TEACHING ABOUT SCIENCE

B THEORETICAL MODELS: CELL MEMBRANES

This is a lesson aimed at helping students to develop their understanding of the role of theoretical models in science, using models of the structure of cell membranes as an example.

Teachers' notes

downloaded from www.nuffieldfoundation.org/aboutscience

Resources for students and teachers (separate download)

download from www.nuffieldfoundation.org/aboutscience

OHP B0.1 Aims of the lesson
Sheet B1.1 Structural models of cell membranes
Sheet B1.2 Time line
Sheet B1.3 Lipid layer evidence
Sheet B2.1 Electronmicrograph evidence
Sheet B2.2 Danielli and Davson model
Sheet B2.3 Robertson model
Sheet B3.1 Freeze fracture electronmicrograph evidence
Sheet B3.2 NMR and X-ray diffraction evidence
Sheet B3.3 Singer and Nicholson model
Sheet B3.4 Plasticine model

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TEACHERS' NOTES

FOCUS

Experimental data provide the basis from which scientific understanding of the natural world develops. However, scientific understanding does not emerge unproblematically from the data without the creative, intuitive thinking of scientists. In other words, scientists have to decide what kind of data to collect, and how to think about that data in order to build scientific knowledge about the world.

In situations where there is more than one model available, new evidence may support one model more than the others. In these situations scientists need to decide whether such evidence is sufficient for them to shift their support to this model.

The overall focus of this teaching is to make clear to students that scientific understanding does not just emerge from experimental data, and to develop their confidence in evaluating the extent to which evidence supports scientific explanations.

RATIONALE

This teaching sequence aims to help students to develop their ideas about the role of theoretical models in science. Students tend to believe that theoretical models emerge directly from data, and that features of the theoretical model correspond directly to features in the real world. This teaching sequence aims to encourage students to recognise that when scientists develop theoretical models they often need to make an intelligent guess about aspects which go beyond what is suggested by available data. The sequence will then show students how competing models can co-exist until more evidence is collected which will allow the models to be evaluated further. The scientific community will eventually accept a successful model as the consensus view if it continues to be supported by new evidence.

To illustrate this process, the teaching sequence describes developments in our understanding of cell membrane structure. Students are presented with pieces of evidence relating to membrane structure and a series of theoretical models of the membrane, in chronological order. At each stage of the sequence, students working in pairs are asked to discuss the evidence, before contributing to a feedback session with the teacher. The aim of the teaching is to present a story of the development of scientific understanding in a particular context.

The activities are designed to give students an understanding of how:
• the development of scientific models involves conjecture and creative thinking about data on the part of scientists;
• competing models can arise;
• further scientific research can lead to the acceptance of one model as the most useful.

AS/A2 LINKS

Pilot studies have shown that this activity can be effective with students at a relatively late stage of their course. However, if they have already studied cells, it will need to be made clear that the aim is to look at how ideas are developed in science rather than to look specifically at membranes.

Teachers may prefer to use the activity early in the course before formal teaching about membrane structure. It should be noted that the model developed by Singer and Nicholson bears close resemblance to that presented in textbooks, but there have been developments which should be highlighted in the teaching that follows this activity.

Teaching about the role of theoretical models features in the QCA Subject Criteria. 'AS and A-level specifications in biology should encourage students to develop an understanding of scientific methods.'

At AS-level 'Organisms are organised on a cellular basis and cells are differentiated according to function.' (QCA specification reference 3.6.)
This includes 'the structure of the plasma membrane and its role in controlling the passage of substances in and out of cells'.

KEY SKILLS

The activity gives students the opportunity to gain competence in the following key skill areas:

Communication Level 3

C3.1a Contribute to a group discussion about a complex subject.

Portfolio evidence of this could be in the form of a note from an assessor (the teacher) who has observed the discussion and noted how the requirements of the unit have been met, or an audio/video tape of the discussion.

C3.2 Read and synthesise information from two extended documents about a complex subject.

Portfolio evidence of this could be in the form of a record of what was read including notes, highlighted text or answers to questions about the material.

TEACHING SEQUENCE

The sequence is structured around a series of revisits to the story of how our understanding of the structure of cell membranes was developed during the 20th century:

Activity B1
Evidence which was available before any attempt to model the structure of membranes was made

Activity B2
A stage when there was more than one competing model.

Activity B3
A stage at which there were three suggested models, but the evidence supported one model more than the others.

Introduction (brief)

Resources OHT B0.1 'Aims of the lesson'.

Points to raise This lesson will be rather different from many science lessons (not much writing and lots of discussion). Students should think and talk!

Students are being given the opportunity to step back and consider 'What is this thing called science?' In particular the lesson will consider 'What is the purpose of theoretical models in science and how are they developed?'.

Students will be expected to get involved in paired discussion and feed back their ideas to the whole class (link to key skills).

In this opening presentation the teacher introduces the main aims of the lesson, emphasises the unusual nature of the lesson (history of science, no writing and lots of discussion), and highlights how learning about theoretical models links to other areas of the biology course.

Commentary Trials of this teaching sequence have shown that it is important to state briefly why you think that it is important that students learn about the nature and purpose of theoretical models and how they are developed.

Activity B1 (15 minutes)

Aim At the end of this activity students should:
1.1 recognise that experimental evidence does not in itself lead to an explanatory model.

Student activity B1 (10 minutes)

Resources: Sheets B1.1 Structural models of membranes
B1.2 Time line
B1.3 Lipid layer evidence

Students are presented with the time line to give a structure to the progression of ideas during the lesson. They should be encouraged to recognise the position on the timeline of the material to which they are asked to respond.

Instructions	Commentary
Give each pair of students sheets B1.1, B1.2, and B1.3. Instruct the students to study the evidence and discuss the following questions. **1** From looking at the data in the table, would you agree with the conclusions of Gorter and Grendel? **2** For what aspects of the membrane structure is there no evidence in this data?	This activity is partly a lead-in to the rest of the lesson. It should engage students with the type of material to which they are going to be asked to respond. The evidence of Gorter and Grendel is consistent with their conclusion that the membrane includes a double lipid layer, but gives no indication of the arrangement of the lipids or other substances contained in the membrane.

Dealing with the discussion B1 (5 minutes)

Resources: OHT B0.1 'Aims of the lesson'.

Instruction	Commentary
Take feedback from each group on their opinions about the evidence. Highlight the limitations of the evidence in drawing conclusions about the structure of membranes.	In addressing the teaching aim here, discussion with the group should highlight the difference between a conclusion which is consistent with a piece of evidence, and a theoretical model which includes the conjectural ideas of the scientist.

Link with the next activity

Pose the question: 'How do scientists make the models that help them to understand phenomena?'

Activity B2 (15 minutes)

In this part of the sequence, students have two pieces of evidence and two models contemporary with the evidence. Students are asked to decide in pairs whether or not each model is supported by each piece of evidence (at this point in history the evidence could be used to support either of the models).

Aim At the end of this part of the lesson students should:

2.1 recognise that more than one model may be supported by a given set of evidence.

Student activity B2 (10 minutes)

Resources

Student sheets B2.1 Electronmicrograph evidence
B2.2 Danielli and Davson model
B2.3 Robertson model

Instruction	Commentary
Hand out student sheets B2.1, B2.2 and B2.3 Instruct the students to study the electron-micrograph evidence (sheet B2.1) and discuss it in pairs or groups of three. **1** How are each of the models supported or undermined by the evidence available at the time? **2** What do you think led to each model being devised?	In this task, the students are presented with descriptions of two models which explain how the components of a membrane may be arranged. In addition, they have further evidence from the electronmicrograph image which was available when both models were conceived. At this stage both the models fit the available data. Students therefore need to recognise that the models do not arise simply from the data but involve a degree of creative thinking. The models involve the scientists' own ideas as well as their response to existing data and models.

Dealing with the discussion B2 (5 minutes)

Resources
OHT B0.1 'Aims of the lesson'

Instruction	Commentary
Take feedback from each group on their answers to the questions. Develop their answers to highlight the teaching aim 2.1. A useful question to ask is: • Where have the two models come from? (That is, not just from the data; the models include creative thinking about the data.)	Both models include the lipid bilayer suggested by the evidence. The models differ in the arrangement of the polypeptides. In the Danielli and Davson model the polypeptide molecules are embedded within the lipid layer on both sides. In the Robertson model, there is a polypeptide sheet on the outer surface of the membrane (which is not embedded in the lipid layer) and a layer of either polypeptide or saccharide on the inside.

Link with the next activity	Commentary
Pose the questions: • Are all models equally good? • Is it possible to decide which model is the most useful?	There was no evidence at the time for the arrangement of proteins in membranes; the structure of a protein was first identified for haemoglobin in 1959.

Activity B3 (25 minutes)

Finally students are given more recent evidence and a later model of the membrane. The new evidence is more difficult to follow and guidance should be given to help students understand the material presented. They are again asked to consider the implications of each piece of evidence for each model. At this point, students should be able to identify only one model, the more recent one, which fits all the evidence. This model is the basis of the one which students will study as part of their AS/A-level Biology course.

Aim at the end of this activity students should
3.1 recognise that in some cases it is possible to judge one model as more consistent with the evidence than another.

Teacher activity B3 (5 minutes)

Resources Sheet B3.1 Freeze fracture electronmicrograph evidence
B3.2 NMR and X-ray diffraction evidence
B3.3 Singer and Nicholson model

Plasticine model of freeze-etched membrane (see teacher resource sheet B3.4)

Instruction	Commentary
Hand out sheets B3.1, B3.2, B3.3. The evidence presented in this activity is more technical and requires some explanation by the teacher to make the key features clear to students. 'Freeze fracture electronmicrograph evidence': use a plasticine model of a freeze-etched membrane to show the relationship between the surfaces exposed in the images on sheet B3.1 and the surfaces of the two layers of a membrane. 'NMR and X-ray diffraction evidence': the key elements of this evidence are highlighted in bold on sheet B3.2.	The images on sheet B3.1 require interpretation. Pilot studies have shown that a model showing how the layers of the membrane are fractured away helps students to interpret the freeze fracture images.

Student activity B3 (10 minutes)

Instruction	Commentary
Instruct the students to use all the evidence sheets (B1.3, B2.1, B3.1, and B3.2) and discuss in pairs: **1** How is each of the models, including Singer and Nicholson's (sheet B3.3), supported or undermined by ***all*** the evidence now available (including sheets B3.1 and B3.2)? **2** Which is the most useful model and why?	

Dealing with the discussion B3 (10 minutes)

Instruction	Commentary
Take feedback from each group on their answers to the two questions. Develop their answers to highlight the teaching aim 3.1. This discussion should then move into the closure of the lesson (see below)	This is a key point in the lesson and some time should be spent in discussion to recognise the way the scientific community moves toward a consensus of opinion. The learning aims of the lesson should be stressed explicitly, using OHT B0.1.

Closing the teaching sequence (5 minutes)

Resources OHT B0.1 'Aims of the lesson'

The feedback of student responses to activity B3 should lead into a clear summary of the sequence of events where:

- initial evidence stimulates new thinking in a field;
- several models are developed that involve insights beyond what the evidence suggests;
- further study produces evidence that allows the models to be evaluated and modified if necessary.

Points to raise	Commentary
Go through OHT B0.1 'Aims of the lesson'. Emphasise the key points. Say how you will be looking for students to draw on the ideas here in later lessons when you are using models and theories such as: • enzyme action; • mass flow hypothesis for phloem transport; • DNA structure; • evolution. Finally you may wish to close the lesson by describing ongoing research on the structure and function of membranes. The teacher resource sheet B3.4 gives examples of contemporary research involving an understanding of membrane structure.	Trials of this teaching sequence have shown that: • it is critical that sufficient time is left for a meaningful summary; • students need to feel that they have learnt something from this lesson; • teachers need to emphasise the links between what students have learnt and the rest of their biology/science course(s).