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Практическое пособие по лексике
для студентов старших курсов,
магистрантов и аспирантов
естественных факультетов БГУ

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Кафедра английского языка естественных факультетов

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PART I

RESEARCH AND DISCOVERY

UNIT 1

SCIENCE AND SCIENTISTS. LAWS OF SCIENCE

Study the key words:

Science is the study of the nature and behaviour of natural things and the knowledge obtained about them. A **science** is a particular area of scientific knowledge and study, or the study of an area of human behaviour.

Scientific describes things that relate to science. A **scientist** is someone who works in science.

There are those who consider that some sciences are more ‘scientific’ than others, and they distinguish between **hard** sciences like physics and chemistry and **soft** sciences like psychology and anthropology. The division may be drawn almost anywhere.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Science is a force that should be used for the good of humanity.

Most of these academies of science had no ecologists in them and didn’t regard ecology as a science.

The Centre is running a series of talks on the relationship between science and literature, in which writers, poets and scientists discuss how scientific ideas over the past two centuries have influenced literature and social change.

Scientists in the hard sciences should not be too content with themselves. How many different answers exist, for example, to the following questions: how old is the universe, is the universe expanding or contracting, how many fundamental particles exist, when is the next earthquake due, what causes AIDS or Alzheimer’s disease?

The statistics brought out a gender division between hard and soft science: girls tending towards biology, boys towards maths and physics.

Exercise 2. The words in the box can all come in front of 'science'. Find combinations that refer to:

1 science that is not concerned with practical or commercial applications (2 expressions),
2 science that is concerned with practical or commercial applications,
3 science books and TV programmes meant for the general public,
4 science that does not have serious theoretical backing,
5 science that requires many resources and very large sums of money,
6 what economics is sometimes known as: the _____ science.

	big	
pseudo-		basic
	science	
popular		applied
dismal		pure

Now use the expressions to complete these extracts. Each expression is used once.

a. Asimov spoke out in favour of science and reason and against ______ science and superstition.
b. Research and development largely takes place in industry, and although it involves some ______ science, it really consists of the application of science and the improvement of technology.
c. Developing and marketing new drugs has little to do with _____ science and everything to do with power and money.
d. *Black Holes and Time Warps* goes far beyond the average _____ science books by presenting the general reader with a detailed historical account of one area of physics research.
e. In ______ science, the national pride that sets country and scientist against scientist can be costly. The great projects of understanding have now reached such a scale that they are best served by the united efforts of all the world.
f. Some economists are trying to give their ________ science sex appeal.
g. When the Gillette company started investigating the _____ science of shaving in the 1950s, it was reacting to the threat of a cream that would dissolve beards.

Exercise 3. Match these sciences to their areas of study.

1 anthropology	a environment,
2 biology	b human mind and behaviour,
3 chemistry	c language,
4 ecology	d living things,
5 economics	e matter and forces,
6 linguistics	f money, industry, and trade,
7 mathematics	g numbers, quantities, and shapes,
8 meteorology	h people, society, and culture,
9 physics	i substances and their reactions,
10 psychology	j weather.

Exercise 4. Look at the examples and complete the commentary below.

Economists have begun to study the implications of near-rationality. To do so, they are drawing on research in sociology, anthropology, and above all, psychology. Since economics is a <u>behavioural science</u>, this extension of its research programme is long overdue.

At university, I rediscovered that attraction in <u>earth sciences</u>, finding out how ordinary things, rocks, rivers and the wind, became the way they are.

He is fascinated by the car in its fundamental role. "Ergonomics is really the application, the technological side, of the other <u>human sciences,"</u> he explains. "We are constantly aware that the skill involved in driving a car is phenomenal, but taken for granted. "

There has been a huge increase in medical and biomedical science over the decade. In the US, for example, one-third of all scientists are now engaged in the <u>life sciences.</u>

Newton's three laws of motion, which, it was thought, could theoretically explain (eventually) all the phenomena of the natural world. The influence of this work spread beyond the <u>natural sciences</u> to virtually all subjects.

Decisions taken in the 1950s led to the bulk of science funding going into medicine, <u>physical sciences</u> such as nuclear power, and space research.

Wisdom argues that the <u>social sciences</u> should rub shoulders with the natural sciences on equal terms.

The ____________ **sciences** are those dealing with the naturally occurring world in general. They include ___________ **sciences** such as physics and chemistry. __________ **sciences** include geology and oceanography. _____________ **sciences** include areas such as medicine and biology.

Studies of human behaviour such as economics or sociology are _________ **sciences**, _________ **sciences**, or _________ **sciences**.

Study some more key words:

A statement in mathematics or logic that is the product of reasoning is a **theorem.** The explanation of this reasoning is the theorem's **proof,** often in the form of a series of **equations.**

A **formula** is a series of mathematical, chemical, or other symbols that express a scientific rule.

General statements that are confirmed by observation are **principles** or **laws**.

Theorems, principles, and laws are often preceded by the name of the person who first **formulated** them.

Exercise 5. Match the two parts of these extracts.

1. The basis of Bayes' theorem is that if the outcome of one event is known, this affects the probability of another event occurring.
2. Pythagoras's theorem was independently discovered many times by different thinkers.
3. It is a commonplace observation that work expands to fill the time available for its completion.
4. The team divided DNA sequences into short 'words' of arbitrary length and counted the number of times each word occurred in the complete sequence.
5. Hardware follows the law postulated by Intel co-founder Gordon Moore, which states that computing power available for a given price doubles every two years.
6. In this picture, which is now known as Mach's principle, the resistance to motion - or inertia -
7. Hubble's law says that a galaxy which is twice

a (although Pythagoras was probably not one of them).

b as far away as another is moving away from us at twice the speed.

c For example, there might be a one-in-five chance of frost on March nights, and a one-in-fifty chance of snow. But if there was frost on the previous night, the chances of having snow are modified.

d Software development, however, is governed by the rule known as Hofstadter's law: It always takes longer than you expect, even when you take into account Hofstadter's law.

e They found a pattern of word frequencies that closely matched that seen in human languages, a pattern known as Zipf's law.
f With those words *The Economist* coined Parkinson's Law in 1955, naming it after the author of the article, Professor C. Northcote Parkinson.
g we feel when we try to push an object is a result of trying to make it accelerate relative to the distribution of all the matter in the Universe.

UNIT 2

SCIENCE AND TECHNOLOGY

Study the key words and the examples:

You are certainly familiar with the traditional branches of science e.g. chemistry, physics, botany and zoology. But what about these newer fields?

- **genetic engineering:** the study of the artificial manipulation of the make-up of living things;
- **molecular biology:** the study of the structure and function of the organic molecules associated with living organisms;
- **cybernetics:** the study of the way information is moved and controlled by the brain or by machinery;
- **information technology:** the study of technology related to the transfer of information (computers, digital electronics, telecommunications);
- **bioclimatology:** the study of climate as it affects humans;
- **geopolitics:** the study of the way geographical factors help to explain the basis of the power of nation states;
- **nuclear engineering:** the study of the way nuclear power can be made useful;
- **cryogenics:** the study of physical system at temperatures less than -183° C;
- **astrophysics:** the application of physical laws and theories to stars and galaxies.

The verbs in the sentences below are all useful in scientific contexts.

He **experimented** with a number of different materials before finding the right one.
The technician **pressed** a button and lights started flashing.
When she **pulled** a lever, the wheel began to rotate.
The zoologist **dissected** the animal.

When they were combined, the two chemicals **reacted** violently with each other.

After **analysing** the problem, the physicist **concluded** that there was a flaw in his initial hypothesis.

James Watt **invented** the steam engine and Alexander Fleming, another Scot, discovered penicillin.

After **switching** on the computer, insert a floppy disc into the disc drive.

You must **patent** your invention as quickly as possible.

Exercise 1. Complete this table.

Science	**Subject of study**	**Scientist**
Genetic engineering	Manipulation of **DNA**	genetic engineer
Molecular biology		
Bioclimatology		
Astrophysics		
Cybernetics		
Information technology		
Ergonomics		
Genetics		
Civil engineering		

Exercise 2. What are the nouns connected with the following verbs?

1 discover 3 rotate 5 patent 7 dissect 9 combine
2 invent 4 conclude 6 analyse 8 experiment.

Exercise 3. Complete the sentences by forming a word from the root in brackets at the end of the sentences. Use a dictionary if you need to.

Example: When you have finished your <u>*dissection*</u> please turn to page 55. (dissect)

1. I came to the _______ that the theory was incorrect (conclude).
2. Researchers must first make a careful _____ of the problem (analyse).
3. Fleming was responsible for the _____ of penicillin (discover).
4. The _____ of the earth on its axis causes night and day (rotate).
5. The _______ of these two gases can be dangerous (combine).
6. The scientist carried out many _______ (experiment).
7. Joe is a systems _______ (analyse).
8. We owe a great deal to the _______ of the steam engine (invent).
9. The ______ of the steam engine was James Watt (invent).
10. You must take out a ________ on this idea (patent).

11. There was a violent _________ when the chemical was added (react).
12. Scientists have to _______ (theory).
13. They also have to _______ (hypothesis).
14. Don't forget to switch on the video _______ (record).

UNIT 3

TECHNOLOGY AND TECHNOLOGISTS. INVENTORS AND INNOVATORS

Study the key words:

Technology describes scientific knowledge applied for practical purposes. A **technology** is scientific knowledge applied in a particular area. **Technological** describes things relating to technology. **Technologists** are researchers who work in a particular area of technology.

Some technologies are more complex than others. Products, systems or industries using advanced technologies are **high-technology**, **high-tech**, or **hi-tech**. Those at the other end of the scale are **low-technology** or **low-tech**, but not '**lo-tech**'.

Exercise 1. Read and translate the following paying special attention to the underlined words.

<u>Technology</u> has made the world much smaller.

Over $1 billion a year has gone on research into nuclear fusion, a <u>technology</u> that has not yet generated a joule of electricity.

Why has the pace of <u>technological</u> change accelerated so rapidly in the 20th century? Science is always on the move. Its preference is to find a question that nobody knew needed answering, answer it and then move on, leaving <u>technologists</u> to turn the answer into a machine, a drug or a computer program.

Pressure has increased for the European Space Agency to cut back its big, <u>high-technology</u> projects, such as the spaceplane Hermes and the space station module Columbus.

Since the 1950s the Defense Advanced Research Projects Agency has laid the foundations of various <u>high-tech</u> industries, such as computing and satellite building.

Gerald Harris says he does not like anything <u>hi-tech,</u> so he has kept everything in his home-made submarine nice and simple.

.... training doctors and nurses to work in the villages, and concentrating resources on cheap but effective medicines and <u>low-technology</u> equipment.

The best-selling mopeds are made by Tomos, a firm that is content to produce low-tech, but unbeatably cheap, machines.

Study some more key words:

Invention or **inventiveness** is the ability to design new machines, devices, or products. An **invention** is a new machine, device, or product.

People who **invent** things are **inventors.** The associated adjective is **inventive.**

Innovation is the act of thinking of new ideas, developments, and improvements. These are **innovations** and the people **innovating** them are **innovators.** The associated adjective is **innovative.**

The first, **experimental**, versions of a new technological idea are **prototypes.**

Exercise 2. Read and translate the following paying special attention to the underlined words:

He worked for the Bell Telephone Laboratories, helping that renowned centre of invention to develop automatic tracking radar, television transmission systems and efficient coding devices.

The country with the most Nobel prizes per head - Britain - is notoriously slow at commercialising inventions. Japan, to this day, stands as living proof that brilliant technological inventiveness can exist in a country with a lacklustre tradition of basic science.

Even after the industrial revolution had applied science to technology, the successful inventors, the Edisons and Marconis, were little concerned with science.

Newcomen invented a steam engine by copying a piece of apparatus invented by Denis Papin, a French scientist.

People are so much more flexible and inventive than robots.

The first invention is but a fraction of innovation. One reason is obvious: the first invention is, by later standards, primitive. The first electronic digital computer contained 18,000 vacuum tubes and filled a room 100 feet long.

The Japanese appetite for foreign technology is one that supplements a fruitful home-grown crop.

The Japanese innovate at home and actively collaborate in the innovations of others.

The idea of representing data with music rather than showing it on a computer screen is just one of many innovative ideas to help the 100,000 scientists and engineers around the world whose disabilities include blindness, deafness, impaired mobility and dyslexia.

The technology, known as Electronic Paper, has been developed by Thorn EMI's Central Research Laboratories. CRL has built a 13-centimetre screen to prove that the idea works, and promises a prototype version in six months.

Exercise 3. Read this article from *The Economist* and answer the questions.

THE SHOCK OF THE NOT QUITE NEW

It is a commonplace that technologies move only slowly from the first invention to a widespread use. What is striking in the history of technological innovation, however, is that the dispersion of a new technology is not just slow but extraordinarily uncertain even after its first commercial applications have been realised.

This runs against the conventional wisdom, which holds that the uncertainties are much reduced after the first commercial use. The evidence to refute that view comes not just from any old technologies, but from many of the most important innovations of this century.

Consider the laser, a comparatively young technology with more development in store. Beyond uses in measurement, navigation and chemical research, applications have expanded to include the reproduction of music (to make the laser a household product); surgery; printing; the cutting of cloth and other materials; and, its most significant use to date, telecommunications.

Together with fibre optics, the laser has revolutionised the telephone business, yet lawyers at Bell Labs were initially unwilling even to apply for a patent for their invention, believing it had no relevance to the telephone industry.

If that story sounds familiar, there is a reason: such a pattern of innovation is not exceptional, nor even quite common, but typical. The steam engine was invented in the eighteenth century as a way of pumping water out of mines; it remained nothing more than a pump for many years. Then it became a source of power for industry, then a source of power for transport, then a way to generate electricity. The first inventors never dreamed of such a breadth of application (or of electricity, for that matter).

1. If something is a commonplace, is it unusual?
2. If something disperses, it sp________s
3. Does 'realised' mean 'understood' in its context here?

4. Is the conventional wisdom a minority view?
5. If an opinion is refuted, is it disproved?
6. Has the laser reached the end of its development?
7. ‘Applications have expanded’: they have g________n.
8. The most significant use of something is its most i________t use.
9. Is ‘apply’ used here in the same way as ‘application’ in the previous paragraph?
10. If something follows a pattern, have similar events already happened?
11. These inventors never dreamed the applications would be so wide_________.

UNIT 4

RESEARCH AND RESEARCHERS. EXPERIMENTATION

Study the key words:

People trying to find facts about something **study** it or **do research** in it, into it, or on it.

A piece of research may be referred to as a **study** or a **research study**. These terms also refer to the published results of the research.

Scientific research often takes place in **laboratories**, or **labs**. These are also **research laboratories** or **research labs.**

People doing research are **researchers**.

Language Note. Research is a noun and a verb. As a noun, it is usually but not always an uncount noun.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Psychiatrists have spoken with respect of her researches into the possibility of detecting mental illness through handwriting.

Ciba-Geigy, the Swiss pharmaceutical giant, has reduced from 18 to 7 the number of subjects which it researches in-house.

Many studies have shown that in the laboratory at least, amphibians such as frogs fail to develop normally at the acidity levels of some ponds.

Asking social science researchers to explain the four or five most important findings of a major research study is more likely to cause resentment than enthusiasm.

Sapienza’s book ‘Managing Scientist’ offers a painless way to improve the psychological health of just about any lab.

At one event, BT's research lab at Martlesham showed off its leading-edge ideas.

Exercise 2. Match the two parts of these research report extracts.

1. This is the start of NASA's 10-year programme to pick up the first radio signals from an alien civilisation.
2. The 'vinegar syndrome' that rots movie film stored in sealed cans has been beaten at last.
3. These molluscs, with their beautifully spiralled shells, suffered a catastrophic extinction. So what killed the ammonites?
4. Electrons behave as waves when viewed on extremely small scales.
5. Massive oil spills not only harm wildlife, they also do psychological damage to the human inhabitants of the blighted environment.

a. A team of Californian researchers has linked severe depression to the wreck of the Exxon Valdez in Alaska three years ago.
b. NASA researchers believe contact with other intelligent life will be one of the most significant events in the history of the human race.
c. Now researchers working for IBM have detected such waves on a metal surface at room temperature.
d. Researchers working for Kodak, which made most of the film now in storage, have found a way of absorbing the chemical that destroys the film base.
e. Researchers working in Papua New Guinea think they may have been wiped out when the level of oxygen in the oceans rose dramatically, stimulating the evolution of oxygen hungry fish that simply out-competed them for resources.

Study the key words:

Experiments are scientific tests that are **carried out, conducted, made**, or **performed** to see what happens to something in particular conditions.

A **field experiment** is one done in real surroundings and not in a laboratory.

A **thought experiment** is done by thinking about a problem, rather than experimenting on it.

The related adjective is **experimental**.

Exercise 3. Read and translate the following paying special attention to the underlined words.

Peter Molan of the University of Waikato, Hamilton, has carried out experiments showing that samples of honey are effective against Staphylococcus aureus and other infectious bacteria.

Scientists must apply for permits to conduct any experiments involving the manipulation of genes.

In the early 1900s Pavlov made experiments on learnt-reflex responses. One way of eliminating any doubts about the links between the visual areas discovered in the human brain and those found in monkeys would be to perform the PET imaging experiment on a macaque.

Kareiva applauded the innovative approach of Naeem et al, who carried out experiments on ecosystems under controlled and duplicable conditions. Kareiva is of the view that field experiments on ecosystems will always be necessary, but they tend to be hard to repeat.

Galileo is said to have dropped two spheres of different weights from the top of the leaning tower of Pisa to demonstrate that the spheres would strike the ground together. But, in fact, he deduced this fast using a thought experiment.

Berlin's underground system has become a giant experimental maze, where the experimental animals are human. As part of a project for the whole system, 'scientifically designed' signs have been put up to guide passengers through the city's labyrinthine Alexanderplatz station.

Exercise 4. Complete this article from *The Economist* with the listed words. (*a* occurs six times and *b, c,* and *d* once each.)

a experiment c experimenter
b experimentally d experiments

TESTS OF THE TRUTH

What do the following have in common? A hundred million dollars' worth of electronics buried under the Illinois prairies, an electric current passing through a schoolgirl's test tube in the Canary Islands, and the build-up of carbon dioxide in the atmosphere? They can all be described as _________ (1).

The CDF detector at Fermilab is trying to measure the mass of an elusive sub-atomic particle called the top quark; the child in Las Palmas is being taught about the chemistry of oxygen and hydrogen; the build-up of carbon dioxide in the atmosphere is a huge unplanned climatic ______ (2).

The aim of science is to find reliable knowledge about the world. The reliability that people have come to expect from the natural sciences comes, in large part, from ______ (3).

Some sciences, such as astronomy, tend to concern themselves more with observation than_____ (4) as such. But they all rely on physical laws that have been, to some extent and at some point, _______ (5) tested.

In principle, the difference between an ____ (6) and simple observation is this: in an _____ (7) some aspect of nature is under the control of the _______ (8).

The most influential account of science this century is that given by Sir Karl Popper. Sir Karl claims that there is an asymmetry between truth and falsehood; no statements can be proved true but some statements can be proved false. Science, he continued, is defined by this falsifiability: it is the fact that they can be proved false, but have not been, which gives accepted scientific statements their value. In this view of science, controlled ______ (9) seems to take on primary importance.

UNIT 5

OBSERVATION AND HYPOTHESIS. REASONING AND INTUITION

Study the key words:

A phenomenon is something that is seen to occur or exist: it is **observed.**

Information obtained by making **observations** and making **measurements** of them is **data.**

Data is **collected or gathered.** It is then **processed** and **analysed** in a process **of analysis.** Unprocessed, unanalysed data is **raw data.**

Scientists look for meaning in data: they **interpret** it in order to reach **conclusions** or to **conclude** things. Data and other information form the **evidence** for these conclusions.

An experiment may be done to **test a hypothesis:** to see whether a suggested explanation for something is true.

Approaching scientific problems by **hypothesizing** about them and testing these hypotheses by observation and experimentation is often described as being **empirical.**

Language Note. The plural of **phenomenon** is **phenomena**. The form **data** can be used as a singular or plural. Sometimes **datum** is used for the singular. **Analyse** is spelled **analyze** in American English.

Exercise 1. Read and translate the following paying attention to the underlined words.

Scientists find chaotic dynamics useful in explaining observed phenomena such as the way populations grow.

Fleming made the initial observations, but Ernst Chain and Howard Florey developed the first antibiotic.

Rather than spend weeks cruising the ocean gathering data, a pair of researchers have scaled down the ocean and rebuilt it in their laboratory.

The report criticises NASA's insistence that all raw data from the EOSDOS satellites must be processed into a single standardised format.

The study of lifestyle threw up overwhelming evidence. 'When we analysed the data, we were able to conclude that smoking was emphatically a cause of lung cancer.'

One of the study's tasks is to test the hypothesis that 10 years of a diet very low in fat and high in fruits and vegetables will lower the incidence of breast cancer in women.

So it seems that galaxies weigh more than the sum of their visible parts. To solve the problem of this 'missing mass', scientists have hypothesised the existence of all sorts of mysterious 'dark matter'.

Geology has moved out of the \archive and into the laboratory. Students are now taught to collect data, design hypotheses, erect models and test them against more data.

Study some more key words:

If you **deduce** or **infer** something, you come to the conclusion that it is true because of other things you know are true.

Deduction and **inference** can refer both to a conclusion and to the process of reaching it.

Reasoning like this is **deductive** in its logic and may be described as **logical.**

If you **intuit** something, you feel that it is true even if you have incomplete or no evidence for it**. Intuition** can refer both to the feeling that something is true as well as the process of thinking in this way. Thinking like this is **intuitive**. An intuition is, informally, a **hunch.**

Something that is **counter-intuitive** does not seem reasonable.

Exercise 2. Read and translate the following paying attention to the underlined words.

‘Using and Applying Mathematics’ requires pupils to initiate mathematical investigations, to choose applications and to apply reasoning, logic and proof to their work.

Crick and Watson were working far more from logical reasoning about how genetics should work than from laboratory data about how it did work.

The eclipses revealed that Pluto's diameter is 2,300 km and Charon's diameter is 1,190 km. These figures were used to deduce the volume of each object.

In economics, hypotheses are generated by a process of logical deduction from sets of initial assumptions about the behaviour of consumers, producers, etc.

He referred to ‘those students who agree in thinking that the science of deductive economics is in its infancy’.

Wolpoff has been strongly critical of using DNA data to infer patterns of human history.

The enlarged areas of the brain are known to be involved in dealing with language. So a clear inference can be made. Too many brain cells in the right hemisphere, along with too much cross-talk between the hemispheres, is confusing the part of the left hemisphere that deals with language.

Some mathematicians are worried by a recent trend that permits 'theoretical' mathematicians to intuit ideas and not worry too much about their rigorous proof.

…his telling of the discovery of PAS, which reads more like a spiritual vision based on scientific intuition, rather than a methodical piece of deduction.

A scientist with no imagination would find it impossible to form new hypotheses against which to test results, and the intuitive leap that produces an explanation for previously inexplicable phenomena is arguably a form of applied hunch.

Another major theme is that of quantum theory. The puzzling nature of the theory is underlined from its earliest development, especially its counter-intuitive aspects.

Exercise 3. Which word is missing from each of these sentences: reasoning or intuition? (Each word occurs three times.)

1. Computers are better at mathematics, and at precisely specifiable scientific ________, than many humans are.

2. Experiments do not always need laboratories and equipment. With thought experiments, scientists can rely on pure ______ to make a discovery about nature, or to expose a paradox or inconsistency within accepted theories, without ever lifting a test tube.
3. 'My ________ told me that would be a problem,' he says. 'I had no evidence for saying that, just a gut feeling'.
4. White saw in the universities too little faith in _______, too much faith in the intellect.
5. The breakthrough came about, not through theory, but because Whitcomb, was, as another aeronautical engineer commented, 'a guy who just has a sense of ________ about these kinds of aeronautical problems. He sort of feels what the air wants to do.'
6. The most widely used aptitude tests are designed to measure your ability in verbal, numerical and diagrammatic ________ .

UNIT 6

THEORY AND THEORIES

Study the key words:

A **theory** is an idea or set of ideas designed to explain something. The related adjective is **theoretical.** People who produce and work on theories are **theorists** or **theoreticians.**

A **model** of a phenomenon, system, or process is a theoretical description of it, designed to aid understanding of how it works.

Language Note. **Theory** is also used as an uncount noun to talk about the theories of a particular area as a whole. **Model** is also used as a verb: scientists model phenomena, systems, and processes, for example on a computer.

Exercise 1. Read and translate the following paying attention to the underlined words.

If two alternative theories explain the same phenomenon, the simpler theory is the more useful.

Theory tells us that temperature measurements need to be repeated every five years to pick up warnings of real climate change.

A key feature of the scientific method is that the theorist can make a definite prediction of the value of some measurable quantity, and the experimenter can then go ahead and check it to some level of accuracy.

Whatever happens when S-L9 crashes into Jupiter in July, it will be duly recorded from sites around the world. The instruments and methods that will be used in observing the event are being designed to measure what theoreticians predict will happen.

Benson and Siebert used experimental data for ice and for pairs of water molecules in the gas phase to construct a theoretical model of liquid water.

Kevin Zahnle of NASA Ames Research Center has modelled the motion of meteorites travelling through the thick Venusian atmosphere.

Exercise 2. Put the sections of this *New Scientist* review of *Betting on Theories* by Partick Maher into the correct order.

DO SCIENTISTS PLAY DICE?

a. Dinosaurs were wiped out by a meteorite. The universe began in a big bang singularity. Electrons are quantum-wave particles. Species evolve through chance mutation and natural selection.

b. At first sight, the answers appear self-evident. A theory is deduced as a plausible explanation of facts derived from observation or experiment.

c. But how do scientists confirm their theories? When does a theory pass from suggestive hypothesis to unassailable truth? How do scientists choose between rival theories? Philosophers of science have been worrying away at these questions for years.

d. Emissions of greenhouse gases cause global climate change. Gravity is the local distortion of space-time by mass. All ravens are black.

e. Some scientific theories merely satisfy our curiosity; others form the foundations of understanding upon which our very survival depends or are the basis of billion-dollar industries.

f. Whatever their significance, scientific theories are absolutely fundamental to Western science-based culture and civilisation.

g. It gains credibility through the further accumulation of evidence confirming its expectations or predictions. It gains in credibility if the new evidence is not anticipated by rival theories… .

UNIT 7

PRESENTING FINDINGS

Study the key words:

Scientists usually **publish** their **results** or **findings** in **articles** or **papers** in scientific **journals.**

Articles and papers are **submitted** to journals for assessment before **publication**. Articles are submitted in a process of **submission.**

Exercise 1. Read and translate the following paying special attention to the underlined words.

Luigi Galvani, a professor of anatomy, discovered by accident that electricity could move frogs' legs. He published his findings in 1791.

The researchers are blocking publication of a paper by a rival group which reanalyses results generated by the Fermilab's Tevatron particle collider.

In the test, volunteers were presented with a child one metre tall and an adult 1.8 metres tall. The volunteer 'drivers' were asked to stop a safe distance in front of the pedestrian. Describing their results in the journal 'Perception', the researchers say that drivers were more likely to make errors when the image was a child's.

The Director of the Office of Scientific Integrity, Lyle Bivens, said Mr. Gallo was guilty of deliberate deception when he claimed in 1984 that he had grown the Aids virus without French help. He had overridden objections from fellow scientists before the article was submitted to 'Science' magazine. They wanted the French to be given more credit, but Mr. Gallo had deliberately deleted all references.

For some years it has been common practice for everyone working on an experiment to be named on all the papers published. As a result, the vast majority of authors on a given paper do not write a single word of it, make no direct contribution to the published results and most likely do not even read it until after submission.

Study some more key words:

Scientists may give presentations of their work at **conferences** or **congresses**: gatherings of scientists who meet to discuss their work. These and other types of scientific gatherings are referred to as **meetings**.

If someone **delivers, gives,** or **presents a paper** at a meeting such as this, they make an oral presentation.

Exercise 2. Read and translate the following paying special attention to the underlined words.

In a <u>paper</u> <u>presented</u> at an international <u>congress</u> on refrigeration in Montreal last year, Raymond Solomon from the American chip company Intel says that by the year 2000 a typical processor chip may have as many as 100 million transistors and generate 20 watts of heat.

Adults who survive childhood leukaemia after radiation therapy do not have an increased risk of having children with severe birth defects, say the American researchers who presented their findings to a <u>conference</u> on genetics held in Paris last week.

Barbara Brown <u>delivered</u> a paper at the Frankfurt <u>meeting</u> in which she showed that dental morphology in Homo erectus is little different in early African specimens nearly 2 million years old and Chinese specimens about 0.5 million years old.

Addressing the conference, Boris Turukhano <u>gave a paper</u> on storing information in holograms.

Exercise 3.Complete the sentences using appropriate grammatical forms of words from the article from *The Economist* below. (The number of letters in each missing word is indicated in brackets.)

1. Before an article is published in a journal, it is assessed by people who know about the subject in a process of ______ review. Someone who assesses an article in this way is a ________ (4 and 7).
2. Two informal expressions relating to the way that results are communicated unofficially are_____ _______ and ______ (6, 4 and 9).
3. If information is communicated to a large number of people, it is _____ (12).
4. If information is communicated when it should not be, it is ________ (6).
5. Information, perhaps about someone's private life, communicated informally, is _________ (6).
6. If something is formally approved, it is ______ (8).
7. A place for storing information that is no longer being actively used is an _______ (7).

BREAKING THE NEWS

Except in the jealous, competitive world of molecular biology, publication in a journal has become mere ratification of a result that has already been well disseminated and, as it were, pre-peer-reviewed. John

Maddox, the editor of Nature says that for physicists at least he is becoming little more than an archive for results everyone knows already.

Whereas the telephone had much less effect on research than on other professions, electronic mail has produced a sort of computer logorrhea. Everything from a result to a piece of gossip is passed through this ubiquitous, international rumour mill.

One effect of this fast and effective grapevine is that fads and fashions sweep through fields faster. … The pace has quickened, but the need to be first, on the grounds that no one remembers the second person to make a discovery, has not relaxed. As a result, scientists now sometimes announce their results at press conferences, short - circuiting the laborious – and leaky – system of peer review.

Paul Chu of the University of Houston, sent to a journal his announcement of a new superconductor with what many people think was a deliberate error in the chemical formula: ytterbium instead of yttrium. The incorrect formula did leak, perhaps via one of the referees whom the journal asked to assess the paper, proving the leakiness.

UNIT 8

DISCOVERIES AND BREAKTHROUGHS

Study the key words:

The **discoverer** of something is the person who finds it or becomes aware of it for the first time by **discovering** it or by **making a discovery.**

A discovery may be described as a **breakthrough.** People may say that it is **ground-breaking** or that it **breaks new ground.**

Scientists who are the first to do work in a particular area are **pioneers.** They are said to **pioneer** particular developments or do **pioneering work** in a particular area.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Wallace was the co-discoverer with Darwin of the process of evolution by natural selection.

Neuroscience stands today roughly where atomic physics was in 1919, when Ernest Rutherford discovered the nucleus, or where molecular biology stood in 1944 when Oswald Avery proved that genetic material was made of DNA.

An ink pen running at regular intervals over a paper chart was the hint that led Jocelyn Bell Burnell to make an astonishing discovery about the universe. Nobody yelled ‘eureka’. At the time, she was a 24-year-old PhD student at Cambridge, doing a routine monitoring job. But she rapidly acquired an international reputation for her discovery of the pulsar, a new type of star.

The sheet of material, about 5mm square, exhibits all the properties of a superconductor. However, Tomoji Kawai says that more tests are needed to confirm their findings. Japanese physicists hailed the discovery as a breakthrough.

In the 1940s, Griffin made the ground-breaking discovery, with his colleague Robert Galambos, that bats use radar navigation.

Where their report breaks new ground is in demonstrating that the longer-term climate shifts seen in earlier records are themselves marked by strong variations of less than ten years’ duration.

The team were well aware that the pioneers who studied nearby galaxies in the 1930s and 1940s mistook growing nebulae and star dusters for individual stars.

Hodgkin pioneered the use of computers to handle the complex mathematics involved in determining crystal structures by X-ray crystallography.

The general theory of relativity predicts that for any given mass, there is a critical radius known as the Schwarzchild radius, named after the pioneering work of Karl Schwarzchild in 1916. Once any mass is squeezed within the confines of its Schwarzchild radius, space-time is curved so tightly around the mass by its own gravity that it is cut off from the gravity outside and becomes a black hole.

Exercise 2. Read this review from the *New Scientist* of a book called *British Medicine in an Age of Reform* and answer the questions.

MEDICAL MYTHOLOGY

One of the problems with science and medicine is still the extent to which they have a mythology instead of a hystory. It is full of stereotyped pioneers breaking new ground and noble images of heroes, even heroines.

The purpose of this mythology is not hard to find. It clearly attempts to buttress the mythology that emerging professions like to have of themselves. In an excellent esay, Perry Williams looks at he mythology of nursing and promptly demolishes it in favour of a straightforward account of how modern nursing developed.

Most telling is his entirely convincing account of how the Florence Nightingale myth has worked against the interests of nurses. He replaces the image of the selfless, caring woman on the Crimean wards with that of the ruthless, determined reformer of hospital building, administration and standards of hygiene. "The lady with the lamp" becomes the woman holding the new broom and the bucket of disinfectant.

1. Is 'stereotyped' used showing approval?
2. If X buttresses Y, does it support Y?
3. Is an emerging profession one that has been recognized for a long time?
4. Which of these things can also be demolished? a) arguments, b) meals, c) houses.
5. Does 'straightforward' indicate approval?
6. If an account is telling, is it revealing?
7. Why does this myth work against the interests of nurses?
8. If someone reforms something they bring about c__________s.
9. What do new brooms do, metaphorically speaking?

PART II

PHYSICS

UNIT 1

PHYSICS AND PHYSICISTS

Study the key words:

Physics is the study of **matter:** the substances out of which the universe is made, and **forces:** the interactions between them.

People working in physics are **physicists**.

Exercise 1. Read and translate the following paying special attention to the underlined words.

He does not mention the simplest world, which would consist of nothing whatsoever. There would be no space, no time, no laws of physics, and perhaps no mathematics and logic. To put it another way, there would be no universe.

More than three centuries after Isaac Newton proposed his theory of gravity, physicists are still not sure how strong the force is.

Physicists confront the interesting idea that God, in the beginning, created matter and a few laws of physics, and then pushed it all off into space, saying, ‘Goodbye and good luck’.

Exercise 2. The words in the box often come in front of “physics”. Find combinations that refer to the study of:

1 the basic components of matter (2 expressions),
2 physics as a science based on calculation,
3 physics as a science based on observation,
4 the physics of the atom nucleus,
5 physics for the 300 years before Einstein,
6 solid matter.

	experimental	
theoretical		quantum
	physics	
solid-state		Newtonian
particle	nuclear	

Exercise 3. Now match the two parts of these extracts.

a. Paul Dirac was one of the founders of quantum physics, which was to alter people’s perception of the world, throwing up predictions that defied common sense.
b. … W and Z bosons. These two fundamental particles are crucial to the standard model of particle physics,
c. Superconductivity – the disappearance of electrical resistance at extremely low temperatures –
d. Einstein’s theory of relativity rules out such behaviour, because the velocity of the particle must become greater than that of light.
e. Within hours of the test Paul Vericel, director of the Centre d’Experimentation du Pacifique, said, ‘We are not testing bombs.
f. What about the Cambridge physicist who, earlier this century, was approached by a young man who wanted to go into theoretical physics.
g. This century has seen more of a separation between theoretical.

1. ‘No future in it’, said our chap. ‘It’s all been sorted out. We now understand the universe pretty well.’
2. and experimental physics, with the theoreticians winning most of the prizes.
3. Newtonian physics provides no such limit on the maximum speed of a particle.

4. is the single most tantalising item of ignorance in solid-state physics.
5. the underlying theory of forces and matter that physicists now generally accept.
6. This physics, describing the very small, initially stole the limelight from Einstein's relativity, the physics of the very big.
7. We are testing nuclear physics.'

UNIT 2

MATTER. STATES AND PROPERTIES

Study the key words:

The basic types of substances into which matter can be broken down are the **elements.** Chemical combinations of elements are **compounds.**

Elements are characterized by the structure of their **atoms.** The related adjective is **atomic.** The nature of an element is determined by its **atomic structure;** elements are listed in the **periodic table** according to their atomic structure.

Atoms combine to form **molecules.** The related adjective is **molecular.** The nature of a combination of atoms is determined by its **molecular structure.**

Exercise 1. Read and translate the following paying special attention to the underlined words.

Mendeleyev left gaps in the periodic table for the elements he expected to be discovered.

Each chemical element had its number and fixed position in the table, and from this it became possible to predict its behaviour: how it would react with other elements, what kind of compounds it would form, and what sort of physical properties it would have.

These special properties arise from the material's unique atomic structure. Diamond is a pure form of the element carbon. Its atoms are packed tightly together in a regular arrangement in which each one is surrounded by four others.

There are various ways to make atoms tangible. For chemists, the easiest thing is to tell a computer the positions of all the atoms that make up a molecule. The computer can then generate a three-dimensional likeness of the molecule.

Physicists and chemists still do not completely understand how molecules in these materials behave, but finding out would be a big step towards understanding the relation between their structure and dynamics. To explore solids and liquids at the atomic and molecular level, we need to look inside them.

Kekule's sudden revelation of the molecular structure of benzene. What came to him as he sat dozing beside the fire, was the image of a snake biting its own tail, which gave him the idea that the structure could be ring-like instead of string-like.

Exercise 2. One key word from this section is missing from all these sentences. Which is it and what is its grammatical form?

The hard stuff. Visible light can cause ______ to react with each other. Shorter wavelengths reason oil and water will not normally mix is that oil _______ (and things which dissolve in oil) are more attractive however. Other scientists have been trying to join the ______ together. A strong, light material made from fused you sniff glass of wine, about 10m trillion odorous ______ get up your nose. Your brain senses a smooth, region of India. Chemists know the structure of these ______ and understand fairly well how they affect quality. Ozone is an unstable form of oxygen gas with _____ made up of three oxygen atoms rather than the usual problem in astronomy. Kroto believed that these _____ must be formed in the atmospheres of giant carbon.

Study the key words:

Matter exists as **solids, liquids**, and **gases**. These are its basic possible **states**. There are others, as the first example in Ex. 1 indicates.

A space where there is no matter in any state is a **vacuum**.

The ways in which a substance behaves in different circumstances are its **properties.**

Exercise 3. Read and translate the following paying special attention to the underlined words.

A new state of matter called a Luttinger liquid has been found by three teams of physicists in the US. In this state, electrons become linked, moving together like carriages in a train, rather than independently as they normally do.

To most people a material is a mixture of properties and substance; glass is transparent and made of sand. To scientists, materials are characterised by their microscopic structure; glasses are solids with no internal structure to the arrangement of their atoms. In this they are more like liquids than other solids.

The xenon atom is held onto the surface only by very weak chemical bonds. This means that the whole process has to take place at very low temperatures so that thermal vibrations do not bounce the xenon around, and in a vacuum so that gas molecules do not disturb it.

Exercise 4. Choose the correct alternative to complete these statements. (In one case, two of the alternatives are correct. In all the others, only one is correct.)

1. If you can see very clearly through a material, the material is
   a. translucent b. translucid c. transparent
2. If you cannot see through a material, it is
   a opal b opalescent c opaque
3. A substance that dissolves in liquid is
   a dissolute b dissolvable c soluble
4. A liquid that dissolves substances is a
   a solvent b soluent c solutent
5. A material that is hard but breaks easily is
   a battle b brittle c bristle
6. If a material bends easily, it is
   a bendible b flexible c flectable
7. A material that does not bend easily is
   a rancid b rigorous c rigid
8. A metal that can easily be beaten into new shapes is
   a beatable b malleable c mullible
9. A material that conducts electricity is
   a conducive b conductive c conductor
10. A material that catches fire easily is
    a flameable b flammable c inflammable

Exercise 5. Read the examples and complete the commentary using the key words.

Each silicon atom is attached to four oxygen atoms in a tetrahedron. This produces a molecular structure which is not only remarkably stable under chemical attack but is also mechanically strong and has a high melting point. These properties are all displayed by silicon dioxide (SiO_2), variously known as silica, sand or quartz.

If the pressure of air above the water is reduced, its boiling point also decreases. If it is put in a vacuum, its boiling point is reduced to near zero degrees C.

At room temperature and pressure, hydrogen is a gas with two atoms bound together to form a molecule: H2. But squeezing it and then cooling it changes things. Like most gases, hydrogen first liquefies and then solidifies.

In 1984, Canon started using amorphous silicon as a coating on the photosensitive drums of its copying machines. To lay down the coating, it allows silicon vapour to condense on the metal.

Water must have circulated around the planet, evaporating from the oceans and falling as snow in the polar regions.

Within hours of its entry, the probe melted down and finally vaporised in the intense heat of Jupiter's lower atmosphere.

The temperature at which a solid becomes a liquid is its __________ and the point at which a liquid becomes a gas is its ______ _______ .
When a gas or liquid becomes a solid, it ________ .
When a gas or a solid becomes a liquid, it _______ .
When a substance becomes a gas or ______ , it ______ or _____ ; if it returns to its previous state, it _______ .

UNIT 3

MASS AND ENERGY

Study the key words:

The **mass** of a given amount of matter is perceived as its weight, or in terms of its **inertia** its reluctance to move if stationary, or to change its motion if moving.

The speed of an object is its **velocity**. The **momentum** of an object is its velocity multiplied by its mass.

The **acceleration** of an object is the rate of increase in its speed when it **accelerates**.

The study of the motion of object is **mechanics.**

Newtonian mechanics relates to ordinary objects travelling relatively slowly, at much less than the speed of light.

Quantum mechanics or **quantum theory** relates to the behaviour of objects the size of atoms or less.

Exercise 1. Read and translate the following paying special attention to the underlined words.

What is mass? On an everyday scale, it seems easy enough to understand. The more matter there is in something, the heavier it is. But at smaller scales mass is not really understood at all.

The most intriguing problem centres on inertia - the property of matter that makes heavy things hard to get moving, but once moving, hard to stop.

The rotation of any object is measured in terms of angular momentum, which depends on the linear momentum (the object's mass multiplied by its velocity) and the distance of the object from the centre of rotation.

The resistance to motion, or inertia, we feel when we try to push an object is a result of trying to make it accelerate relative to the average distribution of all the matter in the Universe.

People are notoriously poor at estimating an object's acceleration.

As Werner Heisenberg showed almost 70 years ago, the mechanics of the subatomic world meant that an uncertainty is attached to any measurement of physical properties such as energy.

In classical physics, using the laws of Newtonian mechanics, we can calculate the exact path taken by the ball in going from A to B. We can even calculate the position and speed of the ball at any instant while it was in flight.

Quantum mechanics rules in single atoms, whereas notions like electricity conduction work in groups of millions of atoms.

Quantum theory proves, or allows for the probability, that time travel is possible even if we will not have the technology for some time.

Exercise 2. Complete this article from the *New Scientist* with the words listed (*a* and *c* twice each, and *b* four times).

a accelerate b inertia c velocity

THE TROUBLE WITH INERTIA

Inertia is so familiar that its attributes seem beyond question, but they have perplexed scientists of the calibre of Einstein and Richard Feynman.

If an object is at rest, or moving at constant ______ (1), its ______ (2) remains hidden. But try to _______ (3) it and ________ (4) suddenly rears its head, fighting against the change in _______ (5). This is summed up in Newton's second law of motion: F=Ma, force equals ________ (6) times acceleration.

But where does the ________ (7) come from? Einstein believed that it was somehow induced in objects whenever they _______ (8) relative to the rest of the universe, though quite how this interaction worked he never made clear.

Study some more key words:

Energy is the power that enables a system or machine to work.

Energy shows itself in different ways: for example, in **kinetic energy**, the energy of moving objects; and in **thermal energy**, in the heat produced by burning fuels such as coal or gas.

When energy is lost or **emitted** from a source, there is **radiation**.

Exercise 3.Read and translate the following paying special attention to the underlined words.

As Einstein realised early this century, mass is a form of energy: the two are interchangeable. So the masses of atoms and nuclei depend not only on the total mass of their constituents, but also on the energy that binds them together.

Gas is more efficient: 55% of its thermal energy can be converted into electricity. With coal, the ratio is one-third in older stations, 50% in ultra-modern ones.

The kinetic energy of a mountain-sized object travelling at 25 kilometres per second is enormous.

Electrons lose energy in the form of electromagnetic radiation as they travel on curved paths. The higher the energy of the electrons, or the tighter the curve, the more radiation they emit.

Exercise 4. The word 'energy' has been omitted five times from this *Independent* article. Where does it go?

MASS IS ENERGY

A fast particle or spaceship will appear to get distorted in shape as an outside observer watches it speeding along. Under normal conditions, a spaceship just needs to apply more thrust to go faster. But if it is already at very high speeds, a curious effect takes over: the velocity can't go much higher than it is already, yet the being poured in can't just go away. What happens? The poured in ends up augmenting the solid mass of the spaceship itself.

This should sound suspiciously familiar. The mass growth is pretty small at first, just a tiny fraction of the poured in - what you get by dividing by c^2, where c^2 is the square of the speed of light. Turn that equation around and you get the more familiar form, that equals mass times c^2,or $e=mc^2$.

Exercise 5. Read the following passages and do the exercise below.

ENERGY SOURCES

Coal. It was coal that produced the energy to run the factories of the first big industrial countries, such as Britain and Germany. Coalminers worked long hard hours in cold dark coalmines to bring this black rock above ground. They called it black gold.

Oil and **gas**. Texas, Saudia Arabia, Kuwait and Venezuela; these are only a few of the places where oil had been found. Today, big oil companies still spend millions of dollars looking for oil, and when they find it, a new oil well is started and the company makes even more millions. Sometimes they don't find oil underneath the earth. They find gas. But gas, too, can be used for heating and cooking.

Nuclear or **atomic** energy. It is incredible to think that from the nucleus of the atom – one of the smallest things in the world – can come enormous amounts of energy. This energy, which is called nuclear or atomic energy, can either be controlled in nuclear power stations to create electricity for millions of homes, or it can be used in war to destroy millions of homes.

Hydroelectric power. Water from fast running rivers is another source of energy. By building large dams to control the water, millions of kilowatt of power can be produced. Countries like Sweden and Norway, get most of their electricity from hydroelectric power.

Solar and **wind** energy. In the future, much of our energy may come from the sun. In some countries, solar collectors on the roof can already create enough solar power to heat and provide electricity for a house in both winter and summer. One day we may also see small wind mills on every roof. Even a small wind can provide enough power to run lights and most electrical machines in the home.

Now change the words in dark print to make the sentences true, according to the information in the passages.

1. The colour of a piece of coal is **gold**.
2. Sweden and Norway produce a great deal of **solar energy.**
3. There are many **water** wells in Saudi Arabia.
4. Another word for atomic energy is **hydroelectric** energy.
5. When oil companies look for oil they sometimes find **coal** instead.
6. **Solar collectors** can be used to catch the power of the wind.
7. A **nuclear power station** is used to stop water in fast-running rivers.
8. **Hydroelectric** power can be used in war to kill millions of people.

UNIT 4

FORCES

Study the key words:

A **force** is an effect of attraction or repulsion between two bodies or particles.

The four forces are:

- gravity or gravitation, the attraction of objects towards each other because of their mass;

- electromagnetism, electrical effects binding matter or pushing it apart;

- the **strong interaction** or **strong nuclear force**;

- the **weak interaction** or **weak nuclear force.**

These last two, sub-atomic, forces are explained in the examples in Exercise 1.

Physicists are attempting to explain the latter three of these forces in **grand unified theories, or GUTs.**

Exercise 1. Read and translate the following paying special attention to the underlined words.

The less dense the universe, the less the <u>force</u> of <u>gravity</u> will tend to slow its expansion as time goes by.

A falling apple is one thing, the gracious progress of a distant planet quite another. That, at least was the situation before Newton came along with universal <u>gravitation.</u> The glory of his idea was that it explained these two phenomena in terms of one theory.

At the US Open tennis tournament this week, a system that may finally end disputes over line calls will be put to the test. Unlike existing line sensors, which rely on a ball breaking a laser beam, the new system is based on <u>electromagnetism</u>. Tennis balls impregnated with 5 grams of iron powder are detected by electrodes buried beneath the lines of the court.

Before 1932, physicists knew of only two forces of nature, gravity and electromagnetism. Protons and neutrons in nuclei are now understood to be held together by another force, the <u>strong interaction.</u>

Gauge theories describe forces in terms of 'gauge bosons', particles which transmit forces between other particles. In the 1960s, gauge theorists began to have some success in their understanding of the <u>weak interaction,</u> the force which occasionally turns a neutron into a proton, an electron and a neutrino.

The search for proton decay was sparked off in the 1970s by the grand unified theories which attempt to explain at a single stroke the common origins of the strong and weak nuclear forces and electromagnetism. According to these theories, the proton, and consequently all matter, cannot be immortal.

Exercise 2. Read this article from *The Economist* and complete it using the words listed. (*a* occurs four times, *c* three times, *b* and *d* twice each.)

a force   b forces   c particle   d particles

THE BIG PICTURE

…Within a second of creation, the universe reached a state about which there is plenty of agreement. It was small, immensely hot and filled with a dense soup of the fundamental ______ (1): quarks (which are heavy) and leptons (which are light). It is this state that fascinates ____ (2) physicists. Their passion is the unification of ______ (3).

Today's universe contains four observable ________ (4): the electromagnetic and gravitational ones, which work over long ranges, and the weak and strong nuclear ones, which work only locally.

Inside _____ (5) accelerators it is possible to show that the weak ______ (6) and electromagnetism are two parts of a single 'electro-weak' ______ (7). Above a certain energy, the difference between electromagnetism and the weak _____ (8) vanishes. The next aim ______ (9) physics is to find a theory that unites the strong ______ (10) with the electro-weak interaction.

Such a grand unified theory (GUT) would describe phenomena that take place at energies unobtainable in any accelerator. It would also describe the behaviour of the big bang. So one way to sort out the various GUTs is to see which can be used to tell believable and, ideally, testable stories about the big bang.

UNIT 5

PARTICLES

Study the key words:

Atoms are made up of **particles** with different characteristics.

At the centre of an atom is its **nucleus**, made up of particles called **protons** and **neutrons.**

The atomic number of an element is the number of protons in each atom nucleus. Its **atomic weight** is a measure of the atom's mass.

Different **isotopes** of an element are atoms of that element with the same number of protons in their nuclei but different numbers of neutrons.

Surrounding the nucleus are particles called **electrons**. Atoms that have gained or lost electrons have been **ionized** and are **ions**.

Interactions between particles depend on their electric **charge**: the way they are **charged**, positively or negatively.

Language Note. The plural form of **nucleus** is **nuclei. Ionize** is also spelled **ionise** in British English.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Nature provides 92 elements, ranging from hydrogen with one positively charged proton in its nucleus, to uranium, with 92 protons and 146 neutrons, particles with more or less the same mass as a proton, but no electric charge.

Atoms can be thought of as miniature solar systems, with a nucleus at the centre and electrons orbiting at specific distances from it. Electrons, being negatively charged, usually orbit as close as possible to the positively charged nucleus.

If you make atoms hot enough, they shed their electrons and become ions; the ions and electrons produce a plasma, the sort of fire that is seen in the sun.

The temperature at the centre rose above 2000 degrees C, breaking up the molecules of hydrogen and then ionising both the hydrogen and helium atoms.

Tin has been found floating in the space between the stars. The element, which has atomic number 50, is by far the heaviest ever found in he interstellar medium.

Because these particles are of low atomic weight, X-rays pass straight through them. Uranium atoms come in two types; there is a heavy isotope, uranium-238, and a light isotope, uranium-235.

Exercise 2. Read this article from the *New Scientist* and answer the questions.

ELEMENTARY, MY DEAR MENDELEYEV

Chemistry without the periodic table is as hard to imagine as sailing without a compass.

As news of his remarkable accomplishment spread, Mendeleyev became something of a hero, and interest in the periodic table soared. In all, Mendeleyev predicted 10 new elements, of which all but two turned out to exist. He later proposed that the positions of some pairs of adjacent elements be reversed to make their properties fit into the periodic pattern.

He suggested swapping cobalt with nickel and argon with potassium, which he believed had been wrongly placed because their atomic weights were different from the values chemists had determined.

It took until 1913, some six years after Mendeleyev had died to clear up this ambiguity. By then chemists had gained a much better understanding of the atom, and in that year, Henry Moseley showed that the position of an element in the table is governed not by its atomic weight but by its atomic number.

The atomic number of an element defines the number of protons in its atomic nucleus, which in a neutral atom is equal to the number of electrons surrounding it. Moseley proved that the characteristic frequency of the X-rays generated by a particular element is directly related to its atomic number.

One source of confusion for Mendeleyev was that the atomic weight that chemists measure is an average of the slightly different weights of all the different isotopes of an element.

Mendeleyev's intuition had been right, however, and atomic number was used successfully to assign a place in an expanded table for the noble gases - helium, neon, argon, krypton, radon and xenon – which had been discovered in the 1890s.

1. How many of the new elements predicted by Mendeleyev are now known to exist?
2. Mendeleyev suggested that cobalt and nickel should change p_____s in the table.
3. If X is governed by Y, is it dictated by Y?
4. If X is characteristic of Y, is it typical of Y?
5. These gases are called 'noble' because they were a) discovered by aristocrats, or b) originally thought not to form parts of compounds and are thus ‘superior’ to other gases.

Study some more key words:

The particles making up atoms are often referred to as **elementary particles, fundamental particles, or sub-atomic particles.**

Sub-atomic theory is concerned with particles and **waves**. A wave is a disturbance that travels from one place to another through matter or space.

Quantum research depends greatly on **particle accelerators,** machines that accelerate particles to very high velocities so that their properties can be analysed. Particle accelerators are also referred to by journalists as **atom smashers.**

Particle accelerators are used to study not only matter, but also the **antiparticles** that make up **antiatoms,** the basis of **antimatter,** as the example explains.

Exercise 3. Read and translate the following paying special attention to the underlined words:

The neutron was first identified by James Chadwick at the Cavendish Laboratory, Cambridge, in 1932. It was the first electrically neutral elementary particle to be identified; previously, only the positively charged proton and negatively charged electron were known.

Physicists are homing in on yet another of the fundamental particles of matter. In what may be the largest single calculation ever performed by a computer, they have worked out the properties to be expected of objects known as “glueballs”. As their name implies, glueballs are the things that stick other particles together.

There are various pairs of properties which quantum mechanics says cannot both be subjected to precise measurement at the same time. One such pair is the position and velocity of a sub-atomic particle. If, for example, you have a good fix on its velocity, then you cannot know where it is, not because you are not clever enough, but because its position is indeterminate.

Quantum theory says that light is simultaneously a wave and a stream of particles called photons.

Atom smashers of ever-greater power have produced a theory, the Standard Model, which works well in explaining the nature of matter and the forces that hold it together.

The LEP is one of the most powerful particle accelerators in the world. Housed in a gigantic circular tunnel, it spans the border between Switzerland and France. Its powerful magnets keep high-energy beams of electrons and positrons flying around the ring before smashing them into one another. Physicists then pore over the debris of these collisions in search of the fundamental building blocks of the Universe.

The time has come for physicists to take a step up from antiparticles to antiatoms. They are looking at ways of bringing the antimatter of counterpart of electrons, called positrons, and antiprotons close enough for long enough to form stable antihydrogen atoms.

Exercise 4. Read the article from *The Times* below and in it find equivalent expressions to the numbered expressions listed. (The words occur in the same order as the questions. The number of letters for each word is given in brackets, along with the paragraph it occurs in.)

1 things that look exactly like other things (13; paragraph 1),
2 matter or material (5; paragraph 1),
3 describing something that looks exactly the same as something else, but with reversed symmetry (6-5; paragraph 2),
4 common (11; paragraph 3),
5 features (15; paragraph 3),
6 identical to (17, 4; paragraph 4),
7 destroyed (11; paragraph 5).

SHADOWY DOPPELGANGENGERS

Physicists at the European Particle Physics laboratory in Geneva have created anti-atoms, shadowy doppelgangers of hydrogen, the stuff of which the universe is mostly made. These fugitive anti-atoms lasted the barest millionths of a second, and could only be detected by the process of smashing them to pieces once more and observing the wreckage.

The first suggestion that matter might exist in a kind of mirror-image form came from the physicist Paul Dirac more than 60 years ago. He predicted the existence of the positron, a particle identical with the electron – but with a positive rather than a negative charge.

It turned out that positrons were really quite commonplace, being formed by the decay of some radioactive isotopes and the impact of cosmic rays on the atmosphere. Physicists found they could be made by bombarding materials with electrons, and a family of anti-particles followed – anti-protons, anti-neutrinos and others. They have the same mass as their opposite numbers but the electrical charges and other characteristics are reversed.

The one particle which is indistinguishable from its anti-matter particle is the photon, the particle of light. This means that a world made of anti-matter would appear no different to us from the one made of real matter.

It is possible, if unlikely, that there are objects in space – whole galaxies even – that appear outwardly normal but are not made of matter but anti-matter. A spaceman visiting such an anti-world would be instantly annihilated, as his matter met an equal mass of anti-matter.

All that would be left would be a burst of gamma-rays, because matter and anti-matter cancel each other out, their mass converted to energy according to Einstein's famous equation, $e=mc^2$.

UNIT 6

NUCLEAR FISSION AND NUCLEAR FUSION

Study the key words:

Things relating to the nucleus of the atom are **nuclear.**

Nuclear fission releases energy by breaking down the nucleus of uranium or plutonium atoms in a **chain reaction**. This is sometimes referred to, especially by journalists, as **splitting the atom**.

The minimum amount of uranium or plutonium required for such a reaction is the **critical mass.**

Fission is the source of energy used to generate electricity: **nuclear energy** or **nuclear power**; and of bombs and other arms: nuclear weapons.

Radioactivity is the emission by **radioactive** substances of energy in the form of harmful rays.

The atoms of radioactive elements **decay** to produce other elements. The time it takes for half of a particular quantity of a radioactive material to decay in this way is its **half-life**. Half of the remaining quantity will decay in the following period of the same duration, and so on.

Radioactivity spreading after the explosion of a nuclear weapon is **fallout**.

Exercise 1. Read and translate the following paying special attention to the underlined words.

In the space of a few months, the number of known fundamental particles doubled from two to four; the atoms of the lighter elements, far from being indivisible, were broken open at will; and powerful new machinery for both producing and detecting the particles came into use. These discoveries gave nuclear physics a new impulse.

Scientific knowledge is value-free. Which means that just because you know how to split the atom, it doesn't necessarily follow that you must kill people with an atom bomb.

Splitting the atoms all at once might not be so hard. The neutrons given off when the atoms came apart - a process called fission - could split more atoms in turn. In a lump the right size and shape - a critical mass - every neutron produced would stand a good chance of hitting and splitting another nucleus. The chain reaction would lead, in the right circumstances, to a vast explosion.

If we could find an element which is split by neutrons and which would emit two neutrons when it absorbed one neutron, such an element, if assembled in a sufficiently large mass, could sustain a nuclear chain reaction. The chain reaction would give rise to a potentially huge amount of energy.

France now relies on nuclear energy for 75% of its electricity, compared with 19% in America, 28% in Japan and 33% in Europe as a whole.

It is hard not to believe that if the cash thrown at nuclear power had been put into almost any other technology, it would have eventually produced something commercially viable.

After the blast at Hiroshima, Rotblat and a group of nuclear physicists began to advocate control of nuclear weapons.

The Nirex repository will hold plutonium whose radioactivity will scarcely diminish over 10,000 years.

Acord learnt that he could capture fast neutrons and use them to transmute the nuclear waste product technetium-99, a highly radioactive gamma emitter that has a half-life of 212,000 years, into ruthenium-100, which is stable.

Radiocarbon dating estimates the age of a sample of organic material from the amount of radioactive carbon-14 it contains. The older a sample, the more time its carbon-14 has had to decay (half the carbon is lost every 5,730 years) and the smaller the proportion of this isotope compared with the two stable isotopes, carbon-12 and carbon-13.

Americium is highly radioactive, emitting alpha particles and gamma rays as it transmutes to neptunium. It has a half-life of 430 years; in other words, half of the sample will undergo radioactive decay during this time.

The plutonium fission bomb has left few traces. A 1,200-foot crater has long since been filled in and radioactive fallout removed by the Atomic Energy Commission.

Exercise 2. The words in the box often come after 'nuclear'. Divide them into two groups of six expressions each, those that relate to:

1 nuclear energy
2 nuclear weapons

stations
plant test
disarmament industry
proliferation nuclear fuel
waste reactor
warhead arsenal
explosion

Study some more key words:

Nuclear fusion is the combining of two lightweight atomic nuclei at very high temperatures to produce energy.

Some physicists say that this can be done at low temperatures in a process of **cold fusion**.

Exercise 3. Read this article from *The Economist* and complete each in the table with 'yes', 'no', or 'not mentioned'. (The first line has been completed for you.)

AT THE GOING DOWN OF THE NUCLEAR SUN

Nuclear fusion promises to be an exciting and elegant way to generate power, but it is no more of a panacea than nuclear fission has been.

Although both are nuclear reactions, fusion and fission are very different beasts. Small atomic nuclei will give up energy if clumped together. That is fusion. Large nuclei will give up energy if broken apart. That is fission. All elements except iron, which is perfectly happy to stay as it is, can in principle be made to release energy in one or other of these ways. In practice, fusion works best with very light nuclei, fission with very heavy ones.

Some heavy nuclei are unstable. If you hit one with a neutron, it will break up into smaller nuclei and more neutrons. These neutrons can go on to hit other nuclei in turn. Get enough such nuclei close together and the knock-ons will produce a chain reaction. Unfortunately, the heavy elements required, uranium and plutonium, normally are expensive and rare, and the new nuclei produced are radioactive and dangerous. Worst of all the chain reaction can spin out of control, leading to a meltdown.

Fission is reasonably simple to start. The first fission reactor, built on a squash court in Chicago under the guidance of Enrico Fermi, worked first time. But - witness Chernobyl - it can be hard to stop. Fusion, on the other hand, is hard to get started. While fissile nuclei are eager to fall apart, those which might fuse are loath to get close enough together to do so.

To bring two light nuclei close enough to fuse means overcoming their natural repulsion They have to be moving fast, which means they have to be hot - hence the term thermonuclear to describe fusion reactors and their untamed relations - hydrogen bombs. Getting things hot enough while keeping them under control is hard. But if you can arrange it, the result will be more attractive than a fission reactor in a number of ways.

The first has to do with the fuel. First-generation fusion reactors will use a mixture of deuterium and tritium, heavy forms of hydrogen that contain extra neutrons. Deuterium is plentiful in the oceans. Tritium can be manufactured by splitting lithium nuclei in half with neutrons, which is easily done in most sorts of nuclear reactor, and could be done in a fusion reactor. So fuel is not much of a problem.

Nor is the exhaust. The end product of a fusion reaction is not a pile of radioactive muck. It is helium, a harmless gas.

	Fission	**Fusion**
Works well with light elements	no	yes
Works well with heavy elements		
Nuclei produced in reaction are dangerous		
Reaction is easy to start		
Reaction is easy to stop		
Fuel is easily obtainable		
Produces radioactive waste		

UNIT 7

SOLID STATE PHYSICS

Study the key words:

The study of the properties of solids is **solid-state physics.**

Solids studied include **crystals,** solids whose molecules are in regular geometrical shapes, and **alloys**, combinations of different **metals**, such as copper and tin in bronze.

The adjective relating to crystal is **crystalline** and the adjective relating to metal is **metallic.**

A substance that conducts electricity is a **conductor**. One that does not is **an insulator**. (Substances can also be conductors and insulators in relation to heat.)

One that conducts electricity without resistance is **a superconductor,** possessing the property of **superconductivity**.

Exercise 1. Read and translate the following paying special attention to the underlined words.

The effect of increasing funding for particle physics is to starve other, perhaps more immediately useful areas of physics. Solid-state physics has paid dearly for this.

If a molten metal alloy can be cooled quickly enough, it can freeze into a solid before it has a chance to crystallise properly. Unlike normal metals or alloys, the resulting amorphous alloys have no crystalline structure on a scale of more than a few hundred atoms. They thus can have unique electronic and magnetic properties, but are hard to make because cooling has to be very rapid.

Pauling developed a method for predicting the way in which atoms might arrange themselves to give a crystal structure.

Helium is a non-metal, although the ending '-ium' is usually reserved for metallic elements.

In an ordinary conductor such as metal, vibrations of the atoms impede the flow of electrons that forms an electric current.

Diamond conducts heat nearly four times better than copper, yet it is a good electrical insulator.

A superconductor is a material that has no electrical or thermal resistance. Useful stuff.

French researchers claim to have achieved superconductivity at the relatively high temperature of 250K, or about the temperature of a cold night in Siberia.

Exercise 2. Put the sections of this article from the *New Scientist* into the correct order.

WONDERFUL PROPERTIES

a. Superconducting materials change from a normal electrical conductor to a superconductor at some critical 'transition temperature', which is usually well below ordinary temperatures.

b. The situation changed dramatically in 1986 with the discovery by Bednorz and Muller of superconductivity near the relatively high temperature of 30K in a metal oxide, lanthanum barium copper oxide.

c. No one understood why superconductivity should happen at all until 1957, when John Bardeen, Leon Cooper and Robert Schrieffer at the University of Illinois showed how it could happen. They envisaged a state

in which the phonons – the vibrations of atoms in the solid – behaved in a curious way.
d. Instead of scattering the conduction electrons, at a particular temperature – and hence energy – the phonons would cooperate by allowing electrons to form special ‘Cooper’ pairs that could transport electrical charge without resistance.
e. But until 1986, the highest transition temperature was about 23K, for the niobium-germanium alloy Nb_3Ge, which is well below the boiling point of liquid nitrogen (77K), the lowest temperature for most practical applications.
f. A Dutch physicist, Heike Kamerlingh Onnes, discovered superconductivity in 1911 in frozen mercury at a transition temperature of 4.15K and since then dozens of metals and alloys have been found to be superconducting.
g. This was followed by the discovery of cooper oxide ceramic materials with an even higher transition temperature of 125 K. Apart from their relatively high transition temperatures, these materials are remarkable because ceramics are usually excellent insulators.

UNIT 8

SPACE AND THE UNIVERSE. THE COSMOS

Study the key words:

Space or **outer space** is the area beyond the earth and its atmosphere, and the objects it contains.

The **universe** is space viewed as a whole, and the matter and energy in it.

The study of objects in space is **astronomy**; its specialists are **astronomers.** The related adjective is **astronomical**.

Astrophysics is the application of physical theories to explain the nature and behaviour of phenomena in space. People doing this are **astrophysicists.** The related adjective is **astrophysical.**

One model of the origin of the universe is the **big bang** theory: the hypothesis that the universe began with the explosion of infinitely dense matter several thousand million years ago and that it has been expanding ever since.

Another is the **steady state** theory.

One issue in the big bang theory is the rate of expansion of the universe, or the **Hubble constant**.

Measuring the **red shift** of distant objects is a way of determining the speed at which they are moving away from us: there is a tendency for light to move to the red end of the spectrum as the speed of movement away from the observer increases.

The study of the origin, nature, and evolution of the universe is **cosmology**, and people undertaking it are **cosmologists.** The universe is sometimes referred to, especially in this context, as the **cosmos**.

Related adjectives are **cosmological,** and in some contexts, **cosmic. Cosmic background radiation** is radiation emitted throughout the universe and thought to have originated with the big bang.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Mankind is set to boldly step up the search for life in <u>outer space</u> with the launch of a new mission to identify Earth-like planets that may support forms of life.

There follows a brief account of <u>astrophysical</u> methods by which the age of the <u>Universe</u> has been estimated.

… the central problem of modern <u>astronomy</u>: the fact that although <u>astronomers</u> see only those things that give off light or some other radiation, theory and circumstance tell them that this universe is dominated by matter which makes no such display.

<u>Astrophysicists</u> work in a laboratory the size of the whole universe, where matter can be studied under extreme conditions not available on earth.

Astronomers need distance indicators to work out how fast the universe is expanding, and from this, how old it is. To describe the rate of expansion of the universe, astronomers use a quantity called a <u>Hubble constant</u>, which is expressed in kilometres per second per megaparsec. Imagine two galaxies, one of them one megaparsec farther away from the Earth than the other. If the Hubble constant was 80, the more distant galaxy would be moving away from us 80 kilometres per second faster than the nearer one. In the same way, the Hubble constant gives the time that has elapsed since the <u>big bang</u>. A rapidly expanding universe would have been able to reach its present size faster than one that had been expanding more slowly.

In the 1920s, Edwin Hubble observed that distant galaxies look redder than nearby ones. The `<u>red shift</u>` means that galaxies are receding, and the light from them is being stretched out. The farther the galaxy, the redder its light, so the faster it is receding.

In 1948, Hoyle and his two co-propounders of the steady-state theory of cosmology, Bondi and Gold proposed that the Universe had no beginning and would never end; as it expanded, matter was continuously created out of empty space to fill the gaps.

Cosmology is painfully short of facts. There are only four good ones: the galaxies are speeding away from us, the Universe is a bit older than the Earth, the background radiation indicates a hot beginning, and the hydrogen to helium mass ratio is what you would expect from a nuclear furnace. Particle physicists, who have recently joined the ranks of modern cosmologists, seem to think that all the really exciting science occurred before the Universe was between 10 and 32 seconds old.

To understand the Universe when it is very small, we need a cosmological model which incorporates the principles of quantum theory.

…the discovery of cosmic background radiation. In 1965 two physicists, Penzias and Wilson, checked the prediction of Gamov that the Big-Bang fireball should have cooled to about minus 270 degrees C by this time. They measured the temperature of radiation from outer space and roughly obtained that temperature.

Exercise 2. Read this article from the *New Scientist* and answer the questions.

THE END OF UNIVERSE AS WE KNOW IT?

The Universe could be more than twice as old as most astronomers believe and be destined to collapse in a 'big crunch' in 79 billion years. This is the implication of a radical new model for the Universe being proposed by an American cosmologist. He says that all the present observations tally with it.

Most astronomers believe that the Universe is only 10 to 15 billion years old and will exist forever. But a major problem for cosmologists is that some stars in our own galaxy appear to be older than this.

Edward Harrison of the University of Massachusetts has explored one possible solution. He makes the standard assumption that the Universe began with the big bang and that its properties are determined by only two numbers: the Hubble constant, which describes the present expansion rate of the Universe; and UC omega, the mass density of the Universe.

Harrison’s values for the Hubble constant and UC omega together set the age of the Universe at 35 billion years. This allows more than enough time to accommodate the oldest stars in our Galaxy, and suggests that our Galaxy was born within about 15 to 20 billion years after the big bang. Hitherto, most astronomers have thought that the Galaxy formed within about a billion years of the big bang.

Because UC omega exceeds 1 in Harrison's model, it means that the Universe will someday collapse. At the moment, the Universe is expanding, and is 90 per cent as big as it will ever be. The Universe will attain its maximum size 22 billion years from now, when it will be 57 billion years old. At that time, the gravitational pull of all the mass in the Universe will halt its expansion. For the following 57 billion years, the Universe will get smaller and smaller until it compresses itself into a point and annihilates itself. The total time from the big bang to this big crunch will be 114 billion years.

According to this model, our Universe is finite in size and can be viewed as a sphere of space-time. The distance from the Earth to the opposite side of the Universe is 102 billion light years. At the moment, says Harrison, we can observe most of the Universe, because we can detect light from objects as far away as 98 billion light years.

This is not inconsistent with the Universe being 35 billion years old, because these objects emitted their light when they were much closer to us than they are today. The only objects we cannot see are the few that lie between 98 and 102 billion light years away, because their light has not yet had time to reach us.

In contrast, the conventional view is that the Universe is infinite and we can only observe a tiny part of it. But Harrison thinks his model is more attractive. 'The Universe is closed and finite, does not involve meaningless infinities of space and time and is almost entirely observable,' he says.

1. Do observations support the new model?
2. Is a standard assumption the received wisdom?
3. If X determines Y, does it govern Y?
4. Does this theory allow for the age of the oldest galaxies?
5. If something attains a certain size, it r___s that size.
6. To annihilate something means to d____y it completely.
7. Which idea here is repeated in the final paragraph?
8. If X is not inconsistent with Y, does it contradict Y?
9. To what two-word expression earlier in the article is 'conventional view' similar in meaning?

UNIT 9

THE SUN AND THE PLANETS

Study the key words:

A solar system contains **planets** and other objects that orbit a central **sun.** Objects in space are sometimes compared in size to our sun and measured in **solar masses**, the sun being equivalent to one solar mass.

The planets closest to our sun are the **inner planets** or **terrestrial planets**. Those further away are the **outer planets** or **jovian planets.**

Any system of planets revolving around a star is a **planetary system**. Interplanetary is used to refer to things such as space or travel between the planets.

The things relating to Earth are **terrestrial**. Things not from Earth are **extraterrestrial**.

Exercise 1. Read and translate the following paying special attention to the underlined words.

Mercury is the most inhospitable of planets in the Solar System. The Sun blazes down on its barren landscape, raising the temperature to 430 degrees C, twice as hot as a typical domestic cooker.

The probes would continuously return information about the nature of the interplanetary environment near the earth and quantify the influence of the solar wind, the stream of protons, electrons and helium nuclei constantly emitted from the Sun.

Being able to compare the internal structure of Mercury, Venus, Earth and Mars (the four inner planets) is crucial to our understanding of how the Solar System formed and the subsequent evolution of the planets.

Pluto and most moons of the outer planets consist of rock and water ice in varying amounts.

The Solar System has equal numbers of terrestrial and jovian planets, and this pattern is likely to be typical of other planetary systems too.

The hope of finding life elsewhere has helped drive planetary science.

Exercise 2. Read this article from the *New Scientist* and answer the questions.

WHERE THE PLANETS BOLDLY GROW

Do stars other than the Sun have planetary systems?

Our solar system divides into two groups of planets. The terrestrial planets, Mercury, Venus, Earth and Mars, are small rocky bodies of low mass with limited atmospheres and negligible number of satellites. The jovian group, Jupiter, Saturn, Uranus and Neptune, in contrast, are gas giants with large rocky cores and huge hydrogen and helium atmospheres. They have rings and many satellites.

Pluto may not be a true planet, but an escaped satellite: with a mass only a quarter of that of our moon, it is much more like a satellite than a planet.

The Solar System has equal numbers of terrestrial and jovian planets, and this pattern is likely to be typical of other planetary systems too. Where might we find other planetary systems?

We can begin by ruling out those kinds of stars that are not likely to have planets. The Sun is a single star. Near the Sun about half of all stars are also single; the rest belong to groups of two or more. The complicated gravitational fields around these multiple stars make it unlikely that they have planetary systems.

The Sun belongs to the second generation of stars to be produced since the Universe began. These contain elements with atomic weights greater than those of hydrogen and helium.

Other more widely spread stars that formed closer to the dawn of the Universe began life with only the two lightest elements. These old stars would not have been accompanied by the clouds of dust - made of silicon, oxygen and carbon - that are probably needed to trigger the formation of planets. Dust is certainly needed to form planets like the Earth.

1. Do the terrestrial planets have many moons?
2. A planet' s core is under its s___e.
3. What might Pluto have escaped from?
4. Which planet are the jovian planets named after?
5. If you rule something out, do you exclude it?
6. It is impr____ that these stars have planets.
7. Which are the two lightest elements?
8. If something triggers an event, does it cause the event?

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