Cambridge Assessment International Education

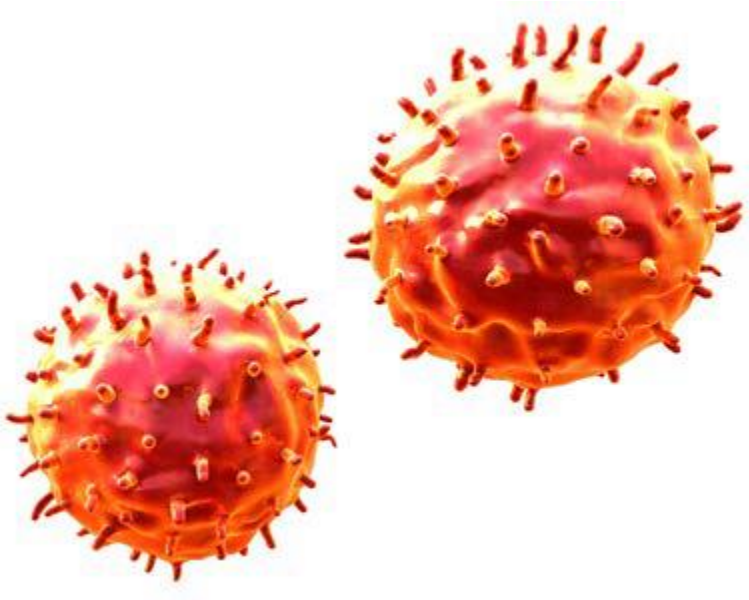
Teaching Pack

Investigating the effect of changing temperature on respiration in yeast

Cambridge IGCSE™

Biology 0610

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE® (9–1) Biology 0970
- Cambridge IGCSE® Combined Science 0653
- Cambridge IGCSE Co-ordinated Sciences (Double Award) 0654
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) 0973
- Cambridge O Level Biology 5090
- Cambridge O Level Combined Science 5129



Version 1

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Briefing lesson

Lab lesson: Option 1 – run the experiment

Lab lesson: Option 2 – virtual experiment

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Investigating the effect of changing temperature on respiration in yeast

This *Teaching Pack* focuses on an investigation into the effect of changing temperature on the rate of respiration in yeast.

Yeast is a single-celled microscopic fungus. The carbon dioxide produced during aerobic respiration by yeast is important in many industrial processes, including bread-making. The carbon dioxide released by the yeast causes the bread to rise. Bioengineers often investigate the factors that affect the rate of respiration to refine the conditions of a reaction vessel that use yeast cultures. They can improve the efficiency and productivity of many industrial processes.

This experiment has links to the following syllabus content (see syllabus for detail):

- 12.2: Aerobic respiration

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- demonstrate knowledge of how to safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 12.2: Aerobic respiration

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about aerobic and anaerobic respiration.

Briefing lesson: Different dependent variables

Resources	• Teacher instructions 1 (printed onto stiff card/ laminated) • Teacher instructions 2 • Worksheets A, B and C • 20 % yeast suspension (10 cm^3) • 0.005 % methylene blue solution (10 cm^3) • Boiling tube rack • Boiling tubes x 3 • Graduated pipette or syringe 5-10 cm^3 • Test-tube holder • Stopwatch
Learning objectives	By the end of the lesson: • **all learners** will be able to outline how the rate of respiration of a yeast suspension can be estimated. • **most learners** will be able to explain how the rate of respiration of a yeast suspension can be estimated. • **some learners** will be able suggest some of the problems, and how they can be overcome, during an investigation into the rate of respiration of a yeast suspension.

Timings	Activity
10 min	**Starter/Introduction** Learners must be familiar with the key terms important to this series of lessons. To reinforce this knowledge, make a 'loop activity' using some or all of the terms. Type some or all of the terms with their definitions into a spreadsheet. Now, move all the terms down by one cell so that term and definition no longer match. Type START against the first definition and END against the last term (see diagram below; an example is provided in Teacher Instructions 1). START definition term 1 Term 1 definition term 2 Term 2 definition term 3 Term 3 END Print the spreadsheet onto stiff card and cut up so that each piece of card has a term and a definition. Shuffle the cards and then hand one to each member of the class. The student with the 'START' card reads out the definition and the person with the matching term identifies themselves, reads out the term and then reads the definition on their card. This continues until it reaches the 'END' card. The cards can be shuffled and the loop activity repeated to see if the students can do it faster the second time.
	Main lesson Inform learners that there are a large range of methods that can be used to measure the rate at which organisms respire. Challenge them to engage in a 'think, pair, share' activity to brainstorm some of the methods that could be used to

	investigate the rate of respiration in an organism. Give learners 20-30 seconds to consider the question (think), then 5 minutes to discuss with their neighbour (pair), before you select a few learners at random to provide their contributions (share). Provide learners with Worksheet A. This follows on from their previous activity and consists of a series of questions related to the subject matter they will encounter in this investigation. Provide them with around 15 minutes to complete this task, before engaging learners with the mark scheme displayed on the board. Finally, ask learners to gather around the teacher's bench to view the basis of the investigation – how a respiring yeast suspension is able to decolourise methylene blue dye. Mix 10 cm^3 yeast-glucose suspension with 10 cm^3 methylene blue and show how the blue colour of the indicator decolourises over a short period of time. Ask learners to return to their desks and provide them with Worksheet B. This provides them with the list of equipment that they will require to undertake this practical and also reminds them of the key points they must include in a plan so that another person could follow it. As you circulate around the class, use appropriate prompts to stimulate discussion, examples of which are listed in Teacher Instructions 2 that are targeted to learners of different abilities.
	**Plenary** To promote higher-order thinking about the method and the underlying scientific basis, hold a brief round of closed '*always true/ sometimes true/ never true*' statements, which are aimed at refreshing prior knowledge. These could include the following examples: o 'Methylene blue is brown in colour.' (never true) o 'The blue dye will decolourise.' (sometimes true – if the yeast cells are respiring) o 'The yeast suspension must have a supply of glucose in order to respire aerobically.' (always true) If the class is large, then learners could be provided with a sheet of paper with 'true' and 'false' printed upside down (Worksheet C). When they hold up their pieces of paper, you will be able to assess all members of the class. To indicate that their answer is 'sometimes true,' learners could put their other hand in the air when they hold up 'true' in order to indicate that they have a justification to make.

Lab lesson: Option 1 – run the experiment

Resources	• Worksheets D1 and E1 • Graph paper • 20 % yeast suspension • 0.005 % methylene blue solution • Boiling tube rack • Boiling tubes x 12 • Sticky labels • Bunsen burner • Graduated pipette or syringe 5-10 cm^3 • Test-tube holder • Stopwatch • Kettle full of water • Large beaker containing a thermometer • Water baths x 5, set to 20, 30, 40, 50 and 60°C
Learning objectives	By the end of the lesson: • **all learners** should describe how to investigate the effect of changing temperature on the rate of respiration in yeast. • **most learners** should be able to explain some of the considerations that are taken during an investigation into the effect of changing temperature on the rate of respiration in yeast • **some learners** will be able to suggest improvements to an investigation into the effect of changing temperature on the rate of respiration in yeast.

Timings	Activity
5 min	**Starter/Introduction** Share a copy of Worksheet D1 with each learner, which provides the method for the investigation, and Worksheet E1, which has an unlabelled diagram of the equipment. Instruct learners that they will work in pairs during this lesson to conduct the experiment. Ask learners to read the method carefully and underline the verbs in each instruction, and then label the diagram. Provide an opportunity for learners to ask questions about the method, and then decide which member of each pair is to collect which items of equipment.
50 min	**Main lesson** Learners should collect and set up their apparatus. As they do so, make sure you draw their attention to precautions they should take, for example, the care needed when using the yeast suspension and the water baths at higher temperatures (e.g. test-tubes should be removed using test-tube holders). Learners carry out their method for finding the time taken for the blue indicator to decolourise at different temperatures. During the lesson, you should check that learners are entering their data into their table on Worksheet E1.

	As they undertake the experiment, ask learners to identify any steps in the method with which they experienced problems or difficulties; these notes will be useful when they come to evaluate the procedure in the *Debriefing lesson*. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
	**Plenary** Learners will be at different stages of the practical activity towards the end of the lesson, with some likely to need the full hour to completely finish. If any learners finish early, provide them with graph paper and encourage them to plot a graph of their results (they should place temperature on the x-axis and the **mean** time to decolourise on the y-axis). They should complete this for homework in advance of the *Debriefing lesson*.

Teacher notes

Watch the distillation video (teacher version) and read these notes.

Each group will require:

- 20 % yeast suspension*
- 0.005 % methylene blue solution
- Boiling tube rack
- Boiling tubes x 12
- Sticky labels
- Bunsen burner
- Graduated pipette or syringe 5-10 cm3
- Test-tube holder
- Stopwatch
- Kettle full of water
- Large beaker containing a thermometer
- Water baths x 5, set to 20, 30, 40, 50 and 60°C

Safety

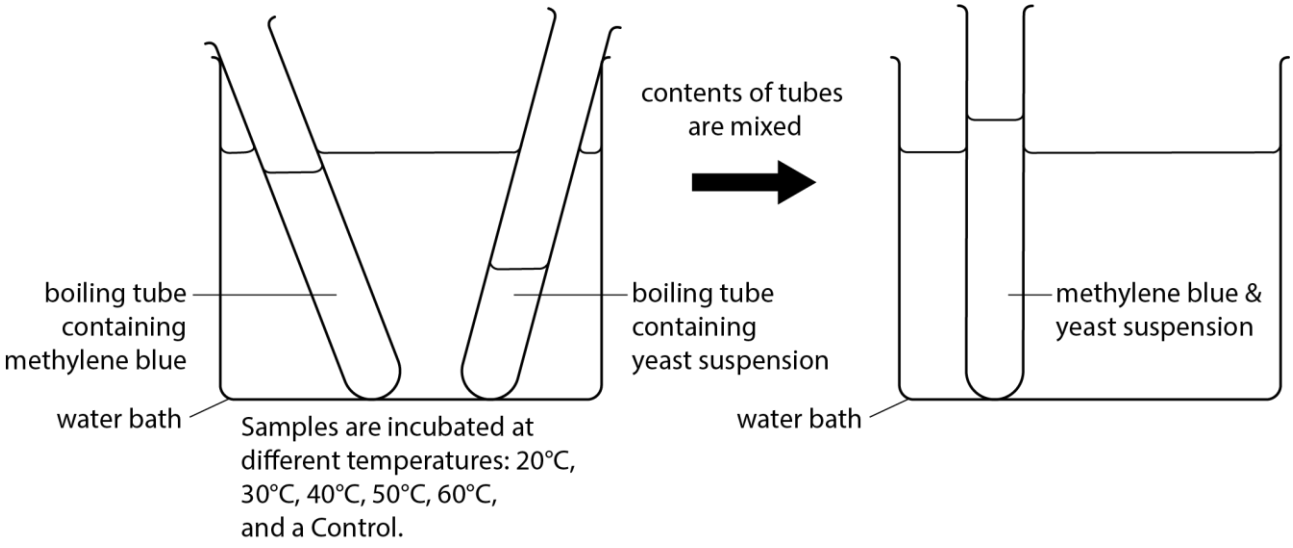
The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
Yeast suspension	Allergen	If inhaled, move person into fresh air. In case of skin contact, wash off with soap and plenty of water. In case of eye contact, flush eyes with water as a precaution. If swallowed, rinse mouth with water.
Methylene blue (dilute) aqueous solution	 GHS08 (*health hazard* **HH**)	**In the eye:** Flood the eye with gently-running tap water for at least 10 min. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor. **Dust breathed in:** Remove the casualty to fresh air. See a doctor if breathing is difficult. **Spilt on the skin or clothing:** Remove contaminated clothing. Wash off the skin with soap and plenty of water. Rinse contaminated clothing. **Spilt on the floor, bench, etc.:** Scoop up solids (take care not to raise dust).

Substance	Hazard	First aid
		Wipe up solution spills or any traces of solid with a damp cloth and rinse it well.
Glassware	Risk of cuts due to sharps, e.g. broken glass or scalpels. Wounds can lead to infection, especially if the blade or point is contaminated.	**Minor cuts:** Rinse the wound with water. Get the casualty to apply a small, sterile dressing. **Severe cuts**: Lower the casualty to the floor. Raise the wound as high as possible. If feasible, ask the casualty to apply pressure on or as close to the cut as possible, using fingers, a pad of cloth or, better, a sterile dressing (adding further layers as necessary). If the casualty is unable to do so, apply pressure yourself, protecting your skin and clothes from contamination by blood if possible. Leave any embedded large bodies and press around them. Send for a first aider.
Hot water baths set at 50 °C and 60 °C	Burns	Flood burnt area with water for at least 10 minutes. For serious injuries see a doctor.

Experiment set-up



How to make the yeast suspension

This comprises 20 g of dried yeast in 100 cm^3 of 1% glucose solution, with 0.1 g sodium phosphate and 0.2 g sodium bicarbonate.

Keep incubated at 40 °C for at least 24 hours prior to the experiment, in order to ensure that the yeast is actively dividing and respiring.

Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet D1 and Worksheet E1.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step	Notes
1. Using a syringe, measure 2 cm^3 yeast-glucose suspension into six boiling tubes. These should be marked with a series of different temperatures, and one marked 'control.'	The syringe should be small enough to measure small volumes precisely. Choose temperatures that chosen to reflect those over which the yeast is most likely to be active.
2. Using a different syringe, measure 5 cm^3 methylene blue into a different set of six boiling tubes labelled with the same temperatures.	Choose temperatures that chosen to reflect those over which the yeast is most likely to be active.
3. Place each pair of boiling tubes into their respective water baths for at least ten minutes.	This ensures that the contents of the boiling tubes reach the required temperature before mixing.
4. Place the pair of boiling tubes labelled 'control' into a beaker of freshly-boiled water for at least ten minutes.	This high temperature will kill the yeast cells and denature their enzymes.
5. Remove one pair of boiling tubes from the water bath, and pour the methylene blue into the boiling tube containing the yeast-glucose suspension.	Methylene blue will decolourises in the presence of respiring cells. The rate of aerobic respiration of the yeast can be estimated from the time taken for the mixture to decolour.
6. Place a rubber bung onto the boiling tube. Invert the mixture to mix it thoroughly and start the timer.	This mixes the yeast suspension and the methylene blue thoroughly.
7. Place the boiling tube back into the water bath. Do not touch or the tubes during the incubation period.	Any movement will result in the reappearance of the blue colour.
8. Record the time at which the blue colour decolourises.	Comparing the colour of the reaction mixture with a tube containing fresh yeast-glucose suspension may make the end point of the reaction easier to deduce.

9. Mix the contents of each pair of boiling tubes in this way and record the time taken to decolourise is recorded, one pair at a time.	Take care to stop the stopclock at the equivalent point in each experiment – when the blue colour has completely disappeared.
10. Repeat the whole experiment two more times for each temperature and for the control.	This is in order to calculate a mean rate of reaction.

Clean-up

After the experiment learners should:

- clean all glassware
- tidy up their work space
- ensure any spillages have been mopped up
- return all equipment and any unused chemicals to you.

Lab lesson: Option 2 – virtual experiment

Resources	• Worksheets D2 and E2 • Graph paper
Learning objectives	By the end of the lesson: • **all learners** should describe how to investigate the effect of changing temperature on the rate of respiration in yeast. • **most learners** should be able to explain some of the considerations that are taken during an investigation into the effect of changing temperature on the rate of respiration in yeast • **some learners** will be able to suggest improvements to an investigation into the effect of changing temperature on the rate of respiration in yeast.

Timings	Activity
15 min	**Starter/Introduction** Share a copy of Worksheet D2 with each learner, which provides an activity based on the method for the investigation, and Worksheet E2, which has an unlabelled diagram of the equipment and sample data. Ask learners to read and make suggestions – in pencil – to complete the missing words or labels. Provide an opportunity for learners to compare their suggestions with each other.
30 min	**Main lesson** Learners watch the video as a summary of the experiment. Ask your learners to identify any key points they have missed out of their own method. For example, it is likely that some learners will not have recognised the need for pre-incubation of the yeast and methylene blue. You may then wish to give them some time to make adjustments to their plan. Learners should take a few minutes to think about the answers, reflecting on the tasks of the main lesson to help them. Then they should be asked to discuss the answers with a partner for another 2 minutes, before writing down their final answers. If necessary, prompt discussion to elicit deeper understanding. All learners circulate around the room to compare and contrast their final answers.
15 min	**Plenary** Provide learners with graph paper and encourage them to plot a graph of their results (they should place temperature on the x-axis and the **mean** time to decolourise on the y-axis). This will be analysed in the *Debriefing lesson*.

Debriefing lesson: Modifying an investigation

Resources	• Worksheets F and G
Learning objectives	By the end of the lesson: • ***all*** learners should be able to analyse their data to make a conclusion regarding the effect of changing temperature on the rate of respiration in yeast. • ***most*** learners should be able to modify their method to investigate the effect of changing another factor on the rate of respiration in yeast. • ***some*** learners should be able to evaluate a method to investigate the effect of changing another factor on the rate of respiration in yeast.

Timings	Activity
15 min	**Starter/Introduction** Ask learners to consider their graphs from the *Lab lesson*. Group pairs of learners together and ask them to spend 2–3 minutes comparing each other's work – did they obtain similar results?
40 min	**Main lesson** Challenge learners to answer Worksheet F on their own. This activity shows an alternative set of data. The questions ask learners to consider what they did during the practical, and why, and encourage further analysis and evaluation of their data. As learners answer the questions, remind them in particular about the subjectivity of their end-point judgements, and the fairly large intervals between the temperatures that they used which would limit the accuracy of their estimate of the optimum temperature. Ask learners to discuss their answers with a partner. Invite each pair to offer their refined answers to the class and generate a class-wide discussion. Second, arrange learners into groups of 3–4 and explain that you want them to modify the method they employed in the Lab lesson in order to investigate the effect of a change in another factor on the rate of respiration in yeast. Provide each learner with a copy of Worksheet G. Inform them that they will need to collaboratively evaluate the method they employed in the previous lesson and decide which steps should be modified, how and why. Provide learners with the factor that they should investigate; the example of pH is described in the Answers. You can withhold the checklist on Worksheet G for the first 5 minutes in order to keep the discussion regarding evaluation and planning more open, and then provide an opportunity for learners to reflect on what they had missed in their initial plan. Conclude with a whole-class discussion to give learners the opportunity to reflect on their work. The expected outcomes of this activity are given in the answers to Worksheet G; use this to make sure all learners have met the expected outcomes and to extend their thinking.

Plenary

Encourage learners to construct Venn diagrams to compare the practical investigation involving temperature, and the practical investigation that they have just modified. For example, they should draw a circle labelled 'temperature' overlapping with another circle labelled 'pH'. The effect of changing temperature and pH on the rate of respiration in yeast have many things in common (there is an optimum value, yeast will die at extreme values, and so on). However, there is much that is unique to each (e.g. changing temperature increases the kinetic energy of particles, pH interferes with the charges of molecules, and so on).

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson:*		
Teacher Instructions 1: Revision dominoes	**18**	
Teacher Instructions 2: Planning prompts	**19**	
A: Measuring the rate of aerobic respiration	**20**	**31**
B: Planning sequence	**22**	
C: True-false card	**23**	
For use in *Lab lesson: Option 1:*		
D1: Method	**24**	
E1: Equipment setup and table	**26**	
For use in *Lab lesson: Option 2:*		
D2: Method: missing statements	**25**	
E2: Equipment setup and sample data	**27**	
For use in the *Debriefing lesson:*		
F: Analysing data	**28**	**32**
G: Modifying an investigation	**29**	**33**

Teacher instructions 1: Revision dominoes

START	the chemical reactions in cells that break down nutrient molecules and release energy for metabolism
respiration	produced during respiration, this chemical is used by cells for processes such as active transport
ATP	a gaseous reactant of aerobic respiration
O_2	a toxic product of respiration
CO_2	required in the processes of aerobic and anaerobic respiration
glucose	the site of aerobic respiration in eukaryotic cells
mitochondria	**END**

Teacher instructions 2: Planning prompts

While your learners engage with **Worksheet A**, circulate and provide some prompts as necessary to aid discussions. Choose appropriate prompts on the basis of the ability of the learners.

demand	prompt
LOW	is this a safe experiment?
↓	what is the title of the experiment?
↓	what is the difference between the independent and dependent variables?
↓	think about the order in which you will do things.
↓	consider what you would predict and phrase this as a hypothesis.
MEDIUM	think about the dependent variable – how will you judge when to stop the timer?
↓	why should we keep all factors apart from the temperature constant?
↓	why should we repeat the experiment at each temperature?
↓	what is a 'control?' why is it necessary?
HIGH	think more about the independent variable – consider the terms 'range' and 'interval.'

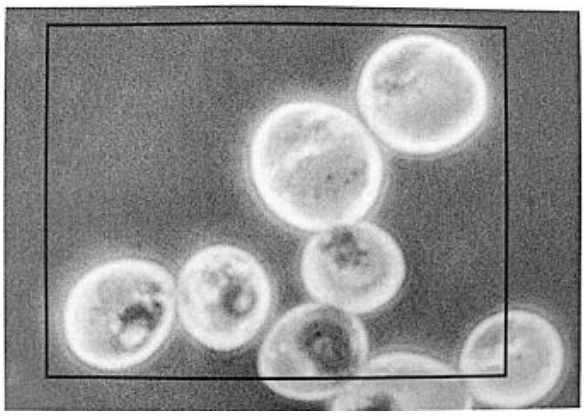
Worksheet A: Measuring the rate of aerobic respiration

In aerobic respiration, glucose reacts with oxygen to produce carbon dioxide and water:

$$\text{Glucose} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water}$$

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

Yeast is a single-celled microscopic fungus. The carbon dioxide produced during aerobic respiration by yeast is important in many industrial processes, including bread-making. The carbon dioxide released by the yeast causes the bread to rise. A photomicrograph of some yeast cells is shown in **Figure 1**.



x 1500

1. In the box below, make a large drawing of the 5 whole cells shown in the area in the Figure.

Remember that when you draw a diagram you should use a sharp pencil and draw clean, unbroken lines without shading.

Worksheet A: Measuring the rate of aerobic respiration *continued*

2. Use the magnification to calculate the width of the cell labelled A. Show your working.

……

……

……

A bioengineer intends to measure the **rate of respiration** of a suspension of **yeast cells**. They wish to do this in order to refine the conditions of a reaction vessel that use yeast cultures. They can improve the efficiency and productivity of many industrial processes.

3. Use the information provided to suggest **three** methods that could be used to measure the rate of respiration in a suspension of yeast. Ask your teacher if you need a hint to get started.

1……

……

2……

……

3……

……

4. Suggest reasons why the methods you have suggested may **not** provide accurate data. Ask your teacher if you need a hint to get started.

……

……

……

Worksheet B: Planning sequence

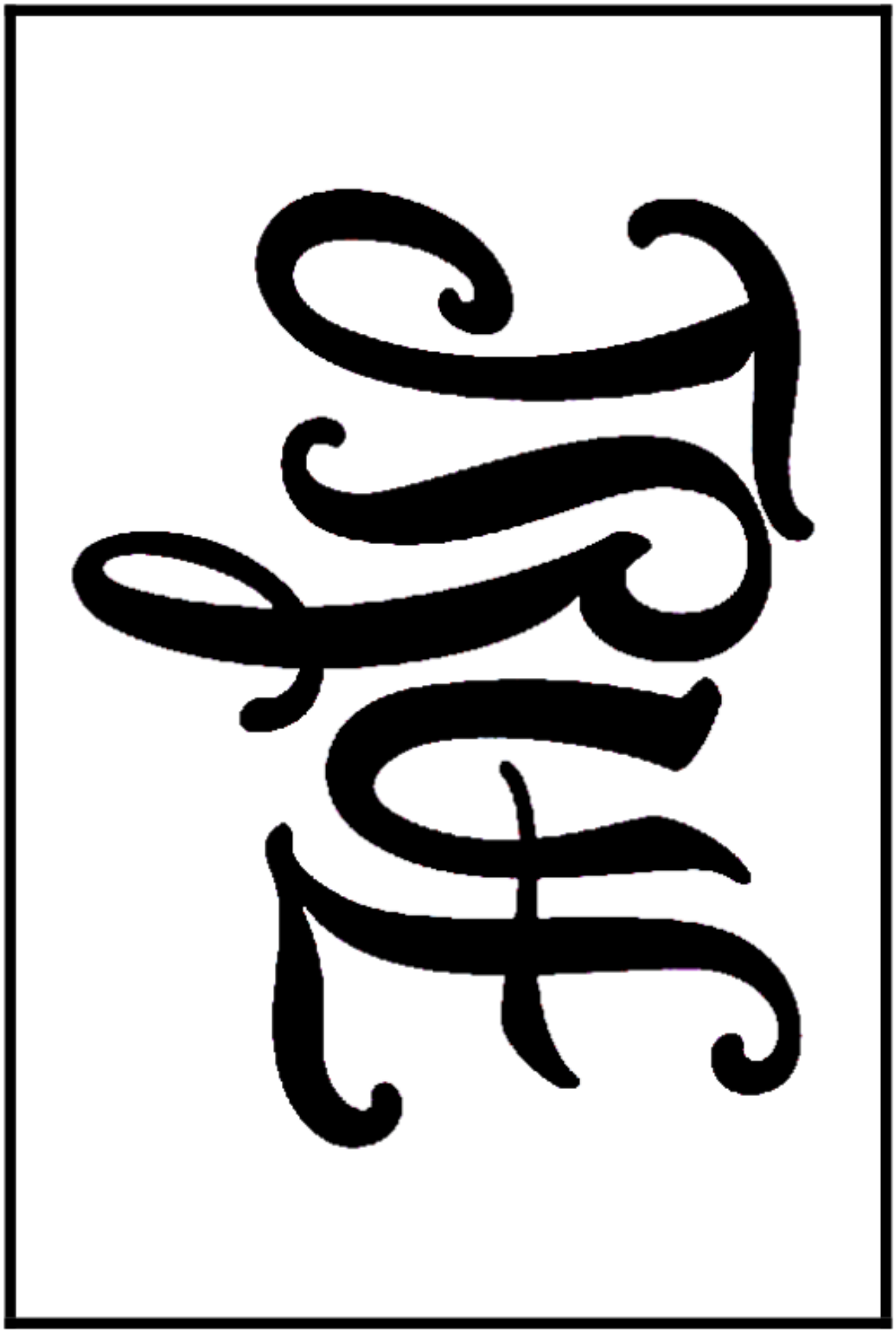
Your teacher showed you how to estimate the rate of respiration in a suspension of yeast by measuring the **time taken** for the yeast to **decolourise** a special dye, called **methylene blue**.

Plan an investigation to determine the effect of changing temperature on the rate of respiration in yeast cells. Number them from 1 to 10 to create a suitable sequence. Then use them as prompts to write your own plan.

Remember that a good plan requires you to focus on **what** will be investigated and **how** this will be achieved.

Decide how to measure the dependent variable, how often to measure it and consider whether you need to try to standardise the measuring procedure.	
Write a clear title for the experiment to clearly define the purpose of the experiment.	
Use the title to write a hypothesis.	
Identify any variables you should standardise. These are variables that may alter the results if they change. Decide how to keep them the same.	
Assess the risks of the procedure as low, medium or high by considering the hazards.	
Identify the independent and dependent variables, in other words, consider what you will change and what you will measure. The title and hypothesis can help with this – consider how the experiment will test your hypothesis.	
Decide how many times you will repeat each measurement to identify any anomalous results and to get a mean value.	
Decide how to change and measure the independent variable, the range of values to use, how many values to use and the intervals between the values.	
Work out the order in which you would need to do everything.	
Decide on a control that removes the effect of the independent variable.	

Worksheet C: True-false card



Worksheet D1: Method

1. Using a syringe, measure 2 cm^3 yeast-glucose suspension into six boiling tubes. These should be marked with a series of different temperatures, and one marked 'control.'

2. Using a different syringe, measure 5 cm^3 methylene blue into a different set of six boiling tubes labelled with the same temperatures.

3. Place each pair of boiling tubes into their respective water baths for at least ten minutes.

4. Place the pair of boiling tubes labelled 'control' into a beaker of freshly-boiled water for at least ten minutes.

5. Remove one pair of boiling tubes from the water bath, and pour the methylene blue into the boiling tube containing the yeast-glucose suspension.

6. Place a rubber bung onto the boiling tube. Invert the mixture to mix it thoroughly and start the timer.

7. Place the boiling tube back into the water bath. Do not touch or the tubes during the incubation period.

8. Record the time at which the blue colour decolourises.

9. Mix the contents of each pair of boiling tubes in this way and record the time taken to decolourise is recorded, one pair at a time.

10. Repeat the whole experiment two more times for each temperature and for the control.

Worksheet D2: Method: missing statements

1. Using a syringe, measure _____ yeast-glucose suspension into six boiling tubes. These should be marked with a series of different temperatures, and one marked 'control.'

2. Using a different syringe, measure 5 cm^3 _____ _____into a different set of six boiling tubes labelled with the same temperatures.

3. Place each pair of boiling tubes into their respective water baths for at least _____minutes.

4. Place the pair of boiling tubes labelled 'control' into a beaker of _____ _____ water for at least ten minutes.

5. Remove one pair of boiling tubes from the water bath, and pour the methylene blue into the _____ _____ containing the yeast-glucose suspension.

6. Place a rubber bung onto the boiling tube. Invert the mixture to mix it thoroughly and start the timer.

7. Place the boiling tube back into the _____ _____. Do not touch or the tubes during the incubation period.

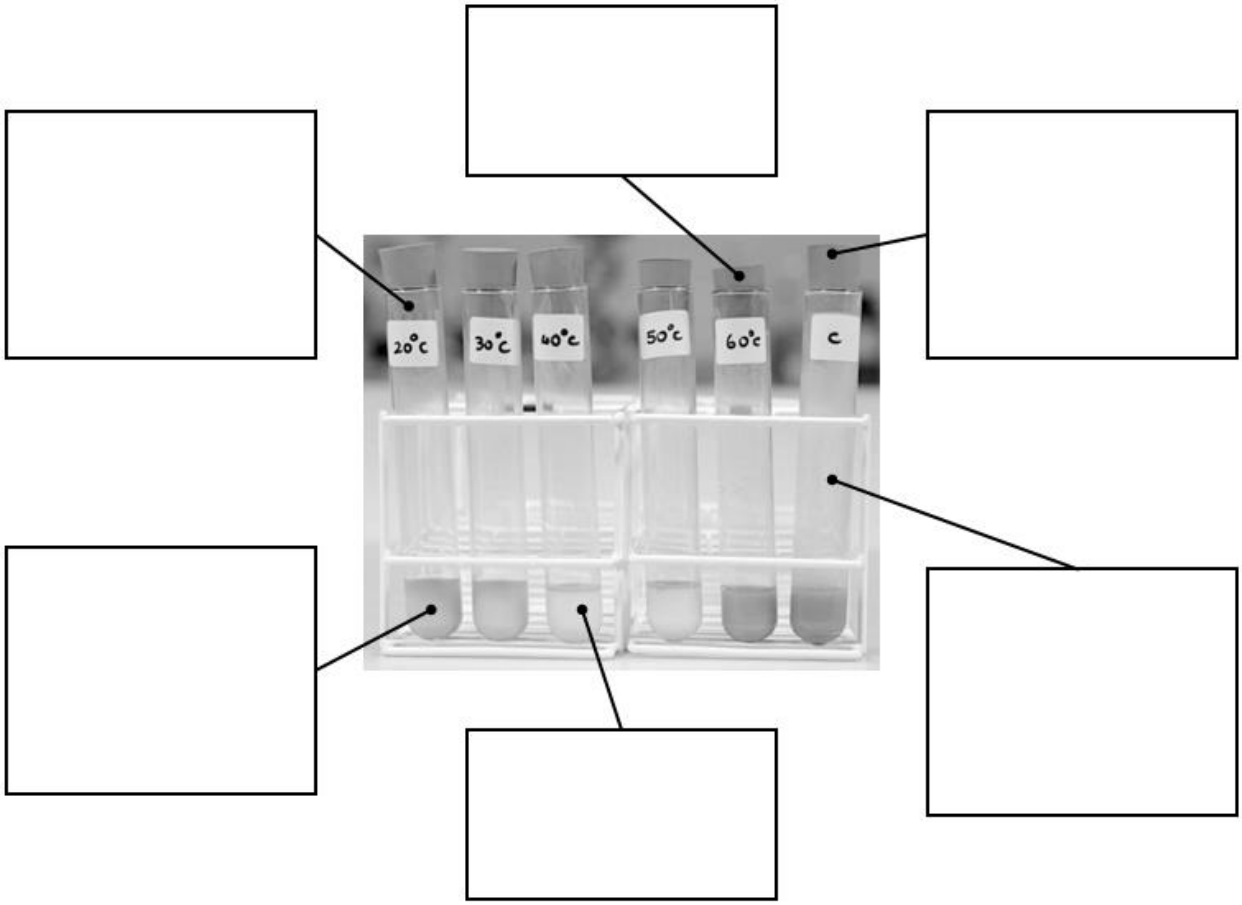
8. Record the time at which the blue colour _____.

9. Mix the contents of each pair of boiling tubes in this way and record the _____ _____ to decolourise is recorded, one pair at a time.

10. Repeat the whole experiment _____ more times for each temperature and for the control.

Worksheet E1: Equipment setup and table

Label the diagram of the equipment setup.

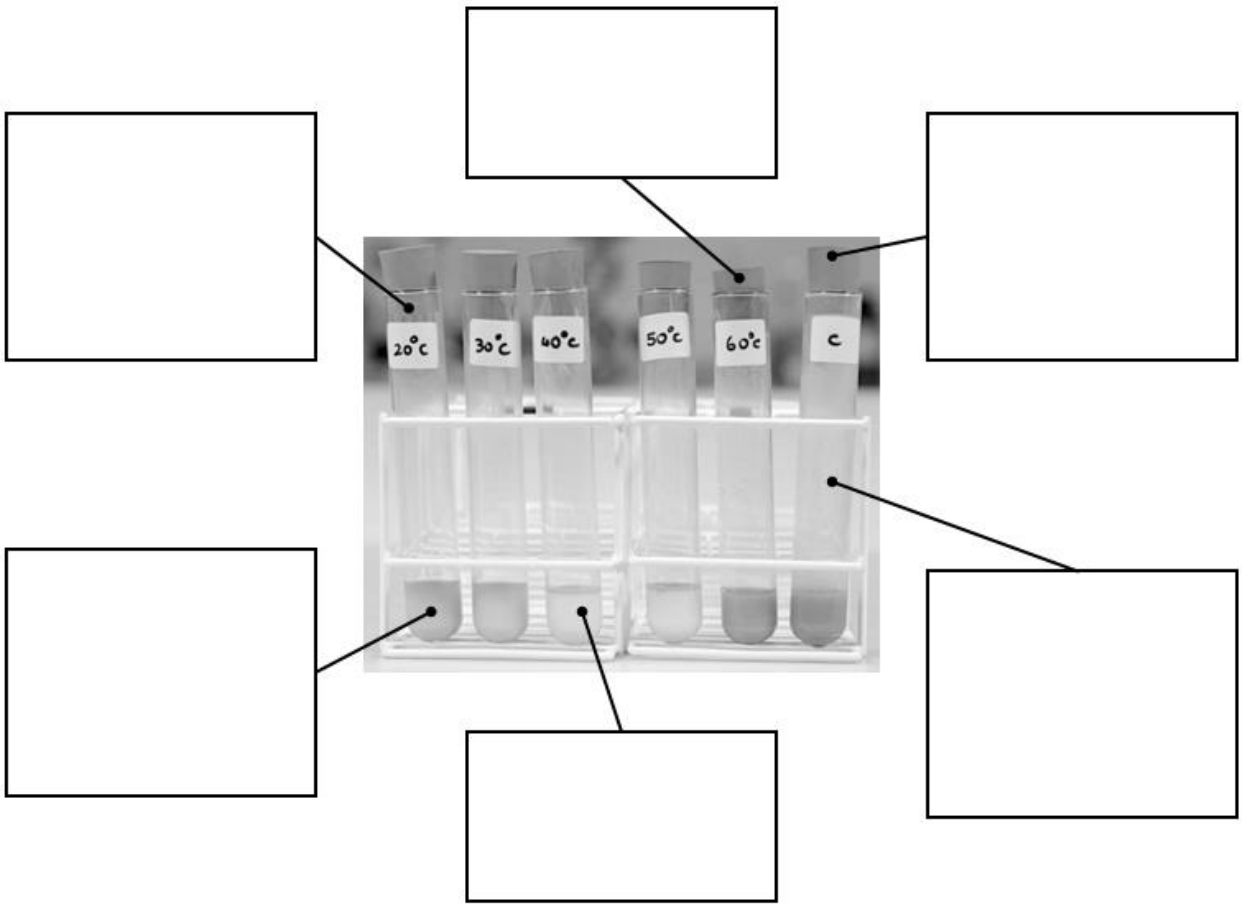


Use the table below to record your data from the investigation.

Temperature/ °C	Time taken for stain to decolourise/ seconds			
	Repeat 1	Repeat 2	Repeat 3	Repeat 4
20				
30				
40				
50				
60				
Control				

Worksheet E2: Equipment setup and sample data

Label the diagram of the equipment setup.



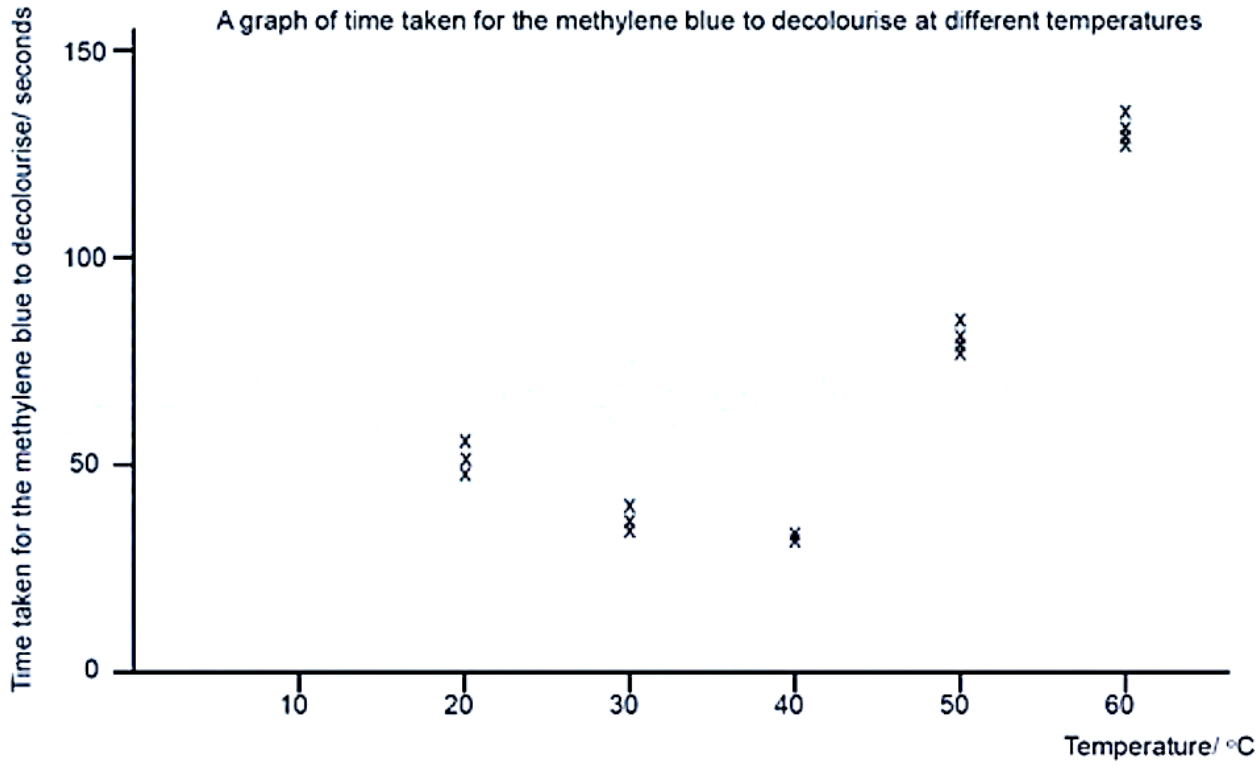
Use the sample data below in the upcoming discussions.

Temperature/ °C	Time taken for stain to decolourise/ seconds			
	Repeat 1	Repeat 2	Repeat 3	Repeat 4
20	49	55	52	52
30	43	41	45	43
40	31	32	31	31
50	78	83	85	82
60	134	122	140	132
Control	DNC	DNC	DNC	DNC

DNC: did not change

Worksheet F: Analysing data

The graph below should look similar to the one that you have prepared. Use this to help you answer the questions that follow.



1. The student estimated that the optimum temperature for yeast respiration is 40 °C. Do you agree with this conclusion? **Explain** your answer.

2. **Suggest** one significant source of error in measuring the dependent variable in this investigation.

3. **Explain** why the yeast suspension placed into the boiling water not decolourise the methylene blue solution.

4. **State** the temperature for which the student obtained the most reliable data. **Explain** your choice.

5. **Draw** a line of best fit through the points on the graph and use it to **estimate** the time taken for the methylene blue to decolourise at 10 °C.

Worksheet G: Modifying an investigation

In this activity, you will modify the method you used in your investigation to investigate the effect of changing a different factor on the rate of respiration in yeast.

Write the research question provided by your teacher below:

How does a change in _____ affect the rate of respiration in yeast?

1. Complete the table below to compare the investigation you carried out with the investigation you are required to plan.

feature	previous investigation	modified investigation
independent variable (IV)		
range of IV		
intervals of IV		
standardised variables (min. 3)		
control experiment		

2. Use the table above to help you write a plan for this modified investigation.

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Worksheet G: Modifying an investigation *continued*

3. Identify a hazard in the experiment and how a safety precaution will be followed to minimise risk.

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4. Compare your method with that of your partner. How is it different to yours?

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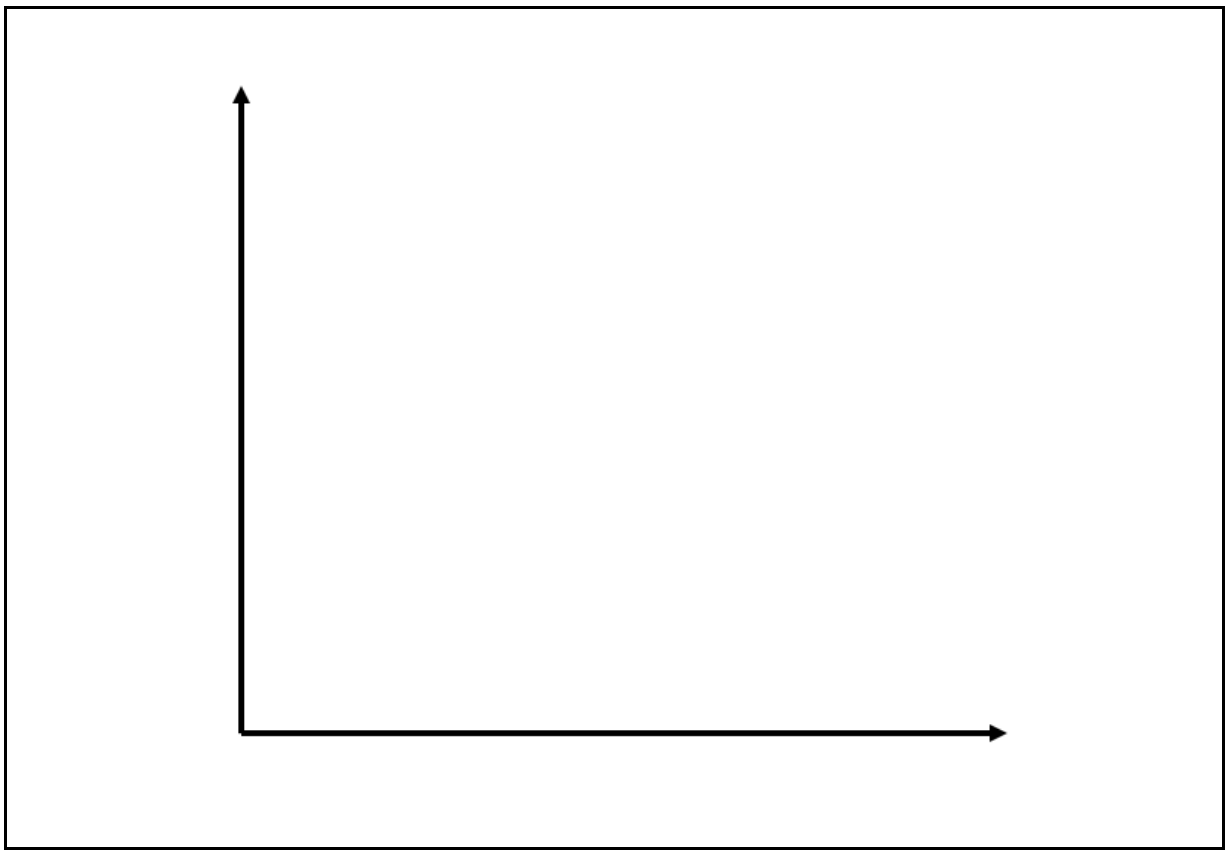
5. Add labels to the pair of axes below and predict the results of your modified investigation by sketching a line of best fit.



Worksheet A: Answers

1. The diagram should only show the five whole cells shown in the figure and should be drawn with a sharp pencil such that the lines are unbroken. No shading should be included.

2. 11.33µm.

3. Three methods that could be used to measure the rate of respiration in a suspension of yeast in a boiling tube would be to measure:
   - The volume of carbon dioxide evolved.
   - The change in pH of the suspension (carbon dioxide dissolves in water to give a weakly acidic solution).
   - The increase in the number of yeast cells (a microscope would be required).

4. The methods described may now provide accurate date because the change in the dependent variable may not be sufficient to determine. Therefore, any errors will be large and will lead to inaccurate data.

Worksheet F: Answers

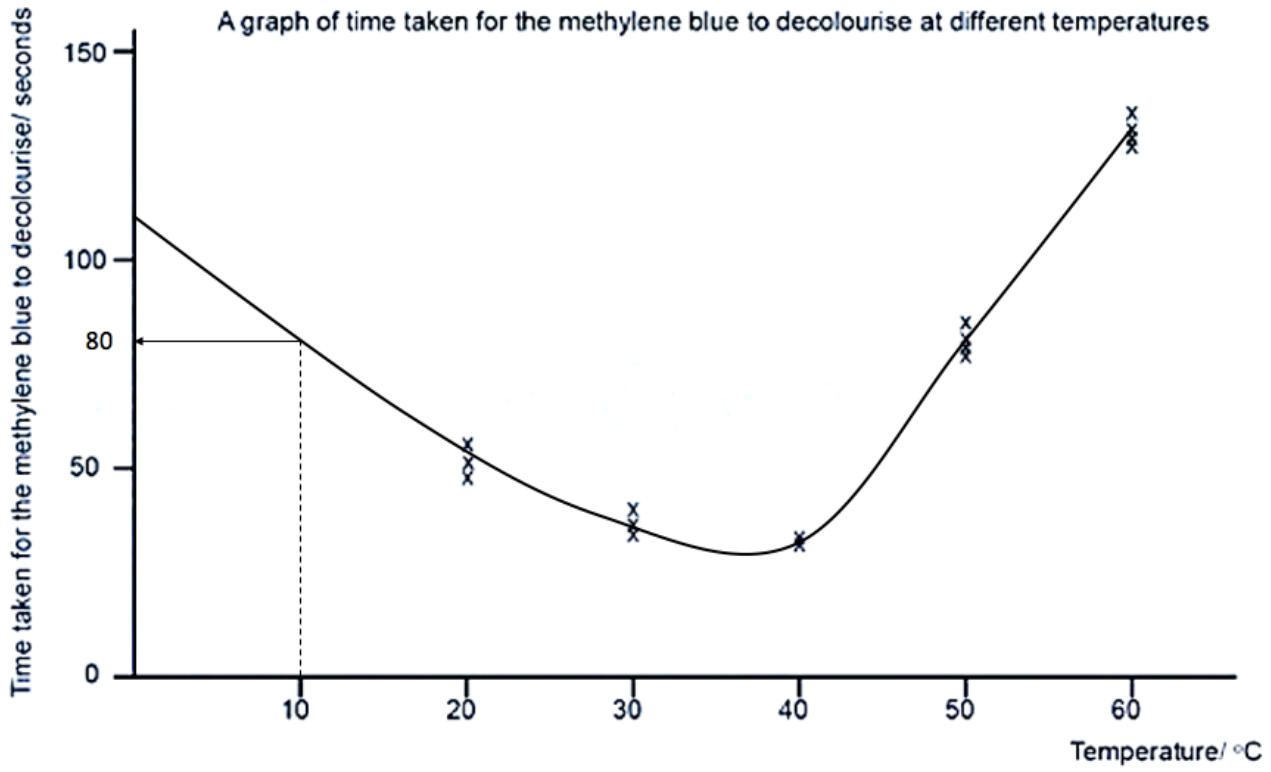
1. Although the methylene blue decolourised in the lowest time at 40 °C, there were no experiments conducted at temperatures between 30 °C and 40 °C or between 40 °C and 50 °C. It is possible that the optimum temperature for respiration in yeast exists at a temperature between these values.

2. Judging whether the methylene blue has completely decolourised is subjective, and this is based on the opinion of the experimenter.

3. This is because the yeast cells that were placed into the boiling water were killed, and therefore were unable to respire. In the absence of respiring cells, the methylene blue did not decolourise.

4. The most reliable data was obtained for the temperature at 40 °C. The three repeat readings were closest together.

5. A suggested line of best fit is shown below, which provides an estimated time of 80 seconds:



Worksheet G: Answers

Assuming that the research question provided is '*how does a change in pH affect the rate of respiration in yeast?*' then expected answers will be as follows:

1. See the table below.

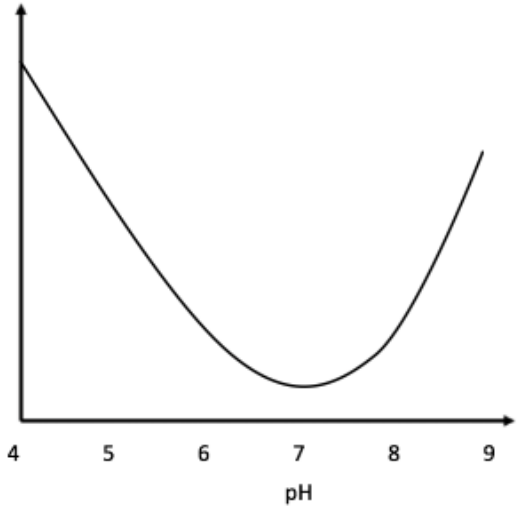
feature	previous investigation	modified investigation
independent variable (IV)	temperature	pH
range of IV	20 °C to 60 °C	4 to 9
intervals of IV	10 °C	1
standardised variables (min. 4)	pH of reagents, volume of yeast suspension, concentration of glucose, volume of methylene blue indicator	temperature of reagents, volume of yeast suspension, concentration of glucose, volume of methylene blue indicator
control experiment	suspension of boiled yeast	suspension of boiled yeast

2. Prepare a range of yeast suspensions of different pH values between 4 and 9. Add the same volume of this suspension to the same volume of methylene blue, start the timer, and incubate the tube at room temperature. When the methylene blue decolourises, stop the timer. Repeat this three times and calculate a mean value for each pH.

3. A hazard in the experiment would be the use of solutions that increase or reduce pH (these could be corrosive). A precaution would be to wear hand and eye protection.

4. *The learner's answer to this question will depend on their response and the response of their partner.*

5. A prediction of the relationship between pH and the rate of respiration in yeast is:



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