Cambridge Assessment International Education

Skills Pack

Dissection of a fish head and the structure and function of the gills

Cambridge International AS & A Level

Marine Science 9693

Version 1

Cambridge Pathway

Contents

Icons used in this pack:

Briefing lesson

Planning lesson

Lab lesson

Debriefing lesson

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 *Skills 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 2 (AS Level Data-handling and investigative skills) or Paper 4 (A Level Data-handling and investigative skills).

This is one of a range of *Skills Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

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Planning lesson (1 hour*)
This lesson focuses on planning a dissection.
It ends with a demonstration video of the activity.

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Lab lesson (1 hour*)
This lesson focuses on carrying out the dissection including the collection and recording of observations and measurements.

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Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of qualitative and quantitative data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

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

In this pack, you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Dissection of a fish head and the structure and function of the gills

This *Teaching Pack* focuses on the ventilation mechanism and gas exchange in a fish. Learners dissect a fish head to see the internal structures.

This investigation can be used as a case study to help learners develop their observation skills and techniques such as making scientific drawings. It also provides an opportunity to use mathematical approaches, such as the application of the formula magnification = image size ÷ actual size, and the evaluation of the quality of data using descriptive statistical methods.

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

- 4.1.4: make observations and drawings from unfamiliar structures or specimens from the key groups in topic 4.2 and additionally *Cnidaria* in topic 5.2
- 4.2.8: state the main internal and external features of a typical adult bony fish, including bony skeleton, operculum, gills, swim bladder, scales, externally visible lateral line, fins (pectoral, caudal, pelvic, anal and dorsal)
- 4.2.10: state the main internal and external features of a typical adult cartilaginous fish, including cartilaginous skeleton, gill slits, gills, denticles, lateral line, fins (pectoral, caudal, pelvic, anal and dorsal)
- 4.2.12: understand that bony fish and cartilaginous fish are both chordates (i.e. in the Phylum Chordata) and that all organisms in this phylum share common features (at some point in their development), including notochord, dorsal neural tube, pharyngeal slits and post-anal tail
- 6.1.5: recall and apply the formula: magnification = image size ÷ actual size
- 6.1.6: make observations, drawings and magnification calculations from unfamiliar structures or specimens (taken from any of the key groups in topic 4.2, topic 5.2 or the cell structures in Learning outcome 6.1.1)

The dissection covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- experimental planning and knowledge of techniques, including making estimates, predictions and hypotheses
- presentation and display of data and observations in suitable formats
- evaluation of experimental methods and quality of data.

Activities in this Teaching Pack help learners develop their mathematical skills, including**:**

- understand the use of descriptive statistics to simplify data, including the mean, median, mode, range, standard deviation (s), standard error (SM) and 95% confidence intervals (95% CI)
- calculate standard deviation (s), standard error (SM) and 95% confidence intervals (95% CI) using given formulae
- use standard deviations (s), standard errors (SM) or 95% confidence intervals (95% CI) to plot error bars on graphs

Briefing lesson: Gas exchange in a fish

Resources	• Teacher Instructions 1 • Worksheet A (1 per learner) – you may wish to print this as a 5-page booklet • Modelling clay (ideally a range of colours; for each group of 4 learners) • Toothpicks (5-10 for each group of 4 learners) • Sticky notes (5-10 for each group of 4 learners) • Glass rod (1 for each group of 4 learners) • Access to the internet.
Learning objectives	By the end of the lesson: • ***all*** learners should be able to outline the structure and function of the gas exchange system in fish • ***most*** learners should be able to describe and explain the structure and function of the gas exchange system in fish • ***some*** learners will be able to interpret data on the structure and function of the gas exchange system in fish.

Timings	Activity
15 min	**Starter/Introduction** It is assumed that learners will arrive to this lesson with a good understanding of the structure and function of the gas exchange system in fish. The purpose of this starter activity is to help learners revise this knowledge before the Planning lesson. Engage learners with an activity called '*Less is more*.' This requires them to write a short paragraph, using as few words as possible, that must include the 4, 8 or 12 words listed in Teacher Instructions 1. This activity is an opportunity to differentiate the lesson for learners of all abilities. To review their work, ask learners who chose the three different difficulty levels to come together as groups, and decide which individual has 'won' the competition. This is the learner who has used all of the words, correctly, in the shortest paragraph possible.
40 min	**Main lesson** Inform learners that in the upcoming practical lesson, they will carry out a dissection of a fish head to see the internal structures. Before they do this, however, they will consider the structure and function of the gills and use descriptive statistical methods to analyse some data. Inform learners that these activities will help them collect and analyse their own observations and data during and after the practical activity. Organise the class into pairs. Provide each learner with Worksheet A. This consists of two tasks that require learners to consider the gas exchange system in fish. Assure learners that by working together, they will share ownership of these tasks, which will increase their confidence. Learners will need access to the internet, as well as their textbooks and a calculator, to effectively complete these activities. Encourage learners to manage their time effectively so that both tasks can be completed in 30 minutes. Allow learners to take photographs of their work using phones or cameras if possible. As groups work, move around the class and offer your own thoughts. Enquire about what is going well. Ask learners questions such as '*what mistakes have you made and how did you overcome them?*'

Plenary

Prepare a cloze passage that summarises the wide range of concepts that learners have encountered in this lesson. Examples are provided below:

- ‘Gills are...’ (low demand)
- ‘It is possible for...’ (intermediate demand)
- ‘The standard error is....’ (high demand)

Learners can submit their responses as pairs. Alternatively, you may wish to ask learners to record their own answers individually, which you can formatively assess to determine progress and understanding in advance of the Planning lesson.

Planning lesson: Recording observations

Resources	• Teacher instructions 2, printed on large A2 (or A3) paper (1 copy) – you may wish to cut out the image to remove the header and footer • Teacher instructions 2, printed on A4 paper (1 copy per pair of learners) – you may wish to cut out the image to remove the header and footer • Worksheet B (1 per learner) • Worksheet C (1 per learner) – you may wish to print this as a 5-page booklet • A4 paper (1 sheet per group of 3 learners) • Sharp pencil (1 per group of 3 learners)
Learning objectives	By the end of the lesson: • ***all*** learners will be able to list the qualities of a good scientific diagram • ***most*** learners should be able to draw a good scientific diagram • ***some*** learners will be able to evaluate the quality of a scientific diagram and suggest improvements

Timings	Activity
15 min	**Starter/Introduction** Ask learners to arrange themselves into groups of 3. Two members of each group should volunteer to be 'describers.' The other one will be the 'translator.' Inform learners that they are going to play a competitive game in which describers must describe in detail an image (a photomicrograph) to their interpreter team-mates, in order for them to recreate the photomicrograph using a pencil on a sheet of A4 paper. Ask all of the describers, from all groups, to gather around the teacher's table. Inform describers that you will show a photomicrograph (included in Teacher Instructions 2) for just 20 seconds. During this time, it will be important for you to watch how the describers decide how to memorise the photomicrograph in advance of describing it to the interpreters. It is important that no interpreters can see the image (you may wish to do this outside of the room). Next, allow 3 minutes for the describers to guide the interpreters to draw the photomicrograph. Tell learners that they are not allowed to show the interpreter how to draw by pointing or using hand movements in any way; they can only use the spoken language. During the 3 minutes, walk around the room and give your own feedback. It is likely that learners' drawings are sketchy and messy with corrections and rough lines. Ignore this for now. This will help to inform the next activity. At the end of the 3 minutes, hand out to all groups A4 copies of the photomicrograph in Teacher Instructions 2. Inform them that it shows gill filaments. Provide an approximate magnification factor, and suggest to more able/ confident learners that they could estimate the actual size of the specimen in the photomicrograph.
40 min	**Main lesson** Using Teacher instructions 3, draw on the board a perfect scientific diagram of the image shown in Teacher Instructions 2 (see Worksheet B for guidance). If you prefer, you could display the image in Teacher instructions 3. Ask learners how this diagram differs to theirs; provide 5 minutes for learners to discuss this in their groups of 3 and agree on a list of 3-4 points. Take a few suggestions from various groups and then inform learners that the image shown in Teacher instructions 3 shows a scientific diagram of the image shown in Teacher Instructions 2. Suggestions may include the fact that their diagram is much smaller, has sketchy lines and shading, and that the proportions of the structures are not correct. Host a brief discussion and draw a mind map for the whole class to see, with the central question: '*What makes a good scientific diagram?*'

	To extend the discussion, ask learners if these observations and measurements are qualitative or quantitative data. Does that affect how they will make the observations or measurements? Explain that they need to be making these observations and measurements during a dissection. Share with learners Worksheet B, which requires them to design a mark scheme for their work. If any group finishes before the others, hand out copies of the original image on Teacher Instructions 2 and challenge them to calculate the magnification of the image. Show learners the Biological drawings video and ask them to identify anything that they did not include in their mark scheme. This will provide an opportunity for all groups to finalise their work, which will be an important reference document in the Debriefing Lesson.
	**Plenary** Inform learners that, next lesson, they will undertake a dissection of a fish head in order to explore its gas exchange system. To prepare for this, they should read Worksheet C, which describes the method. Ensure that any questions related to this have been addressed before learners leave.

Lab lesson: Getting practical

Resources	• Worksheet C (read for homework) • Laboratory dissection equipment as listed in the Teacher Notes (per pair of learners, or per learner, depending on class size and equipment/ fish specimen stocks)

Learning objectives	By the end of the lesson: • ***all*** learners should be able to record observations from a fish head dissection. • ***most*** learners should be able to use their observations to identify and describe the structure of the gas exchange system in fish. • ***some*** learners will be able to use their observations to explain the structure of the gas exchange system in fish.

Timings	Activity
5 min	**Starter/Introduction** Check that learners have brought with them Worksheet C, which should have been read for homework. Ask learners if they have any questions about the method before they get started.
45 min	**Main lesson** Briefly outline the safety precautions of the experiment. Draw a mind map to act as a risk assessment on the board. Use this to identify the hazards and how to avoid these. Learners undertake the practical activity. As they work, emphasise that learners need to record scientific diagrams and measurements during this activity, as explained in Worksheet C. **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.
10 min	**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 before others, provide a piece of plain paper and encourage them to draw a diagram of the lamellae they see at a magnification of x 40. Alternatively, encourage them to mentor learners who are still working. Further develop a collegiate atmosphere by encouraging learners to help each other clear and tidy away their equipment.

Teacher notes

Watch the video showing the dissection of a fish head and exploration of the structure and function of the gills (teacher version) and read these notes.

Each group will require:
- Fish head (be aware of cultural sensitivities). Most supermarkets or fishmongers will be happy to give fish heads for free/very low cost if you contact them in advance. Try to get them as fresh as possible as the gills will still be a dark red colour. Good fish to use are salmon, perch or mullet.
- Dissection board / tray
- Scalpel
- Large scissors
- Fine scissors
- Fine forceps
- Glass rod
- 30 cm ruler (should be made of material that is easily cleaned)
- Pipette
- Microscope slide
- Coverslip
- Microscope
- Distilled water
- Bowl
- Paper towels
- Disinfectant spray and cloths
- Gloves (latex and / or non-latex in case of any allergies)

Safety

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

Some associated safety precautions include:

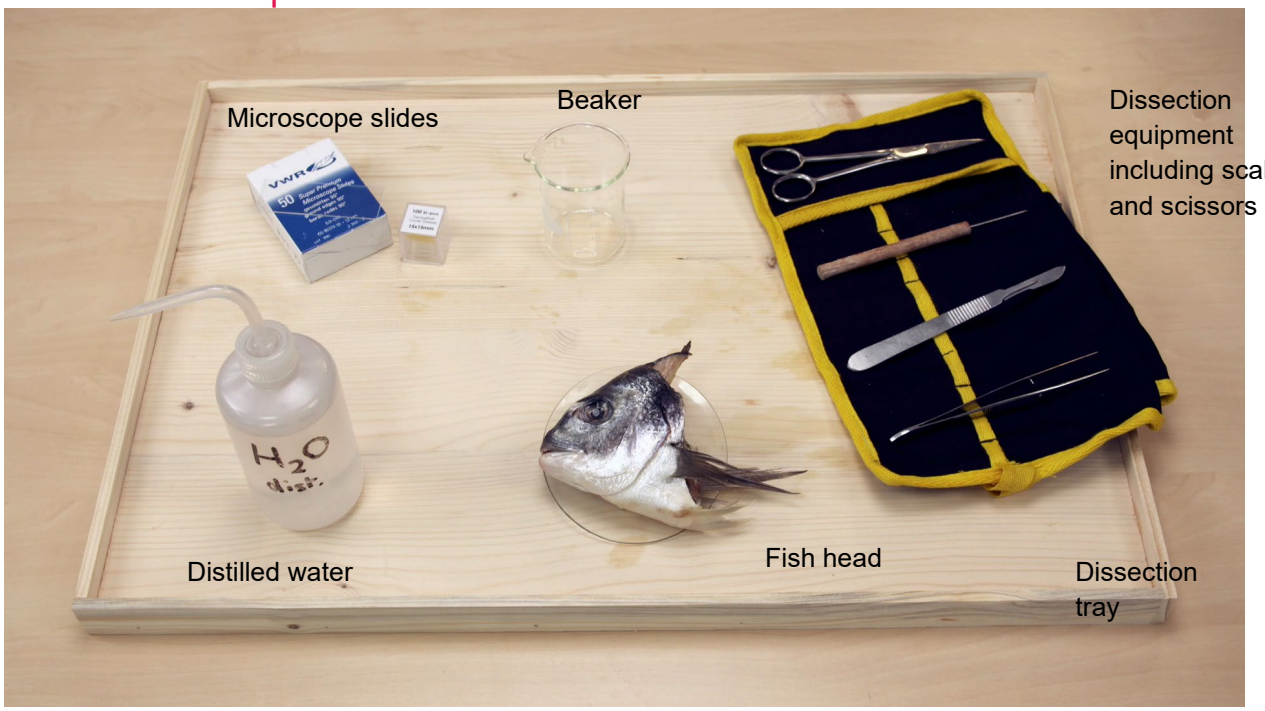
1. All learners should wear lab coats or plastic / disposable aprons.
2. Raw meat should not come into contact with the skin; gloves should be worn and hands washed after the dissection.
3. Learners should wear eye protection to prevent material getting into the eye in cases where blood or juices accidentally spray.
4. Although gloves will be worn, learners should still cover any existing cuts on their hands with plasters.
5. Learners should not put their hands in their mouth.
6. Learners should not touch their pens, notepads or other surfaces with contaminated gloves;
   a. gloves must be removed when making the anatomical drawings or writing down measurements
   b. or answers to questions.
7. Make sure that the scalpels are sharp so less force is needed and there is less risk of learners slipping and causing injury.
8. Make sure learners are aware of the safe method of using the scalpel: cutting in a downwards motion away from the body; fingers should be kept clear of the blade; and cutting should be done on a dissection tray.
9. Learners carrying scalpels could present a hazard to other people in the classroom, so make sure they are aware of the safe way to carry them.
10. There should be a clear disposal box for learners to put used scalpels into; you or the technician, are responsible for sterilising these after use.

11. The scalpels should be counted out and in.
12. Check for latex allergies before carrying out the experiment; signs of allergy include itchiness and rashes. Look out for severe allergic reactions such as difficulty breathing and / or swelling of the face, body or tongue.
13. Learners must not use their own rulers to make measurements.

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

Hazard	Risk	Prevention	First Aid
Handling raw meat	Possible infection	Wear gloves; do not put hands in mouth; do not touch surfaces, books, pens or paper with dirty gloves; wash hands thoroughly at the end of the experiment.	**In the eyes**: Flood the eye with gently-running tap water for 10 minutes. If discomfort persists, see a doctor. **Swallowed**: do no more than wash out the mouth with water. Do not induce vomiting. See a doctor if necessary. **Spilt on the skin or clothing**: Remove contaminated clothing; wash skin thoroughly with (antibacterial) hand soap and running water. **Spilt on the floor or bench**.: clean the area thoroughly using an appropriate disinfectant (you must do a risk assessment for any disinfectant used).
Scalpel	Cuts	Make incisions away from the body in a downwards motion on a white tile; keep fingers away from the blade; return scalpels to the front when not in use; carry them safely, away from the body but not pointing outward towards others.	**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.
Latex gloves	Allergic reaction	Ask learners if they know they have an allergy to latex before the practical. Offer alternative gloves, e.g. nitrile.	Remove the gloves and wash hands under water. Look out for severe allergic reactions such as difficulty breathing and/or swelling of the face, body or tongue. Seek emergency medical attention immediately.

Dissection set-up



Teacher method

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

Do not share this method with learners.

Before you begin

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

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment required
- cultural or religious beliefs / sensitivity of the learners: some learners might be unable to, or find it uncomfortable to, handle raw meat.
- an appropriate source of the fish heads: how easily can you obtain them? Do you have a trustworthy source?
- the condition of the fish heads – ensure that the operculum (covering the gills) is intact
- if learners are mature enough to handle the scalpels and the raw meat.

Dissection

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

Steps	Notes
1. Run through the safety instructions. Ask if any learners have a latex allergy. Make it clear that learners must be wearing gloves when handling the fish head to avoid the risk of infection or contamination from raw meat. Eye protection and lab coats (or plastic aprons) should be worn and care should be taken when using and carrying the scalpels around the classroom.	*Count the number of scalpels you hand out. You might wish to demonstrate how to carry the scalpels around the room: with the blade pointing downwards and away from the body.*
2. Demonstrate to learners how to use the scalpel effectively and safely.	*Use the scalpel to make clear cuts in a downward motion away from the body. Keep the fish a good distance from the body. Do not use a sawing action.*
3. Distribute the fish heads and ask learners to place their specimens on their dissection trays.	*Check each fish head to determine if any structures are missing and amend the instructions accordingly.*
4. Lift up the operculum to show the gills below, and then use the scissors to remove it.	*The operculum covers the gills below. To get better access to the gills, the operculum must be removed from the fish's head.*
5. Display the internal structure of the opercular cavity then cut through the bone at the top and bottom of the gills where they attach to the inside of the head to remove them.	*Now that the operculum has been removed, it will be possible to see the complete structure of the gills. There are 4 gill arches on each side of the fish head and through each of these blood vessels flow to supply blood to and from the gills. The arches in turn support the gill filaments, on which*

	are the gill lamellae, which are very small so cannot be seen here. These structures help to increase the surface area of the gills to its maximum to promote more efficient gas exchange.
6. Use the forceps to lift up the gill filaments and cut them away from the skin they are attached to.	*To see the structure of the gills more clearly, we next remove them from the opercular cavity by cutting through the bone attaching the gills to the inside of the head.*
7. Place the gills in water to show the gills as they would be when the fish is in water.	*When the gills are in air you can see that the gill filaments clump together, reducing surface area. To see the structure of the gills more clearly as they would be when the fish is in water, you can place the gills in a beaker of water. When the gills are placed in water, the filaments fan out, producing the maximum surface area for gas exchange.*
8. Trim a piece of gill filament off the gill within a scalpel and place it on a slide with a drop of distilled water. Cover with a slide slip and view the lamellae on a microscope at a magnification of x 100. Count how many lamellae you can see in three different fields of view.	*The gill lamellae are very small, so it is best to view them under a microscope. To do this, trim a small piece off one of the gill filaments with scalpel and mount it on a slide. Looking at the filament under a microscope shows the lamellae as feather-like projections from the gill filament. Capillaries in each lamellae carry blood close to the surface where gas exchange occurs. The lamellae help to further increase the total surface area available for gas exchange in the fish's gills.*
9. Learners should gather all of the equipment that they have used into their dissection tray and return this to the front of the class.	*You may use this opportunity to help learners explain how the structures of the fish head promote maximum efficiency in gas exchange. Using pumped ventilation, bony fish, even when moving slowly, can move large amounts of oxygen rich water over their gills, where the surface area produced by the filaments and lamellae ensure the maximum extraction of oxygen from the water and into the fish's blood supply.*
10. Learners should gather all of the equipment that they have used into their dissection tray and return this to the front of the class.	*Count the number of scalpels handed in, to make sure that they have all been returned.*
11. After disposing of the fish material, learners should remove their gloves and put these into the bin. Learners should sanitise their desks using antibacterial spray and then wash their hands thoroughly.	*The remains of the fish can be disposed of in the technician's general waste.*

Clean-up

After the experiment learners should:

- tidy up the work space

- return the dissected fish material to the teacher to be disposed of
- return all equipment
- wipe down their work space using disinfectant spray
- remove their gloves and throw these into the bin
- wash their hands thoroughly under running water using soap.

The dissected fish material should be wrapped in newspaper or other suitable medium and thrown into the bin at the end of the dissection. Double-bag the waste bag for disposal in an industrial bin.

Debriefing lesson: Analysing observations

Resources	• Worksheets B and C (completed in the previous lessons) • Mini-whiteboards or A3 paper (1 per pair of learners) • Thick marker pens (1 per pair of learners)/ access to the internet
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe the observations and data obtained during the practical lesson. • ***most*** learners should be able to explain the observations and data obtained during the practical lesson. • ***some*** learners will be able to evaluate the observations and data obtained during the practical lesson.

Timings	Activity
	**Starter/Introduction** Host a brief discussion to help learners distinguish between *qualitative* data and *quantitative* data. Help learners understand that their scientific drawing is a form of data – of a qualitative nature. The measurements they took to calculate the value of magnification, and the number of gill filaments, are examples of quantitative data.
	**Main lesson** Ask learners to apply the mark scheme they designed in Worksheet B to their own drawing of the fish gills. After 5-10 minutes, ask learners to contribute to a discussion to find out which of the 10 marks they most often failed to achieve. Why? Decide on three 'top tips' to help the class improve if they are asked to produce similar work in the future. Remind learners that they recorded the number of gill filaments in three fields of view under the microscope (magnification x100). Gather together class data, perhaps by asking learners to write their three figures on the class board, or alternatively on a digital platform, by recording them in a shared spreadsheet such as Google Sheets. Challenge learners to work individually or in pairs to calculate the mean, standard deviation, standard error of the mean, and the 95% confidence intervals for the entire dataset. They should refer to their answers in Worksheet A to help them with this exercise. When they have the final values, they should record them on the mini-whiteboard. They should then be encouraged to hold up their answer when instructed. After agreeing on the values for the 95% confidence intervals, ask learners to explain how they would use these to determine the significance of any difference between the mean numbers of gills in the fish they used, and the mean numbers of gills in fish that have amoebic gill disease (AGD). This is a disorder caused by a pathogen that infects the gas exchange system of some fish. Give learners 5 minutes to discuss their answers in pairs, before asking for some suggestions. Guide learners to understand that if the 95% confidence intervals are calculated for the filament numbers in fish with AGD, it will be possible to plot a bar chart that has error bars for both bars. If there is any overlap, then this would indicate that the difference between the two mean values is unlikely to be significant. However, the lack of an overlap is likely to show that the difference is significant, although a statistical test would need to be undertaken in order to establish this. Ask extension questions of learners that focus on the three terms: accuracy, reliability and validity, e.g. • Accurate – how could the number of gills be counted in a precise way? Expected answer: By using a microscope with a sufficient magnification and resolving power. • Reliable – how many fields of view should be used, from which a mean value should be calculated? Expected answer: At least three, but ideally more, which would allow

	anomalous data to be identified and excluded from the calculation of a mean. • Valid – which other differences between the fish would need to be standardised in order for the comparison of their gill numbers to be valid? Expected answer: Factors such as the age, sex, and mass of the fish with and without AGD.
	**Plenary** Some learners could be challenged to suggest what else they could draw and/ or measure from the fish head, and how they would go about adapting the method they used to allow for this. For example, some learners might wish to investigate the length of the gill filaments, which could be measured using a stage micrometer and an eyepiece graticule, or the relationship between the mass of a fish and the number, or surface area, of its gill filaments.

Worksheets and answers

	Worksheet	Answers
For use in *Briefing lesson*:		
Teacher Instructions 1: Less is more	**20**	**N/A**
Worksheet A: Activity assortment	**23**	**34**
For use in *Planning lesson*:		
Teacher Instructions 2: Say what you see – photomicrograph	**21**	**N/A**
Teacher Instructions 3: Say what you see – diagram	**22**	**N/A**
Worksheet B: Designing a mark scheme	**28**	**35**
Worksheet C: Fish head dissection method	**29**	**N/A**
For use in *Lab lesson*:		
Worksheet C: Fish head dissection method (complete)	**29**	**N/A**
For use in *Evaluation lesson*:		
Worksheet B: Designing a mark scheme (complete)	**28**	**35**
Worksheet C: Fish head dissection method (complete)	**29**	**N/A**

Teacher instructions 1: Less is more

In this activity, allow learners to select one of the levels of difficulty as outlined in the table.

The challenge is to use all of the words, in the correct context, to answer the following question. Encourage learners to write the shortest possible sentence/ paragraph possible.

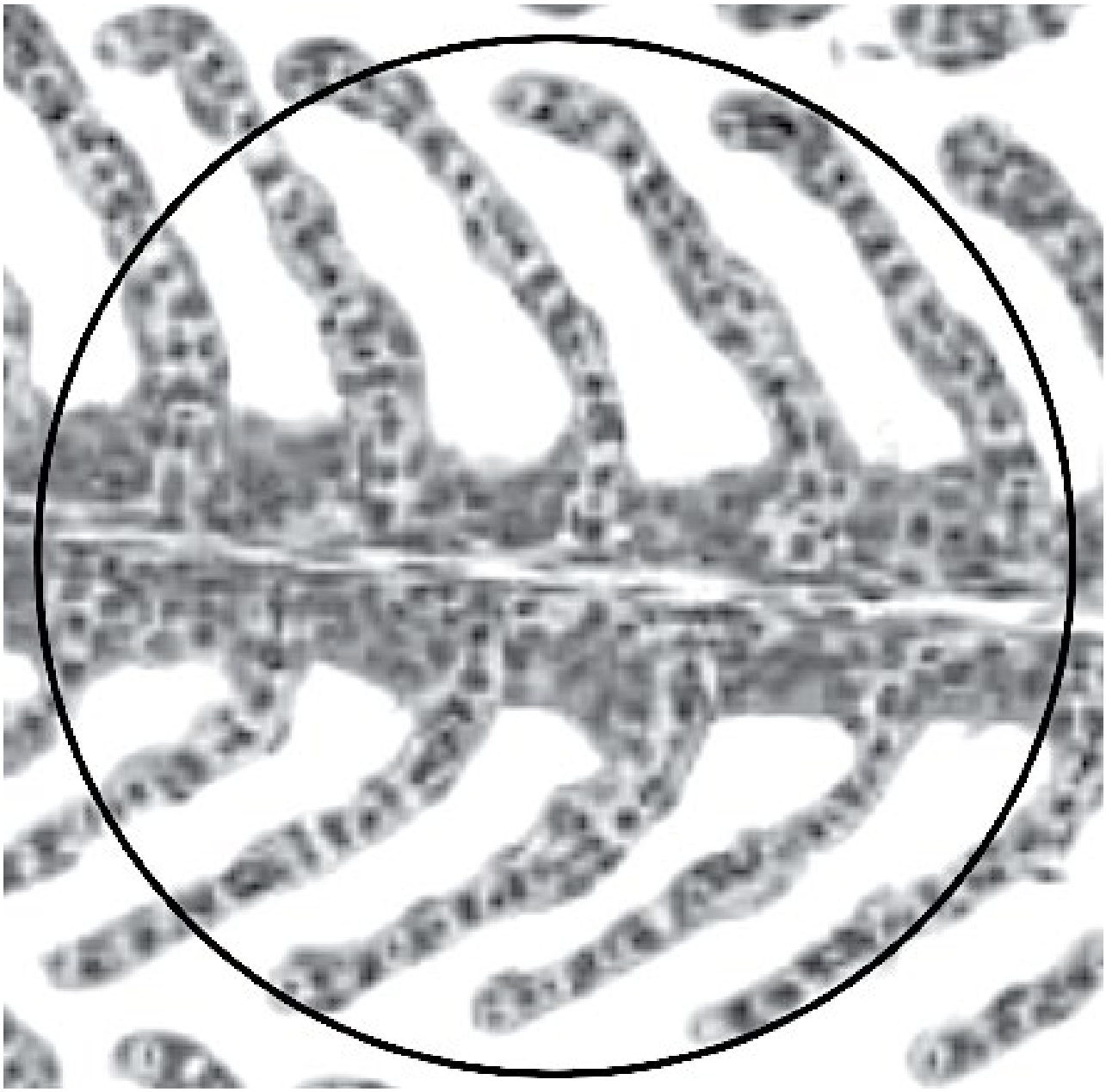
"*Explain how the structure and function of gills result in an efficient absorption of oxygen from water.*"

Low demand	Intermediate demand	High demand
1. *capillaries* 2. *diffusion* 3. *gill* 4. *surface area*	1. *capillaries* 2. *diffusion* 3. *dissolved gases* 4. *epithelium* 5. *gills* 6. *lamellae* 7. *operculum* 8. *surface area*	1. *buccal cavity* 2. *capillaries* 3. *countercurrent* 4. *diffusion* 5. *dissolved gases* 6. *epithelium* 7. *gills* 8. *gradient* 9. *lamellae* 10. *operculum* 11. *pressure* 12. *surface area*

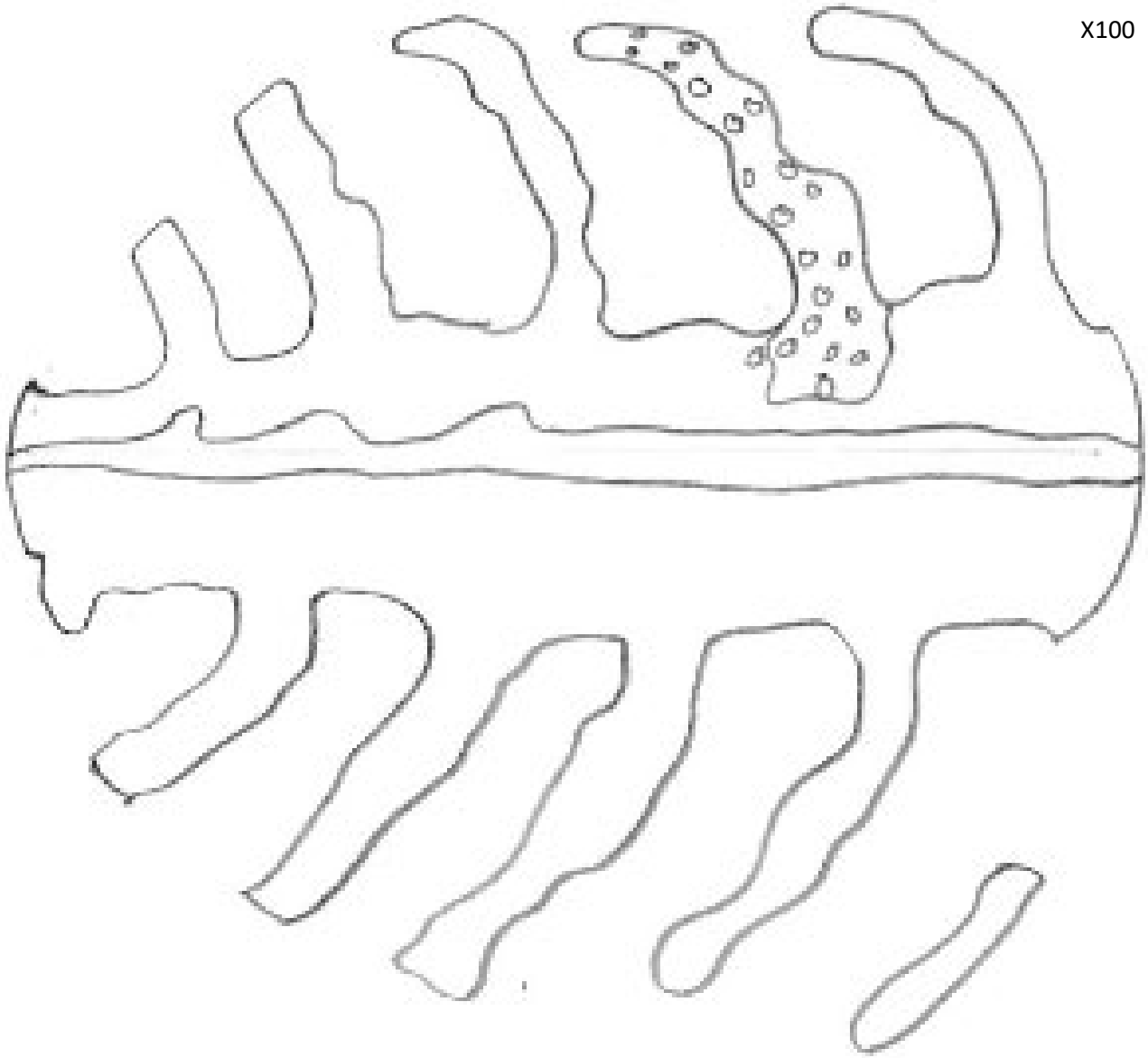
Suggested answers are as follows. The key terms are underlined.

Low demand	Intermediate demand	High demand
The gills have a high surface area to maximise diffusion between the water and the capillaries.	*Protected by the operculum, the gills have branches called lamellae. These have a thin epithelium and a high surface area to maximise diffusion of dissolved gases between the water and the capillaries.*	*A reduction of pressure inside the buccal cavity causes water to pass in. As it flows out, under the operculum, it passes over the gills. These have branches called lamellae, which have a thin epithelium and a high surface area to maximise diffusion of dissolved gases between the water and the capillaries. The direction of blood flow in these capillaries is opposite, or countercurrent, to the flow of water over the gills. This maintains a high diffusion gradient for the dissolved gases to diffuse between the water and the capillaries.*

Teacher instructions 2: Say what you see - photomicrograph



Teacher instructions 3: Say what you see – diagram



Worksheet A: Activity assortment

You should work in **pairs** to complete **both** activities. Spend the same amount of time on each activity.

ACTIVITY 1: Modelling gills in three dimensions
You should spend 15 minutes on this activity.

Fish have a ventilation system that is different to animals. Instead of lungs, they have gills.

The diagram overleaf shows the location and structure of the gills of a fish.

In this activity, you will produce a three-dimensional model of a fish head using modelling clay. This model should show how the mouth, operculum, and the gills interconnect.

You have the following resources available:

- Modelling clay
- Toothpicks and small pieces of card/ post-it notes (to help you label your model)
- Glass rod (use this to mimic the flow of water during ventilation; push it into the mouth, through the buccal cavity and out through a gill slit)

You should use **Figure 1** and further internet research to help you build your model. Some useful sites that show examples of the three-dimensional structure of a fish head include:

- http://www.biology-resources.com/all-fish.html
- https://tpwd.texas.gov/kids/wild_things/fish/howdofishbreathe.phtml
- https://thefishsite.com/articles/channel-catfish-life-history-and-biology

Space for sketching and planning

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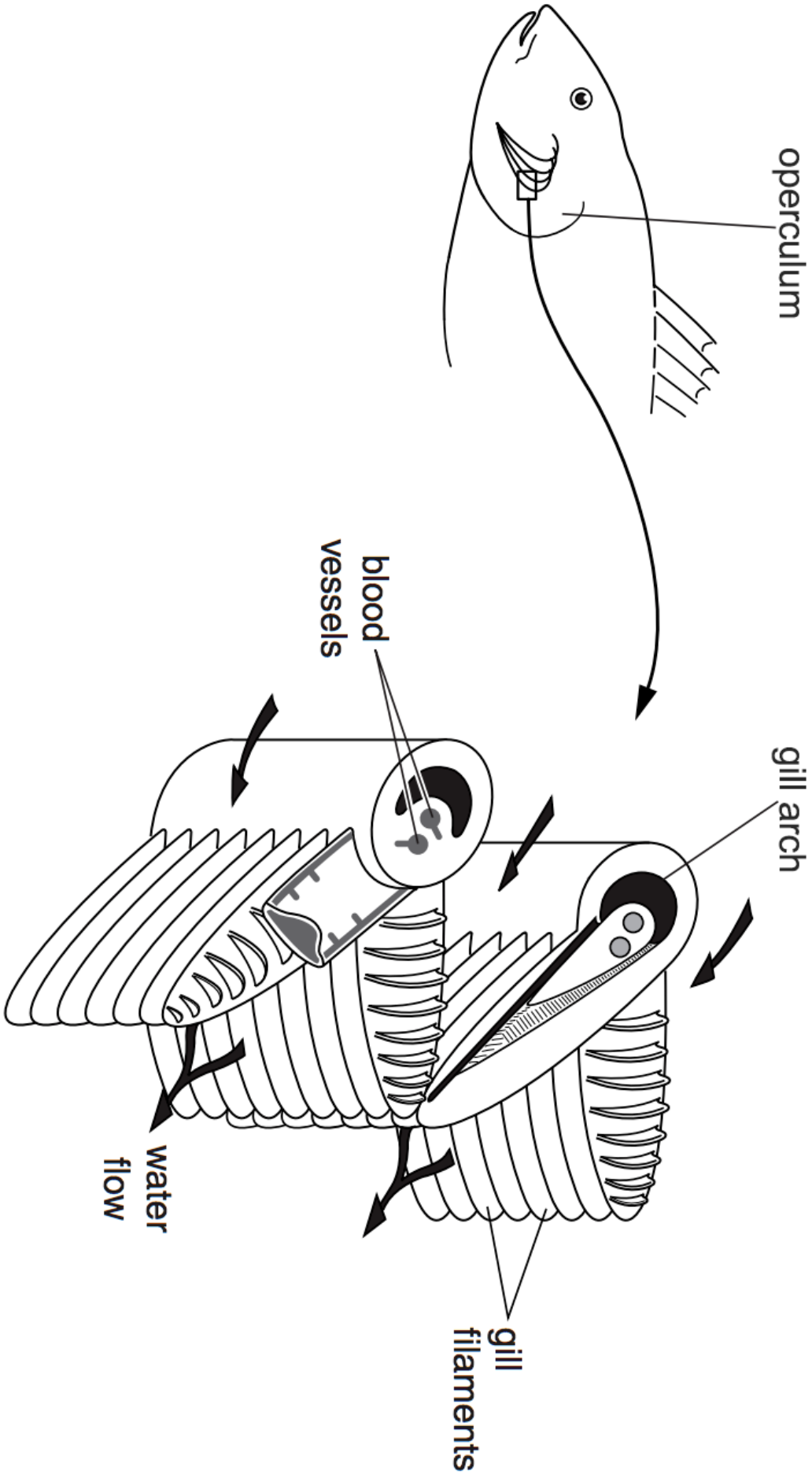

Figure 1: The structure of the gills of a fish

ACTIVITY 2: A study into the surface area of gills – data analysis

You should spend 15 minutes on this activity.

A marine scientist measured the surface area of the gills (relative to body surface area) of a group of 20 fish belonging to the Atlantic mackerel (*S. scombrus*) species, and a group of 20 fish belonging to the Atlantic Spanish mackerel (*S. maculatus*) species.

The table shows the values of the means ($\bar{x}$) and standard deviations (s) of the data.

Species of fish	gill surface areas (relative to body surface area)/ mm^2	
	mean ($\bar{x}$) of 20 individuals	standard deviation (s) of 20 individuals
S. scombrus	*838.0*	*32.4*
S. maculatus	*728.0*	*20.8*

Suggest one explanation for the difference between the mean gill surface areas of these fish, in terms of behaviour or habitat.

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The information provided below shows how these values were calculated.

Calculating the mean of a dataset ($\bar{x}$)

The **mean ($\bar{x}$)** is the most commonly used average value in most scientific investigations. It can be calculated by dividing the sum of all the data points by the number of data points:

$$\bar{x} = \frac{\sum x}{n}$$

Where:

$\bar{x}$ = mean
$\sum$ = sum of
n = sample size

Calculating the standard deviation of a dataset (s)

The **standard deviation (s)** of a dataset, which is a measure of the spread of data around the mean value, can be found using the following formula:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Where:

s = sample standard deviation
$\bar{x}$ = mean
$\sum$ = sum of
n = sample size

Knowing the value of the mean and standard deviation for a dataset allows us to calculate a value called the **standard error of the mean (S_M)**.

Calculating the standard error of a dataset (S_M)

When it is impractical to record data for all members of a population, the data is collected for just a sample of that population. In these cases, it is important to determine how accurately the sample mean reflects the population mean; this measure is called the standard error of a mean. The standard error provides an indication of the degree of similarity of the mean of the sample population to the mean of the whole population.

The value of the standard deviation is then divided by the square root of the sample size. This provides the value for the standard error:

$$S_{\mathrm{M}} = \frac{s}{\sqrt{n}}$$

Where:

S_{M} = standard error
s = sample standard deviation
n = sample size

Calculating the 95% confidence interval (95% CI) of a dataset (s)

Finally, and perhaps most importantly, the standard error can be used to calculate the **95% confidence interval (95% CI)** for a sample mean:

$$95\%\ \mathrm{CI} = \bar{x} \pm \left(2 \times S_M\right)$$

The 95% CI represents the range of the sample data in which the true value of the population mean lies, with 95% probability. This can be indicated using an error bar on a graph or chart. For a given sample mean, the error bar extends to the value of 95% CI either side of the sample mean.

- There is a probability of 0.95 that the actual population mean of the dataset lies within this ranges.
- If the error bar is small, then the calculated mean is close to the true mean and the data is reliable.
- Smaller error bars are less likely to overlap. The greater the overlap between any two bars, the greater the probability that there is not a significant difference between the two datasets. This suggests that any perceived difference between the sample means may be due to chance (although a statistical test should be conducted to confirm this).

Your task is to calculate the 95% CI for both species of fish and draw error bars on the bars overleaf. Underneath the graph, evaluate what these error bars suggest about the difference between the mean gill surface areas of these two species.

Space for working:

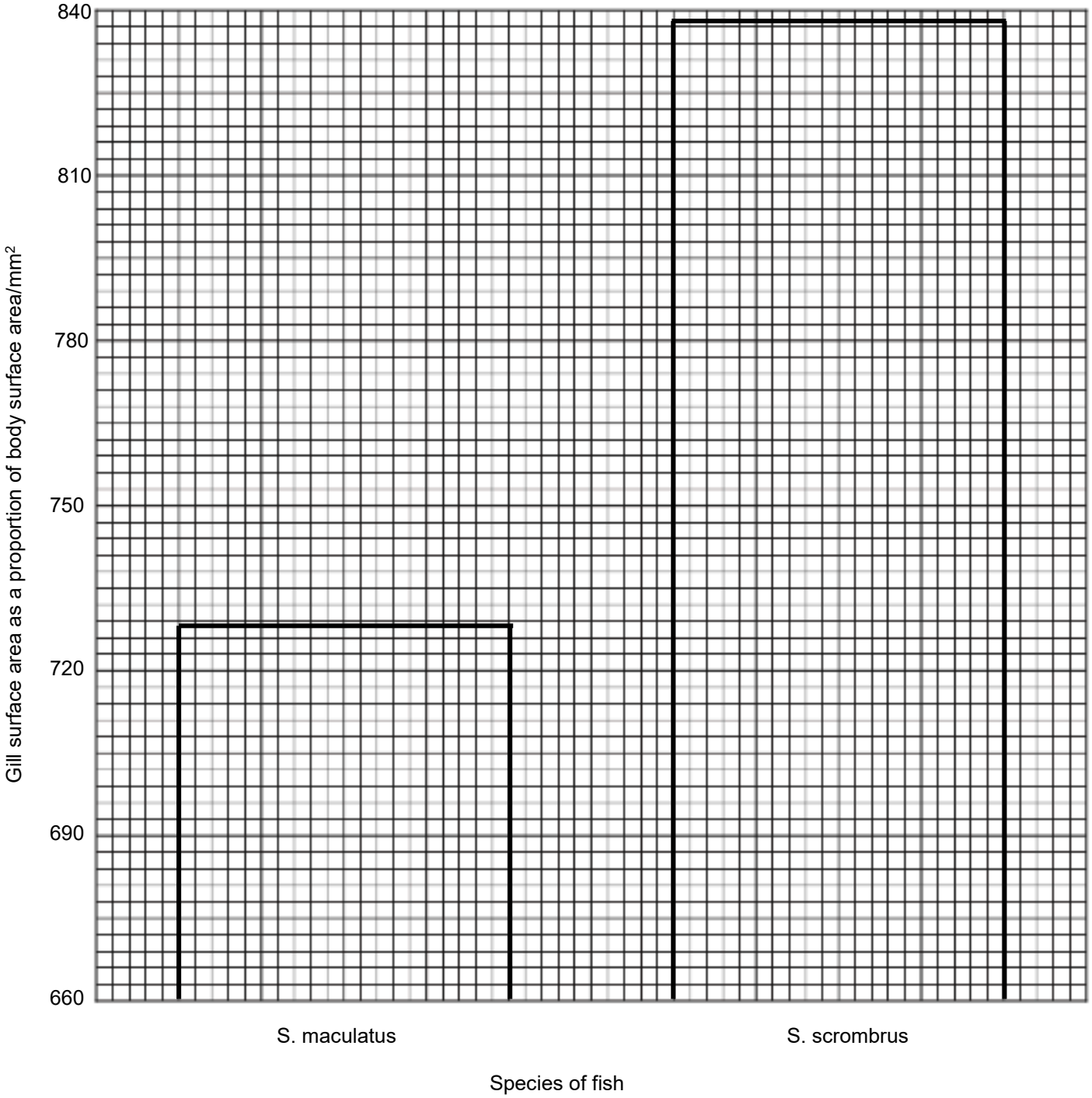

Figure 2: A comparison of the gill surface areas of *S. scombrus* (Atlantic mackerel) and *S. maculatus* (Atlantic Spanish mackerel)

Evaluate what these error bars suggest about the difference between the mean gill surface areas of these two species.

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Worksheet B: Designing a mark scheme

You should work in **pairs** to complete this activity. You will design a mark scheme to assess any scientific drawing.

Your teacher has now explained the difference between a 'sketch' and a scientific drawing. Here is some further guidance to help you understand what makes a good scientific drawing. You may wish to use a highlighter pen or underline/ box key terms to help you design your mark scheme:

> "*A good scientific drawing uses the majority of the space available and is a good representation of the specimen: it should be approximately the correct shape and proportions of structures should also be approximately correct. Draw the specimen that has been asked for – e.g. if only three cells are requested, do not draw any more. Use a pencil, not a pen, but do not use shading, stippling or dots, and use fine, clear, unbroken and non-overlapping lines, showing clear outlines. Use ruler-drawn label lines, without an arrowhead, to identify structures on diagrams. These label lines should not cross each other and should end by touching, or just entering, the part you are labelling. Labels should be written horizontally (no matter what angle the label line is at), and they should not be written on the drawing. However, for the diagram itself, drawing aids, such as a ruler or a compass, should be used. Finally, if your diagram is of a specimen viewed using a microscope, don't forget to include the magnification factor.*"

Record your mark scheme here. The first one has been done for you.

marking point	marks
It fits at least half of the space provided	*1*

Worksheet C: Fish head dissection method

This activity focuses on the ventilation mechanism and gas exchange in a fish. You will dissect a fish head to see the internal structures.

Important safety information

- Make sure you have a good supply of gloves on your table.
- You must remove your gloves and wash your hands before writing down measurements, or making drawings.
- Do not use your own ruler to make measurements, use the one provided.
- If you are working in pairs, take it in turns to do the dissecting and measurements, and the drawing and recording, to minimise the number of times you need to change gloves and wash your hands during the dissection.
- Make sure you know how to use the scalpel safely. Ask your teacher if you are unsure.

Make sure you remove your gloves and wash your hands each time you use your pencil. Then put a fresh pair of gloves on to continue the dissection.

Instructions

1. Before you start, you must be wearing gloves when handling the fish to avoid the risk of infection or contamination from raw meat. Eye protection and lab coats should be worn and care should be taken when using and carrying the scalpels around the classroom.

2. Arrange your equipment as shown in **Figure 1**. You should be looking at the side of the fish head. You may wish to use a pipette and distilled water to investigate how water flows from the mouth of the fish and out of the operculum, over the gills. Note the movement of the lower jaw. Its movement is limited to a hinge mechanism, opening and closing to take in water and prey.

Figure 1

3. Lift up the operculum to show the gills below, and then use the scissors to remove it (**Figure 2**). Using fine scissors, remove the operculum from the fish head to expose four gills, each attached to a bony gill arch. The operculum moves back and forth to enable the flow of water over the gill arch and filaments.

Figure 2

4. Display the internal structure of the opercular cavity then cut through the bone at the top and bottom of the gills where they attach to the inside of the head to remove them (**Figure 3**).

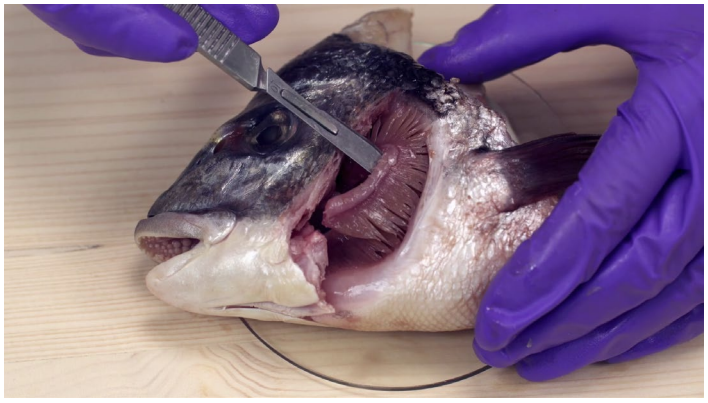

Figure 3

5. Use the forceps to lift up the gill filaments and cut them away from the skin they are attached to (**Figure 4**). Locate the gill slits and gill filaments. The gill slits form the entrance to the gills. The gill filaments are feathery structures where gaseous exchange takes place. Identify gill rakers attached to the arch. These small finger-like projections prevent damage to the gills that could be caused by small food molecules.

Figure 4

6. Place the gills in water to show the gills as they would be when the fish is in water (**Figure 5**). Draw a diagram of the gills as they sit in the water (use the box overleaf). Guidance is provided to help you calculate the magnification of your drawing.

Figure 5

Make a large drawing of the gills in the space below

Measure the length of the gills in your drawing.

…… mm

Measure the length of the gills. You may need to take them out of the water.

…… mm

Calculate the magnification of the gills in your drawing. Show your working.

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7. Use fine scissors or a scalpel to cut off a section of gill filament (1-2 mm long) from the arch. Place it in the centre of a microscope slide. Use a pipette to add 2 drops of distilled water onto the filament and apply a cover slip. Lower the cover slip at an angle to prevent the formation of bubbles (**Figure 6**).

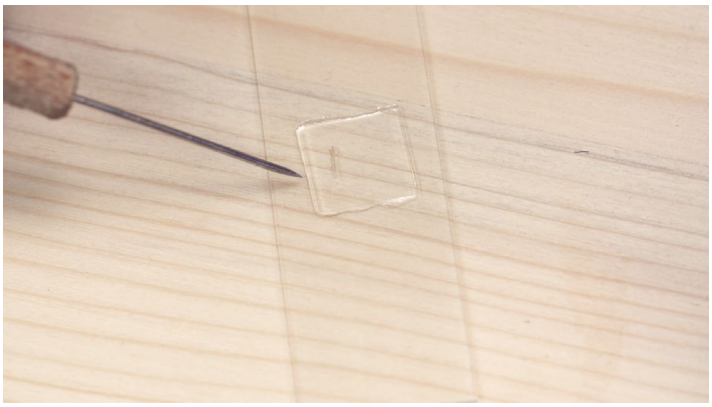

Figure 6

View the lamellae on a microscope at a magnification of x 40 (use the ×4 and ×10 objective lenses). Count how many lamellae you can see in **three** different fields of view.

field of view at x100	number of entire gill filaments visible
1	
2	
3	

Space for other observations/ measurements

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Worksheet A: Answers

Expected answers for the question that asked learners to suggest an explanation for the difference between the mean gill surface areas of these fish include:

- *S. scombrus* may occupy a habitat with a lower water temperature (which contains less dissolved oxygen).
- *S. scombrus* may be a more active, faster-swimming fish. It may, therefore, have a higher oxygen demand.

This is because *S. scombrus*, with its greater gill surface area, is able to absorb more dissolved oxygen than *S. maculatus*.

Expected answers for the task in which learners are required to calculate the 95% CI for both species of fish and draw error bars on the bars overleaf are as follows.

Calculation of the standard error of the mean (S_M) is as follows:

S. scombrus	***S. maculatus***
$S_M = 32.4 \div \sqrt{20}$ $S_M = 7.24$	$S_M = 20.8 \div \sqrt{20}$ $S_M = 4.65$

Calculation of the 95% CI error bars is as follows:

S. scombrus	***S. maculatus***
95% CI = $838 \pm 2 \times 7.24$ 95% CI = 838 ± 14.48 The upper limit of the error bar is: $(838 + 14.48) = 852.48$ mm^2 The lower limit of the error bar is: $(838 - 14.48) = 823.52$ mm^2	95% CI = $728 \pm 2 \times 4.65$ 95% CI = 728 ± 9.3 The upper limit of the error bar is: $(728 + 9.3) = 737.3$ mm^2 The lower limit of the error bar is: $(728 - 9.3) = 718.7$ mm^2

There is a probability of 0.95 that the actual population means for the two species lie within these ranges. Learners should identify that there is no overlap between the two plotted error bars. The upper limit of the error bar for *S. maculatus* (737.3 mm^2) is much less than the lower limit for *S. scombus* (823.52 mm^2). This suggests that there is a significant difference between the mean gill surface areas for these two species, although a statistical test should be conducted to confirm this.

Worksheet B: Answers

An example set of ten marking points is provided below.

marking point	marks
The diagram is drawn so that it fits at least half of the space provided	1
It accurately shows the shape of the structure	1
It accurately shows internal details	1
There is no shading/ stippling/ dots	1
Lines are clear and not unbroken	1
Lines do not overlap	1
All parts are labelled	1
Label lines have no arrowheads	1
Labels are written horizontally	1
A magnification factor is included	1

Total: 10

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