perspectives on science

The History, Philosophy and Ethics of Science

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Contents

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About *Perspectives on Science*

Welcome to *Perspectives on Science*.

Have you ever become involved in an argument about science and its applications? (Should animal experiments be allowed? Is space research good use of government money?) Or wondered about deep questions underlying the study of science? (Was there a time before the Big Bang? Is the mind distinct from the brain?) If so, then this is the course for you!

Perspectives on Science is designed to help you address historical, ethical and philosophical questions relating to science. It won't provide easy answers, but it will help you to develop skills of research and argument, to analyse what other people say and write, to clarify your own thinking and to make a case for your own point of view.

You will spend approximately half the course developing key skills and vocabulary relating to historical research and to ethical and philosophical discussion and argument. Then you will carry out a project in which you research the 'story' behind a question with a scientific dimension, and explore ethical and philosophical aspects of that question. You will be asked to present the outcome of your research both orally and in writing.

About this book

The first three parts of this book use case studies and examples to focus on the history, ethics and philosophy of science. In the History part, the emphasis is on developing research skills – gathering and summarising information, and assessing information sources for reliability. The Ethics part introduces some helpful ways of thinking about ethical questions (so-called ethical frameworks), which you then apply to a range of scientific issues. The Philosophy part explores some philosophical questions relating to science, and shows how careful presentation and analysis of arguments can help you refine your ideas, deepen your understanding and communicate your views effectively.

The final part of this book contains information and advice to support your Research project. This includes guidance on planning and organising your work, and materials to help with written and oral presentation.

Each part of this book includes the following features:

Main text

This is the main reading material in the book, in which information is presented and ideas discussed. The text in each part is organised into sections

which are subdivided into lessons – these may, or may not, coincide with the actual sessions arranged by your teacher/tutor/lecturer.

Within the main text, some words are printed in **bold**. These are key terms relating to the study of history, philosophy and ethics, and are defined in the *Glossary* printed at the back of this book (pages 223–8). You will probably need to use several of these terms in your Research project.

Activities

The text includes many *Activities*. Some are intended for individual work, while others are designed for groups. It is likely that you will be asked to carry out some of these activities in class or in private study time.

Activity 1

Questions

There are plenty of *Questions* in this book. Most of the questions are designed to help you think and get to grips with the ideas presented in the main text, and to summarise what you have learned. Some of the questions have definite, precise answers, but in many cases the process of thinking through the question is at least as important as your final answer.

Further work

Some activities and questions are designated as *Further work*. These are unlikely to be covered in formal class sessions, but you might tackle some of them during private study time.

Further work

Project hints

Within the first three parts of this book, you will find *Project hints*. These alert you to material that is of direct relevance to your Research project (though in fact all the material is of course relevant!), and include suggestions for topic areas that might be developed into research questions.

Project hint

The '5 W' questions provide a useful framework for analysing any source of information.

Course references

In the fourth part of this book, *Course references* direct you back to activities, lessons or sections that relate to aspects of your Research project.

Course reference

Lesson 2.3 in the Philosophy part of this course is about the careful use of language and techniques for defining terms.

Resource links

The notes headed *Resource links* guide you to additional resources relating to particular topics. You might use these in relation to activities during the first part of the course, or as pointers towards information sources for a Research project. Links to useful websites are provided on a dedicated 'hotlinks' page on the Heinemann website at www.heinemann.co.uk/hotlinks. When you access the site, the express code is 9600P.

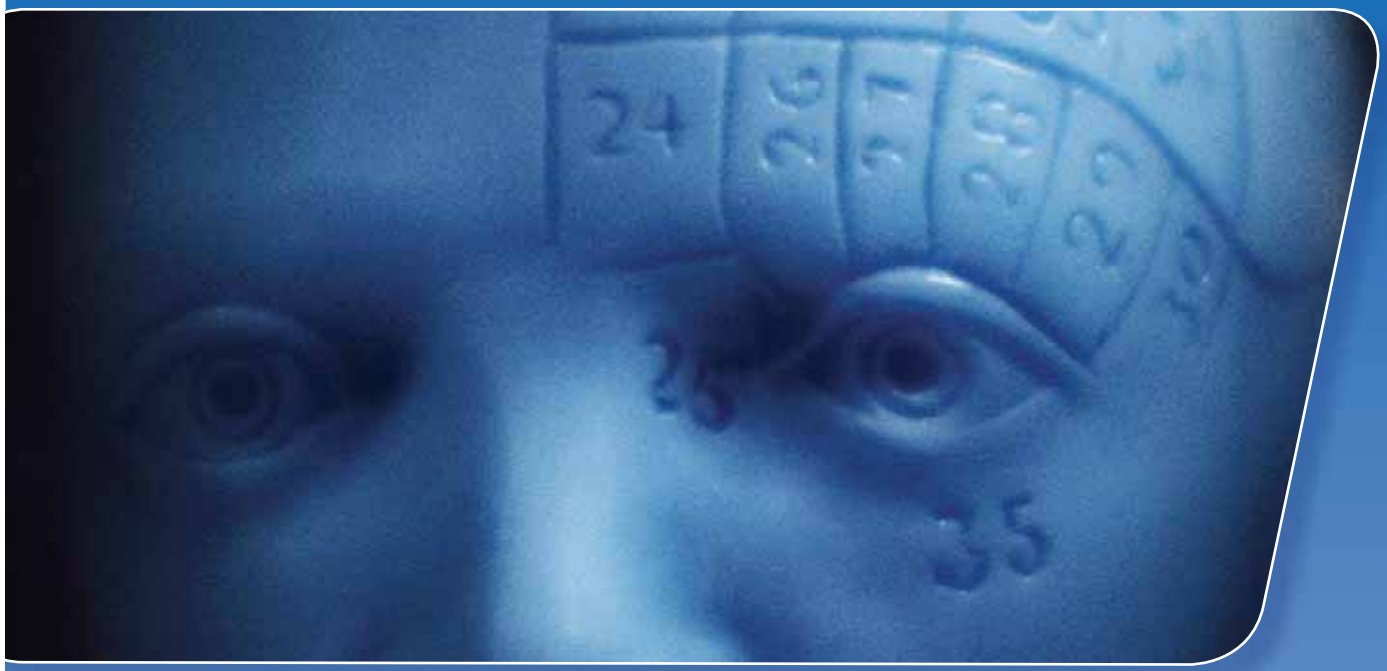
Resource link

The Times archive can be accessed online.

Finally, while the material is presented as a textbook, the *Perspectives on Science* team hope you will treat it as a book to be read for interest and enjoyment. Above all, we hope it will make you think!

PART 1

RESEARCHING THE HISTORY OF SCIENCE



1 Introduction to researching the history of science

1.1 Questions, questions

Science and history

Not long ago it was quite unusual in the UK for a post-16-year-old student to study both history and science. The two subjects were seen as being very different. It was thought that students of each subject needed different strengths and qualities. Despite this, the history of science has attracted interest from scientists and historians for many years, and there have been many popular books on the subject. Some of the teachers of history of science courses and the writers of the books were originally scientists, some were historians and some are simply historians of science. Perhaps the differences between the two subjects are not that great (Figure 1).

▲ ***Figure 1*** *Stephen Hawking and Simon Schama: how different are they?*

Activity 1 *Science and history compared*

In small groups, discuss the following questions.

1 What do historians and scientists do that is similar?
2 In what ways are history and science different?

Asking questions

To be an historian of science, like both historians and scientists, you have to ask questions. Finding the right questions to ask may be the most difficult part of the work. When researching an historical event it is useful to start with the '5 W' questions:

- *What* happened?
- *Who* were the people involved?
- *When* did it happen?
- *Where* did it happen?
- *Why* did it happen?

The answers to these questions allow us to pose many more questions, such as what were the motives of the people involved, what were the influences on them, what were the consequences of the decisions and the actions that they made.

Note that some of the answers to these questions may be **objective facts** (dates, places, names) and others **subjective opinion** (motives, influences), and that the answers depend on the sources used. Some may also involve **speculation** (guessing!) about past or future events.

Project hint

The '5 W' questions provide a useful framework for analysing any source of information. Use them with the literature sources you consult for your Research project.

Activity 2 *Finding answers*

Practise answering the '5 W' questions listed on page 2 for a recent news item. The topic need not necessarily be scientific; it could be a sporting occasion or a celebrity event. Find out the answers to the '5 W' questions. What further questions would you like answered?

Historians and scientists need to be able to produce a report on their findings. Write a brief report (a few hundred words) on your chosen news item, ensuring that you answer all the questions that you have posed.

Further work

1 *This question may require you to look back on some work you would rather forget! Imagine that a scientific investigation that you have done previously (e.g. at GCSE) may be of historical significance. What questions should you pose and what answers would you give? Write a brief report on your historical research.*

2 *Read the following short extract from an article about killing pests. Analyse the article using the '5 W's and note any instances of speculation or opinion.*

"*Corpses of the dead kill the living*

A cheap eco-friendly alternative to pesticides will soon be tested in Tanzania.

The African army worm (*Spodoptera exempta*) can reach plague proportions, with over 1000 caterpillars per square metre, and wipe out over 90% of a maize crop. At the moment the only cost-effective way to control it is to bombard it with pesticides, but these have obvious disadvantages: a 1990 UN report estimated that 11 million farmers in Africa suffer from pesticide poisoning each year.

A more environmentally friendly solution is to use a kind of nucleopolyhedrovirus (NPV) that infects only the army worm. Applied in large quantities it can start a massive outbreak devastating the pest. But mass-producing viruses like NPV in the quantities required to tackle army worms costs more than pesticides.

So David Grzywacz at the University of Greenwich in London is instead copying a method used in Brazil to deal with outbreaks of the velvet bean caterpillar that feeds on soya. There, workers watch for outbreaks early in the season, infect the caterpillar with a virus, then collect tonnes of dead, virus laden caterpillars. The caterpillars can be mashed up and used as a spray to tackle later outbreaks.

This is significant because farmers are already used to spraying. 'The easier it is to use, the easier it will be to get them to adopt it,' says Grzywacz. He hopes mass production of NPV virus in Tanzania will enable the virus to be sold to farmers for just a tenth of the price of pesticides.

Randerson, J. (2003) New Scientist, ***2425***, *p.12*"

PART 2

DISCUSSING ETHICAL ISSUES IN SCIENCE

1 Introduction to discussing ethical issues in science

1.1 Right and wrong

What is right and what is wrong?

Ethics is an intellectual discipline, just as subjects such as mathematics, music, history and science are. Each of these intellectual disciplines has its own ways of working. By and large, the ways of working that are appropriate to one discipline can't simply be transferred to another. For instance, the laws of mathematics can help us to prove that the number of prime numbers is infinite and that the square root of two is irrational, but they can't help us to decide whether Beethoven's Ninth is his greatest symphony. And the scientific way of working that helps us to determine the factors that affect the boiling point of water (pressure and impurities in the water) doesn't really help us to understand why Harold lost the Battle of Hastings.

The discipline of **ethics** is all about deciding what is morally right and what is morally wrong and why. **Morals** are beliefs about whether things are right or wrong. For example, is it right or wrong to eat meat, to have sex before you are 16 years old, or sometimes to tell lies? Ethics has its own ways of working. Fortunately, while some of us are hopeless at mathematics and others of us are tone deaf or have no interest in history, just about all of us spend quite a bit of our time reasoning ethically. So, you almost certainly already have quite a bit of knowledge to help you understand ethics.

In this course we are particularly concerned with ethical questions in science. For example, is it acceptable to use animals in medical experiments, to undertake human reproductive cloning or to develop nuclear bombs? However, the reasoning that is used to answer such questions follows the same rules and procedures as the reasoning to answer any ethical question. We will start, therefore, with an apparently simple everyday question, 'Why is it wrong to steal?' (Figure 1).

▲ ***Figure 1*** *Stealing is generally regarded as wrong.*

Activity 1 *What is wrong with stealing?*

In pairs or small groups, spend 5 minutes thinking of as many possible different reasons why it might be wrong to steal. At this stage, don't start arguing about whether each reason is valid or not – just generate a number of possible reasons and write them down.

Activity 2 *Exploring your reasons*

After spending 5 minutes or so on Activity 1, start trying to explore the reasons a bit further. Think of their implications. For example, suppose one of your reasons for believing that stealing is wrong is that in the absence of this widely-held view people would be very afraid that their property would be forcibly taken from them. One implication is that we might expect people with lots of personal property to feel more strongly that stealing is wrong than people with little personal property. Do you think this is the case?

Thinking carefully, as in Activity 2, should help you to refine your reasons so that, even if you don't believe all of them, you can mount an intellectual defence of each of them. Of course, if you don't believe one of the reasons in your pair or small group, try arguing with whoever proposed it to see if you can validly change his or her mind. At the same time, you need to be open to the possibility that this person is right and that you will have to change your mind.

Activity 3 *Categorising reasons*

Try to put your reasons from Activities 1 and 2 into categories. For example, if you believe that the reason why it is wrong to steal is that having this prohibition is the best policy for the majority of society, this is an example of utilitarian thinking.

We shall have more to say about **utilitarianism** in the next lesson but suffice to say that utilitarians think that things are right in the world if they maximise the amount of happiness and wrong if they lead to more unhappiness. So a utilitarian would favour a law 'Don't steal' if, overall, this led to greater happiness than allowing a free-for-all.

Another category – though one that fewer people use nowadays than in the past – is that of **divine command**. If you feel that stealing is wrong because it breaks one of the Ten Commandments or is forbidden in the Qur'an, for example, then you presumably have a strong religious faith and believe that the scriptures of your faith help you decide what is right and what is wrong.

Another category might be that people have certain rights, and these include the right to retain your own property. In everyday language we might say that it isn't fair to steal from someone. But try thinking about whether it makes a difference how the person acquired whatever it is that someone else wants to steal. For example, is stealing from someone who has worked hard to acquire

property worse than stealing from someone who has won it on the lottery or inherited it from their parents?

Activity 4 *What is theft?*

Explore precisely what is meant by theft. For example, suppose I have a girlfriend/boyfriend and you don't, and you attempt to entice my girlfriend/boyfriend away from me. Is this theft? If you think it is, explain why. If you think it isn't, explain why it isn't. Is it theft when a government requires its citizens to pay taxes? And what about the fact that tax rates are nearly always higher for people with greater incomes – is this stealing? Are there any distinctions that can be drawn between income tax and inheritance tax? Quickly jot down your ideas, then spend about 10 minutes discussing them with other people.

Further work

1 *Find out about the land distribution programme in Zimbabwe instituted by Robert Mugabe's government. Discuss whether this is an example of theft and therefore unethical, or an example of reducing indefensible inequalities and so ethical.*

2 *Consider why theft seems to be almost universal in human societies even though nearly everyone thinks it is wrong.*

1.2 Introducing ethical frameworks

Ethical frameworks

There is no one universally agreed way of deciding what is right and what is wrong. Instead there are a number of **ethical frameworks** that can be used. Quite often the same answers to ethical questions are reached whichever framework is used, but sometimes the different frameworks generate very different answers. Most people don't fully appreciate the reasons why they hold the ethical views that they do. Appreciating the range of different ethical frameworks should help you to sharpen your ethical thinking and evaluate ethical arguments used by others.

What are the consequences?

The simplest approach to deciding whether an action would be right or wrong is to look at what its consequences would be. No one supposes that we can ignore the consequences of an action before deciding whether or not it is right. The deeper question is whether that is all that we need to do. Are there certain actions – such as telling the truth – that are morally required whatever their consequences? Are there other actions – such as betraying confidences – that are wrong whatever their consequences?

PART 3

THINKING PHILOSOPHICALLY ABOUT SCIENCE

1 Introduction to thinking philosophically about science

1.1 Processes of science

What is philosophy?

Philosophy is the name we give to the study of the most fundamental questions in life. Philosophers consider such questions as: where did the universe come from? Does science remove any place for God? Can we know anything for certain? What is science? What is truth? What is the human mind? Is there life elsewhere in the universe? Do our genes determine our actions? Am I the same person today as I was yesterday? Might there one day be intelligent machines?

As soon as you begin to think about these questions seriously, you are doing philosophy. It is quite likely that you have already been doing some philosophical thinking but without realising that is what you are doing. If, for example, you have discussed with a friend a question such as whether the universe began with the Big Bang, or whether there is a soul (and if so how it is related to the brain), or whether a machine could think, then you have already started doing philosophy.

The way that philosophy is done is by argument. Someone puts forward a philosophical **point of view** (a **proposition**) and other people challenge this person to explain it clearly and give his/her reasons for believing it. Much of your time in this part of the course will be spent in arguments like this.

As well as being intrinsically fun and interesting, the skills you will develop here – skills in explaining ideas clearly and thinking logically – will be useful to you in the other subjects you study, and indeed in any situation in life where you are called on to explain the reasons for your point of view.

Reading about philosophy

For a good introduction to philosophy see Professor Simon Blackburn's book *Think* (Oxford University Press).

Another good introduction is the book by Jenny Teichman and Katherine Evans called *Philosophy: A Beginner's Guide* (Blackwell Publishing).

A book which covers many of the themes explored in this part of the course is *Philosophy Matters* by Roger Trigg (Blackwell Publishing).

The Philosophers' Magazine contains many excellent, accessible articles of philosophical interest. The magazine contains sections dedicated to science and ethics, and interviews with leading thinkers. There are also some philosophical games to enjoy.

Resource link

By far the best site from which to begin researching philosophical ideas is Epistemelinks. This site is a dedicated philosophy search engine. The sites to which you are then linked are reputable sources of information.
The Philosophers' Magazine website is a good general source.

The editor of *The Philosophers' Magazine*, Julian Baggini, has also published a good primer for philosophical arguments, *The Pig that Wants to be Eaten and 99 other Thought Experiments* (Granta) as well as *Making Sense: Philosophy Behind the Headlines* (Oxford University Press) which introduces philosophical issues behind questions in the news.

A collection of thought-provoking philosophical questions is Stephen Law's *The Philosophy Files* (Orion books).

Nigel Warburton's book *Philosophy – The Basics* (Routledge) provides a helpful guide to some key theories in philosophy.

Finally, *Bad Thoughts*, by Jamie Whyte (Corvo Books) entertainingly exposes the flaws in many commonly used arguments.

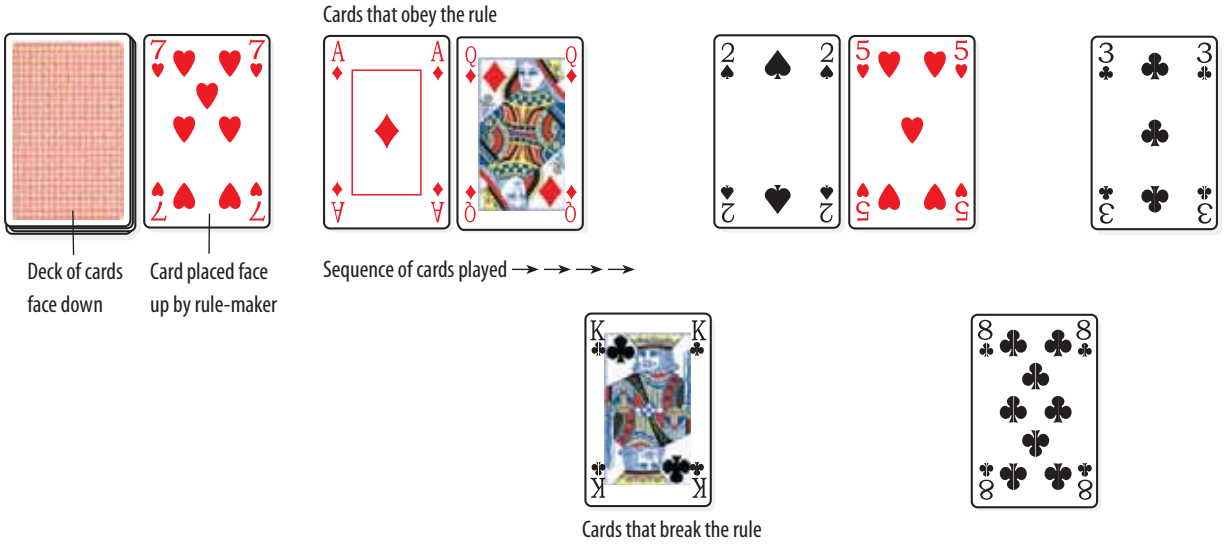
What is science?

One way to begin thinking about this philosophical question is by thinking about how science operates. The ways in which science operates can be illustrated by various games. Two such games are described in the next activities. As you play the games, think about how they illustrate how science is done.

Activity 1 *Eleusis*

Play the card game Eleusis (see below and overleaf). The game involves trying to discover a rule that someone has invented but has not told you. In some ways, this is similar to scientists trying to discover natural laws. After playing a few rounds of the game, discuss the processes by which you tried to discover the rule.

Playing Eleusis



Cards must be alternately ...higher...lower...higher...lower...than the preceding card. (A = 1, J = 11, Q = 12, K = 13.)

▲ ***Figure 1*** *Playing Eleusis.*

Eleusis

Eleusis is played in groups of four or five people. One person is the rule-maker. The other three or four players are each dealt 10 cards. It is the task of the rule-maker to invent a rule that determines how the cards are to be played, and it is the task of the other players to discover what the rule is.

Rules can be very simple (e.g. always play a red card after a black card) or more complex (e.g. the sum of the last three cards played has to equal 10 with picture cards counting as 1). To start with, the rule-maker should try to think of quite a simple rule.

The game starts when the rule-maker turns over a card from the unused pile. The person on the rule-maker's left then places a card from his/her hand next to the upturned card. The rule-maker then says 'yes' or 'no' depending on whether the played card follows the rule that has been chosen. If it obeys the rule, then the card is kept in place. If it does not obey the rule, then it should be moved down to form another line as shown in Figure 1. Play then proceeds round the group in this manner. As play continues, two lines of cards should be built up – one being the sequence of correct cards and the other the rejects. In this manner, all players should be able to see the sequence of correct and incorrect plays.

After placing a card a player has the chance to declare what he or she thinks the rule is. The rule-maker then has to say if the player is correct or not. A correct guess ends the round and the person guessing right has won.

If all 10 cards from each hand have been played and the rule has not been guessed, then the rule-maker has 'won' and has to declare what the rule was.

Activity 2 Twenty questions

One player (the experimenter) is sent out of the room temporarily while the rest decide between them which object in the room is to be the target. When the experimenter comes back into the room, he/she is allowed to ask 20 questions in order to identify the target object – but each question must only be answered 'yes' or 'no'. The experimenter must identify the object after 20 questions or lose the game.

Play this game and discuss how it illustrates processes in science.

Processes of science

The formulation of questions in Twenty questions is a similar process to the design of experiments. In Eleusis, an 'experiment' is carried out by playing a card and seeing whether the outcome is as predicted. Just watching the game without being able to decide which cards are played is similar to the process of making observations in science (as in astronomy, for example).

The terms **hypothesis** and **model** are often used to describe processes in science – and can be applied to these games. When a player has an idea about what he or she thinks the rule/object is, then he/she is making a model. In order to find out whether or not the model is correct, the player makes and tests a hypothesis (an assumption or guess). The player chooses some

aspect of his/her model that enables him/her to make a prediction of the sort: 'assuming xx is allowed by the rule, then playing this card will get the answer yes'. If the hypothesis survives the test, the model is used to predict the outcome of future tests. As more tests are carried out, the model might receive further support or might be shown to be incorrect. This is analogous to the scientific process of making a prediction that is then tested by experiment.

The term **theory** is used in science to mean an underlying framework of rules, often relating to a particular model. This is unlike common everyday usage where the term is often used to mean a guess.

The process of arriving at a model from experiment and observation can involve both **induction** and **deduction**. Induction means 'generalising from experience'. When scientists use induction, they form a theory that goes beyond what they observe. If, for example, I observe 1000 white swans, I may use induction to form the theory that 'all swans are white' (Figure 2). I have evidence for this theory, but I have not proved it true (there may be non-white swans I have not observed). Deduction means using logic to prove something. Suppose that all swans are indeed white. Then I can deduce that the next swan I see will be white. Here, the conclusion follows logically from the starting point of the argument. In the Eleusis game, *induction* is used to work out what the rules are. Once the rules are known, you can *deduce* what cards are allowed.

▲ ***Figure 2*** *White swans.*

Further work

Make notes to summarise the main points that Eleusis and Twenty questions illustrate about the processes of science. Write a paragraph setting out your thoughts about what science is.

1.2 Science and pseudo-science

Science or pseudo-science?

▲ ***Figure 3*** *Are horoscopes scientific?*

There is a range of writings and activities that we come across in our daily lives that have the appearance of being based on science, but do not work in ways that can genuinely be regarded as scientific. As an example, consider the horoscopes that appear in newspapers (Figure 3) or the huge number of diet books that are published each year. **Pseudo-science** is the name given to activities that superficially appear scientific but do not genuinely belong to science.

Project hint

For your Research project, it might be interesting to explore the scientific basis for a pseudo-science and to discuss the ethical and philosophical implications of promoting a pseudo-science as if it were scientific.

PART 4

CARRYING OUT A RESEARCH PROJECT

1 Introduction to carrying out a Research project

1.1 The *Perspectives on Science* Research project

What is the Research project?

A major part of your work for *Perspectives on Science* is the Research project. During the second half of the course, you will spend approximately half the lesson and homework time researching a topic of your choice. You will need to write a report of your research, which should be about 6000 words (maximum 7000) and give a 10-minute oral presentation on your project to an audience including your teacher/lecturer. Your teacher/lecturer will mark the report and presentation and your overall grade for the whole course will be determined by these marks.

For your Research project you will need to do the following.

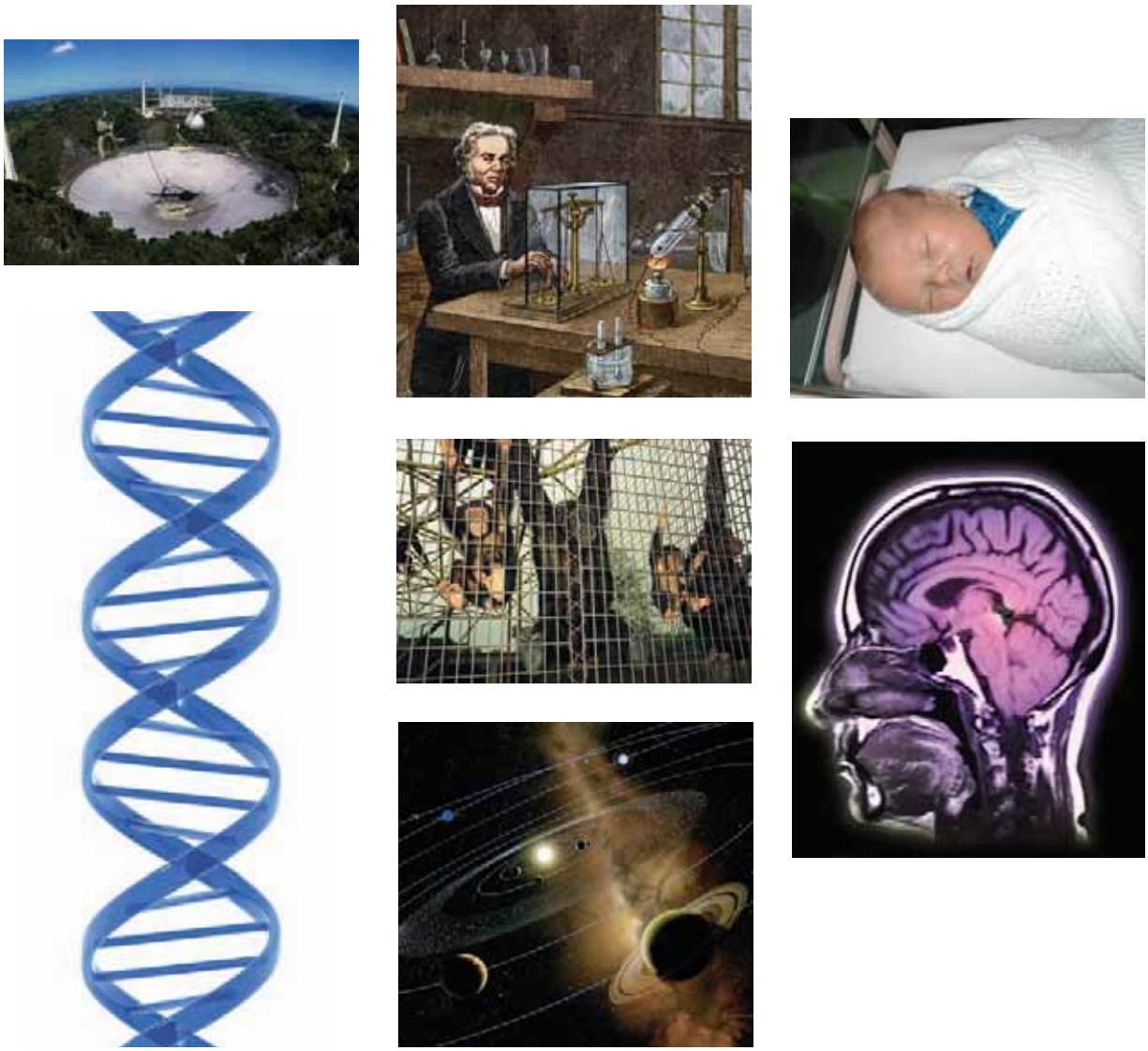
- Decide on a research topic. It is very helpful to write your project title in the form of a question. Your project then involves researching how the question might be answered.
- Produce a summary of the science 'story' behind your question. You will need to consult a range of information sources and use them to give an account of the science as it is currently understood and how this understanding has developed.
- Discuss philosophical and ethical aspects of your question. You will need to state a point of view, and present and discuss philosophical and ethical arguments that relate to this viewpoint.

The research proposal

About half-way through your course, you will be asked to decide the topic for your project. You will need to discuss and agree your proposal with your teacher/lecturer.

The Course specification lists the broad research topic areas (Figure 1) within which you may do your project. They are:

- the origins of the universe
- the human mind
- the beginning and ending of life
- genetics
- animal welfare
- scientific revolutions
- the mechanistic universe.



▲ ***Figure 1*** *The Research project must lie within one of seven broad topic areas.*

You need to think of a research question within one of these areas. Your project is most likely to be successful and enjoyable if you can answer yes to the following:

- Do you find the topic interesting?
- Does the topic relate to areas of science where you feel reasonably confident of your understanding?
- Does your project title raise a question that people have strong (and different) opinions about? Are there ethical and philosophical aspects to this question?
- Do you have some idea as to where you can start finding out more information about the topic?

Your research proposal should contain brief notes on:

- your choice of research question (which should fall within one of the specified topics)
- a rationale for the project – why you propose to research this question
- an outline of the science background to your question
- an identification of the philosophical and ethical aspects of your question.

Activity 1 *Writing a research proposal*

Write a proposal for your Research project. State the question you are proposing to research, write a few sentences explaining why you want to research this particular question, give a brief outline of the relevant science and indicate the ethical and philosophical aspects that you propose to discuss.

Discuss your proposal with your teacher or lecturer and modify it as necessary before submitting it.

1.2 Planning the Research project

Research and writing

You will have several weeks to carry out your Research project. A substantial amount of work will be involved and it is important to make the best use of your time. During this period you will probably have some lessons in which you are asked to take part in particular activities or tasks which contribute to your project, and others in which the time is made available for your own individual work. To make the best use of your time, you will need to keep in mind the two end-products of your project: the written report and the oral presentation. The written report is the main way in which you will report on your research (Figure 2). The report should be about 5000–6000 words long (maximum 7000 words).

▲ ***Figure 2*** *Writing up.*