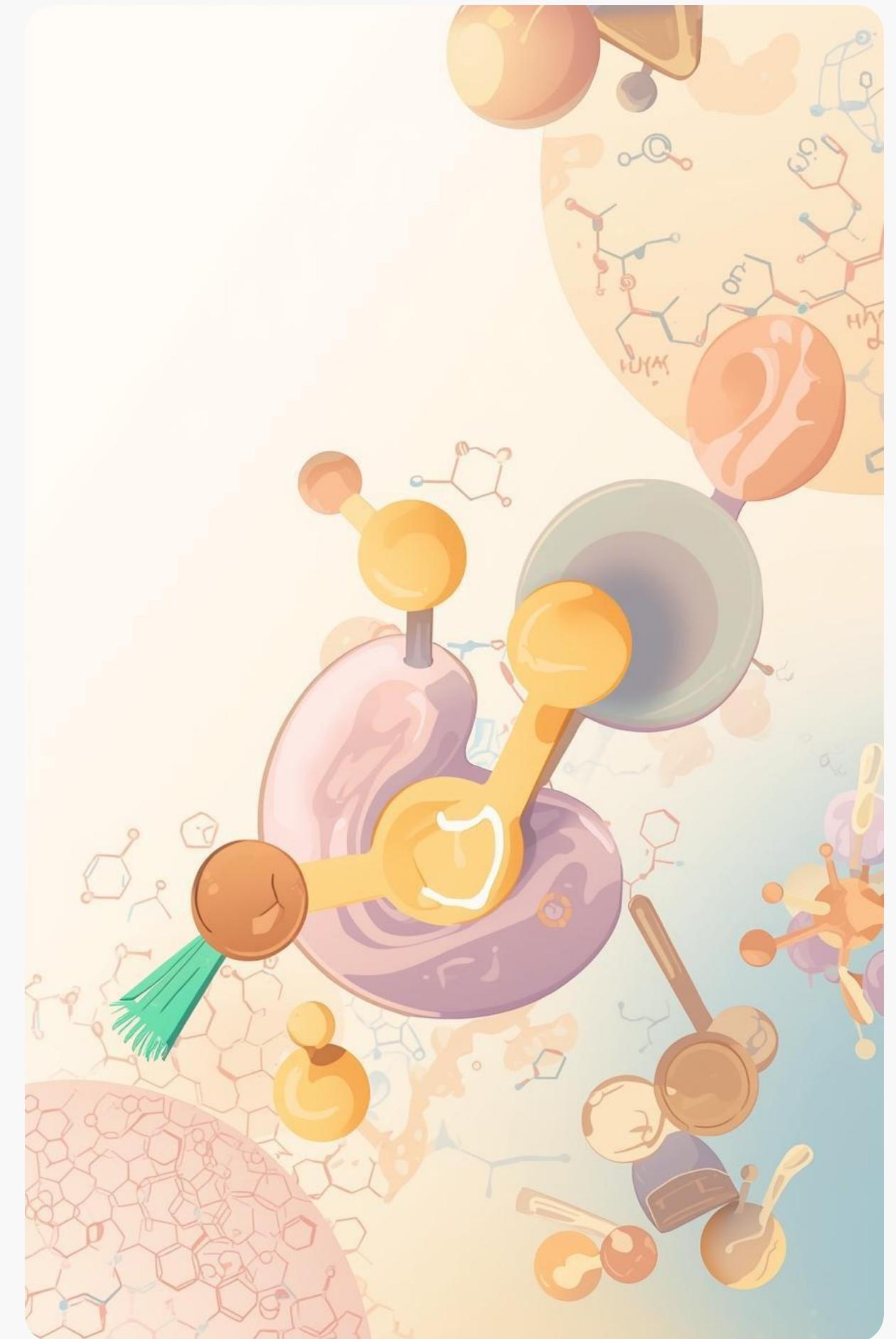


# Enzyme Theory: Biological Catalysts

MYP 4 UNIT 2 LESSON 6





# Objective

To explain what an enzyme is and why the shape of an enzyme is important for how it works.

# Introduction to Enzyme Theory

Enzymes are biological catalysts. This means that they speed up chemical reactions but are not broken down in the process. They are found inside cells and within body systems, such as the digestive system. Some are involved with catabolic reactions, and others with anabolic reactions.

## Here are some facts about enzymes:

- They are made of protein.
- Enzymes end in '**ase**', e.g., protease breaks down protein, carbohydrase breaks down carbohydrates (sugars), and lipase breaks down lipids (fats).
- The part where reactions take place is called the **active site**. The active site has a specific shape.
- Enzymes react with **substrates**. For example, the enzyme amylase (found in saliva and secreted by the pancreas in the digestive system) reacts with the substrate starch.

# Introduction to Enzyme Theory

- When an enzyme and substrate combine, they form an **enzyme-substrate complex**.
- Products are produced by enzyme reactions. For example, the products of starch digestion by amylase are the sugar maltose. Maltose is, in turn, broken down into glucose by the enzyme maltase.
- The way that enzymes react with the substrate is called **the lock-and-key mechanism**.
- The enzyme is the 'lock' which has a specific shape into which one substrate (the 'key') fits.
- Bonds are either broken or formed once the reactants are in the active site, forming new products.

# Enzyme function

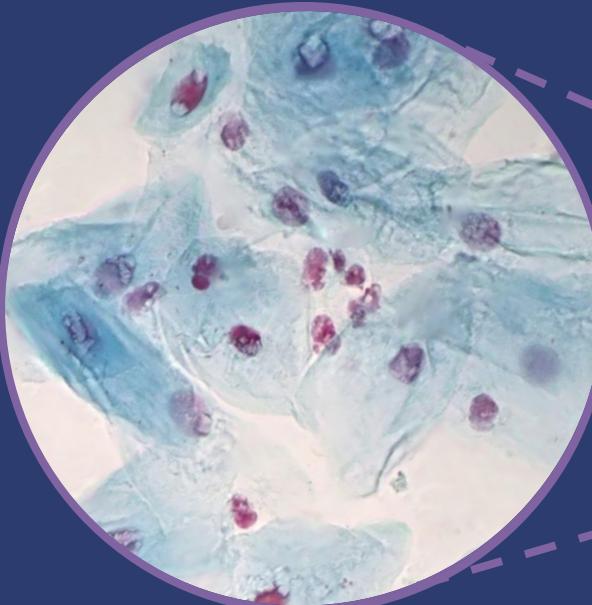
All organisms are made of one or more cells.

All cells contain biological molecules called **enzymes**.

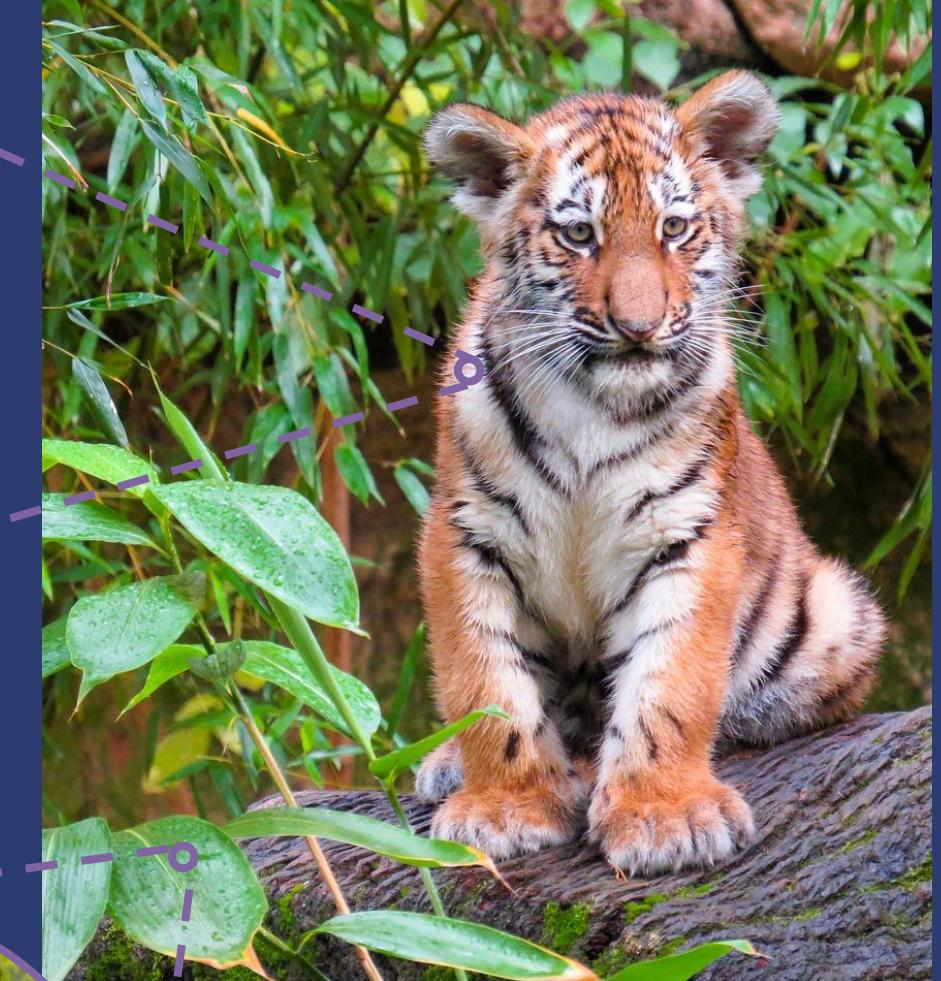
Enzymes are critical for life.

They are essential for all biological processes.

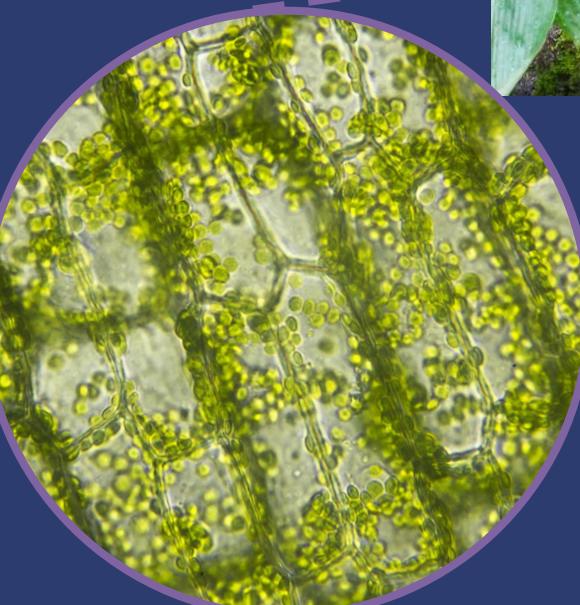
- ❖ **Without enzymes, life on Earth would not exist.**



Animal cells



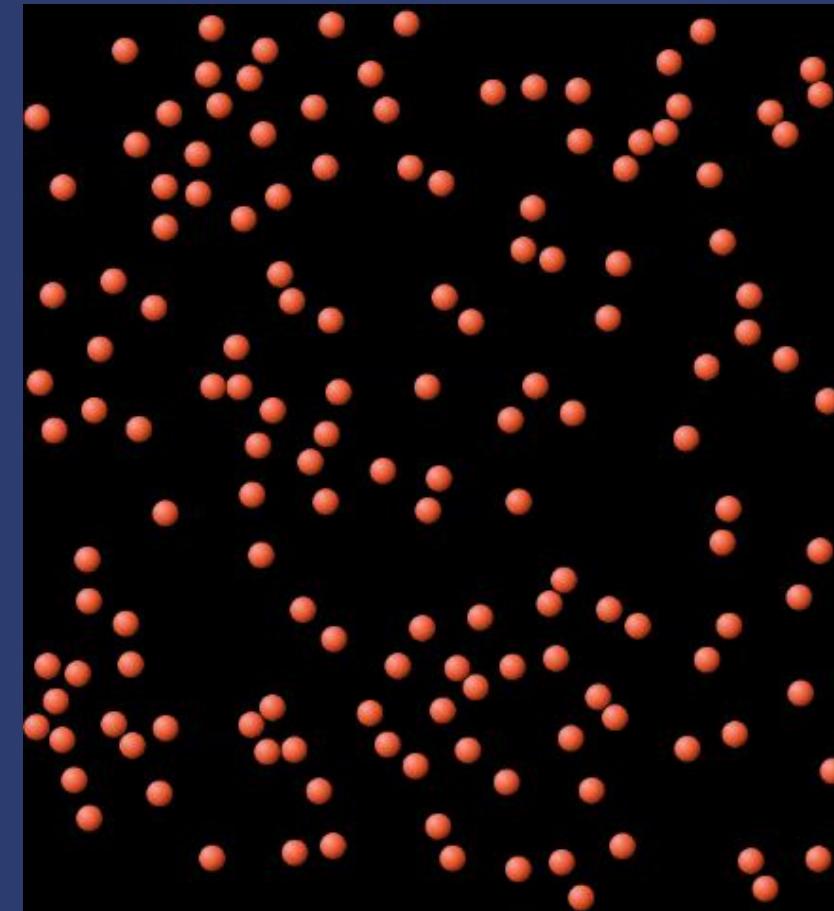
Plant cells



Some processes in cells happen without enzymes.

One example is diffusion, which happens because of the random motion of particles.

Diffusion moves particles of substances into, around and out of cells.

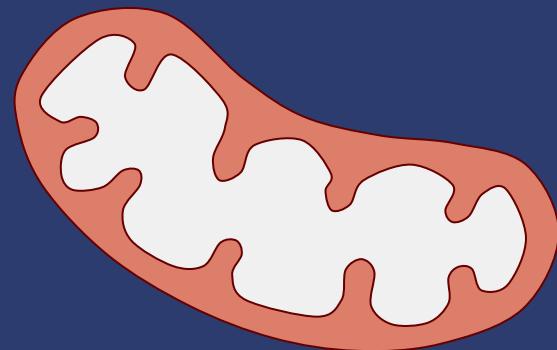


random motion  
of particles

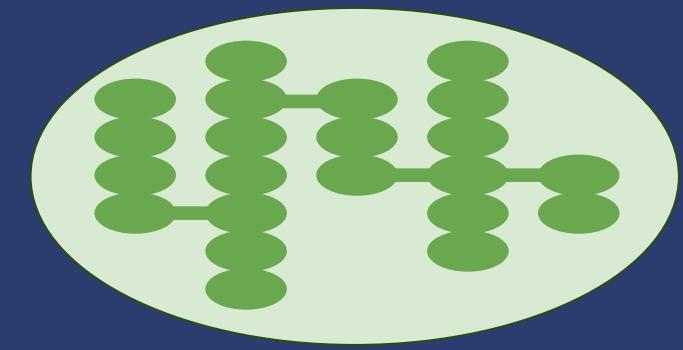
Simulation by PhET Interactive Simulations,  
University of Colorado Boulder, licensed under  
CC-BY-4.0 (<https://phet.colorado.edu>)

# Enzyme function

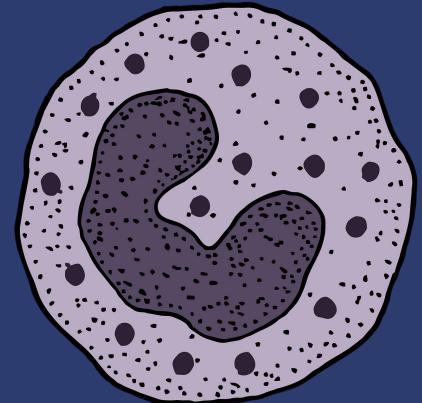
But enzymes are essential to control a vast range of chemical reactions that happen within and outside of cells.



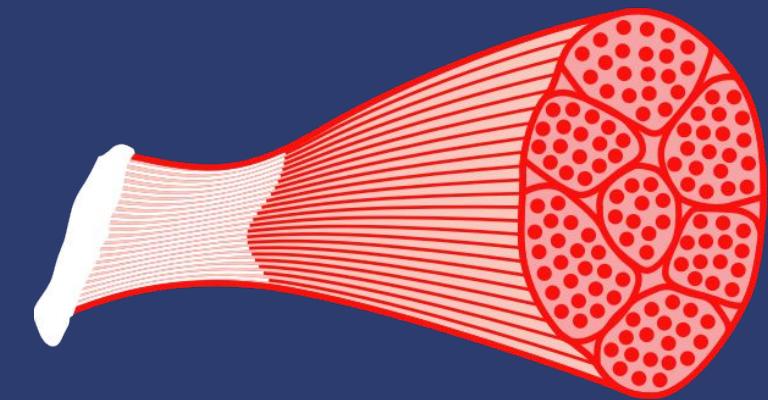
respiration



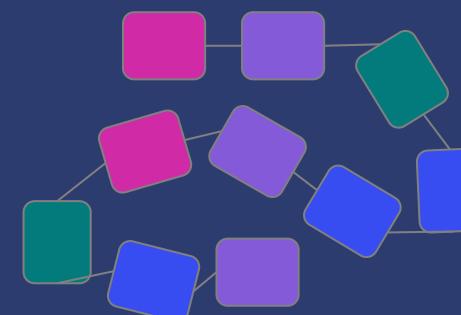
photosynthesis



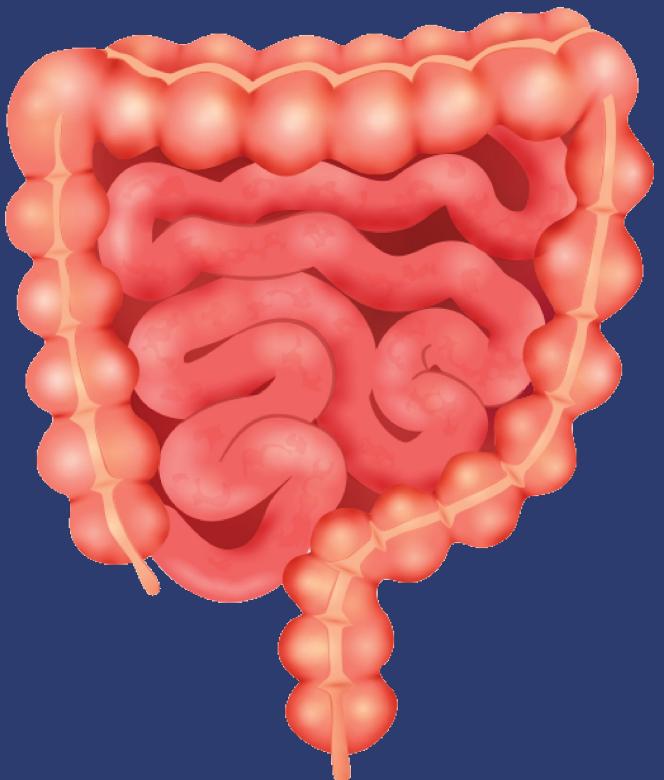
immune  
responses



muscle  
contraction



protein  
synthesis

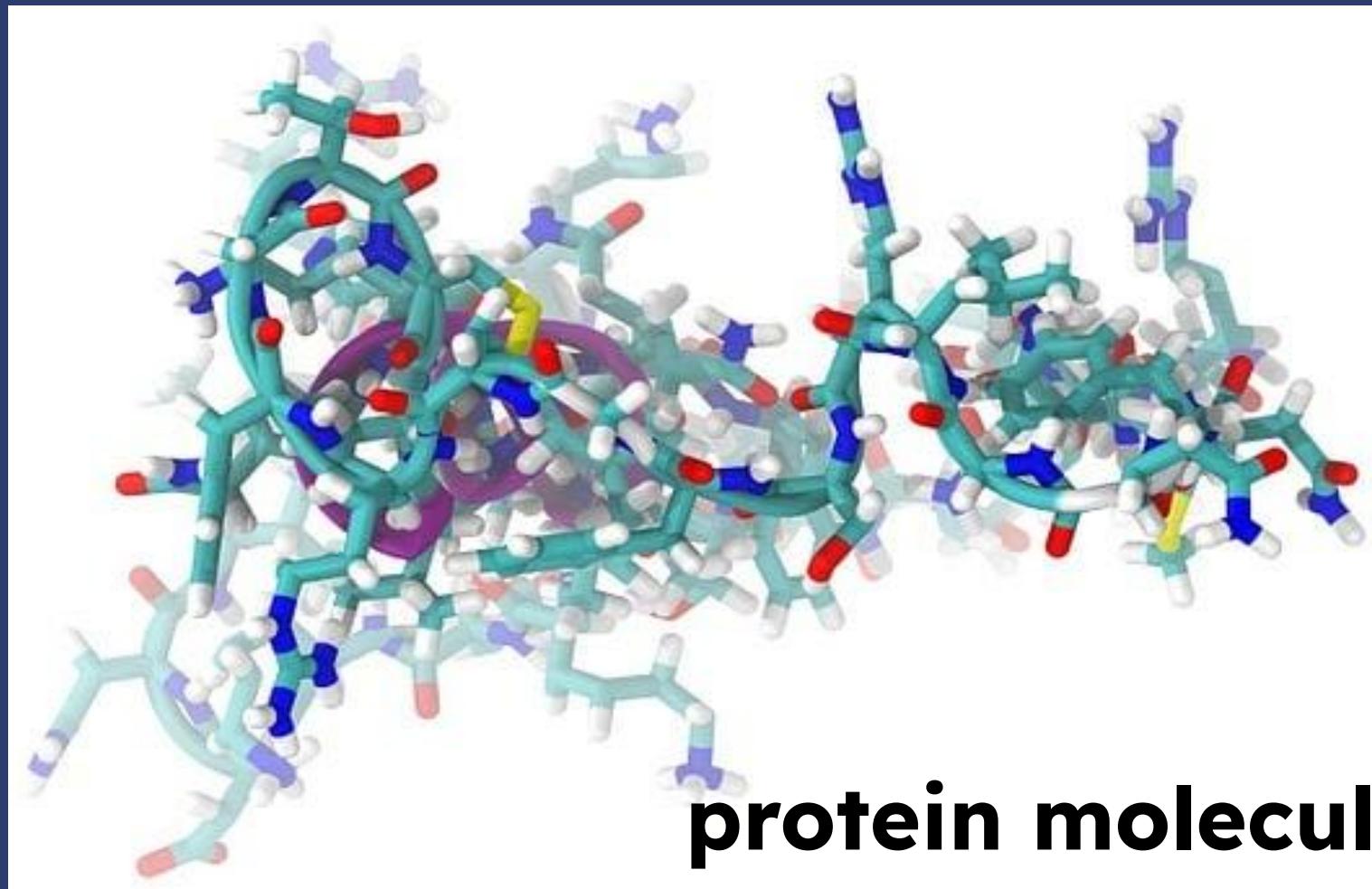


digestion

Life on Earth is able to exist in all its complexity and diversity as a direct result of enzymes.

# Enzyme structure

An enzyme is a protein.

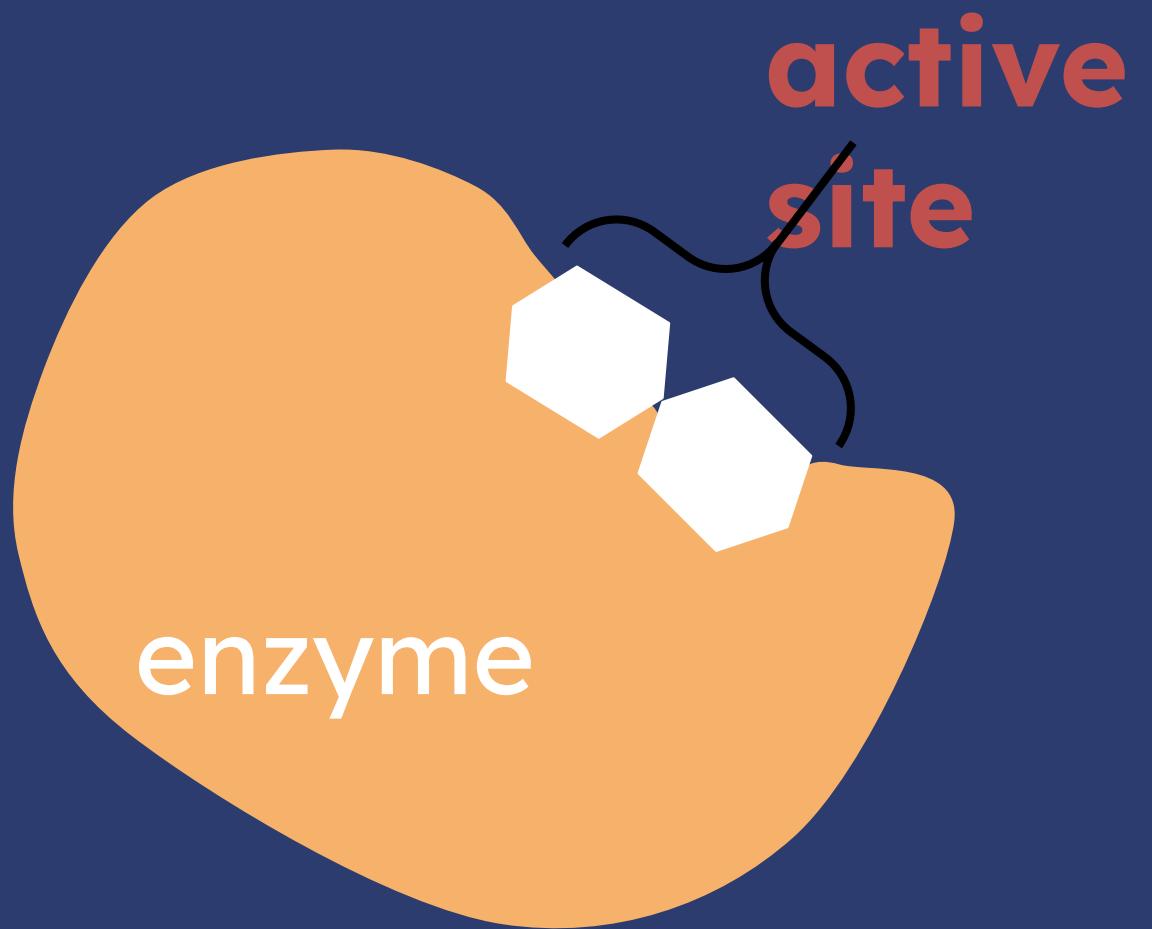


It is made of amino acids built into a chain, folded into a complex 3D shape.

An enzyme's shape includes an **active site**.

This is where the chemical reaction takes place.

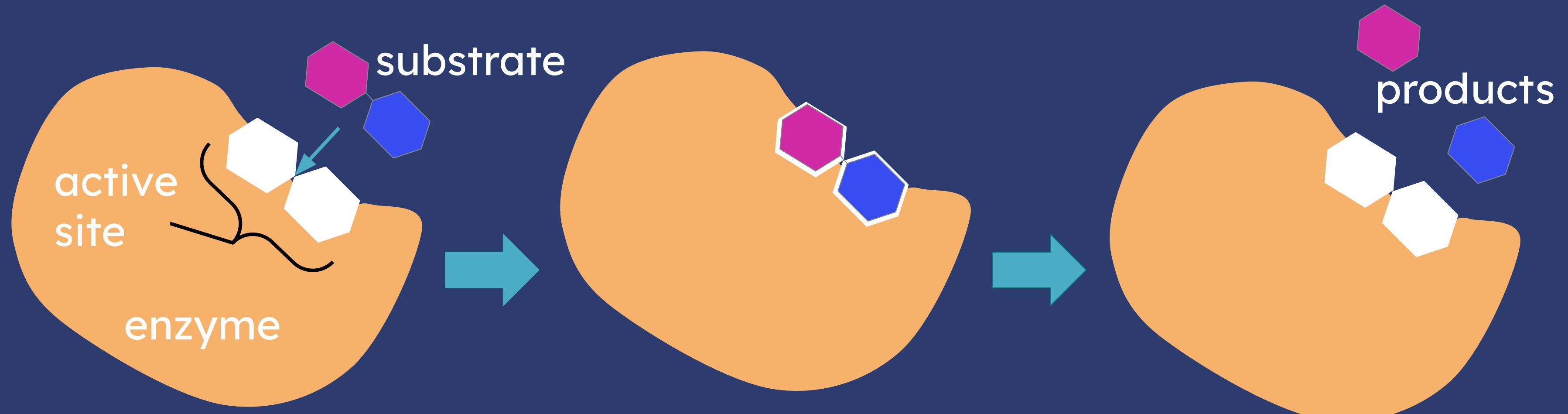
Enzymes are not used up in their reactions: they are free to catalyse reactions over and over again.



a simplified diagram of an enzyme

# Enzyme structure

During an enzyme reaction:



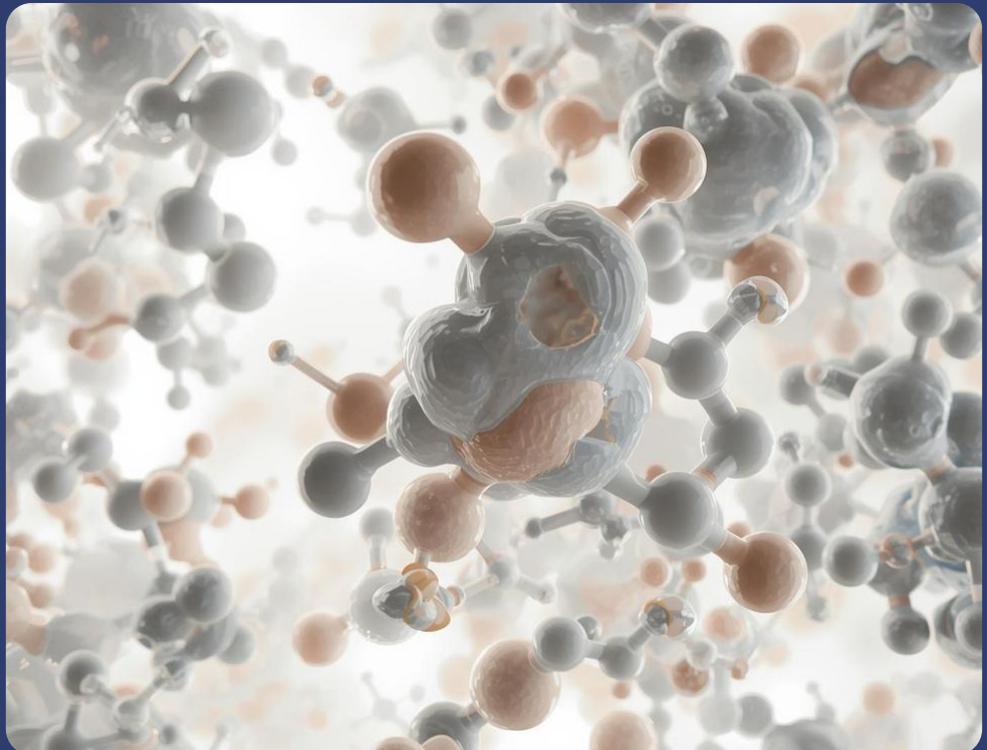
**the substrate(s)**  
binds to the  
**active site**

an  
**enzyme-substrate**  
complex is formed

the product(s) is  
released and the  
enzyme is reused

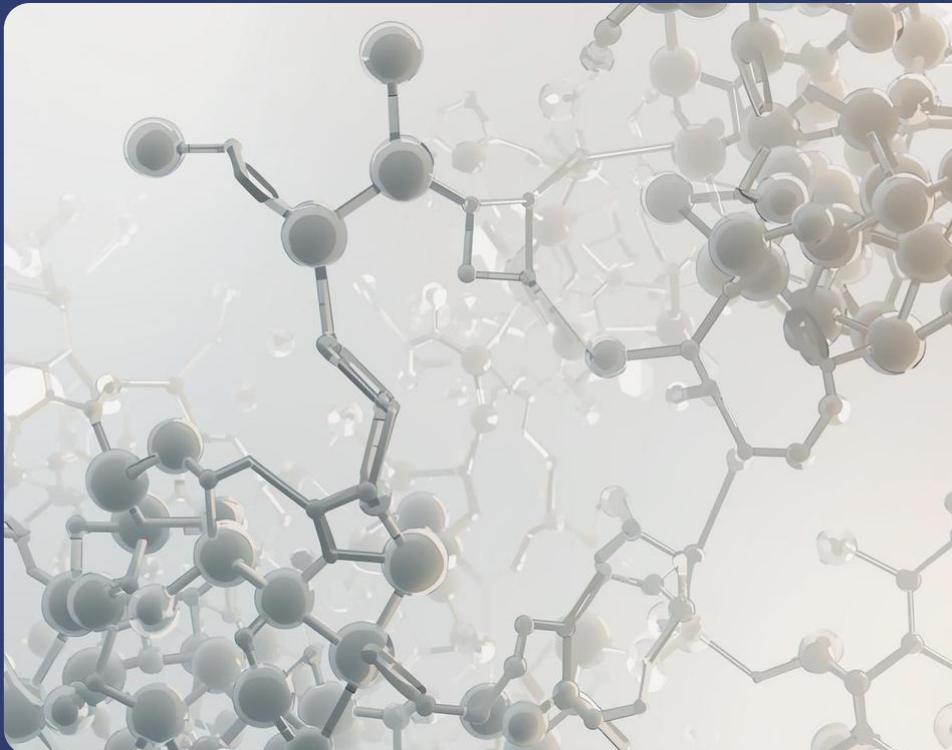
# Key Facts About Enzymes

## Protease



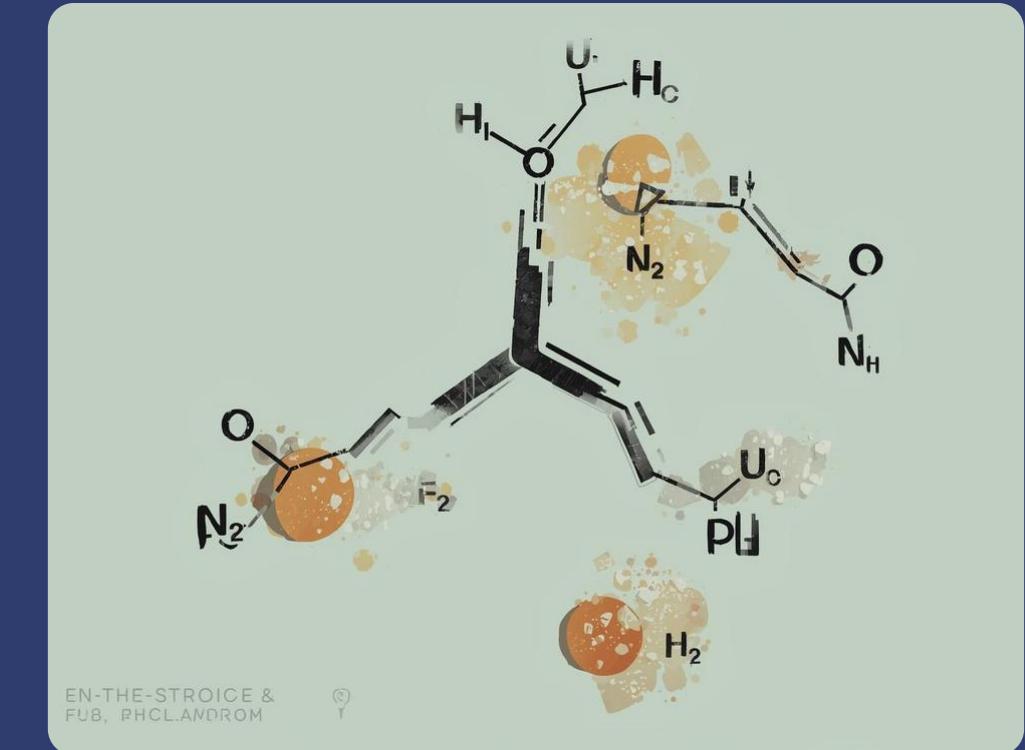
Protease breaks down proteins into smaller peptides and amino acids for absorption.

## Carbohydrase



Carbohydrase facilitates the breakdown of carbohydrates into simpler sugars like glucose.

## Lipase



Lipase is essential for digesting fats, converting them into fatty acids and glycerol.

# Key Facts About Enzymes

## Amylase



Amylase helps to **break down starch** into simpler sugars during digestion.

## Maltase



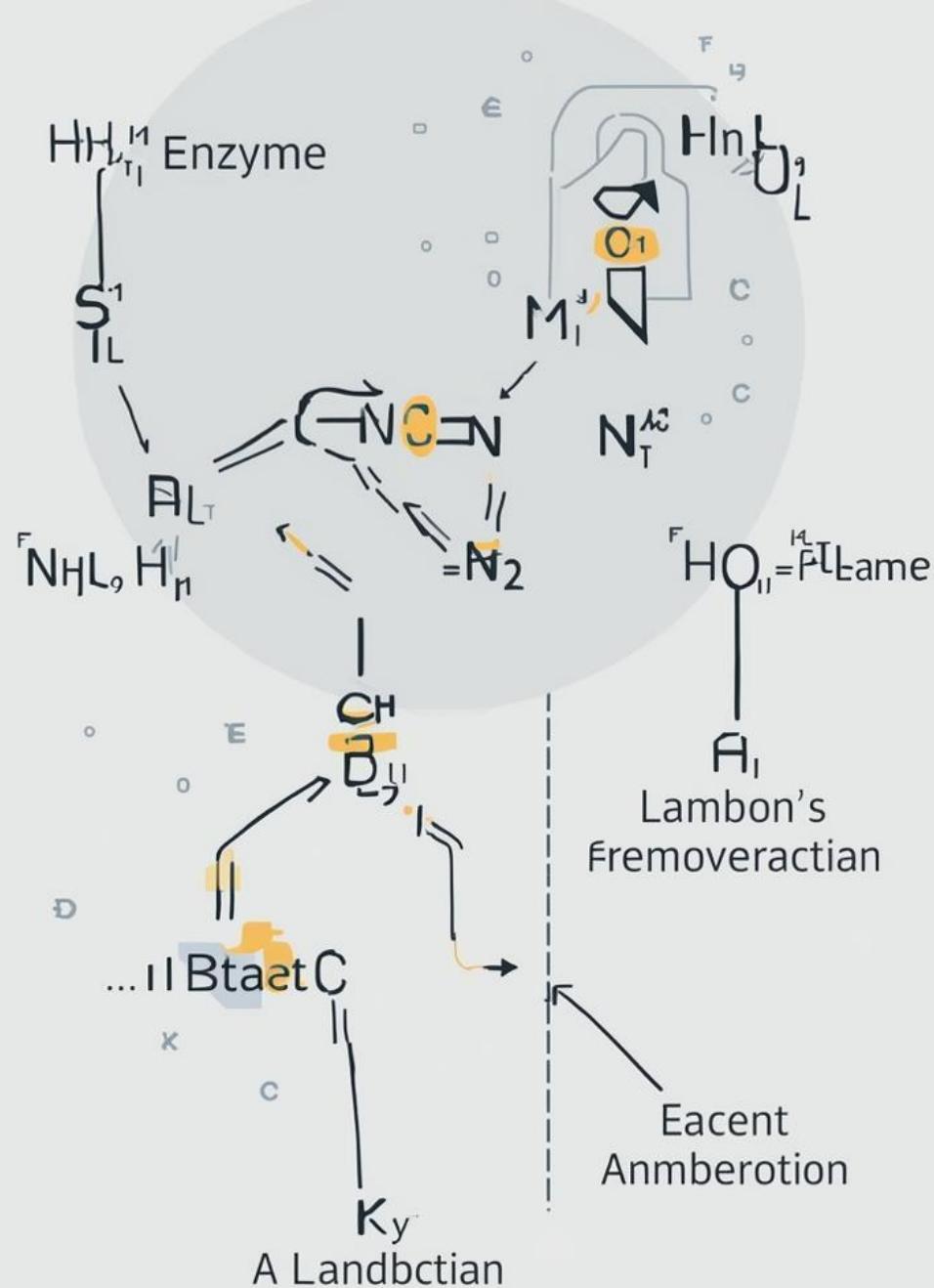
Maltase converts maltose into **glucose**, providing essential energy for the body.

## Lactase



Lactase breaks down lactose into **glucose and galactose**, aiding digestion for lactose-intolerant individuals.

Mokeing cunpoy  
on Rleyen Clerreof **s**ineraction



Bypacisminal - Eneyee: Sustiestoro!

# Lock-and-Key

## Mechanism

**Specificity in Enzyme-Substrate Interactions**



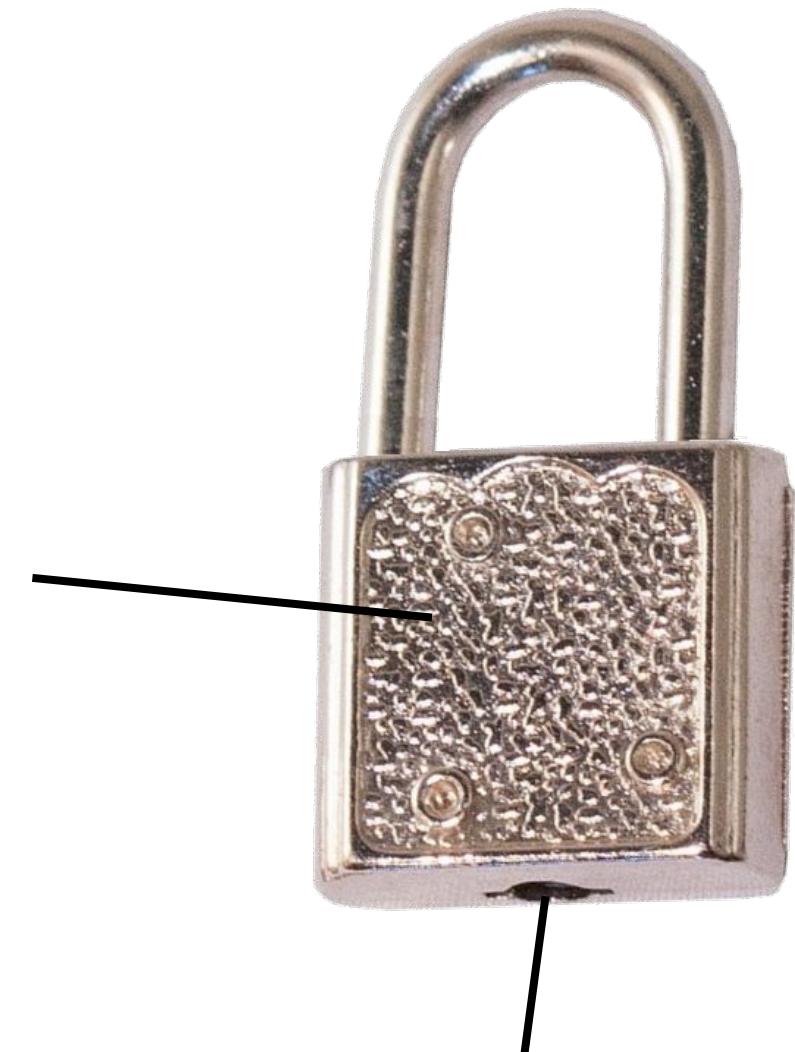
Enzymes operate like keys fitting into locks, ensuring that only specific substrates bind to their active sites, which leads to precise biochemical reactions and product formation.

# Enzyme specificity

We can use a lock and key as a **model** of an **enzyme** and **substrate**.

In this model:

the lock is  
the enzyme



the key is the  
substrate

the keyhole is the active site

Locks are specific for their key.



Keys come in many different shapes.

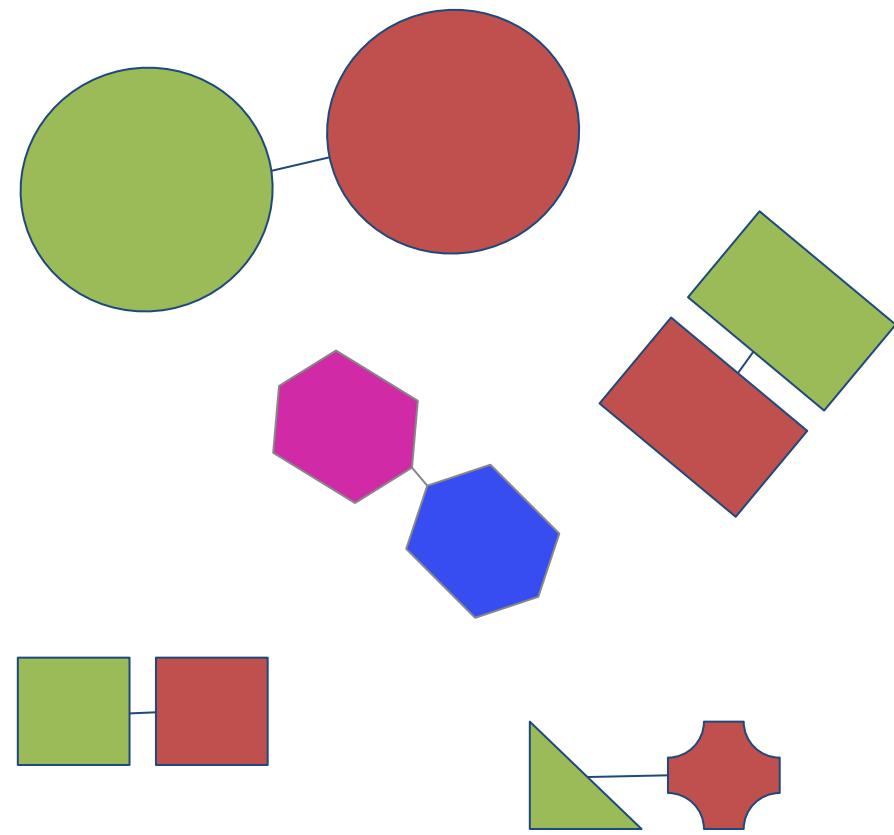
A photograph of a single metal key standing upright against a white background. The key has a standard notched profile.

But only one key has the correct shape ...



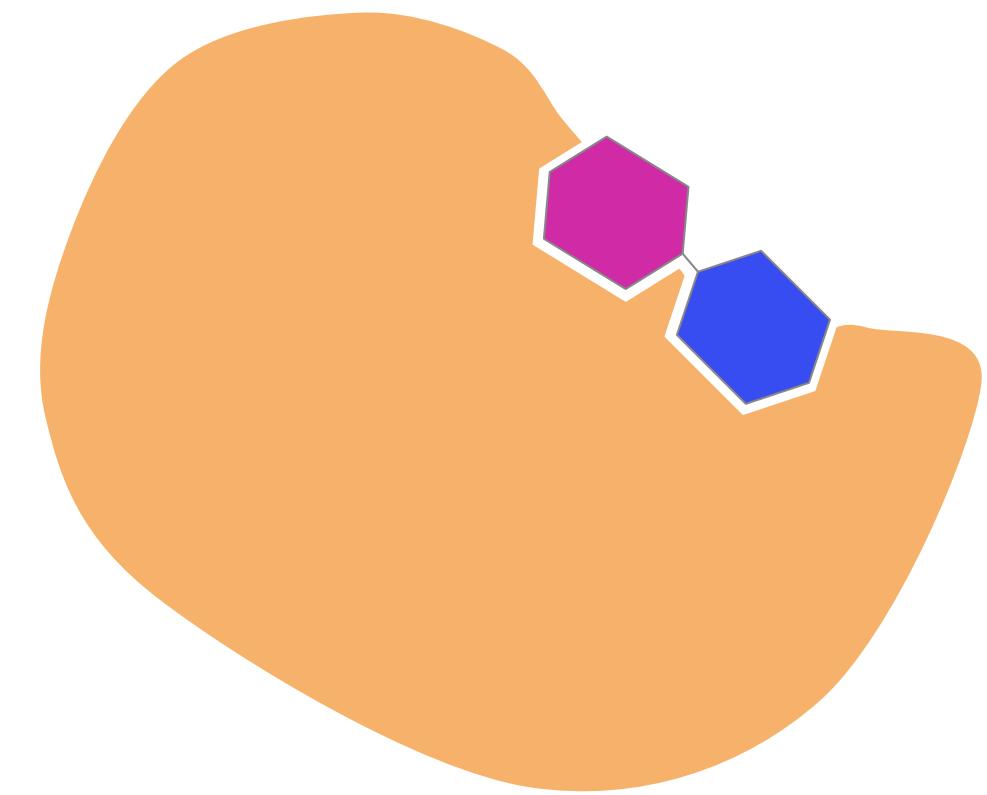
... to fit into the lock's keyhole.

**Enzymes are specific for their substrate.**



Substrate molecules can have many different shapes.

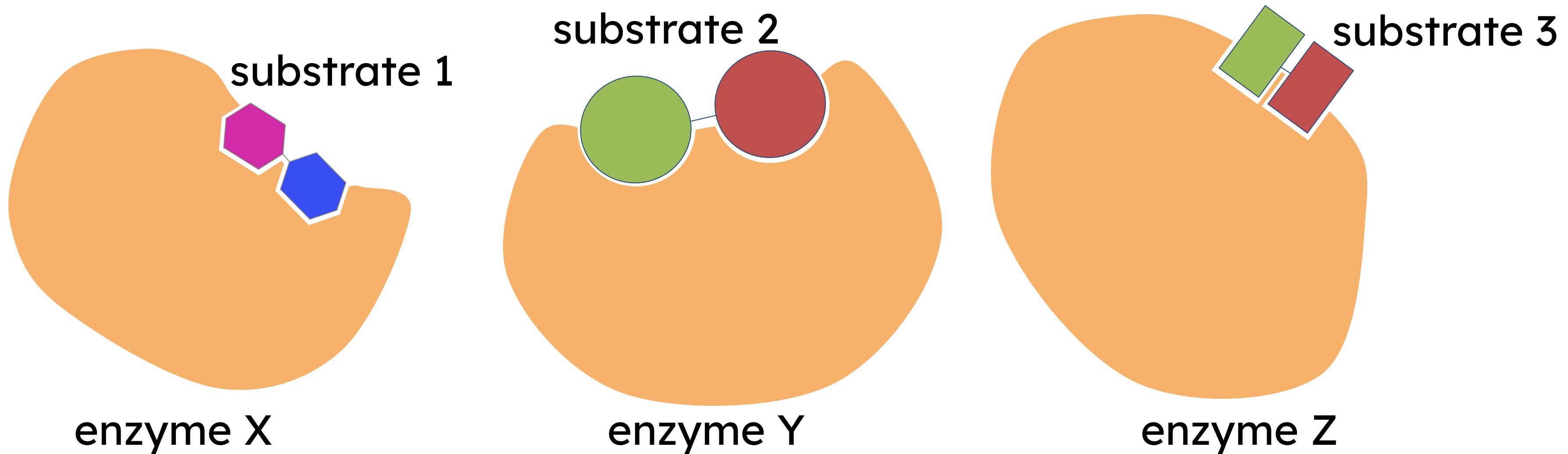
But only one substrate has the correct shape ...



... to fit into the enzyme's active site.

# Enzyme specificity

Because an **enzyme** is specific for its **substrate**, each enzyme can only **catalyse** one chemical reaction.

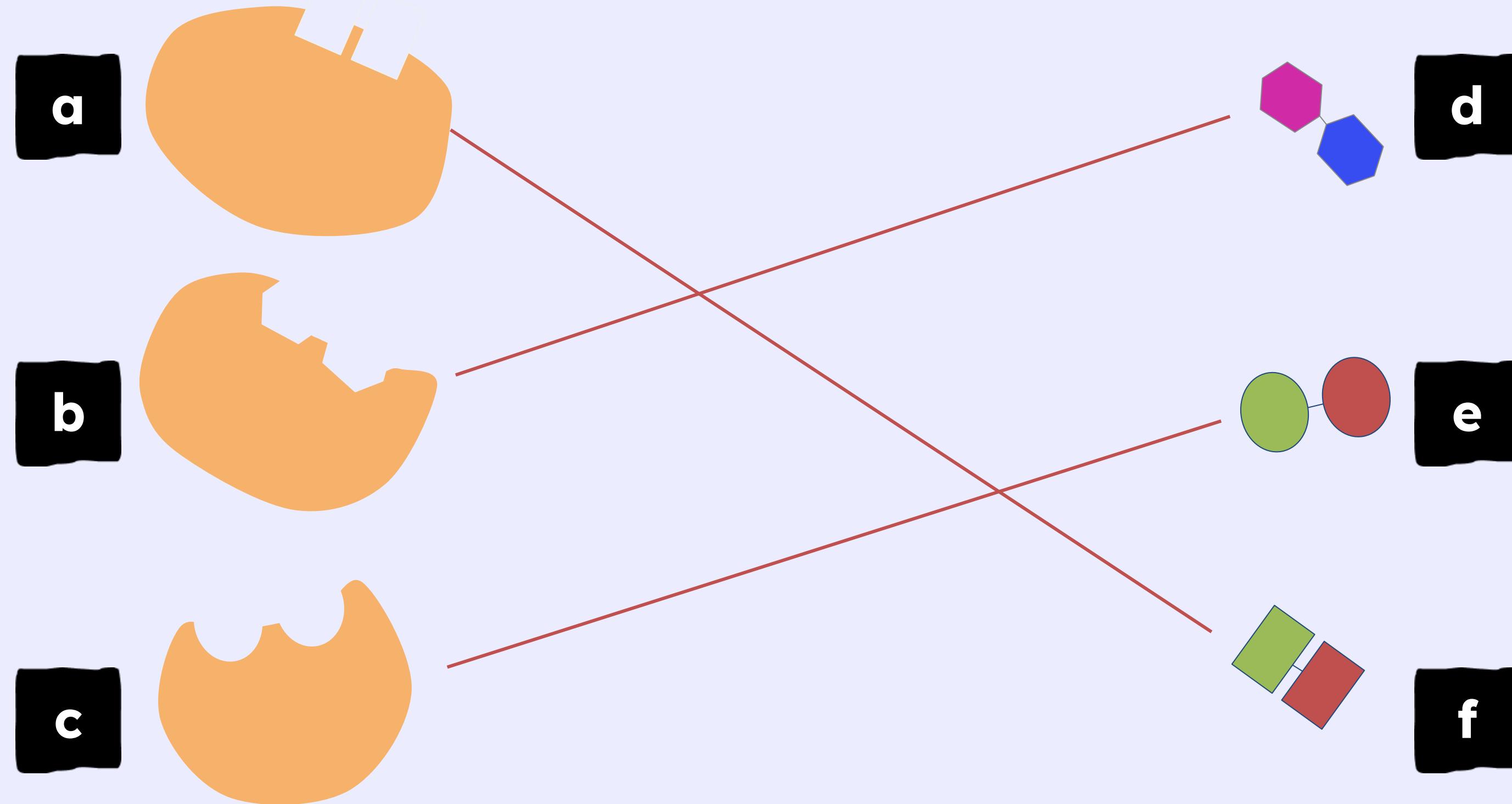


Different chemical reactions need different **enzymes**.

# Enzyme specificity



Match the enzyme to its substrate.



# Enzyme specificity

Each enzyme is highly specific. It can only catalyse one chemical reaction.

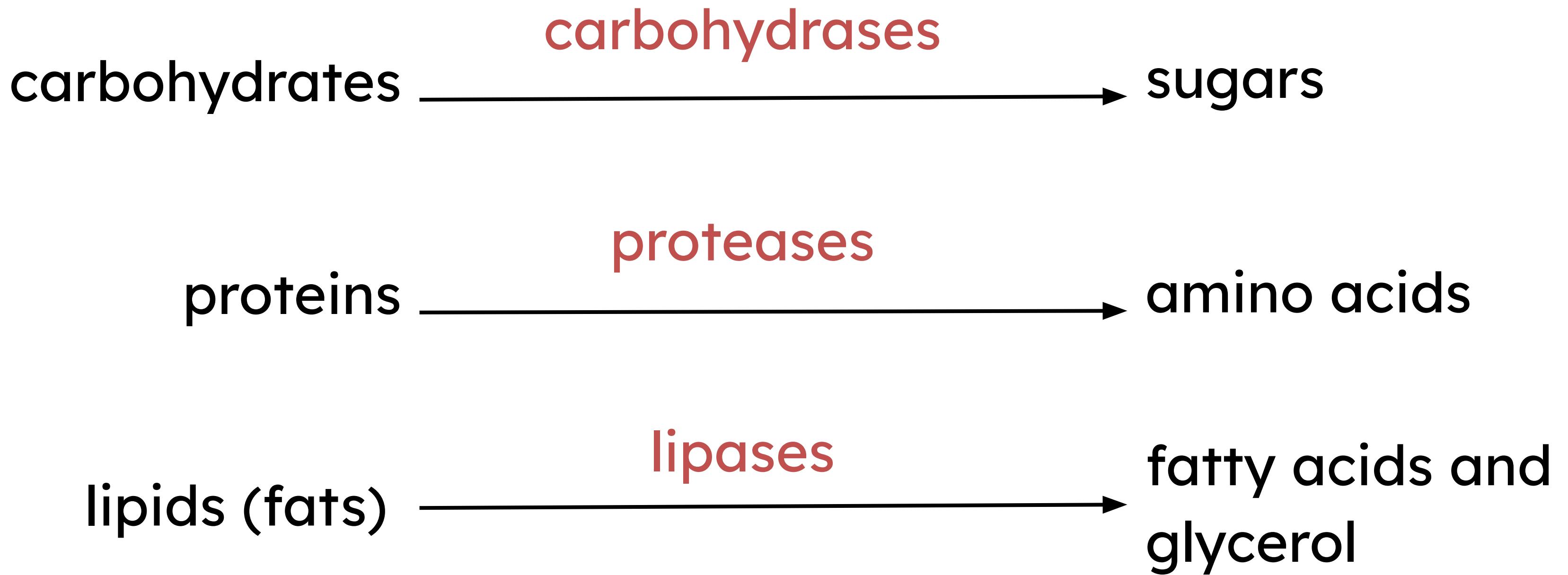
Most enzymes have the ending **-ase**.

- Enzymes that break down carbohydrates are called **carbohydrases**.
- Enzymes that break down proteins are called **proteases**.

What do you think enzymes are called which break down lipids (fats)?

- These are called **lipases**!

To summarise:



What is the name of the group of enzymes that break down fats?

- a carbohydrases
- b proteases
- c lipases ✓

# Digestive Enzymes

## Amylase



Amylase efficiently **breaks down starch** into maltose, aiding digestion in the mouth and pancreas.

## Maltase



Maltase converts maltose into **glucose**, providing essential energy for the body's cells during digestion.

## Protease



Protease plays a key role by **breaking down proteins**, ensuring nutrients are absorbed effectively in the stomach.

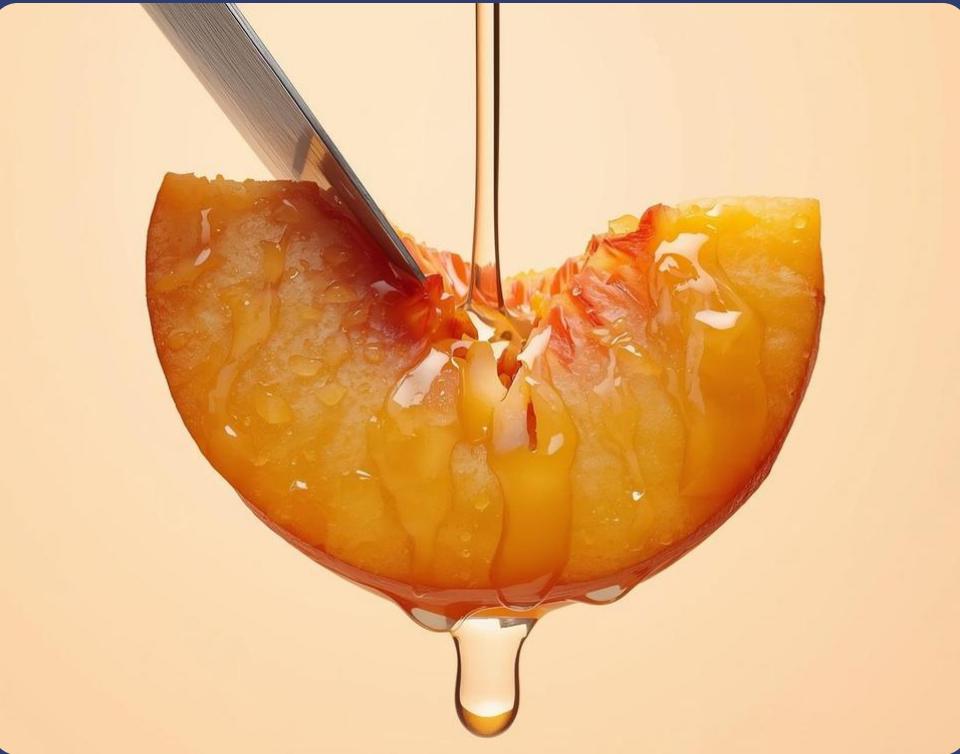
# Digestive Enzymes

## Lipase



Lipase is essential for **breaking down fats** into fatty acids and glycerol.

## Sucrase



Sucrase facilitates the **conversion of sucrose** into glucose and fructose for energy.

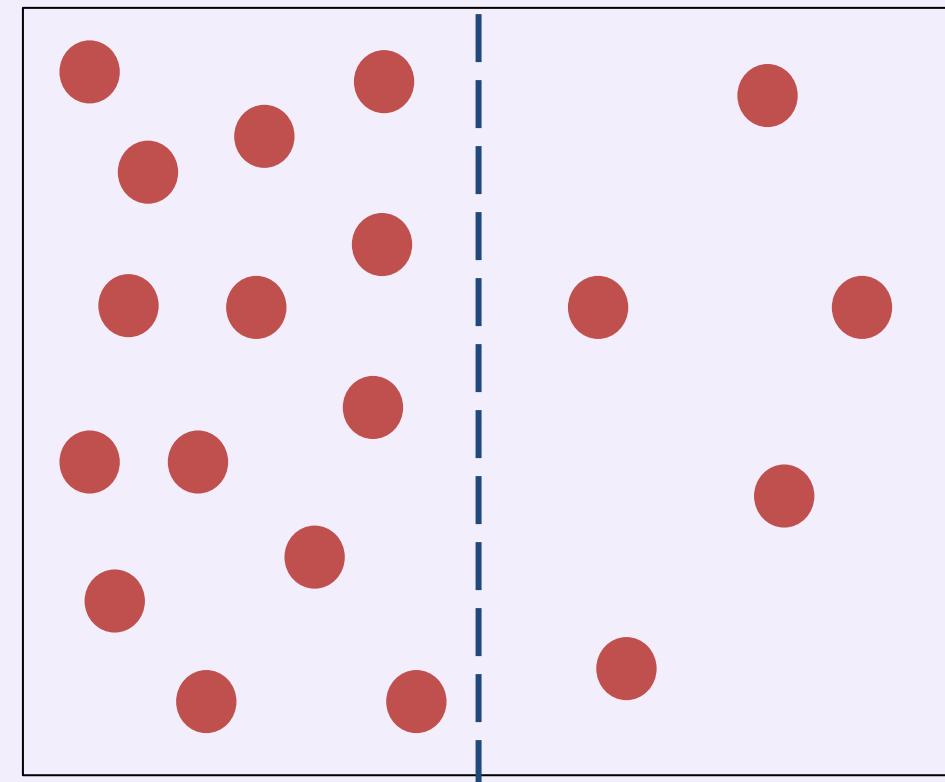
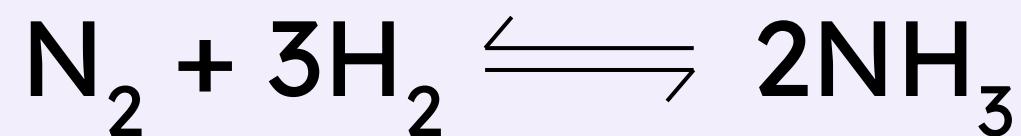
## Lactase



Lactase is vital for **digesting lactose**, allowing the body to process dairy products.

Which of these reactions are controlled by enzymes?

Fe  
(iron)  
catalyst



Haber process

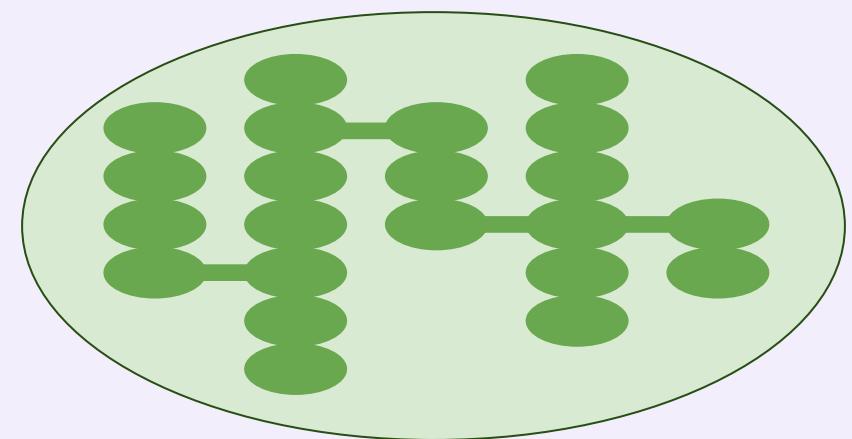
a

diffusion

b

photosynthesis

c ✓



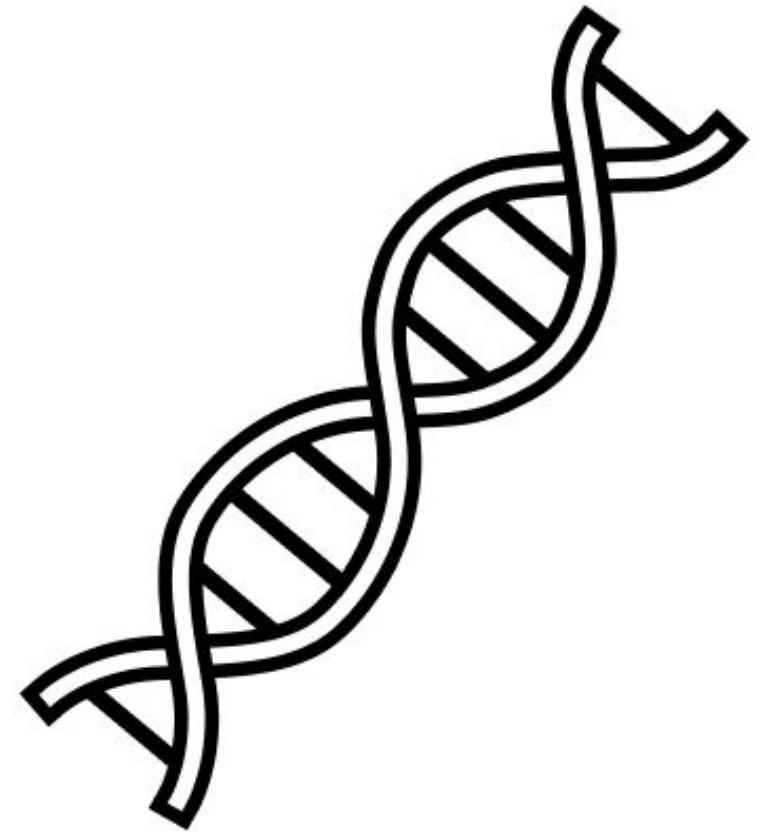
Put these phases of the enzyme reaction in the correct order.

- a** The enzyme-substrate complex is formed. 2
- b** The product is released. 3
- c** The substrates bind to the active site. 1

# Explaining effects of substrate concentration and temperature on enzyme rate

**Biology**

Unit: Biological molecules and enzymes



# Outcome

I can explain how and why the rate of an enzyme reaction is affected by substrate concentration and temperature.

# Keywords

## rate of reaction

A measure of how much change occurs per unit of time.

## concentration

A measure of the quantity of a dissolved substance in a given volume of solution.

## optimum

The conditions where maximum rate of reaction occurs.

## bond

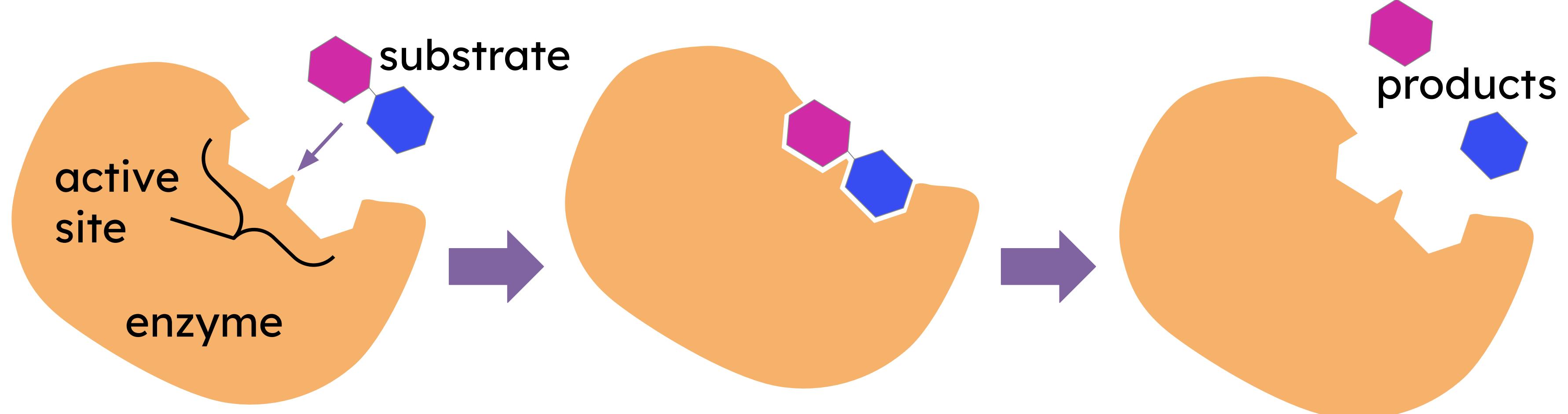
A force of attraction between atoms in a compound.

## denatured

A permanent change in the shape of an enzyme that stops it from working properly.

# Effect of substrate concentration on rate

An enzyme is a biological catalyst: it speeds up the rate of a reaction.



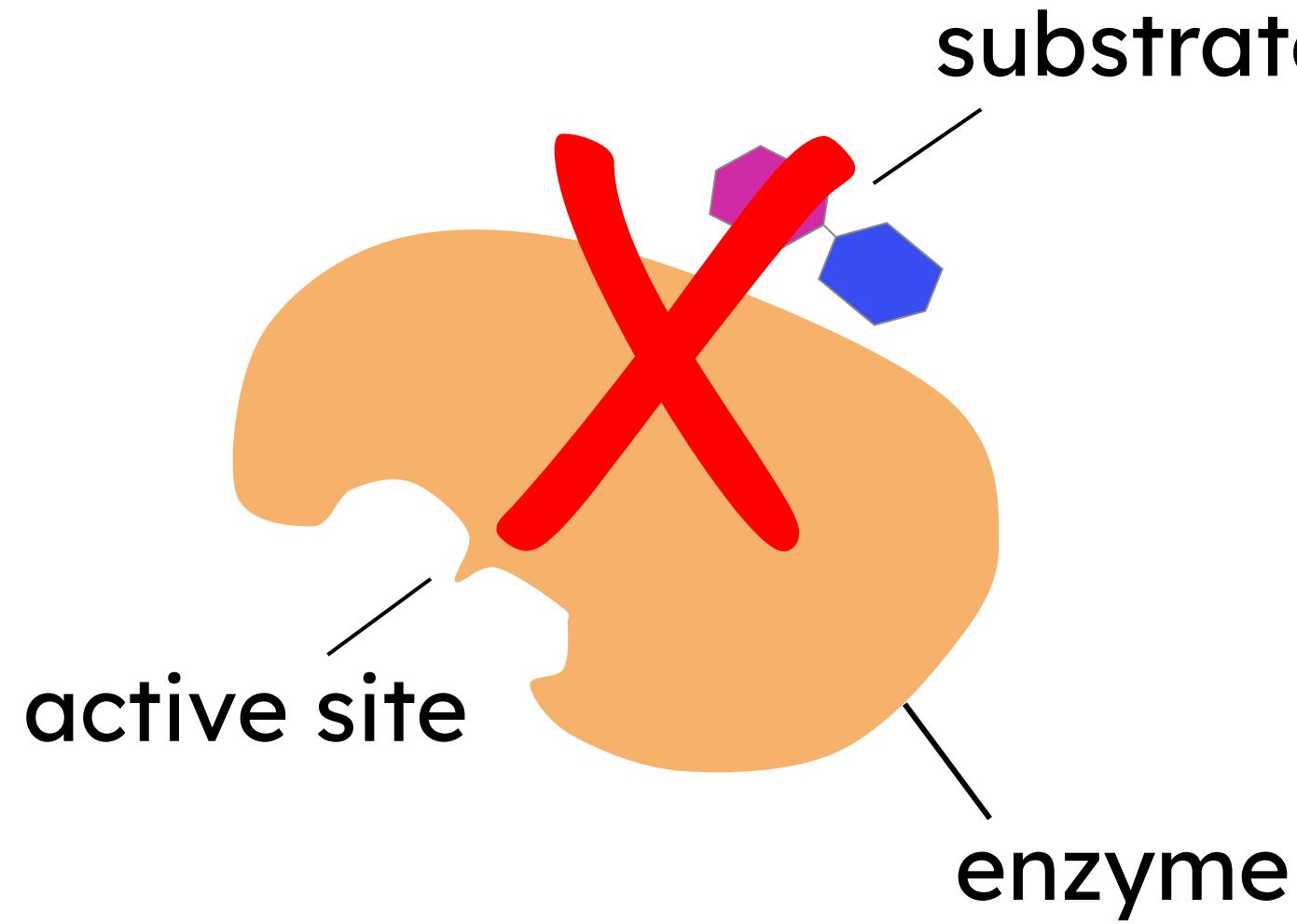
The substrate and enzyme are present.

The enzyme-substrate complex is formed.

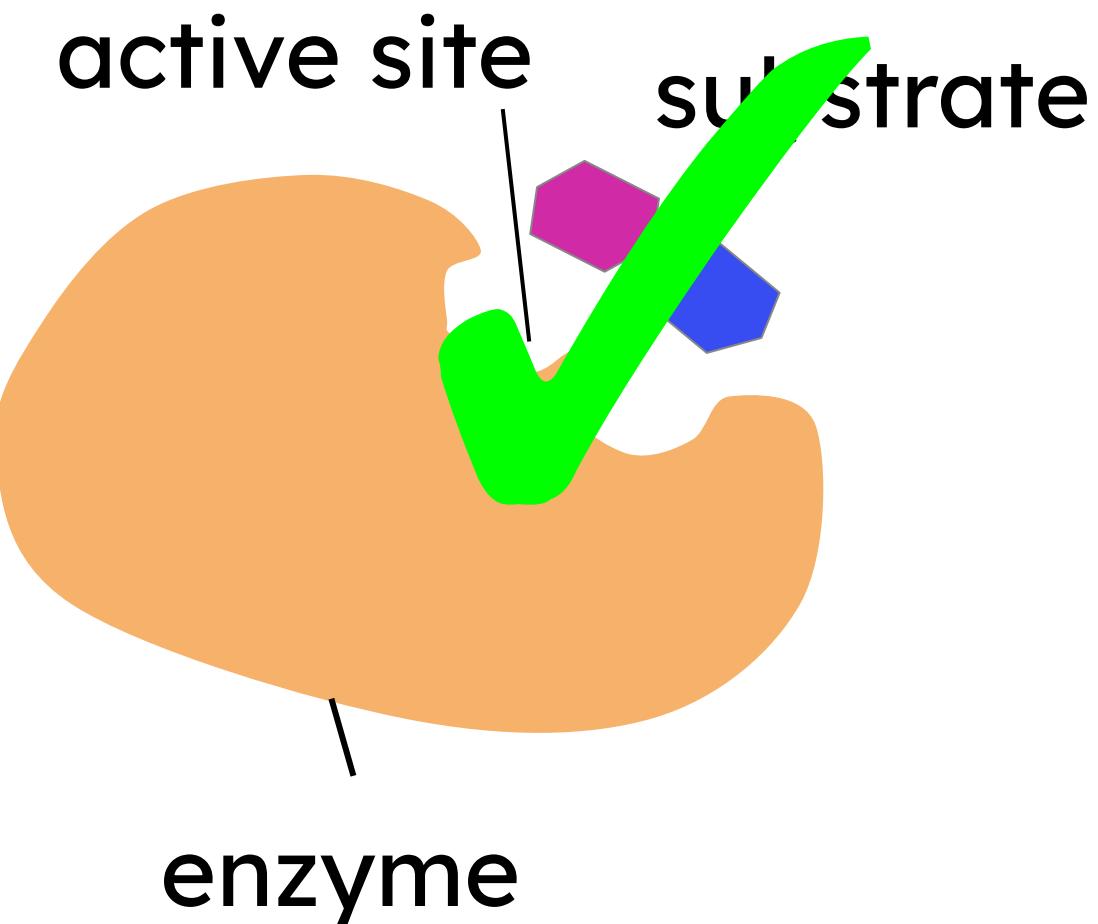
The products are released.

# Effect of substrate concentration on rate

In enzyme-catalysed reactions, the enzyme and substrate must collide at the **active site** for the reaction to occur.



If the substrate does not collide with the active site, no reaction occurs.

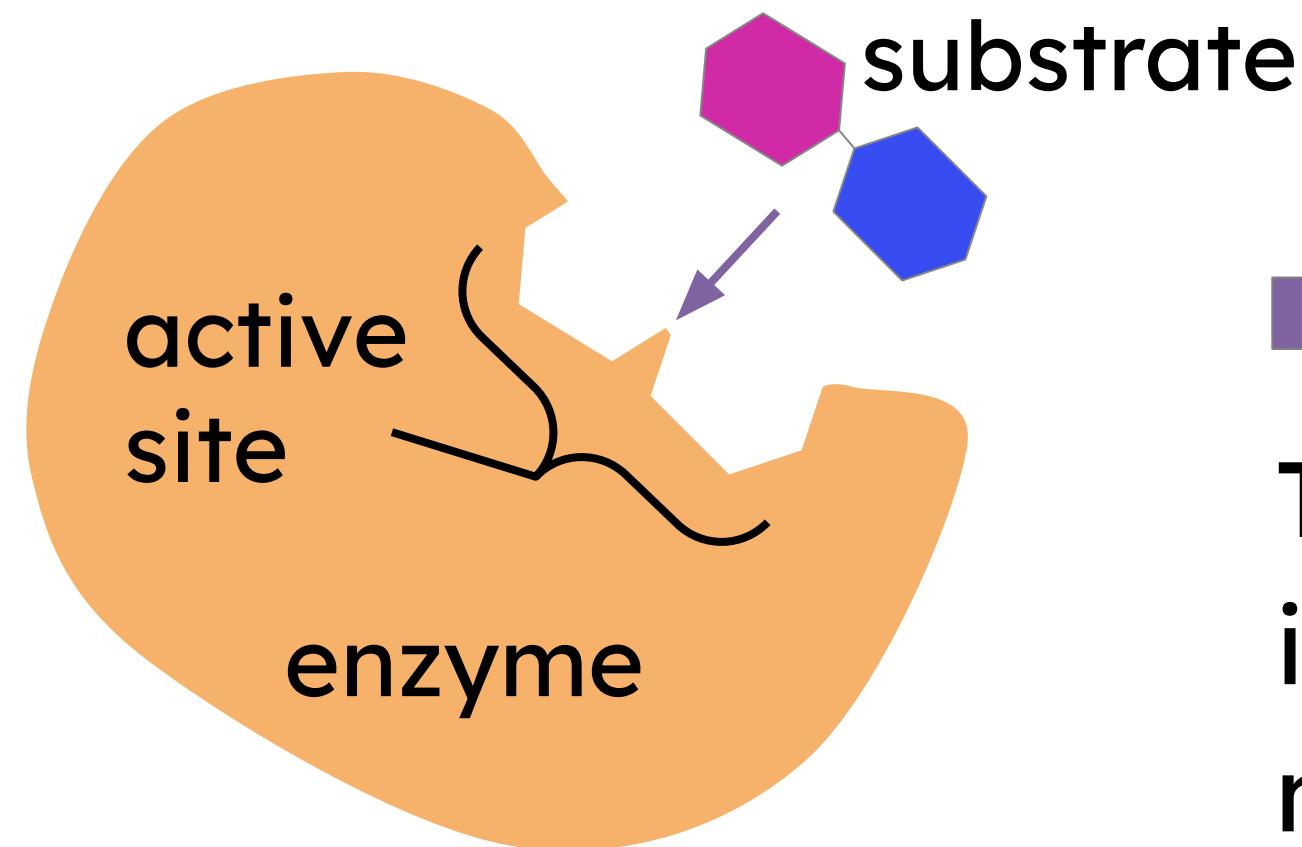


If the substrate collides with the active site, the reaction will occur.

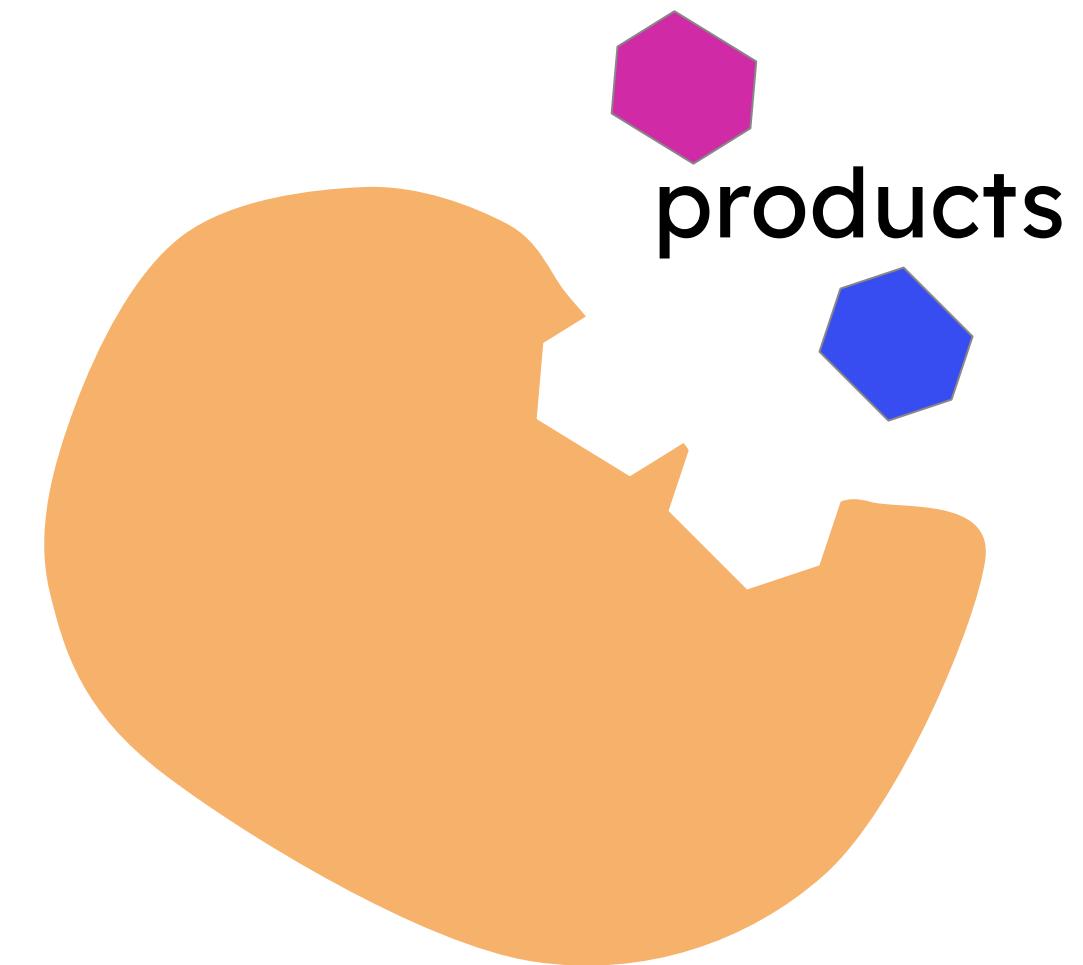
# Effect of substrate concentration on rate

We can measure how fast the reaction occurs.

For example, we can measure how much substrate is changed into product over time (e.g. every second).

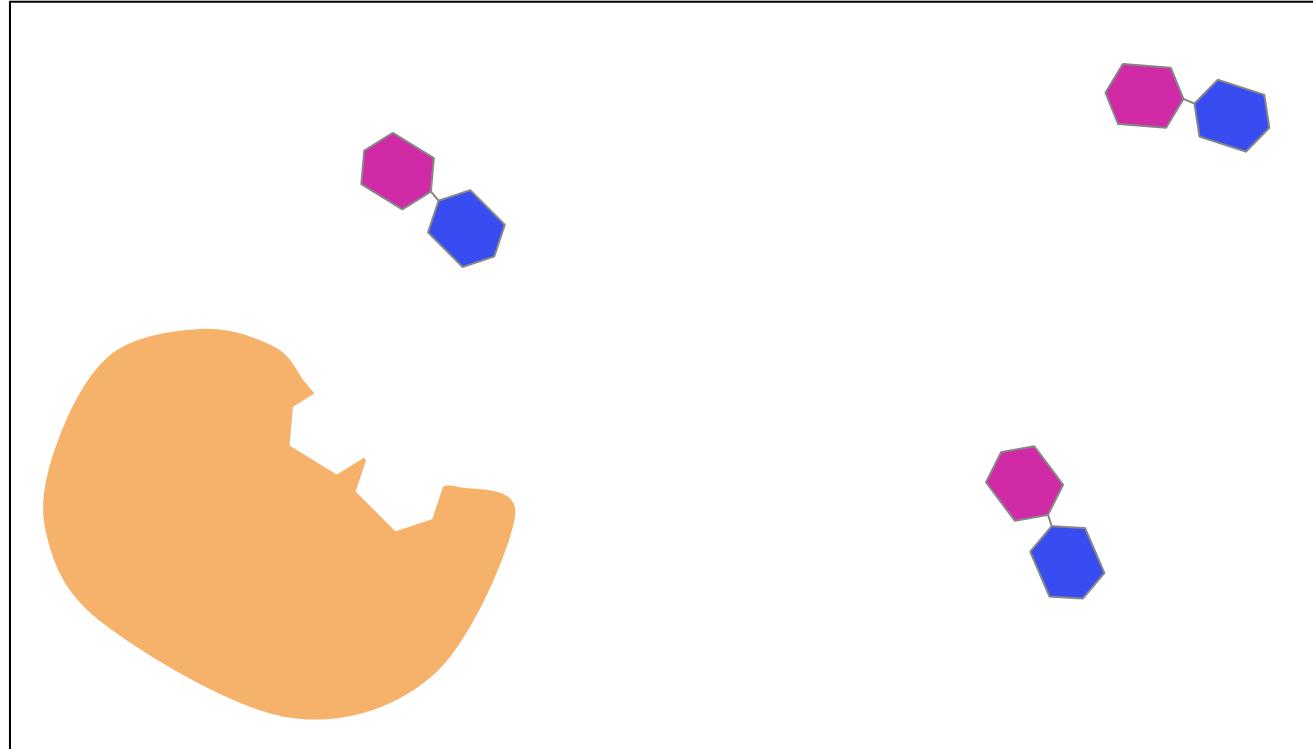


The **rate of reaction** is a measure of how much change occurs per unit of time.



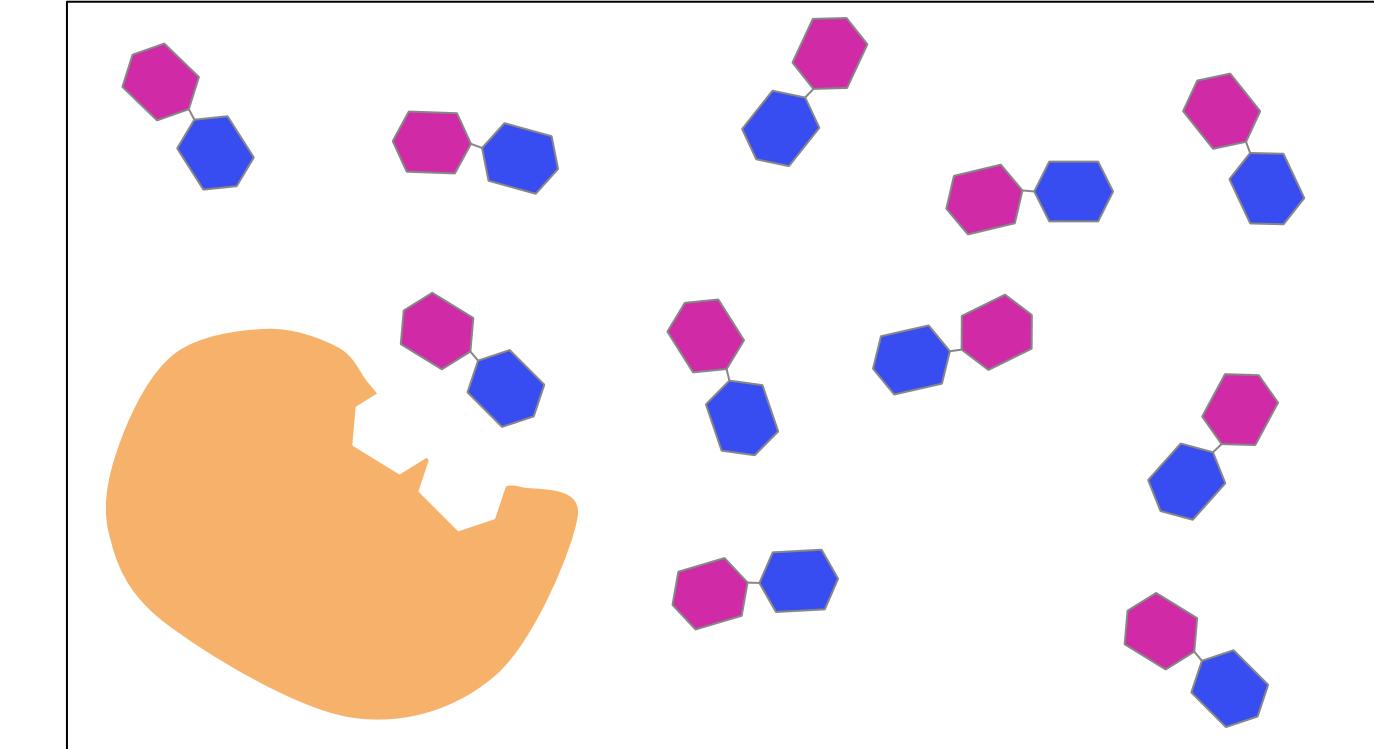
# Effect of substrate concentration on rate

The **concentration** of substrate will affect the **rate of reaction**.



Low substrate concentration:

- Few substrate molecules.
- Lower frequency of successful collisions.

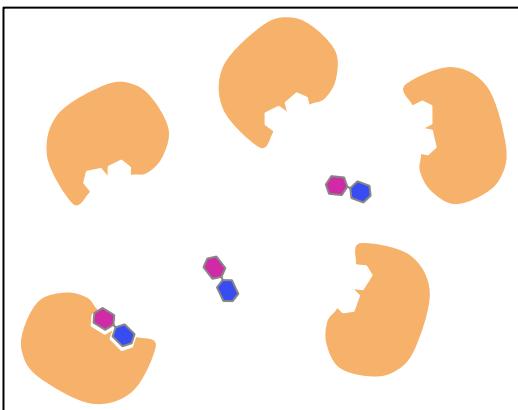


Higher substrate concentration:

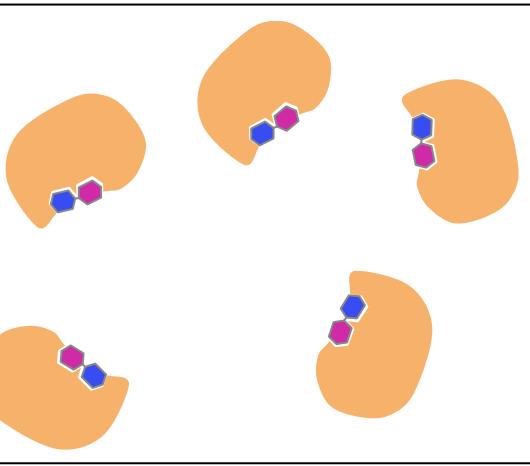
- More substrate molecules.
- Higher frequency of successful collisions.

# Effect of substrate concentration on rate

**Low substrate concentration:**  
Few enzyme active sites full; reaction rate is low. As concentration increases, rate increases.



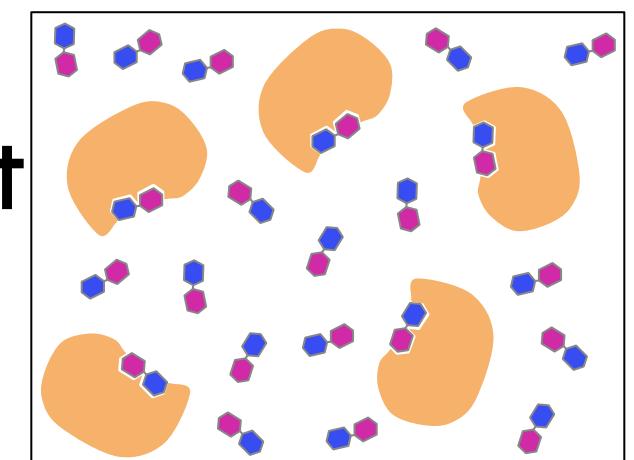
Rate of reaction



**Optimum substrate concentration:**  
All enzyme active sites are full; reaction rate is at maximum.

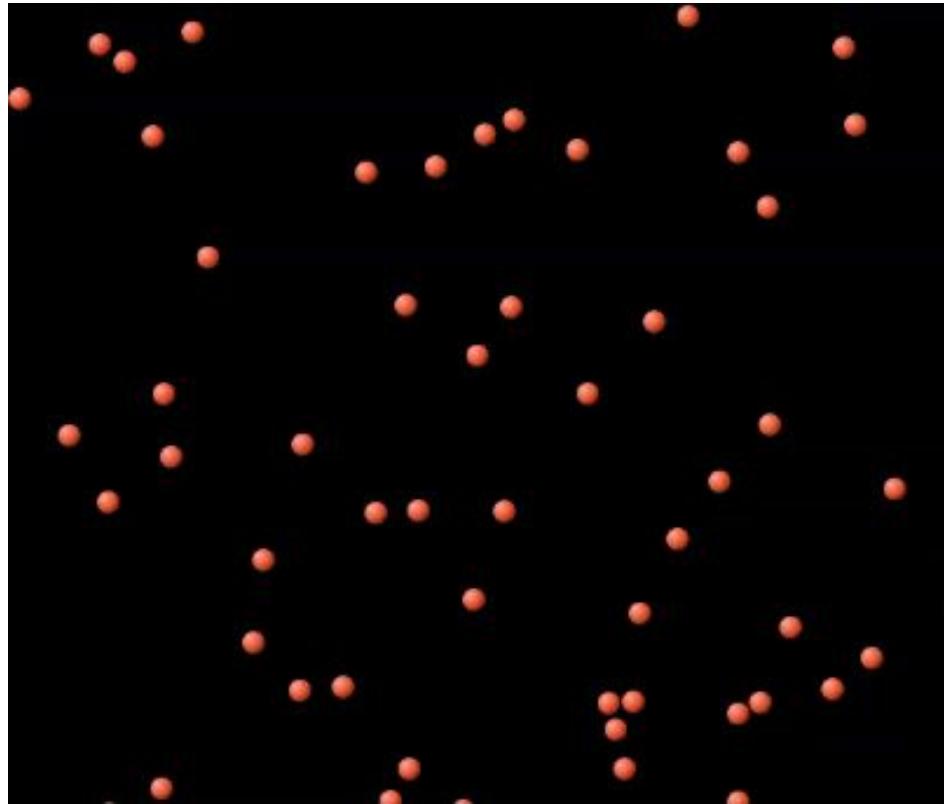
Substrate concentration

**Higher than optimum substrate concentration:**  
No additional enzyme active sites available; reaction rate cannot increase further.



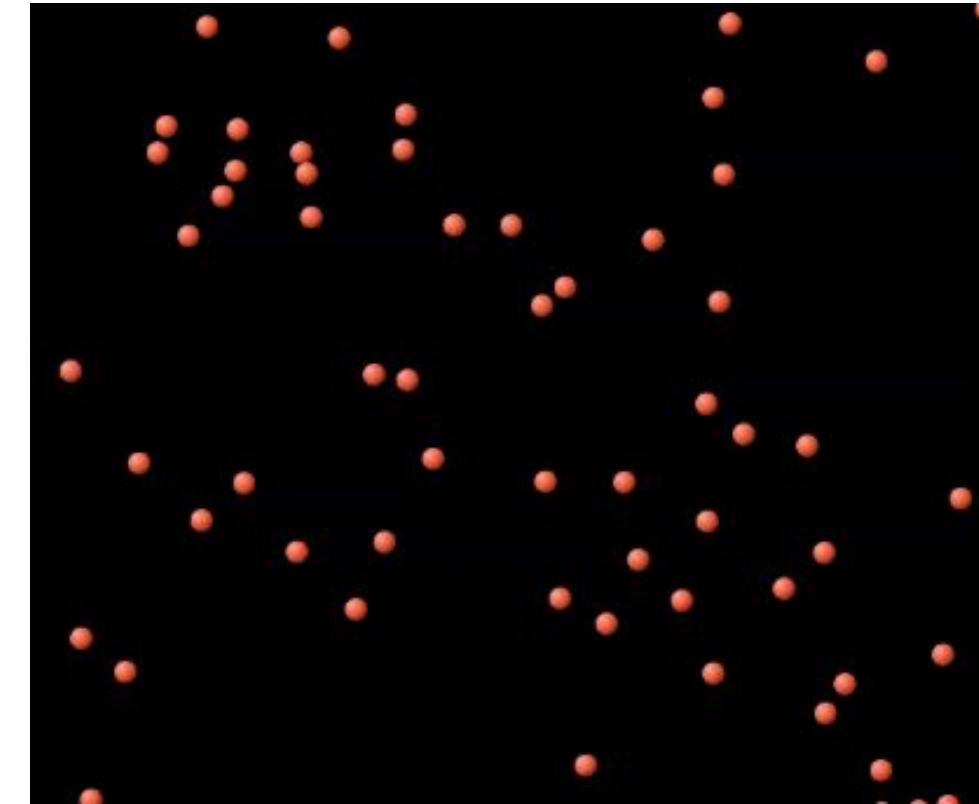
# Effect of temperature on rate

The temperature will affect the **rate of reaction**.



**At low temperatures:**

Particles move slowly and with less energy.  
Lower frequency of successful collisions.



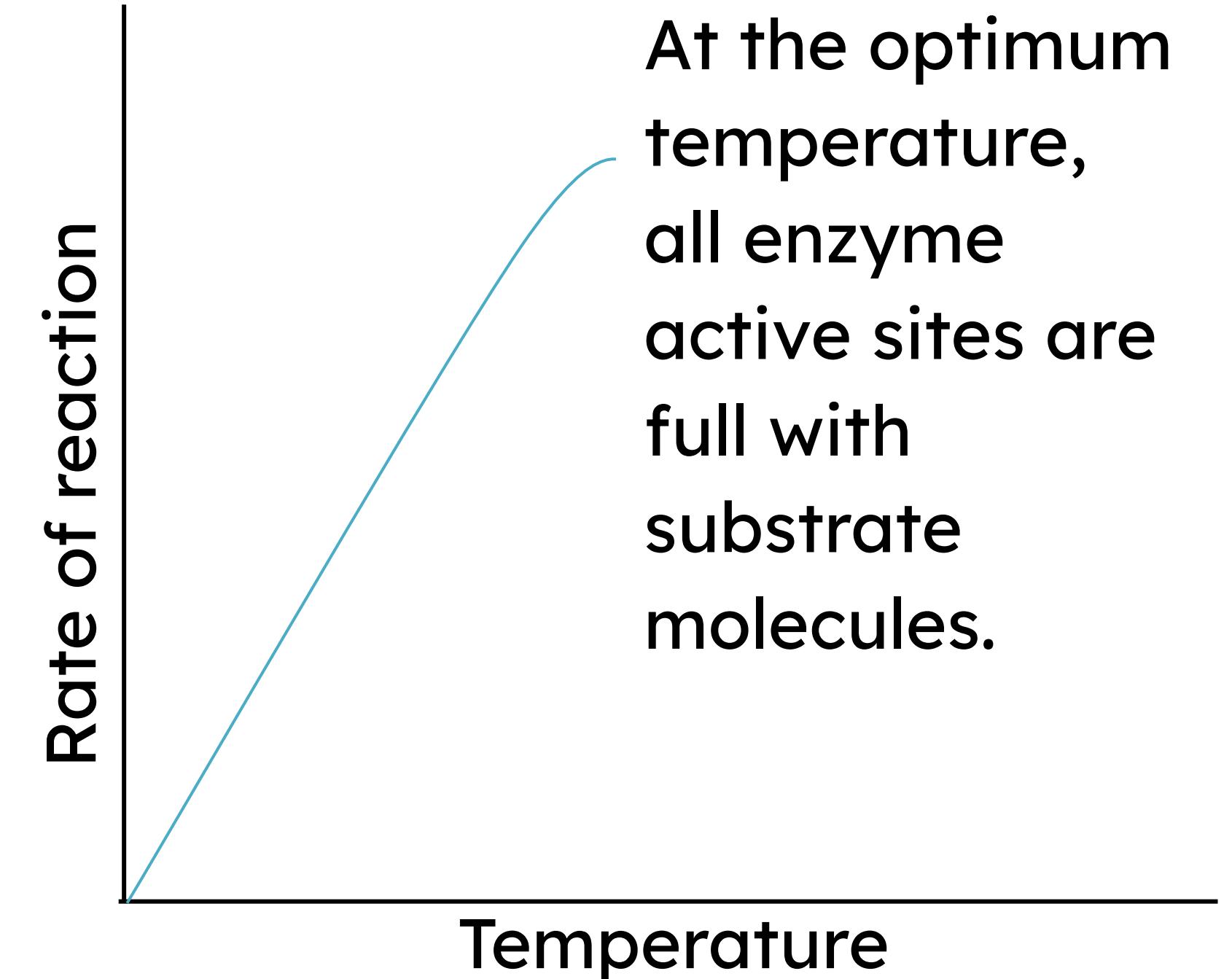
**At higher temperatures:**

Particles move faster and with more energy.  
Higher frequency of successful collisions.

# Effect of temperature on rate

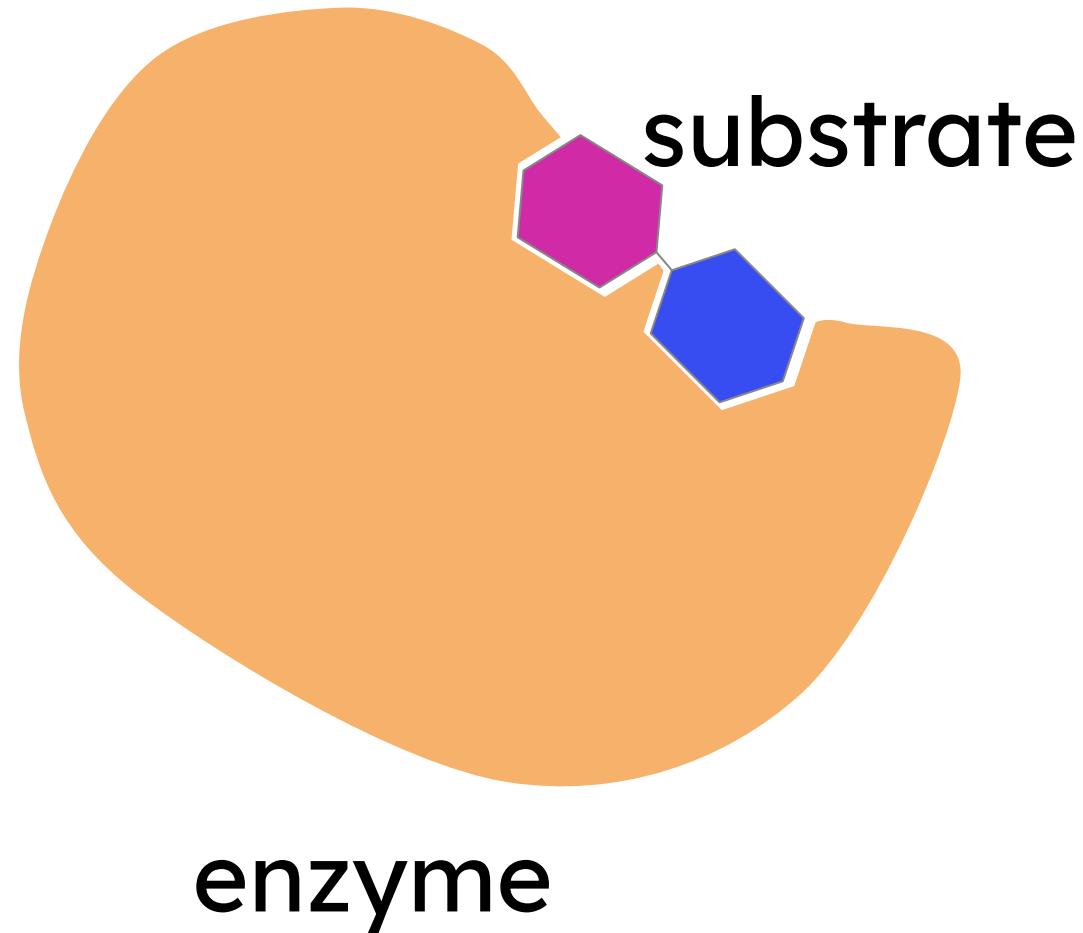
As temperature increases towards the **optimum** temperature, successful enzyme-substrate collisions happen at a higher frequency and with more energy.

This causes an increase in the **rate of reaction**.



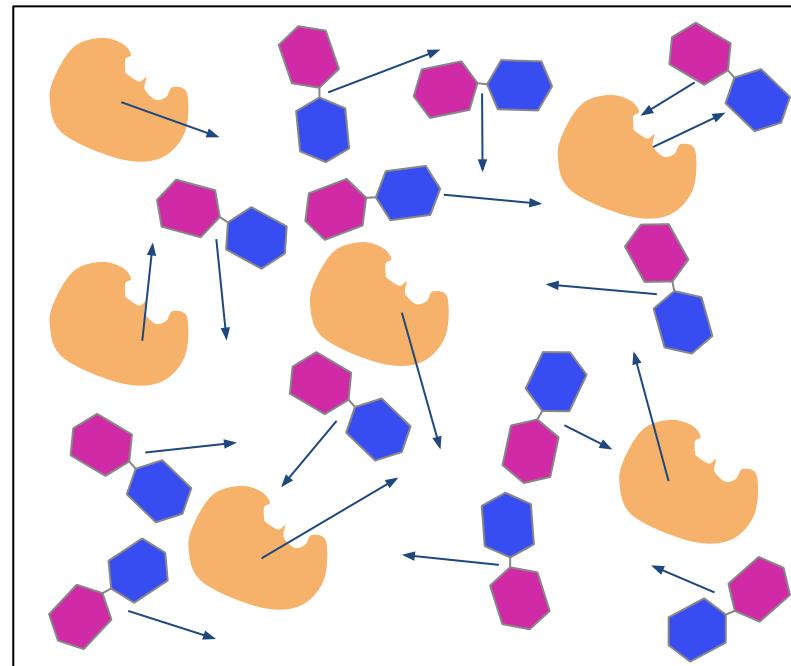
# Effect of temperature on rate

An **enzyme** active site is specific for its **substrate**, like a lock and its key.

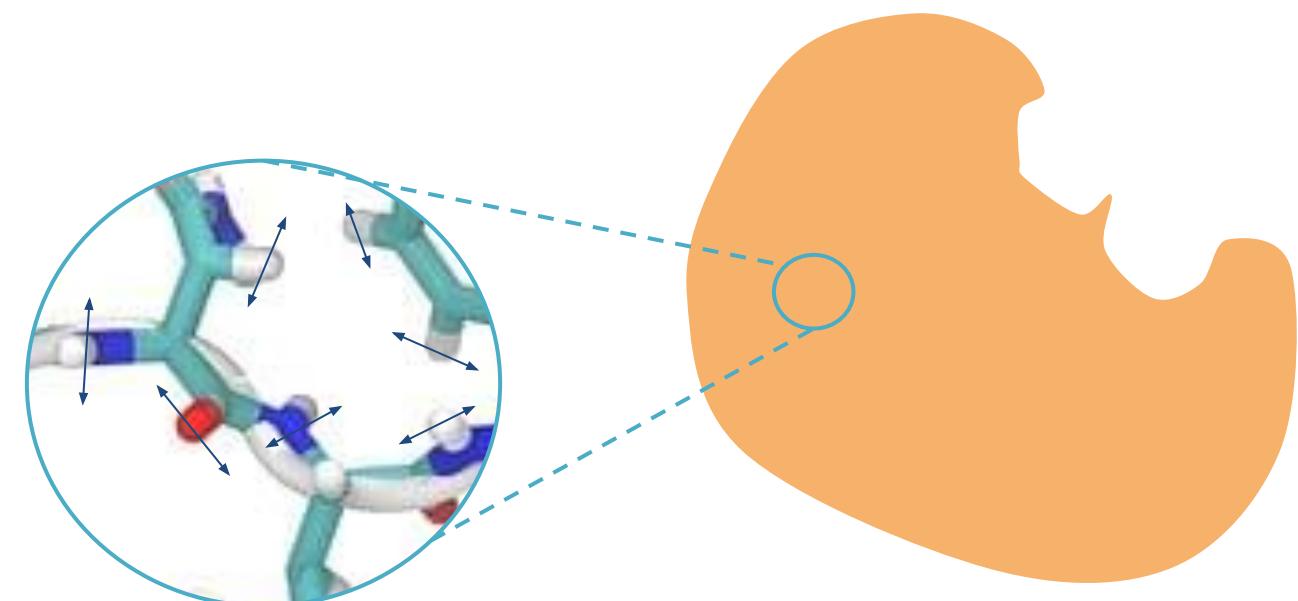


# Effect of temperature on rate

As temperature increases, molecules move faster as they have more energy.



The enzyme and substrate molecules move faster.



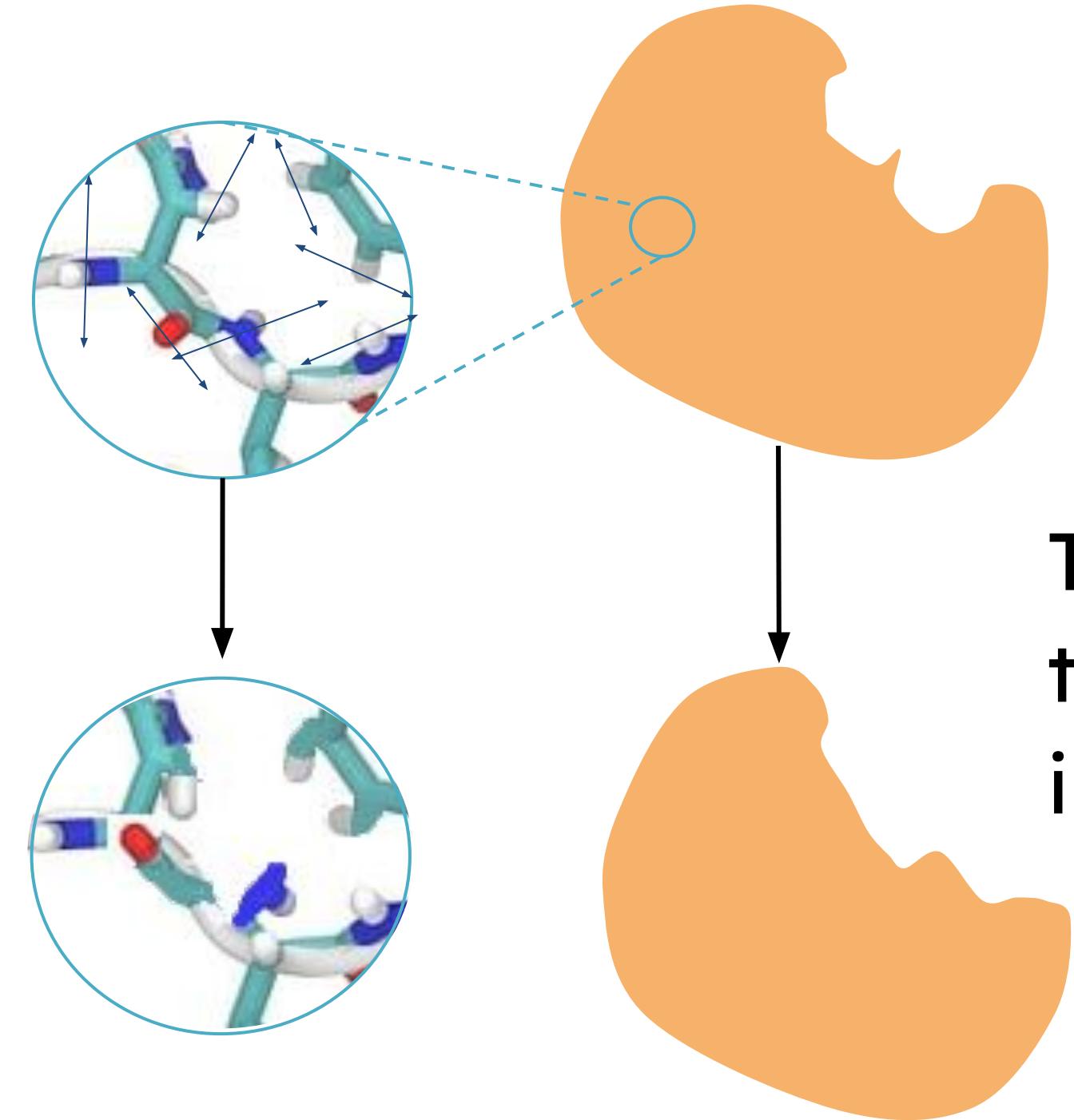
The molecules that make up the enzyme vibrate faster.

# Effect of temperature on rate

As temperatures increase above the **optimum** temperature, the molecules that make up the enzyme continue to vibrate with more force.

The **bonds** holding the enzyme molecules together start to break.

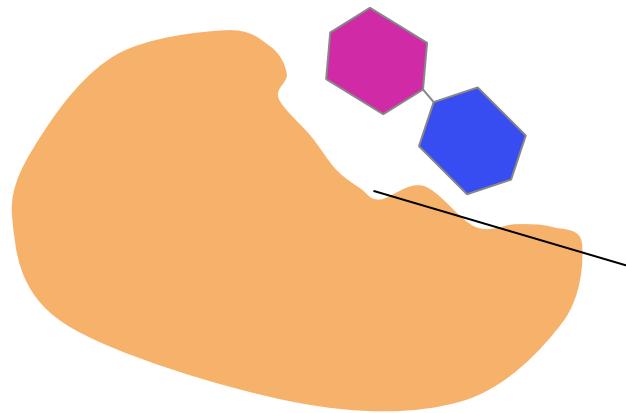
The enzyme changes shape.



The enzyme **denatures**: the substrate cannot fit into the active site.

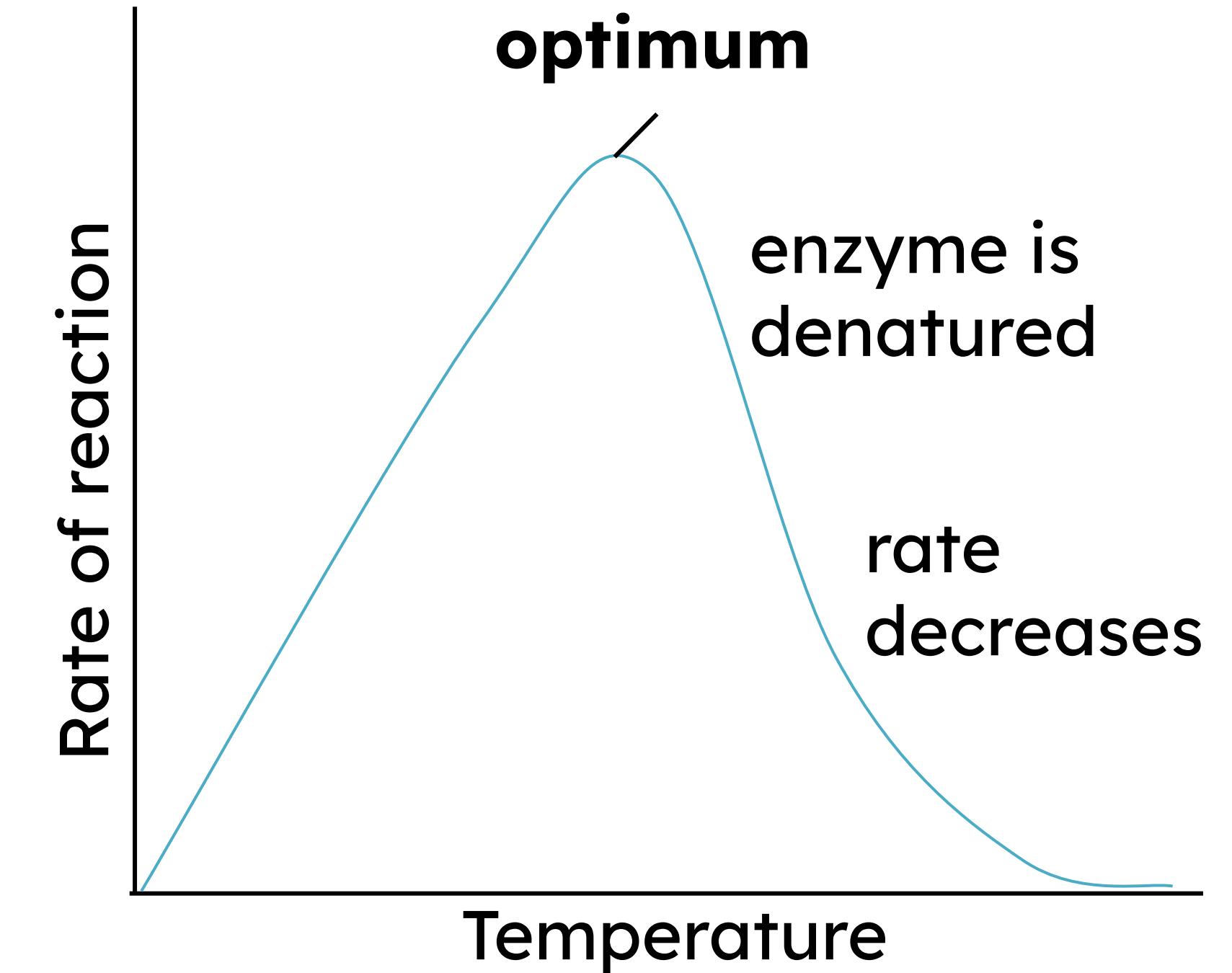
# Effect of temperature on rate

As the temperature **denatures** the enzyme by breaking chemical **bonds**, its active site no longer fits the substrate.



denatured  
active site

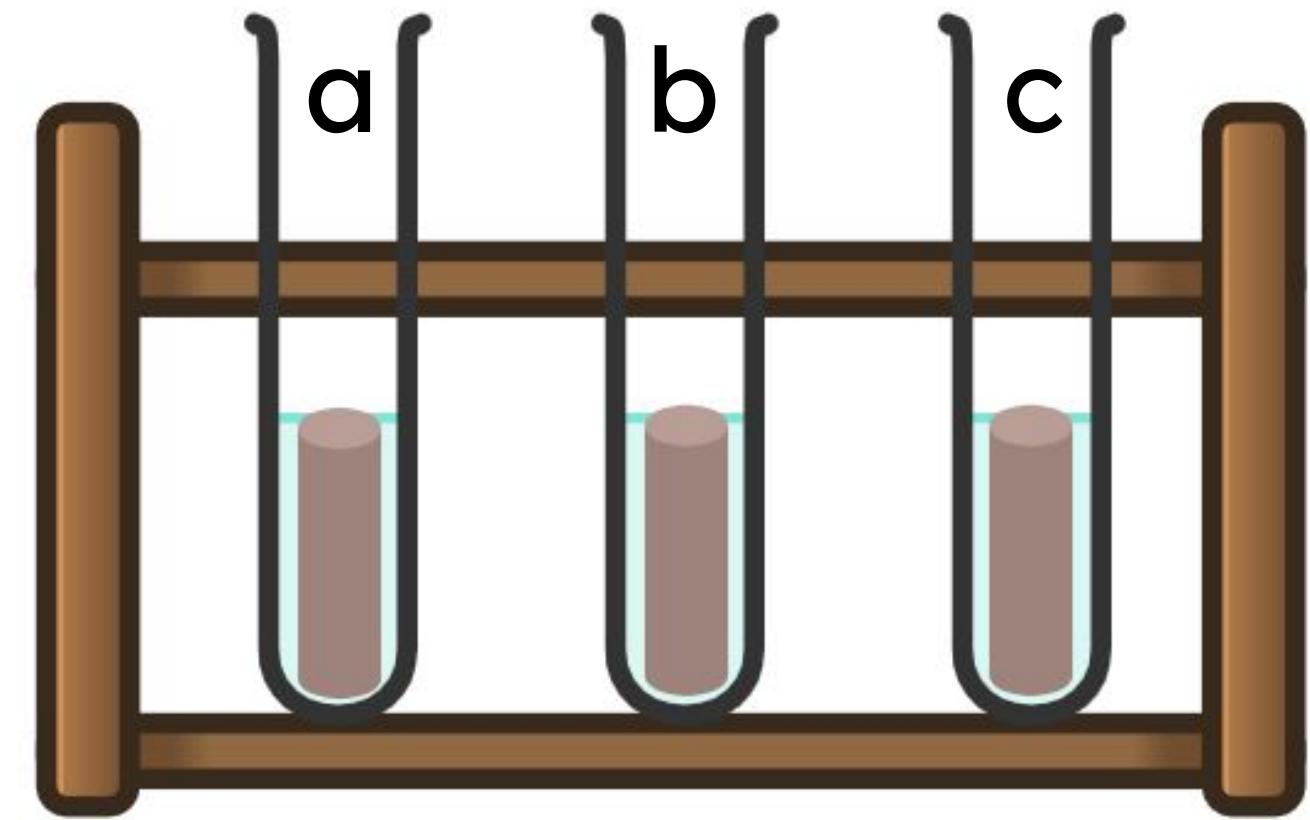
Therefore, at temperatures above the **optimum**, the rate decreases to zero.



# Effect of temperature on rate

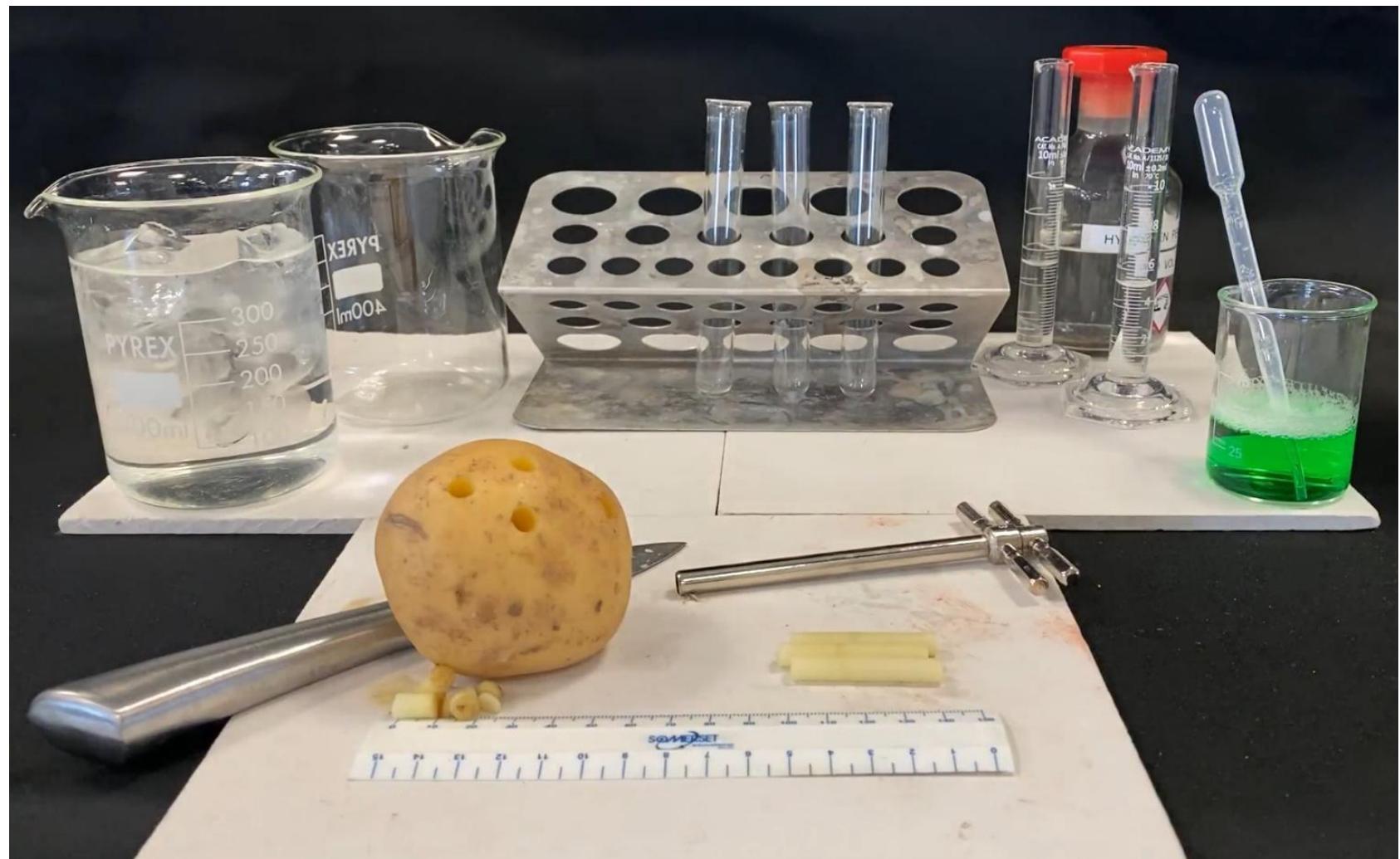
We can observe the effect of temperature on **rate of reaction**.

1. Put potato cores in each of the following conditions and leave for at least 5 minutes:
  - a. Cold
  - b. Room temperature
  - c. Hot
2. Measure  $5\text{ cm}^3$  hydrogen peroxide with  $1\text{ cm}^3$  washing up liquid into three test tubes.
3. Insert one potato core from each condition into its own test tube.
4. Observe the height of bubbles produced after a few minutes.



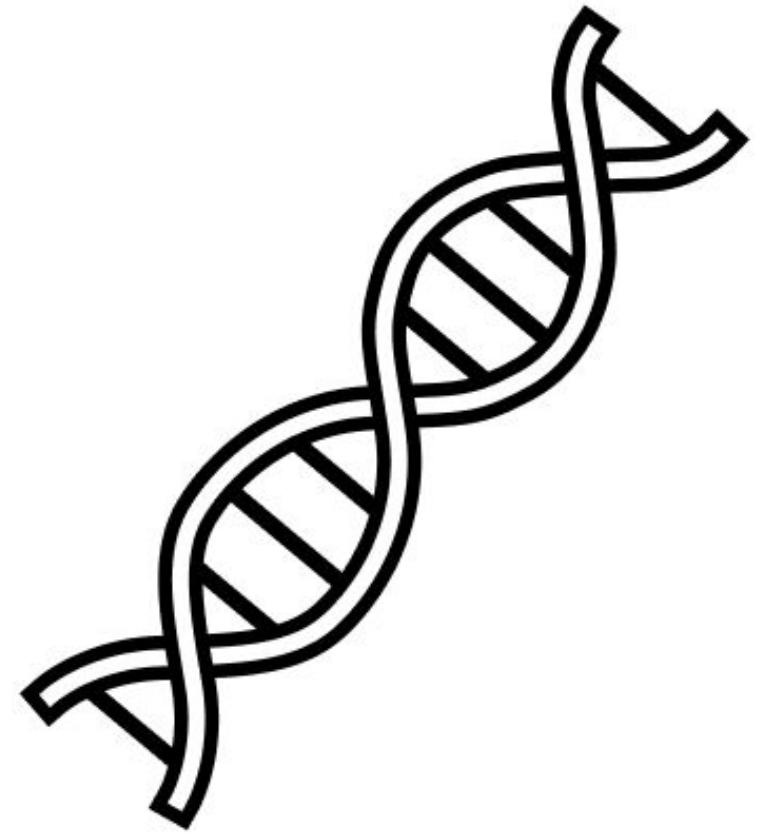
# Effect of temperature on rate

Watch the demonstration to observe what happens:



Watch ►

# The effect of pH on the rate of an enzyme reaction: practical



## Biology

Unit: Biological molecules and enzymes

# Outcome

I can carry out an investigation into the effect of changing pH on the rate of an enzyme reaction.

# Keywords

**rate of reaction** How fast a chemical reaction occurs.

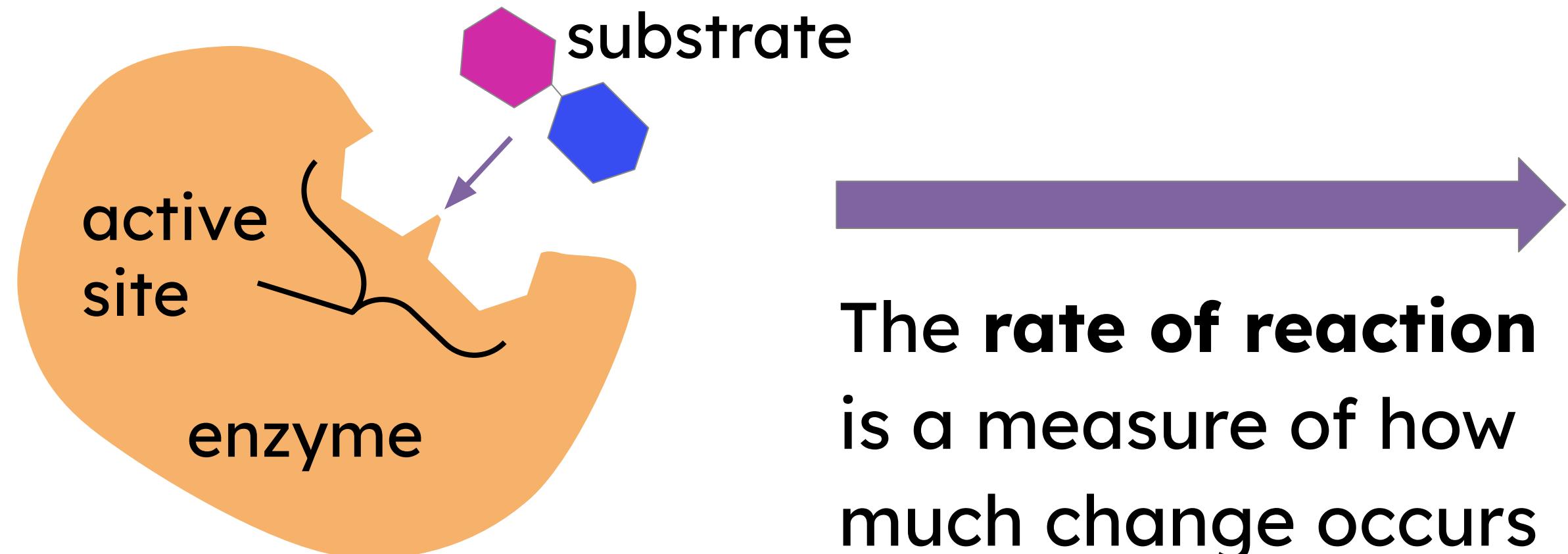
**pH** A measure of how acidic or alkaline a solution is.

**amylase** An enzyme that breaks down starch into maltose (a type of sugar).

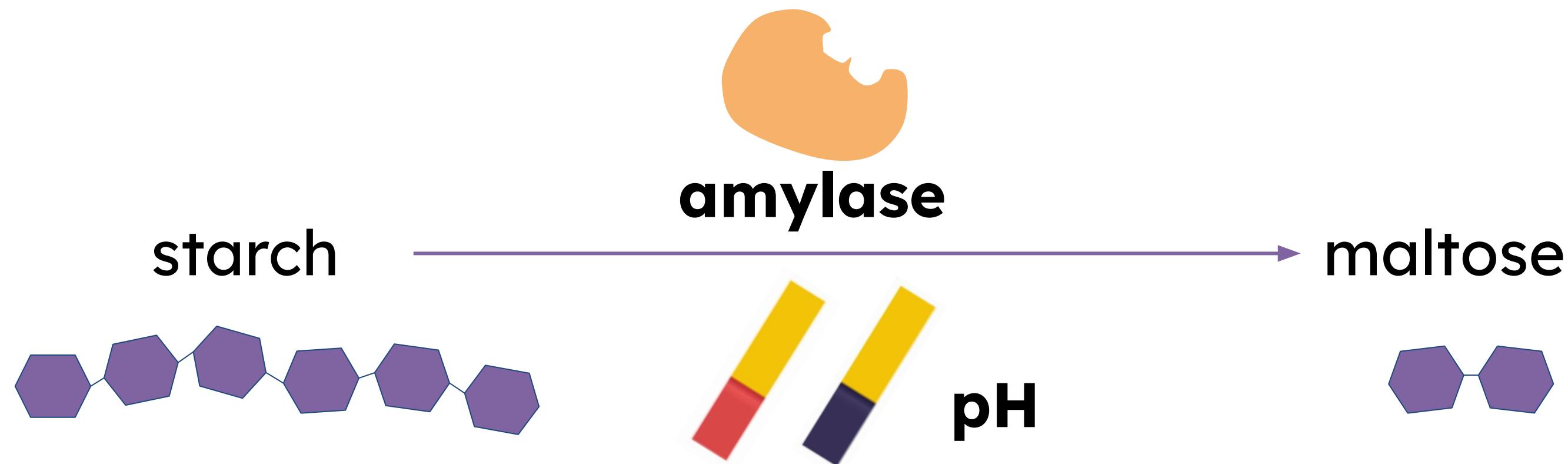
**starch** A carbohydrate, which is a polysaccharide (a polymer of sugar).

**continuous sampling** A method that involves taking regular and frequent samples.

Enzymes are biological catalysts.  
They speed up the rate of a chemical reaction.



We are going to investigate the effect of changing pH on the **rate** of activity of the enzyme **amylase** as it digests **starch** into maltose (a type of sugar).



To measure the **rate of reaction**, we will use iodine solution.



Iodine is usually  
orange / brown.



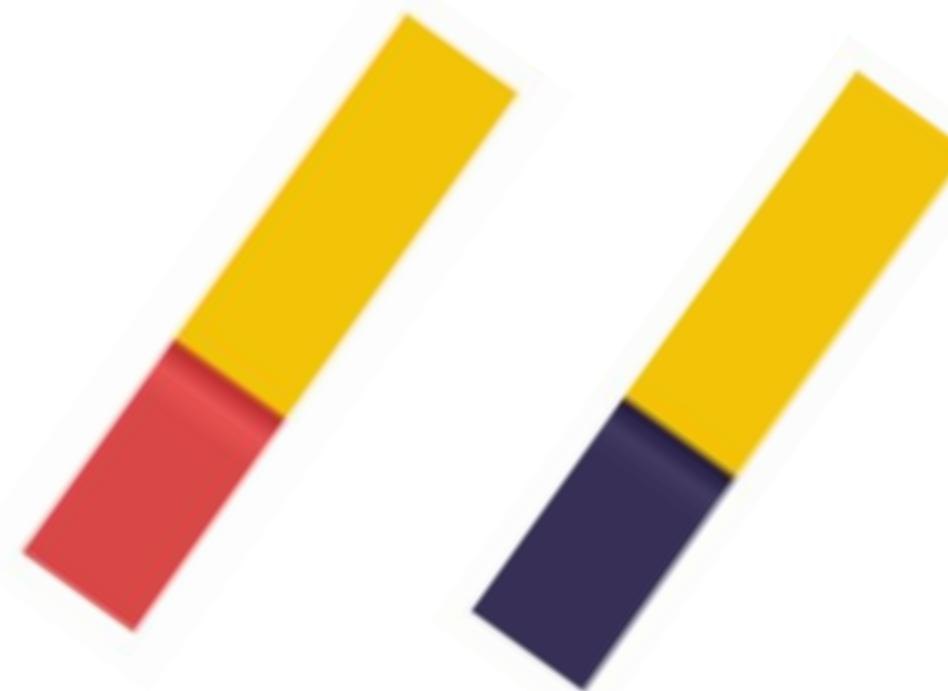
Iodine turns blue / black  
when **starch** is present.

We expect the quantity of starch to reduce as time passes, because it will be digested into maltose by the **amylase** enzyme.

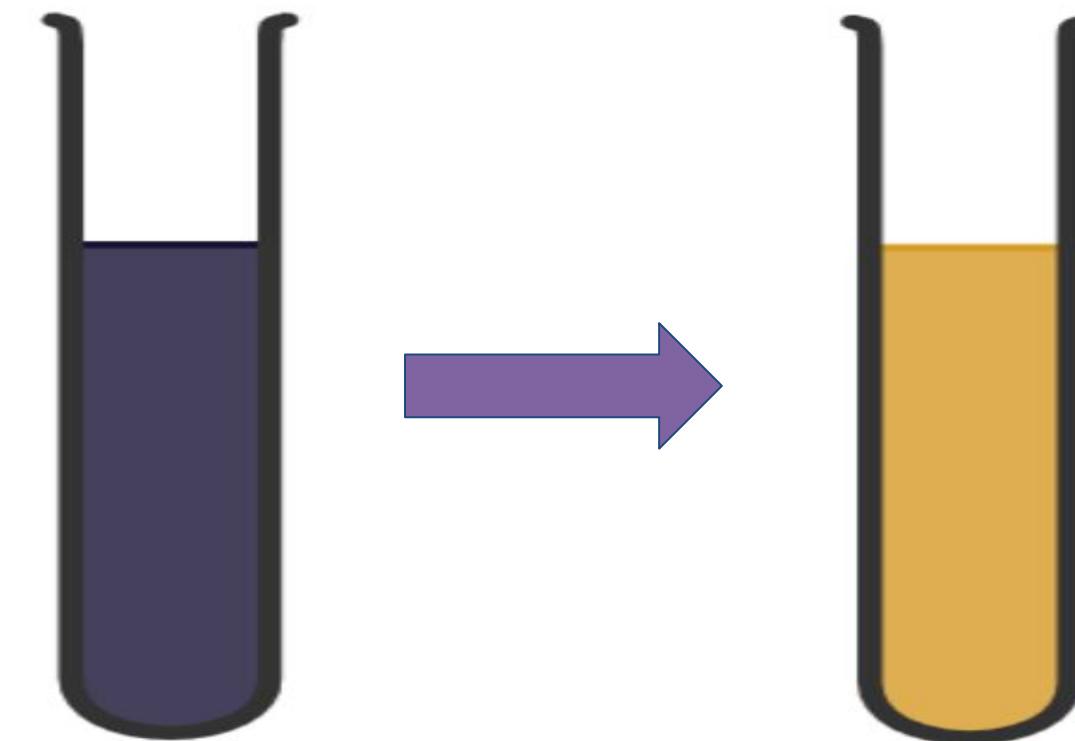
We are going to change the pH of each reaction and measure the effect this has on the **rate of reaction**.

Our variables will be:

Independent: the pH

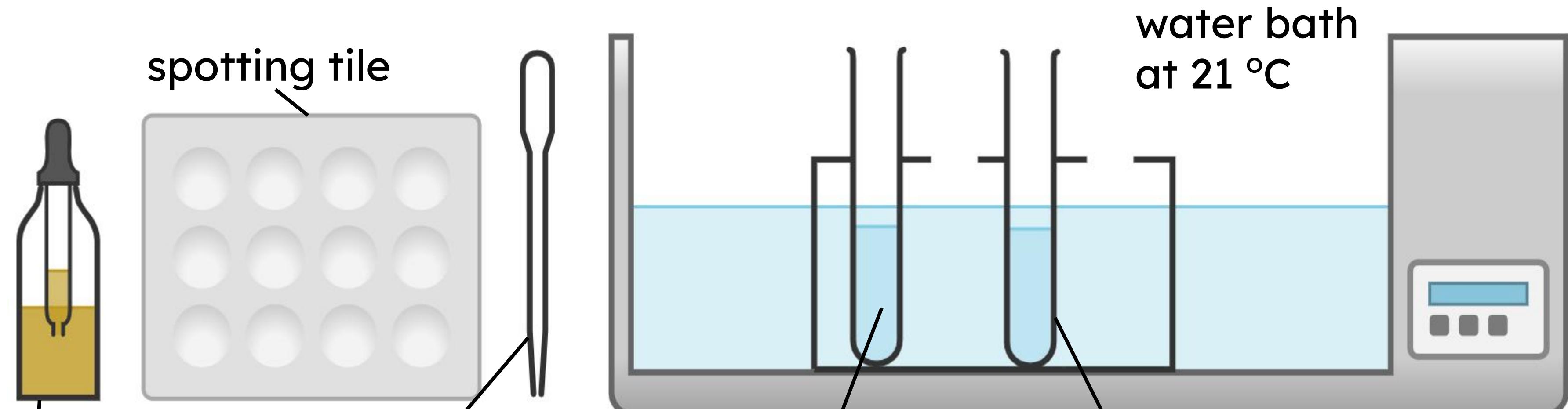


Dependent: presence / absence of starch, over time



# Preparing the practical

For this practical, you will need the following equipment:



Iodine solution

plastic pipette

5 cm<sup>3</sup> starch  
in a test tube

5 cm<sup>3</sup> amylase with  
1 cm<sup>3</sup> pH7 buffer in  
a test tube

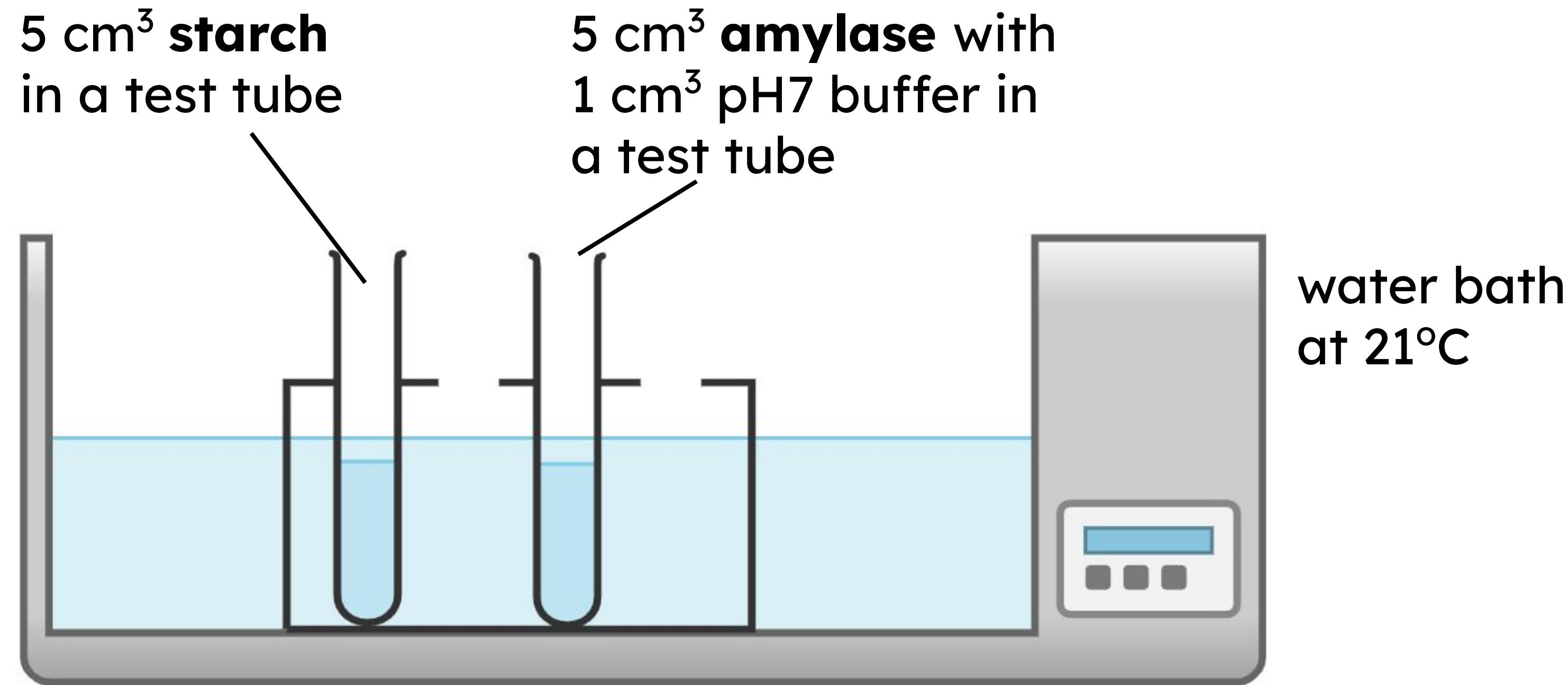


Caution: iodine solution is an irritant.  
Wear safety goggles.



# Preparing the practical

You will need to leave the starch and amylase+buffer in the water bath for 5 minutes to get to temperature.



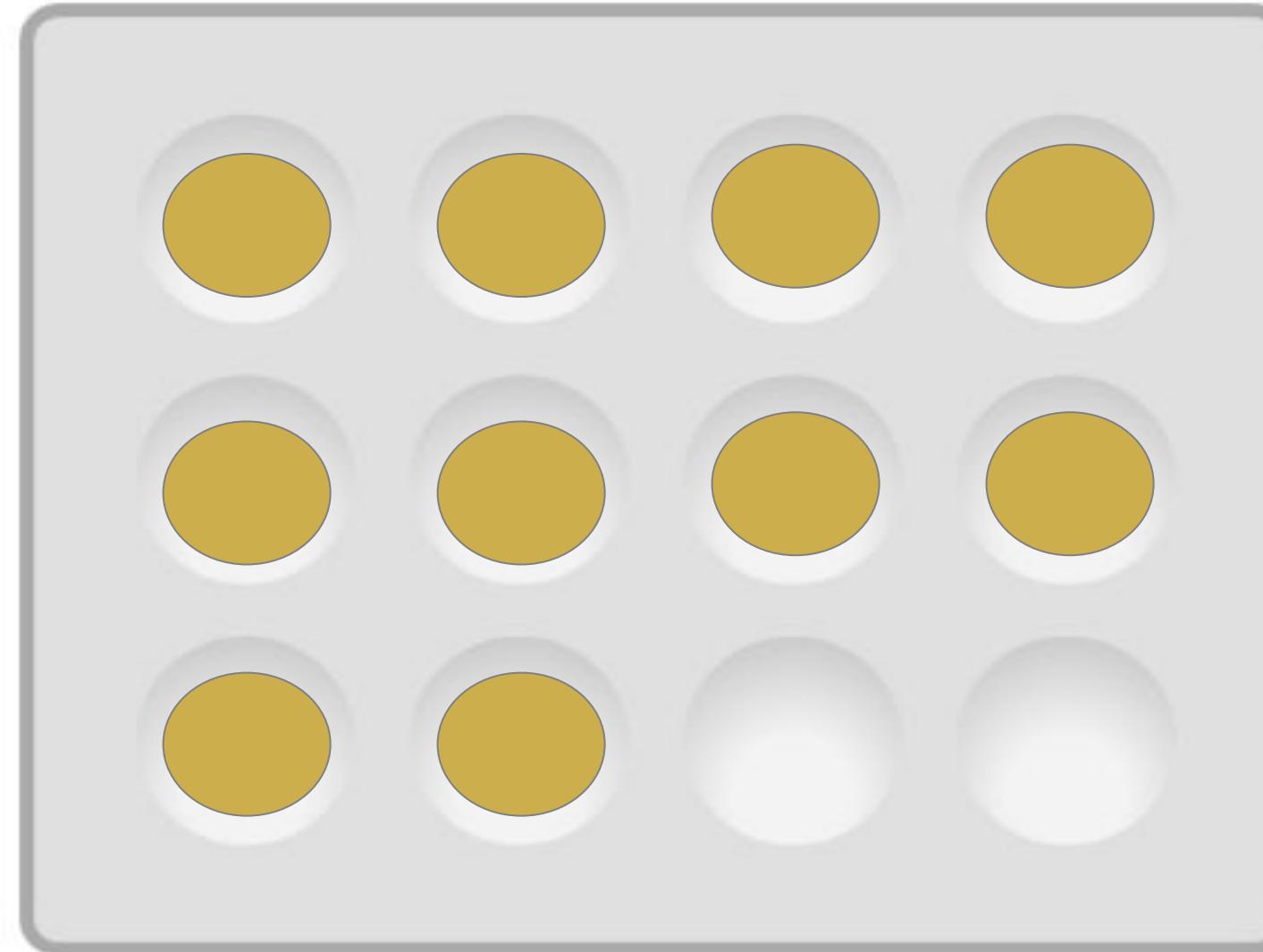
# Preparing the practical

You will need to add a few drops of iodine solution to each of ten spots on the spotting tile.

You will also need a stopwatch.

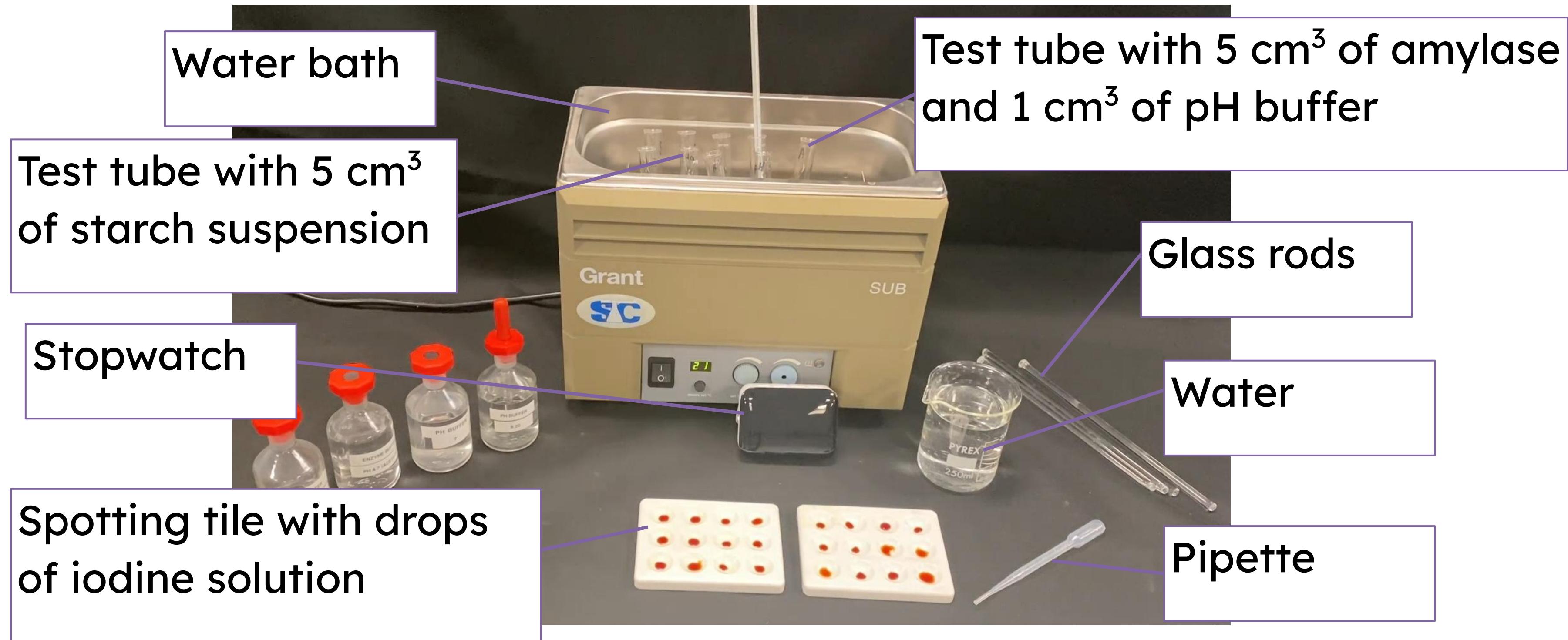


Caution: iodine solution is an irritant. Wear safety goggles.



Iodine solution in each of ten spots on the spotting tile.

## Set up your equipment and materials neatly.



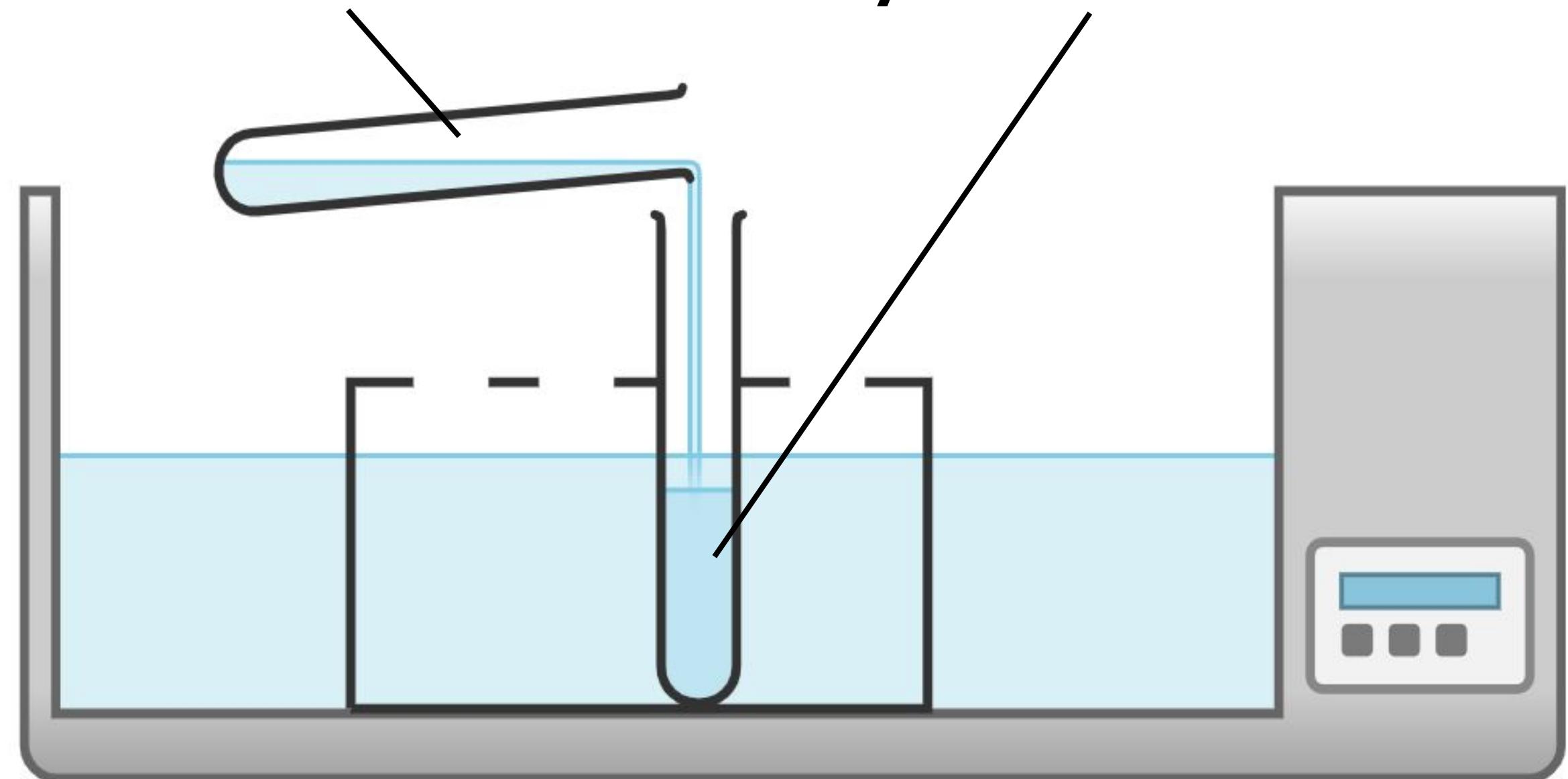
# Completing the practical

Once the **starch** and **amylase+buffer** have been in the water bath for 5 minutes, combine these two test tubes into one and return it to the water bath.

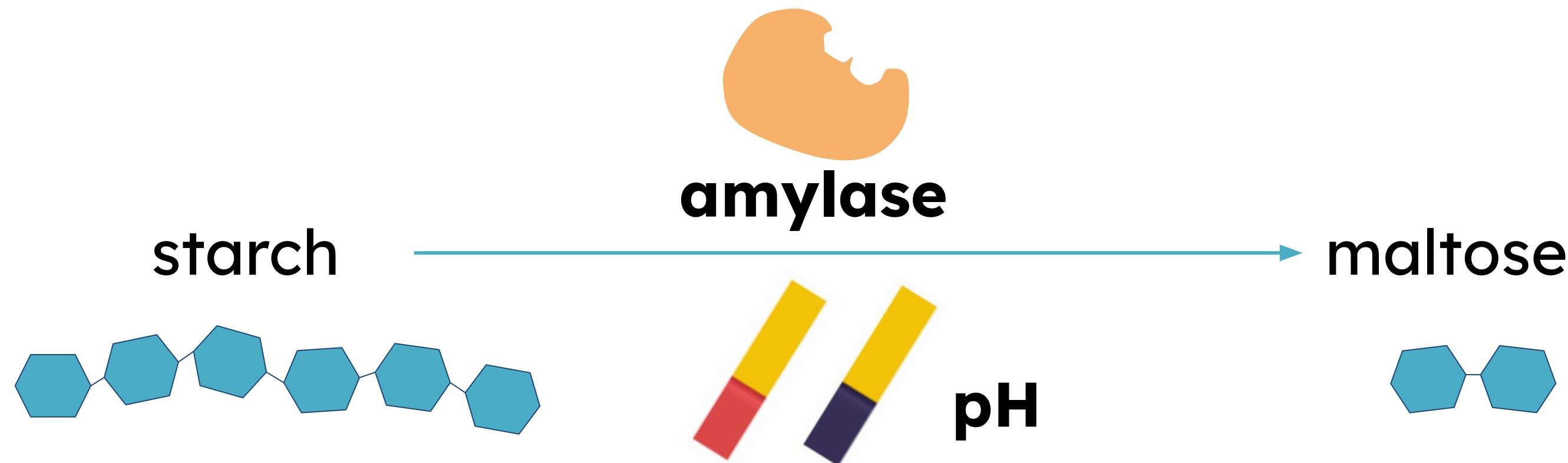
Immediately start the stopwatch.



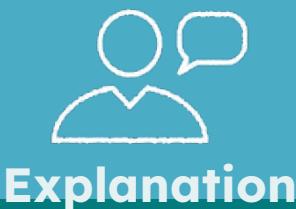
Pour the **starch** solution into **amylase+buffer** solution.



The **amylase** will digest the **starch** into maltose once the two solutions are combined.



# Completing the practical



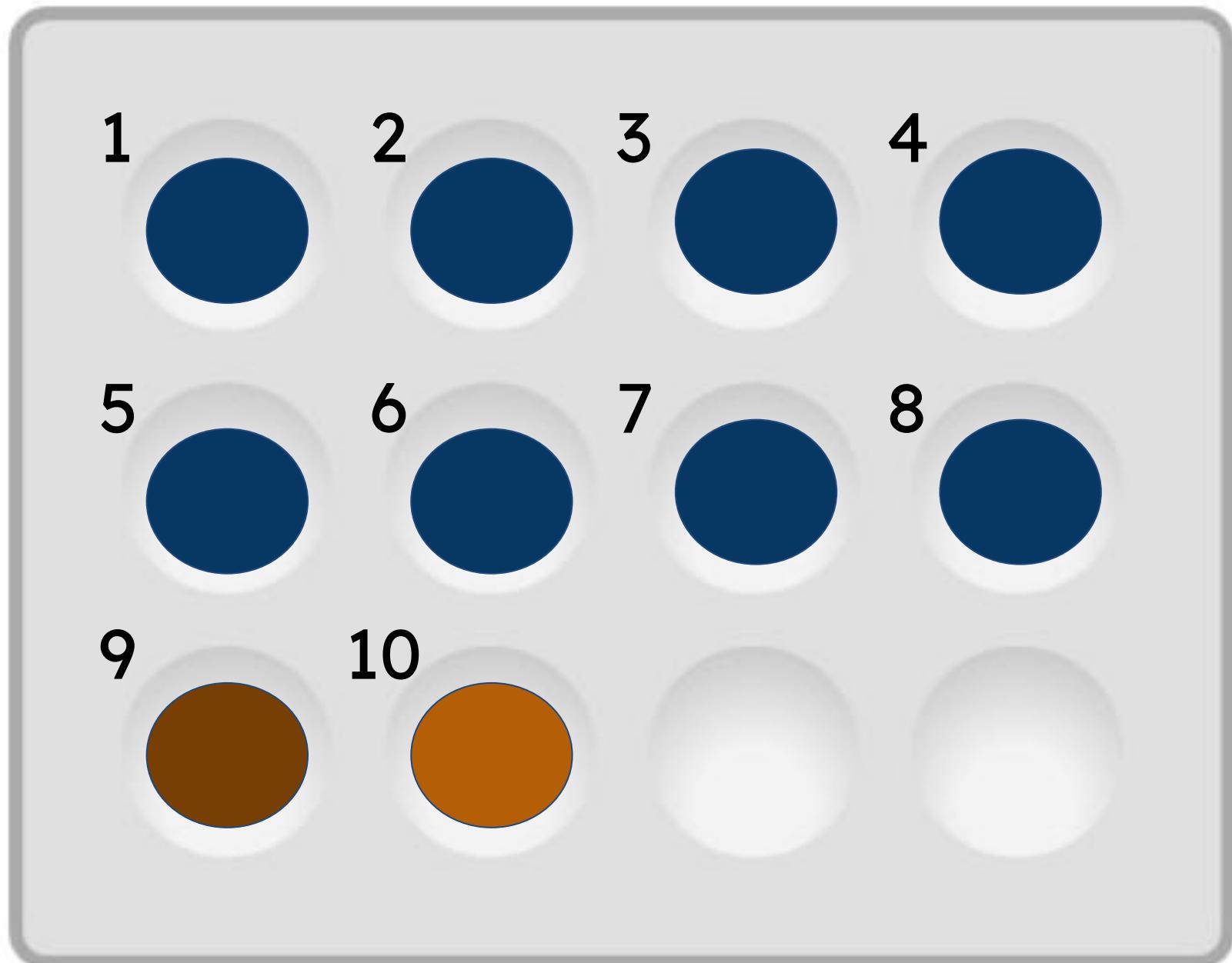
We are going to **continuously sample** this reaction.

To do this, take a sample of the solution **every minute** for up to ten minutes.

Add the sample to iodine solution in the spotting tile.

Record the time the iodine is orange / brown; the reaction has finished.

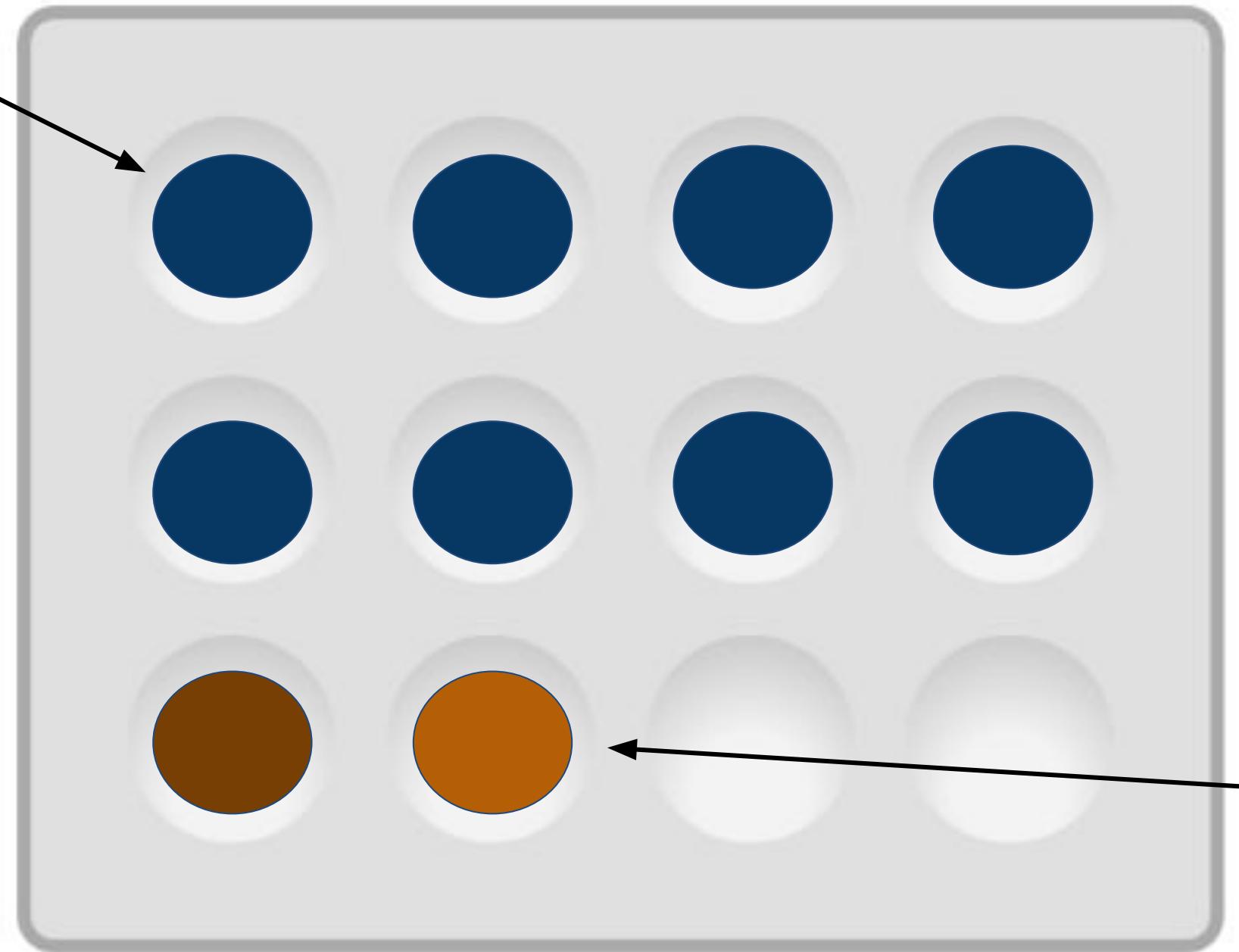
If there is no colour change, stop after ten minutes have passed.



Samples combined with iodine solution in the spotting tile.

# Completing the practical

To start with, iodine will turn blue / black because **starch** is present.



If **amylase** is able to catalyse the reaction, the amount of **starch** will reduce.

Eventually, there will be no **starch** present, and the iodine will remain orange / brown.

Once we have results for the pH7 buffer solution, repeat the experiment using buffer solutions of pH2 and pH12, separately.



pH2 is acidic



pH12 is alkaline

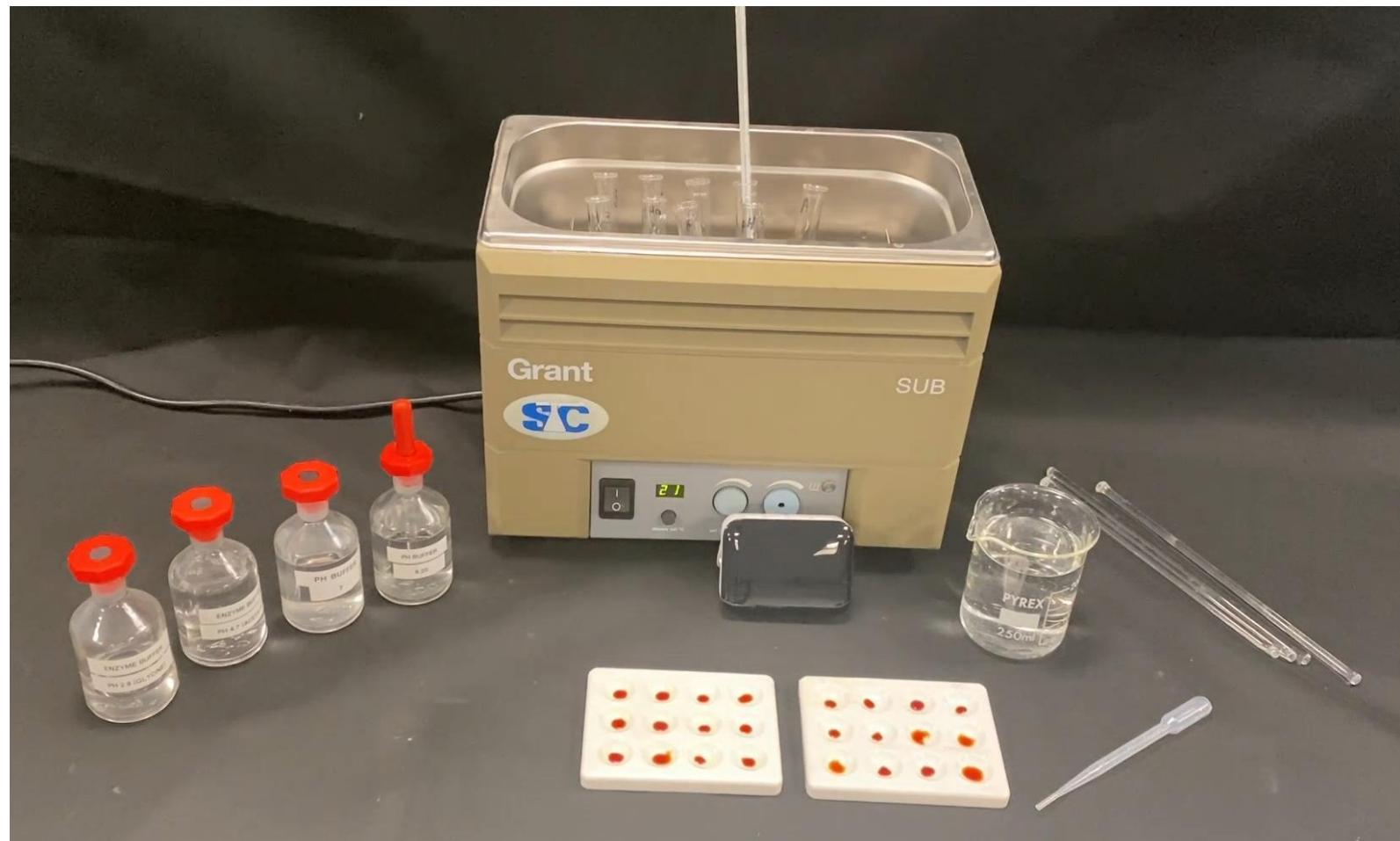


Caution: acidic and alkaline solutions are irritants.  
Wear safety goggles.



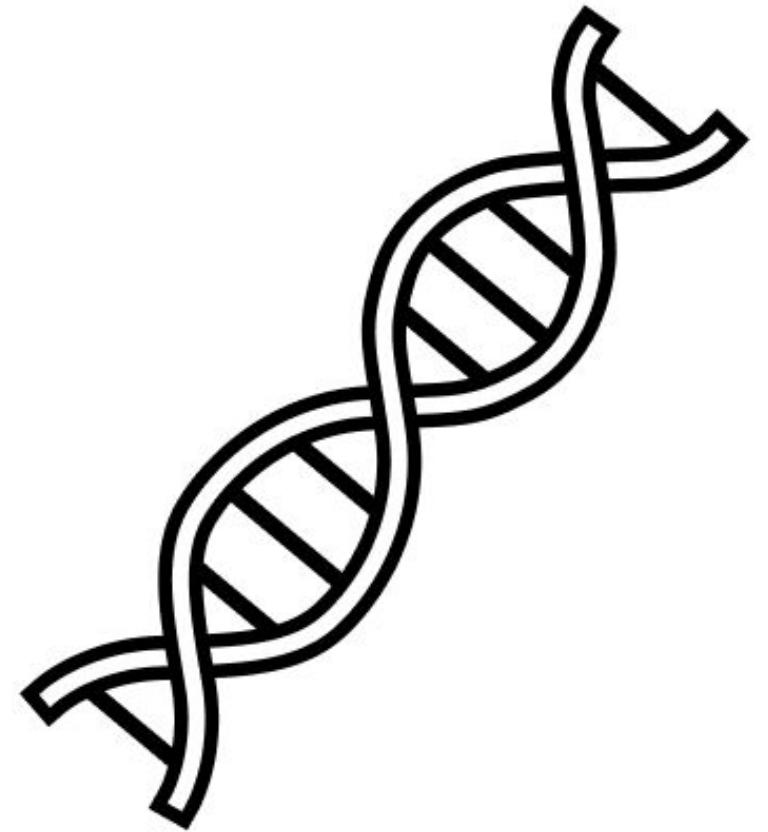
# Completing the practical

Watch the video clip which shows how to carry out this practical.



Watch 

# The effect of pH on the rate of an enzyme reaction: data analysis

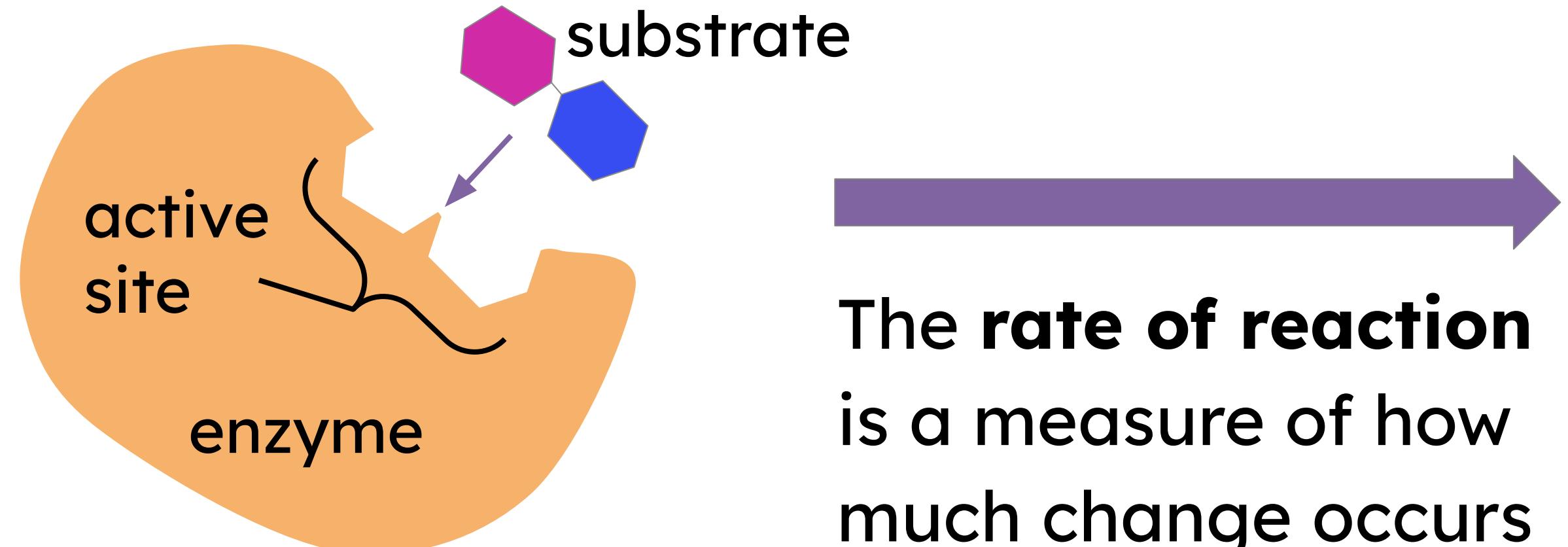


## Biology

Unit: Biological molecules and enzymes

# Interpreting experiment data

Enzymes are biological catalysts.  
They speed up the rate of a chemical reaction.

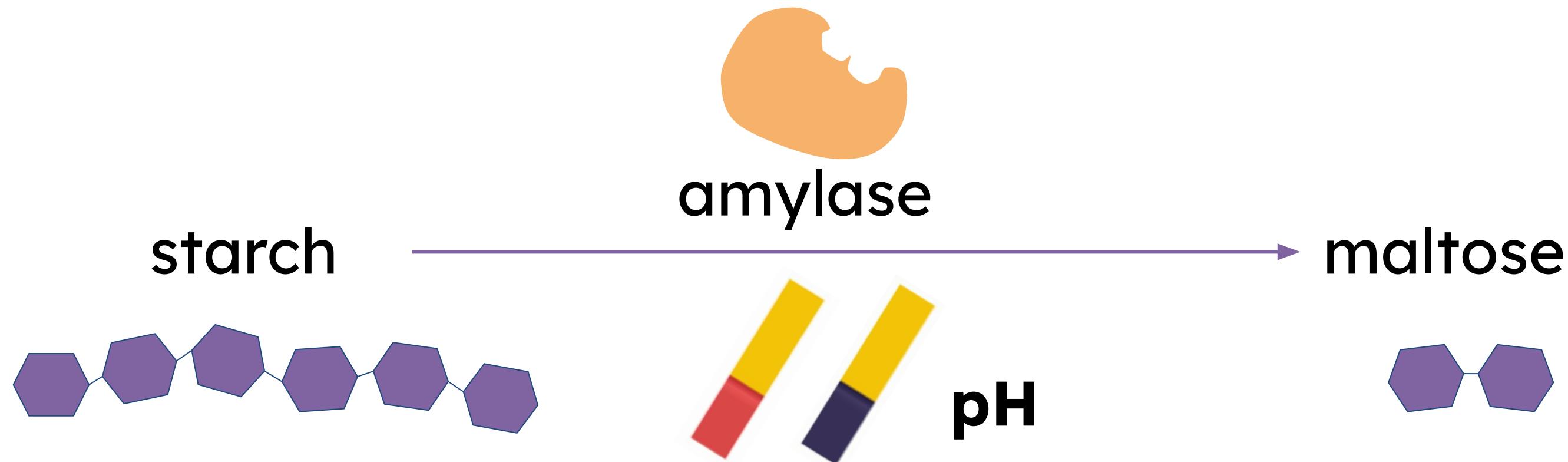


The **rate of reaction** is a measure of how much change occurs per unit of time.

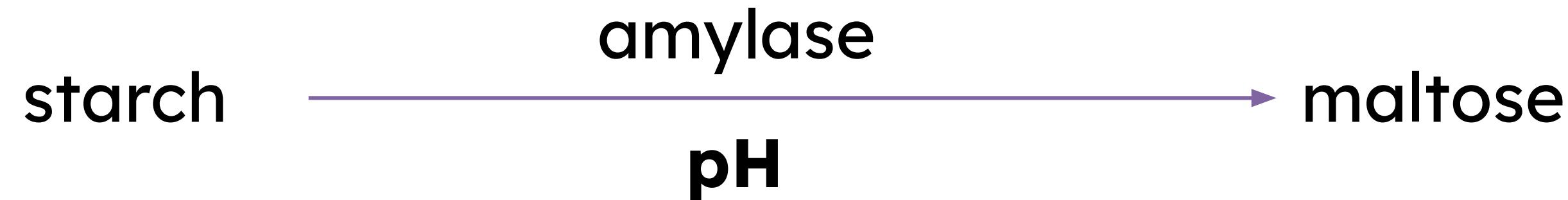
# Interpreting experiment data

In the reaction catalysed by the enzyme amylase, starch is converted into maltose (a form of sugar).

The **rate of reaction** should change at different pHs.



# Interpreting experiment data



We can make a prediction about this reaction.

At the optimum pH, rate should be highest.

At other pHs, the rate will be less.

We are going to analyse data from an experiment and decide whether it increases or decreases our confidence in this prediction.

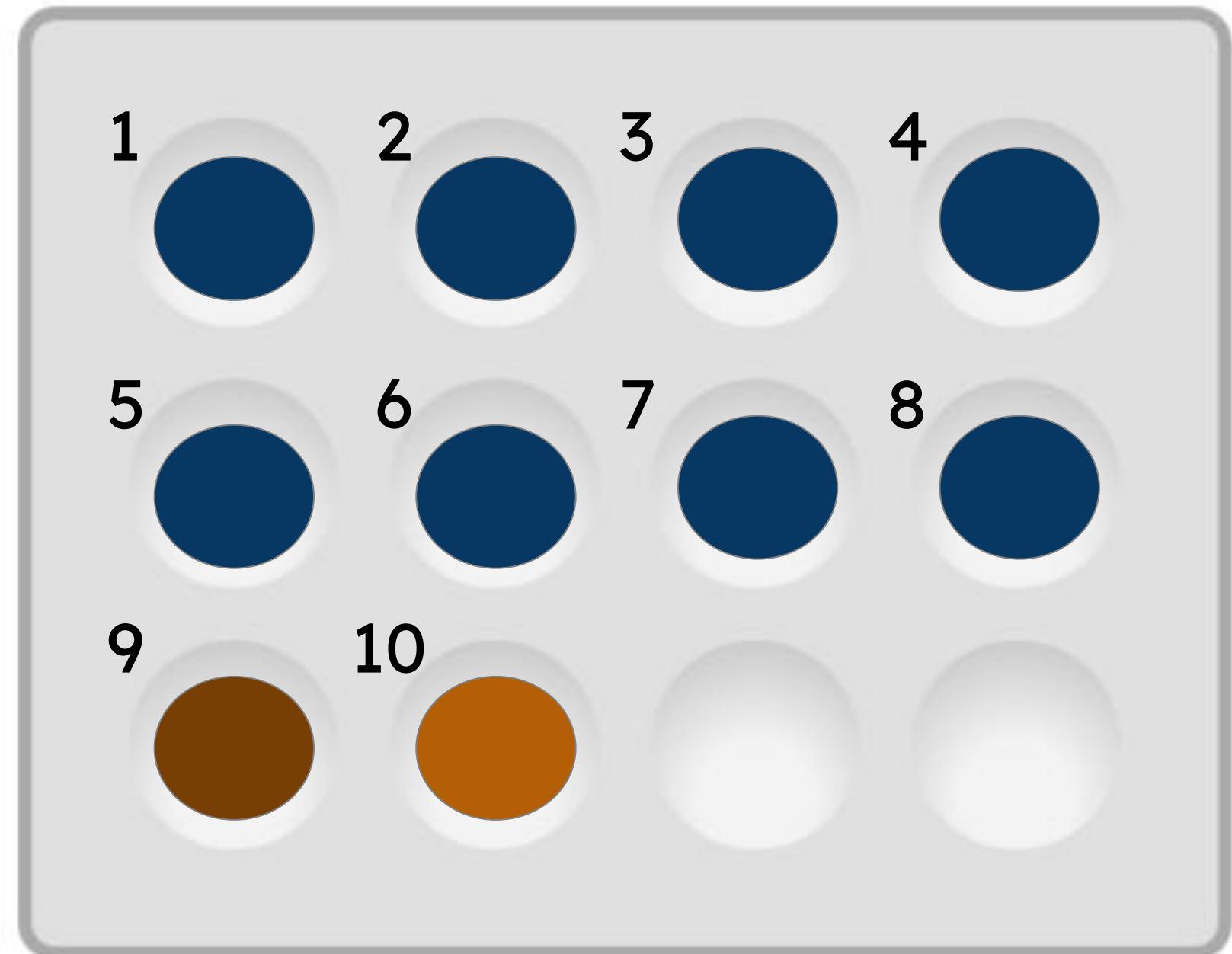
# Interpreting experiment data

In the experiment, the reaction mixture was continuously sampled.

To do this, a sample of the reaction mixture was taken every minute. The sample was added to iodine solution in a spotting tile.

The **end point** of the reaction is reached when all the starch has been broken down to maltose.

At this point, iodine solution remains brown when the sample is added.



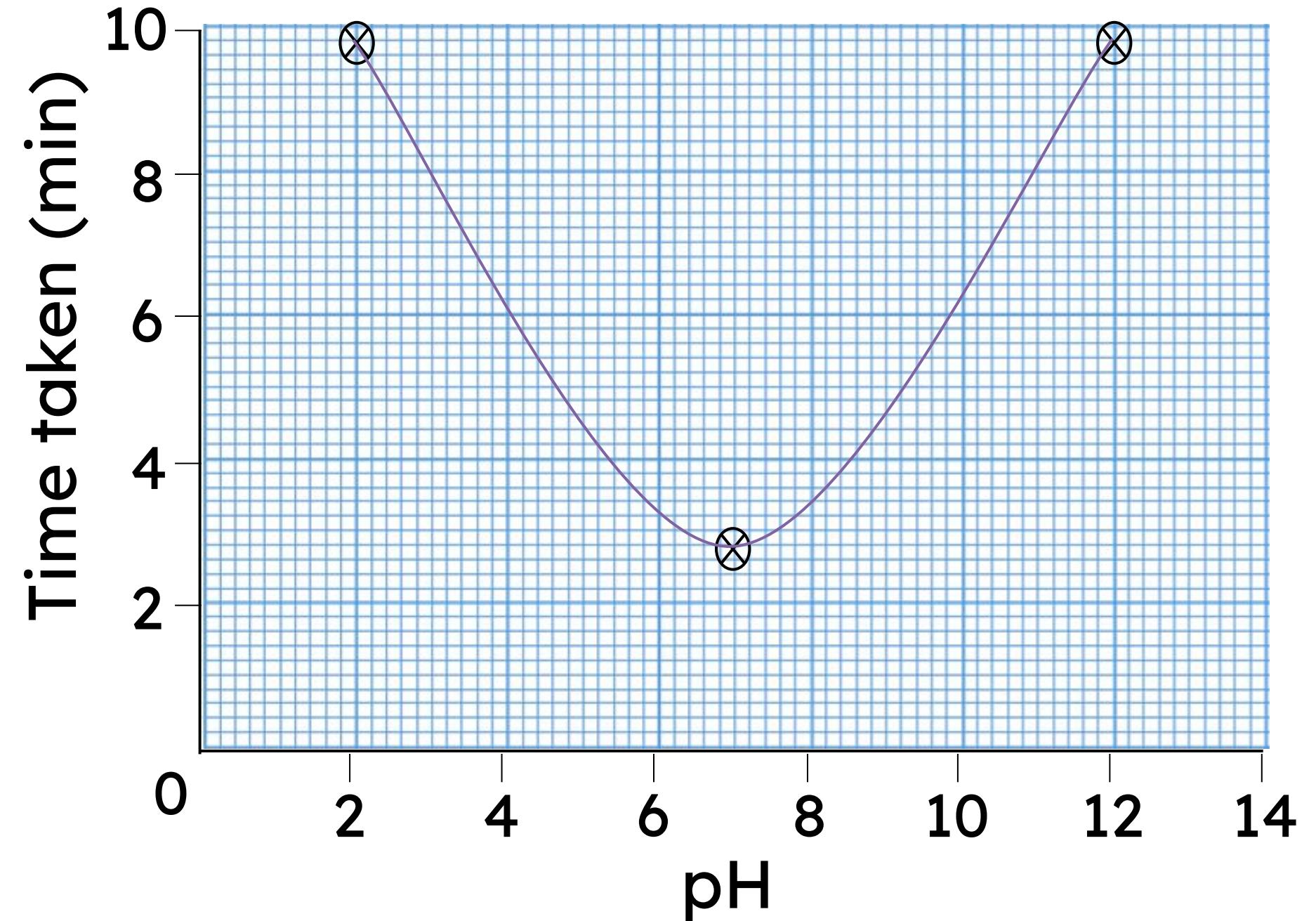
Samples combined with iodine solution in a spotting tile.

# Interpreting experiment data

Look at the results from this experiment:

pH of buffer	Time taken to reach end point (min)
7	3
2	>10
12	>10

Let's plot the data on a graph:



Scientists convert the time taken into rate.

To calculate rate:

$$\text{rate} = \frac{1}{\text{time taken}}$$

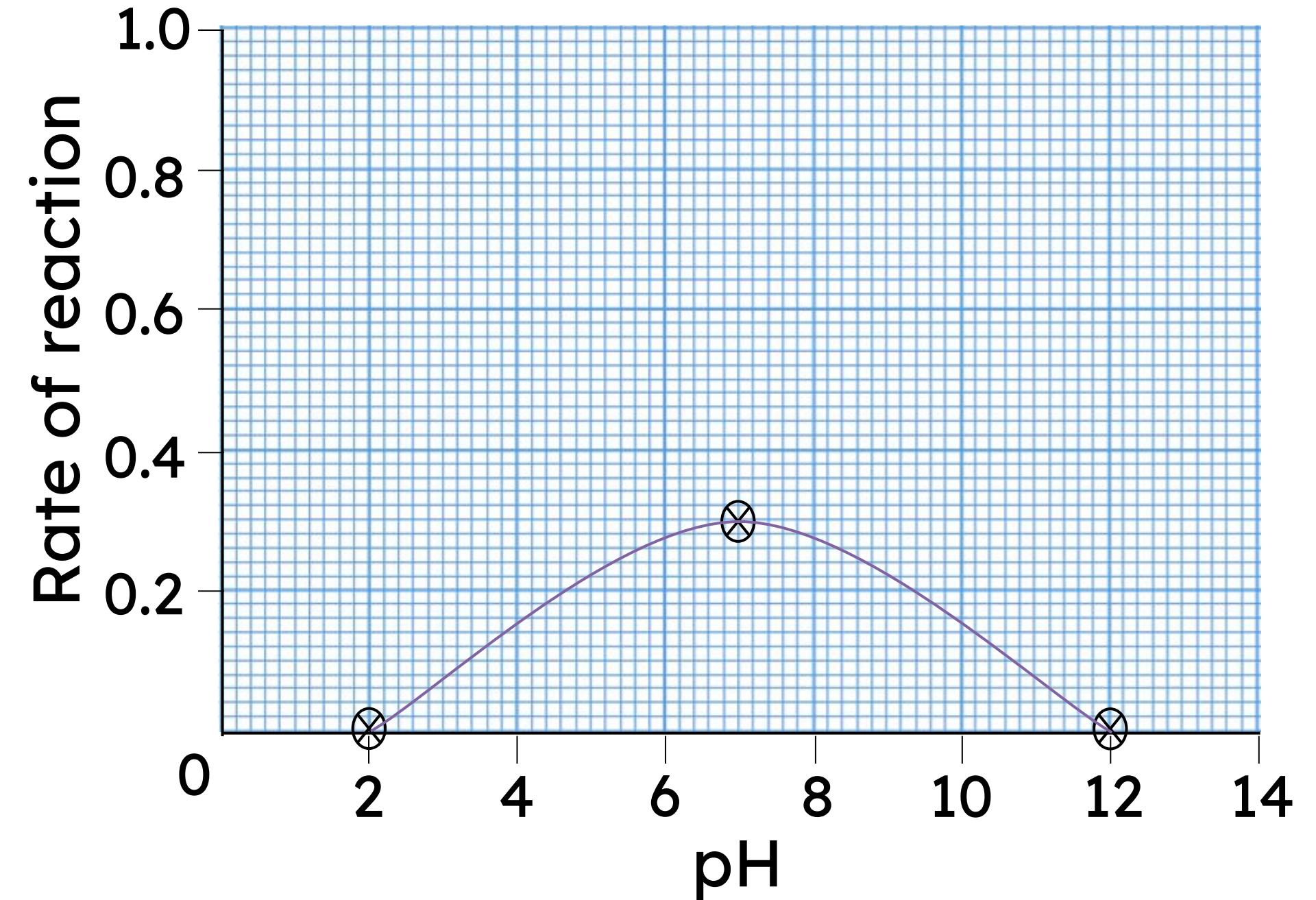
We can do this with the data from this experiment.

pH of buffer	Time taken (mins)	Rate of reaction
7	3	0.3
2	>10	0.0
12	>10	0.0

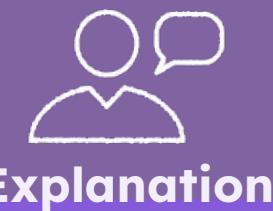
# Interpreting experiment data

We can plot rate on a graph:

pH of buffer	Rate of reaction
7	0.3
2	0.0
12	0.0



# Interpreting experiment data

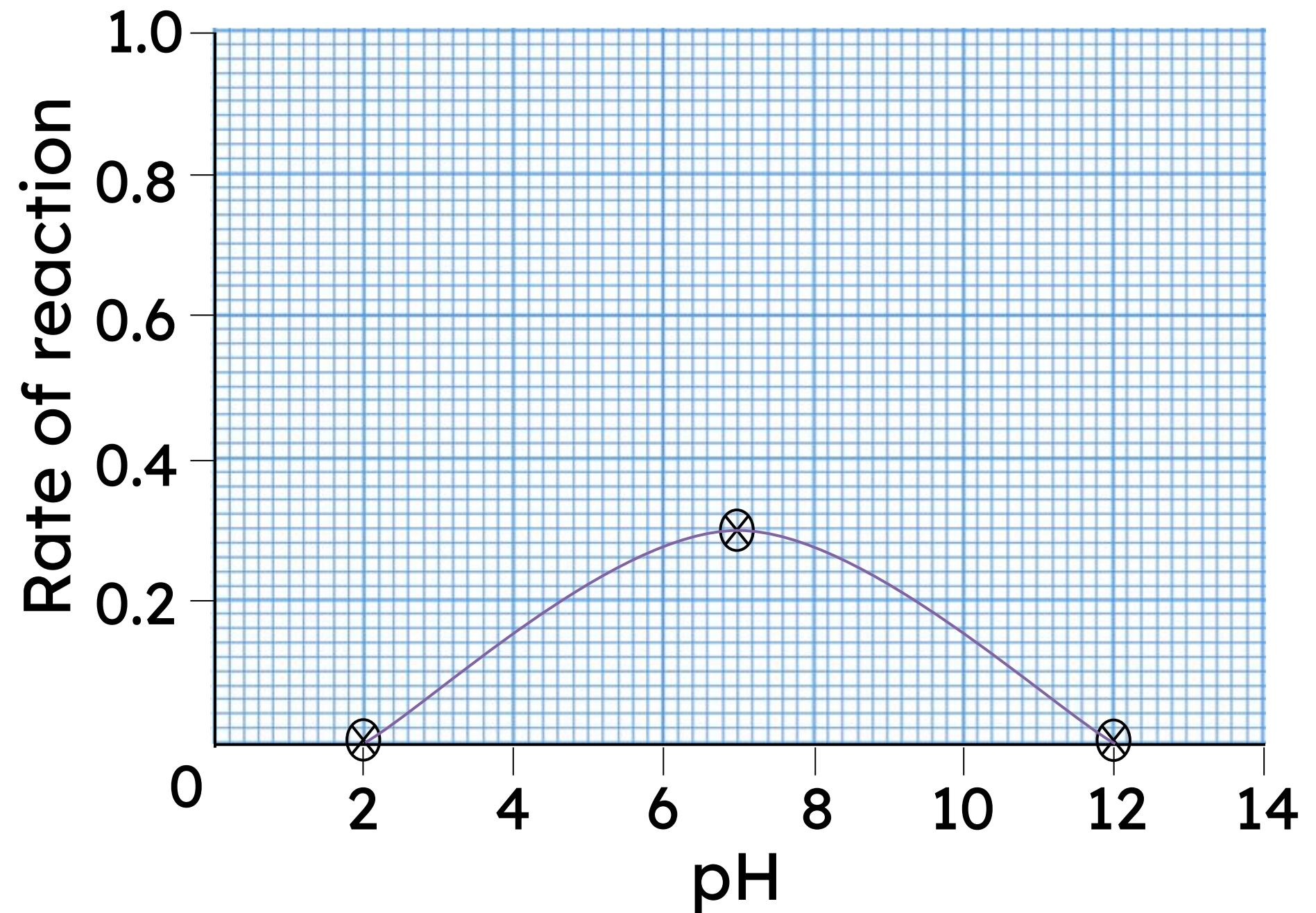


Our original prediction was:

- ✓ At the optimum pH, rate should be highest.
- ✓ At other pHs, the rate will be less.

These results increase confidence in our prediction.

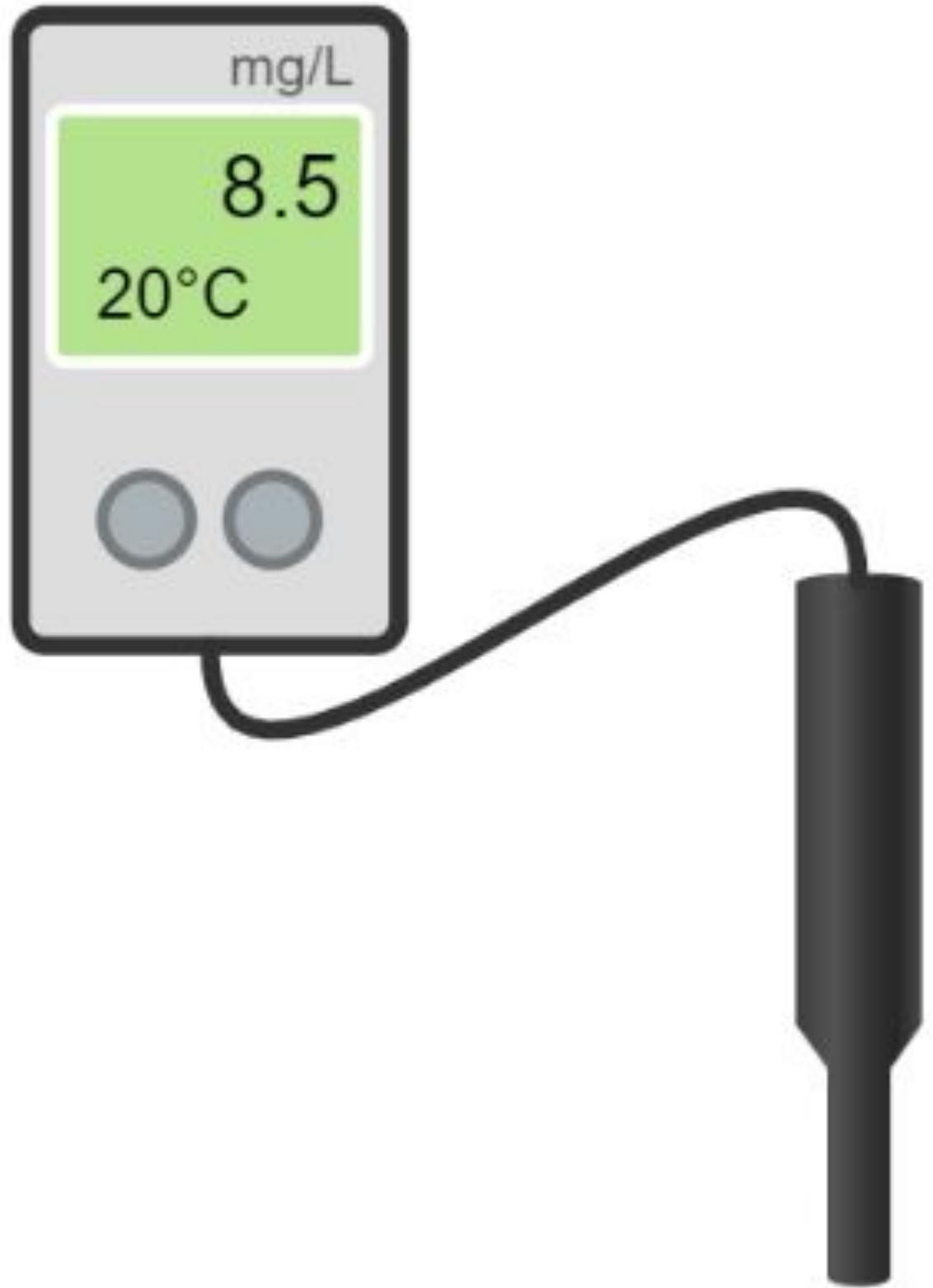
Our results are:



How could we improve our confidence further?

We could:

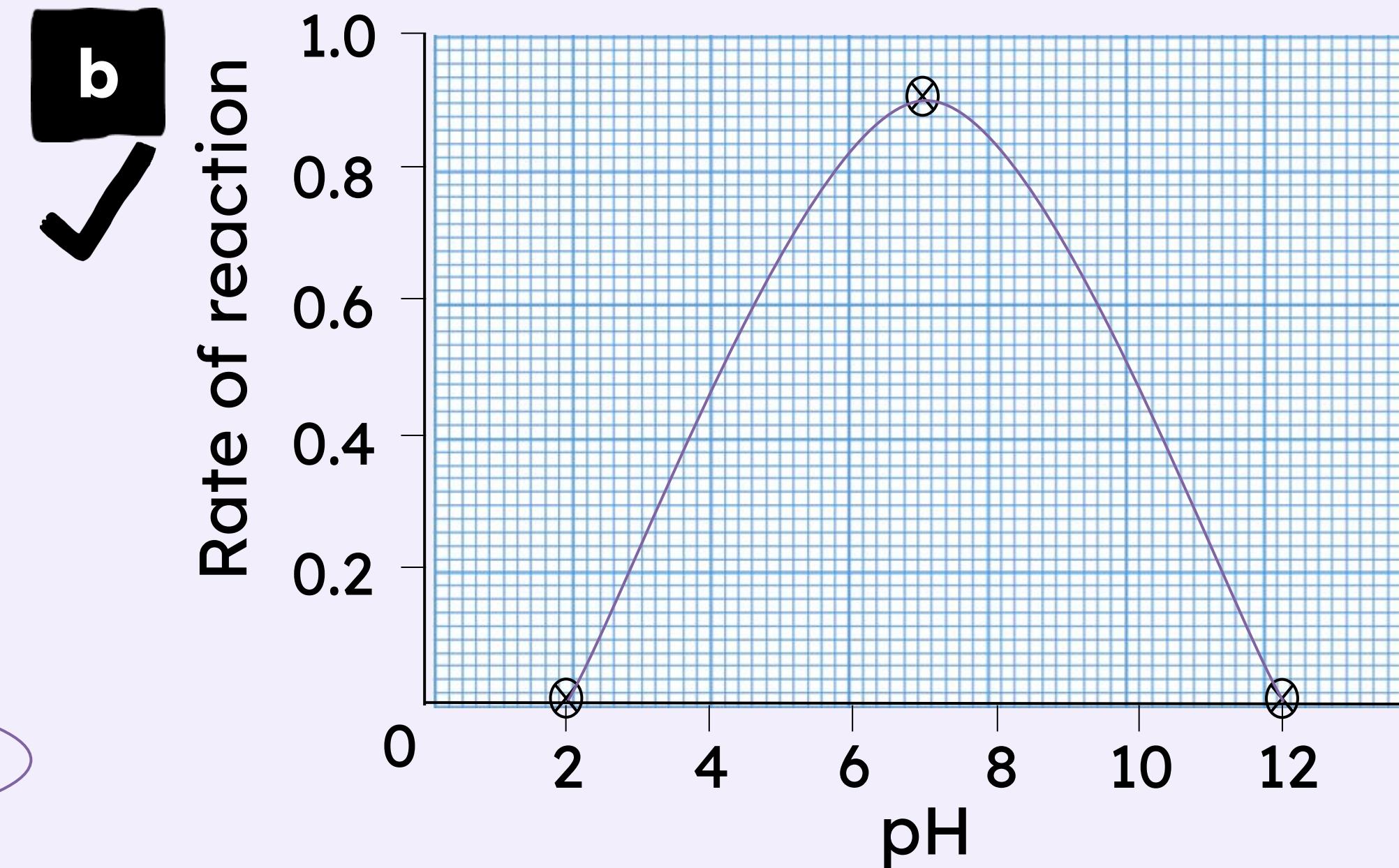
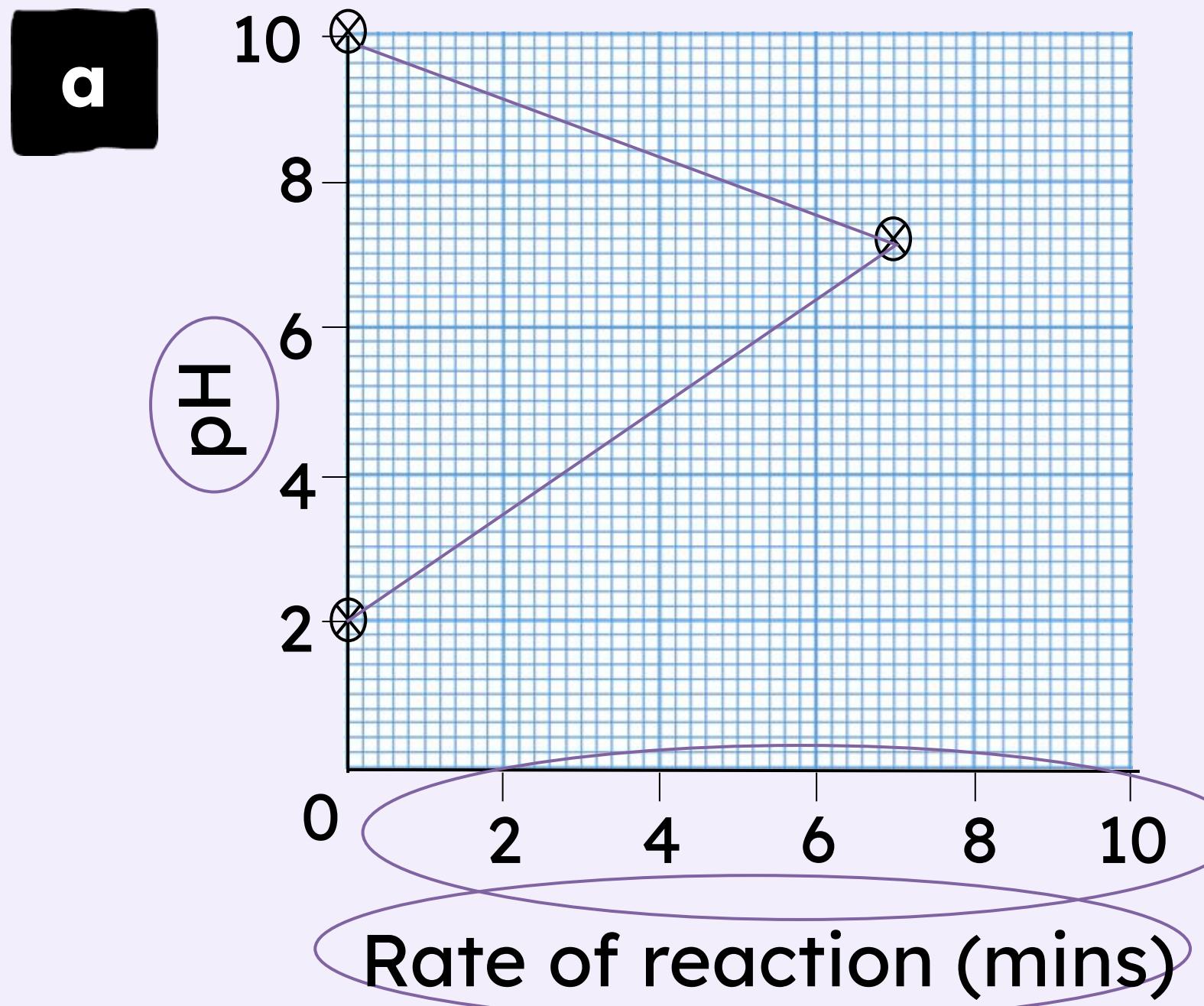
- Repeat our experiment and calculate the mean.
- Test using more pHs.
- Sample more frequently.
- Use a data logger to collect the results.



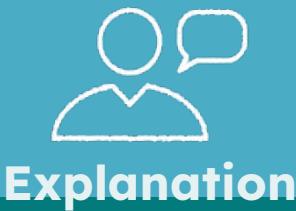
# Interpreting experiment data



Which graph is drawn correctly? What is incorrect about the other graph?

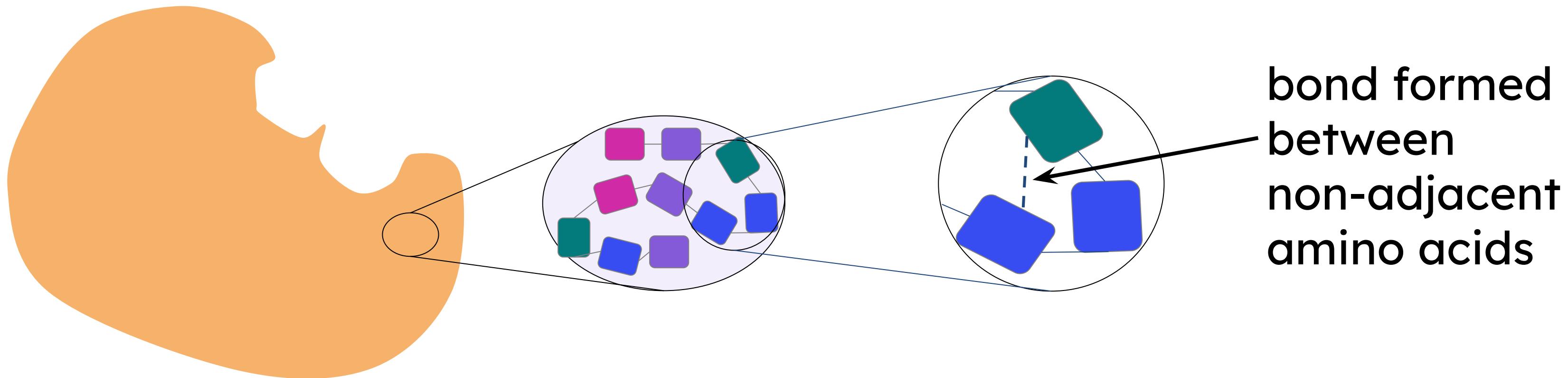


# Explaining effect of pH on enzyme activity

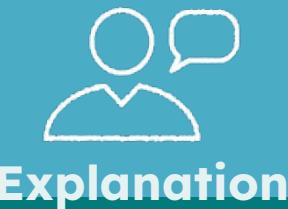


Enzymes are formed from a chain of amino acids which are folded into a specific shape.

The shape is maintained by bonds between parts of the protein chains.

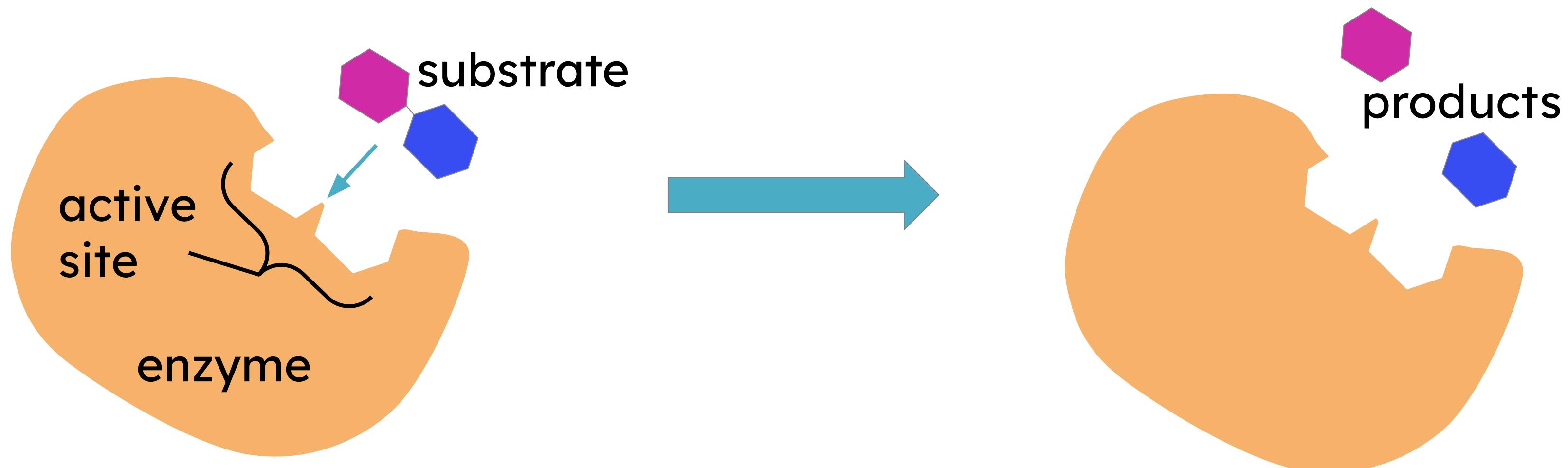


# Explaining effect of pH on enzyme activity

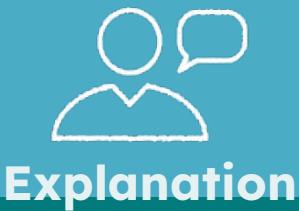


Maintaining the shape of an enzyme is very important.

Part of the enzyme is the **active site**. This is where chemical reactions are catalysed.

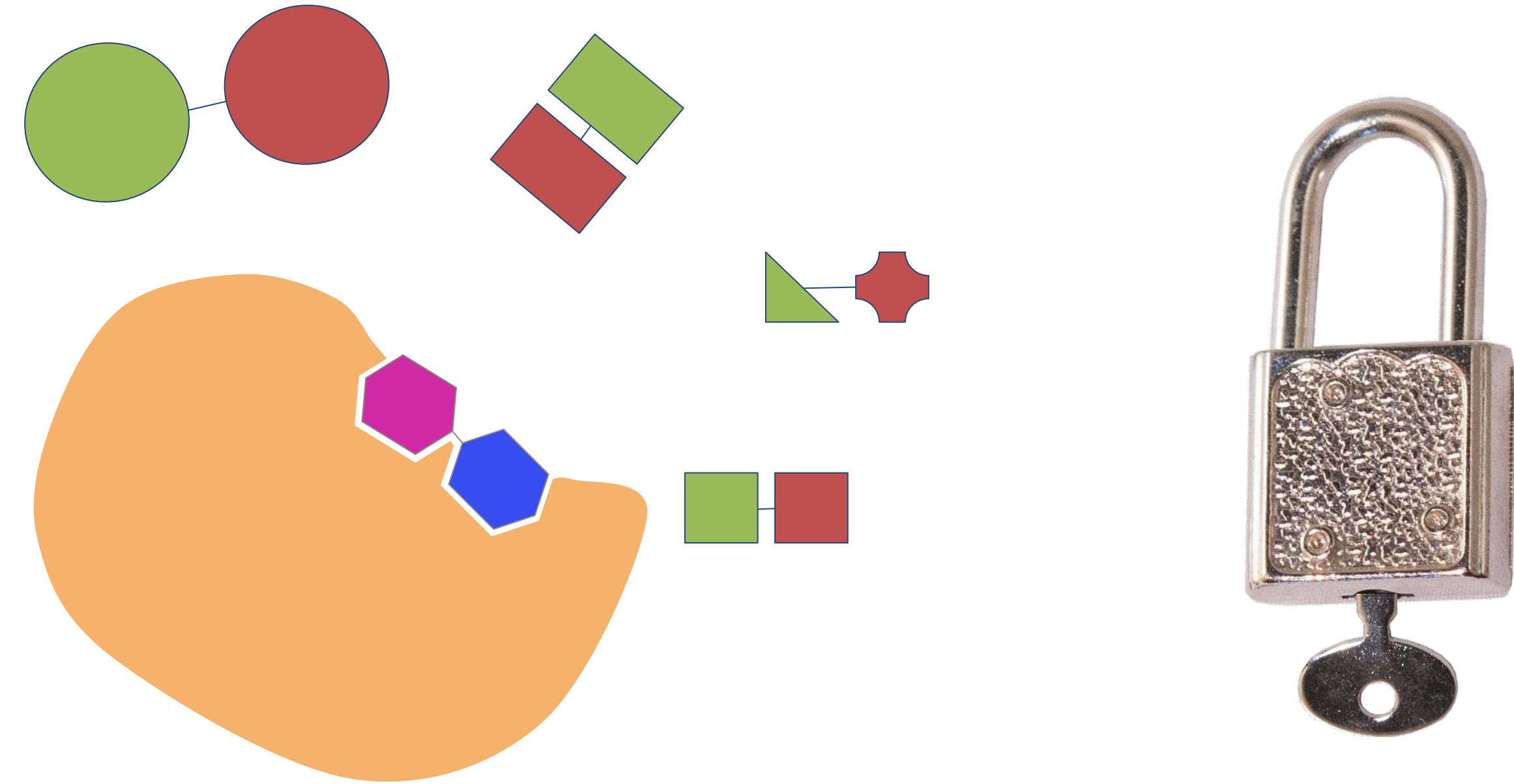


# Explaining effect of pH on enzyme activity



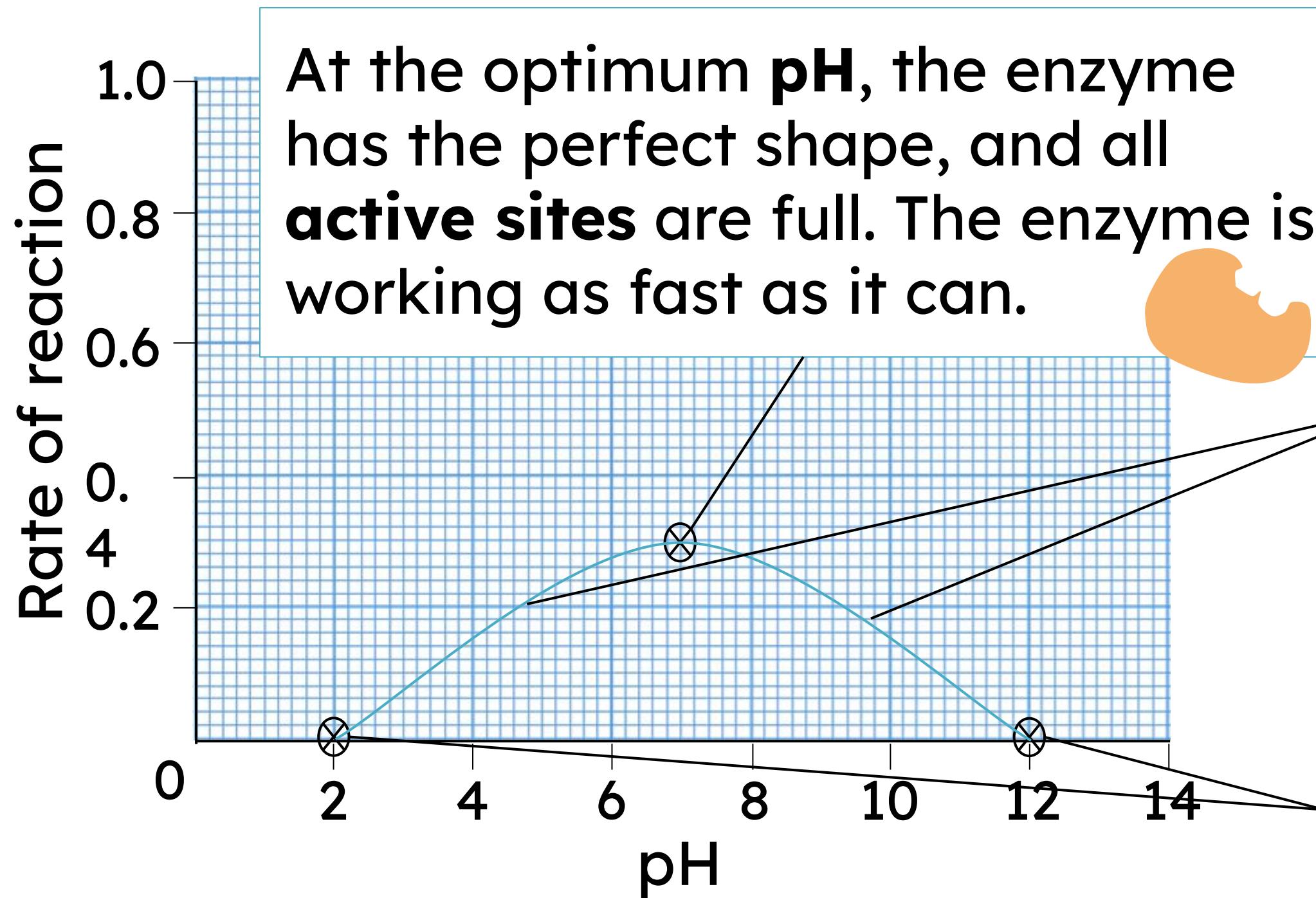
The **active site** has a very particular shape.

Only one substrate will fit the active site. Just as only one key will fit a lock.



# Explaining effect of pH on enzyme activity

Many of the bonds that maintain the enzyme's shape are affected by the **pH** of the environment.



At the optimum **pH**, the enzyme has the perfect shape, and all **active sites** are full. The enzyme is working as fast as it can.

At other pHs, the enzyme's shape changes as bonds are broken. This is called denaturing.

Denaturing reduces its ability to catalyse the reaction and rate decreases.

The rate will reduce to zero as the enzyme is completely **denatured**.

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