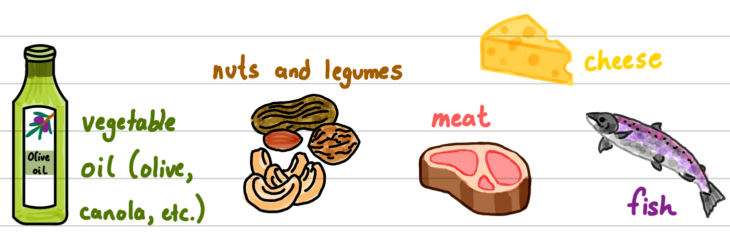


other fat polymers:



properties: non-polar and not water soluble. More difficult to break down but energy-rich

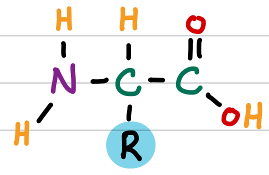
Sources:



function/uses: broken down during respiration for energy when needed (long-term energy storage)
used as protection of organs and insulation for electricity (nerves) and heat

Biomolecules

PROTEINS

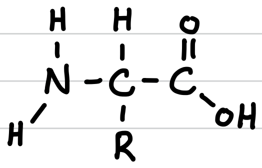


20 different 'R' groups which can contain S

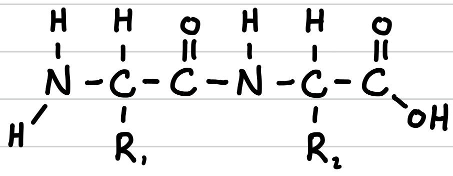
Composition: all proteins contain carbon, hydrogen, oxygen, and nitrogen (and sometimes sulfur)

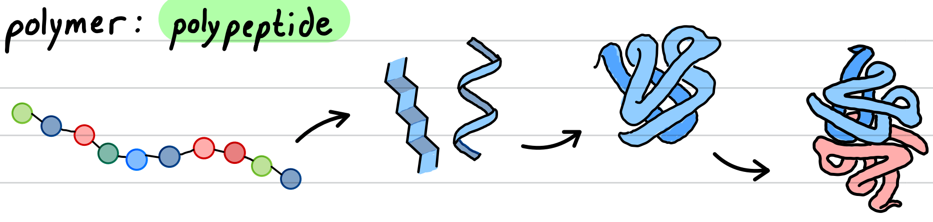
Structure: proteins are made of 1 or more chains of amino acids

↳ Monomer: amino acid ⟷ dimer: dipeptide ⟷ polymer: polypeptide



20 different amino acids





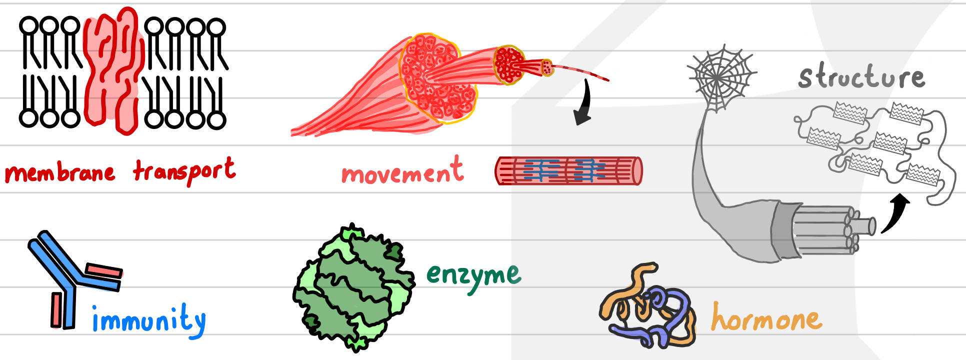
polypeptides can fold into various structures

properties: amino acids are typically soluble in water

the order of amino acids determines the 3-D structure of the protein: different structure, different protein

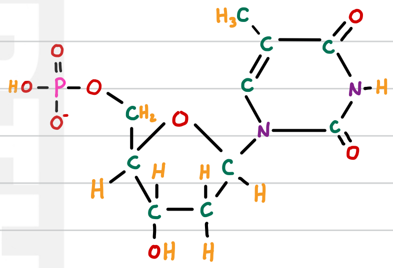
↳ proteins are the most diverse biomolecule

function/uses: proteins have many functions such as:



Sources:

NUCLEIC acids

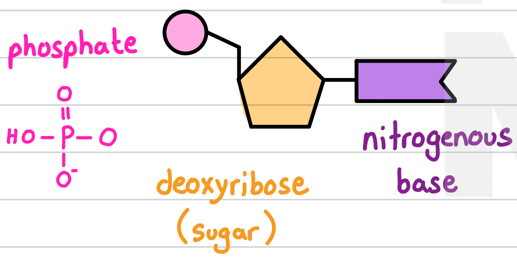


Composition: all nucleic acids contain carbon, hydrogen, oxygen, nitrogen and phosphorus only

Structure: nucleotides form long chains. Two main types: DNA and RNA

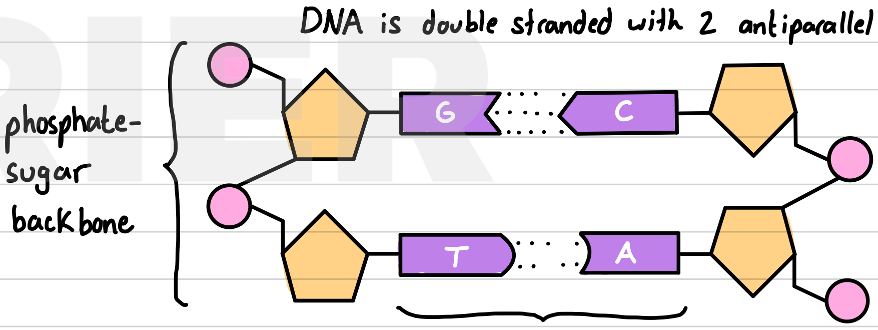
↳ Monomer: nucleotide ⟷ polymer: polynucleotide (DNA)

↳ Deoxyribonucleic acid



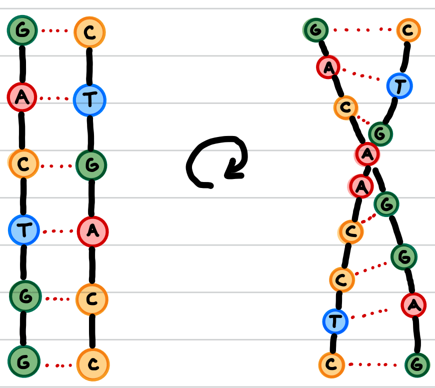
4 different bases:
- Adenine (A)
- Thymine (T)
- Cytosine (C)
- Guanine (G)

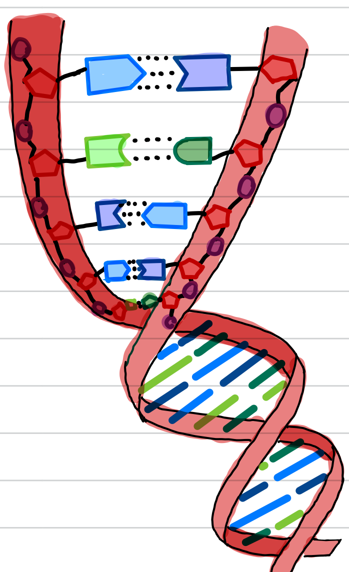
DNA is double stranded with 2 antiparallel strands



complementary base pairs hold strands together (A only hydrogen bonds with T, C only hydrogen bonds with G)

properties: DNA twists into a double helix structure





function/uses: the order of nucleotide bases (A, A, T, C...) provides instructions to make proteins *

As proteins are involved in nearly as aspects of cellular functions, DNA is crucial and referred to as the 'molecule of life'

Sources: as DNA is found in nearly all cells, nucleic acids are present in virtually all foods

* more on this in unit 2

Enzymes and Metabolism

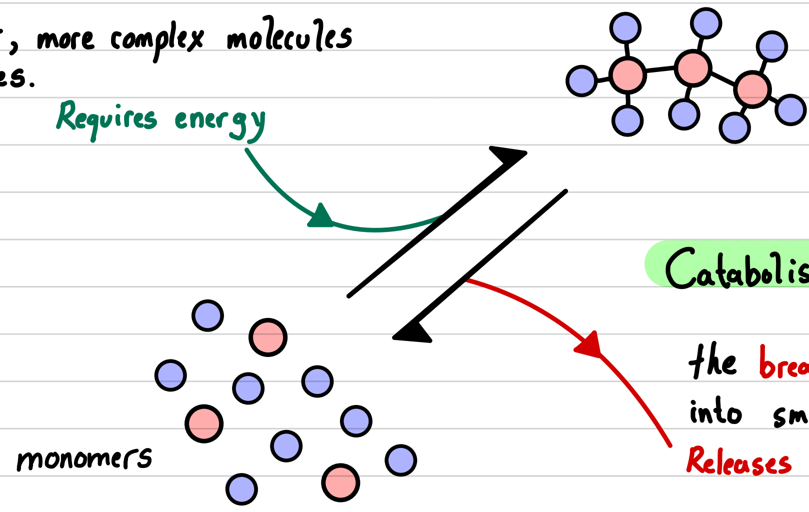
Most chemical reactions occuring in cells can be classified as either:

Anabolism:

the synthesis of larger, more complex molecules from smaller, simpler ones.

Requires energy

ex: photosynthesis
building muscle
building bone



ex: cell respiration
breakdown of fats, proteins, sugars

Catabolism:

the breakdown of larger, more complex molecules into smaller, simpler ones.

Releases energy

problem: most of these reactions take a long time to occur, so slow that an organism would die waiting!

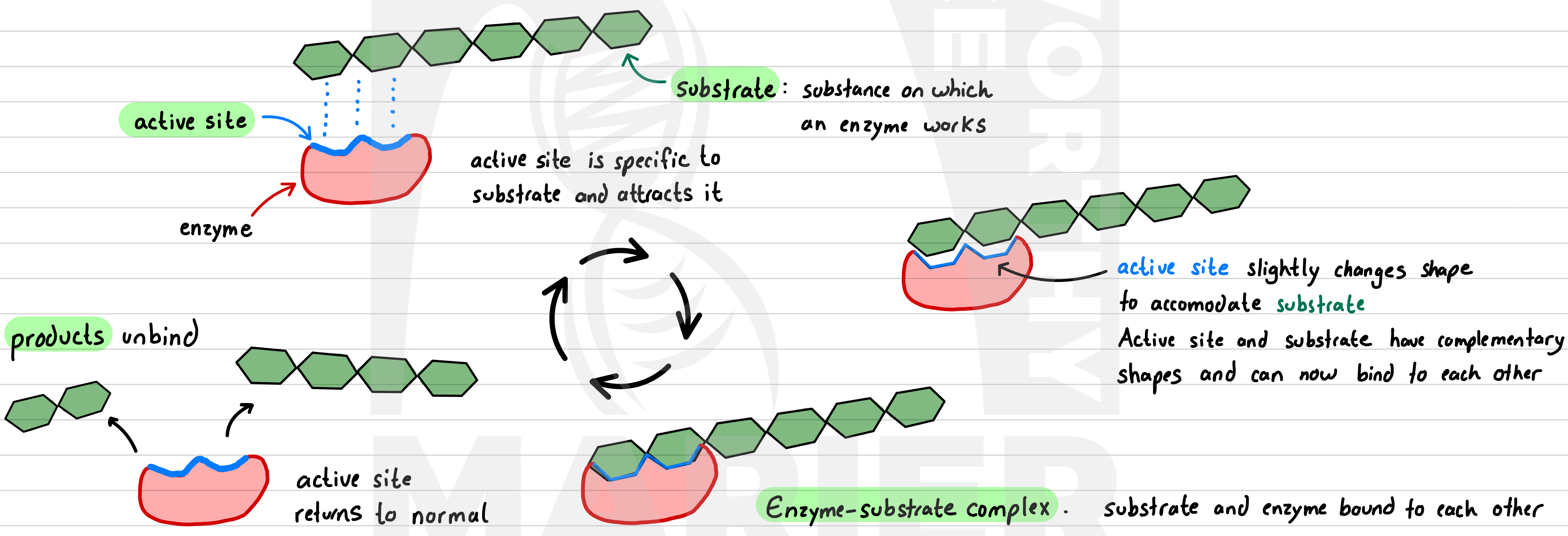
↳ solution = enzymes! The majority of chemical reactions occuring in organisms (both catabolic and anabolic) are regulated by enzymes

Enzymes: proteins that function as biological **catalysts** (a substance that increases the rate of a chemical reaction without being changed)

↳ enzymes facilitate a reaction by making it easier to take place, thus speeding it up
↳ as they do not react, they can be reused over and over (unless they get damaged)

reactant(s) (substrate) —enzyme→ product(s)

Induced-Fit Model of Enzyme activity



* enzyme ready to be reused

Metabolism: web of all enzyme-catalysed reactions in an organism

↳ most metabolic reactions do not occur in a single step, i.e A → B (why?) Too much energy involved to control

ex: cellular respiration $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ if this occured in one step it would be combustion

instead, glucose is broken down into many intermediates by specific enzymes where the energy released can be controlled and stored in usable form → ATP

A → B → C → D → E → F → G → H; G → I → J → K → L; J → M → N

every reaction is catalyzed by a different enzyme

the product becomes the substrate for the following reaction

* without enzymes, reactions would occur too slowly and chaotically to be useful for living organisms *

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Factors Affecting Enzyme Activity

The rate of a chemical reaction is how quickly a reaction proceeds.

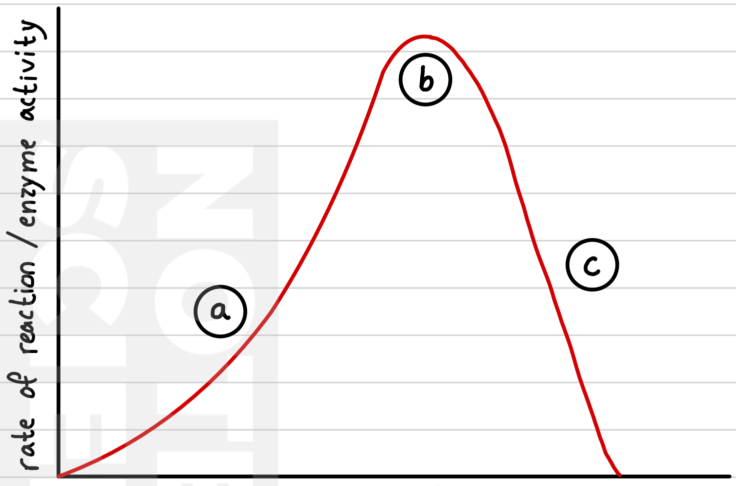
↳ for enzyme-catalyzed reactions, this will depend on how often a substrate collides and binds with an active site

While enzymes are not used up during the reaction they catalyze, their activity (i.e. how quickly they work) is impacted by different environmental conditions

① **Temperature**: the average kinetic energy of particles

↳ as chemical reactions depend on collisions, temperature impacts the force and frequency of these collisions

The impact of rising temperature on enzyme activity

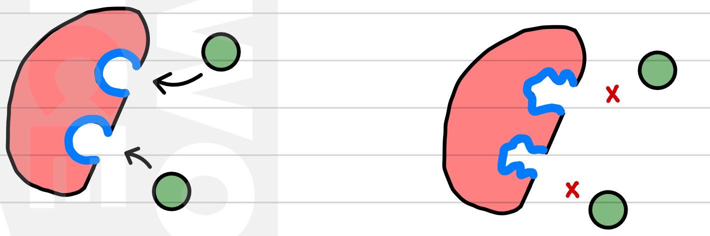


ⓐ as temperature rises, particles have more kinetic energy, meaning they are moving faster → more effective collisions between substrates and the active site of enzymes → more reactions catalyzed over time

ⓑ **the optimum temperature**: temperature at which enzyme activity is at its maximum

ⓒ as the temperature rises above the enzyme's optimum, the high kinetic energy starts to disrupt and alter bonds within the enzyme

↳ this causes the shape of the active site to become permanently altered → **denaturation**. Therefore, the substrate can no longer bind to active site, reducing rate. As temperature increases, more and more enzymes denature. So despite having more collisions, substrates cannot bind



functional enzyme   denatured enzyme

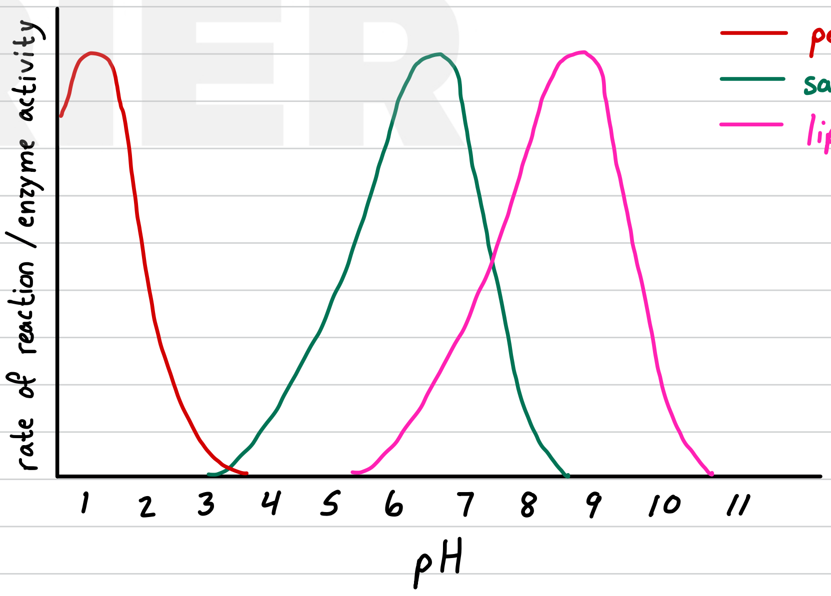
* this is why humans maintain a constant body temperature, in order for enzymes to operate efficiently

② **pH**: a measure of acidity or alkalinity of a solution. The more [H⁺] the more acidic

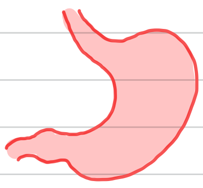
↳ the manner in which proteins fold (structure) is determined by bonding between amino acids. Changing pH alters the chemical environment and can alter these bonds, causing protein shape to temporarily change

The impact of pH on enzyme activity

As different enzymes have different amino acid sequences, their structures and how they bond differs

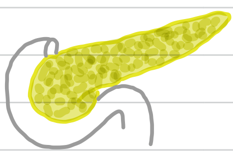


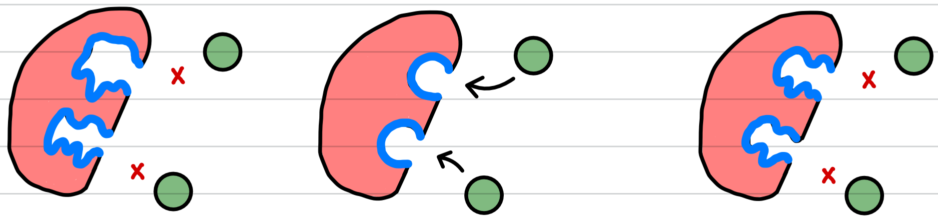
Some enzymes may work optimally in acidic conditions, such as pepsin in the stomach which breaks down proteins



most enzymes in humans work at ~ neutral pH, such as amylase which is secreted in the saliva in the mouth. This breaks down starch into disaccharides

Some enzymes work optimally at alkaline conditions such as lipase, secreted by pancreas which breaks triglycerides into fatty acids + glycerol





too acidic - denatured   optimal pH   too alkaline - denatured

* these will all be explored further in LS - digestive system

Assessment Tasks

Answer the following questions:

① Complete the following table summerizing biomolecules:

Biomolecule	elements present	monomer	polymer	animal food source	plant food source
Proteins					
			triglyceride		
		monosaccharide			
	C, H, O, N, P				

② A DNA sample was analyzed and it was found that it contained 15% Adenine (A).
What percentage of the DNA is Cytosine (C)? Explain your answer.

③ Describe the difference between how nucleotides are bonded to each other and how complementary bases pairs are bonded

④ Research and describe a non-biological catalyst of your choice. What substrate does it act upon and what products are formed?

⑤ Research an anabolic and catabolic enzyme for each biomolecule and complete the following table.

Biomolecule	anabolic enzyme			catabolic enzyme		
	enzyme name	Substrate	product	enzyme name	Substrate	product

⑥ All enzymes have their own optimal conditions. In humans, what temperature would you predict this is? Explain.

⑦ When humans body temperature rises above normal for a prolonged period of time this can be deadly.
Explain why using your understanding of enzymes

⑧ Explain why 1 enzyme cannot catalyze all types of chemical reactions.

⑨ The following diagram is from an enzyme-catalyzed reaction. Label the following.