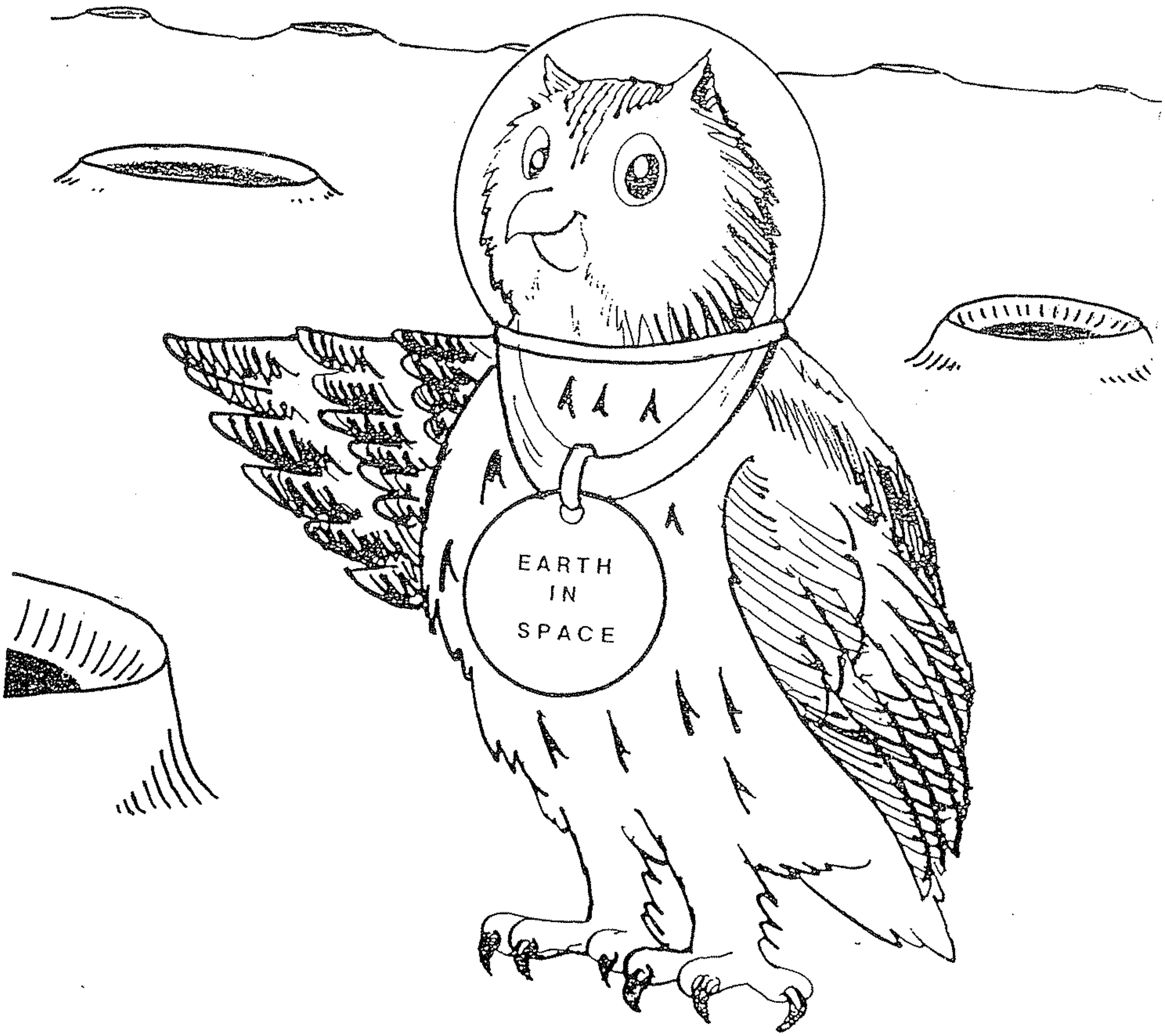
X 18875

Leeds National Curriculum Science Support Project



Throughout the work on the Earth in Space, size and scale cause significant problems for learners. Because of the vast distances and sizes involved it is very difficult to find scales which are accurate and yet practical to use in diagrams in books or in the classroom.

The restrictions of the printed page mean that diagrams throughout these materials, and in books and posters, are not drawn accurately to scale and should be used with that in mind so that they do not present a misleading picture.

THE EARTH IN SPACE

SCIENCE MAP

The Earth is a large spherical planet: we live on the surface of it.
(See Learning Guide: The Earth)

The Earth turns on its axis, taking 24 hours to rotate once.

Day and night occur because at any one time half the Earth is in sunlight (day), half is in darkness (night).
(See Learning Guide: Day and Night)

We can measure time with a sundial.

The Sun's apparent daily motion is from east to west across the sky because the Earth spins from west to east.

Sunrise occurs at different times at different geographical locations due to the Earth's rotation.

The Earth, Moon and Sun are part of the solar system with the Sun at the centre. The Earth orbits the Sun, taking one year to complete one orbit.

The Moon is the Earth's only natural satellite, and it takes one lunar month to complete one orbit of the Earth.
(See Learning Guide: The Earth, Moon and Sun)

When an astronomical body casts its shadow over, or obscures from sight, another body this is called an eclipse.
(See Learning Guide: Eclipses)

The Earth's axis is tilted and always points i
direction: this results in a change in the or
the Earth relative to the Sun during the E
long orbit of the Sun.

In summer the Sun has a greater heating eff
its rays meet the Earth's surface at a more (
than in winter, when the lower angle
increased surface area to be heated.

In summer the inclination of the Sun is hig
winter due to the Earth's tilt towards the Su

In summer the portion of each latitude v
sunlight is greater than that which is in dar
place on that latitude has longer dayligh
winter.
(See Learning Guide: The Changing Year)

The Sun always lights up half the Moon's surface. The phases of the Moon occur because we see more or less of the illuminated side of the Moon at different times. The phases make up a regular monthly pattern.
(See Learning Guide: Phases of the Moon)

The Sun shines on all parts of the Moon's surface at some time during a complete rotation of the Moon.

The Moon rotates on its axis at such a speed that it always presents the same face to the Earth as it orbits the Earth.

The Moon is smaller than the Earth.

The Sun is a star. It is at the centre of the solar system. It is the only body in the solar system which gives out light and is the main heat source.
(See Learning Guide: The Solar System)

The Sun is much larger than the Earth. It is the largest object in the solar system.

Planets, including the Earth, orbit the Sun and some of them are orbited by natural satellites (moons). The solar system is very large and very empty. The planets are very far apart.
(See Learning Guide: The Solar System)

Planets, and moons, reflect light.

The surface temperatures of the planets decrease with distance from the Sun.

Satellites, moons, asteroids, meteoroids, and comets are also part of the solar system.

Planets are kept in their orbits by the pull of the Sun's gravity.

The Universe contains everything that ex
made up of galaxies, which are collections
of stars. Our solar system is part of one ga
the Milky Way.
(See Learning Guide: The Universe)

From our viewpoint on Earth, stars which are at very different distances from us appear as a group. People have seen patterns in these groups and called them constellations.

The positi
nature c
component
the Univers
over long ti

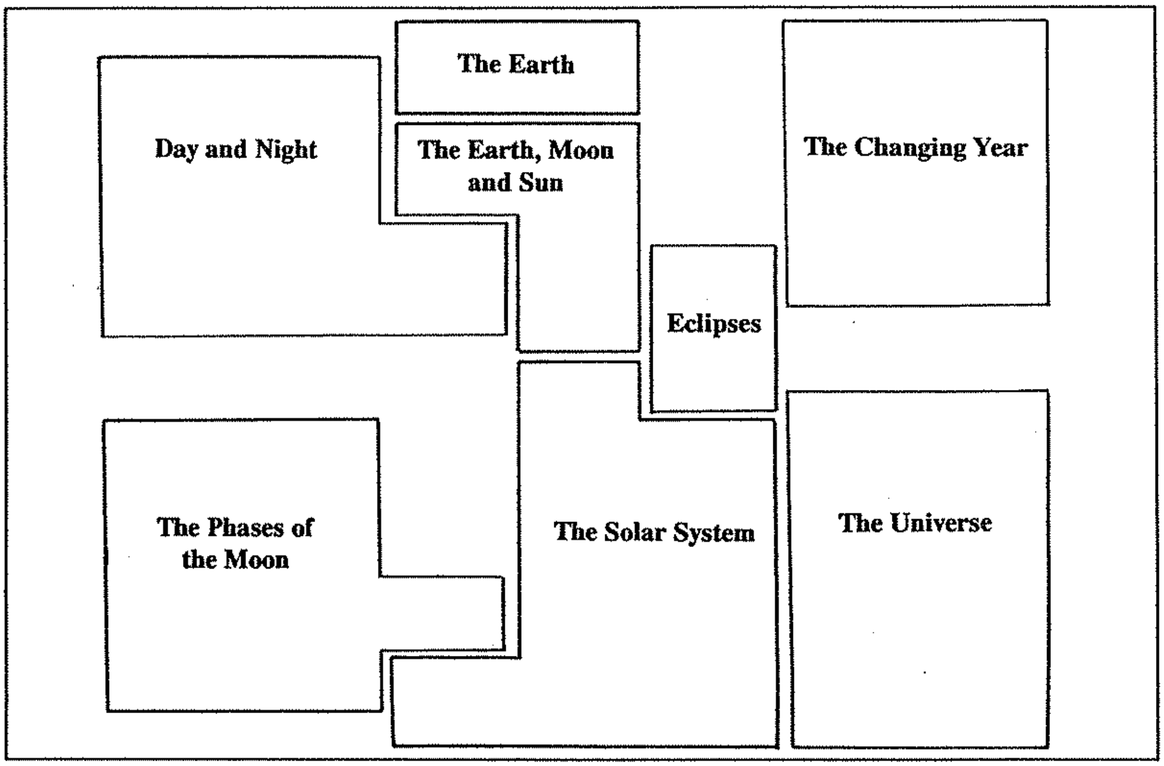
Many stars are larger than the Sun (the farther away an object is the smaller it looks).

Stars that
brighter in
are not n
nearer, they
ju ghter

3

THE EARTH IN SPACE

SCIENCE MAP



Outline of the of Science Map overleaf ▼ **Gravity Map**

The map overleaf shows those ideas which make up a sound basis to work towards in the early secondary years. This is proposed as a coherent framework in itself which at the same time provides an appropriate basis for development. Critical ideas around which understanding is structured are identified in the map as shaded boxes and these goals make up the right hand column of the Learning Guides.

Aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils is outlined in The Teacher's View.

THE EARTH IN SPACE

The following sections have been designed for use in association with one another. The Learning Guides are supported by the Research Summary, the Science Map and The Teacher's View. It will also be helpful to refer to the Science Map and The Teacher's View when using the Research Summary.

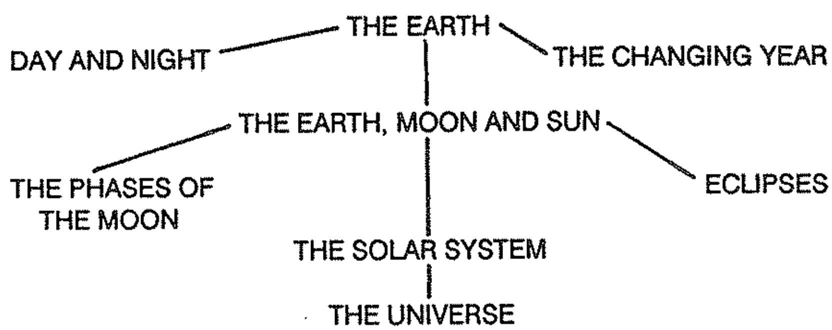
CONTENTS

Science Map

This map shows those ideas which make up a sound basis for understanding the Earth in Space to work towards in the early secondary years. This is proposed as a coherent framework in itself which at the same time provides an appropriate basis for development. Critical ideas around which understanding is structured are identified in the map as shaded boxes and these goals make up the right hand column of the Learning Guides.

Learning Guides

These guides are the nucleus of the materials. They are folded so that children's prior ideas from the Research Summary are set alongside goals from the Science Map and they describe the challenges pupils face when it comes to restructuring their ideas. They also suggest interventions which could be used in teaching schemes to help pupils reach the goals. Related extracts from the National Curriculum are included. The Learning Guides in this domain are:



Research Summary: Children's Ideas

This is a brief outline of research into children's ideas, setting out the main prior ideas and understandings which teachers might expect to meet among pupils. These ideas make up the left-hand column of the Learning Guides.

The Teacher's View

This section outlines those aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils.

Additional Materials

A Brief Astronomical History.
A Glossary of Terms.
A List of Resources and Suggestions for Visits.

THE EARTH IN SPACE 18875

THE CHANGING YEAR

Children's Prior Ideas

Most children of all ages think the seasons change because the Earth is further away from the Sun in winter than in summer.

Other children suggest that:

Heavy winter clouds stop the heat from the Sun reaching the Earth.

Changes in plants cause the different seasons.

In winter the Sun moves to the other side of the Earth to give them their summer.

As the Sun goes around the Earth it goes through different atmospheres which give the seasons.

In winter the cold planets take the heat from the Sun.

(See The Earth in Sp Research Summary)

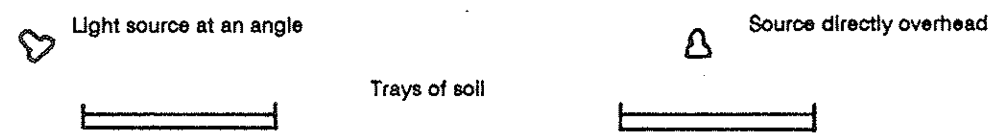
The Challenge for Pupils

Explaining the changes in the seasons, day length and inclination of the Sun during the year is a very difficult task for most children. It is unlikely that a child would arrive at an explanation unaided so the task will be for the pupil to come to understand and use the science model.

A starting point might be to offer the children a model of the scientific view of the tilted Earth orbiting the Sun and ask them to devise tests/experiments to support, or disprove it. (The model could be a globe and light source or a model of the sort suggested in Baxter's Earth in Space teaching pack.) The model could also be used to predict what season it will be when the Earth is in various positions, or to predict the position of the globe given the season.

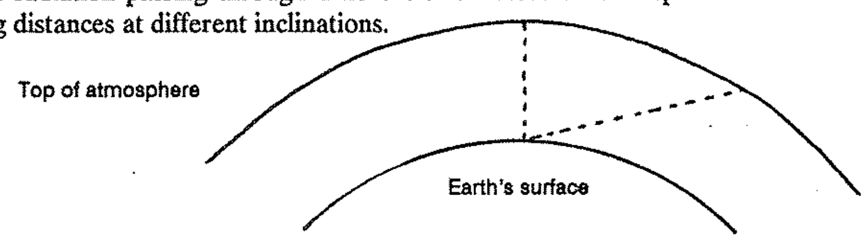
In working with the models the child will need to realise that the phenomena are seen from a point on the Earth's surface and in some cases they need to physically look at what is happening in the model from that point of view, rather than from outside the model.

They will need to appreciate the effect of changing the angle of heating a surface when considering the change in the seasons. This could be done by taking the temperatures of trays of soil heated from various angles, possibly using temperature sensors and a computer to plot the results on a graph over a period of time.



Alternatives might be to use a liquid crystal thermometer strip held at different angles in the rays of a slide projector or OHP. If an alcohol thermometer is used a metal disk, for example a two pence coin, could be attached to the bulb with an elastic band and the disk inclined at different angles.

The Sun's radiation passing through different thicknesses of atmosphere could be shown using diagrams and measuring distances at different inclinations.



When looking at the change in the length of daylight the children might use a globe with model figures and a source lighting half the sphere. Turning the globe through a 'day' at different angles to the light source gives a very clear display of how long the figure is in light at different times of the year. When considering the inclination of the Sun a s ller, point, light source may be more appropriate.

Goal

The Earth's axis is tilted and always points in the same direction: this results in a change in the orientation of the Earth relative to the Sun, during the Earth's year long orbit of the Sun.

In summer the Sun has a greater heating effect because its rays meet the Earth's surface at a more direct angle than in winter, when the lower angle causes an increased surface area to be heated.

In summer the inclination of the Sun is higher than in winter due to the Earth's tilt towards the Sun.

In summer the portion of each particular latitude which is in sunlight is greater than that which is in darkness, so a place on that latitude has longer daylight than in winter.

Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Pupils should observe closely the local natural environment to detect seasonal changes, including length of daylight, weather and changes in plants and animals and relate these to the passage of time. (KS1 Sc4 v)

They should observe over a period of time, the length of daylight, the position of the Sun....(KS1 Sc4 v)

They should learn about the motions of the Earth, Moon and Sun in order to explain....day length, year length.... and the seasons. (KS2 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/1d be able to describe the apparent movement of the Sun across the sky.

Sc4 v/3e know that the appearance of the Moon and the altitude of the Sun change in a regular and predictable manner.

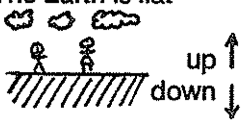
Sc4 v/4e be able to explain day and night, day length and year length in terms of the movements of the Earth around the Sun.

Children's Prior Ideas

Children hold various ideas about the planet Earth which might be grouped as follows:

<u>Flat Earth, with absolute down and space limited.</u>

The Earth is flat

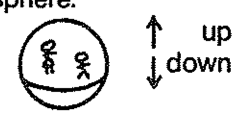


or shaped like a saucer.

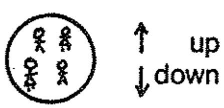
<u>A spherical Earth with absolute down and space limited or all around.</u>

We live on the inside of the sphere.

We live on the top half of the sphere.

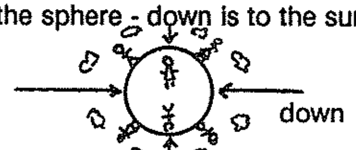


People live all over the sphere.

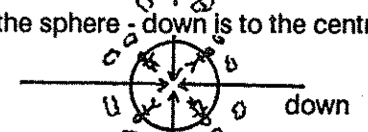


<u>Spherical Earth with an Earth referenced down and sky all around.</u>

People live all over the sphere - down is to the surface of the Earth.



People live all over the sphere - down is to the centre of the Earth.



Some children also suggest that there are two Earths - one is flat that we live on and one is round in space.

(See The Earth in S[illegible] Research Summary)

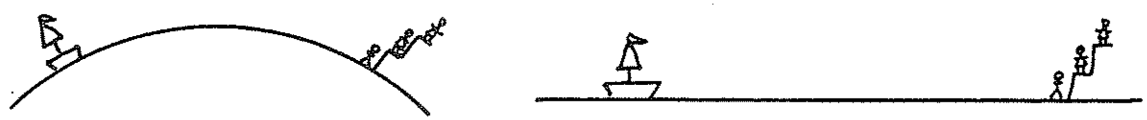
The Challenge for Pupils

Children's ideas about the shape of the Earth appear to be deep rooted and the subject may need to be revisited several times before they fully accept the spherical Earth, with sky all around and down being to the centre of the Earth.

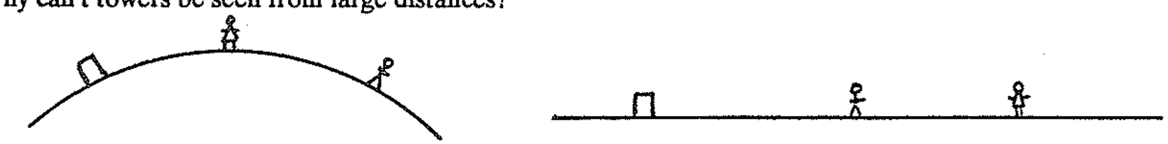
A starting point might be for groups of children to look at the various flat Earth/spherical Earth arguments and to discuss the evidence supporting them. ◈THINK LINK◈ This could also be considered from a historical position.

The pupils could consider:

a) What would a ship disappearing over the horizon look like from different positions?



b) Why can't towers be seen from large distances?



Both these situations could be explained by the Earth being the edge of a plate so it may be worth stressing that the phenomena could be seen in all directions, not just one.

Using a globe or other sphere, the children could place model people on it when thinking about where people live on the surface of the Earth and the direction of down. (See The Earth's Gravity Learning Guide in 'Gravity')

THE EARTH

Goal

The Earth is a large spherical planet: we live on the surface of it.

Related National Curriculum Programme of Study Key Stage 3

Pupils should further develop their study of the solar system through observation and secondary sources. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Pupils should examine ideas that have been used in the past and more recently, to explain the character and origin of the Earth.... (KS4 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/2e know that the Earth, Sun and Moon are separate spherical bodies.

DAY AND NIGHT

Children's Prior Ideas

The children's ideas as to why it gets dark at night fall into four main categories:

Those suggesting an 'animate' Sun:

the Sun goes to sleep
- " turns off or goes out
- " hides behind hills or trees
- " is on the ground
- " goes to a different country

Others offering 'covering' theories:

the Sun gets covered by clouds
- " gets covered by the Moon or planets
- " gets covered by night, dark or atmosphere

Explanation involving astronomical movements or orbits:

the Sun moves up and down as the Earth rotates.
the Sun goes around the Earth once a day.
the Earth revolves around the Moon.
the Earth goes around the Sun once a day.

Of those who offer a rotational explanation the time taken can vary considerably:

the Earth rotates in six minutes.
it takes the Earth 200 hours to rotate.
the Earth spins on its axis once a day.

(See The Earth in Sp[illegible] Research Summary)

The Challenge for Pupils

Many of the children's prior ideas are based on the physical evidence they see of the Sun moving across the sky, going behind clouds or out of sight. The key movement in thinking is to understand that the same effects result from the Earth's turning. The pupils will also need to appreciate that the Earth receives light from the Sun and, because the Earth is spherical, half of it is lit at any one time.

To avoid causing confusion we need to be careful about the use of the term 'day' which is sometimes used to mean the 24 hour day and at other times used to refer to the period of daylight.

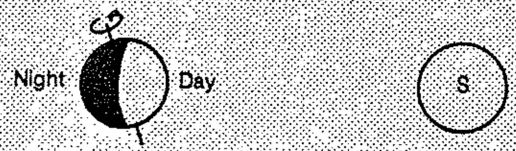
A park roundabout might prove a useful tool to experience the changing view from a turning body. Alternatively, an individual child could note the relative position of a particular item as they physically turn through a half or full circle.

The children could test their own ideas, or a selection of other people's suggestions, about day and night, using simple models involving spheres and light sources, to see if they work. Their ideas could be refined and re-tested, or a class could evaluate several and feed back their results to the whole class. Most children will know that a 'day' lasts for twenty-four hours and could compare any distances travelled in the model to see if they are realistic. They would have to ensure all parts of the world received some sunlight during the day. Ready-made cards asking such questions might be useful to prompt groups who are having difficulty in testing their model, or they could suggest further activities such as 'where would the Moon fit into your model' for those who complete the task.

Photographs of stars taken over a period of time, and therefore appearing as curved lines, may provide a useful resource when considering the turning of the Earth.

Goal

The Earth turns on its axis, taking 24 hours to rotate once. Day and night occur because at any one time half the Earth's sphere is in sunlight (day), half is in darkness (night).



Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Pupils should observe closely the local natural environment to detect seasonal changes including length of daylight,....and relate these changes to the passage of time. (KS1 Sc4 v)

They should observe, over a period of time, the length of daylight, the position of the Sun and where possible the Moon in the sky.... (KS1 Sc4 v)

Pupils should track the path of the Sun using safe procedures such as a shadow stick or sundial. (KS2 Sc4 v)

They should learn about the motions of the Earth, Moon and Sun in order to explain day and night, day length.... (KS2 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/1d be able to describe the apparent movement of the Sun across the sky.

Sc4 v/3e know that the appearance of the Moon and the altitude of the Sun change in a regular and predictable manner.

Sc4 v/4e be able to explain day and night, day length and year length in terms of the movements of the Earth around the Sun.

THE EARTH IN SPACE

THE EARTH, MOON AND SUN

Children's Prior Ideas

Although the idea of a Sun-centred system seems to develop with age, Earth-centred notions persist.

Pupils' ideas might be grouped as:

Earth-centred 'magic' models.

During the day the Sun is nearer, at night the Moon is nearer.

OR

Spinning Earth-centred models.

Earth spins in the centre, giving day and night.

OR

Earth-centred with orbiting Sun and/or Moon.

Earth may be static or spinning.

OR

Sun-centred, with orbiting Earth and/or Moon.

OR

Sun-centred, with orbiting Earth and Moon orbiting Earth.

Many children also have little grasp of the relative sizes of the Earth, Moon and Sun, or the distances between them.

(See The Earth in Sp· Research Summary)

The Challenge for Pupils

Many children have difficulty in understanding the spatial arrangement of the Earth, Sun and Moon: after all, the evidence of the Sun and Moon moving across the sky points to an Earth-centred system. Hence it is sensible to consider the Earth, Sun and Moon relationship before attempting to model the whole solar system.

In constructing models the children will need to consider carefully the relative sizes and distances between the bodies. They will also need to relate the movements to the times involved.

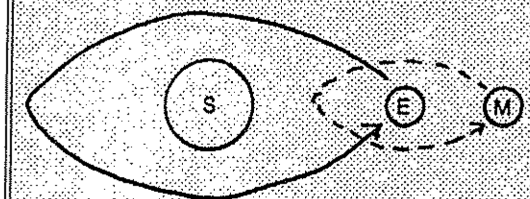
◈ THINK LINK ◈ The children could consider what evidence there is to support Sun-centred or Earth-centred systems and construct model systems. They could also look at the historical development of Earth-centred/Sun-centred theories.

A possible scale model would use a beach ball (2 feet diameter) for the Sun, a pea 215 feet away for the Earth and a pin head six inches from the Earth for the Moon. The Sun's diameter is about 100 times larger than the Earth's and the Earth's diameter is about four times that of the Moon.

Goal

The Earth, Moon and Sun are part of the solar system with the Sun at the centre. The Earth orbits the Sun, taking one year to complete one orbit.

The Moon is the Earth's only natural satellite and takes one lunar month to complete one orbit of the Earth.



Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources.
They should consider ideas about the position of the Sun and planets in the solar system.... (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Pupils should track the path of the Sun using safe procedures such as a shadow stick or sundial. (KS2 Sc4 v)

They should study, using direct observations where possible, the night sky including the position and appearance of....the Moon.... (KS2 Sc4 v)

They should learn about the motions of the Earth, Moon and Sun in order to explain day and night, day length, year length.... (KS2 Sc4 v)

Pupils should have opportunities to use the idea of gravitational force to explain the movement and positions of the Earth, Moon, Sun, planets and other bodies in the Universe. (KS4 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/1d be able to describe the apparent movement of the Sun across the sky.

Sc4 v/2e be able to explain day and night, day length and year length in terms of the movements of the Earth around the Sun.

Sc4 v/5g be able to explain the motion of planets in the solar system.

THE SOLAR SYSTEM

Goals

> The Sun is a star. It is at the centre of our solar system. It is the only body in the solar system which gives out light and it is the main heat source.

> Planets, including the Earth, orbit the Sun and some of them are orbited by natural satellites (moons). The solar system is very large and very empty. The planets are very far apart.

Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources.
They should consider ideas about the position of the Sun and planets in the solar system....
They should study the extent of human exploration of space. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stage 1, 2 and 4

Pupils should track the path of the Sun using safe procedures such as a shadow stick or sundial. (KS2 Sc4 v)

They should study, using direct observations where possible, the night sky including the position and appear bright planets and the Moon. (KS2 Sc4 v)

They should learn about the motions of the Earth, Moon and Sun.... (KS2 Sc4 v)

They should be introduced to the order and general movements of the planets around the Sun. (KS2 Sc4 v)

Pupils should consider the possibilities and limitations of space travel and the use of the data gained. (KS4 Sc4 v)

Pupils should have opportunities to use the idea of gravitational force to explain the movement and positions Earth, Moon, Sun, planets and other bodies in the Universe. (KS4 Sc4 v)

Pupils should know that other planets are geologically active and that their present composition is related distance from the Sun. (KS4 Sc4 v)

Pupils should understand that the Sun is powered by nuclear fusion processes. (KS4 Sc4 v)

Pupils should examine ideas that have been used in the past and more recently to explain the character and origi Earth, other planets.... (KS4 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/1d be able to describe the apparent movement of the Sun across the sky.

Sc4 v/2e know that the Earth, Sun and Moon are spherical bodies.

Sc4 v/5g be able to describe the motion of planets in the solar system.

Sc4 v/6g know that the solar system forms part of a galaxy which is part of a larger system called the Universe.

Children's Prior Ideas

Very little research has looked at children's ideas about the solar system but it seems many children think the Earth is at the centre of the solar system.

Few children have any grasp of the relative sizes of, and distances between, the Sun, Moon, Earth and other planets.

Children often think that the solar system contains only the Sun, planets and Moon.

They appear to have little understanding of the differences between the stars and the planets, or the materials they are made of.

15

See The Earth in Space Research Summary)

The Challenge for Pupils

Before thinking about the solar system children need to have considered the Earth, Moon and Sun relationship. (See Learning Guide: The Earth, Moon and Sun.) They will need to think about the vast distances between planets, their relative sizes and their actual dimensions.

When making models care will be needed with scale, particularly if different scales have to be used for the size of the planets and the distances between them.

A useful scale for models would be:

SUN	ball 2 feet in diameter
MERCURY	mustard seed 82 feet away
VENUS	pea 142 feet away
EARTH	pea 215 feet away
MARS	large pin head 327 feet away
JUPITER	orange 0.25 miles away
SATURN	orange 0.4 miles away
URANUS	plum 0.75 miles away
NEPTUNE	cherry 1.25 miles away
PLUTO	pin head 1.5 miles away

On this scale:

The Moon would be a pin head 6 inches from the Earth.

Alpha Centauri, the nearest star to the Sun would be a 2 foot diameter ball 10,000 miles away (in Australia).

The Andromeda Galaxy, the nearest galaxy to our own, would be 5,000 million miles away. Remember, this is using our scale!

If these distances were scaled down to fit the school grounds or a sports pitch, it becomes very difficult to find objects small enough to represent some of the planets. Therefore it is better to model the distances quite separately from a discussion of the sizes. This can be done by using children to represent each planet when distances are being considered. Similarly, if the scale for sizes was increased, (so as to make the Sun about three metres in diameter for example) it should be made clear to the class that the distances between the planets would not fit into the classroom.

For the pupils to have the notion of the planets all being very different and for them to understand the differences between the Sun and the planets they will need information about the various astral bodies. Data bases and computer programmes will prove very useful in providing information in a flexible manner which the children can manipulate.

The eliptical nature of the orbits of the planets could be introduced, and also the effect of Neptune being outside Pluto for part of its orbit, once the children have grasped the size, scale, differences and orbit ideas.

THE EARTH IN SPACE

ECLIPSES

Children's Prior Ideas

For many children there appears to be confusion between eclipses and the phases of the Moon. They often explain the phases in terms of the Moon being covered or a shadow being cast upon the Moon.

(See The Earth in S Research Summary)

The Challenge for Pupils

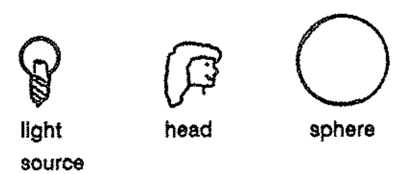
In order to consider how an eclipse occurs children will first need to have a grasp of the spatial relationship of the Earth, Sun and Moon. (See Learning Guide: The Earth, Sun and Moon)

Because there is confusion between eclipses and the phases of the Moon, the difference should be stressed to the children or the two ideas be treated in isolation - perhaps consolidating one before introducing the other.

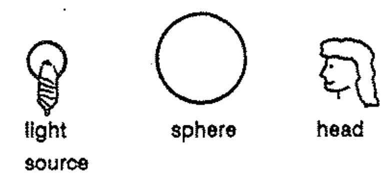
The crucial alignment of the Earth, Sun and Moon, and the fact that the Moon is tiny will need to be stressed to explain why we do not get eclipses every day and why they occur at certain places on the Earth.

They could make models with a light source and various spheres and investigate the shadows cast in various alignments of the spheres. They might use a light source, a sphere and their own head, either as the Earth or Moon, to observe what happens.

Example:



LUNAR ECLIPSE



SOLAR ECLIPSE

Because eclipses do not only occur in the Earth, Moon and Sun system the children might consider other combinations of arbitrary bodies, such as multiple moons, and construct eclipses for other planets or systems.

Goal

When an astronomical body casts its shadow over, or obscures from sight, another body this is called an eclipse.

Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should learn about the motions of the Earth, Moon and Sun in order to explain....eclipses.... (KS2 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

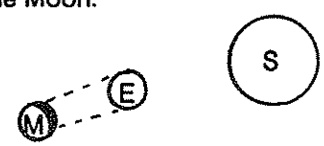
Sc4 v/2e know that the Earth, Sun and Moon are separate spherical bodies.

THE EARTH IN SPACE

THE PHASES OF THE MOON

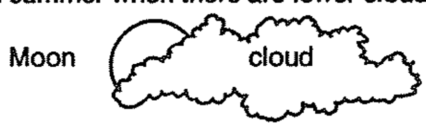
Children's Prior Ideas

Most children explain the phases of the Moon in terms of something covering, or casting a shadow on, the Moon. The most common explanation offered by children of all ages is that the shadow of the Earth covers the Moon.

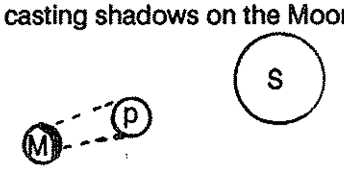


Similar ideas include:

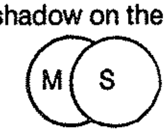
- clouds covering parts of the Moon, giving full moons in summer when there are fewer clouds;



- planets casting shadows on the Moon;



- the Sun casting its shadow on the Moon;



- other bodies in the solar system casting shadows on the Moon.

Some children account for the Moon's phases in terms of it being tilted on an axis and turning a little so that you can only see a half or a quarter, or in terms of the Moon going round the Earth so you see it less and less and more and more.

(See The Earth in Space Research Summary)

The Challenge for Pupils

The children need to abandon their 'covering' ideas and replace them with an explanation in terms of the position of the sunlit half of the Moon seen from the Earth. In order to do this they will need to:

- appreciate that the Moon is lit by light from the Sun, which always illuminates half the Moon's sphere;
- understand that a range of shapes can be seen;
- understand that the shapes change in a regular pattern.

The difficulty for many children is in understanding the spatial relationship involved. They also have difficulty in understanding that the phases occur because they are observed from the Earth, not because of a change in the amount of the Moon's surface receiving sunlight.

The children would need to start by making regular observations of the Moon and recording the different shapes seen, in order to look for the pattern of the changes. This is not an easy task to organise due to weather, cloud cover, timing, children remembering to make the observation and so on, but it is worth doing. One way might be to allocate each child a particular night to make their observation and report back to a class chart, as well as making their own records of as many nights as possible. A long strip of black paper divided into sections, one for each day, onto which pupils can stick the shape of the Moon, cut out of white paper, makes a very visual display and a useful, accessible data bank.

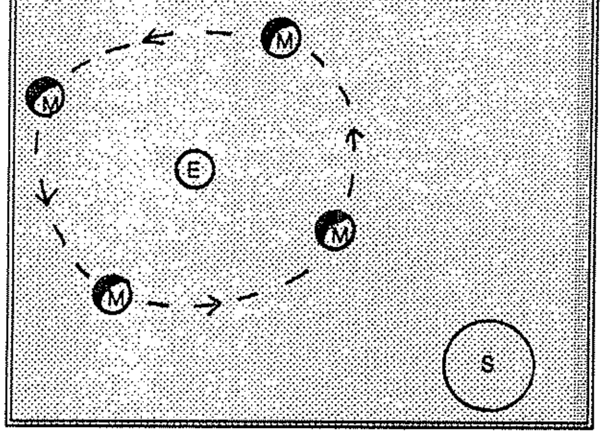
Pupils could then be asked to offer explanations of the phases and test their ideas by making models using a light source and spheres. The models should be able to form all the shapes the children observed, and in a regular pattern. A polystyrene base tile with spheres on sticks and an external light source provides a useful model. The tile can be rotated to give the effect of the Moon's orbit.

A larger demonstration involves the children standing in a group in the centre of the playground with a child 'orbiting' the group with a sphere painted half white and half black. If the sphere always faces in the same direction the children will see varying amounts of the white, 'lit', half during the full circle.

It is worth noting that many of the children's prior ideas involving covering or shadows may have been influenced by ideas about eclipses, possibly leading to confusion. It may be worth spending some time in explaining the differences

Goal

The Sun always lights up half the Moon's surface. The phases of the Moon occur because we see more or less of the illuminated side of the Moon at different times. The phases make up a regular monthly pattern.



Related National Curriculum Programme of Study
Key Stage 3
Pupils should further develop their study of the solar system through observation and secondary sources. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

Children should observe, over a period of time,....when possible the position of the Moon in the sky and its changing appearance. (KS1 Sc4 v)

They should study, using direct observations where possible, the night sky, including the position and appearance of the....Moon. (KS2 Sc4 v)

They should learn about the motions of the Earth, Moon and Sun in order to explain....the phases of the Moon... (KS2 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/3e know that the appearance of the Moon and the altitude of the Sun change in a regular and predictable manner.

THE EARTH IN SPACE

THE UNIVERSE

Children's Prior Ideas

Very little research has explored children's ideas about the stars or the Universe in general.

Children tend to think that stars are all the same size, brightness and distance from the Earth. They also think of the constellations as groups of stars and expect them to form patterns clearly resembling people animals or objects.

Some children think that stars go to the other side of the Earth during the day or that life could survive on a star.

Pupils have very little grasp of the scale of the Universe, the size of the stars or the distances between them.

They are generally unaware that the Universe is changing and think that the solar system is at the centre.

(See The Earth in Sp[illegible] Research Summary)

The Challenge for Pupils

When thinking about the Universe, children, in common with adults, have difficulty in coming to terms with the vast sizes and numbers involved and it is very important to convey the idea of scale. If the solar system is represented by a one pence piece, the nearest star would be 70m away and our galaxy would stretch out for 1000km. Other galaxies would be several thousand km away, to scale.

It may be helpful to offer children a series of scaling opportunities or ladders of size. There is simply no easy way of addressing this problem.

We can turn this problem to good account since children are fascinated by the vastness of space - here is an opportunity for flights of fancy.

Goal

> The Universe is everything that exists. It is made up of galaxies, which are collections of millions of stars. Our solar system is part of one galaxy, called the Milky Way.

Related National Curriculum Programme of Study Key Stage 3

They should consider....the position of the solar system in the Universe.

They should study the....use of satellites to....observe the wider Universe. (Sc4 v)

Related extracts from the National Curriculum Programmes of Study: Key Stages 1, 2 and 4

They should study, using direct observations where possible, the night sky.... (KS2 Sc4 v)

Pupils should have opportunities to use the idea of gravitational force to explain the movement and positions of....other bodies in the Universe. (KS4 Sc4 v)

Pupils should examine ideas that have been used in the past and more recently, to explain the character and origin of the Earth, other planets, stars and the Universe. (KS4 Sc4 v)

They should study the 'life cycle' of stars. (KS4 Sc4 v)

Related National Curriculum Statements of Attainment

Pupils should:

Sc4 v/6g know that the solar system forms part of a galaxy which is part of a larger system called the Universe.

THE EARTH IN SPACE

LEARNING GUIDES APPENDIX: RELATED EXTRACTS FROM THE NATIONAL CURRICULUM PROGRAMME OF STUDY FOR KEY STAGE 3

References relating to the Learning Guides are underlined below:

Sc4 strand v - the Earth's place in the Universe

Pupils should further develop their study of the solar system through observation and secondary sources. They should consider ideas about the position of the Sun and planets in the solar system, and the position of the solar system in the Universe. They should study the extent of human exploration of space and the use of satellites to monitor conditions on the Earth and to observe the wider Universe. They should be introduced to the idea of gravitational force.

Children's ideas about

THE EARTH IN SPACE

RESEARCH SUMMARY

This is a brief outline of research setting out the main prior ideas and understandings which teachers might expect to meet among pupils.

Children's ideas about
THE EARTH IN SPACE

Before reading this summary of children's prior ideas, it may be helpful to look at the Science Map and The Teacher's View so as to have a useful overall perspective from which to view children's understandings.

Introduction

Although several pieces of research have been undertaken in areas involving the Earth and space, the majority of work has been concerned with children's views of the shape of the Earth. The relationship of the Earth, Sun and Moon, their movements and reasons for such phenomena as day and night, and the seasons have also received some small attention but there appear to have been no studies looking further afield at the planets, the stars, the solar system or the Universe.

Research findings are summarised under the following headings:

The Earth
Day and night
The Earth, Moon and Sun
The phases of the Moon and eclipses
The changing year
The solar system, and beyond
The studies.

The Earth

Several studies have been carried out to investigate children's views of the Earth as a body in space. These are summarised in Figure 1.

Both Nussbaum [1] and Baxter [2] observed notions which children hold in their development from a flat Earth with limited sky and an absolute 'down' to a spherical Earth surrounded by sky with 'down' being towards the centre of the Earth.

Nussbaum's findings were supported in studies by Mali and Howe [3] and Sneider and Pulos [4], while the work of Vosniadou and Brewer [5] also cited many similar explanations offered by children.

The following figure (Figure 1) shows the ideas identified by Nussbaum, Baxter and Vosniadou and Brewer, and indicates how similar ideas found in the different studies appear to fall into several steps of a developmental sequence.

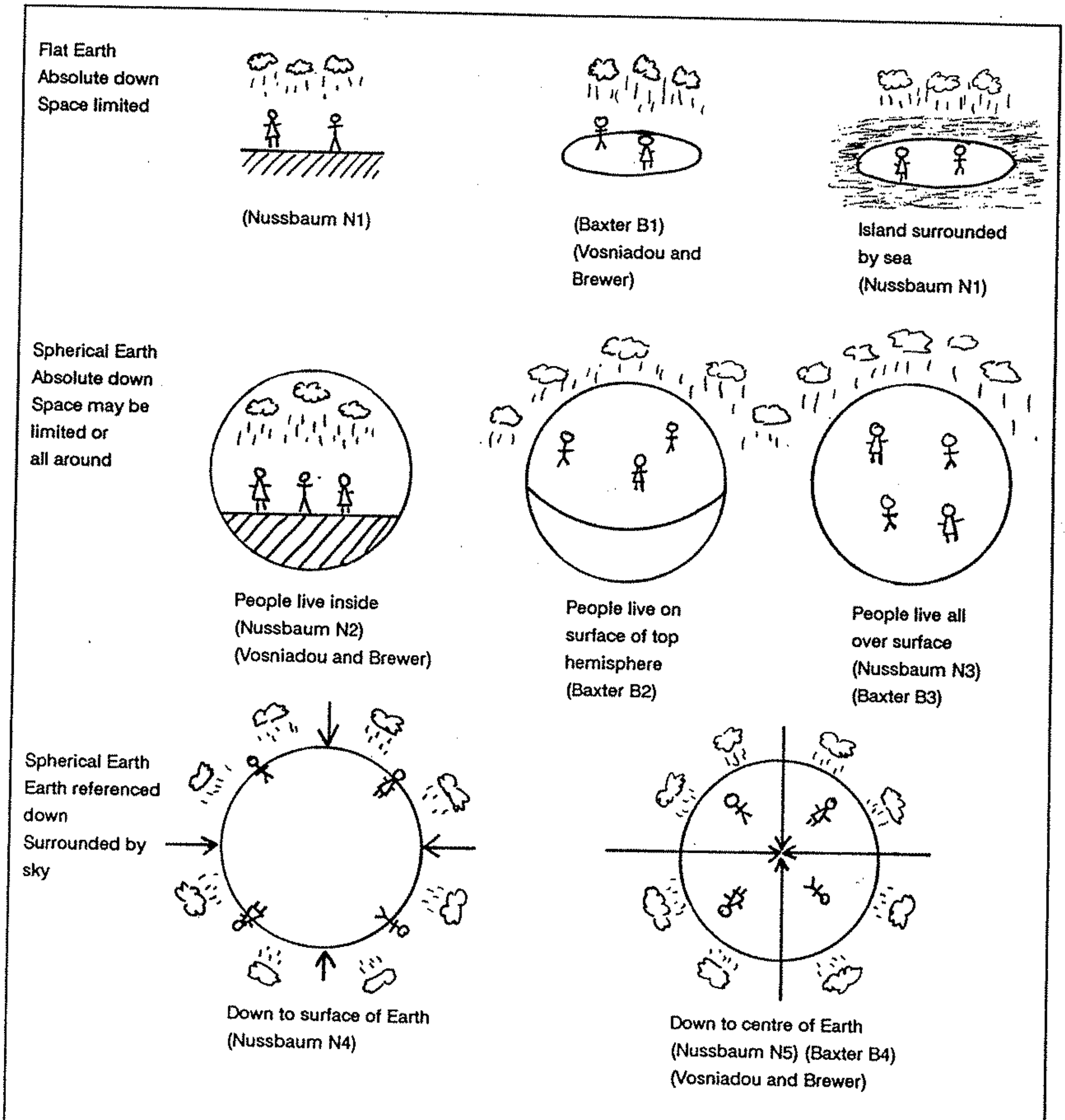


Figure 1: Children's notions of the Earth's shape, sky and the direction of 'down'

The latter study also suggested that some children consider there are two Earths, one flat on which we live, and one spherical in space, and found that while many children thought the Earth was round, at ages eight and nine they thought that it was round like a plate and had an edge.

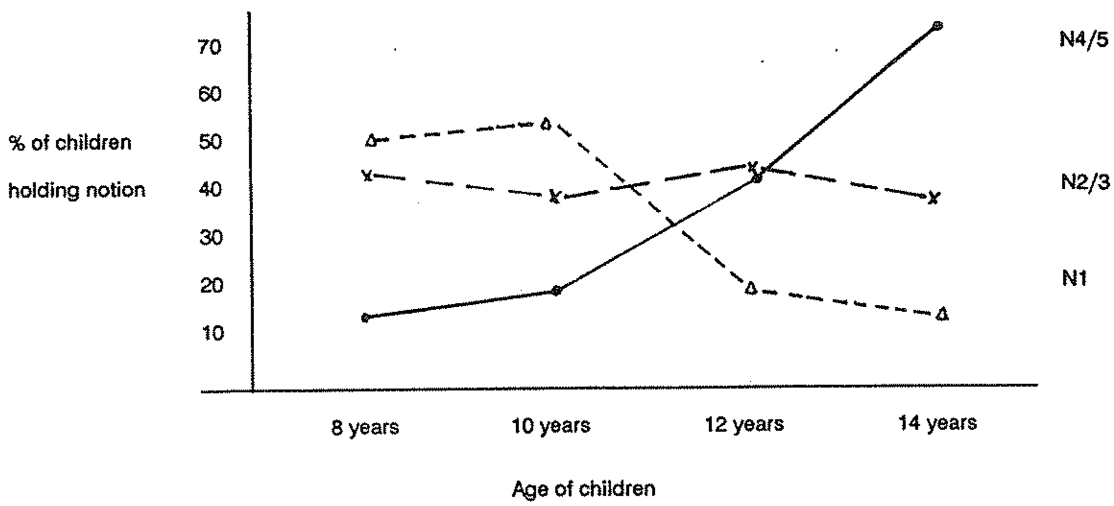


Figure 2: Frequency profiles of Nussbaum's pupils' notions

In comparing the profiles of different ages of children, Nussbaum also suggests that conceptual progress takes place with age, or with schooling, for groups of children such that most eight and ten year-olds hold notion N1, most twelve year-olds hold notions N2 or N3 while most fourteen year-old children hold notions N4 or N5 (Figure 2).

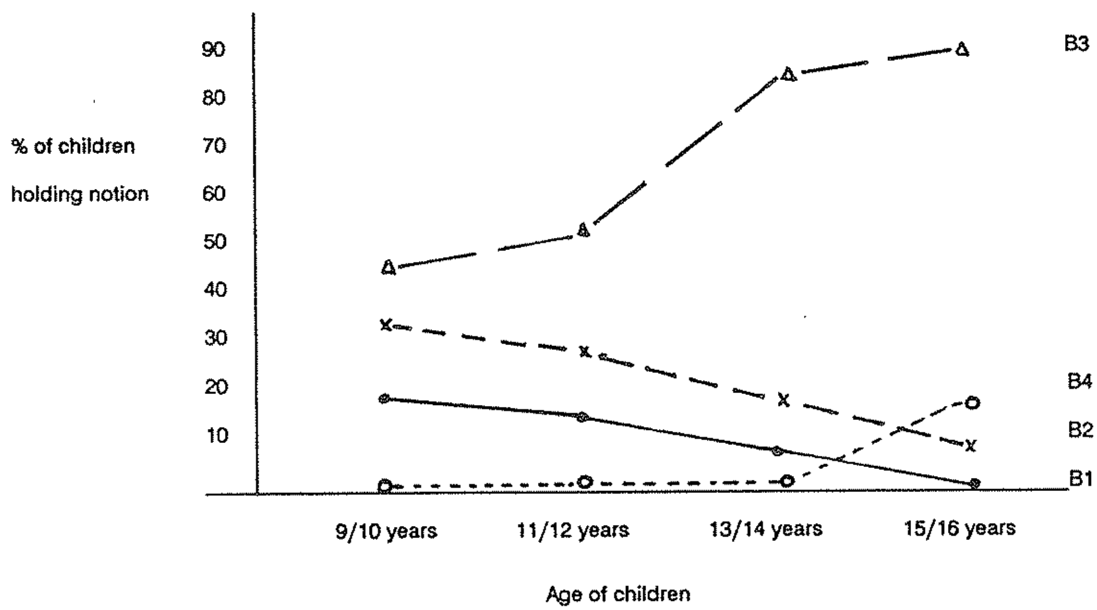


Figure 3: The prevalence of Baxter's pupils' notions about planet Earth

While noticing a decline in the number of children holding notions B1 and B2 with increasing age, Baxter also suggests that notion B3 is the one held by most children. It gains support with age, up to age sixteen, while the accepted science view, notion B4, is used by very few pupils and only the older ones, (Figure 3). Nussbaum's profiles also suggest that, since the scientific concept of Earth was introduced into the curriculum formally at the fifth grade, age eleven, conceptual change in an individual does not immediately follow instruction. If this were so one would expect to see notions N4 and N5 held by most twelve year-olds, and that is not the case.

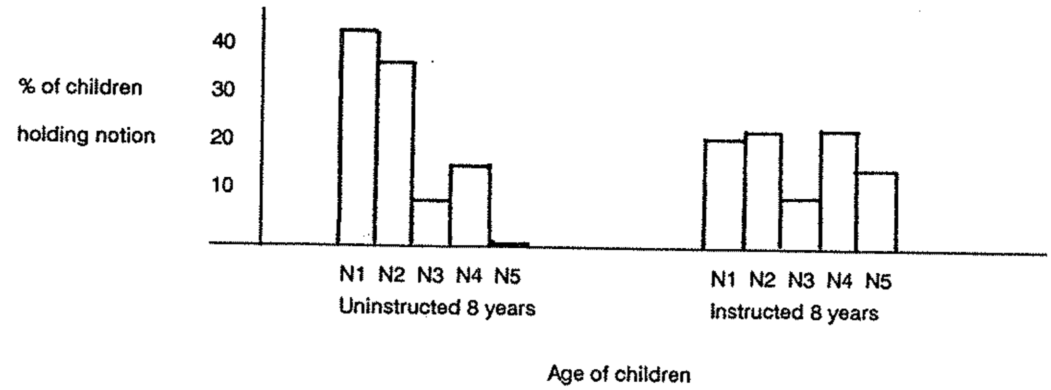


Figure 4: Frequency profiles of Nussbaum's notions of eight year-olds before and after instruction

Nussbaum with Sharoni-Dagan [6] also evaluated the effect of a unit of instruction on eight year-olds, observing that while 12% of the pupils held notions N4 and N5 before instruction, 42% held them after completion (Figure 4). The notion frequency profiles of instructed eight year-olds also compared favourably with frequency profiles of other age groups (Figure 5).

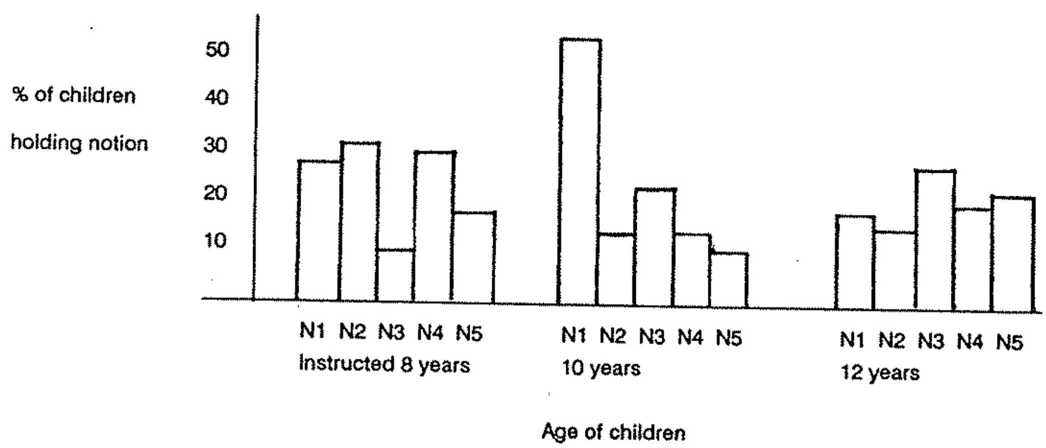


Figure 5: A comparison of Nussbaum's notion frequency profiles of instructed eight year-olds with uninstructed ten and twelve year-olds

Day and night

The studies of Vosniadou and Brewer, Baxter, and Klein [7] into children's views of why it gets dark at night suggest a development, with age, of children's thinking from more directly observable reasons to those involving astronomical movements. From the latter two studies it was also noted that many younger children considered the Sun to be animate.*

---

* *See Research Summary: Living Things*

The children's notions of day and night could be seen to fit into four bands of thinking:

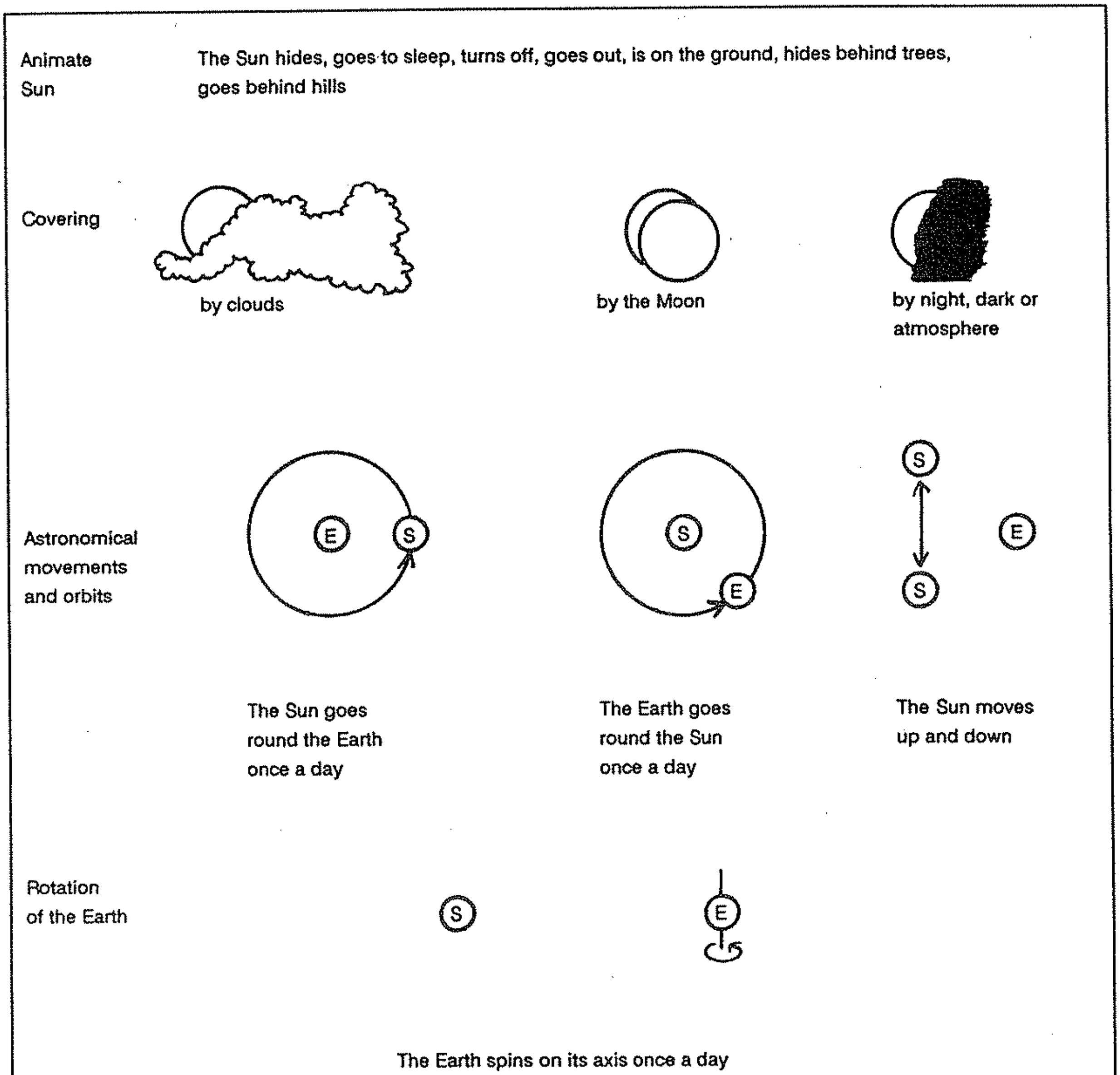


Figure 6: Children's notions of why it gets dark at night

Sadler's study of fourteen year-olds identifies a variety of ideas children hold about the cause of day and night [8]. He also notes that, although over half the interviewed students had taken or were taking a one year course of which a quarter was astronomy, these students did not seem to have the correct view any more often than the other children, but they did use many more scientific terms in their explanations.

The prevalence of Baxter's pupils' notions about day and night are shown in Figure 7. It can be seen that at ages fifteen and sixteen many children still hold covering and orbital theories of day and night.

28

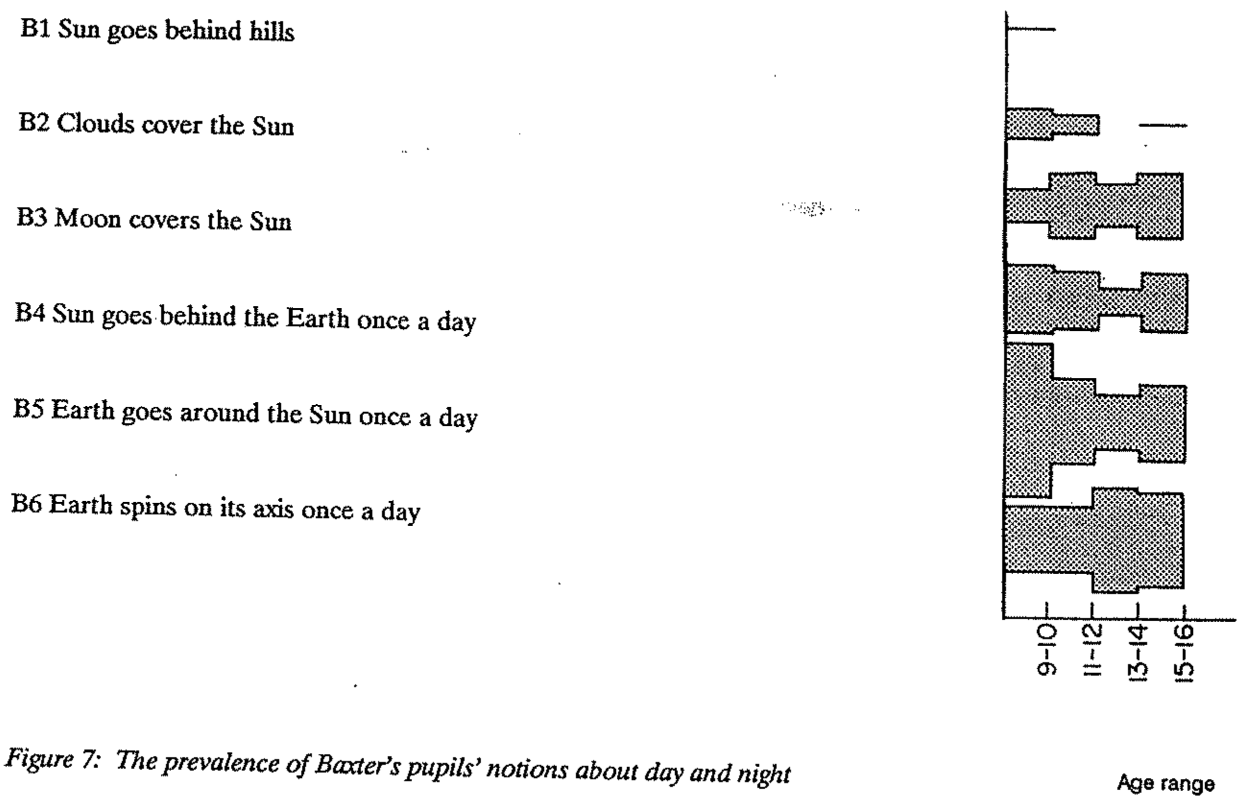


Figure 7: The prevalence of Baxter's pupils' notions about day and night

The Earth, Moon and Sun

Although little work has been carried out regarding children's views of the solar system as a whole, three studies have looked at children's ideas about the relationship between the Earth, Sun and Moon. Vosniadou and Brewer observed a move with age in children's thinking from an Earth-centred to a Sun-centred solar system. However, children, even at an older age, were much less clear as to the position of the Moon.

Jones, Lynch and Reesink [9] examined children's notions of the size, shape and relationship to each other of the Earth, Sun and Moon. They also found evidence of a move from Earth-centred to Sun-centred thinking, noting five different models (Figure 8). Their study also found that children's ideas of the shapes of the Earth, Sun and Moon changed with age. Younger children suggested two-dimensional or non-spherical three-dimensional shapes while the older children chose spheres. However, when the relative sizes of the three were considered, there was no apparent move towards a correct understanding as the children got older. Instead, the evidence suggested a gender-related selection of correct size, with far fewer girls than boys choosing the correct model.

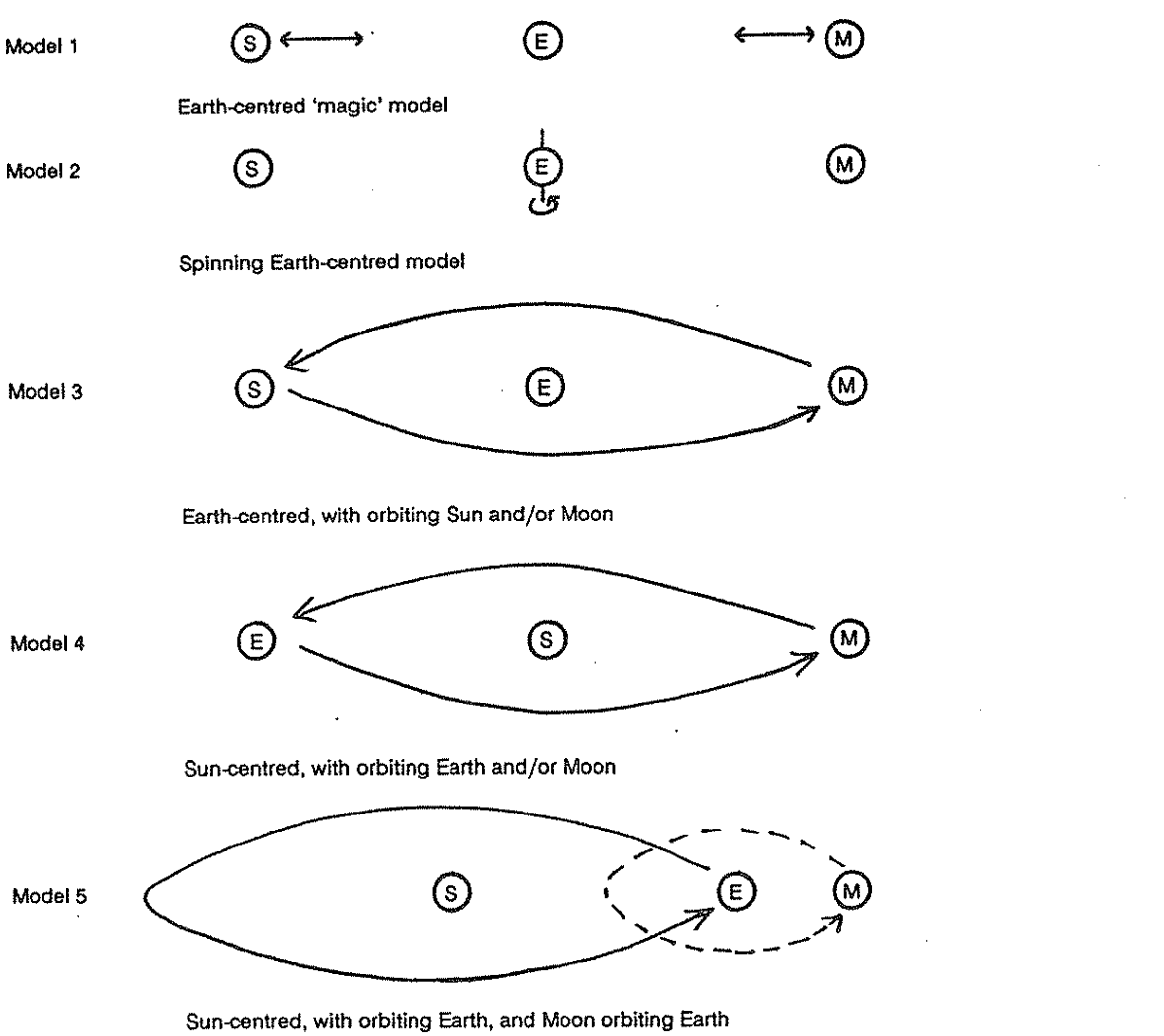


Figure 8: Jones, Lynch and Reesink's models of children's thinking about the relationship of the Sun, Moon and Earth

Sadler observed a lack of understanding of both the relative sizes and relative distances apart of the Earth, Sun and Moon. Almost every student drew the three the same size or between half or double each other's diameter. The Sun and Moon were drawn within one to four Earth diameters away from the Earth. These misconceptions, Sadler suggests, may be compounded, or indeed caused, by the models used in classrooms or by diagrams in books, which do not use the true scale for size and distance.

The phases of the Moon and eclipses

Other than the work relating to its relationship with the Earth and Sun, the only research which appears to have been carried out about the Moon concerns the phases of the Moon. Baxter suggests five children's notions. All four alternative notions involve a covering of, or casting of a shadow on, the Moon by increasingly more distant objects (Figure 9).

30

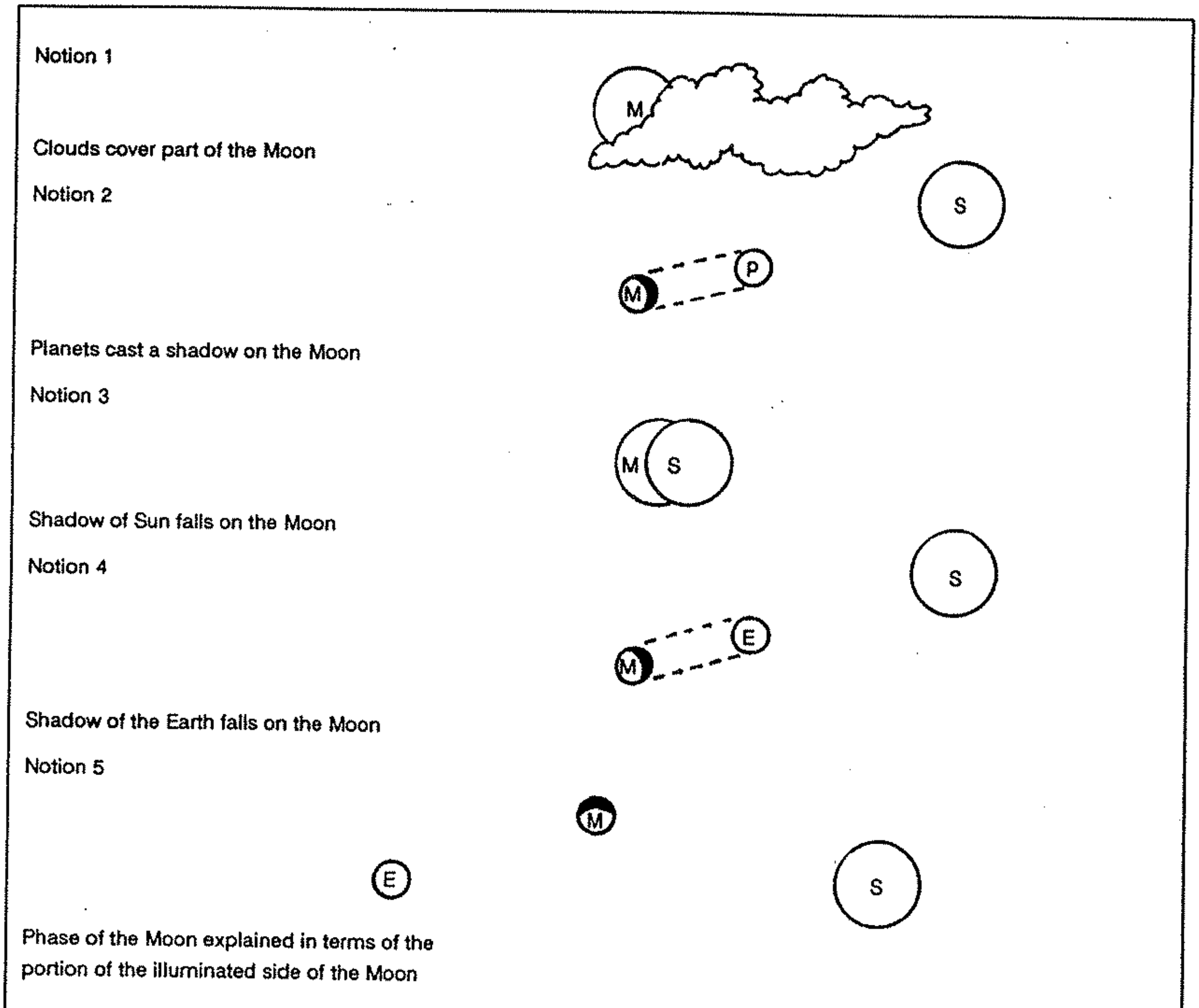


Figure 9: Baxter's suggested notions of children's thinking about the causes of the phases of the Moon

The prevalence of notion four (Figure 10), the notion held by the majority of children at all the ages right up to sixteen, also suggests a confusion between eclipses and the cause of the phases of the Moon.

Baxter's findings (Figure 10) are supported by Sadler who found that 37% of his sample attributed the phases of the Moon to the Earth's shadow covering the Moon, 25% thought the Moon moved into the Sun's shadow, while 36% of the students thought the Moon moved around the Earth. The same study also found that children had very little understanding of the time taken for the Moon to rotate, the Moon to orbit the Earth or the Earth to orbit the Sun. The students did, however, have a better knowledge of the time taken for the Earth to turn once and orbit the Sun.

Targon [10] found that 65% of his sample had no knowledge, and a further 23% only fragmentary knowledge, of the phases of the Moon; 6% held the correct notion and 8% had an 'alternative' eclipse notion.

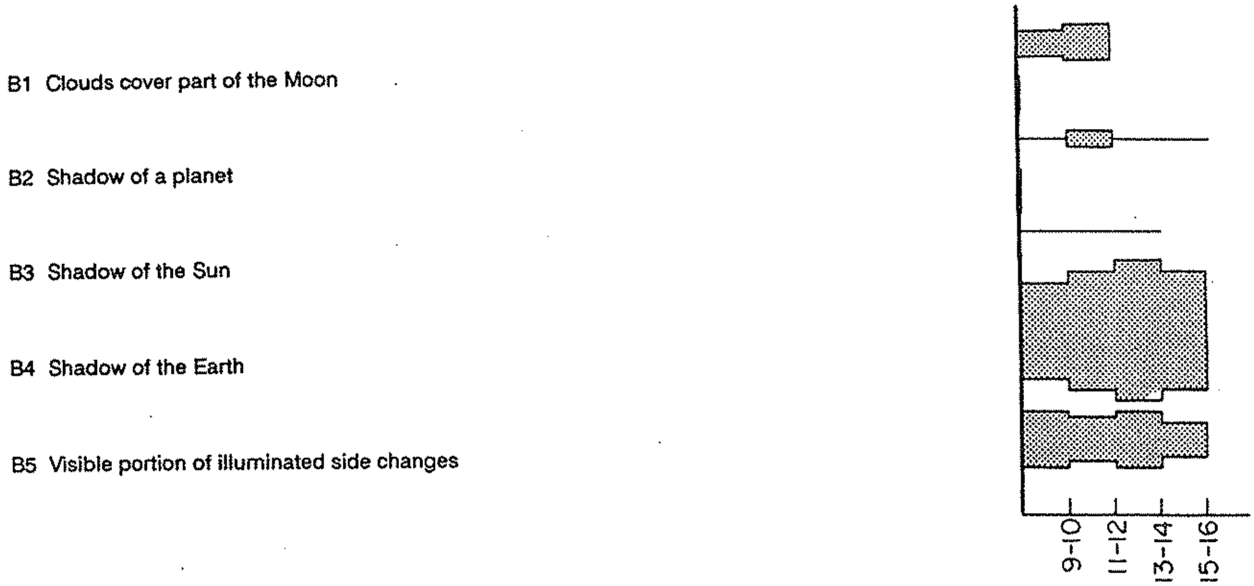


Figure 10: The prevalence of Baxter's pupil's notions about the phases of the Moon

The changing year

When considering ideas about what caused it to be cold in winter Baxter observed a trend in the children's thinking: moving with age from explanations involving nearer and more familiar objects to explanations involving more distant and less tangible objects and the movement of astral bodies. However, by far the most common suggestion, at all ages, was that the distance of the Earth from the Sun was the cause of the seasons. Many children believed the Earth was nearer the Sun in the summer than in the winter and thus it was hotter in summer. This idea was also observed by Sadler. The prevalence of Baxter's pupils' notions about the cause of the seasons are shown in Figure 11.

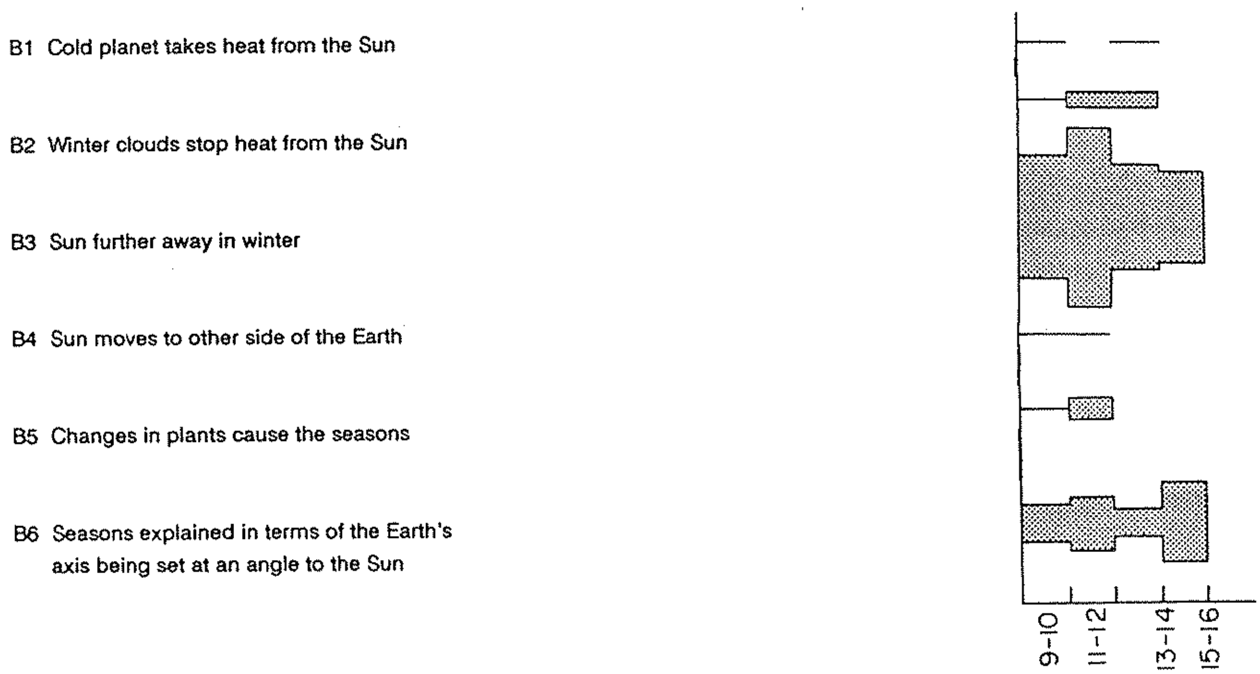


Figure 11: The prevalence of Baxter's pupils notions about the seasons

Ojala [11] noted a variety of responses from trainee teachers when asked which was the most important factor in determining 'temperature differences on the globe?'. Their explanations were presented in seven categories, which increasingly approached correctness.

Of the students, 5% offered 'childlike, teleological explanations', 11% gave answers with no explanation and a further 8% confused cause and effect. Variation in distance from the Sun was suggested by 16% of the sample, with three types of answer. Some thought that the equator would be warmer than the arctic regions because it was nearer the Sun, while others thought the areas of the Earth facing the Sun would be warmer than those facing away. A third type of response reasoned that the Earth's eccentric orbit caused the Earth to be nearer the Sun at certain times, summer, and further away at others, winter.

The largest category of explanations, 32%, thought that the angle of the Sun's rays was the most important factor. Other answers related to the inclination of the Earth's axis, left the planetary relationships open or thought the angle of inclination of the radiation varied.

The word 'location' or 'latitude' was mentioned by 20% of the students in their explanations. In some cases this was combined with the angle of inclination of the Sun, and in others it was in relation to the equator. Only 6% of the students gave a 'correct answer', that the Earth's spherical shape is the most important factor in explaining temperature differences. Ojala comments that illustrations in text books played a large part in students forming incorrect models and notes that 'pupils interpret diagrams on the basis of their knowledge at that point in time. It is very probable that they do not make a mental model comparison with reality and notice the incorrect proportions given in the diagrams. They interpret the images as they see them and reach logical conclusions on the basis of them'.

Explanations involving distance from the Sun of parts of the Earth, angle of inclination or distance from the Sun of the Earth during its orbit of the Sun could well be based on text book illustrations.

The solar system, and beyond

Very little research appears to have been carried out into children's notions of other astronomical areas. Lightman, Miller and Leadbetter [11] found that only 55% of adults thought the Sun was a star, while 25% thought it was a planet. Only 24% thought that the Universe is expanding. They also noted that astronomical literacy was 'entwined with social institutions and values, as well as with education,' with younger people, males and better educated people having more astronomical knowledge.

Prior ideas about the Sun, the planets, the stars and the Universe seem as yet untapped, though Baxter does cite a few in his teaching pack, and these might prove fruitful areas for further research.

The studies

The research into ideas about the Earth's shape includes: Nussbaum's study of American and Israeli children; his work with Sharoni-Dagan [6] concerning 114 Israeli eight year-olds; Mali and Howe's [3] study of 250 Nepalese children aged eight, ten and twelve; and Sneider and Pulos' [4] work with 159 Californian children aged nine to fourteen.

Studies with smaller samples were undertaken by: Klein [7], who considered the ideas of twelve Mexican-American and twelve Anglo-American children aged seven and eight; and by Jones, Lynch and Reesink [9] in their study of 32 Tasmanian primary children. Having interviewed 25 fourteen year-old students, Sadler [8] used multiple choice tests with 213 American students, aged 14-17.

Targon's [10] subjects were 61 University students while Lightman, Miller and Leadbetter [12] surveyed 1120 American adults and 87 Finnish second year primary school teacher trainees were studied by Ojala [11]. Vosniadou and Brewer [5] carried out a cross cultural study of 60 American and 90 Greek children while Baxter [2] studied 100 English children aged from 9-16.

References

1. Nussbaum J
1985
The Earth as a cosmic body.
In: Driver R, Guesne E, Tiberghien A (eds) Children's Ideas in Science. Open University Press, Milton Keynes: Chapter 9

2. Baxter J
1989
Children's understanding of familiar astronomical events.
International Journal of Science Education, Volume 11, Special Issue: 502-513

3. Mali GB, Howe A
1979
Development of Earth and gravity concepts among Nepali children.
Science Education 63(5):685-91

4. Sneider C, Pulos S
1983
Children's cosmographics: Understanding the Earth's shape and gravity.
Science Education 67(2):205-22

5. Vosniadou S, Brewer WF
A cross cultural investigation of children's conceptions about the Earth, the Sun and the Moon: Greek and American data.
In: Mandl H, De Corte E, Bennett N, Friedrid HF (eds.) Learning and Instruction. European Research in an International Context, Volume 2.2. Pergamon Press.

6. Nussbaum J, Sharoni-Dagan N
1983
Changes in second grade children's preconceptions about the Earth as a cosmic body resulting from a short series of audio tutorial lessons.
Science Education 67(1):99-114

7. Klein CA
1982
Children's concepts of the Sun, a cross cultural study.
Science Education 65(1):95-107

8. Sadler PM
1987
Misconceptions in astronomy.
Paper presented at the second international seminar: Misconceptions and educational strategies in science and mathematics. 26-29 July 1987, Cornell University, Ithaca, NY, USA.

35

9. Jones BL, Lynch PP, Reesink C
1987
Children's conceptions of the Earth, Sun and Moon.
International Journal of Science Education 9(1):43-53

10. Targon D
1987
A study of conceptual change in the content domain of the Lunar phases.
Paper presented at the second international seminar: Misconceptions and educational strategies in science and mathematics. 26-29 July 1987, Cornell University, Ithaca, NY, USA.

11. Ojala J
1990
The third planet.
Unpublished paper.

12. Lightman AP, Miller JD, Leadbetter JB
1987
Contemporary cosmological beliefs.
Paper presented to the second international seminar: Misconceptions and educational strategies in science and mathematics. 26-29 July 1987, Cornell University, Ithaca, NY, USA.

36

THE EARTH IN SPACE

THE TEACHER'S VIEW

This section outlines those aspects of a deeper understanding which the teacher needs to have in mind whilst working with pupils. Ideas in any aspect of science are constructed at ever increasing levels of sophistication and there are inevitably more sophisticated understandings than can be represented in these brief notes.

Teachers will probably be familiar with the main ideas required for teaching Earth in Space at Key Stage three. The terms in the glossary will help elucidate the concepts shown on the map. The main ideas which teachers, unfamiliar with astronomy, will need to give careful thought to are those relating to

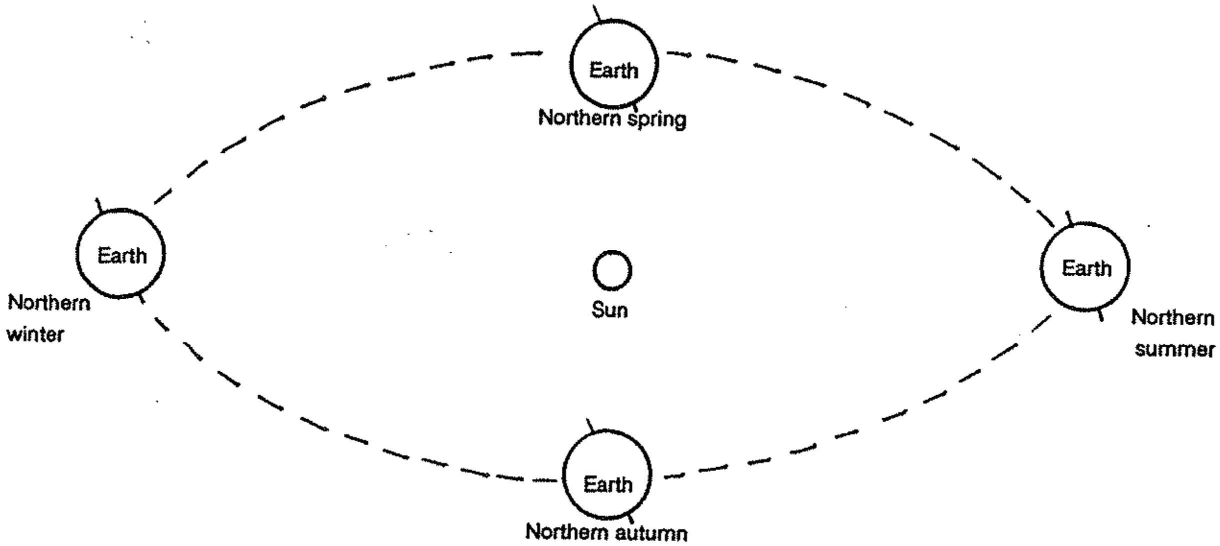
The tilt of the Earth's axis
Temperature differences through the year
The changing length of daylight
The inclination of the Sun
The phases of the Moon
Eclipses.

The tilt of the Earth's axis

If the Earth's orbit of the Sun is taken as the horizontal, then the Earth's axis is tilted from the perpendicular to the orbit, by approximately 23.5°, and it always points in the same direction. As the Earth orbits the Sun the tilt causes a change in the orientation of the Earth relative to the Sun and this in turn gives rise to various phenomena which we experience as annual changes which are explained in the following sections.

Temperature differences through the year

During the course of one orbit of the Sun the northern hemisphere is tilted towards the Sun for part of the orbit. This would be summer in the northern hemisphere. At the other side of the Earth's orbit the northern hemisphere is tilted away from the Sun and it would be winter there. As the Earth travels in its orbit, with its axis pointing in the same direction, there are times when the the northern hemisphere is neither pointed towards nor away from the Sun and at these times it will be spring or autumn.

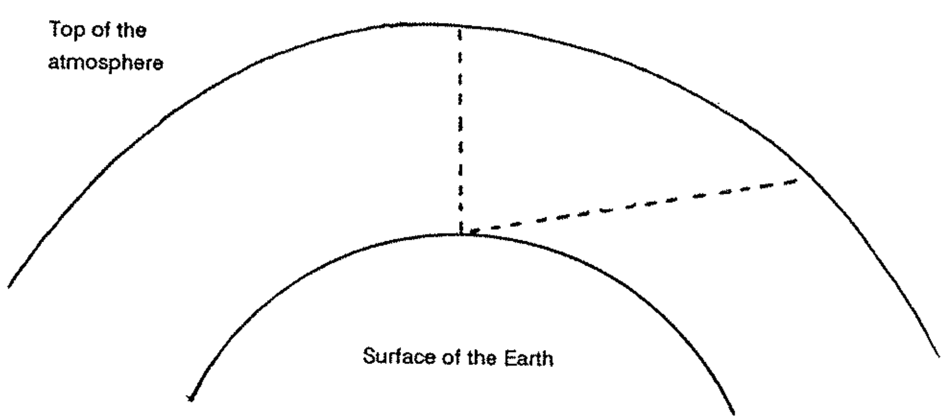


The change in orientation of the Earth gives rise to the different temperatures experienced at different times of the year. This is not, as is often thought, because of a change in distance from the Sun, caused by the tilt or the non-circular orbit of the Earth.

The difference in distance, from being tilted towards rather than away from the Sun, is negligible in comparison to the distance of the Earth from the Sun. Although the Earth's orbit is not quite circular and therefore the Earth is not always the same distance from the Sun this does not relate to winter and summer in the expected way. Indeed the Earth is nearer to the Sun in December than in July.

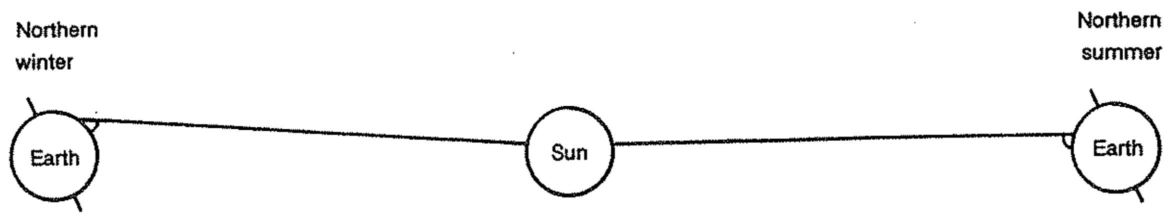
The different temperatures experienced at different times of the year are due to three factors.

1) The Sun's radiation passes through a greater thickness of atmosphere in winter and so less radiation reaches the Earth's surface. The Sun's rays have to travel further through the atmosphere when they are inclined to the vertical. Less radiation reaches the Earth's surface.



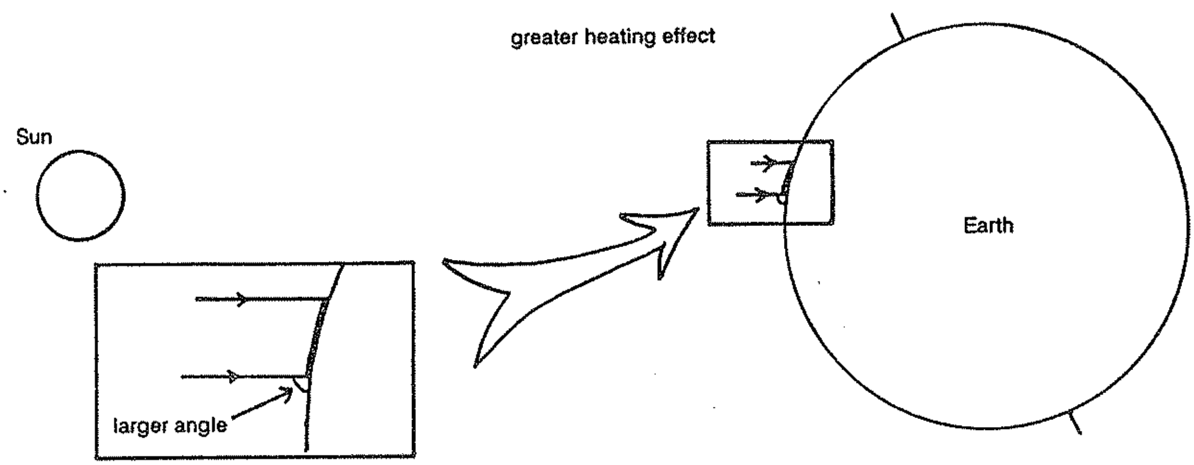
39

2) The inclined radiation from the Sun covers a greater area of the Earth's surface in winter than in summer and so a unit area is heated less. In our summer, when the northern hemisphere is tilted towards the Sun, the rays meet the Earth's surface at a higher angle than in winter when the northern hemisphere is tilted away from the Sun.

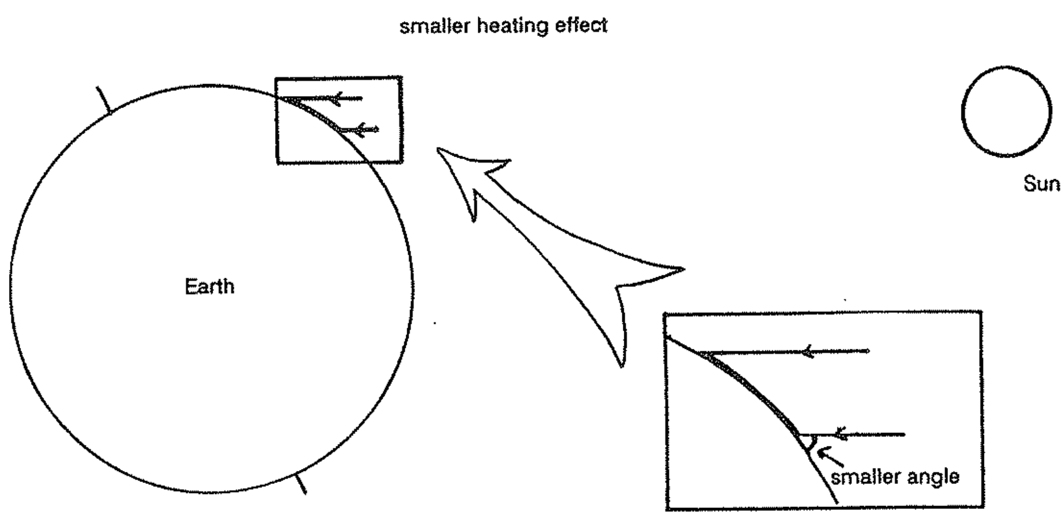


The heating effect is much less at the lower angle because the same energy is spread over a greater area.

NORTHERN SUMMER



NORTHERN WINTER



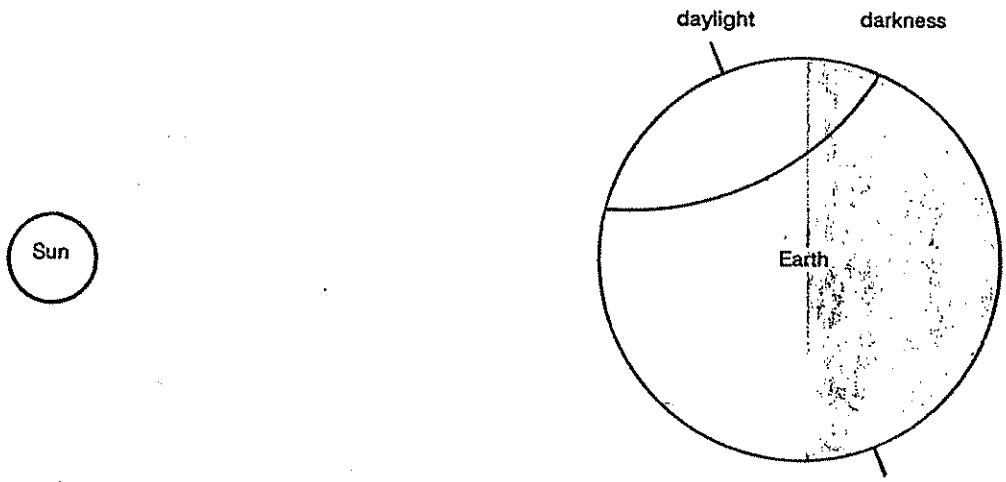
3) The length of daylight is shorter in winter than in summer.

40

The changing length of daylight

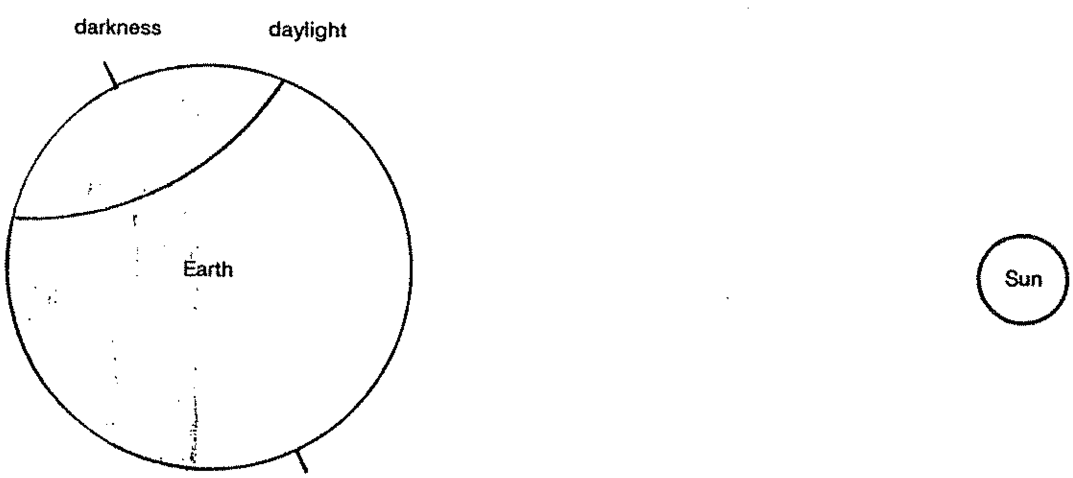
The length of daylight also changes through the year due to the change in orientation of the Earth. For any place on the Earth, the circle through which it turns, during a day, is its line of latitude.When it is tilted towards the Sun more of the line of latitude is in sunlight than is in darkness, so a place on that line of latitude will have longer daylight than darkness.

NORTHERN SUMMER



When it is tilted away from the Sun the line of latitude is more in darkness than in sunlight and therefore a place on that line of latitude has shorter days and longer nights.

NORTHERN WINTER



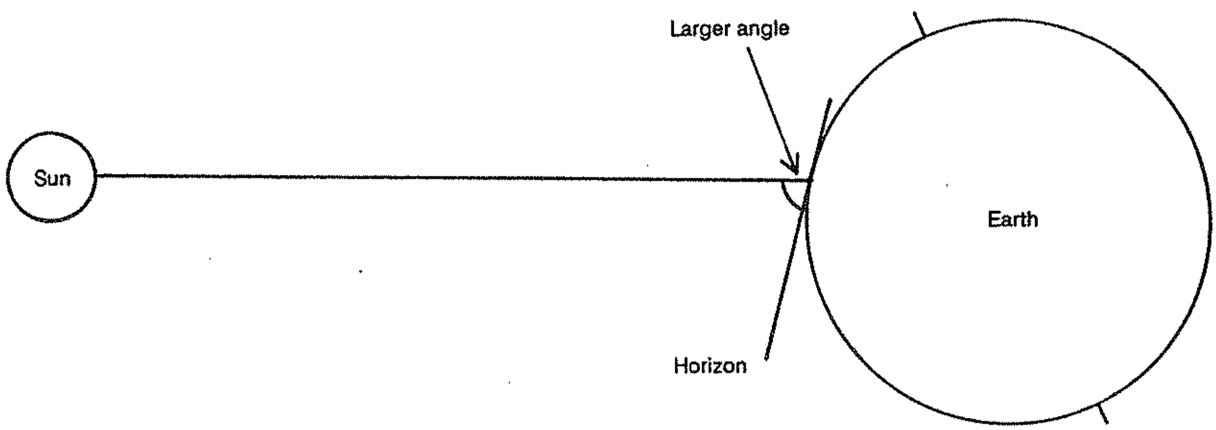
As the orientation varies through the year so the length of daylight varies.

41

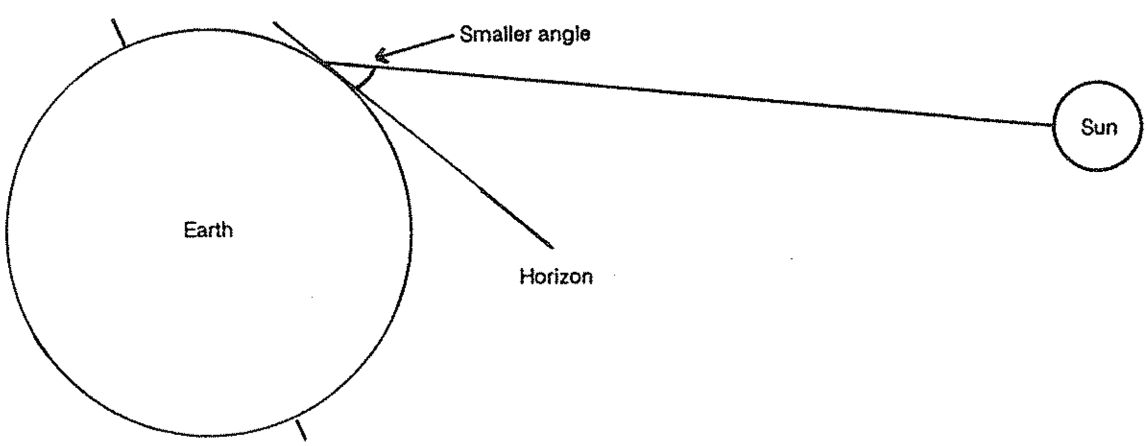
The inclination of the Sun

The inclination of the Sun - the height of the Sun in the sky at mid-day - is also affected by the change in orientation of the Earth. In our summer, when the northern hemisphere is tilted towards the Sun, the Sun appears at a higher angle to the horizon than in winter, when the northern hemisphere is tilted away from the Sun.

<u>NORTHERN SUMMER</u>



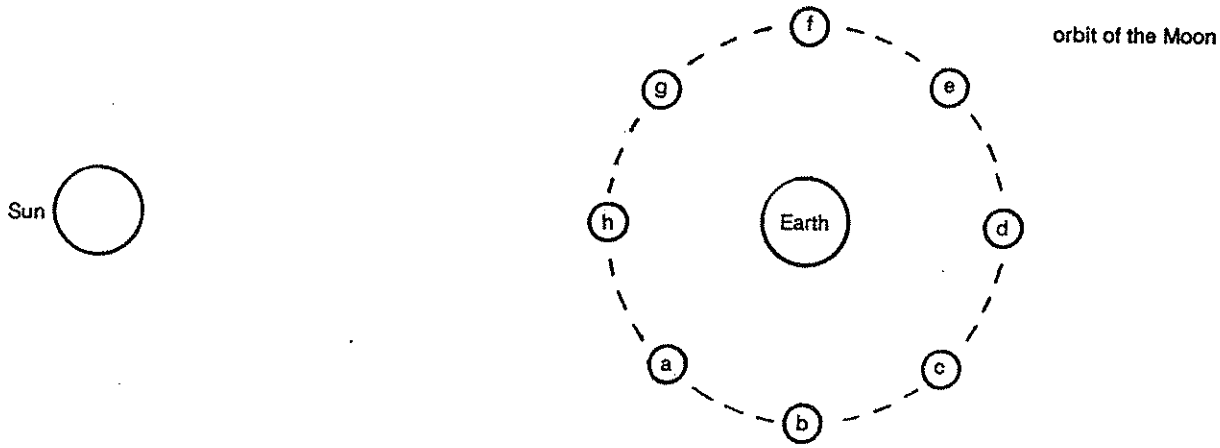
<u>NORTHERN WINTER</u>



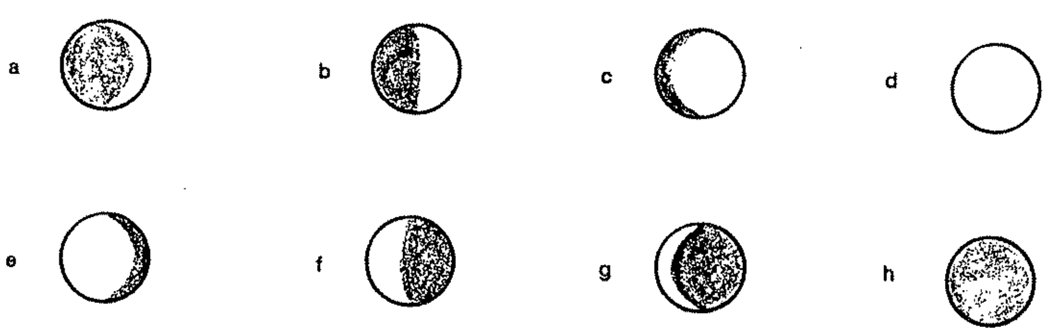
42

The phases of the Moon

The Sun always lights up half the Moon's surface. From our standpoint on the Earth we see differing amounts of the illuminated part of the Moon as the Moon orbits the Earth.



At the various points in the orbit, indicated by the letters, from the Earth the Moon would look like this:



The changes in the shape we see are small from one day to the next. The changes occur in a regular pattern.

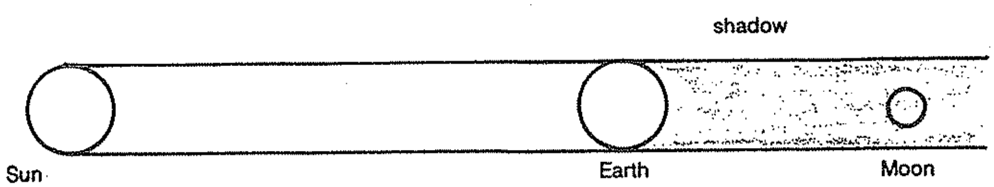
(It is very difficult to show on one diagram the Moon's orbit, the illuminated part of the Moon and the view we get of the Moon from the Earth.)

43

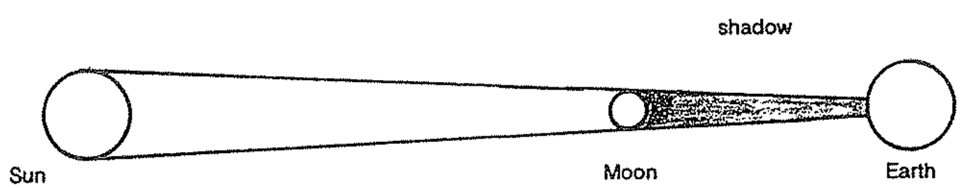
Eclipses

There are two types of eclipse experienced on the Earth, both of which occur when the Sun, Moon and Earth are aligned in a straight line.

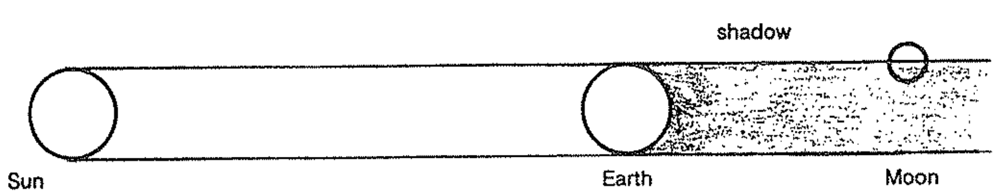
When the Earth lies between the Sun and the Moon a lunar eclipse occurs. The Earth's shadow is cast over the Moon therefore blocking the Sun's light from illuminating the Moon.



When the Moon lies between the Sun and the Earth a solar eclipse occurs. The Moon's shadow is cast on to the Earth therefore blocking the Sun's light from reaching the Earth.



If the Sun, Moon and Earth are not directly aligned a partial eclipse may occur, with only some of the Sun's light being obscured.



Eclipses are not only experienced on Earth. When any astronomical body casts its shadow over, or obscures from sight, another body, this is called an eclipse.

44

THE EARTH IN SPACE

A BRIEF ASTRONOMICAL HISTORY

3000 BC Babylonian astronomical records begin.

2000 BC Sumarians recorded figures in the sky - constellations.

1000 BC Chinese astronomical records begin and the **Egyptians** based a calendar on Sirius, the brightest star in the sky.

700 BC to 50 AD Babylonian priests computed the positions of the Moon and the planets, listed eclipses. They predicted the times when planets would be closest to and farthest from the Sun and when objects would be seen for the first and last time in a year.

600 BC Thales of Miletus (Greek) recorded constellations, some of which are still recognised today.

467 BC Chinese observation of 'Halley's' comet.

444 BC Chinese calculation of solar year as 365.25 days.

4th Century BC Eudoxus (Greek) explained the Universe as a system of 27 Earth-centred spheres which fitted around each other and rotated carrying the heavenly bodies. The stars were fixed to the outermost sphere. He, like other early Greek astronomers, made extensive observations.

4th Century BC Aristotle (Greek) believed the Earth was at the centre of the Universe and was orbited by the Sun, the planets and the stars. The Universe was made up of 55 celestial spheres. His theories dominated scientific thinking for the following 2000 years and may have impeded the development of science during that time.

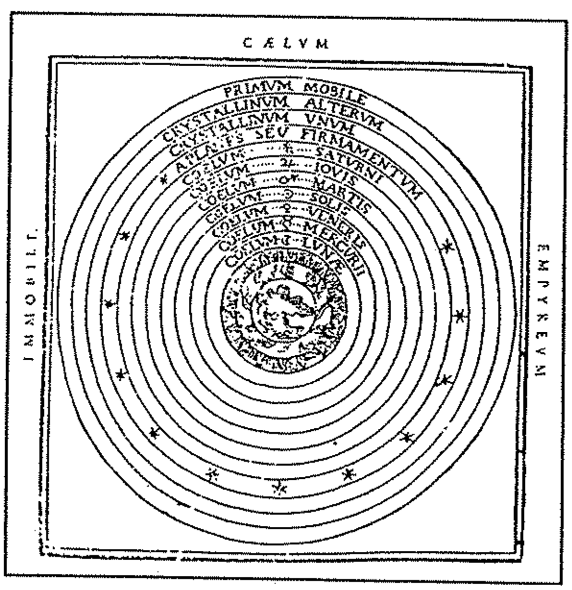
3rd Century BC Aristarchus (Greek) measured the radii of the Sun and the Moon and their distances from the Earth. He also suggested a Sun-centred system where the sphere of stars was so far away that the Earth's orbit around the Sun was like a point in comparison. His idea did not find support among his contemporaries.

287-212 BC Archimedes (Greek) mathematician and astronomer.

273-192 BC Eratosthenes (Greek) calculated the size of the Earth. The Earth had long been known to be spherical and various estimates of the circumference had been made but Eratosthenes was the first to measure it with great accuracy. By measuring the length of the shadow cast by a pole at Alexandria, at noon, he was able to calculate the difference of Alexandria's latitude from that of Syene. Because he knew the distance between the two places he was therefore able to calculate the circumference of the Earth.

100 BC Hipparchus (Greek) drew up the first star chart.

140 AD Ptolemy (Egyptian) presented an Earth-centred model of the Universe where the planets moved in small circles, called epicycles, whose centres moved around the Earth on larger circles. His ideas remained influential for 15 centuries.

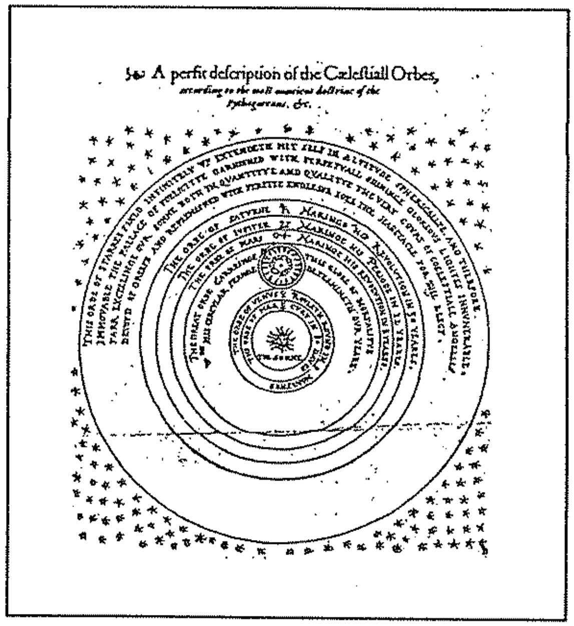


The Ptolemaic System

500 AD to 1500 AD - no great astronomical advances or discoveries. Some observations were made and Aristotelian ideas were studied, developed and criticised.

1473-1543 Nicolaus Copernicus (Polish) suggested that the motion of the planets could be explained if the Sun was at the centre of the solar system, not the Earth, and that the planets move around the Sun. His theory also put the Sun at the centre of the Universe and the stars on the outer most fixed spheres. In order to match theory to observation he used epicycles, and he also employed many of Ptolomy's observations. Copernicus published his theory in 1543 in the book called De Revolutionibus (on the revolution of the celestial system).

The Copernican System



His idea of a moving Earth was criticised on religious grounds by some Catholics, Protestants and Jews. Most practising scientists were not convinced enough by his arguments to justify revising all their thinking and to learn a new system. One serious objection was that his system predicted stellar parallax which was not observed. Also his theory did not make sense in terms of the Arisotelian laws of physics of the day, and he was unable to offer new explanations to support his model.

1546-1601 Tycho Brahe (Danish) was an observer who for twenty years made accurate measurements of the positions of the stars and the planets, prior to the invention of the telescope, and he catalogued 777 stars. He did not support the Copernican system and suggested his own Tychonian idea in which the Sun orbited the Earth while Mercury and Venus orbited the Sun. During the last ten months of his life Brahe was assisted by Johannes Kepler.

1571-1630 Johannes Kepler (German) took Brahe's observations and perfected the heliocentric theory. He published two laws in 1609 and a third in 1618. His first law stated that the planets orbit the Sun in ellipses, with the Sun at one focus. This discovery of elliptical orbits greatly enhanced the accuracy of the earlier calculations and was a major move from the view that the orbits must be circular because God could not have made them anything other than the perfect figure. Kepler's second and third laws relate to the speed of planets and length of time of their orbits.

1564-1642 Galileo Galilei (Italian) was the first to use a telescope for astronomical observation. He made various discoveries including mountains, craters and dark areas, which he called maria (meaning seas), on the Moon. He also found that the hazy regions of the sky, such as the Milky Way, actually contained individual stars. He discovered moons orbiting Jupiter, which proved that all bodies did not revolve around the Earth, and observed that the shape of Saturn was more complex than a sphere. His discovery of the phases of Venus gave Galileo crucial evidence for refuting the Earth-centred theory, in which Venus should always appear as a crescent. He wrote his Dialogue Concerning the Two Chief Systems of the World, in which he presented the heliocentric theory as better than the Ptolemaic system. Church authorities took great offence at his work and he was later forced to recant his heretical notion.

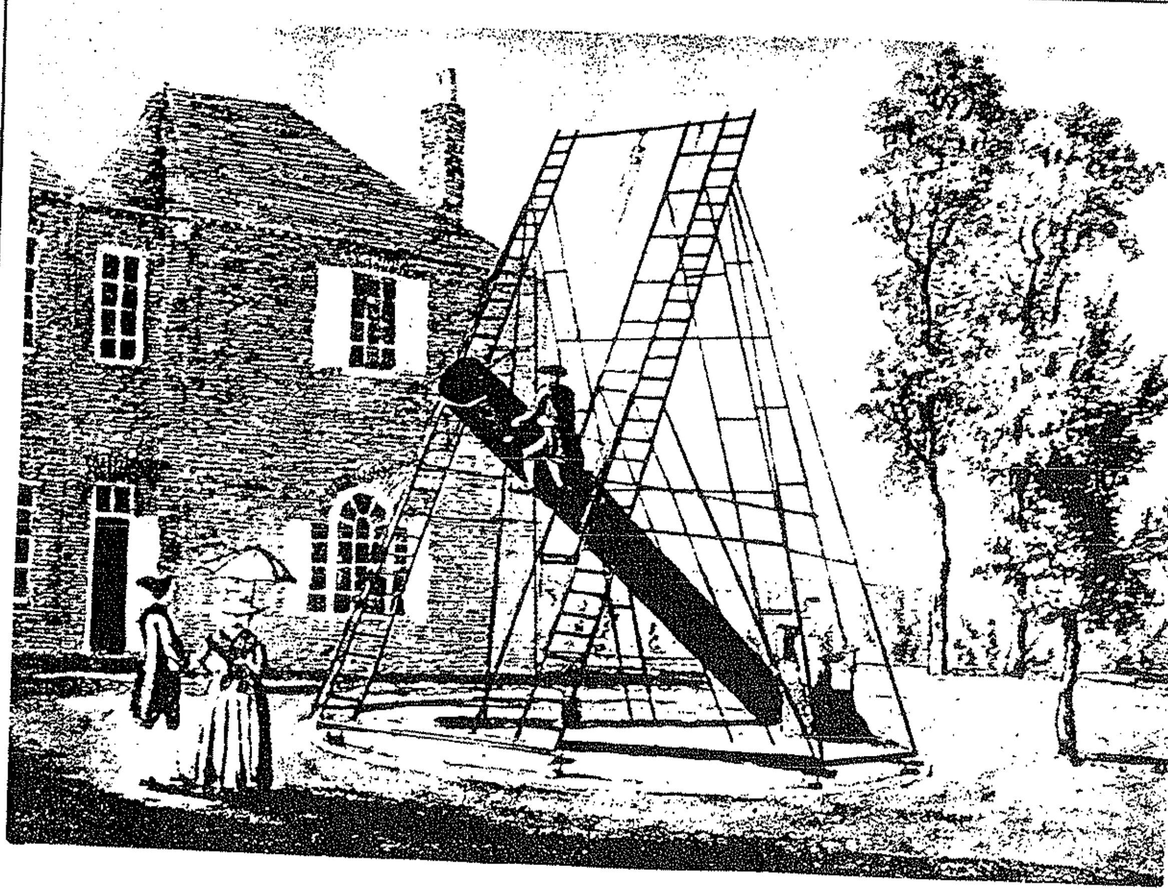
1608 Hans Lippershey (Dutch) invented refracting telescope.

1642-1727 Issac Newton (British) born in the year of Galileo's death. By the time Newton published his work - The Principia - in 1687, the Sun-centred system was accepted. In it he showed that the motions of the planets could be explained by the same law of gravitation that governs bodies on Earth. He was the first to realise that gravity was universal. He was perhaps the greatest scientist of his time, also discovering that light could be broken down into a spectrum and inventing both calculus and the reflecting telescope.

1656-1742 Edmund Halley (British) published 'A Synopsis of the Astronomy of Comets'. He analysed all available observations of comets and claimed that observations in 1531, 1607 and 1682 could all be explained by a single comet in a 76 year elliptical orbit about the Sun. He calculated that it would reappear near Christmas 1758, by which time he would have been 102 years old. He made a plea for astronomers to look for the comet, and it was seen as he predicted and was given his name.

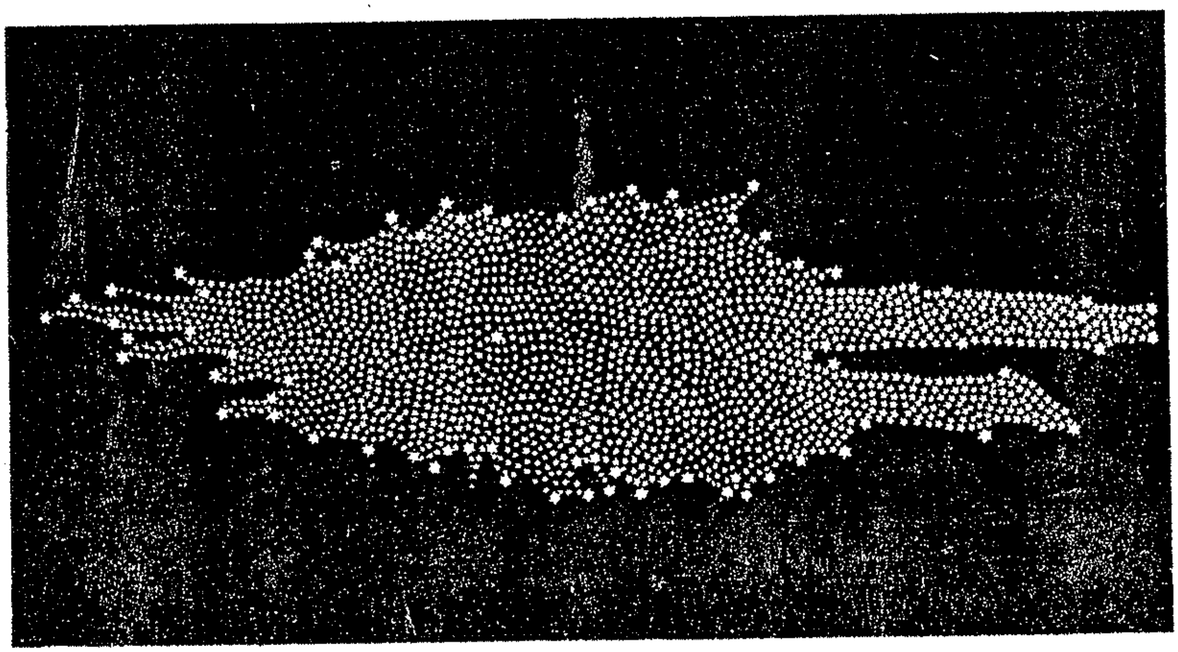
1678-1771 Jean-Jacques Dortous de Mairan (French) wrote the 'Physical and Historical Treatise on the Aurora Borealis', in which he suggested that the Earth and the Sun were connected by bridges of gas, and made the first modern anaylsis of the nature of stars. He suggested that the 'corona' of the Sun was evidence of gas streaming outwards and that the gas reached the Earth causing the Northern Lights. He suggested that streams of gas emanating from other 'more monstrous' stars might appear as nebulous patches in the sky and he concluded that 'truly nebulous matter exists in the sky'.

1738-1822 William Herschel (German) spent his early life as a musician, living in England from 1757, and was appointed director of public concerts in Leeds in 1762. His interest in astronomy grew and he eventually became a professional astronomer. In 1781 he had discovered the planet Uranus, the first astronomer to discover a primary planet, and in 1782 he was appointed astronomer to the court of George III. He built larger and larger telescopes and set about observing the grand pattern of the Milky Way.



Herschel's 20 foot reflecting telescope

He expected to find several nebulae which had remained undiscovered but in a seven year period actually found two thousand. He correctly predicted that paired stars would undergo tiny displacements detectable within his lifetime, but whereas he had intended to use the pairs to measure stellar distances, he found that many of the pairs were rotating around each other. They were bound by gravity and thus he extended Newton's laws to the realms of the stars.



Herschels' diagram of our galaxy

Unfortunately, his ideas were based on the false presumption of all stars having the same brightness and therefore faint stars being further away. His own observations of double stars contradicted this but, as no other method was available for estimating distances, he justified his ideas by saying that factors of two or three in brightness of stars were unimportant. Further evidence has shown that the brightness of stars varies by factors of a million or more. His results indicated a diameter for the Milky Way of 800 times the distance to Sirius but he later amended this to 2300 times the distance and acknowledged that he could not see the stars at the edge of the Milky Way. The diameter of the Milky Way is now known to be about 5000 times the distance to the nearby stars so Herschel's calculation was extremely close.

1750-1848 Caroline Herschel (German) sister of William, became an astronomer in her own right and was probably the first woman to be acknowledged in this field. She discovered several comets which would be no mean feat today but even more so 200 years ago. Her work with William was invaluable in his discoveries.

1850 onwards on the basis of the work of early astronomers there have been many advances in astronomy over the last 150 years, too numerous to be detailed here. Stars have been analysed, counted, labelled and catalogued, nebulae and star clusters discovered and discussed. Telescopes have become even more powerful, the exploration of space has begun and man has walked on the Moon and in space.

THE EARTH IN SPACE

188715

A GLOSSARY OF TERMS

Asteroid a minor planet.

Atmosphere the layer of gas around the surface of a planet or moon.

Comet a large ball of frozen ice, rock and carbonaceous material that moves through our solar system as it travels on an extremely large orbit round the Sun.

Constellation a name given by ancient civilisations to patterns of stars which are in fact at very different distances from us.

Crater a pit on the surface of a solid planet or moon caused by the impact of a rock from space.

Day the time taken for the Earth to complete one rotation on its axis.

Eclipse a phenomenon which occurs when the shadow of the Earth falls on the Moon or a shadow of the Moon falls on the Earth.

Galaxy a collection of millions of stars travelling together through space.

Meteor a piece of comet and asteroid debris that enters the Earth's atmosphere and either burns up or falls to the Earth's surface as very small pieces.

Meteorite a meteor which reaches the ground.

Milky Way the spirally-shaped galaxy of about 100,000 million stars, of which our Sun is just one star.

Moon a natural satellite going round a planet.

The Moon is a natural satellite which orbits the Earth. It is the fifth largest of the planetary satellites, with a rough, brownish surface and is the poorest reflector of light in the solar system. It has no observable atmosphere, is 382,400km from the Earth and has a force of gravity about 1/5th that of the Earth.

Month the time taken for the Moon to orbit the Earth.

Synodic month the time it takes the Moon to go round the Earth and return to the same position relative to the Sun, is 29.5 days.

Sidereal month the time it takes for the Moon to go round the Earth and return to the same position relative to the stars, is just over 27 days.

Nebula a collection of stars lying far beyond our galaxy.

Orbit the path taken by an object round another object.

Planet a large object going round a star. It does not give out any light of its own. The Sun has nine planets. In order from the Sun they are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

Satellite	an object which orbits a planet, for example the Moon and artificial satellites.
Solar system	a system of planets, moons, asteroids, comets and satellites and the star they orbit. It usually refers to the Sun and its planets etc.
Star	a very big, extremely hot ball of gas which gives out heat and light. We can see about 3,000 stars with the naked eye, all of which are part of the Milky Way.
Sun	the nearest star to the Earth, it is at the centre of the solar system. The Sun was formed from hydrogen gas 5,000,000 years ago and has a surface temperature of about 5,800k. The Earth is 150,000,000km from the Sun.
Universe	is made up of lots of galaxies and contains everything there is.
Year	the time taken for the Earth to orbit the Sun.

S3

THE EARTH IN SPACE

A LIST OF RESOURCES AND SUGGESTIONS FOR VISITS

Published materials

THE EARTH IN SPACE*
J Baxter, County of Avon Resources for Learning Development Unit, Bishop Road, Bishopton, Bristol BS7 8LS

EARTH ATMOSPHERE AND SPACE/EARTH IN SPACE (INSTRUMENT PACK)
M and D Slater, Molehill Press, Grange Farmhouses, Geddington, Kettering, Northampton NN14 1AL

LEARNING THROUGH SCIENCE (SKY AND SPACE PACK)
MacDonald Educational

EARTH AND SPACE (PRIMARY AND SECONDARY BOOKLETS)
The Association for Astronomy Eduaction and the Association for Science Education

EARTH IN SPACE
D Ashton, RESOURCE, Exeter Road, Off Coventry Grove, Doncaster DN2 4PY

EARTH IN SPACE
L194 - CLEAPSS, School Science Service, Brunel University, Uxbridge UB8 3PH

* These materials are derived from a constructivist view of teaching and learning

---

Useful addresses

THE ASSOCIATION FOR ASTRONOMY EDUCATION, 34 Acland Crescent, Denmark Hill, London SE5 8EQ

NASA EDUCATION AND AWARENESS BRANCH, John Kennedy Space Centre, Florida 32899, USA

Possible visits

AMATEUR ASTRONOMY CENTRE
Bacup Road, Todmorden, Lancashire OL14 7HW

ARMAGH PLANETERIUM
College Hill, Armagh, Northern Ireland BT61 9DB
(Exhibition, displays, 105 seat planeterium, mail order facilities) (0861) 523689

JODRELL BANK SCIENCE CENTRE
Lower Withington, Macclesfield, Cheshire SK11 9DL
(Exhibition, interactive area, 134 seat planeterium) (0477) 71339

LIVERPOOL MUSEUM AND PLANETRIUM
William Brown Street, Liverpool L3 8EN
(67 seat planeterium, exhibition) (051) 207-0001

LONDON PLANETERIUM
'arylebone Road, London NW1 5LR
' seat planeterium, exhibition) (071) 486-1121

L MARITIME MUSEUM AND OLD ROYAL CONSERVATORY
London SE10 9NF
:hibitions, Greenwich Meridian, planeterium, large refracting telescope)