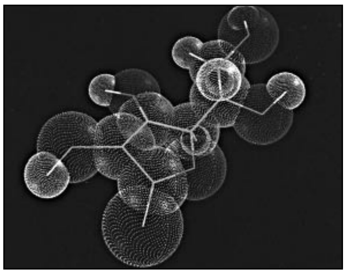
The inside story



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UNIT 16

In this unit, molecular structure provides a context within which students work on standard form for numbers less than one. They also explore current scientific models for the development of the Universe and consider scientists' views about whether human life is a cosmic accident or not.

Using this unit

The unit is intended for students at the Intermediate/Higher Tier of GCSE. Students are expected to be familiar with the concept of standard form for numbers greater than ten (this is covered in the unit *The Designer Universe?*). There is only a brief note on standard form for numbers less than one in the text, so the students will need to have been taught this before they attempt the unit. The unit is expected to take about 1½ to 2 hours.

It begins by examining the spiritual issue at the heart of the unit - are human beings important in our vast and complex Universe? This is returned to in the concluding sections by considering quotations from eminent scientists. The rest of the unit uses different contexts in which students practise using standard form for numbers less than one. The difficulty of the tasks increases throughout the unit.

Students will need a calculator for tasks 3 and 4 (they will need to be able to enter numbers in standard form and interpret answers shown in standard form).

Mathematical content

Number (AT2)

- **Positive and negative powers of ten**
- **Standard form for all numbers**
- **Manipulation of numbers in standard form**

Algebra (AT2)

- **Substitution in formulae**

Spiritual and moral development

The unit aims to promote a sense of wonder about the Universe. Students are also encouraged to reflect on the origins of the Universe and their place within it.

TEACHER'S NOTES

Background

Many people assume that modern scientific theories about the development of the Universe and life on Earth contradict Christian beliefs about creation and the existence of a loving God. This unit seeks to investigate this view by inviting students to consider the conditions required before life could develop. For some scientists, the need for these very precise conditions can suggest the activity of a purposeful designer. This coincides with views found in religious writing such as the Psalmist quoted at the start of the unit.

In *The Designer Universe?* students were asked to consider the special conditions which exist on Earth which make it suitable for the development of life. This unit continues this theme. Life on Earth could not have developed unless conditions in the early Universe were very precisely controlled. A few elementary scientific ideas are introduced in the unit but many of the ideas within this field are beyond the scope of this unit.

Interested teachers and students can explore the ideas in this unit further by reading either of the first two books in 'Additional Sources'. Both are available in paperback and easy to read. The writers of the unit are aware that some Christians may not accept current theories about the development of the Universe and life on Earth. Such theories are only scientific models, but they are nonetheless widely accepted amongst eminent scientists, many of whom are Christians.

TEACHER'S NOTES

Additional sources

Books:
John Polkinghorne, *Quarks, Chaos and Christianity* (Triangle 1994)
John Houghton, *The Search for God – Can Science Help?* (Lion 1995)
Michael Poole, *A Guide to Science and Belief* (Lion 1994)
P. C. W. Davies, *The Accidental Universe* (Cambridge University Press 1982)
A. Watts, *The World of the Atom* (Aladdin Books Ltd. 1989)
Glen and Susan Toole, *Understanding Biology for Advanced Level* (Stanley Thornes 1995)
Littlefield and Thorley, *Atomic and Nuclear Physics* (D. van Nostrand Co. Ltd. 1963)
Further Science from the 'Science at Work' series (Longman 1993)

Posters:
The London Planetarium, Marylebone Road, London, NW1. (0171-935-6861)

Notes on the Activities

Where do we fit in

In this first section, the spiritual content of the unit is introduced. A wall display of pictures of stars, galaxies and planets could incorporate some of the students' answers to question 4 in task 1. The London Planetarium has some excellent posters.

Class discussion

The students' responses to task 1 can provide the basis for a whole class discussion. In particular the following can be addressed:

- their thoughts on the size and age of the Universe;
- their understanding of the Psalmist's writing;
- their views on their own place within the universe.

How big is "small"?

In this section, students are asked to interpret numbers in standard form and to compare them.

Splitting the atom

In this section, students work on the structure of the atom. Task 3, question 3 requires the students to manipulate numbers in standard form. A calculator would be useful.

Exploding stars

The section begins with examining the importance of carbon. Students should have their attention drawn to the Polkinghorne quotation. A calculator is needed from question 2 in task 4 onwards.

So what is the inside story?

In the final section, the significance of the ideas explored in the previous sections is examined. Students could be asked to write their response to the final question as a preparation for a class discussion.

Class discussion

The unit would be best finished by discussing together the students' thoughts on the following:

- the origins of the Universe: accident/chance versus design;
- the impact on our lives of our views about the origins of the Universe.

Answers

Task 2:

1. a) 0.01; b) 0.0001; c) 0.000000001; d) 0.000001; e) 0.001.
2. cell 1 x 10^{-2}; bacteria 1 x 10^{-3}; virus 1 x 10^{-4}; molecule 1 x 10^{-6}; atom x 10^{-9}.
3. cell.
4. a) false; b) true; c) true; d) false.

Task 3:

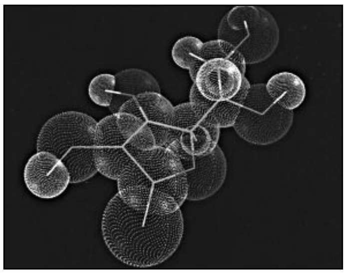
1. a) proton and neutron; b) electron, proton, neutron; c) 2000 (accept 1000).
2. a) 10^3 (or 1000);
   b) proton 1.672 x 10^{-24}g, neutron 1.675 x 10^{-24}g, electron 9.11 x 10^{-28}g.
3. a) 2.6776 x 10^{-26} kg; b) 2.26 x 10^{-28} kg.

Task 4:

1. a) 1 x 10^{-2} seconds; b) 2 x 10^2 seconds; c) 1,000,000,000 °K; d) 1 x 10^6 years; e) 1 x 10^7 years; f) 1 x 10^{10} years.
2. 2 x 10^{24} in a gram; 2 x 10^{27} in a kg.
3. 2 x 10^{19} in a second; 2 x 10^{16} in a millisecond.
4. 10^6 or 1 million.
5. a) $M_{hydrogen}$ = 1.66 x 10^{-27} kg;
   M_{carbon} = 1.992 x 10^{-26} kg;
   M_{oxygen}=2.656 x 10^{-26} kg.
   b) $R_{hydrogen}$ = 1.4 x 10^{-15} m;
   R_{carbon} = 3.205 x 10^{-15} m (to 4 significant figures);
   R_{oxygen} = 3.528 x 10^{-15} m (to 4 significant figures).

TEACHER'S NOTES

The inside story



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UNIT 16

Where do we fit in?

Some scientists believe that our huge and wonderful Universe has been designed just so people like you and me could exist! If you have studied the unit, *The Designer Universe?*, you will have learnt about the way our Earth is ideally suited to the development of life.

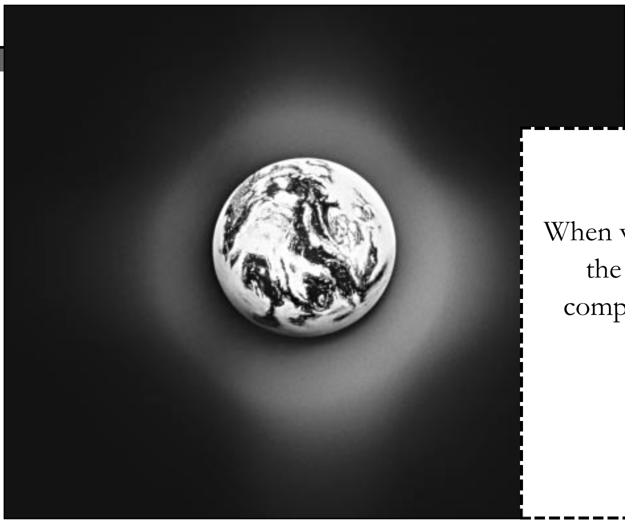
In this unit we will think about the development of our Universe and consider the idea that its whole history has been necessary for the creation of living beings like ourselves. In particular, we will look at some of the smallest things in the Universe.

1

1. What are your thoughts about the size and age of the Universe?
2. People often feel insignificant when they think about these things. Read the following reaction of a writer to his place in the Universe:

> **"When I consider your heavens, the work of your fingers,**
> **the moon and the stars, which you have set in place,**
> **what is man that you are mindful of him,**
> **the son of man that you care for him?"**
> (quotation from *Psalm 8*)

3. Who do you think the writer was talking to?
4. Try to rewrite the quotation in your own words.
5. Do you think that we human beings are important in the Universe?



Note

When we are working with very small sizes, it is helpful to write the numbers in standard form. This particularly helps us compare sizes at a glance. For numbers less than "1" we will need to use a **negative power of ten**.

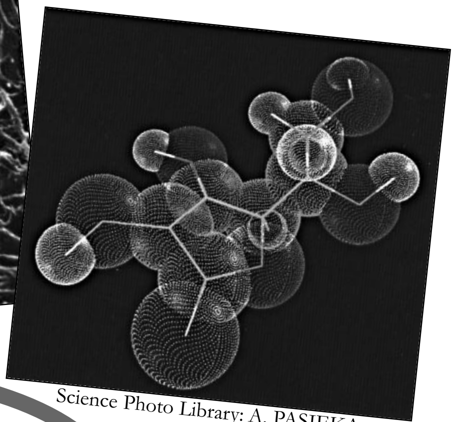
e.g. $2 \times 10^{-3} = 2 \times \frac{1}{1000} = \frac{2}{1000} = 0.002$

How big is "small"?

Read through the following five facts:

- An adult human being has approximately 100 million million **cells** in his/her body.
- Antibiotics are not effective against a **virus**.
- Each one of us has, within our body, ten times as many **bacteria** as we have cells of our own.
- Pondskaters are insects which can stand on the surface of a pond because water molecules attract one another.
- There are more hydrogen **atoms** in the human body than there are atoms of any other type.

Science Photo Library: CNRI



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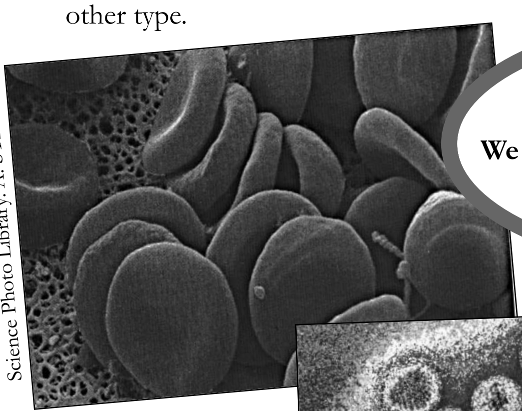
Left: Nerve cells
Below: Vitamin C molecule



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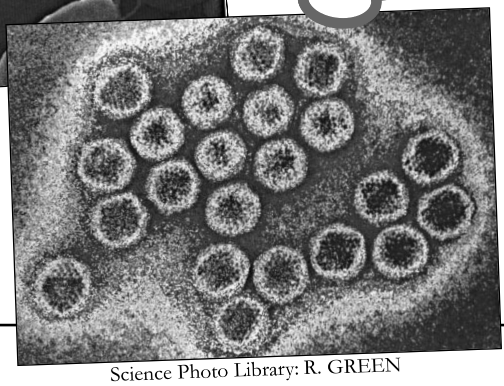
Cells; viruses; bacteria; molecules and atoms. We know they are small, but how small? How do they compare in size?



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Above: Red blood cells
Right: Cold viruses
Far right: *E coli* bacteria

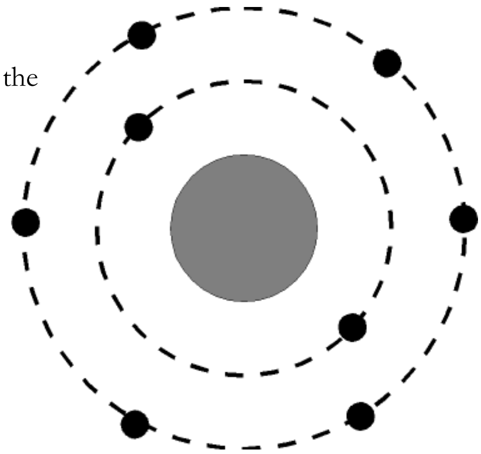
2

1. In each part of this question, the numbers are given in standard form. Write each number as an ordinary decimal.
   a) Most cells are about 1×10^{-2} mm across.
   b) Viruses are no bigger than 1×10^{-4} mm across.
   c) Some atoms are only 1×10^{-9} mm across.
   d) A molecule may be as small as 1×10^{-6} mm.
   e) Small bacteria are approximately 1×10^{-3} mm.
2. Using the information in question 1, write the items, cell, virus, molecule, atom, bacteria, in order of size starting with the largest. Then write, next to each item, its size given in standard form.
3. Which item in the list is approximately 100 times bigger than a virus?
4. For each of the following statements, say whether they are true or false:
   a) Atoms are three times larger than bacteria.
   b) Most cells are at least one hundred times bigger than viruses.
   c) If a cell is 1×10^{-2} mm across and a virus is 1×10^{-4} mm, you could fit 100 viruses across a cell.
   d) If a cell is 1×10^{-2} mm across and a bacteria is 1×10^{-3} mm across, the bacteria would not fit into the cell.

Splitting the atom

All livings things are built from cells and the cells are made up of molecules. Molecules can take many different forms because they are made from combinations of atoms, the smallest building block in the Universe.

Opposite is a model of an oxygen atom. (It is not drawn to scale).
The solid part in the middle is called the **nucleus** and the small dots round the outside represent **electrons** which move around the nucleus.
Splitting the atom is very difficult and releases huge amounts of energy giving us atomic power and the atom bomb.



The nucleus is made up of protons and neutrons. (In the oxygen atom pictured, there are 8 of each.) These are so small that their masses are always given in standard form.

Rest mass of proton: 1.672×10^{-27} kg
Rest mass of neutron: 1.675×10^{-27} kg
Rest mass of electron: 9.11×10^{-31} kg

3

Use your knowledge of standard form to answer the following questions.

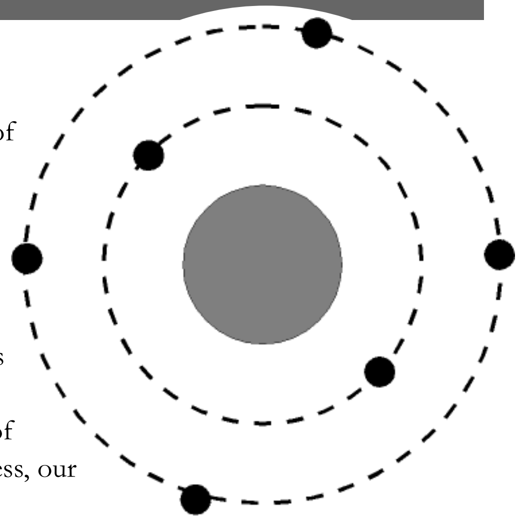
1. a) Which two particles are almost the same size?
   b) Arrange the three particles in order, starting with the smallest.
   c) Roughly how many times heavier is a proton than an electron? Give your answer to the nearest thousand.

2. a) The masses in the table above are given in kg. What would you have to multiply them by in order to change them into grams?
   b) Write each mass in grams in standard form.

3. a) The oxygen nucleus contains 8 protons and 8 neutrons. What would you expect its mass to be? Give your answer in kg and in standard form.
   b) When the protons and the neutrons fuse together into the nucleus some of their rest mass is lost in the effort, so the actual mass of an oxygen nucleus is only 2.655×10^{-26} kg. Compare this with your answer to part a). How much mass has been lost? Give your answer in kg and in standard form.

Exploding stars!

Oxygen is only one of the elements needed to form our bodies. One of the most important is carbon.



A carbon atom is shown opposite.
Carbon atoms can join together to make large molecules that are needed to build our bodies. Carbon was not present in the early Universe, so where did it come from? Most astronomers and physicists believe that carbon is formed deep within stars. Dying stars, called Supernova, explode, scattering carbon into space. Future generations of stars and planets form using this scattered material. Without this process, our bodies could not be created.

4

In this task you will need to use standard form numbers with positive and negative powers of ten.

1. In this question, write any ordinary numbers in standard form and any standard form numbers as ordinary numbers.

   a) Protons and neutrons first appeared when the Universe was only 0.01 seconds old.
   b) After about 200 seconds hydrogen and helium were formed.
   c) At this time, the temperature was about 1×10^9 °K. It had to be 'just right' for the neutrons and protons to fuse successfully.
   d) After about a million years the Universe was cool enough for electrons to attach themselves to nuclei and form atoms.
   e) After about ten million years, gravity caused first generation stars to form.
   f) Nuclear reactions inside these stars formed carbon when the Universe was about ten thousand million years old.

Work in standard form for the rest of these questions, showing all your working.

2. Two million, million, million, million protons would weigh just over a gram. Write this number in standard form and hence work out how many protons would weigh about a kg.

3. When a torch lights up, about 20 billion billion electrons pass through the wire every second. Write this number in standard form and hence calculate the number of electrons passing through the wire in one millisecond.

Note

One billion is one thousand million.

One millisecond is one thousandth of a second.

4. One page of this book is about 2×10^{-2} cm thick. If an atom is 2×10^{-8} cm how many atoms thick is this page?

5. Use the table to answer the questions below

Type of atom	A = number of protons and neutrons
Hydrogen	1
Carbon	12
Oxygen	16

   a) The mass, M, of an atom can be calculated from the following formula:

$$M = A \times 1.66 \times 10^{-27} \text{ kg}$$

   Use the formula to calculate the masses of the three atoms in the table.

   b) The approximate radius, R, of an atom in metres is given by the formula:

$$R = 1.4 \times \sqrt[3]{A} \times 10^{-15}$$

   Use this formula to calculate the radii of the three atoms in the table.

"We are all made from the ashes of dead stars."
John Polkinghorne

So what is the inside story?

So it seems that we can only exist because the Universe is old enough to have produced second generation stars and planets. What is more, many scientists believe that conditions in the early Universe had to be very finely balanced, otherwise things would have happened too quickly, or too slowly for all the elements necessary for life to form.

Professor Paul Davies is an eminent physicist who does not claim any religious faith but his studies of the Universe led him to describe it as

"... a Universe full of stunning surprises."

and he concludes ...

"... it is difficult not to be struck by some of the surprisingly fortuitous accidents without which our existence would be impossible."

So, is our presence here on Earth just some cosmic accident or is it because of a design behind the Universe? What do you think?