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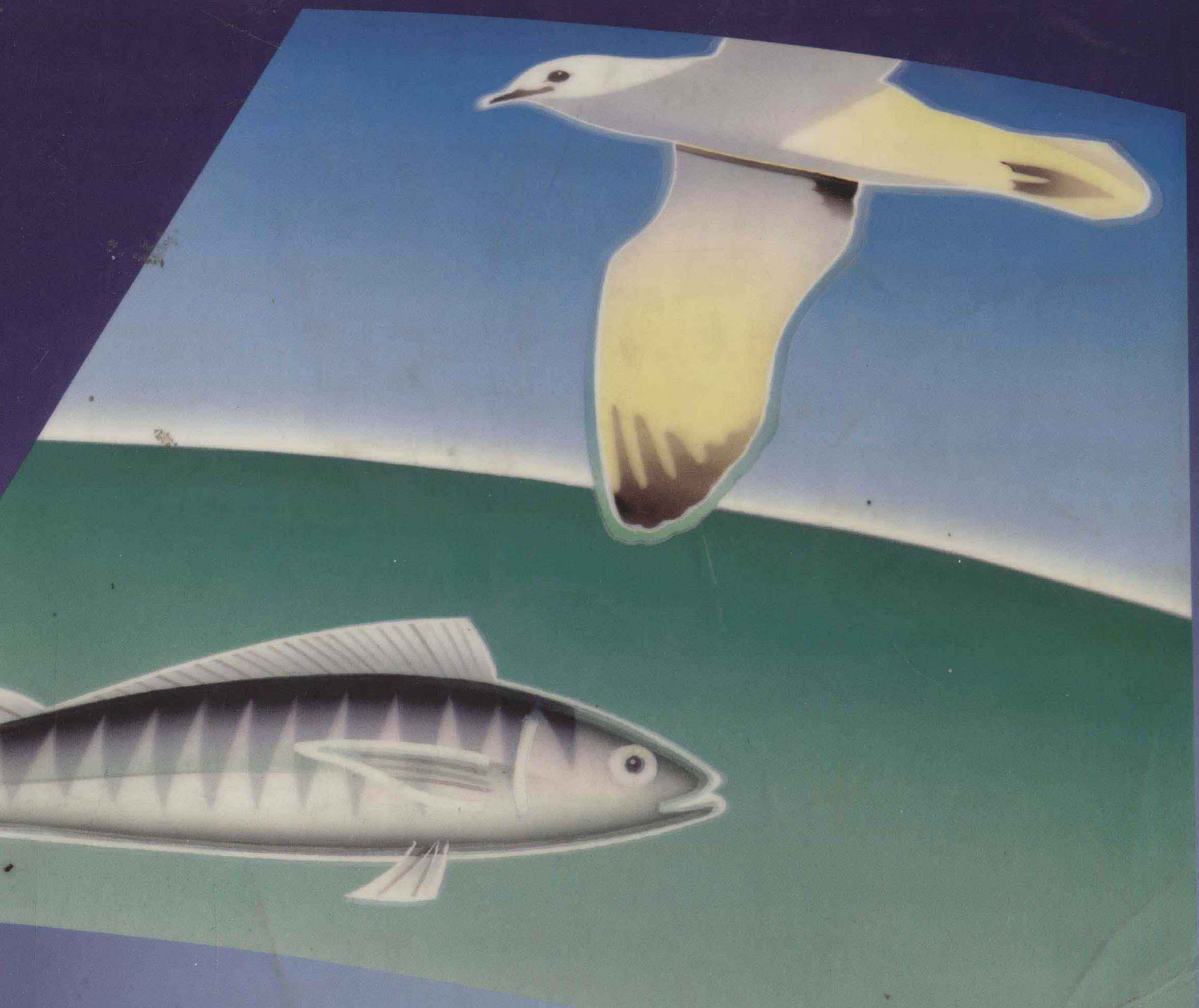

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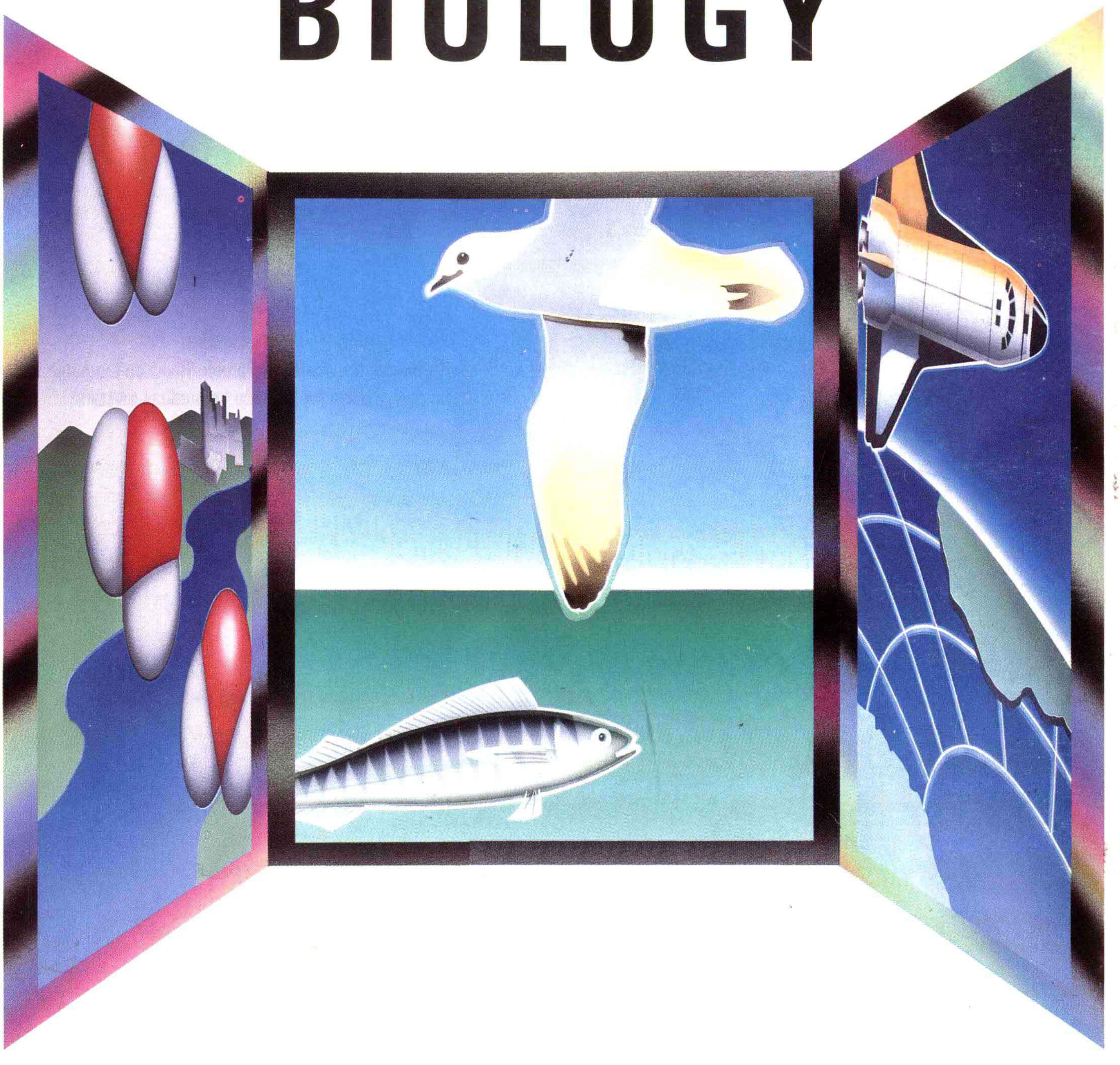

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Contents

Introduction

What is science?

Before you can join in and be a scientist you need to know something of what scientists have already discovered and how they do their work. All the people pictured in figures 1 to 4 are scientists. What is special about being a scientist? What do scientists do and how do they do it?

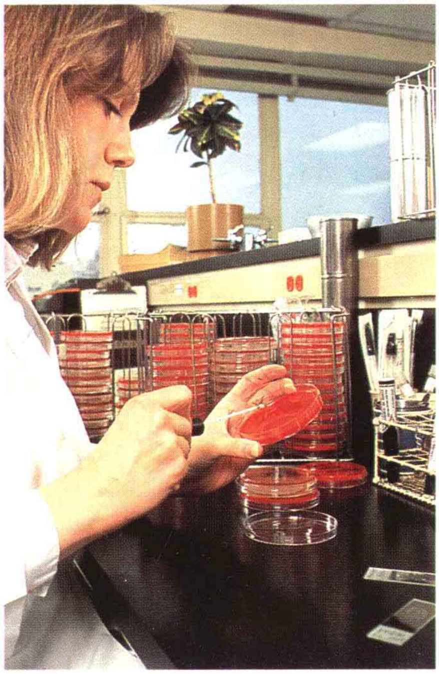


Figure 1

Figure 2

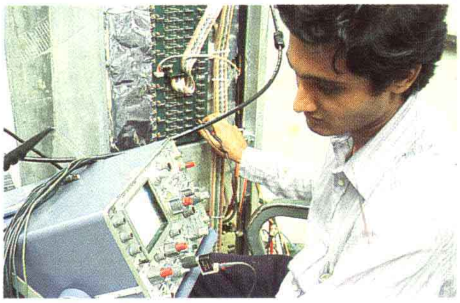


Figure 3

Figure 4

Some people compare being a scientist with playing a game. It can be great fun but it is also very competitive. Scientists like to be first to publish new results and theories and they may win awards and be remembered for their work. Scientists, like sports professionals, need plenty of training and have to work hard for success.

Often scientists work in teams and enjoy the excitement of working out ideas and making discoveries as a group. Members of a team play the game according to agreed rules. One of the rules in the game of science is that the results of experiments are not accepted until they have been published and checked by other scientists. The editors of science journals send new articles to "referees" to make sure that they are written according to the rules and are fit to print.

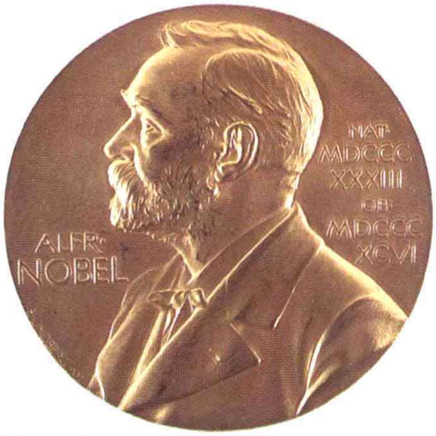


Figure 5
The Nobel medal which is given to the winners of the annual prizes for physics, chemistry, medicine, literature, and the promotion of peace. The awards are made from the bequest of Alfred Nobel, the Swedish inventor of dynamite, who died in 1896.

Science helps us to make sense of the world we live in. Every day we experience regular patterns: the Sun rises each morning, sugar always dissolves in water, plants wilt without water. This gives us a sense of order which lets us make predictions: the Sun will rise tomorrow morning, the next spoonful of sugar will dissolve in a cup of tea, the rubber plant will die if we forget to water it.

So scientists look for order in what they observe. To see order, they must first make observations and take measurements. In this way they collect much information about the world we live in. They look for patterns in their knowledge.

For example, meteorologists are scientists who study the weather. They record huge numbers of measurements of air pressure, rainfall, temperature and windspeed. The measurements are not taken at random. Meteorologists have theories about which are the important readings to take. Computers are programmed according to these theories to process the mass of data.

We see one way of making a pattern out of all the facts about the climate every time we watch a weather forecast on television. The lines on the weather map have been worked out from all the measurements and satellite observations.

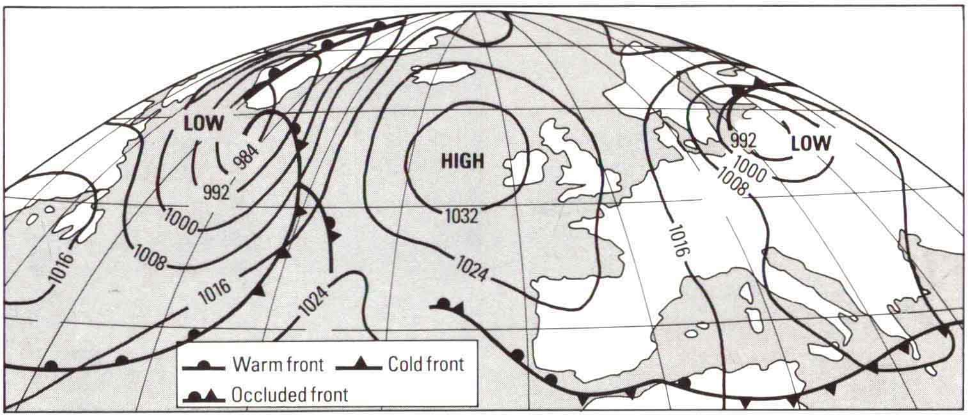


Figure 6
Weather maps like these are published in newspapers.

Once scientists have found patterns it becomes possible to make predictions. Some predictions are very reliable. Astronomers can predict the movement of the planets and comets very accurately. Sometimes the predictions are less certain, as you will know if you have ever been misled by a weather forecast.

As they are collecting facts and looking for patterns scientists also seek explanations. Why is the world as it is? Why do things behave in the way that they do? Inventing theories to explain what we know is an important part of science.

One of the things that you will be doing as you study this science course is seeing for yourself some of the things which scientists have already found. We will be taking you on a "conducted tour" to give you firsthand experience of what scientists have discovered.

While on this tour you will be taught some of the practical skills needed to use scientific equipment and methods. Learning skills needs practice, as you will know if you play a musical instrument or are learning to type. The practice may not always be enjoyable but it is necessary.

If you have ever been a tourist on holiday you will know that it can be interesting – at least for a time. However in the end being a tourist is not as interesting as living your own life where you belong. So it is with science.

To understand science you need to have experience of asking questions and planning investigations. You have to be involved in experiments where the answer is not known in advance. We hope that by the end of this course you will have had several opportunities to join in and be a scientist, using your knowledge and skills to carry out investigations.

Biology is the life science. As members of the living world human beings have always been interested in studying living organisms. At the beginning of the twentieth century biologists spent a great deal of time collecting and recording information about all forms of life. Observation played a very important part in their work and it led to an awareness of the enormous variety that exists among organisms. You can begin to look at this *diversity* in the first two chapters of this book and also to see, in Chapter **B**23, how it led Darwin and Wallace to put forward their theory of evolution.

It is obvious that no one person could ever be expected to know about all the different forms of life. Fortunately, biology is not just a collection of facts. Today biologists are concerned with acquiring an understanding of life and using it to solve problems which affect humans. As in all science, *observation* has an important role in biology. Having made the observations, the next stage is to look for *patterns* or generalizations. A pattern must be *tested* and when it is established that a pattern exists it can be used to make *predictions* about other organisms. In this way the task of a biologist is simplified because it becomes possible to have an understanding of organisms which have never been studied at first hand. The diversity of organisms may be impressive but it is equally remarkable to find that there are patterns which establish that there is also an underlying *unity* among organisms. The key to understanding both the diversity and unity of life was provided by a very exciting discovery which was announced in May 1953. This was a discovery in which knowledge and expertise from biology, chemistry and physics merged to solve the structure of a molecule called DNA.

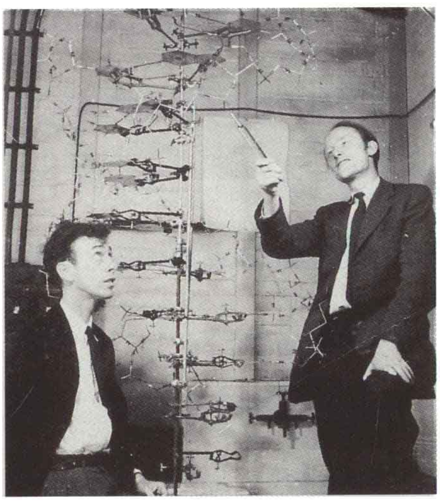


Figure 7
James Watson and Francis Crick standing in front of the double helix model.

DNA stands for deoxyribonucleic acid and it is the chemical substance of which genes are made and is therefore found in chromosomes. It is the hereditary material of all cells. The way in which the atoms are arranged to form a molecule of DNA was one of the most exciting discoveries of the twentieth century.

James Watson and Francis Crick (figure 7), two scientists who were working at the Cavendish Laboratory in Cambridge, suggested that the structure of the molecule is like a twisted ladder, an arrangement which has become known as a *double helix*.

Two other scientists, Rosalind Franklin and Maurice Wilkins, who were experts in a technique called X-ray crystallography, took photographs which supported the idea that the molecule was a double helix. (See figure 8.)

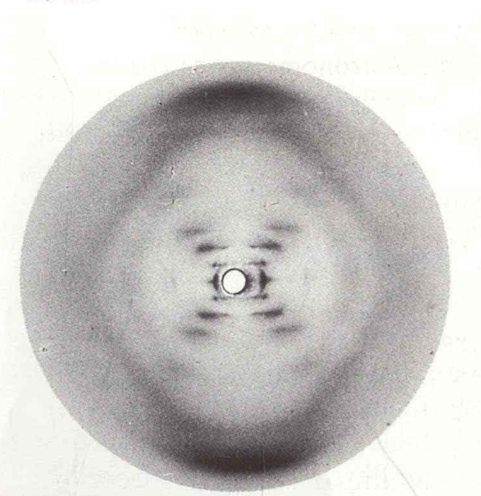


Figure 8
Rosalind Franklin's X-ray photograph of DNA. It was taken in 1952.

The "rungs" of the ladder are formed from pairs of *bases*. There are only four different bases and they are known by their initial letters A, C, T and G. A always pairs with T and C with G. (See figure 9.)

In 1962 the Nobel Prize for Medicine and Physiology was awarded to Francis Crick, James Watson and Maurice Wilkins for the part they played in establishing the structure of DNA. Sadly, Rosalind Franklin had died in 1958 at the age of thirty-seven but she also should be remembered for the outstanding part she played in the discovery of the structure of this remarkable molecule as a double helix.

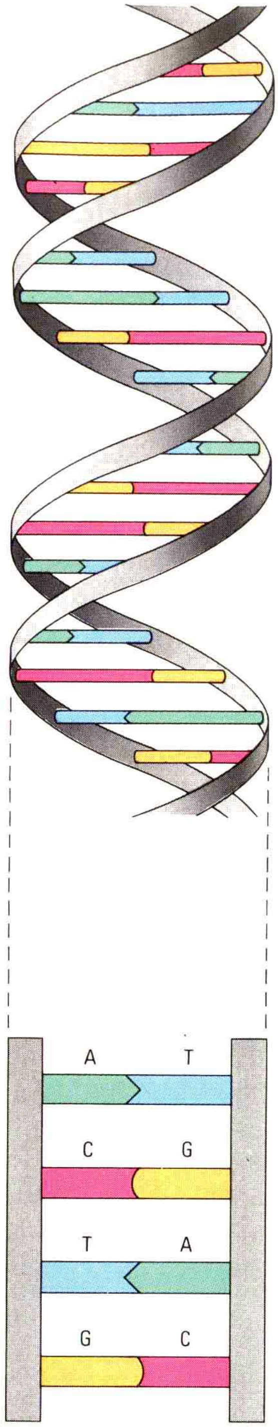


Figure 9
A diagram showing the structure of DNA. You can see more details of the structure in your Chemistry book, figure **C**5.49.

You can find out about chromosomes and genes in Chapter **B**22. Because we now know the structure of DNA we know that what living organisms inherit is a chemically coded message: a message which lies in the order of the four bases. There are almost endless possible arrangements for the order of these four bases. This is what gives DNA the unique property of being able to carry all the information which is passed from one generation to the next.

DNA is the hereditary material of all living organisms but different species have different amounts of it. It distinguishes a bacterium from a horse and a mushroom from an oak tree and so it accounts for both the unity and the diversity of life.

A knowledge of the structure of DNA has led to enormous advances in many areas of science, from getting nearer to understanding what causes cancer to helping to solve the world food problem.

One of the aims of studying biology is to help us to understand how living organisms *function* and much of this book is about that. In addition we need to understand that all organisms interact with each other and with the environment in which they live. This important aspect of biology – called *ecology* – is the subject of Chapters **B**13 to **B**18. We have already cut down a large part of the rain forests and have hunted some animals so much that they are in danger of disappearing. These things were done without people realizing the results they would have. If we can think "biologically" about such matters we can avoid making similar mistakes and may even be able to put right some of the damage already done. We need a supply of food and it has to come from other living organisms but we must have a balanced approach to how we use other organisms for our own purposes. If we are aware of the consequences then we can conserve our resources for the future.

Co-ordinated Sciences

This is a Co-ordinated Science course. You may have seen the word *co-ordinated* used elsewhere. What do you think the following newspaper story means?

> "Police carried out a *co-ordinated* raid on ten warehouses in the London area last night. As a result fifteen people were arrested and are being held for questioning."

To be *co-ordinated* the raid must have been carefully organized. Each person in the police team knew exactly what was happening elsewhere and when it was happening. That is what we and your teachers have tried to do with this science course.

You have different books for Biology, Chemistry and Physics, but the separate parts of the course have been carefully co-ordinated so that ideas you meet in one subject can be used in another. For example you will need to use ideas about energy in all your sciences. You will learn about energy first in Physics. When you come to use energy ideas in Biology and Chemistry, your teachers will know and expect to use what you have learned in Physics.

To help you to make the most of this co-ordination we have included a large number of cross references in each of the books, For example when you first come to the subject of photosynthesis in Biology you will be reminded that you can find out more about colour in your Physics book and about the making of starch and sugar in Chemistry.

Sciences are only a part of your school timetable. Your work in this course will also have links with other subjects such as Mathematics, Geography, and

Design and Technology. You should be on the look out for opportunities to take advantage of these links.

How to use this book

This book is divided into four topics. It is possible that you will study them in the order in which they are printed. But your teacher may decide on another order. You will have to make use of the knowledge and understanding you have gained in Chemistry and Physics to make sense of all the chapters.

The commentary text advises you on how to go about different parts of your work. Commentary text is printed in type like this.

You do not have to know everything in this book. The book contains more than you have to study so that you and your teacher have some choice about the way you will learn.

Your teacher will guide you. The commentary text will also help you to decide which bits to study in detail, which parts to read for interest and which sections to leave out all together.

Throughout this book, there are symbols to help you to recognize the skills and processes which you need to apply. When one of these is used in the work of this book you will often see the appropriate word in the margin. However, you will find there are often opportunities which are not marked in this way. Here are the skills and processes we shall emphasize.

O OBSERVE

Observation

This is the skill we use when we look carefully at organisms and how they work. We also use it when we watch what is happening in an experiment.

M MEASURE

Measurement

This is an important skill that we use when we are obtaining and recording results.

I INTERPRET

Interpretation

We shall use this word to mean any activity that involves trying to find new things from observations or measurements. "Interpretation" may mean "making a deduction", or "making a prediction", or "relating observations and measurements to some other ideas in science".

A APPLY

Application

Applying what you have learned and understood is an important skill.

P PLAN

Planning

Planning is a very important part of any scientific investigation. Before making measurements, and often before making detailed observations, you must decide what it is you want to do and what you hope to gain from the investigation.

You will also be able to plan your own experiments. You will find some suggested problems to investigate in this book. You may have better ideas of your own. Successful investigations require careful planning and your teacher will give you guidance about how to set up a scientific inquiry.

Reading a textbook is not the same as reading a story. You have been familiar with stories ever since you started to read. You know the ways in which story books are organized. Textbooks are different. You will have to learn how to make sense of technical writing. You may be given worksheets by your teacher which will help you to make sense of some of the types of text in this book.

Topic **B1** The variety of organisms

You recognize people by their characteristics.

Chapter **B1** What's what?

B1.1 Sorting things out

Would you make a good witness of an accident? Most people think that they would, but the police are continually amazed at how many eye-witnesses give different, even conflicting accounts of an event. Unfortunately, not many of us are budding Sherlock Holmeses. As the great detective once complained, "You see, but you do not observe".

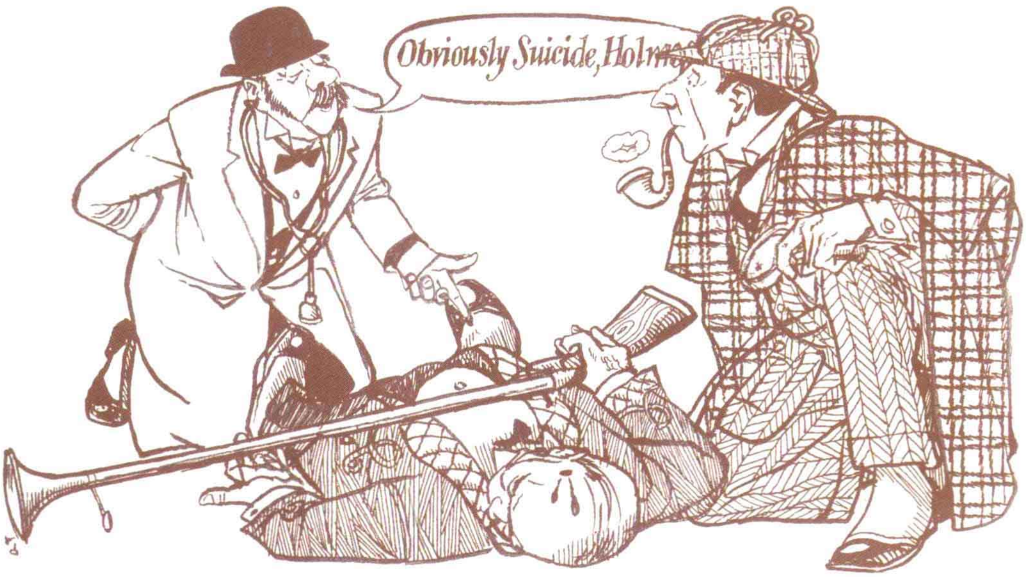


Figure 1.1
"You see, but you do not observe."

The problem is that although we notice many different things, we are not always able to work out and remember which are the most important and, as a result, we forget nearly everything that we see.

There are hundreds of thousands of types of organism, each with a different name. In Chapters **B**1 and **B**2 you can see something of the diversity of organisms in the world, and the reasons for their complex names.

Organisms have bodies that are built of many different parts and it is possible to describe the many features, or *characteristics*, that they may have. The colour of your eyes or hair and your height are all characteristics that you and your friends have in common. That is not to say that you all have blue eyes or that you are all the same height. In fact you recognize your friends by the combination of characteristics they have.

1 What characteristics do you use to recognize your friends?

How do biologists recognize different organisms? They start by looking very carefully for the similarities and differences between organisms. Worksheet **B1A** will help you to do this.

Figure 1.2
Not all of these woodlice are the same. (× 1.5)

O OBSERVE

Figure 1.2 shows a number of animals called woodlice. They are found in damp, dark places, particularly under stones and rotting vegetation. At first sight they all look the same, but if you look carefully you will see that there are differences between them.

2 How many different sorts of woodlice are there in figure 1.2?

If you study woodlice carefully, you will find that they are not always found in the same places. Some types of woodlice are found in drier conditions than others. Also, they do not all behave in the same way when handled – some are capable of rolling themselves into a small ball, while others are not.

Studying woodlice under natural conditions is difficult, because they live in dark places. If you keep them in the laboratory, however, you will find that a woodlouse of one type will only breed successfully with another of the same type. The same is true for all the other kinds of woodlice.

This suggests that there are natural groups of organisms, which the organisms themselves seem to recognize. Biologists call these groups *species*.

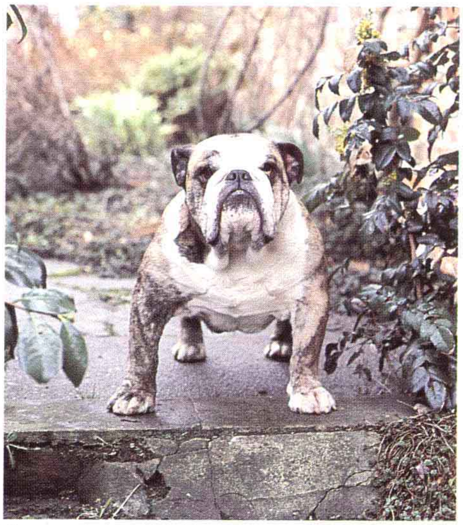
But what exactly is a species? How similar do organisms of the same species have to be? Unfortunately there is no simple answer to this question, and some biologists have argued for years about whether certain organisms belong to the same or different species. One thing that is always true is that members of the same species must be able to breed successfully to produce offspring which can themselves reproduce.

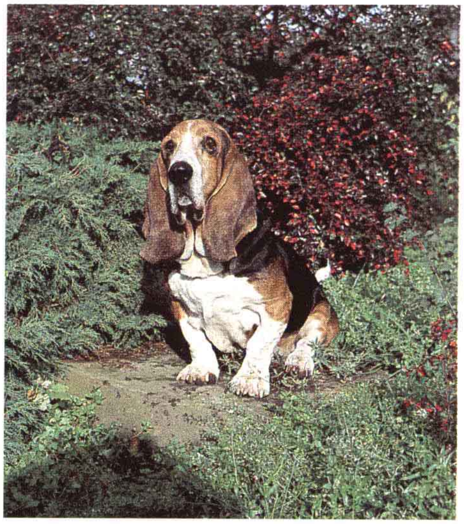
For example, a horse and a donkey are different species, even though they can breed together to produce a mule (figure 1.3). We know they are different species because the mule is sterile, and normally cannot breed.

Bulldogs and basset hounds look very different from each other but they are the same species and can breed together successfully.

There are some species of mosquito which are so similar that biologists cannot tell them apart. However they belong to separate species because they cannot interbreed with each other.

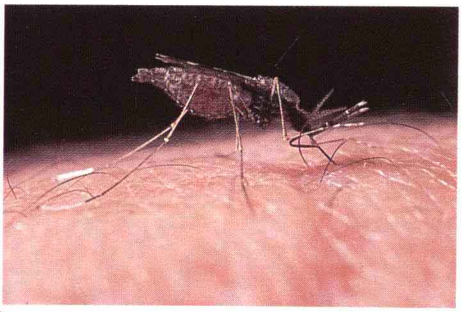
Figure 1.3
A donkey, a horse and a mule.





Figures 1.4 and **1.5**
A bulldog and a basset hound can breed together successfully. Can you imagine what their puppies would look like?

a



b

Figure 1.6
These mosquitoes belong to different species. You cannot easily see any difference between them. (× 6)

B1.2 Countless different types

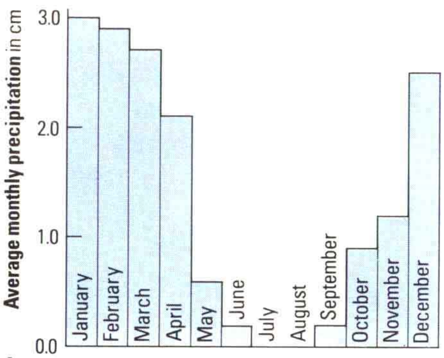
How many different species are there in the world? No one really knows, and no one ever will. It is a sad fact that there are many species in the tropical rain forests that are being destroyed before they have been properly described.

B1.3 The art of survival

The greatest age to which an animal is thought to have lived is about 220 years. This is nothing when the animal is compared with the oldest living organism in the world, shown in figure 1.8.

The oldest living organism in the world is a plant that is thought to be 11 700 years old. It is called the creosote bush and is found in south west California.

Figure 1.8
The creosote bush – the oldest living organism in the world.



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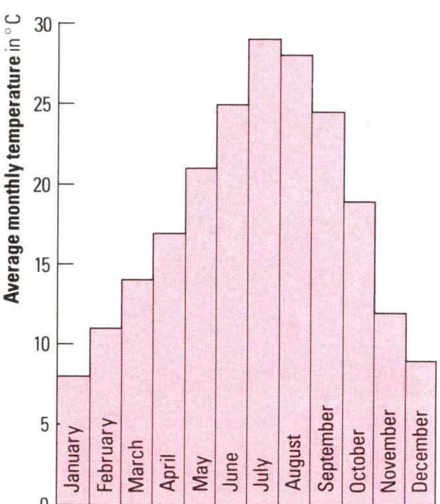
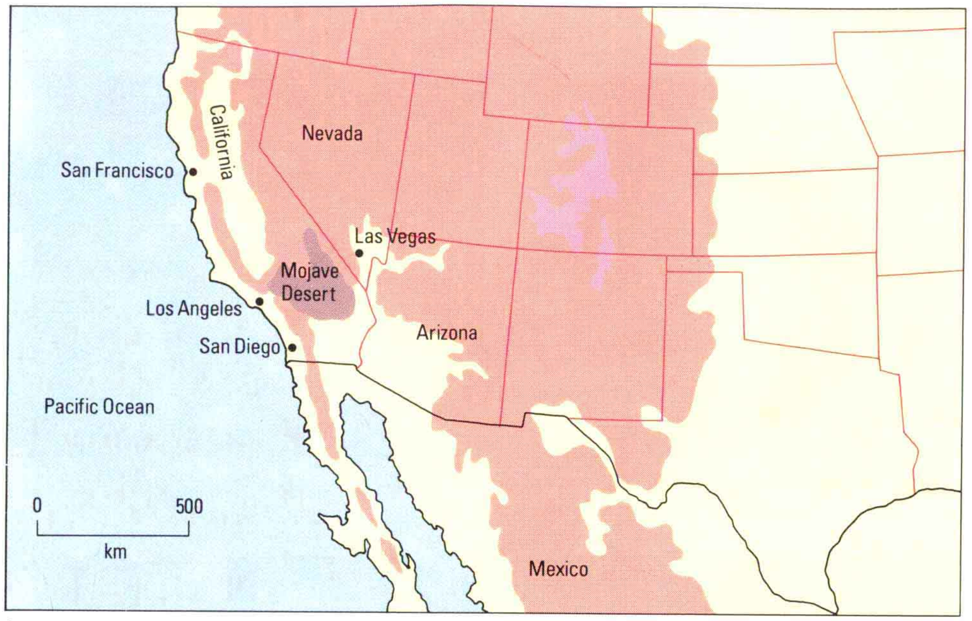


c



a

Figure 1.9
a The map shows the Mojave desert in North America where the creosote bush lives.
b and **c** The histograms show the average monthly precipitation (rainfall) and temperature for the Mojave desert.

3 Try to find out what was happening in the world about 12 000 years ago.

This will help you to get an idea of how old this plant is.

If we are interested in how organisms survive, then this grand old plant should help to provide us with a few clues.

I
INTERPRET

4 From the information given in figure 1.9a, b and c describe the environment in which this plant lives.

5 What problems have to be overcome in order for this plant to survive in its environment?

The creosote bush survives in the Mojave desert because it can obtain enough water from the small amount of moisture provided by dew or by occasional light rain showers. It has roots which can extract water from almost dry soil. They spread over a wide area, and this prevents other plants