MYP 4
UNIT 2
LESSON 3

Aerobic and Anaerobic Cellular Respiration.

Objectives

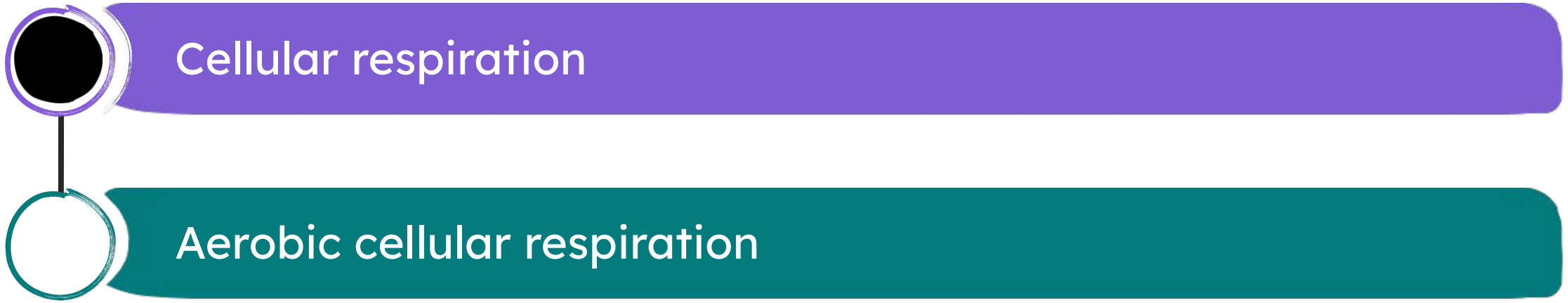
- I can describe the reactants and products of aerobic cellular respiration, and explain where, why and when it takes place.
- I can describe the reactants and products of anaerobic cellular respiration in humans, plants and microorganisms, and explain where, why and when it takes place.
- I can investigate the effect of different substrates on cellular respiration in yeast by using a measuring cylinder to collect the gas produced.
- I can analyse data collected from a measuring cylinder, calculate the rate of cellular respiration, and explain the effect of different substrates on the rate.

Keywords

cellular respiration	an exothermic chemical process that transfers energy for life processes, using glucose as a fuel
exothermic	a chemical process that transfers energy to its surroundings
aerobic	a process that requires oxygen
ATP	a substance used as a chemical store of energy in cells
mitochondria	sub-cellular structures involved in aerobic cellular respiration

Lesson outline

Aerobic cellular respiration in humans and other organisms, including ATP



Cellular respiration

Explanation

Cellular respiration is a chemical process that uses glucose as a fuel to transfer energy for life processes.

Glucose is a sugar.

- Plants and other producers make it using photosynthesis.
- Humans and other consumers digest carbohydrates and sugary foods, releasing glucose.

Photosynthesis in leaves makes glucose.

Food such as pasta contains carbohydrates.

Sweets contain sugars.

Cellular respiration

Check

Which statements about cellular respiration are correct?

a It is a process that creates energy for cells.

b Cells use glucose as a fuel in cellular respiration. ✓

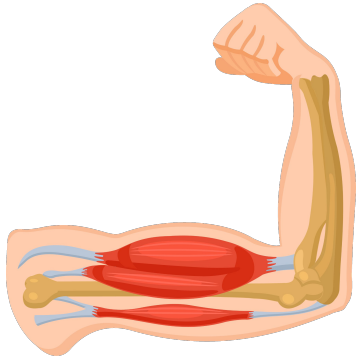
c It takes in energy from the surroundings.

d It transfers energy for life processes. ✓

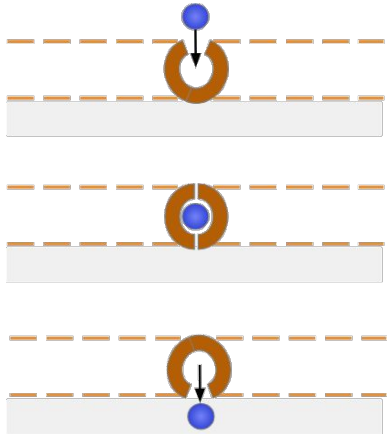
Cellular respiration

Explanation

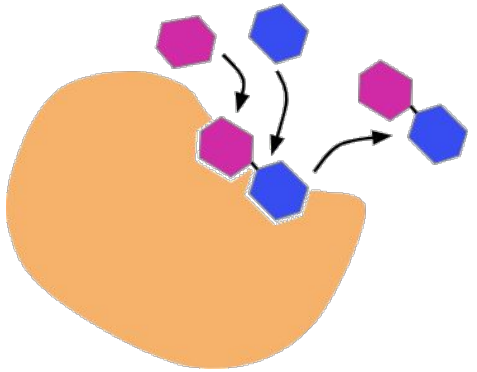
Cellular respiration transfers the energy that is needed for life processes, including:



muscle contraction



active transport of substances through cell membranes



metabolism (making and breaking down substances)

Respiration takes place continuously in every living organism.

If a cell stops respiring, it will eventually die.

Check

True or false?

Living organisms can survive without respiring.

T **True**

F **False** ✓

Why?

Cellular respiration is an essential life process that continuously transfers the energy that organisms need to stay alive. If living organisms don't respire, they die.

Cellular respiration

Explanation

Cellular respiration is an **exothermic** chemical process.

This means that it transfers energy to its surroundings.

Animals such as mammals and birds use this energy to maintain a constant internal body temperature.

chaffinch

polar bear

short-beaked echidna

human beings

Check

True or false?

Cellular respiration is an exothermic process.

T **True** ✓

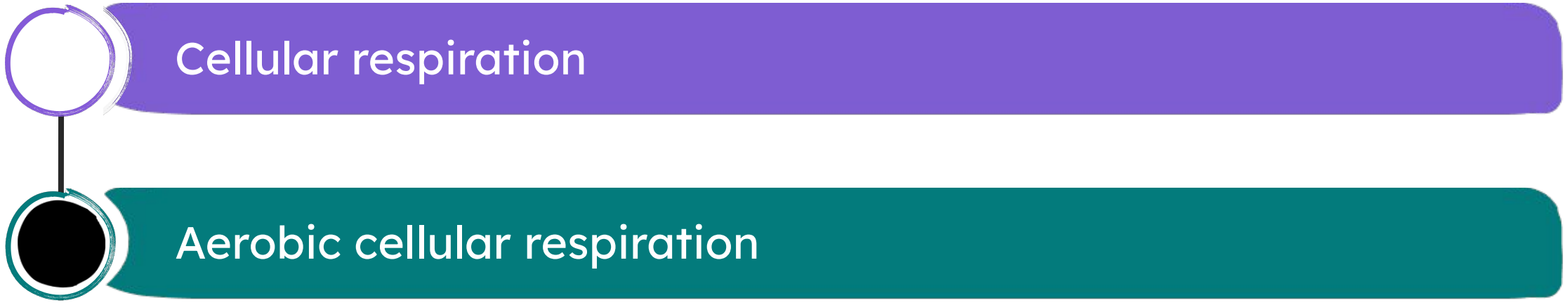
F **False**

Why?

Cellular respiration transfers energy to the surrounding environment.

Lesson outline

Aerobic cellular respiration in humans and other organisms, including ATP



Aerobic cellular respiration

Explanation

There are two main types of **cellular respiration**; **aerobic** and anaerobic.

Aerobic cellular respiration is a type of cellular respiration that takes place using oxygen.

aerobic cellular respiration

requires oxygen

Aerobic cellular respiration

Explanation

Cellular respiration is not just one chemical reaction, but is a series of chemical reactions that happen inside cells.

It is useful to summarise the reactants and products of **aerobic** cellular respiration using equations:

Word equation: oxygen + glucose ⟶ water + carbon dioxide

Balanced symbol equation: $6O_2 + C_6H_{12}O_6 \longrightarrow 6H_2O + 6CO_2$

reactants

products

Aerobic cellular respiration

Check

What is the correct word summary of aerobic cellular respiration?

a glucose → water + carbon dioxide

b glucose + oxygen → water + carbon dioxide ✓

c glucose + carbon dioxide → oxygen + water

d carbon dioxide + water → glucose + oxygen

Aerobic cellular respiration

Check

What is the correct balanced symbol equation for aerobic cellular respiration?

a $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$ ✓

b $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

c $C_6H_{12}O_6 + O_2 \rightarrow H_2O + CO_2$

d $6O_2 + 6CO_2 \rightarrow C_6H_{12}O_6 + 6H_2O$

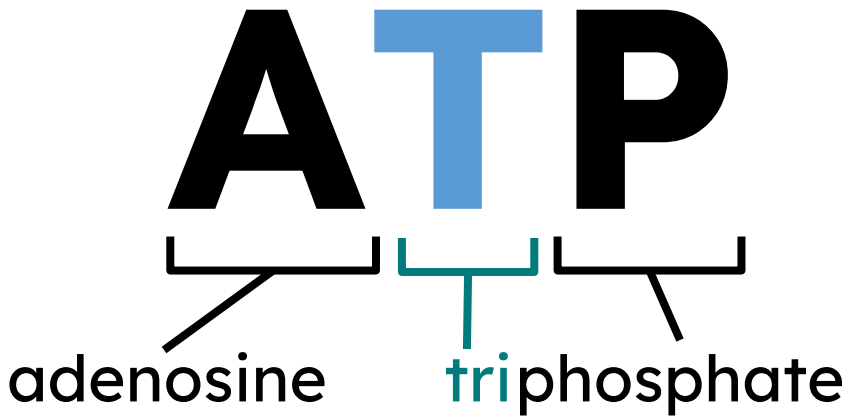
Aerobic cellular respiration

Explanation

Aerobic cellular respiration produces water and carbon dioxide as waste products.

But it also makes a useful product called **ATP**.

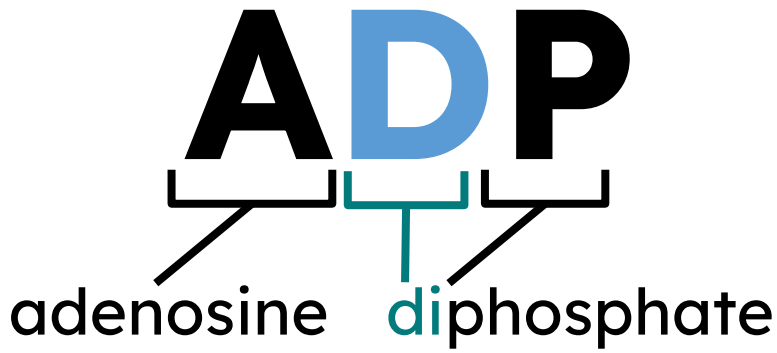
Each molecule of ATP contain three phosphate groups.



Aerobic cellular respiration

Explanation

ATP is made during **cellular respiration** by adding a phosphate group to a substance called ADP.



This is sometimes shown as part of the word equation for **aerobic** cellular respiration:

$$\text{ADP} + \text{P}_i \rightarrow \text{ATP}$$

$$\text{oxygen} + \text{glucose} \rightarrow \text{water} + \text{carbon dioxide}$$

Aerobic cellular respiration

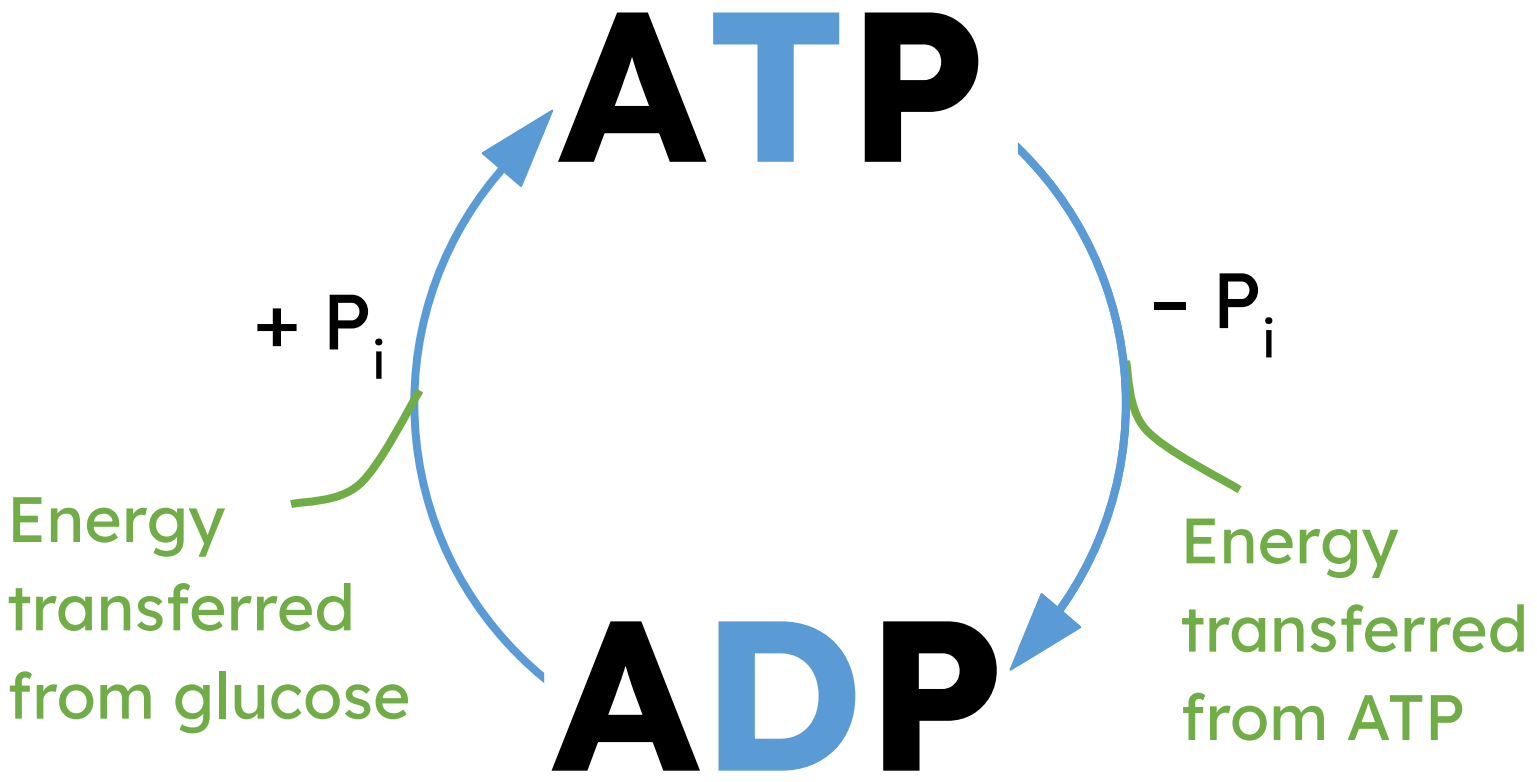
Explanation

ATP is a chemical store of energy. Life processes that require energy get it from ATP.

They do this by converting ATP back to ADP.

This ADP is then made back into ATP during **cellular respiration**.

So, ATP is continuously recycled to provide energy for life processes.

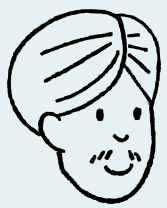


Aerobic cellular respiration

Check

Who is correct?

Water and carbon dioxide are the only products of aerobic cellular respiration.



Andeep

a

ATP is also made during aerobic cellular respiration. It's a chemical store of energy.

Izzy ✓

b

Aerobic cellular respiration makes ADP, which transfers the energy for life processes.

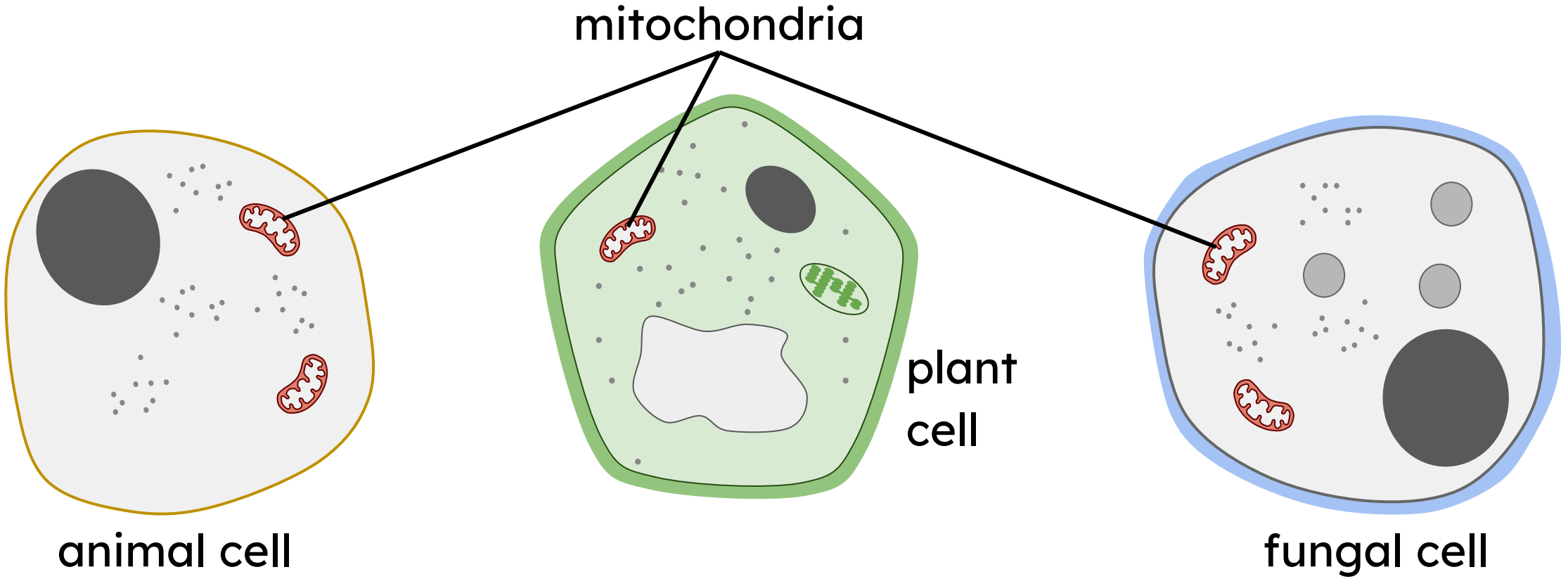
Laura

c

Aerobic cellular respiration

Explanation

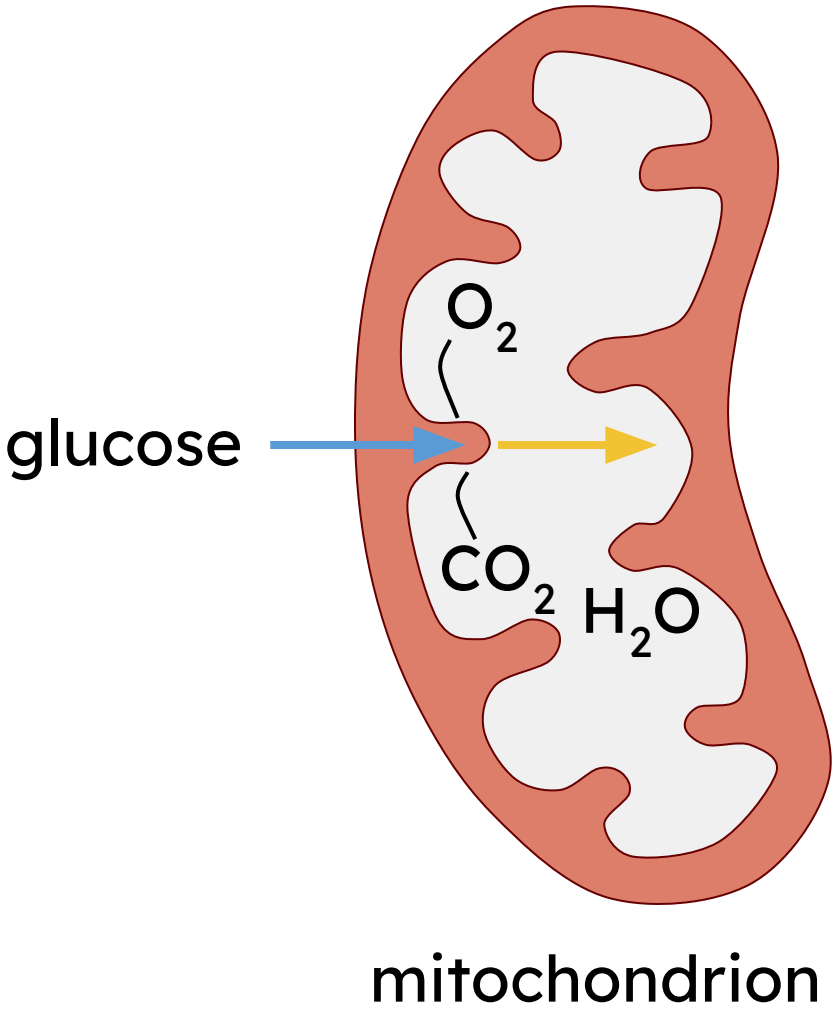
In eukaryotic cells, **aerobic cellular respiration** happens in the **mitochondria.**



Aerobic cellular respiration

Explanation

Aerobic cellular respiration happens inside the **mitochondria**.



- Glucose is broken down.
- Oxygen is used.
- Energy is transferred for life processes.
- Carbon dioxide and water are made as waste products.

The inside of the mitochondrion contains enzymes that catalyse the reactions.

Aerobic cellular respiration

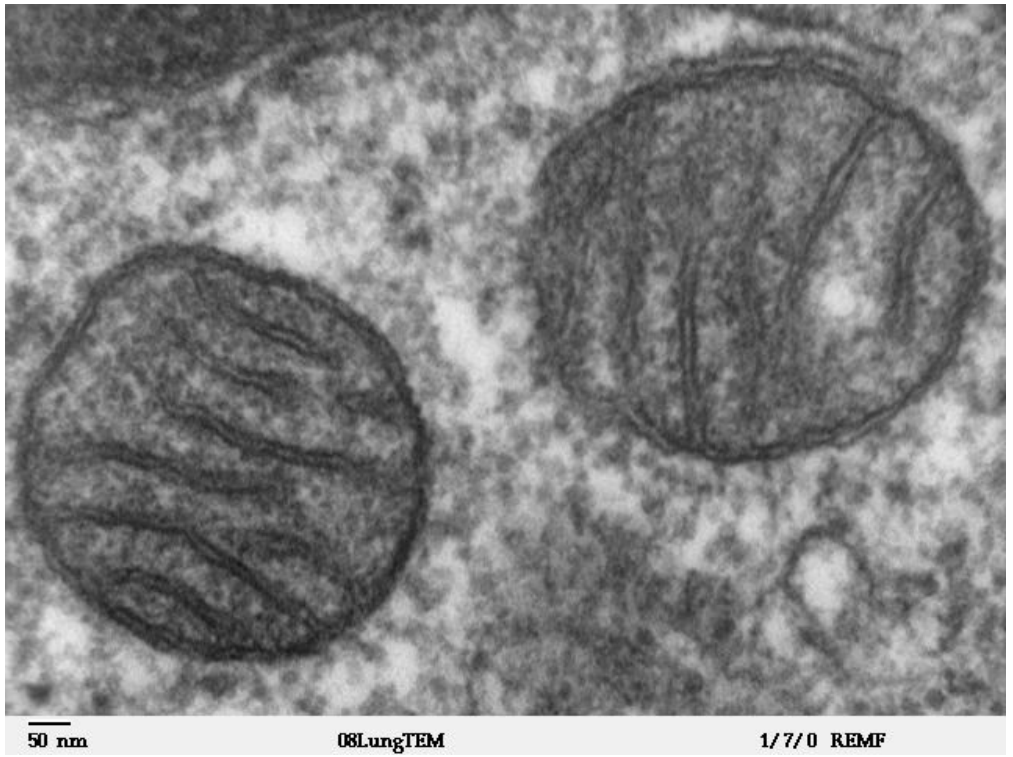
Explanation

Powerful microscopes have enabled us to observe the inside of **mitochondria**.

There are many folds of membrane inside mitochondria.

The reactions of **aerobic cellular respiration** occur across these membranes.

The folds increase the surface area, therefore increasing the rate of aerobic cellular respiration.



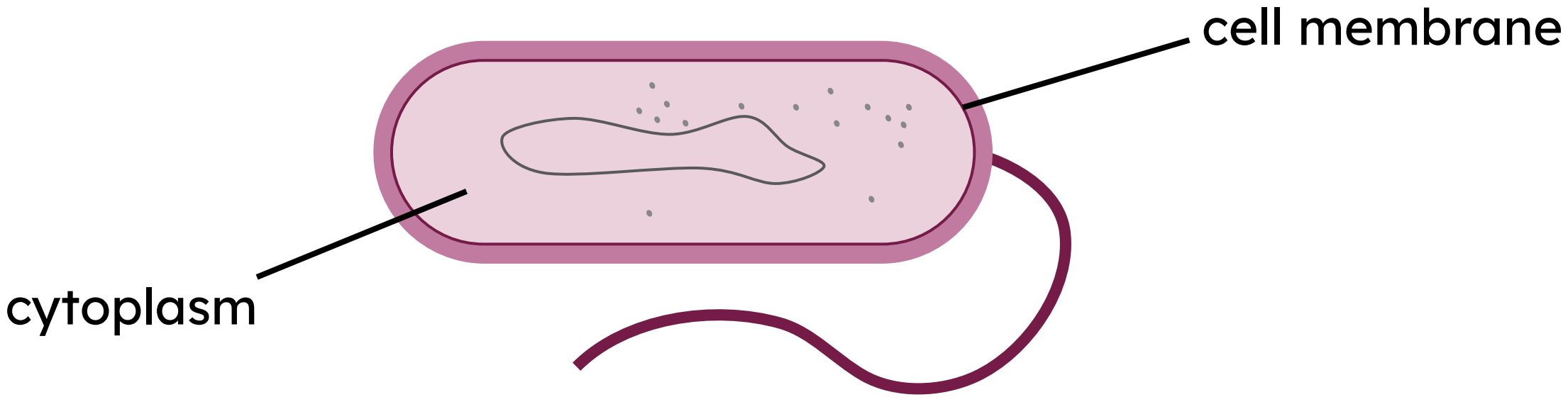
mitochondria observed using an electron microscope

Aerobic cellular respiration

Explanation

Prokaryotic cells, including bacteria, do not contain **mitochondria**, but some can carry out **aerobic cellular respiration**.

In these cells, **aerobic cellular respiration** occurs in the cytoplasm and across the cell membrane.



Check

True or false?

Aerobic cellular respiration takes place in the mitochondria of bacterial cells.

T **True**

F **False** ✓

Why?

Bacteria do not contain mitochondria. They carry out aerobic cellular respiration in their cytoplasm and across their cell membrane.

Lesson outline

Anaerobic cellular respiration in humans and other organisms, including ATP

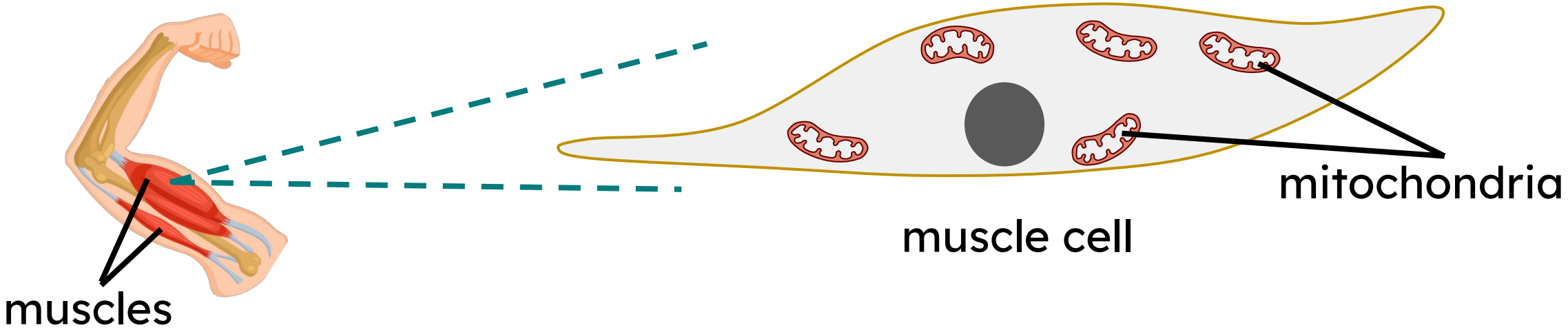
- Anaerobic cellular respiration in humans
- Anaerobic cellular respiration in other organisms

Anaerobic cellular respiration in humans

Explanation

Our muscles work hard when we exercise.

The mitochondria in contracting muscle cells need a lot of oxygen for aerobic **cellular respiration**. This transfers energy for contraction.



Sometimes during exercise oxygen cannot be transported to the muscle cells fast enough.

Anaerobic cellular respiration in humans

Explanation

Anaerobic cellular respiration is another type of cellular respiration.

It takes place when there is no oxygen available for aerobic cellular respiration.

Like aerobic cellular respiration, it is an exothermic chemical process that transfers energy for life processes, using glucose as a fuel.

It transfers less energy than aerobic cellular respiration, but it transfers energy more quickly.

Anaerobic cellular respiration in humans

Explanation

Anaerobic cellular respiration:

- Is a shorter process than aerobic cellular respiration, so produces ATP (and therefore transfers energy) quicker.
- Produces fewer molecules of ATP (and therefore transfers less energy) from every molecule of glucose.

	aerobic	anaerobic
speed	slower	faster
molecules of ATP produced from every molecule of glucose	38	2

Anaerobic cellular respiration in humans

Check

True or false?

Anaerobic cellular respiration occurs without oxygen.

T **True** ✓

F **False**

Why?

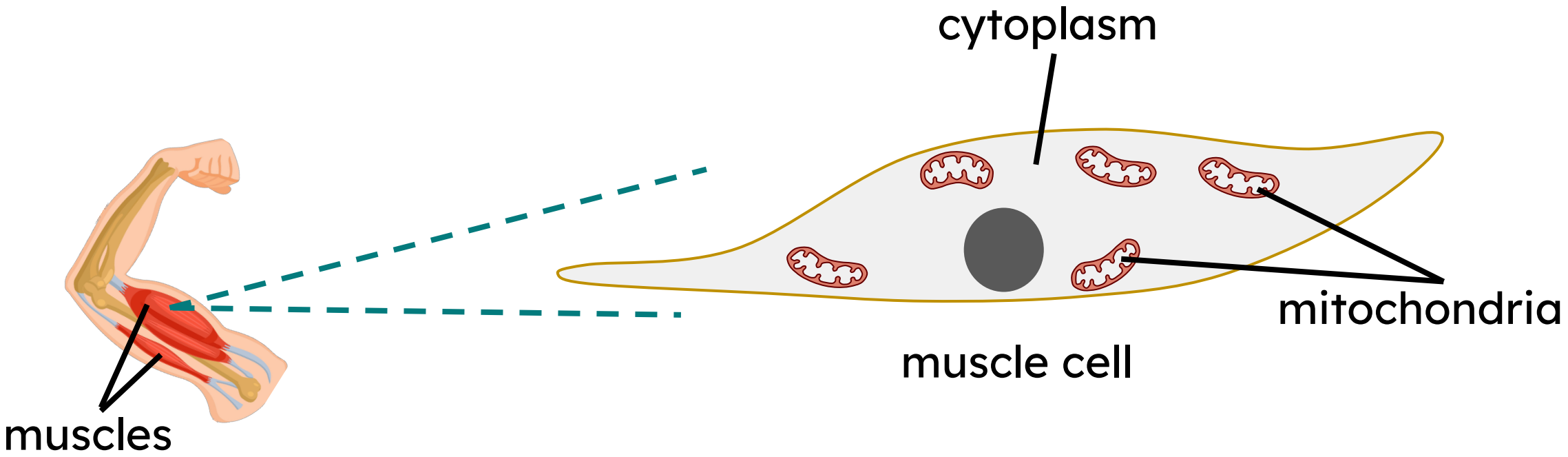
"Aerobic" means requiring oxygen, and "an-" before it means "without". Anaerobic cellular respiration takes place when there is no oxygen available for aerobic cellular respiration.

Anaerobic cellular respiration in humans

Explanation

Anaerobic cellular respiration takes place only in the cytoplasm of cells.

Mitochondria are not involved.



Anaerobic cellular respiration in humans

Explanation

It is useful to summarise the reactants and products of **anaerobic cellular respiration** in humans using equations:

Word equation: glucose → lactic acid

Balanced symbol equation: $C_6H_{12}O$ → $2C_3H_6O_3$

6 reactants

products

Anaerobic cellular respiration in humans

Check

Which of the following is a reactant of anaerobic respiration in humans?

a oxygen

b glucose ✓

c carbon dioxide

d lactic acid

Anaerobic cellular respiration in humans

Check

Which of the following is a product of anaerobic respiration in humans?

a oxygen

b glucose

c carbon dioxide

d lactic acid ✓

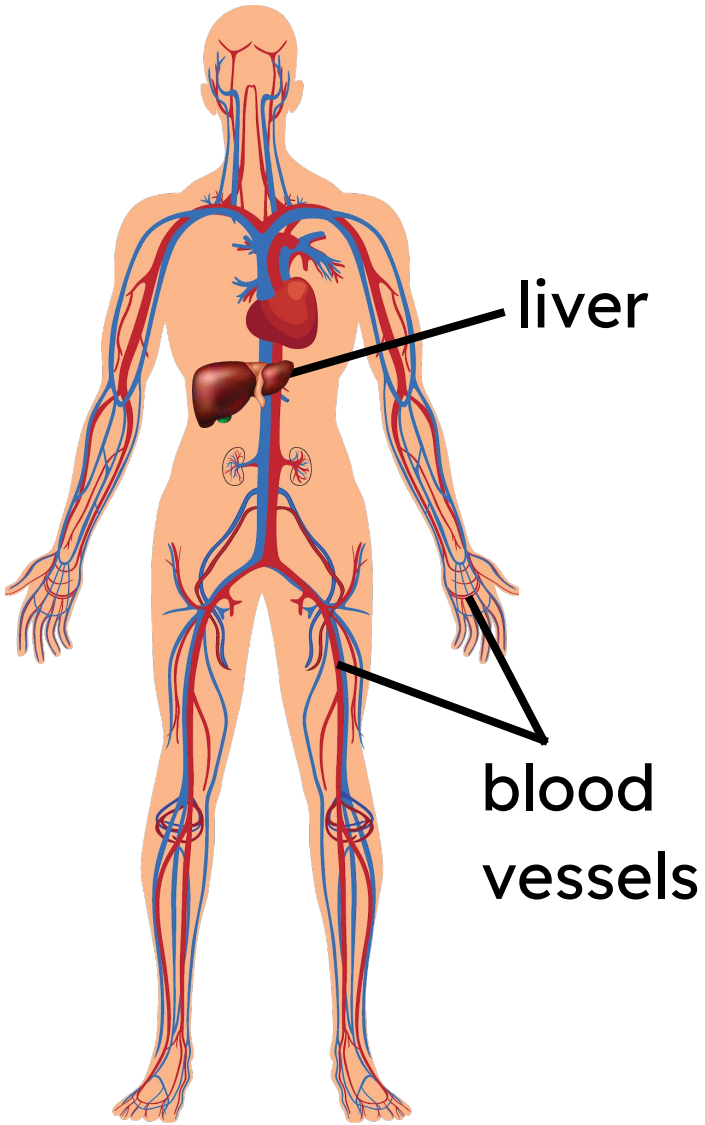
Anaerobic cellular respiration in humans

Explanation

The **lactic acid** produced by **anaerobic cellular respiration** in humans is a waste product that can cause muscle cramps.

It is transported to the liver by the blood where it reacts with oxygen and is either:

- Broken down into carbon dioxide and water then excreted.
- Converted to glucose and then glycogen, which is stored in the liver and muscles.



Anaerobic cellular respiration in humans

Explanation

It’s normal to rest and breathe deeply after you finish exercising.

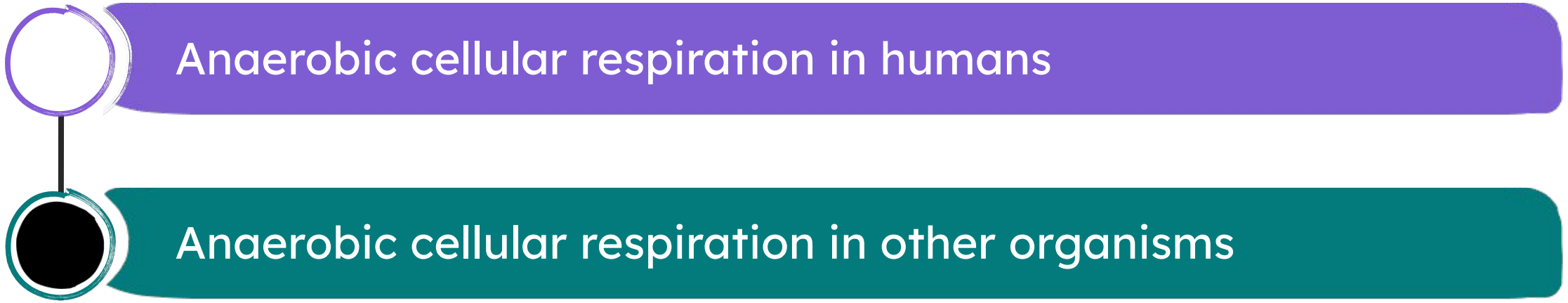
This is because your body needs as much oxygen as possible to remove the **lactic acid** from your cells.

Breathing rate and heart rate remain high after exercise to facilitate this.

The amount of oxygen we need to remove lactic acid from our bodies is called **oxygen debt**.

Lesson outline

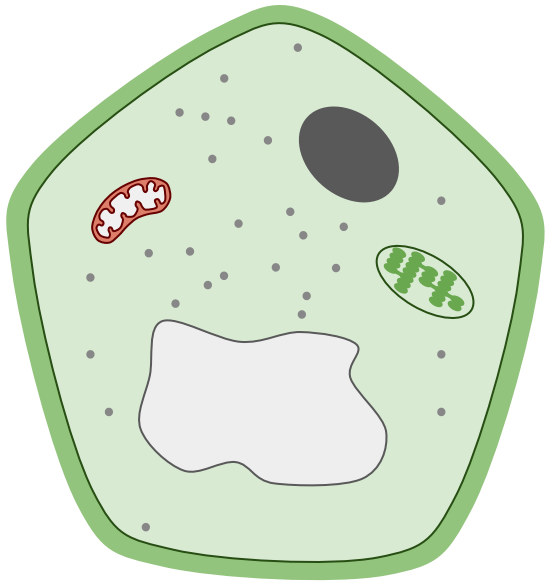
Anaerobic cellular respiration in humans and other organisms, including ATP



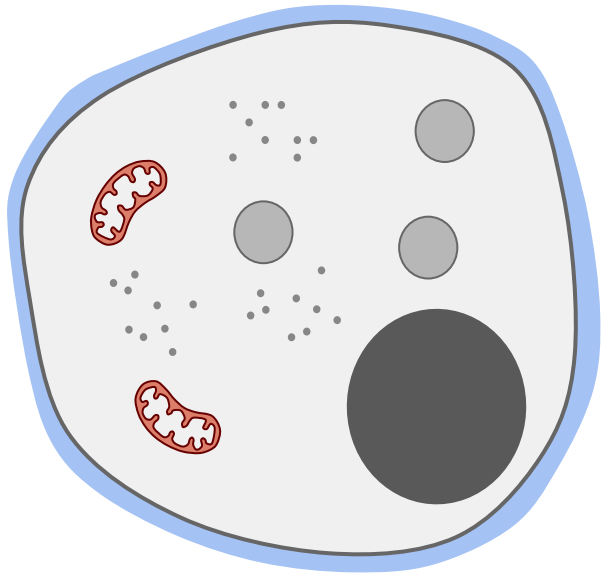
Anaerobic cellular respiration in other organisms

Explanation

Anaerobic cellular respiration also occurs in plants, and in micro-organisms including yeast.



plant cell



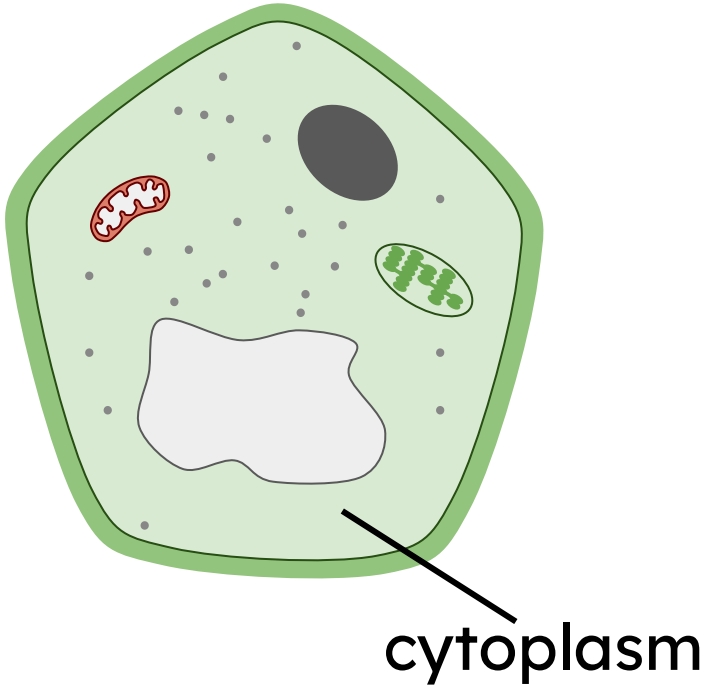
yeast cell

Anaerobic cellular respiration in other organisms

Explanation

There are similarities between **anaerobic cellular respiration** in plants/yeast and anaerobic cellular respiration in humans.

- It occurs when oxygen is not available.
- Glucose is the only reactant.
- It occurs only in the cell cytoplasm.
- It transfers less energy than aerobic cellular respiration.
- It transfers energy more quickly than aerobic cellular respiration.



However, the products are different.

Anaerobic cellular respiration in other organisms

Explanation

It is useful to summarise the reactants and products of **anaerobic cellular respiration** in plants and yeast using equations:

Word equation: glucose ⟶ ethanol + carbon dioxide

Balanced symbol equation: $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

reactant: $C_6H_{12}O_6$

products: $2C_2H_5OH + 2CO_2$

Anaerobic cellular respiration in other organisms

Check

Which of the following is a product of anaerobic respiration in plants and micro-organisms?

a carbon dioxide ✓

b glucose

c water

d ethanol ✓

Check

True or false?

Anaerobic cellular respiration in humans and plants are similar processes.

T **True** ✓

F **False**

Why?

They both are forms of respiration that occur when oxygen isn't available. But they are not identical - they have different products.

Anaerobic cellular respiration in other organisms

Explanation

In plants and micro-organisms, **anaerobic cellular respiration** happens in particular conditions.

wetland

For example, some plants and bacteria live in wetlands where the soil is waterlogged, with a low oxygen concentration.

The plant's roots grow in the waterlogged soil and cannot absorb oxygen from the water so they carry out anaerobic cellular respiration.

Bacteria growing in the waterlogged soil also carry out anaerobic cellular respiration.

Anaerobic cellular respiration in other organisms

Explanation

Anaerobic cellular respiration in micro-organisms is also known as **fermentation**.

Humans have been using fermentation to make food and drink for thousands of years.

Anaerobic cellular respiration in yeast produces ethanol, which is a type of alcohol.

This enables us to make alcoholic drinks by fermenting the sugar in crops.

wine

beer

Anaerobic cellular respiration in other organisms

Explanation

Yeast is also added to bread dough to make it rise during baking.

It breaks down the carbohydrates in the flour into glucose.

There is little oxygen in the dough so the yeast cells use the glucose to respire **anaerobically**.

The ethanol produced evaporates due to the heat of the oven. The carbon dioxide gas produced causes the bread to rise (swell up).

dough

holes in bread caused by bubbles of carbon dioxide gas

Anaerobic cellular respiration in other organisms

Check

Fermentation is a type of anaerobic cellular respiration that occurs in …

a animals

b plants

c micro-organisms ✓

Keywords

cellular respiration	An exothermic chemical process that transfers energy for life processes, using glucose as fuel.
independent variable	The factor that we change in an experiment.
dependent variable	The factor that we measure in an experiment.
random error	Causes results to differ by different amounts due to a factor other than the independent variable (the factor we changed).
systematic error	Causes measurements to differ from the true value by the same amount each time they are taken.

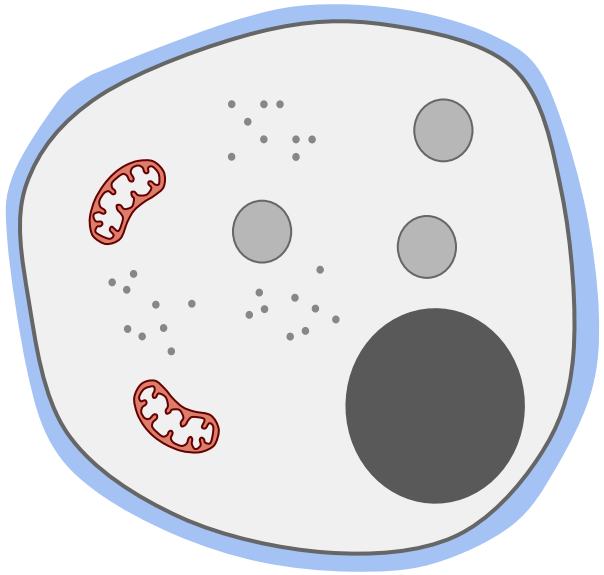
Lesson outline

The effect of different substrates on cellular respiration in yeast: practical

- Apparatus for measuring rate of respiration
- Measuring the rate of respiration
- Results: ensuring validity

Apparatus for measuring rate of respiration

Explanation



yeast cell

Yeast are unicellular microorganisms. They are classified as fungi.

Anaerobic **cellular respiration** in yeast helps us make useful products including bread and alcoholic drinks.

Apparatus for measuring rate of respiration

Explanation

Anaerobic **cellular respiration** is a form of respiration that occurs when oxygen isn't available.

In microorganisms such as yeast, anaerobic cellular respiration can be summarised using the following equations:

Word equation: glucose → ethanol + carbon dioxide

Balanced symbol equation: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

reactant

products

Apparatus for measuring rate of respiration

Check

Which gas is produced by yeast in anaerobic cellular respiration?

a oxygen

b water

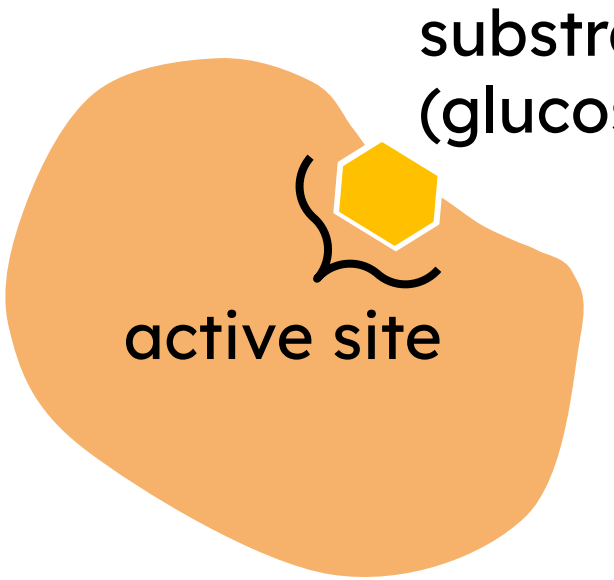
c carbon dioxide ✓

d lactic acid

Apparatus for measuring rate of respiration

Explanation

Anaerobic **cellular respiration** is controlled by enzymes.



simple diagram of
an enzyme

This is like a key
fitting into a lock.

At the start of the process, glucose is the substrate that fits into the active site of the enzyme.

Apparatus for measuring rate of respiration

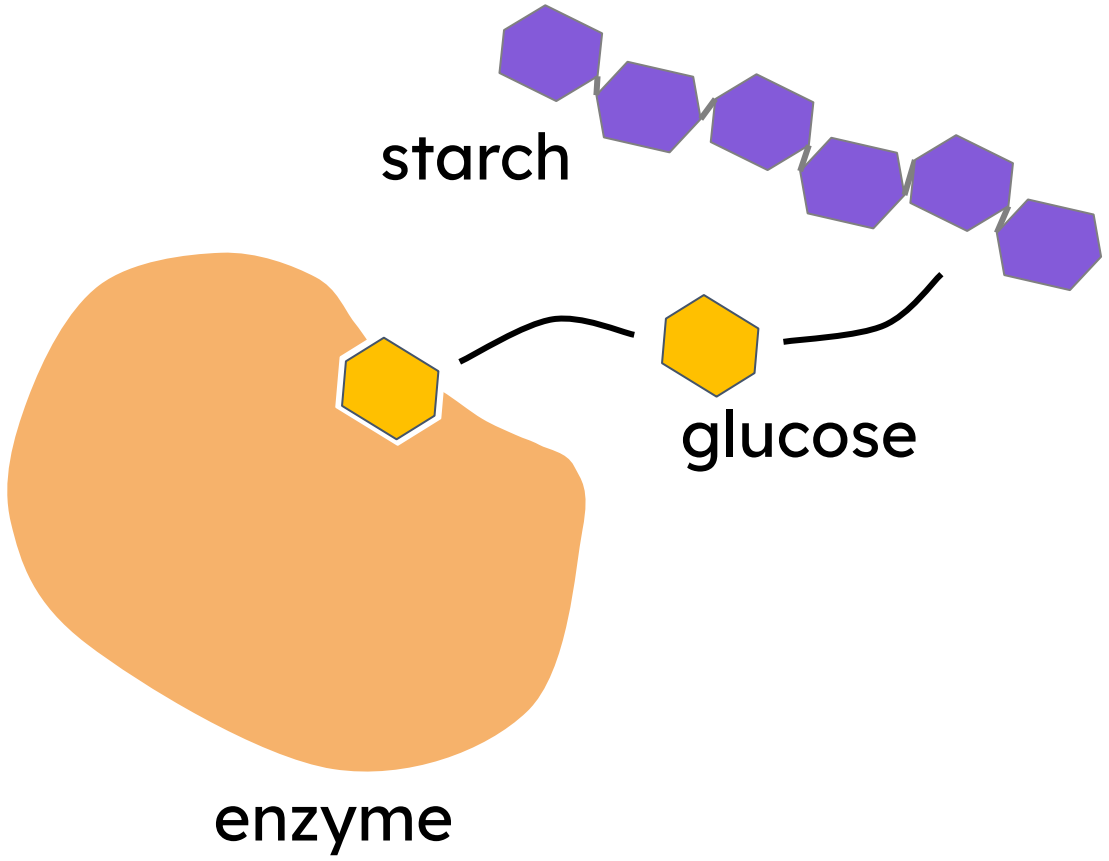
Explanation

Different substrates will not fit into the active site.

This is because the active site of each enzyme is specific to its substrate, like a lock and its key.

Yeast can break down some other carbohydrates to produce glucose to use in cellular respiration.

It takes extra time to break down carbohydrates to produce glucose, so this affects the rate of cellular respiration.



Apparatus for measuring rate of respiration

Check

True or false?

Many different substrates can fit in an enzyme's active site.

T **True**

F **False** ✓

Why?

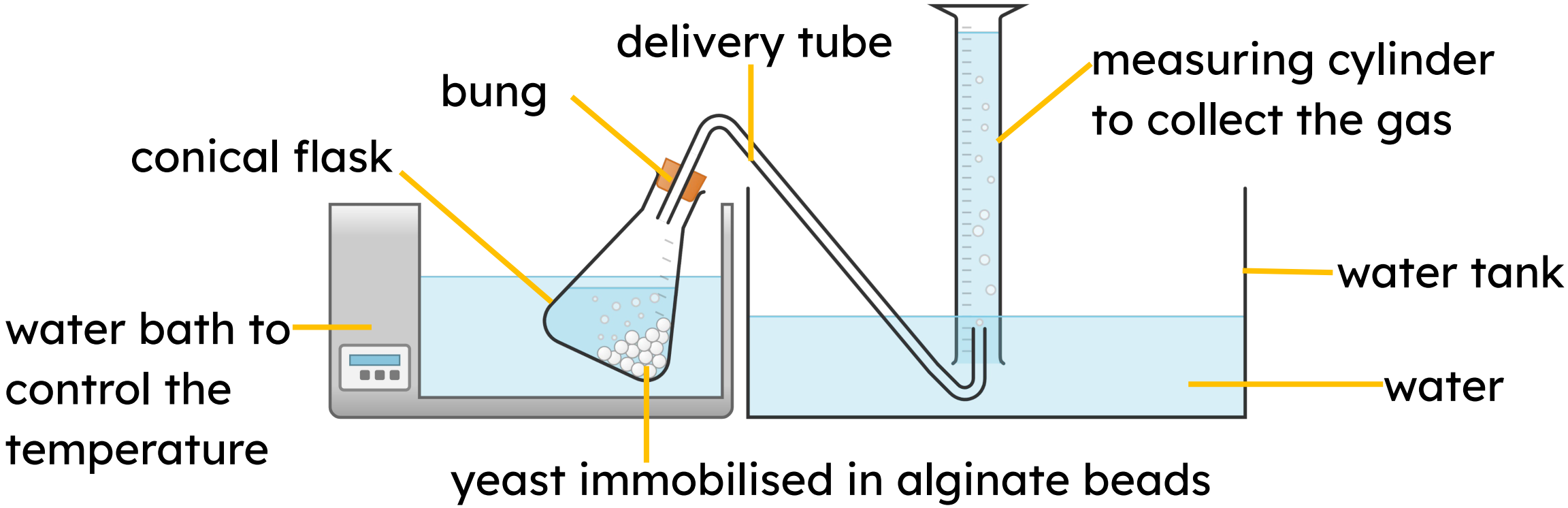
Each enzyme is specific to just one substrate. Other substrates will not fit into the enzyme's active site.

Apparatus for measuring rate of respiration

Explanation

We will investigate the effect of different substrates on the rate of **cellular respiration** in yeast.

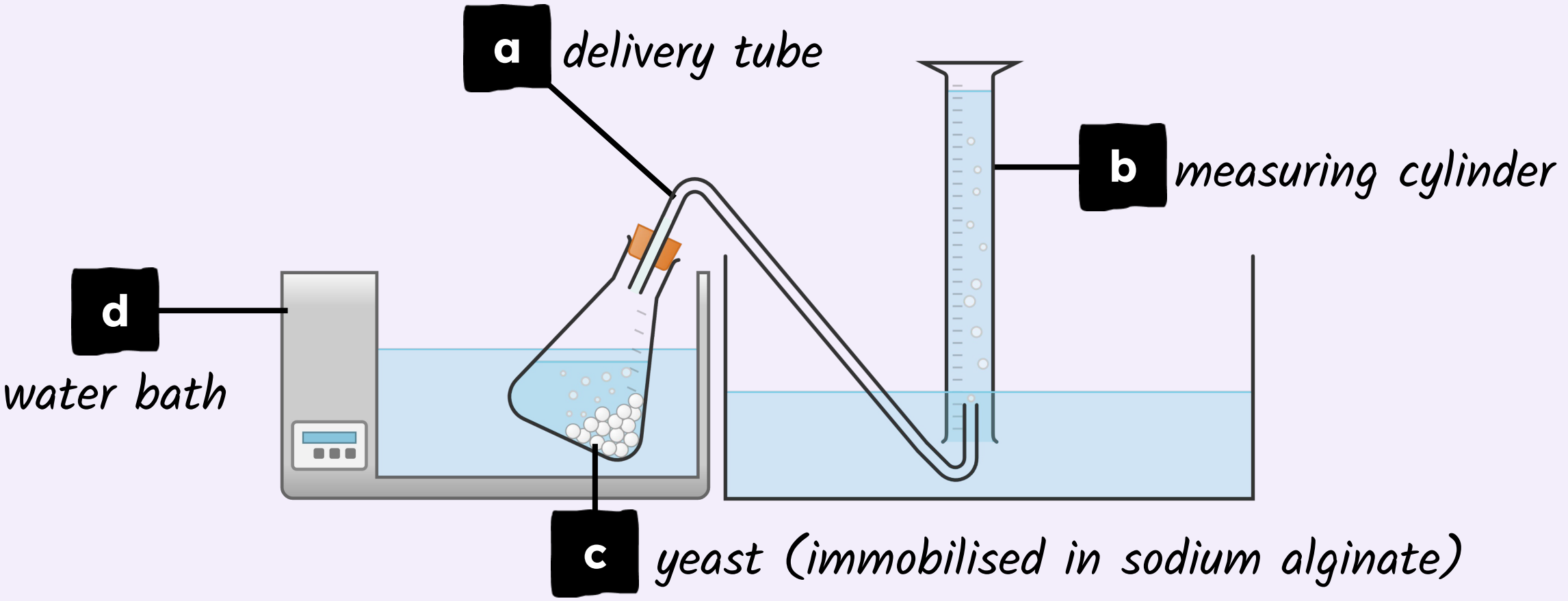
This can be done by collecting the carbon dioxide gas produced by the yeast during respiration.



Apparatus for measuring rate of respiration

Check

Label the apparatus:

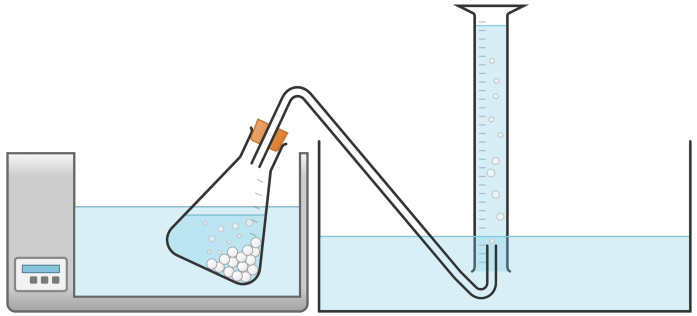


Apparatus for measuring rate of respiration

Explanation

Independent variable (the factor we change):

Type of substrate



Dependent variable (the factor we measure):

Volume of gas collected in the measuring cylinder

Variables that should be controlled (so they don't affect the results):

Mass of substrate

Volume of water

Mass of yeast in alginate beads

Temperature

Length of time the organisms are allowed to respire

… can you think of any others?

Apparatus for measuring rate of respiration

Check

Which is the dependent variable?

a Mass of yeast in alginate beads

b Substrate

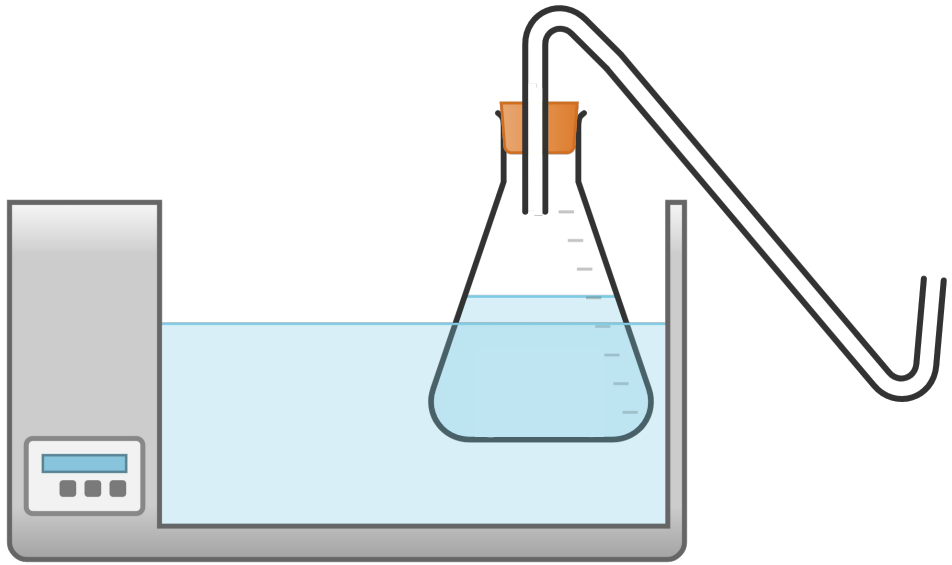
c Temperature

d Volume of gas collected in the measuring cylinder ✓

Apparatus for measuring rate of respiration

Explanation

Method for setting up the apparatus:



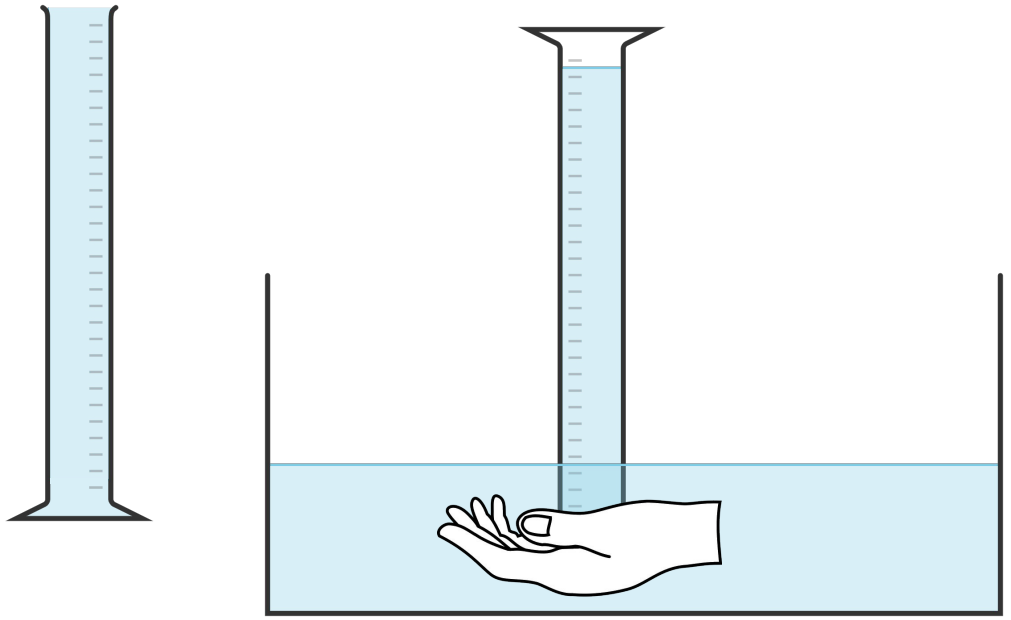
1. Add the substrate to a conical flask.
2. Add water to the conical flask and swirl carefully.
3. Add the alginate beads containing immobilised living yeast cells to the conical flask.
4. Place a bung and delivery tube into the conical flask.
5. Place the conical flask in a 40°C water bath.
6. Wait 5 minutes for the yeast to start respiring at a constant rate.

Apparatus for measuring rate of respiration

Explanation

While you wait 5 minutes for the yeast to start respiring at a constant rate:

1. Fill a measuring cylinder with water.
2. Cover the end of the measuring cylinder and carefully turn it upside down.
3. Place the measuring cylinder in a tank of water and clamp into position.



Watch

Apparatus for measuring rate of respiration

Check

Which of the following is not a step in setting up the apparatus?

a Add the alginate beads containing immobilised living yeast cells to the conical flask.

b Wait 5 minutes for the yeast to start respiring at a constant rate.

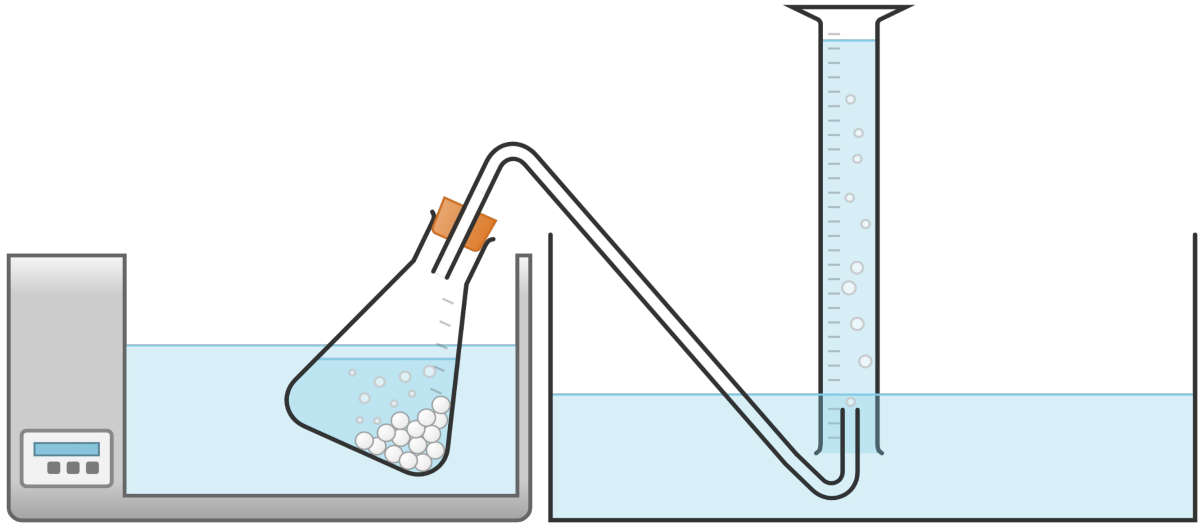
c Place the conical flask in a 100°C water bath and clamp it in place. ✓

d Fill a measuring cylinder with water.

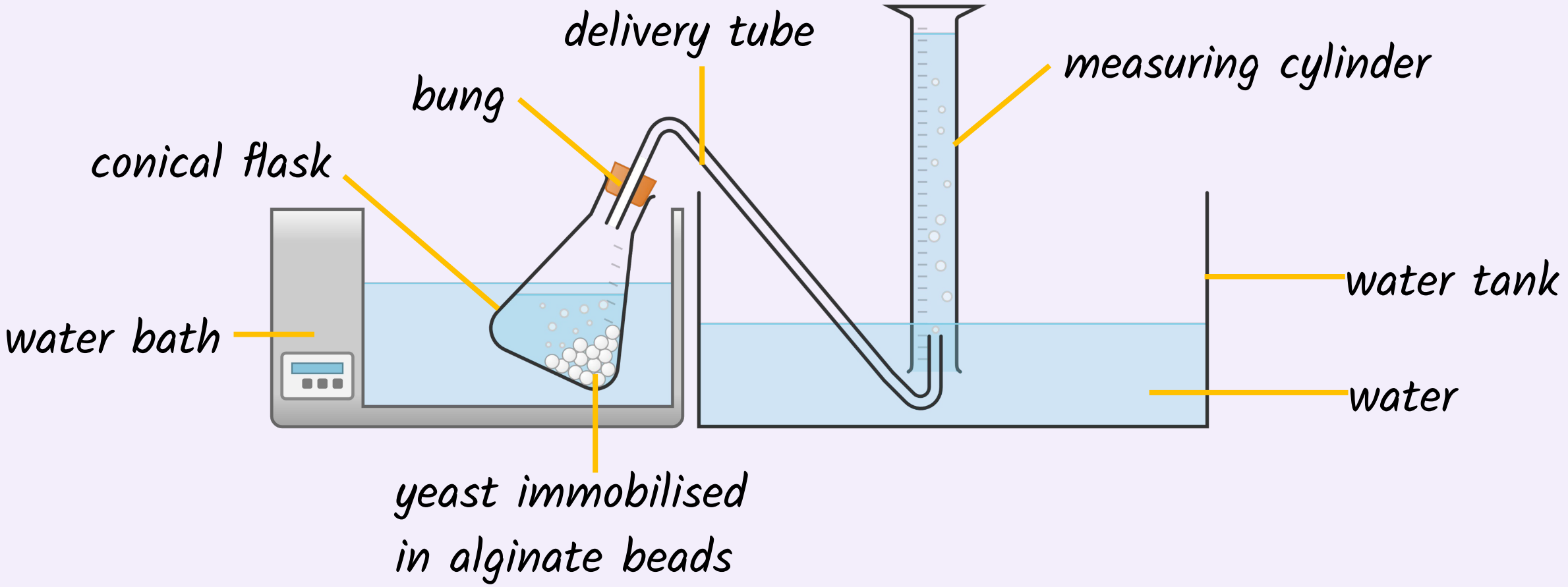
Task A Apparatus for measuring rate of respiration

Practice

1. Follow the method on the worksheet to set up the apparatus.
2. Label the apparatus on the diagram.
3. Explain why using a different substrate will affect the rate of cellular respiration in yeast.



2. Label the apparatus on the diagram.



3. Explain why using a different substrate will affect the rate of cellular respiration in yeast.

Cellular respiration is controlled by enzymes.

Each enzyme has an active site that is specific for its substrate, like a lock and its key.

A different substrate will not fit into the active site.

Yeast can break down some other carbohydrates to produce glucose to use in cellular respiration, but it takes extra time to break down these carbohydrates so this affects the rate of cellular respiration.

Lesson outline

The effect of different substrates on cellular respiration in yeast: practical

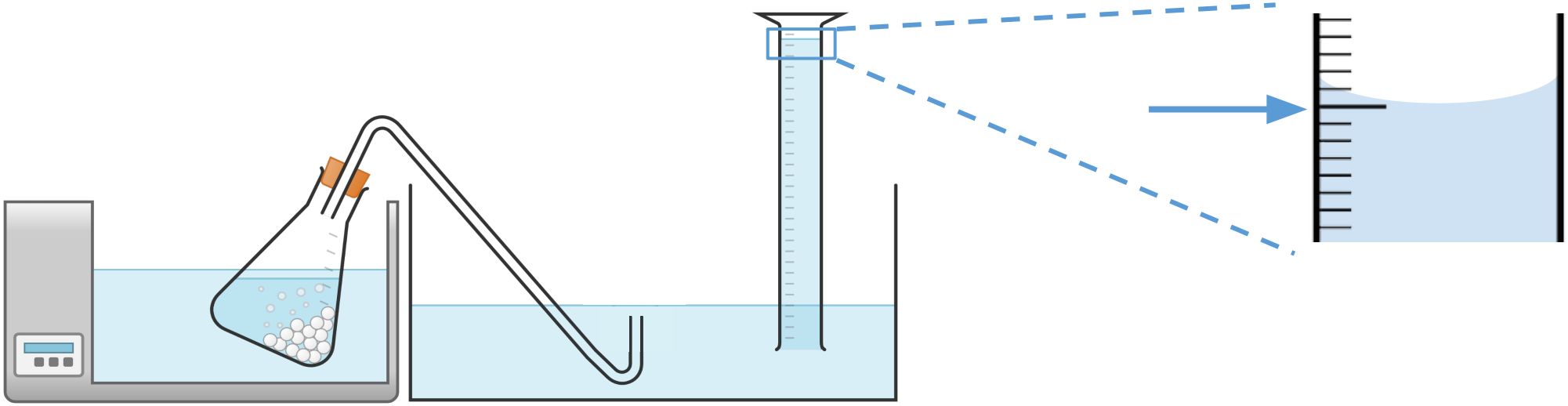
- Apparatus for measuring rate of respiration
- Measuring the rate of respiration
- Results: ensuring validity

Measuring the rate of respiration

Explanation

Method for measuring the rate of respiration:

1. At the start of the experiment, record the volume of gas that is already present at the top of the measuring cylinder.

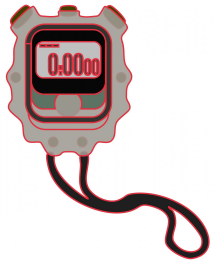


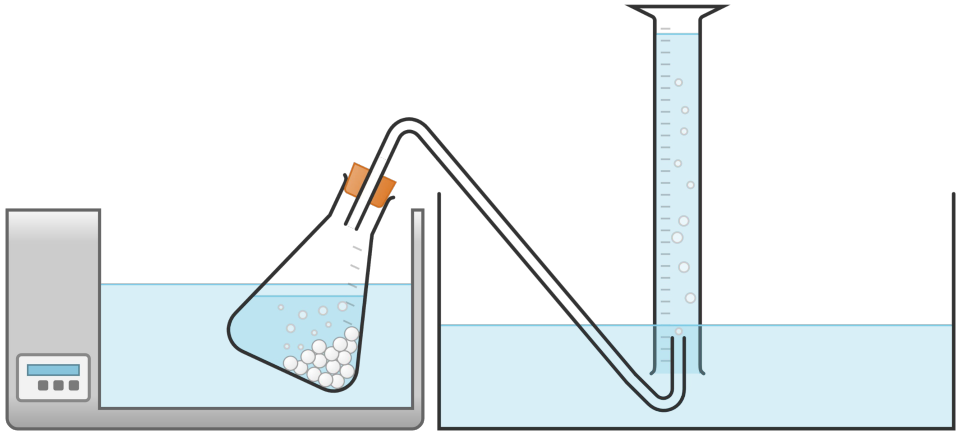
Advice: Make sure you read the volume from the bottom of the meniscus.

Measuring the rate of respiration

Explanation

2. Place the end of the delivery tube into the measuring cylinder.
3. Leave for 5 minutes.
4. After 5 minutes, remove the end of the delivery tube from the measuring cylinder.
5. Record the volume of gas in the measuring cylinder.



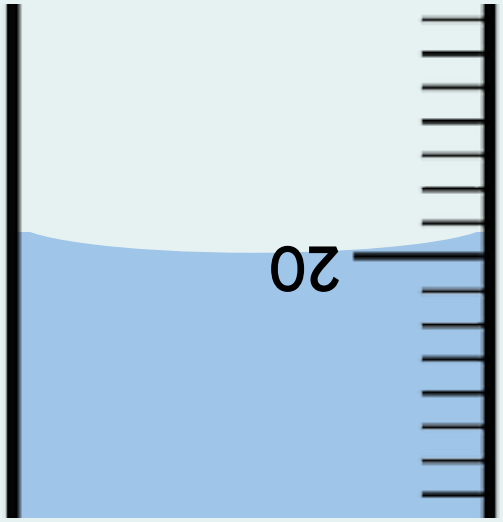


Watch

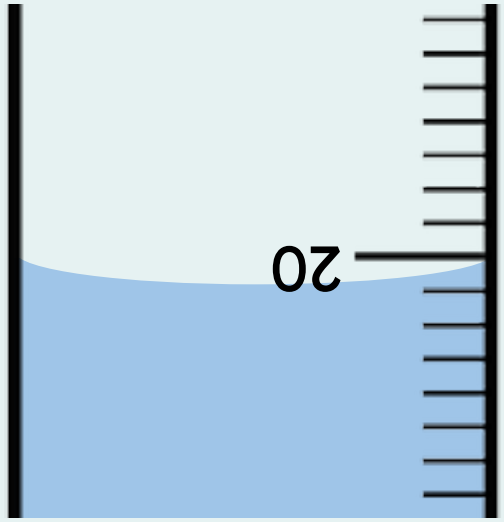
6. Repeat steps 1 to 5 two more times. Remember to record the volume of gas at the start and at the end, each time.
7. Repeat the experiment to collect data for two other substrates.

Check

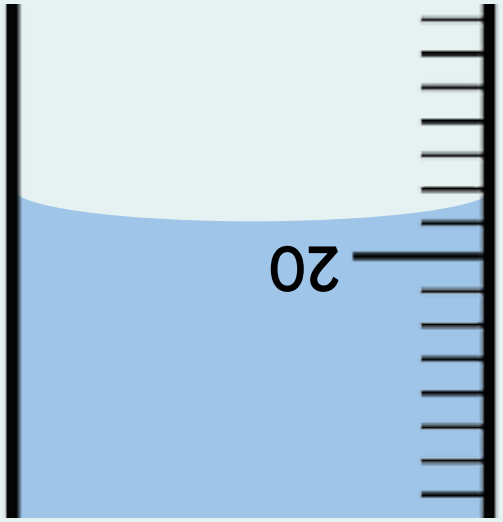
Which measuring cylinder contains 20 cm^3 of gas?



a ✓



b

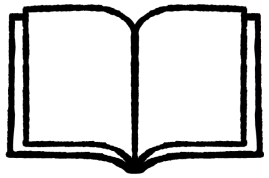


c

Task B Measuring the rate of respiration

Practice

1. Follow the method on the worksheet to carry out the practical investigation.



2. Fill in Table 1 with your results.

Substrate	Volume of gas in measuring cylinder (cm^3)					
	Test 1		Test 2		Test 3	
	At start	At end	At start	At end	At start	At end
glucose						
sucrose						
starch						

2. Fill in the table with your results.

Sample data:

Substrate	Volume of gas in measuring cylinder (cm^3)					
	Test 1		Test 2		Test 3	
	At start	At end	At start	At end	At start	At end
glucose	4	34	6	35	3	30
sucrose	8	23	5	19	6	19
starch	7	10	4	6	9	13

Lesson outline

The effect of different substrates on cellular respiration in yeast: practical

- Apparatus for measuring rate of respiration
- Measuring the rate of respiration
- Results: ensuring validity

Results: ensuring validity

Explanation

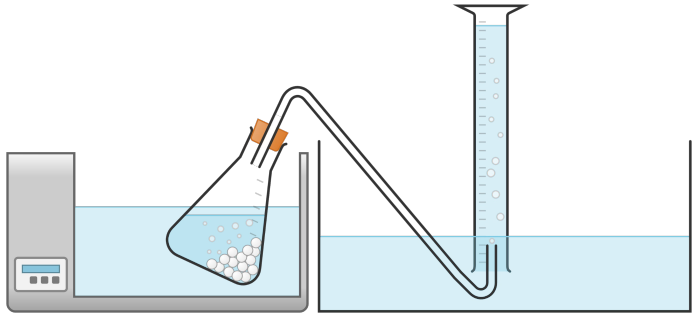
In order to collect valid results from an experiment, only the **independent variable** should affect the **dependent variable**.

Independent variable:

Type of substrate

Dependent variable:

Volume of gas collected in the measuring cylinder



Controlling the following variables increases the validity of the results:

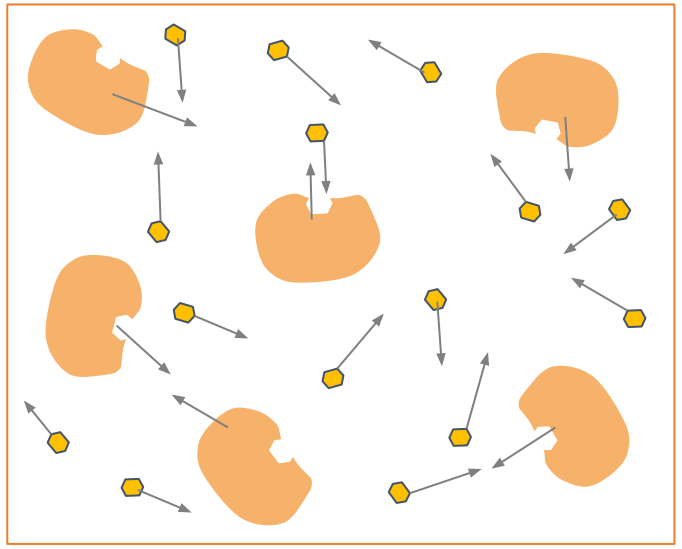
- Mass of substrate
- Volume of water
- Mass of yeast in alginate beads
- Length of time the organisms respire
- Temperature

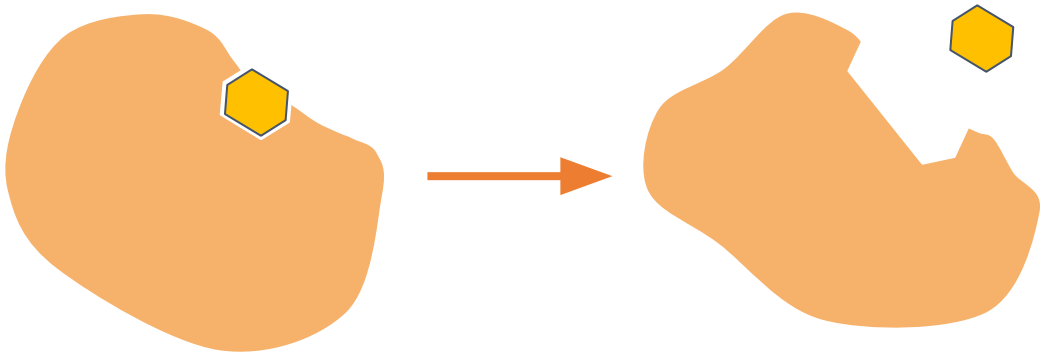
} the same for each substrate

Results: ensuring validity

Explanation

It's important to control the temperature (using the water bath) because temperature affects the rate of **cellular respiration**.





As temperature increases, enzyme and substrate molecules move faster, so there are more successful collisions. Rate of reaction increases.

Above the optimum temperature, the enzyme is denatured and the substrate no longer fits. Rate of reaction decreases.

Results: ensuring validity

Check

True or false?

Increasing the temperature allows enzyme reaction rate to keep increasing forever.

T **True**

F **False** ✓

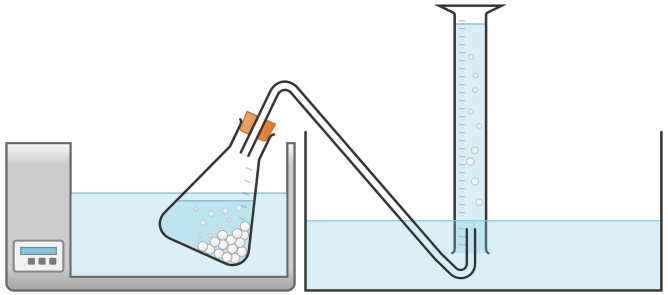
Why?

High temperatures above the optimum cause enzyme molecules to change shape, so the enzyme works less well and reaction rate drops. At very high temperature the enzyme is denatured and stops working (rate = 0).

Results: ensuring validity

Explanation

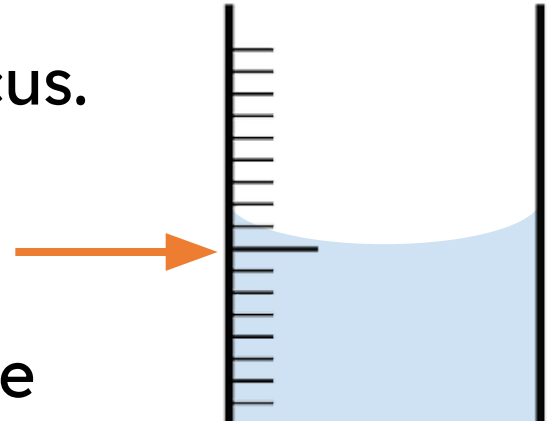
The way we measure and record the volume of gas in the measuring cylinder also affects the results.



The surface of the water in the measuring cylinder is curved.

This is called the meniscus.

We always read the volume from the bottom of the meniscus.



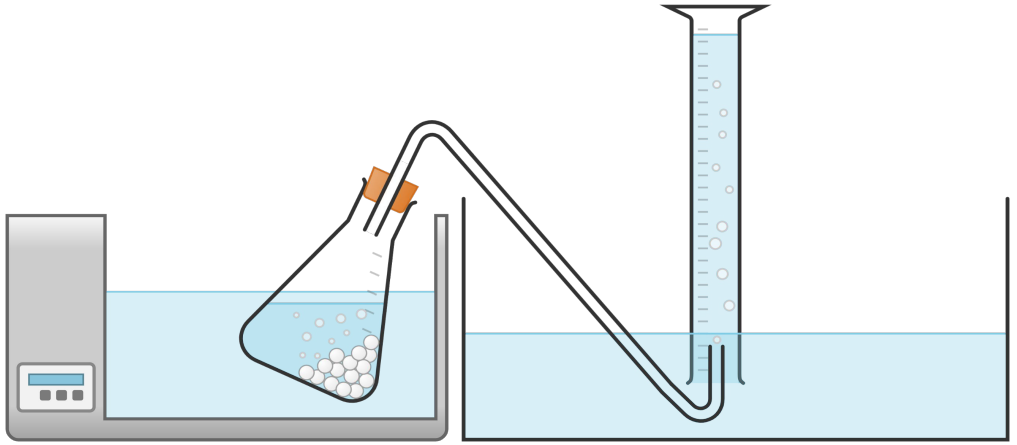
If we read it a different way each time, this would cause **random error** in the data.

Because we read it the same way each time, any difference between the reading and the true value is the same for each reading. This is a **systematic error** that affects all the results the same way, so we can make valid comparisons between them.

Results: ensuring validity

Explanation

The volume of gas in the measuring cylinder at the end of the experiment is not a direct measurement of the rate of **cellular respiration**.



In the next lesson we will:

- process our data
- use the processed data to calculate the rate of cellular respiration in the yeast
- explain the effect of different substrates on the rate of cellular respiration.

Results: ensuring validity

Check

Choose the correct option in each line to complete the explanation.

The volume should always be read from the bottom / middle / top of the meniscus.

This removes meniscus / random / systematic error from the data.

Any difference between the reading and the true value is the same for each reading. It affects all the results the same way, so we can make valid comparisons between them. This is a meniscus / random / systematic error.

1. For this practical investigation, identify the:
   a. independent variable
   b. dependent variable
2. Describe how temperature was controlled.
3. What is a meniscus?
4. Describe how to use the meniscus to measure the volume of gas in the measuring cylinder.

5. Izzy noticed that after 30 minutes the yeast stopped producing carbon dioxide gas. Explain why.

1. For this practical, identify the:
   a. independent variable

   The type of substrate the yeast use to respire.

   b. dependent variable

   The volume of gas in the measuring cylinder.

2. Describe how temperature was controlled.

   The conical flask containing the yeast was placed in a water bath.

3. What is a meniscus?

   The curved surface of water in a container (e.g. measuring cylinder).

4. Describe how to use the meniscus to measure the volume of gas in the measuring cylinder.

Read the volume from the bottom of the meniscus each time.

5. Izzy noticed that after 30 minutes the yeast stopped producing carbon dioxide gas. Explain why.

The yeast may have used up all the substrate they had available for cellular respiration.

If they can no longer respire, they won't produce carbon dioxide gas, as this is a product of cellular respiration.

Keywords

rate	A measure of how much change occurs per unit of time.
cellular respiration	An exothermic chemical process that transfers energy for life processes, using glucose as fuel.
substrate	The substance that fits into an enzyme's active site.
enzyme	A biological catalyst.
active site	The part of an enzyme where the substrate binds.

Lesson outline

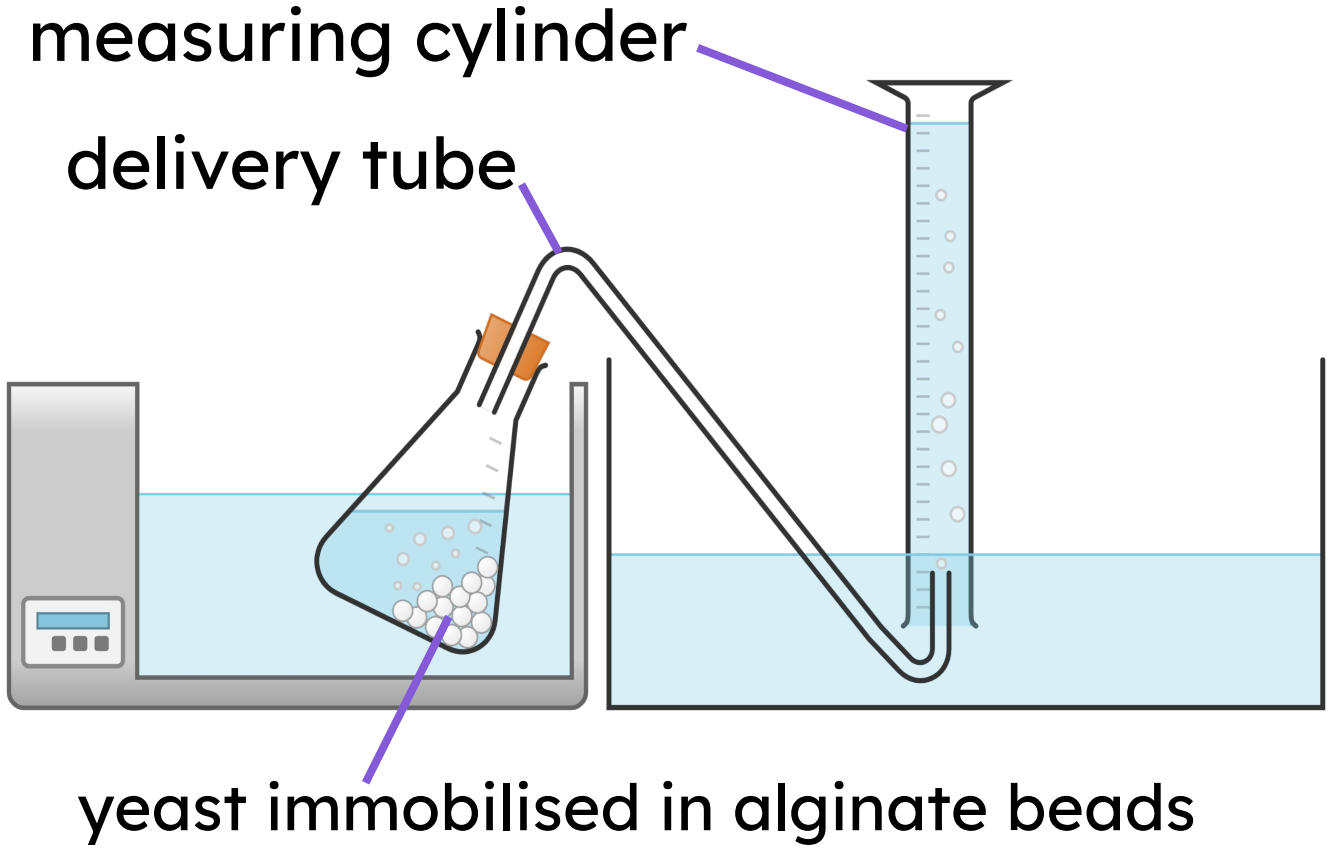
Explaining the effect of different substrates on the rate of cellular respiration

- Data processing: rate of respiration
- The effect of different substrates on respiration

Data processing: rate of respiration

Explanation

The **rate** of anaerobic **cellular respiration** in yeast can be measured using simple apparatus.



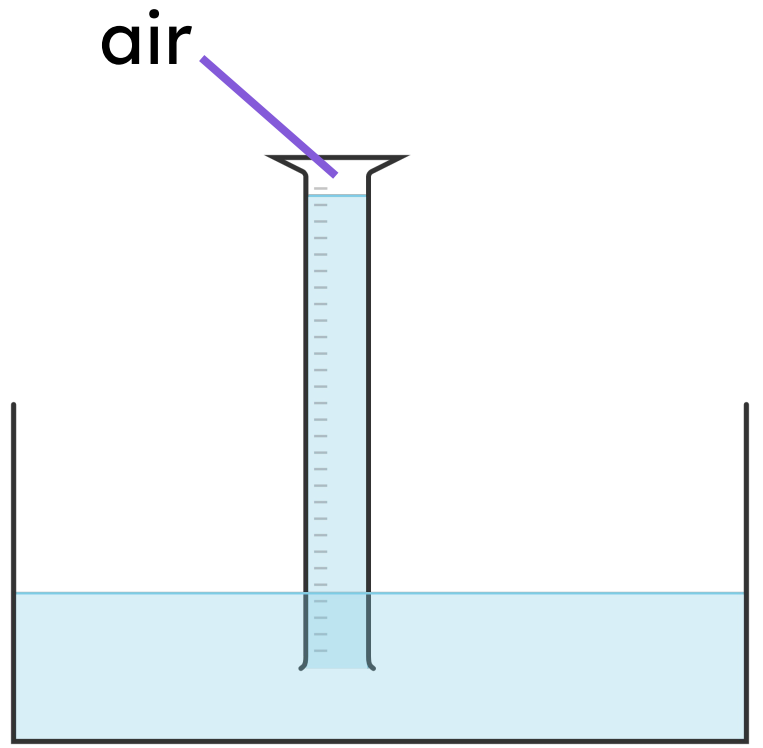
As the yeast respire they produce carbon dioxide gas, which is collected in the upturned measuring cylinder in water.

Measuring the volume of carbon dioxide gas produced enables us to calculate the rate of respiration.

Data processing: rate of respiration

Explanation

When setting up the measuring cylinder, it is usual to find some gas (air) trapped in the top.



This will mean the volume of gas recorded at the end of the experiment is not the true volume of carbon dioxide produced.

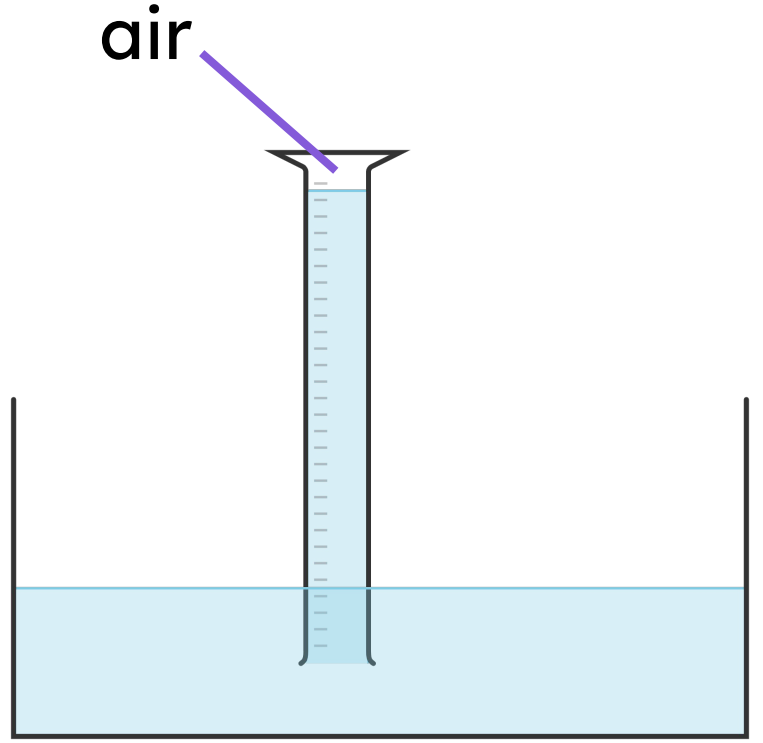
The volume of gas in the measuring cylinder at the start is likely to be different each time we set up the apparatus. It was not controlled.

This will cause random errors in the data, because the amount of difference between the recorded volume of gas at the end and the true volume of carbon dioxide produced will be different each time.

Data processing: rate of respiration

Explanation

The volume of gas in the measuring cylinder at the start of the experiment was recorded.



To ensure the results are valid, we must subtract the volume of gas at the start from the volume of gas recorded at the end of the experiment.

This will tell us how much carbon dioxide gas was produced by the yeast due to **cellular respiration**.

Data processing: rate of respiration

Check

Calculate the amount of carbon dioxide gas produced by yeast with sucrose and starch as substrates.

Substrate	Volume of gas in measuring cylinder (cm^3)		Volume of carbon dioxide gas produced (cm^3)
	At start	At end	
glucose	4	34	30
sucrose	8	23	15
starch	7	10	3

Data processing: rate of respiration

Explanation

The volume of carbon dioxide gas collected is not the **rate** of **cellular respiration**.

A rate is a measure of how much change occurs per unit of time.

In this experiment, we calculate the rate of respiration using the volume of carbon dioxide gas produced in 5 minutes.

rate (cm^3/min) = volume of carbon dioxide gas produced/time (min)

Substrate	Volume of carbon dioxide gas produced (cm^3)	Rate of respiration (cm^3/min)
glucose	30	30 ÷ 5 = 6.0

Data processing: rate of respiration

Check

Calculate the rate of respiration for each substrate.

Substrate	Volume of carbon dioxide gas produced (cm^3)	Rate of respiration (cm^3/min)
glucose	30	30 ÷ 5 = 6.0
sucrose	15	15 ÷ 5 = 3.0
starch	3	3 ÷ 5 = 0.6

Data processing: rate of respiration

Explanation

We can use the data from the practical to compare the rate of respiration for different **substrates**.

A comparison points out similarities and differences by:

- using words such as “more” or “less”
- using words that end in “-er” such as “bigger”, or “-est” such as “biggest”

Example:

The table shows that the rate of respiration is greatest when the substrate is glucose, lower for sucrose, and lowest for starch.

Substrate	Rate of respiration (cm^3/min)
Glucose	6.0
Sucrose	3.0
Starch	0.6

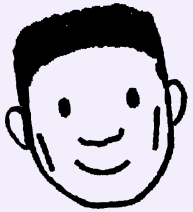
Data processing: rate of respiration

Check

Whose statement best compares the rate of respiration for different substrates?

Aisha ✓

The rate of respiration is highest when glucose is used and lower when other substrates are used.



Lucas

When glucose is used, the rate of respiration is high.

Sofia

The rate of respiration changes depending on the substrate used.

Data processing: rate of respiration

Explanation

When describing data, it is useful to:

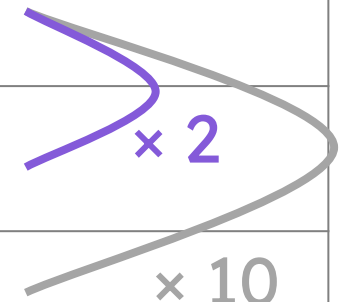
- make a general comment
- describe a specific example from the data.

Example:

General comment: The table shows that the rate of respiration changes as the **substrate** changes.

Specific example: The rate of respiration measured for glucose is double the rate for sucrose, and is ten times the rate for starch.

Substrate	Rate of respiration (cm^3/min)
Glucose	6.0
Sucrose	3.0
Starch	0.6



Data processing: rate of respiration

Check

Which of the statements about the table is correct?

a The rate of respiration for glucose is double the rate for sucrose.

b The rate of respiration for glucose is ten times the rate for starch.

c The rate of respiration for sucrose is five times the rate for starch. ✓

d The rate of respiration for sucrose is faster than the rate for glucose.

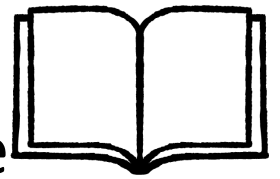
Substrate	Rate of respiration (cm^3/min)
Glucose	5.4
Starch	0.5
Sucrose	2.5

Task A Data processing: rate of respiration

Practice

Answer the following questions about the experiment:

1. Use the sample data on the worksheet to complete Table 2.
2. Explain why the units for rate of respiration in this experiment are "cm^3/min".
3. Use Table 2 to describe the effect of the different substrates on the rate of respiration.



Task A Data processing: rate of respiration

Feedback

1. Use the sample data on the worksheet to complete Table 2.

Substrate	Volume of carbon dioxide gas produced (cm^3)				Mean rate of respiration (cm^3/min)
	Test 1	Test 2	Test 3	Mean	
Glucose	32	27	25	28	5.6
Sucrose	15	21	12	16	3.2
Starch	3	1	5	3	0.6

2. Explain why the units for rate of respiration in this experiment are "cm^3/min".

   A rate is a measure of how much change occurs per unit of time. The rate was calculated by measuring the volume of carbon dioxide produced, measured in cm^3, over 5 minutes.

3. Use Table 2 to describe the effect of the different substrates on the rate of respiration.

   The table shows that the rate of respiration is greatest when the substrate is glucose, lower for sucrose, and lowest for starch.

Lesson outline

Explaining the effect of different substrates on the rate of cellular respiration

- Data processing: rate of respiration
- The effect of different substrates on respiration

The effect of different substrates on respiration

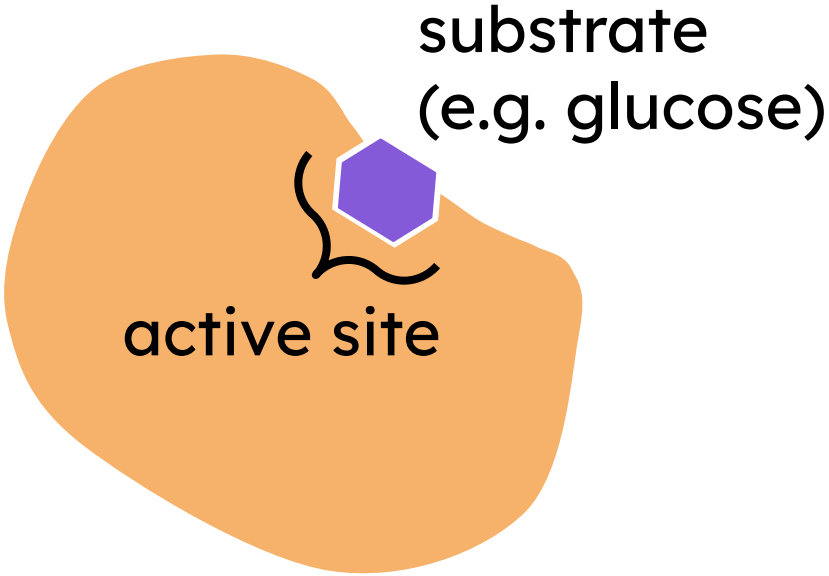
Explanation

The type of substrate used affects the **rate** of respiration because **cellular respiration** is controlled by **enzymes**.

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

Every enzyme has an **active site**.

The **substrate** fits into the active site.



simple diagram of an enzyme

The effect of different substrates on respiration

Explanation

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

In this model:

the lock is the enzyme

the keyhole is the active site

the key is the substrate

The effect of different substrates on respiration

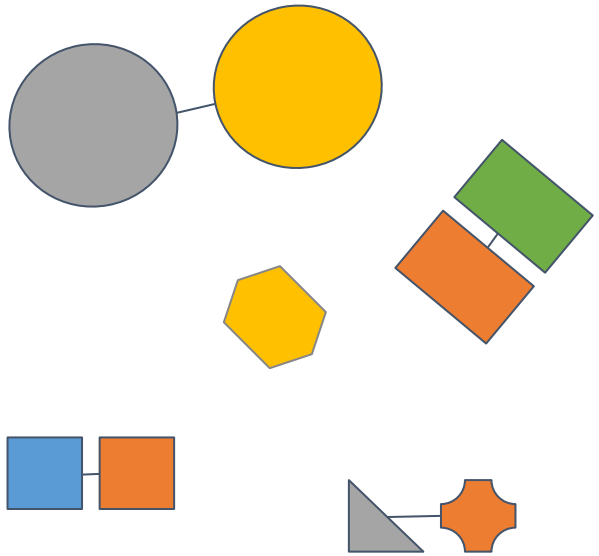
Locks are specific for their key.

Keys come in many different shapes.

But only one key has the correct shape …

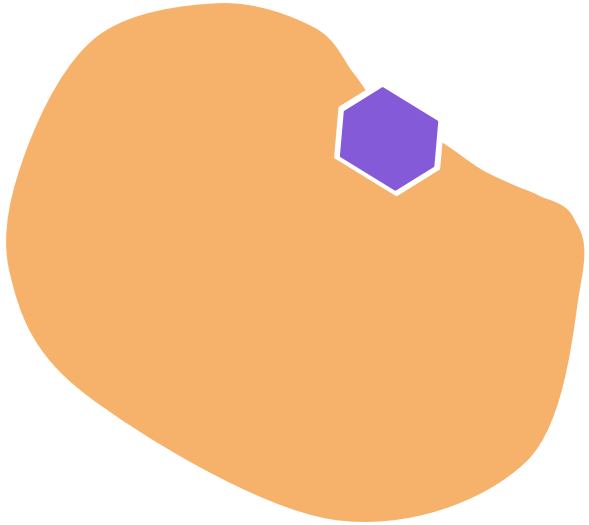
… to fit into the lock’s keyhole.

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.

Check

True or false?

Each enzyme can act on many different substrates.

T **True**

F **False** ✓

Why?

Each enzyme is specific to just one substrate. Other substrates will not fit into the enzyme's active site.

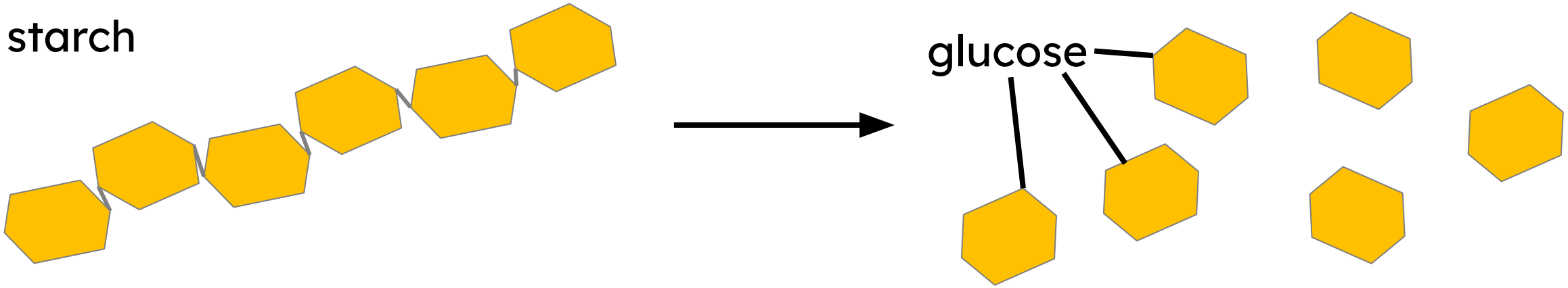
The effect of different substrates on respiration

Explanation

For this practical, the **rate** of **cellular respiration** was highest when glucose was used as the **substrate**.

This is because the **enzyme** that initiates cellular respiration has an **active site** that is specific to glucose molecules.

For yeast to use starch or sucrose for respiration, the starch and sucrose must be broken down into glucose.



This takes time, so the rate of respiration is slower.

The effect of different substrates on respiration

Explanation

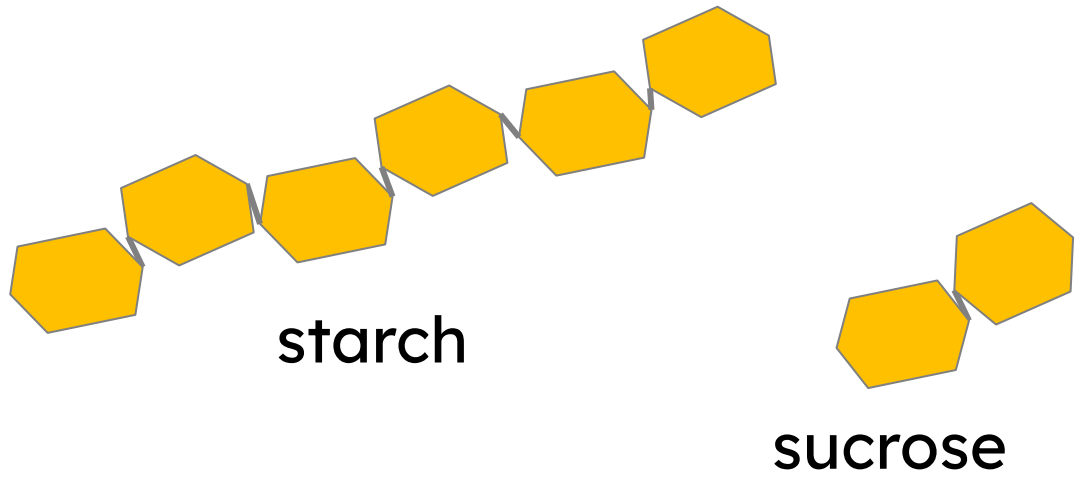
In the sample data, the rate of respiration was:

- fastest with glucose
- slower with sucrose
- slowest with starch.

Substrate	Rate of respiration (cm^3/min)
Glucose	5.6
Sucrose	3.2
Starch	0.6

How can we explain these observations?

Starch is a larger molecule than sucrose, so it takes longer to break down starch into glucose for respiration (and not as long to break down sucrose).



The effect of different substrates on respiration

Check

The enzyme that initiates cellular respiration …

a is specific to starch.

b is specific to sucrose.

c is specific to glucose. ✓

d can use any substrate.

1. Define the following keywords:
    a. Enzyme
    b. Active site
    c. Substrate

2. Use the lock and key model to explain why the rate of respiration is faster when glucose is provided as the substrate, and slower when starch is provided.

1. Define the following keywords:

   a. Enzyme

   A biological catalyst.

   b. Active site

   The part of an enzyme where the substrate binds.

   c. Substrate

   The substance that fits into an enzyme's active site.

2. Use the lock and key model to explain why the rate of respiration is highest when glucose is used as a substrate.

Enzymes are specific to only one type of substrate. In the lock and key model, the enzyme is the lock and the substrate is the key. Only one type of substrate (key) will fit into the enzyme's active site (lock).

The enzyme that initiates cellular respiration is specific to glucose. This means that other carbohydrate substrates, such as starch, must be broken down into glucose first before respiration can take place.

This is why when yeast are given glucose, the rate of respiration is much faster than if they are given starch.

END