OCN 201

Origin of the Universe

Eta Carinae star system

Science and the Scientific Method

Science:

Human search for a natural explanation of what the universe is

How it is constructed, and how it came to be
Scientific method:
Develop an idea to explain observations
Test idea with new observations or by making predictions
If new observations, do not agree with the idea or its predictions, modify idea or develop a new one

Science is the explanation of phenomena by natural processes

Scientific theories must be testable and their conclusions are falsifiable and subject to change.

Definitions used in science:
taken from "Science and creationism 2nd Ed.", National Academy of Sciences, Washington D.C., 1999,
www.nap.edu
Fact

In science, an observation that has been repeatedly confirmed and for all practical purposes is accepted as "true".

Truth in science, however, is never final, and what is accepted as a fact today may be modified or even discarded tomorrow.

Hypothesis

A tentative statement about the natural world leading to deductions that can be tested.

If the deductions are verified, it becomes more probable that the hypothesis is correct.

If the deductions are incorrect, the original hypothesis can be abandoned or modified.

Hypotheses can be used to build more complex inferences and explanations.
Law

A descriptive generalisation about how some aspect of the natural world behaves under stated circumstances

Theory

In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses

Important differences between the scientific use of the words theory and fact and common use of these words.

In science theories do not turn into facts through the accumulation of evidence.

Theories are the end points of science, they explain facts.

They are understandings that develop from extensive observation, experimentation, and creative reflection.

They incorporate a large body of scientific facts, laws, tested hypotheses, and logical inferences.
Can science prove that evolution is true?

A Yes
B No

Examples of theories:

Generally accepted:
- Relativity
- Evolution
- Germ theory of disease
- The Big Bang
- Heliocentric theory
- Plate Tectonics

Generally rejected:
- Flat Earth
- Geocentric theory
- Spontaneous generation (of living things)
- Creationism
- Phlogiston theory of heat

Still tentative:
- Grand unified theories of physical forces
Science and religion

Science

Is the explanation of phenomena by natural processes. Its theories must be testable and its conclusions are falsifiable and subject to change.

Religion

Explanation of human origin and the age of the Earth rely on supernatural explanations, do not produce testable hypotheses and are asserted by their adherents to be unchangeable.

Hypothesis - Theory - Law

Can only disprove ideas, never prove them.

New theory adopted only if better at explaining observations.

Explanations must be testable.

Simple theories better than complex ones.

Correct ideas can be used to predict results.
Example:

Origin of the Universe

Three possibilities- only two are scientifically testable

Possible origins of the universe

A. There was a singular state not describable by science: a god or other omniscient being created it.
B. There was no creation, the universe is unchanging and infinitely old
C. There was a moment of creation which contained the seeds for the future evolution of the universe

Which do you think is correct?
Pythagoras  580-500 BC
Spherical rotating Earth
fire at the centre, magic numbers

Plato  427-367 BC
Planets circling stationary Earth

But.... observations of Mars...
Retrograde motion of Mars seen from Earth

Makes sense if Sun is at centre, but not if Earth is

Eudoxus  408-355 BC

Math model 33 spheres within sphere motions clever attempt to reproduce retrograde motions
Aristotle  384-322 BC
working model with 55 spheres

Theory becoming overly complex and unwieldy

Aristarchus  ~280 BC  Heliocentric system

was correct, but theory ignored
--too radical
Brightness problem, Ptolemy (140 AD) uses epicycles

Geocentric theory of Ptolemy
Each planet moves in a small circle, or epicycle, the centre of which moves in a circular path around the Earth

BUT...overthrows Aristotle's theory for rotation and also his theory of formation of the world

Failure of science to provide answers to basic questions results in religious groups insisting on literal interpretation of bible.

World is again thought to be flat

Roman Empire collapses centres of learning destroyed, knowledge lost. No progress in intellectual activity in the West for ~ 1000 years!

Dark Ages
Renaissance (~1400-1700)  
(French for rebirth)  

Copernicus (1473-1543), Sun centred theory, circular orbits


Keppler (1571-1630), elliptical orbits.

http://www.astunit.com/tutorials/heliocentric.htm

Galileo (1564-1642), telescope, phases of Venus, confirms sun-centred theory denounced by the Catholic Church inquisition in 1633 and forced to recant his ideas.

Church rehabilitates Galileo in 1992 after 359 years!

Newton (1643-1726), force of gravity, rational basis for planetary motion.
Herschel (1738-1822) confirms gravity is universal, discovers Nebulae outside Milky Way

Estimating distances to stars

Investigating the Universe

Estimating distances to stars
Use of parallax, to estimate the distance to the nearest star (Alpha Centauri) as 4 light years.

Light year = distance light travels in one year

= [ ] ?

How far do you think it is to the nearest star outside our solar system?
A. 1 million miles
B. 1 billion miles
C. 1 trillion miles
D. 10 trillion miles
E. More than 10 trillion miles
Distance to a planet (e.g. Mars) can be measured using parallax angle. Angle depends on separation of the observatories and the distance to the planet.

Parallax of a nearby star

By observing a star at 6 month intervals, the Earth's orbit is now the separation of the observatories. Alpha Centauri is 4 light years from Earth.
Using brightness to estimate distance

Identify star types in Milky Way where we know distance

Use absolute use brightness of same star type in other galaxies to estimate distance

Calculate distances to other galaxies
e.g. Andromeda is 2 million light years away

\[ 1.2 \times 10^{19} = 12,000,000,000,000,000,000 \text{ miles} \]

(12 quintillion miles)
Doppler effect applies to light as well as sound

- Star: stationary, approaching, receding
- Wavelength
- Observer

Light from stars is found to be red shifted

Shows that our galaxy is spinning on its axis

Also indicates that stars are moving away from us
Discovery that the farthest galaxies are moving away from the Earth at the greatest speed

Realisation that the Universe is not constant Universe cannot be infinitely old theory of constant Universe defeated

NY Times August 19, 2008

Measuring the Constant

Hubble constant refined to ± 4%
Big Bang Theory

Universe age related to rate of expansion and distance to the stars
Latest estimates is Universe is _______ years old.
Universe created by a big bang
Discontinuity in space-time
Cannot replicate conditions at that time

How old do you think the Universe is?
A. Same age as Earth
B. 1 billion years
C. 6,000 years
D. 10 billion years
E. More than 10 billion years

Hydrogen only original matter in Universe
Galaxies and stars started to form after ~ 300 million years
Gas in nebula aggregates forms a proto star
Gravity compresses star until temperature ~ 10 million degrees
Hydrogen fusion starts, forms chemical elements up to carbon and oxygen, up to iron in large stars
Star shines for billions of years until most of hydrogen used up

Balance of Fusion energy (outwards) and gravity (inwards) in a star

Medium star then expands as heavier atoms fuse, forms a Red Giant which finally cools
Our sun will do this in ~ 6 billion years
For large stars:
As hydrogen runs out, starts to collapse, temperature goes up and then they explode

Supernova explosion lasts ~10 seconds

All elements heavier than iron formed this way

The remnant from Supernova 1987A has been expanding since 1987. Here is what it looked like in 1994, using the Hubble Space Telescope. The inner ring is about 1.3 ly in diameter. The rings are presumably parts of shells of gas ejected by the star long before the explosion.
Fate of the Universe -- Big Crunch or Big Chill? Explosive energy from Big Bang could expand Universe forever. Gravity could also cause it to collapse back, it all depends on the amount of mass in Universe.

The Galaxy song from Monty Python’s “Meaning of life”