

There's no place like home



UNIT 9

This unit looks at some special physical properties of the Universe that make life on Earth possible. Why is the world as it is? Did it all happen by chance, or was it designed?

Using this unit

The unit is designed to show the apparent 'fine tuning' of the universe. It invites the students to consider what conditions on Earth would be like if some of the physical properties were changed, and then considers the Universe in the same way. The unit provides a gentle introduction to the Anthropic Principle and then invites students to think about the evidence for design: "Why is the world as it is?"

A basic knowledge of gravity is assumed.

The work covered is accessible for most students, but is most suited to Higher Level.

Links with GCSE

Sc4 Physical processes

- ◆ Understanding of how gravitational forces determine the movements of the planets, moons, comets, satellites.
- ◆ Knowledge of some ideas used to explain the evolution of the Universe into its present state.

Sc0 The nature of science

- ◆ An understanding of how scientific ideas are accepted and rejected on the basis of empirical evidence, and how controversies can arise from the different ways of interpreting such evidence.

Moral and spiritual aims

- ◆ To reflect on the astonishing degree of balance and 'fine tuning' in the Universe.
- ◆ To understand that some scientists regard this balance as evidence for design in the Universe.
- ◆ To develop a sense of awe at the scale of the known Universe.
- ◆ To develop an awareness of the limits of science; it does not always provide clear-cut answers. Some questions *cannot* be answered by science.

Additional resources

Russell Stannard, *Science and Wonders* (London: Faber & Faber, 1996).
 James Moreland (ed.) *Creation Hypothesis* (Downers Grove: IVP, 1994).
 John Gribbin and Martin Rees, *Cosmic Coincidences* (London: Black Swan, 1991).
 Paul Davies, *The Accidental Universe* (Cambridge: Cambridge University Press, 1982).
 Paul Davies, *God and the New Physics* (Harmondsworth: Pelican, 1993).
 John Polkinghorne, *Quarks, Chaos and Christianity* (London: Triangle, 1994).
 Felix Pirani and Christine Roche, *The Universe for Beginners* (Cambridge: Icon Books, 1993).
 Michael Poole, *A Guide to Science and Belief* (Oxford: Lion, 1994).

Notes on the activities

Activity 1: Life on Earth

Typical are food, water, oxygen, warmth, shelter, but students may also want to include other aspects for animals such as community, love, etc.

Activity 2: Populating Mars

Sensible ideas about how one might create the conditions listed above.

Activity 3: Back to Earth ...

- We would hear things before we saw them.
- Very little water would be left on the surface of the Earth. Most of it would be in the atmosphere; life would be impossible.
- Most of the water on the Earth's surface would be ice. This would have a devastating effect on the whole ecological system, and life would probably be unsustainable.
- If the density of the Earth were to increase, so would its mass. If the volume remained the same, this would quadruple the gravitational field strength.
- The absence of the moon would mean that it would be darker at night. The tides would be affected; little tidal power; no high/low tide ecological niche - effect on the food chain etc.
- At above 25% oxygen content, combustion is almost instant. Even damp vegetation would probably burn.
- Below 15% oxygen, nothing will burn. Breathing will become very difficult.
- The Earth would move through space at much slower speed; atmospheric wind speeds might be affected.
- Volcanic and tectonic activity would be too great to permit life as we know it.

Activity 4: So much for the Earth. What about the Universe?

This is a research task. The results could be presented in the form of a wall display of poster and other information. It could be done in lesson time if facilities permit, or as a homework exercise.

Activity 5: Back to gravity again

- The gravitation field strength increases as the mass increases.
- Mathematical relationship - direct proportionality, shown by a straight line on a graph of mass against gravitational field strength. Note that this is true for smaller values only. Introduce Newton's law of gravitation: $F = GMm/r^2$ and discuss possible reasons for non-linear relationship when planet is large.
- Teachers should try to draw out the nature of a scientific theory as the best idea that fits to available evidence. The "laws of physics" are our 'best-yet' descriptions of how the Universe operates.

Activity 6: What would the Universe be like ...?

Students should explore the effects of having high gravitational field strengths, and the type of life cycles they might have.

Activity 7: The 'finely-tuned' Universe

This could be organised as a formal debate, or as a series of written pieces of work for display. The motion could be reworded as 'This House believes that the Universe is here by chance' if preferred - the arguments for and against remain unchanged.

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This unit looks at some special physical properties of the Universe that make life on Earth possible. Why is the world as it is? Did it all happen by chance, or was it designed?

Think ...

There are in the visible Universe, about a hundred billion galaxies. Each of these has, on average, a hundred billion stars. The Earth is a fairly ordinary planet orbiting a fairly ordinary star in a fairly ordinary galaxy.

But something extraordinary has happened on Earth:

LIFE!

The existence of life on Earth makes it different from any other planet we know about.

1 Life on Earth

What are the special conditions that are needed for life on earth?

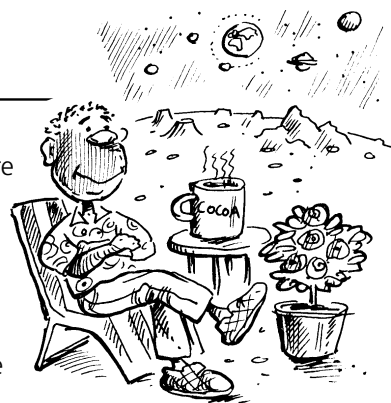
- ◆ Make a list. Don't forget to include plant life as well as animals.

The Earth has just the right mix of conditions for life.

2 Populating Mars

Mars has no human life, and probably no life of any sort. You are part of a small team of experts, chosen to find a way of making Mars habitable for human beings.

1. How could you create on Mars the right mix of conditions for life that we have on Earth?
2. What problems might you encounter in trying to create those conditions?



3 Back to Earth ...

How do you think our world might be different if we changed some things?

Pick three things from the list below. Using as much science knowledge as you can, decide what our world would be like if ...

- (a) Light travelled more slowly than sound
- (b) Water boiled at 15°C
- (c) Water changed to ice at 15°C
- (d) The density of the Earth was four times as great
- (e) There was no moon
- (f) The level of oxygen in the air was doubled
- (g) The level of oxygen in the air was halved
- (h) The Earth went round the sun in 10 years instead of 1
- (i) The Earth's crust were much thinner



Conditions would be very different if just one thing on Earth was changed!

4 So much for the Earth. What about the Universe?

One of the fundamental forces in the Universe is gravity. It is this force which holds the moon in place around the Earth, and the Earth around the sun. Gravity holds the sun itself together!

But what *is* gravity?

We believe there are just four basic types of force in the Universe.

- ◆ Gravitational
- ◆ Electromagnetic
- ◆ Strong nuclear
- ◆ Weak nuclear

Most of modern physics is concerned with trying to find a single theory which will describe how these forces operate.

Find out as much as you can about the four types of forces. Use textbooks, the library, CD-ROM facilities - whatever is available to you.

- ◆ What causes them?
- ◆ What kind of objects do they act between?

Report back your ideas with a poster, or mini-lecture to others.



5 Back to gravity again ...

Isaac Newton was the first scientist to put forward a theory that made sense describing how gravitational forces operate. He said that gravity acts between all things in the Universe that have mass. The bigger the masses involved, the bigger the force of gravity between them. Doubling the mass doubles the force; the force is proportional to the mass. He also said that the force gets smaller if you separate the objects. If you double the distance between objects, the gravitational force is quartered; the force is inversely proportional to the distance squared. This idea is known as Newton's Law of Universal Gravitation.



Newton concluded that this force of gravity:

- ◆ causes objects to fall to Earth;
- ◆ is responsible for the tides;
- ◆ holds the moon in its orbit around the Earth, and the Earth in its orbit around the sun; and
- ◆ is the force that keeps stars and galaxies together.

1. Newton said that gravitational force is caused by something having mass.

What happens to the gravity as the mass increases?

What relationship is there between the mass of a planet and the strength of its gravitational field?

Look at the data alongside:

2. Is there a mathematical relationship between the mass and the gravity on a planet? If so, what is it? Can you explain why the gravity changes with the mass in this way.

Planet	Mass (Earth = 1)	Gravity (Earth = 1)
Mercury	0.06	0.38
Venus	0.82	0.95
Earth	1	1
Mars	0.11	0.53
Jupiter	317.89	11.19
Saturn	95.15	9.41
Uranus	14.54	3.98
Neptune	17.23	3.81
Pluto	0.002	0.31

3. How do the 'laws' of physics differ from legal laws? Where do the laws of physics come from? Are they 'out there' waiting to be discovered?

*"Nature and Nature's laws lay hid in night:
God said, Let Newton be! and all was light."*

Alexander Pope (1688-1744)

"I know not what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Isaac Newton

6 What would the Universe be like if gravity was stronger?

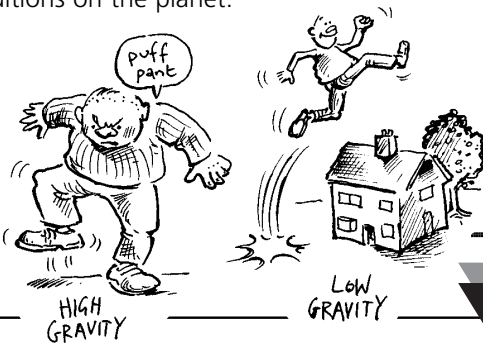
A professor at Cambridge University asked himself that question and imagined another Universe in which everything is identical except for one thing: gravity is much stronger.

What would that Universe be like? What would conditions be like for a Planet X, just like Earth in every other respect?

This is what he found:

	Earth	Planet X
Surface Temperature	15°C	15°C
Distance from nearest star	12×10^{13} km	5×10^5 km
Time of orbit around nearest star	1 year	20 Earth days
Lifetime of parent star	10 billion Earth years	1 Earth year
Highest mountain on planet	8848m	0.3m
Maximum mass of any land creature	12 tonnes	One millionth of a kilogramme

It seems that altering just one fundamental thing about the Universe has a great effect on the conditions on the planet.



"It's life, Jim,
but not as we
know it."

1. What would life be like for any creatures that lived on planet X?
2. What would they look like? What features would they have?
3. Draw or describe a typical inhabitant of Planet X.

Gravity also determines which planets have atmospheres.

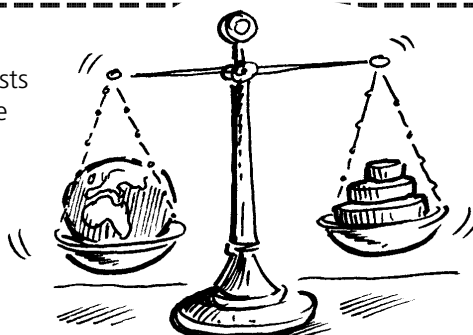
The Earth's gravity is strong enough to keep our atmosphere in place, but weak enough so that atmospheric pressure does not crush us.

Without an atmosphere, life as we know it would not be able to exist on Earth. The atmosphere provides thermal insulation and essential protection from ultraviolet radiation and meteors, as well as air to breathe!



7 The finely-tuned Universe

If any one of the characteristics of our world, even our Universe, were changed by even a small amount, physicists have concluded that life as we know it just would not be possible. Many scientists have been amazed and challenged by the precision and balance of conditions they have observed. It seems that if the Universe were just a little different, we would not be here to observe it; it would have been impossible for intelligent life to develop. This idea is known as the 'Anthropic Principle'.



There are really two versions of the Anthropic Principle - the "Strong" and "Weak" forms. The strong Anthropic Principle says that the Universe had no choice but to appear with the right conditions for life to emerge; it was "designed" in order to produce life. The Weak Anthropic Principle simply says that if the conditions in the Universe had been different, then life would not have arisen, and we would not be here to discuss the question!

"Yet all these conditions were met in our actual universe. This extraordinary set of circumstances, making for the development of life against seemingly impossible odds, has been called the Anthropic Principle.

What are we to make of it? Are they just coincidences? If so, we are talking of odds far in excess of winning the first prize in the national lottery. Or are we to conclude that physics has found God?"

Professor Russell Stannard

"We are the way we are because the Universe is the way it is."

Professor Felix Pirani, London University

"It's not just any old world, but it is special and finely tuned for life because it is the creation of a creator who wills that it should be so."

Rev Dr John Polkinghorne, Cambridge University

"Whence arises all that order and beauty we see in the world?"

Isaac Newton

"There is no reason to assume that the Universe has the slightest interest in intelligence, or even in life. Both may be random accidents like the beautiful patterns on a butterfly's wings; it would fly just as well without them."

Arthur C. Clarke, *The Lost Worlds of 2001*

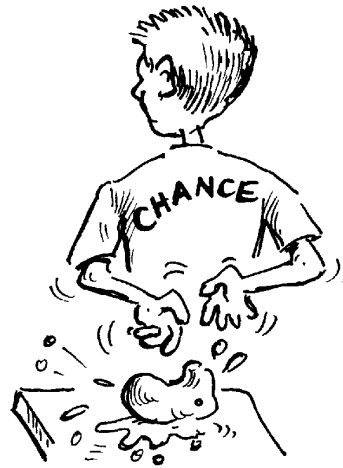
Some scientists find the argument presented by the Strong Anthropic Principle to be very compelling evidence for the existence of a designer God. Others will take the opposite view and believe that given sufficient time, it was inevitable that life would arise through chance.

**What do
you think?**



You are about to take part in a debate: either the Universe has been created by a designer God who designed it or the Universe has arisen through chance.

Working in small groups, prepare a short speech supporting one of these views.



"In the beginning God created the heavens and the earth."
(Genesis 1 v 1)

