"Had I been present at the Creation, I would have given some useful hints for the better ordering of the universe."

Alfonso "the Wise", 1221-84.
King of Castile and León.

THE AGE OF THE EARTH: PHYSICS vs FAITH?

The first of these essays - The Age of the Earth, see figure 1 - has a theme that is common to many of the disputes we are going to consider, namely the conflict between faith and the laws of science. And, together with the subject of evolution, there are many people today who hold rigidly to a literal interpretation of Biblical texts for the creation of the Earth, despite a huge body of scientific evidence to the contrary. "When did everything begin?" is an obvious question that a developed society would ask. Although it seems a simple question there are a couple of major complications. Firstly, any answer is going to precipitate controversy because it will inevitably result in a clash between science and belief. But we must recognize that this quest is like many others ... it is the search for truth through conclusive evidence. For those who believe that the Scriptures "tell it like it is", reconciling biblical accounts with nature is essential and that is where much of the controversy occurs. Secondly, in the past, it was taken for granted that the Earth (or the world) and the universe were of the same age; everything was created at the same time. But, it has become apparent that the creation of the universe and the creation of the Earth are two distinct events, which occurred at two hugely different times. In this essay, we will restrict ourselves to the question of the creation of the Earth because that controversy has a longer history. Also, a full account of the search for the age of the Earth is a long and invovled one, so I have chosen to highlight what I think were the major events; a more detailed history can be found in the splendidly entertaining book *Measuring Eternity: The Search for the Beginning of Time* by Martin Gorst. However, let's start at the beginning!

Although we will concentrate on the disputes that started in the mid-1600's, some background material will be useful. One surprising fact is that the question *"When did the world begin?"* really didn't arise until Christianity. Almost all ancient civilizations believed the universe had existed for ever and that it was eternal. Possibly because of the recurring cycles associated with celestial bodies - for example, the rising and setting of the Sun, the monthly phases of the Moon, the annual cycle of the constellations, etc., - the idea of an eternal world was often associated with cyclical time. So, rather than there being a *"beginning"*, time was thought to repeat in cycles[1] .

In ancient Babylon (ca. 2000BC), the *Great Year* was the time required for the main, wandering celestial objects, i.e., the five known planets, to return to the same positions with respect to the fixed stars or designated constellations. The length of the cycle was taken as 12,960,000 days, i.e., 60^4 days. In turn, this corresponds to 36,000 solar years each of 360 days[2] .

Cyclical time was also the prevailing view in the Hindu faith ca. 1000BC, where the length of the cycle was based on the *mahayuga*, a period of 4,320,000 years. Each mahayuga was composed of four *yugas* of lengths varying in the ratio 4:3:2:1, see figure 2. One thousand

[1] In some civilizations one cycle was referred to as a *Great Year*.

[2] The Babylonian's used a sexigesimal counting system, based on 60. We see remnants of this today with time and angular measurement. In fact, the Babylonians used a 24 hour clock, with 60 minute hours, and 60 second minutes.

mahayugas, i.e., 4.32 billion years, was taken as one *kalpa*, which was taken as one day in the life of the Brahma, one of the trinity of chief Hindu gods. According to an old Hindu text (the *Vishnu Purana*) we are about 2500 years into a 4th yuga, a thoroughly evil age!

A cyclical time span (of 36,000 years?) is also referred to by Plato (428-348BC) in *The Republic* which ...

> ... **has a period which is contained in a perfect number** ...

and in *Timaeus*

> ... **there is no difficulty in seeing that the perfect number of time fulfils the perfect year when all the eight revolutions, having their relative degrees of swiftness, are accomplished together and attain their completion at the same time**.

The *Great year* or *magnus annus* later became popular in Rome. Re-incarnation was the order of the day since it was believed that the events of one cycle were simply repeated in the next; exactly the same people would return to Earth, and all that had happened would happen once again! Time itself was identical from one cycle to the next so there was no way to distinguish one cycle from another[3] .

The concept of cyclical time reached far beyond India and Greece. It is quite common in the Pre-Columbian civilizations of South and Central America, where it appears in the old Indian cultures of the Maya and Aztek peoples. Indeed, the Azteks made use of a calendar carved in a huge circular stone, the Sun stone; one in a museum in Mexico City is 9 feet in diameter! Since time revolved, it had no beginning and so the notion of trying to find when it started just didn't arise!

In contrast, Jewish scripture did not hold to this idea of cyclical time; the story of Creation described a beginning, a first day when God created the heaven and Earth. By the end of the first century AD, Christianity had taken Jewish history as its own and over the ensuing centuries Christian missionaries spread the idea of 'linear' rather than cyclical time throughout the Roman world. However, many people found the idea of a non-eternal world difficult to accept; they took the view that the Creation was simply the beginning of another cycle or a re-birth. So, into the 4th century AD there was still little reason to think that time had a beginning.

When Rome was sacked in 410AD many people in the Roman world were shocked. Rome had been the capital of the Empire, invincible for 800 years; the first 700 years under pagan gods, the final 100 years under Christianity. Surely, many argued, the blame must lie with Christianity; by rejecting their former gods, the people, in turn, had been abandoned by those former gods. Therefore, it was argued, the Christian god must be a false god.

When news of the accusations reached St. Augustine (Aurelius Augustinus, 354-430AD), he began writing *City of God*, in which he argued strongly in favour of a linear concept of time, beginning with the Creation. He condemned ancient Greek cyclical time as a superstition. His three main objections were:

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[3] Indeed, the Greek philosopher Aristotle (384-322BC) - a student of Plato's - whose ideas were to influence religious doctrine very strongly to well into the 17th century, held that the universe had no beginning and will have no end.

1. If life was simply a series of recurring events from a previous era, it denied the uniqueness of Jesus Christ.
2. If life was simply a repeat of earlier events, what incentive was there for people to follow a Christian life.
3. The idea that individuals would carry out exactly the same acts, in exactly the same way, with exactly the same people, was simply absurd!

St. Augustine argued, therefore, that the Creation, as described in the Bible, was not the beginning of another cycle, but the absolute beginning. Before the world was created, time did not exist. One could not ask when, in time, was the world created; the world and time were created together. In addition, the question ... *"What happened before the Creation?"* ... had no meaning since there was no *time* before the Creation. As Christianity took hold in Europe, it became clear that the Biblical record held the key to the beginning of time.

There were those like Isaac La Peyrère (1596-1676) and Father Martino Martini (1614-1661) who raised doubts about the *literal* truth of the Biblical texts. For example, La Peyrère, a French Calvanist and lawyer, thought that people existed before Adam; he argued the idea came from the Bible itself. For instance:

- Why did God mark Cain ... "**lest any finding him should kill him**" ... (Genesis 4:15) if the only people around were his immediate family? Surely, argued La Peyrère, they would know who he was!

- How did Cain, Adam's son, find a wife (Genesis 4:17) unless women were already around?

He acknowledged that Adam was created by God but he was not the father of all mankind, he was simply the founder of the Jewish race. His theories culminated in a book, *Men before Adam*, published in 1655, which was promptly condemned and banned by the Church. Few, took La Peyrère seriously, particularly after he made a deal in 1656 to convert to the Catholic faith and apologize to Pope Alexander VII.

Father Martino Martini, a Jesuit missionary to China, was keenly interested in finding out about the country where he worked. But, the more he learned, the more the Biblical chronology appeared in error. For example, according to Genesis, the Flood drowned all the people of the world except Noah and his family, and according to the Hebrew Bible, this occurred sometime around 2300BC. The Chinese dismissed this idea as impossible; their own history stretched back hundred of years before that date - the dates indicated that the first emperor, Fu Hsi, the legendary inventor of the Chinese script, had begun his rule around 2852BC - and there was no mention of a flood nor of Noah! To overcome this "problem" the Jesuits in China were given permission to substitute the Septuagint version of the Bible for the Hebrew version; the former placed the Flood somewhat earlier (around 2950BC). However, the response in Europe to Father Martini's research was extremely hostile and the claims were dismissed simply as Chinese exaggerations, which would surely be exposed on further investigation.

In spite of La Peyrère's and Martini's misgivings on the accuracy of the Biblical texts - although, more likely, in ignorance of their claims - it was accepted in Europe that the Bible did, indeed, hold the key to the age of the Earth. Using the genealogy offered in Genesis, estimates made long before the 17th century put the date of Creation between 3600-7000BC, see figure 3. Even William Shakespeare made reference to it through Rosalind in *As you like it* (1599), act IV, scene 1:

"**The poor world is almost six thousand years old ...** ".

Interestingly, the motivation for some of the early chronologers, like Theophilus (2nd century AD), was not really to determine the date of Creation *per se*, but to demonstrate that the Christianity - having accepted the birth of Christ as the fulfillment of a prophecy referred to in the Hebrew scripts - was the oldest religion. But, later, determining the age of the Earth by studying the Scriptures was seen as a worthy, intellectual challenge, the most fundamental mystery yet to be solved.

The middle of the 17th century is really when our story starts; that's when a specific day and time was given to the Creation and from that the dates of other Biblical events were determined. The two major players involved in this study were James Ussher (1581-1656), Archbishop of Armagh and Vice-Chancellor of Trinity College Dublin, and his contemporary, John Lightfoot (1602-1675), the Vice-Chancellor of Cambridge University, see figure 4. Although his studies were not wholly original, Ussher is the more well known because his chronology was incorporated into the margins of some Bibles published around 1675 and in the versions authorized by the Church of England in 1701. Consequently, his dates came to be regarded with almost as much unquestioning reverence as "the word of God" as the Bible itself. Indeed, the dates continued to be printed in Bibles well into the 20th century with little indication of their origin.

So, what did Ussher and Lightfoot do? The genealogy in Genesis is very extensive and provides a precise listing all of the male descendants from Adam down to Isaac, see figure 5, but after which the record is less detailed. As an aside, two problems that the Biblical chronologers faced were:

1. the extreme age that many of these people lived ... for example, the Bible states ... "**And all the days that Adam lived were nine hundred and thirty years: and he died.**", and

2. the fact that many were over 100 years old when they fathered offspring! "**Had they abstained from sexual intercourse until the date at which it is recorded they begat children?**" wondered St. Augustine.

The first problem was easily dispelled ... surely, it was a golden age when the climate was healthier, there was little disease and, as the 1st century Jewish historian Flavius Josephus explained:

"**their food was then fitter for the prolongation of life ... and besides, God afforded them a longer timespan on account of their virtue.**"

St. Augustine satisfied himself on the second problem by concluding that very early men must have reached puberty much later in life than modern man. Interestingly, it was St. Augustine who was reputed to have said:

"**Give me chastity and continence, but not yet.**"

The task facing Ussher was formidable and it took him something like 30 years of careful and painstaking research to complete. He faced two main difficulties.

1. Which version of the Bible should he use? Different Bibles give different dates; for example, the Greek Septuagint Bible (used by the Orthodox Churches in Eastern Europe) gives dates that stretch almost 1000 years farther back

than the Hebrew Bible (used by the Catholic and Protestant Churches in the West). To further complicate matters, there was the Samaritan Pentateuch (an ancient version of the first five books of the Old Testament) whose chronology was shorter than the Hebrew version.

2. Although the early genealogy was clear, the later period becomes more complicated and difficult to interpret. Nevertheless, the dates are contiguous up to the destruction of the temple in Jerusalem by the Babylonian king, Nebuchadnezzar (2 Kings 25:1-9). But this is a "floating date"; it needed to be linked directly to more recent events of known date.

For various reasons, Ussher's solution to the first difficulty was to select the Hebrew version. He solved the second difficulty when he discovered he could link Nebuchadnezzar's reign to events that had occurred in Greek history; that enabled him to fix the date of Nebuchadnezzar's death as 562BC (a date that is accepted today). Working through the Old Testament he had deduced that 3,442 years elapsed between the Creation and Nebuchadnezzar's death. Therefore, the Creation occurred in

$$3442 + 562 = 4004\text{BC}$$

But what day in 4004BC? The common belief was that at the Creation the Sun would be at one of its cardinal points, i.e., the summer or winter solstice, or the spring or autumn equinox. The early Christian Church favored spring because that was the season of re-birth and growth. However, by Ussher's time, the balance of opinion was for the autumn equinox; that was harvest-time (relevant since Genesis 1:20, suggests the fruit in the garden of Eden was ripe and ready for eating) and also autumn marked the start of the Jewish year. Ussher took it for granted that the first whole day of the world would be a Sunday, the first day of the week. Thus, he arrived at Sunday October 23! Ussher described his computation in his *Annals of the World iv* (1658) ...

" **... I gathered the creation of the world did fall out upon the 710 year of the Julian Period[4] , by placing its beginning in autumn: but for as much as the first day of the world began with the evening of the first day of the week, I have observed that the Sunday, which in the year 710 aforesaid came nearest the Autumnal Aequinox, by astronomical tables (notwithstanding the stay of the sun in the dayes of Joshua, and the going back of it in the dayes c Ezekiah) happened upon the 23 day of the Julian October; from thence concluded that from the evening preceding that first day of the Julian year, both the first day of the creation and the first motion of time are to be deduced.**"

However, there appears to be a small discrepancy between Ussher and Lightfoot in the actual date and time. Ussher concluded that if October 23 was the first complete day, then the Creation must have occurred the previous evening, for in Genesis 1:2 says:

"**... and darkness was upon the face of the deep.**"

So, 6.00pm on Saturday October 22, 4004BC was Ussher's date and time of the Creation. Other other hand, in 1644, Lightfoot declared that, as the result of his most profound and exhaustive study of the Scriptures:

[4] The Julian Period was a calendar system introduced by Joseph Justus Scaliger (1540-1609). It began at noon on a "hypothetical day", January 1, 4713BC, i.e., a day thought not to exist. The year 710 of the Julian Period is 4004BC.

"**heaven and earth, centre and circumference, were created all together, in the same instant, and clouds full of water,**" and that "**this work took place and man was created by the Trinity on October 23, 4004BC, at nine o'clock in the morning.**"

Lightfoot also determined that Christ was born 3928 years after Creation. Unfortunately, that gives a birth year of 76BC, which is somewhat at odds with the accepted figure!

So October 23, 4004BC has become known as "Ussher's date" for the Creation. Accordingly, Ussher calculated the dates of other biblical events, concluding, for example, that Adam and Eve were driven from Paradise on Monday November 10, 4004 BC, and that Noah's ark touched down on Mount Ararat, after the flood, on Wednesday May 5, 2349BC.

We can also determine an approximate year for the Creation by using a simple calculation described by James Trevil in his book *Reading the Mind of God*, see figure 5. According to Genesis, there are a total of 21 generations from Adam to Isaac over a period of 2106 years. We know that there are a further 38 generations from Isaac to beyond Joseph, i.e., to the birth of Christ, but the overall timespan is unknown. If we take an average of the length of the 11 previous generations before Isaac as representative, we get $550/11 = 50$ years per generation. So, the 38 generations between Isaac and the birth of Christ cover 1900 years. Therefore, the total period from the Creation to the birth of Christ, according to this simple calculation, is 4006 years ... not a bad estimate!

As we have seen, even before Ussher's determination was published, there were concerns about using the Biblical record to obtain the age of the Earth. But, a further question was added to the controversy ...

"When the Earth was formed was it *complete* with mountains, valleys and rivers, or had it aged over time?"

In the early part of the 17th century the prevailing view among scholars was that God would have created a perfect, spherical and smooth Earth. The valleys and mountains, then, were "wrinkles" associated with aging, and volcanoes and deserts were blemishes on the once-perfect landscape. The key, then, was that the Earth was changing; therefore, it was a *dynamic* object. One of the first to develop anything approaching a theory was René Descartes (1596-1650) who suggested that the universe was governed by a few simple laws and it was these "laws of nature" that had transformed the primordial matter of the initial chaos into the world we see today. Descartes did not say how long the Creation would have taken except to say it couldn't have been achieved in less than ...

"**the space of many years**".

Descartes viewed God rather like a clockmaker; He had set the universe in motion but once started it continued to run by the "laws of nature". With this thinking, at least a decade before Ussher published his *Annals*, Descartes introduced a new philosophy that later precipitated a scientific revolution ... that everything in the universe could be explained by a few simple rules. That idea effectively removed God from the day-to-day running of the world.

In England, Thomas Burnet (1635-1715), an ordained priest and Fellow of Christ's College, Cambridge, was an avid supporter of Descartes, but he also believed in the strict truth of the Scriptures. Burnet thought he could combine his religion with Descartes' rationalism to show that the events reported in Genesis - the Garden of Eden and the Great Flood - were really

true. All that one had to do was to "read" nature.

Burnet's studies and thoughts culminated in his *Telluris Theoria Sacra* (The Sacred Theory of the Earth) published in 1681, see figure 6. This was the first attempt of a geological theory of the Earth's formation and arguably it revealed that the Earth was much older than anyone imagined. He assumed that there were no *natural forces* capable of creating mountains but one verse in the Bible stood out for him (Genesis 7:11) ...

> "**In the six hundredth year of Noah's life, in the second month, the same day were all the fountains of the great deep broken up ...**"

Burnet regarded the Flood as world wide in its effects. However, he estimated that a continuous rain for forty days and forty nights (Genesis 7:12) would have only covered the Earth to a depth of 160 feet - certainly not enough to flood the Earth - nor were the waters of the oceans sufficient to have caused the deluge. So, he argued, that verse proved that water gushed up from reservoirs and subterranean chambers below the Earth's surface, and that the Earth's surface itself became broken and ragged. Therefore, the Biblical flood was a real event. Before the Flood, the Earth's surface was a smooth, featureless, perfectly proportioned sphere. But, according to Burnet, the heat of the Sun ...

> "**within the space of some hundreds of years, would have reduc'd this Earth to a considerable degree of driness in certain parts; and also have much rarifi'd and exhal'd the Waters under it ... So we see all Vapours and Exhalations enclos'd within the Earth, and agitated there, strive to break out, and often shake the ground with their attempts to get loose.**"

According to Burnet, the crust eventually cracked and parts of it collapsed inwards. The waters rose, flooded the planet and then receded leaving the surface marred by mountains and scarred by the deep, uneven beds of rivers and seas.

Burnet's description of the creation of the Earth itself - it had the structure of an egg, with a heavy, solid core surrounded by a layer of water and a shell forming a structureless crust - required considerably longer than the six days of Genesis. Burnet claimed that the early verses of Genesis were allegorical and didn't have to be taken literally. 'Surely,' he argued, 'hadn't St. Peter stated in the New Testament (2 Peter 3:8) that ...

> "**one day is with the Lord as a thousand years**"**?**'

So, the Creation might have taken 6,000 years!

In 1680, and prior to the book's publication, Burnet sent a copy of the manuscript to Isaac Newton. Newton, a devout Christian, firmly believed in the literal truth of the Bible and so he disagreed with Burnet. But, Newton had an ingenious solution ... by pointing out that the Earth was formed on the *third day* (Genesis1:9-13), he claimed ...

> "**you may make ye first day as long as you please, & ye second day too ...**"

because the "day", as we know it, i.e., one revolution of the Earth on its axis, was undefined over the first two days! Furthermore, Newton thought it likely that the Earth was not spinning when it was formed and that it started revolving very slowly at first. So, the length of an *early day* would have been much longer than a day today. He had argued, therefore, that the age of the Earth could be enormous but *still consistent with Genesis*. However, Burnet did not incorporate Newton's ideas into his *The Sacred Theory of the Earth*.

Burnet's book, published originally in Latin, but quickly re-written in English at the request of King Charles II, was an immediate success with the public, although some theologians were rather critical of his "meddling" with Scripture. Its main story ... that the Flood had shaped the Earth ... became the accepted theory. In the end, his attempt to reconcile Christian doctrine and science failed but, ironically, instead of establishing the truth of the Bible, he initiated unwittingly a quest to discover *how* the Earth's structure had been produced! His book was published at a time - the second half of the 17th century - that we associate with the birth of science as we know it today ... discovering "facts" through observation and experiment, i.e., research[5] .

It was also a time when some serious doubt over the Earth's relatively young age emerged. Fossil hunters were making a number of perplexing finds. For example, in Amsterdam, sea shells were found buried 100 feet below ground. Clearly, the presence of shells indicated that the area had once been covered by an ocean but how could they have become buried so deep in such a relatively short time span as 5600 years? Then there were fossils found that were unlike any known species; could they be from animals and plants now extinct? But that was unthinkable; surely, God would not have created a species only to destroy it? Besides, it must have taken a good long time for them to exist and then die out. One particular problem was that fossils were found at different depths; if they were the remains of creatures that drowned in the Great Flood, as most people believed, why didn't they occur in a single layer? John Woodward (1665-1722), a professor of medicine at Gresham's College, London, published a theory in 1695 aimed at answering such questions, based on gravity[6] .

Woodward agreed with Burnet, that the water of the Flood had come from below the Earth's surface. However, he suggested it had flooded because the full effect of gravity had been suspended for a while and the water spewed out. The remains of plants and animals were dispersed by currents in the great deluge of water and when God restored the full force of gravity, everything fell and sank at a rate determined by its relative density. The result was that "heavy" fossils were buried deep while "light" fossils appeared in the surface layers. His theory also explained why deposits in Europe contained the remains of creatures like elephants and tropical fish that lived in warmer climates; they would have been transported by the huge current of water. Although it was an ingenious theory, it did not receive much support.

An alternate explanation of the Flood was offered by William Whiston (1667-1752) a short while after Woodward's theory. Whiston came to the conclusion that a comet passing close to the Earth caused an unusually large gravitational effect that produced a subterranean tidal wave. In turn, this powerful wave had crashed through the Earth's crust from the inside and covered the entire surface. In addition, he claimed, the comet's tail, which Newton had described as ...

> "**nothing but fine vapor**",

was captured by the gravitational attraction of the Earth and produced the forty days and nights of rain referred to in Genesis 7:12. Whiston's theory was a little more credible than Woodward's, which required a "miracle". In addition, in working backwards, Whiston

[5] It was not a coincidence that the first, significant scientific societies came into being during this period: the *Accademia del Cimento* in Florence (1657), the *Royal Society* in London (1660) and the *Acadèmie Royale des Sciences* in Paris (1666).

[6] Isaac Newton had published his *Principia Mathematica* in 1687; one section of which - Book III, The System of the World - is a description of gravity and its effects.

discovered the comet that had appeared in 1680 was also the one that had appeared in 1106, 531 and 44BC; that meant the comet took approximately 575 years to complete a revolution. Working back further, he calculated that it had also appeared in 2349BC, the very year that Ussher had given for the Flood! (However, Whiston's estimate of the day - Wednesday November 28 - was a few months later than Ussher's.) In 1694, before publishing his astounding discovery, Whiston sent the manuscript *New Theory of the Earth* to Newton, his former mathematics instructor at Cambridge. Newton was sufficiently impressed that he asked Whiston to join him as his assistant in Cambridge and when he resigned as the Lucasian Professor in 1701, Nerwton appointed Whiston as his successor.

The theories of Burnet, Woodward and Whiston, formulated towards the end of the 17th century, were pretty much the last attempts at confirming and explaining the Biblical record. From that time on, the historical record of the Earth was studied for its own sake and by direct observations of the natural world itself. One brilliant idea was offered in 1715 by Edmond Halley (1656-1742), a good friend of Newton. Halley suggested that by measuring the rate of increase of salinity of the oceans, and assuming that the rate of increase was constant over time, one could work back to determine a time when the oceans contained no salt. That would give the age of the Earth! A brilliant concept, but the rate of increase was far too small for the technology of Halley's day. Although such measurements could not be made - until the late 1800s by John Joly - the notion that there might be "natural clocks" that could be read to reveal the truth, resonanted throughout the scientific world.

A new method for determining the age of the Earth was proposed by George-Louis Leclerc, Comte de Buffon (1707-1788), a highly accomplished French naturalist and scientist, see figure 7. Buffon established himself as a savant at a young age and in 1734 he was elected to the Acadèmie Royale des Sciences. Shortly after, in 1739, he was appointed superintendent of the Royal Garden (Jardin du Roi, now the Jardin des Plantes) and the Cabinet du Roi (today's Museum National d'Histoire Naturelle) in Paris, one of France's leading scientific institutions. Buffon dismissed the explanations offered by the current texts concerning the creation of the Earth's landscape. For instance, he described Burnet's *The Sacred Theory of the Earth* as ...

"**... an elegant romance, a book which may be read for amusement ...**"

He dedicated himself to writing *Histoire Naturelle, Générale et Particulière*, a planned 50 volume encyclopedia, of which, by the time of his death, he had completed 35 volumes! The 20th volume is *Les Époques de la nature* (Epochs of Nature), which was published in 1778/9. He claims that there were 7 epochs; the first - of interest to us in this essay - was the creation of the Earth; the final epoch included the advent of man and the world as it is today. In contrast to all the previous scientists we have encountered, Buffon chose to ignore any Biblical connections; instead, he decided to remain close to the ideas of Newton. His view was that if Newton's laws could explain the motion of planets, the tides and even explain the *shape* of the Earth (see below), why couldn't they tell us something about our history? Thus, Buffon was one of the first to separate the roles of theology and science in explaining nature.

Buffon's three main ideas in *Les Époques de la nature* were:

1. The planets (including the Earth) were created at the same time by a comet colliding with the Sun. A torrent of molten material was sent spinning into space. As it circled the Sun parts of it coalesced into spheres producing the planets that would continue to rotate around the Sun in the same direction. In addition, their orbital planes would be nearly co-planar; Newton had pointed out

that the planets were co-planar to within 7.5°. Also, because of the angle the comet struck the Sun, the planets would all be spinning, and maybe small amounts of material would be "thrown" off some of the planets forming moons.

2. If the Earth was originally molten and spinning, then it had to be an oblate spheroid, i.e., flattened at the poles[7].

3. He determined the age of the Earth on the basis of cooling from a molten state to the present temperature. Rather than speculate, as Newton had done; while considering comets Newton claimed...

"**... a globe of red-hot iron, equal to our Earth ... would scarcely cool ... in above 50,000 years.**"

Buffon decided to experiment. He took 10 iron balls with diameters ranging from 1/2 inch to 5 inches and he determined their cooling rates from white hot to red heat, to lack of glow, to 'hot to the touch' and then to room temperature. He found a relationship between the time taken and size of the ball, which he extrapolated to the diameter of the Earth. From these experiments, he concluded that the Earth took 96,670 years and 132 days to cool to the present temperature! Then, recognizing that the Earth was not made of pure iron, he continued similar experiments with a variety of substances found in the Earth's crust. Finally, after including a refinement of an estimate of the amount heat absorbed by the Earth from the Sun, he concluded that the Earth was 74,832 years old. Also, as part of this study, he determined that it would have taken 35,000 years for the Earth to cool to a point where water could form the oceans.

On the basis of what he had seen of sediments in the Alps and the slow rate of sedimentation in the oceans today, Buffon thought that the time had to be much longer. He was not totally convinced by his extrapolation from small spheres to the Earth and believed he had been far too conservative in his estimate. He proposed - although the manuscripts remained unpublished - estimates as long as 10 million years. Perhaps he felt he lacked convincing evidence; nevertheless, Buffon had started a trend, to use science rather than theology to understand and explain nature.

An example of the ease with which nature can give up her secrets to anyone who looked, occurred to Patrick Brydone (1741-1818). In 1770, he was travelling as a tutor in Sicily when he came across evidence that Mount Etna was very much older than the Biblical timescale. He and his colleagues crossed a lava field that, because of the lack of soil covering it, he felt was recent. However, he discovered that the eruption had been recorded by the historian Diodorus Siculus as occurring in the 3rd century BC; that is, the lava flow was 2000 years old. Brydone was then shown a deep well that had been sunk through several different layers of lava. What was especially significant was that each layer was separated by a substantial layer of soil. Assuming that it took at least 2000 years to form even a thin layer of soil, it would seem that the mountain had to be at least 14,000 years old. Brydone published his exploits, conversations and observations in *A Tour through Sicily and Malta* in 1773. The book was hugely popular throughout Europe - remaining in print for 40 years with eleven

[7] In 1672, it was noticed that pendulum clocks ran slower in some locations on Earth than at others. Newton guessed the cause was because the Earth wasn't a sphere but that it "bulged" at the equator. In 1735, the Acadèmie Royale des Sciences financed expeditions to measure the length of 1° of the Earth's meridian. They confirmed Newton's theory; the Earth was, indeed, an oblate spheroid.

editions - and brought the prospect that the Earth was much older that the Biblical account to a much wider audience than the scientific writings of Buffon would. As a result, it sowed further seeds of doubt in the accuracy of Ussher's chronology.

The origin and distribution of fossils was one of the most troubling questions that faced scientists in the 1760s. Most scientists had dismissed Woodward's and Whiston's ideas as fantasy, so despite the undeniable credibility of Buffon's and Brydone's observations, what was required was a theory of the processes that could explain how fossils came to be buried and then raised to the heights of mountains.

It was a gentleman farmer, James Hutton (1726-1797) , see figure 8, who first provided the key. Hutton was an unassuming man but his ideas were revolutionary; he later earned the title the "founder of modern geology". He inherited a small farm on his father's death and in the early 1750s he visited farms in England and Europe studying farming methods and agriculture. It was likely that his interest in geology was piqued during this period; he must have noticed the different soils in different regions and he would often visit places of geological interest. In 1754 he returned to his farm and for the next 14 years he developed it. Then, in 1768, he leased the farm and moved to Edinburgh. He travelled throughout England and began to formulate and gain evidence for his theory.

Hutton could see that rocks were "decaying", by the action of frosts, rain, feet; indeed, to Hutton it was this decay that produced the soil for his crops. But he also knew that streams and rivers carried this soil away and eventually flushed it into the ocean. For many years, these processes were well known and were used by theologians as an argument against an eternal, or even an old, Earth. If the Earth was very old then surely, the theologians argued, all the mountains would have eroded away to produce flat plains.

What Hutton suggested was that erosion and flushing were not the whole story; they were simply part of a cycle After the tiny particles of rocks reached the sea they settled as sediment on the ocean floor and became compacted and solidified into rock. This rock was then pushed upward above the ocean surface to form "new" land. In turn, this rock would be eroded ... and the cycle would be repeated, so that soil profiles were formed by the weathering of rock over thousands of years. As far as Hutton was concerned the erosion, sedimentation, uplift, erosion cycle could go on for ever suggesting not only an eternal world but one that was changing constantly. So, fossils found in sediments on mountains were not deposited by a retreating ocean, nor after the Flood, but had been literally "uplifted" by some force, which, Hutton believed, was produced by heat and pressure in the Earth's interior.

He introduced his theory at a meeting of the Royal Society of Edinburgh in April 1785. Although he did not accept the literal interpretation of Genesis, he did believe that the self-perpetuating nature of the Earth was the work of a benevolent, life-giving God; Hutton did not consider God to be vengeful nor a destroyer of life as would have happened with the Flood. He published a two-volume book *Theory of the Earth: With Proofs and Illustrations* in 1795, two years before his death. Because he thought the cycles had gone on for ever he concluded in his *Theory of the Earth* that

> "**The result, therefore, of our present inquiry is that we find no vestige of a beginning - no prospect of an end.**"

So, for Hutton, any question about the age of the Earth was without foundation. However, his idea of cycles was not widely accepted, possibly because it was too similar to the idea of endless cycles held by ancient, pagan civilizations. So, at the time of his death, the diluvial theory - that the Earth experienced a great Flood - was still commonly accepted. But Hutton

had managed to persuade a number of influential thinkers so that the inevitable confrontation between science and religion was drawing ever closer.

Possibly the most influential figure to argue against the Biblical account of the history of the Earth was Sir Charles Lyell (1797-1875), who put together a comprehensive theory based on Hutton's ideas. Lyell, see figure 8, travelled extensively throughout his life visiting numerous important geological sites throughout Europe and North America. He studied and measured, for example, the accumulated lava flows from eruptions of Mount Etna to determine the age of the mountain, and the rate at which the Niagara Falls are moving towards lake Erie as a the Niagara River erodes the underlying rock. He became convinced that all geological features were simply the result of forces that were still operating today, such as weather, tides, rivers, volcanoes and earthquakes. There was no need for universal floods nor catastrophes, he argued, all that was needed was time. In 1830-1833, Lyell published in three volumes his *Principles of Geology: Being an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes now in Operation*. In the books he espoused the idea of a history of the Earth that has become known as *uniformitarianism*, although Lyell did not, himself, use the description. There are three main concepts at the very heart of Lyell's theory:

- The laws of nature are the same today as in the past, i.e., that laws are universal and unchanging.

- The same processes operate today as in the past; this is the very essence of uniformitarianism.

- These processes operate at the same rate as in the past, i.e., very slowly. (Today, we call it *gradualism*.)

Uniformitarianism was, therefore, in direct conflict with *catastrophism*, which held that the Earth was young and its features were shaped by sudden cataclysms and catastrophic and supernatural processes. Ironically, the term uniformitarianism was first used in 1832 by William Whewell (1794-1866), a University of Cambridge scholar and a "catastrophist"! (Incidentally, Whewell appears to have invented the English words "scientist" and "physicist"; before this time the only terms in use were "natural philosopher" and "man of science".) What was significant was that Lyell suggested a *universality* in the laws of nature not only in space but in time, and by the mid-1800s uniformitarianism had become the accepted geological theory[8] .

Although theologians realized that such a theory was opposed to a literal interpretation of the Bible, many people were comforted by accepting that the human race was not likely to be wiped out in an instant! What was significant about Lyell's ideas was that, for the first time,

[8] The influence of Lyell's thinking is clear today; we now accept that the history of the Earth is governed by steady, continual changes (as described by Hutton and Lyell) although it is punctuated from time to time by singular, and occasional catastrophic events (like earthquakes and meteorite impacts). Furthermore, in a more general sense, we accept the notion of universality in the laws of nature, e.g., that Newton's Law of gravitation operated in the past and in different locations in the universe as it does on Earth today. As we will see, the theory of uniformitarianism was also important in shaping the development of ideas in other areas. For instance, Charles Darwin's and Alfred Wallace's work on the origin of the Earth's species extended the ideas of uniformitarianism (and gradualism) into the biological sciences. The theory of evolution is based on the principle that the diversity seen in the Earth's species can be explained by small modifications of genetic traits over long periods of time.

instead of geology being *adapted* to fit the Biblical description, the Bible had to be *interpreted* in terms of geology. That led to two main "interpretations" of Genesis:

> 1. The world *was* created in six days, but it was a second-hand (or re-cycled) world. Genesis 1:1 ("**In the beginning God created the heaven and the earth**") described the creation of the original world, whereas Genesis 1:2 ("**And the earth was without form ...**") described the current world. Between these two verses an indefinite period of possibly many millions and millions of years could have passed. Ussher's timescale applies only to this "re-constituted" world.
>
> 2. The alternative option was to accept that the "six days of Creation" were not literally six days, but six *eras* that lasted an indefinite period. Since human beings were the last creatures to appear on Earth, the Biblical account covered only the lifetime of the human race; so Ussher's chronology was solely a history of *mankind*.

Although Lyell's approach could not put an age to the Earth - in fact, as we have already noted, according to the theories of Hutton and Lyell, the Earth *could* be eternal - there were concerns, particularly among physicists, that an everlasting world would violate the laws of nature. Indeed, it was the very *universality* in the laws of nature that Lyell had postulated that eventually enabled physicists to modify Lyell's theory and produce limits to the Earth's age.

Also, in 1859, Charles Darwin published his *The Origin of Species*, in which he put forward his ideas on natural selection. Although this controversy is the subject of another essay in this series, the important thing here is that natural selection was a form of gradualism that took place over a very long time scale[9] .

Nevertheless, from the mid-1800s onward - after Lyell's uniformitarianism and Darwin's natural selection - we see a general acceptance that the Earth was very old, much older than Ussher's estimate (although that did not necessarily imply an acceptance of Darwin's theory of natural selection and evolution). One such detractor was the Scottish physicist William Thomson (1824-1907), see figure 9. He regularly attended Church and believed steadfastly that God had created the universe and mankind. Thomson was a hard-working and highly intelligent scientist. When 22 years old he was appointed professor of physics at Glasgow University - beginning his lectures with prayers - and a few year later, in 1851, he formulated one of the most important laws of physics; the so-called *second law of thermodynamics*.[10]

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[9] Using Lyell's ideas, in 1857, Darwin made an estimate of the length of time it took to produce the Weald of Kent, a narrow channel flanked by chalk cliffs and worn by erosion. He calculated that it must have required 306,662,400 years to produce the Weald. In fact, this time period was the duration of what is called the Tertiary Period and represents, therefore, only a fraction of geological time. He used this figure in early editions of *The Origin of Species* but was forced to exclude it in the 3rd edition after he realized his estimate did not stand up to close scrutiny.

[10] The first law of theormodynamics was a statement of the conservation of energy; that energy is never lost, it is simply converted from one form to another. The second law tells us that the conversion of energy into work is never 100% efficient; some of the initial energy is "lost", e.g., through friction, heat, sound, exhaust. It shows us, for example, why perpetual-motion machines are impossible.

In addition, as a director of the Atlantic Telegraph Company, he also played a key-role in the laying of the first trans-Atlantic telephone cable in 1866 and, as a result, became a very rich man. Eventually, in 1892, for his many achievements as a physicist and inventor he was raised to the peerage becoming Lord Kelvin of Largs, the first scientist to be accorded such an honor. Today, his name (Kelvin) is associated with the absolute temperature scale used in physics and chemistry.

Kelvin was convinced that the world had not existed indefinitely. How could it? ... Where did the energy come from? ... With a finite amount of energy it must have a finite lifetime. First, he considered the Sun; he realized that just like a regular fire, the supply of fuel in the Sun was limited, and so if it were not replenished it would surely burn out. Initially, he determined how much energy a conventional *chemical* fuel (like coal) could supply with an object the size of the Sun. He determined that the Sun would only last some 3,000 years. Clearly, that was not the case, so where did the energy come from? Kelvin guessed that the Sun was formed from a large numbers of meteors; gravity pulled the material together into a tighter and tighter ball and as it did so, there would be more and more collisions with such force that heat would be produced. When the meteoric rock had melted to form a incandescant molten mass, the Sun was born. The Sun's heat was maintained by the energy released as the huge mass slowly contracted under gravity. According to Kelvin's calculations the Sun would then have a lifetime of 20 million years. At more or less the same time Kelvin heard that John Phillips, a former president of the Geological Society from Oxford, had made an estimate of the age of the Earth's crust by measuring the amount of "earthly matter" deposited annually by the Ganges. Accordingly, Phillips determined the time taken for the formation of all the sedimentary strata was about 96 million years[11] .

Kelvin was an astute scientist and eventually took into account the many approximations he had made and eventually concluded that it was ...

> " **... most probable that the Sun has not illuminated the Earth for 100,000,000 years, and almost certain that it has not done so for 50,000,000 years**".

Kelvin was to be disappointed with the response to his calculation; his paper at the September 1861 meeting of the British Association - read in his absence due to illness - was largely ignored! He published his calculations in an article "On the Age of the Sun's Heat" in *MacMillan'sMagazine* in March 1862. However, within two years he had developed a new approach; determining the age of the Earth using parameters directly from the Earth itself. For example, he knew that the temperature of the Earth increased by something like 1°F for every 50 feet in depth so that heat must be flowing outward from the Earth's center. According to Kelvin, therefore, the Earth was cooling. He also knew the thermal conductivity and specific heat of the common rocks and their melting temperatures and he was sure the Earth started as a molten mass. By adapting an equation for the heat flow through solid materials developed by Joseph Fourier in 1807, Kelvin obtained a simple mathematical expression that gave the age of the Earth in terms of known, measurable quantities, see figure 10. The result he obtained, and published in "On the Secular Cooling of the Earth" in the January 1863 issue of *The Philosophical Magazine*, that the Earth solidified 98 million

[11] Both Kelvin's and Phillips' calculations contained many approximations and it was realized that the age determined by Phillips was not the true age of the Earth. However, Kelvin was encouraged by the *approximate* agreement between the two approaches; indeed, he was convinced that whether 20 or 96 million years, the time periods were far, far too short for Darwin's evolutionary processes to occur and so "natural selection" was untenable as a theory.

years ago, was remarkably close to Phillips' estimate of 96 million years. Kelvin's calculation was based on several assumptions:

1. The energy comes from a finite amount of heat energy contained in the Earth's interior.

2. The heat is not being replenished from any source and so as the heat energy flows outward through the Earth's surface, the energy "store" is diminishing.

3. The Earth was a solid, homogeneous sphere.

To the geologists, the time period Kelvin determined was not enough for the cycles of erosion, sedimentation, and uplift they saw preserved in the Earth's rock record and to the evolutionists the time period was simply not long enough for natural selection. But, rather than backing off his original estimate of the age of the Earth, Kelvin continued to try to reconcile it with his estimate of the age of the Sun. As a result, over three decades he continued to revise the age of the Earth downwards after allowing for errors and approximations and by assuming that the initial temperature of the Earth was less and less. By 1897 he had a value of 24 million years, with a possible spread from 20 million to 40 million.

Meanwhile, several other scientists had proposed alternative methods to determine the Earth's age. In 1868, Sir Archibald Geikie, the director of the British Geological Survey, produced an estimate of 100 million years based on present-day erosion rates, and - as was mentioned earlier - in the last decade of the 19th century, John Joly of Trinity College, Dublin, proposed a novel method based on the concentration of sodium in the oceans. Assuming that the sodium salts came from continental erosion by rivers through flowed into the ocean, he calculated the age of the Earth to be about 90 million years.

It's important to realize the impact this had on geology. Kelvin's logic appeared impeccable and the mathematics was straightforward; few could find fault with his approach. Although his opponents pretty much accepted the *accuracy* of his calculations, some were convinced that he must have left something out or that there were simply too many assumptions without enough data. For example, Thomas Huxley (1825-1895) tke leading zoologist (and a staunch supporter of Darwin) later wrote ...

"**... mathematics may be compared to a mill of exquisite workmanship, which grinds you stuff of any degree of fineness; but nevertheless, what you get out depends on what you put in; and as the grandest mill in the world will not extract wheat flour from pea pods, so pages of formulae will not get a definite result out of loose data.**"

In today's parlance ...

"**Garbage in, garbage out!**"

Although the true age of the Earth was still in dispute as the 20th century approached, it was obvious to just about everyone that the Earth was much older than the dates - based on Ussher's chronology - that appeared in the margins of the Old Testament. In 1885, after some 15 years of debate involving theologians from both sides of the Atlantic, the Church of England approved the publication of a revised edition of the Authorized English Bible, with Ussher's dates removed (much to the disappointment of Kelvin, incidentally). The dates continued to appear in other editions for another two decades; Cambridge University Press

removed them from editions published in 1900 and Oxford University Press followed suit in 1910.

The debate between the physicists and geologists, though, had brought the question of the age of the Earth into the public arena and had generated a great deal of interest. The overall result, however, was that both scientific and public support seem to favor Thomson even more. For example, in 1894 - two years after Thomson had become Lord Kelvin - Lord Salisbury, president of the British Association for the Advancement of Science, still maintained that Kelvin's figures remained one of the "strongest objections" to Darwinian evolution. Even Mark Twain got into the act. Some time around 1900, in a brief sketch called *Was the World Made for Man* he wrote

> "**Some of the great scientists, carefully ciphering the evidences furnished by geology, have arrived at he conviction that our world is prodigiously old, and they may be right, but Lord Kelvin ... feels sure it is not so old as they think. As Lord Kelvin is the highest authority on science now living, I think we must yield to him and accept his view.**"

Whoops!! Maybe there's a lesson to be learned here - the opinion of an authority isn't necessarily correct! So, although Kelvin's opponents - the geologists and evolutionists - were frustrated by the debate and the ensuing reaction, particularly since Kelvin and other physicists simply refused to *look* at, or chose to ignore, the geological evidence, the level and standard of criticism and language used was must less extreme than in some of the other feuds we'll look at. Generally speaking, the disputants managed to co-exist and maintain reasonably good relations right up to the end. If there was any agreement, I suppose it was that they disagreed!

Still, by 1894, even Kelvin, now approaching 70 years old, was beginning to wonder whether he had missed something. To him, the growing evidence for an Earth that was, say, a few billion years old was beginning to make him wonder, and contrary to some opinions, he was by no means an inflexible man. However, there was little he could do, for since his estimates, attitudes had hardened. Not only that, for several decades now his calculations had been used in physics classes the world over as examples of heat flow!

So, what happened? Well, the beginning of the end for Kelvin's calculations came with the discovery of radioactivity by the French physicist Antoine Henri Becquerel (1852-1908), see figure 11, early in 1896. In fact, Becquerel's discovery was rather fortuitous. He had thought he had discovered that sunlight produced certain crystals to produce something that caused photographic plates that were well wrapped with paper to become exposed and appear blackened. When in late February 1896 the weather in Paris turned cloudy, he packed away his crystals and photographic plates in the drawer of a cabinet. To his utter astonishment when he developed the plates on March 1st, they were blackened; whatever it was there were invisible radiations from his crystals that caused this blackening. We now know that the uranium in his crystals were spontaneously radioactive and that it was the radiative particles - initially called Becquerel rays - that were penetrating the wrapping paper and causing the plates to become exposed. It took a number of years before the actual process of radioactivity - a word introduced sometime later by Marie Curie to replace the name Becquerel rays - and the processes and types of particles involved were understood. But in 1903 Pierre Curie and Albert Laborde showed that one of the newly discovered radioactive elements, radium, also produced heat continuously. Normally, when you put a warm piece of ordinary metal, like a warm lump of iron, in a cold environment it will cool down; however, a lump of radioactive material, like radium, will keep warm; it is, if you like, generating its own heat rather like you and I. So where would the radium have come from? Well, it was

discovered also that many of the radioactive elements are either descended from each other or related to each other; so, for instance, radioactive uranium slowly turns into radioactive radium and so on, see figure 12. This so-called parent-daughter process means that "heat" can be generated by a number of different elements over a long period of time; it only stops when a non-radioactive, a so-called stable, element is formed, like lead at the end of the chain. This decay chain is carrying on continuously within the Earth, producing internal heat (which Kelvin had neglected - in fact, he'd simply didn't know about it).

Although by now many believed that Kelvin was wrong, his reputation never weakened and he remained a powerful and respected figure in science. There is a good story about how Lord Kelvin's prominance put Ernest Rutherford in a rather difficult position when the latter was invited to address a meeting at the Royal Institution in London in 1904. His talk was about his studies that had shown that radioactive atoms contain great stores of heat and his suggestion that radioactive material was distributed throughout the Earth's interior. He knew that his new ideas would bring him into sharp conflict with Kelvin, now aged 80 years, who was in the audience.

> "**To my relief,**" wrote Rutherford later, "**Kelvin fell fast asleep but as I came to the important point, I saw the old bird sit up, open an eye and cock a baleful glance at me! Then a sudden inspiration came, and I said, 'Lord Kelvin had limited the age of the Earth, provided no new source of heat was discovered. That prophetic utterance refers to what we are now considering tonight, radium!' Behold! The old boy beamed upon me.**"

The effect of the discovery of spontaneous radioactivity and subsequent research prompted by Ernest Rutherford's insights had two major effects on the age-of-the-Earth debate. First, it led to an explanation of the error in Kelvin's analysis; in 1905 the British physicist Lord Rayleigh (John William Strutt, 1842-1919) confirmed Rutherford's suggestion that the occurrence of radioactivity was one of the "missing" factors in Kelvin's calculations. Secondly, it provided a new method of dating the Earth more accurately: in 1907, the same year that Kelvin died, the American chemist and physicist, Bertram Borden Boltwood (1870-1927), suggested that because we know how fast uranium changes into lead, see figure 13, then by measuring the amount of lead in a lump of uranium ore it might be possible to determine the age of the rock in which the ore was found. The greater the percentage of lead, the older the rock. There are two major assumptions here:

1. that all the lead in the uranium ore was once uranium, which is probably a reasonable assumption, and

2. that the rock, and the uranium were produced at the time of the creation of the Earth from the original material of the solar system; that's a little more questionable.

In 1907, using such an approach and after determining the rate that uranium atoms decay, Boltwood calculated the ages of 26 samples of rocks containing uranium. He estimated the youngest was 410 million years old while the oldest was about 2.2 billion years old. Boltwood's reasoning holds true for other radioactive elements as well, such as carbon-14. Carbon-14 decays much more quickly than uranium, so that it can be used to date artifacts over a shorter time span, e.g., within human history.

We know now that there are other "missing" factors in Kelvin's calculations - gravitational energy and meteoritic bombardment; together these three factors have caused and maintained a partial melting in the outer core. As a result there are powerful convectional

processes that produce an uplifting and mixing of molten rock within the Earth - rather like the "stirring" effect in a saucepan of boiling water. So, Kelvin's model of heat loss and his calculations were far too simplistic. In fact, the stirring effect that is taking place, albeit very slowly, and the changes that have taken place, now makes scientists wonder whether the earliest rocks are now buried deep within the Earth and inaccessible! That's what makes the dating process so difficult.

Furthermore, all this turmoil has resulted in a separation within the Earth that Kelvin did not know about. The final result of these processes, which still go on today, is that our Earth has a structure like an onion; starting from the surface inward there is a thin, outer crust of rock, then there is a thicker rock mantle of greater density and a still heavier core mostly of iron and nickel the outer part of which is molten. As we saw earlier, Kelvin had assumed that the Earth was homogeneous, that is, it was made from the same material throughout.

Modern theories and subsequent refinements of the "radioactive dating" approach referred to above have led to far more accurate methods; the oldest rock found on Earth is about 4.3 billion years old. It is likely that the Earth is a little older than this and evidence from a meteorite discovered in Mexico in February 1969 suggest an age for the formation of the solar system of almost 4.6 billion years. This date is currently our best estimate of the age of the Earth. The universe appears to be considerably older than the solar system. The current best estimate is that time itself and the universe were created 13.4 (plus/minus 1.6) billion years ago.

So what can we make of all these controversies? Let's first look at some of the more recent conclusions about the veracity of the account in Genesis. In 1983, James Skehan, a geologist and ordained minister, pointed out (in the *Journal of Geological Education* v. 31, 307 (1983)) that:

> " **... Genesis is not a scientific treatment of the origin or age of the earth, or of life, including that of mankind, ...** "

adding that the first eleven chapters of Genesis, which cover "creation", are most likely

> **... a primitive religious history of Israel, deduced from ... part of the older Babylonian creation myth, *Enuma elish*.**"

Furthermore, he points out that most Biblical scholars believe that Genesis was written after much of the rest of the Old Testament.

So, why are there still so many "young Earther's"? The acceptance of such theories demonstrates, I believe, a lack of critical thinking, i.e., in separating the *real* from the *unreal*. People are often willing to draw conclusions from a limited amount of biased information even when there is a plethora of un-biased and objective data that opposes their views. For example, look how a few reports from patients who believe they have been cured by some form of quack medicine or from people who have reportedly made buckets full of money, will often be more than enough to convince others of the total validity of the claims; they simply have no interest in asking about the majority who did not benefit at all or even suffered.

The problem is that we tend to use different criteria to evaluate ideas we support compared with those we do not; this is a breakdown in critical thinking skills. Often, with ideas that we feel are correct, we ask only that the evidence not force us to think otherwise. For ideas we feel are incorrect, we demand that the evidence force us to change our views to accept the new idea; the latter is a much more difficult standard. As Carl Sagan wrote (in 1995):

"**Keeping an open mind is a virtue - but ... not so open your brains fall out. Of course we must be willing to change our minds when warranted by new evidence. But the evidence must be strong. Not all claims to knowledge have equal merit.**"

Generally, science is based on establishing conclusions from empirical evidence, i.e., observation. One of the problems I have with so called "creation scientists" is that they start with the belief that their theory is correct and then seek evidence that supports it while, at the same time, dismissing competing ideas. It is something I call "pushing the prediction"; to an extent one can accuse Lord Kelvin of doing the same thing because of his fundamental disagreement with Darwinism. It does seem that he always appeared to be trying to *reduce* his estimate of the age of the Earth.

There is a lesson to be learned here. Kelvin, in common with many theoretical physicists, constructed a *mathematical* model of the Earth. Mathematical models by their very definition involve rigid and precise language with little room for ambiguity; once a model is proposed then a result (almost) automatically follows. The difficulty faced by the theoretical physicist is to know which parts of the complexity of nature can be safely ignored and which must be retained. It is not clear that Lord Kelvin, in particular, and many of the other scientists in this controversy, questioned the limits of their approaches. Certainly, as James Trevil points out in his book *Reading the Mind of God*, most academic journals today would not have accepted Kelvin's manuscript for publication without demanding answers to questions like:

- How do your assumptions affect your result?
- What evidence do you have that your assumptions are sensible and valid?

But in 1863 William Thomson was considered one of the leading scientists of the day whose word was accepted with little question. Indeed, after he published his 1863 paper he said

"**It is quite certain that a great mistake has been made - that British popular geology at present is in direct opposition to the *principles of natural philosophy*.**" (My italics).

One may ask whether Kelvin himself practiced the *principles of natural philosophy*. So, a point we should remember is that just because someone is an authority they may not always be correct; they are fallible also!

One final point comes to mind. There is another strong motivation for holding onto ideas, particularly for those who subscribe to the literal truth of Genesis. By holding that Genesis is literally correct, they claim that any theory that contradicts, or even questions, that interpretation, must be wrong. The real difficulty such individuals (and organizations like the Church) face is the feeling that to give up a belief in one, single point is going to undermine the whole thing. Therefore, they become totally inflexible. Furthermore, the idea that the laws of physics (or geology and biology) could control the processes of the Earth is an anathema to such people; for wouldn't that seem to suggest that our lives are purposeless and without meaning? (Although, to be fair, that viewpoint is not shared by most mainline churches.) But, as biologist Kenneth R. Miller puts it:

"**A world truly without meaning would be one in which a diety pulled the string of every human puppet, indeed of every material particle. In**

such a world, physical and biological events would be carefully controlled, evil and suffering could be minimized, and the outcome of historical processes strictly regulated. All things would move toward the Creator's clear, distinct, established goals".

I leave it to you to think about this question: ... *how meaningful would our lives be if we were all merely robots?*

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THE AGE OF THE EARTH:
PHYSICS vs FAITH

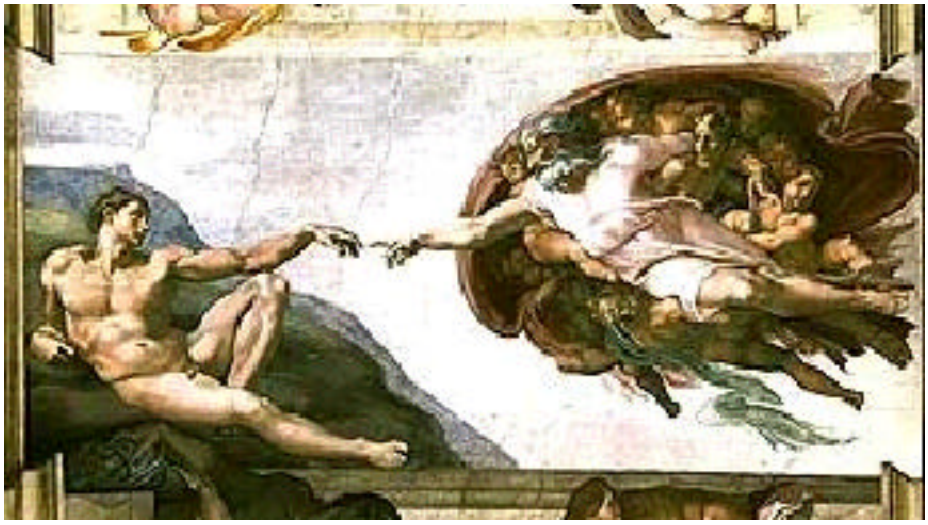

FIGURE 1: *The Creation of Adam*, painted on the Sistine Chapel Ceiling by Michelangelo

1 Kalpa (4.32 billion years)	1000 Mahayugas
1 Mahayuga (4.32 million years)	4 Yugas years
4th yuga	430,000 (a thoroughly evil age)*
3rd yuga	860,000 (a decadent age)
2nd yuga	1,290,000 (an age of labor, pain and suffering)
1st yuga	1,720,000 (a golden age)

FIGURE 2: The Hindu Mahayuga cycle (from the *Vishnu Purana*, about 500BC). One Kalpa is one day in the life of Brahma.

*** We are currently about 2500 years into a 4th yuga.**

(From: http://gfisher.org/9recur.pdf.)
See also: http://my.engr.ucdavis.edu/~das/rao/How_old_are_we.html)

Josephus (37-95AD)	4698/5402/5481/5555BC
Theophilus of Antioch (2nd century)	5517BC
Bede (673-735AD)	5199BC
Alfonso X (1221-1284)	6484/6984BC
Martin Luther (1483-1546)	3961BC
Johannes Kepler (1571-1630)	3993BC
Rabbi Lipman (1579-1654)	3616BC

http://www.answersingenesis.org/home/area/faq/docs/date_of_creation.asp

FIGURE 3: A selection of proposed dates of The Creation [Young's *"Analytical Concordance of the Holy Bible"* first published in 1879, from *"A New Analysis of Chronology and Geography, History and Prophecy,"* by William Hales (1830)].

FIGURE 4: On the left, James Ussher (1580-1656), appointed Archbishop of Armagh, the most senior position in the Church of Ireland, in January 1624. On the right, John Lightfoot (1602-1675), Vice-Chancellor of Cambridge University and an eminent Hebrew scholar.

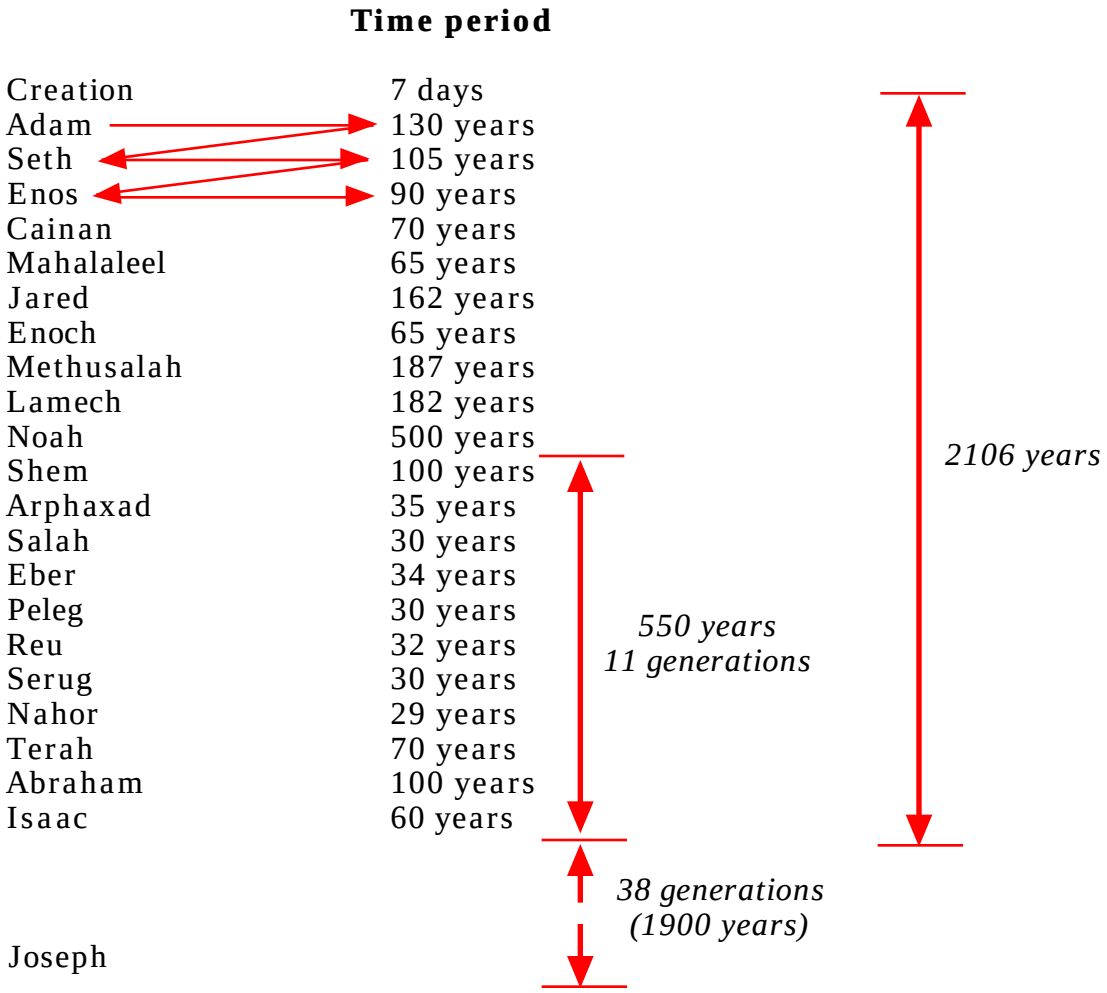

FIGURE 5: An approximate determination of the age of the Earth (i.e., from Adam to the birth of Christ) using an approach described by James Trevil (in *"Reading the Mind of God"*) and attributed to a friend (Douglas Macayal). The periods of the two relevant groups (from Adam to Isaac and from Jacob (son of Isaac) to Joseph (father of Christ)) when added puts the Creation at 4006BC.

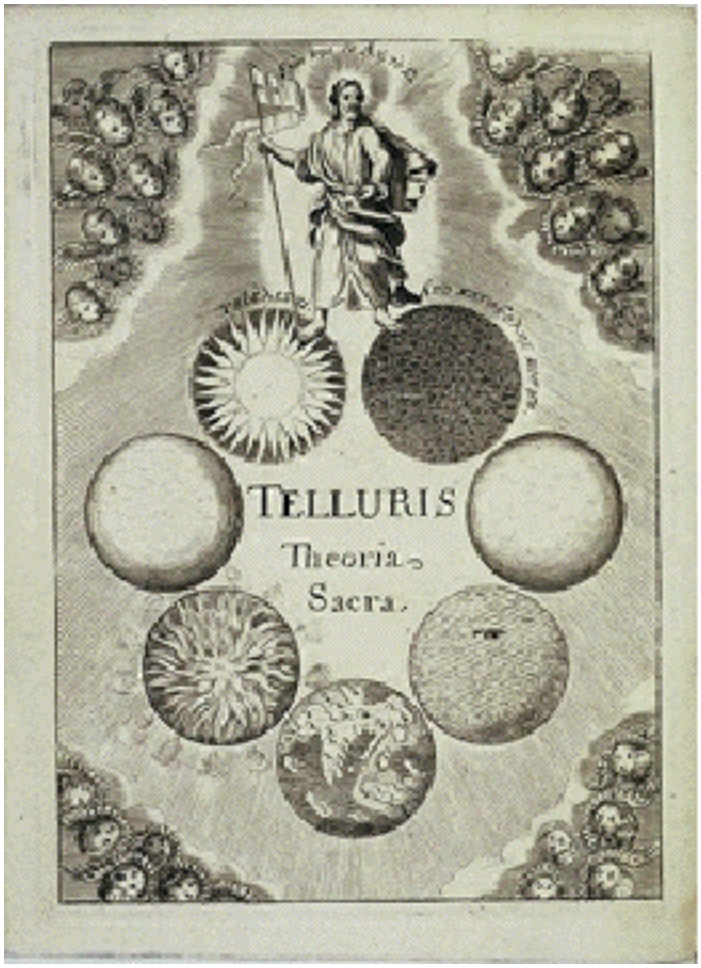

FIGURE 6: Frontispiece of Burnet's "Sacred Theory of the Earth" Christ stands on two of seven globes depicting the progression of life. Above the "IS" in telluris we see the formation of the Earth, and confusion. The next (clockwise) shows a perfect Earth, followed by the Great Flood with Noah's Ark. Next there is the current Earth, heavily scarred, followed by the second destruction of the Earth by fire. Then the Earth is perfect again and Christ reigns for 1000 years with his saints during this period. After the final judgment, the Earth becomes a star.

FIGURE 7: Statue of George-Louis Leclerc, Comte de Buffon (1707-1788) in the Jardin des Plantes, Paris. Note the pigeon on his head! (Picture taken by the author in 2002.)

FIGURE 8: On the left, Dr. James Hutton (1726-1797), gentleman farmer, who introduced the idea that the Earth operated on a continuous cycle of erosion, sedimentation and uplift. On the right, Sir Charles Lyell (1797-1875), who put together the first comprehensive theory of the Earth's geological features, based on Hutton's ideas.

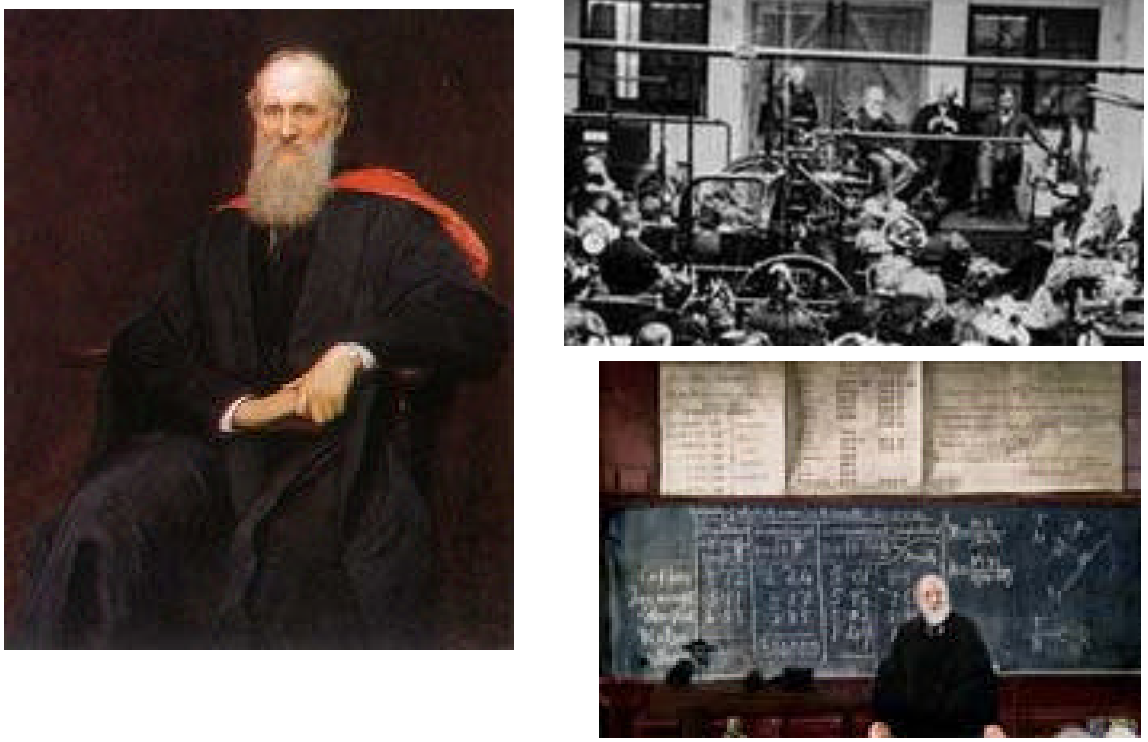

FIGURE 9: William Thomson (1824-1907), later Lord Kelvin of Largs, professor of physics, later Chancellor of Glasgow University and vice-Chancellor of Cambridge University. Above right, Lord Kelvin opening the Laboratories in Free School Lane, Cambridge (1894). Bottom right, Lord Kelvin delivering his final lecture at Glasgow University in 1899.

FIGURE 10: Starting with Fourier's equation for the flow of heat due to a difference in temperature, William Thomson (Lord Kelvin) deduced an expression for the age of the Earth (t) in terms of the initial temperature of the Earth (T_i), the current surface temperature (T_s), the thermal diffusivity (K), i.e., how fast the cooling take place, and the temperature gradient (dT/dx).

$$t = \frac{(T_i - T_s)^2}{\pi K \left(dT/dx\right)^2}.$$

Using reasonable values: $T_i = 1510^\circ C$, $T_s = 10^\circ C$, $K = 1.0 \times 10^{-6}\ m^2/s$ and $dT/dx = 0.015^\circ C/m$, we obtain

$$t = 101 \text{ million years.}$$

FIGURE 11: Antoine Henri Becquerel (1852-1908), the French scientist who discovered natural radioactivity in 1896.

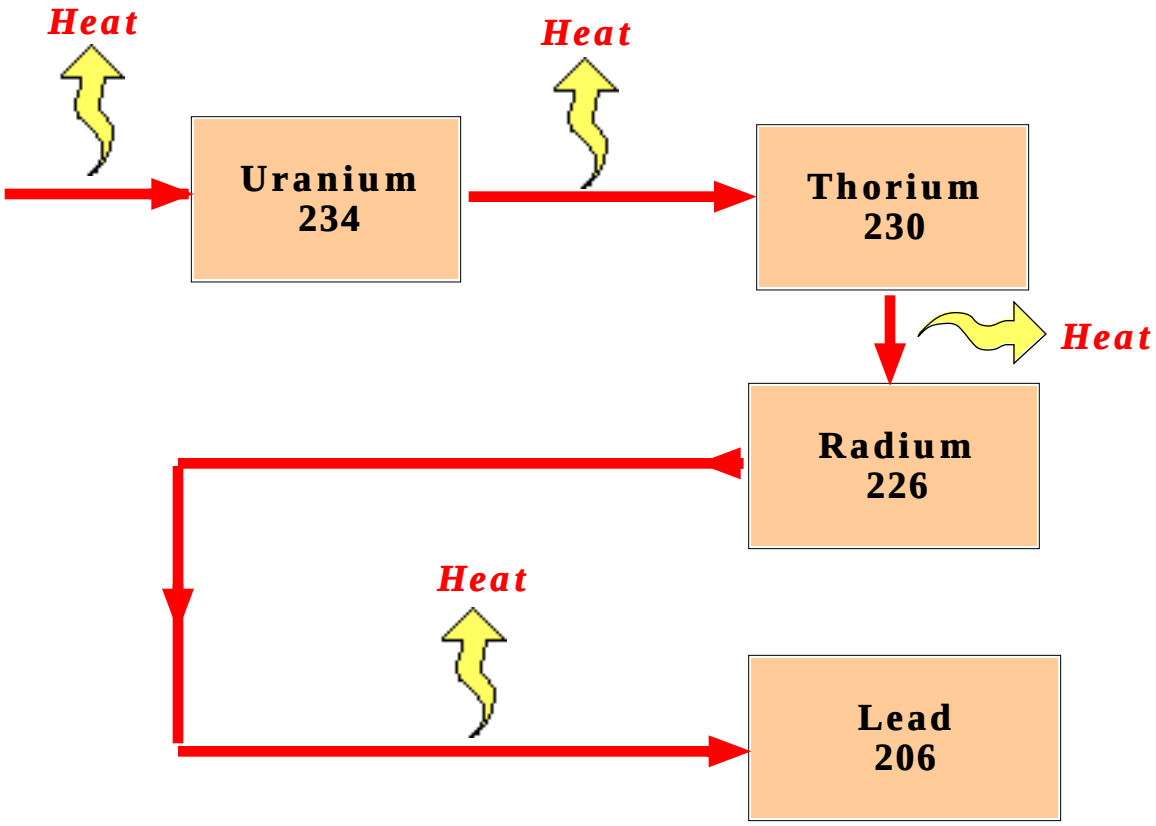

FIGURE 12: Part of the radioactive decay chain from Uranium to Lead; there are 14 steps altogether. Each step can take from seconds to millions of years. Over the lifetime of the Earth - *about 4.6 billion years* - about one-half of the initial Uranium in the Earth has been converted to Lead.

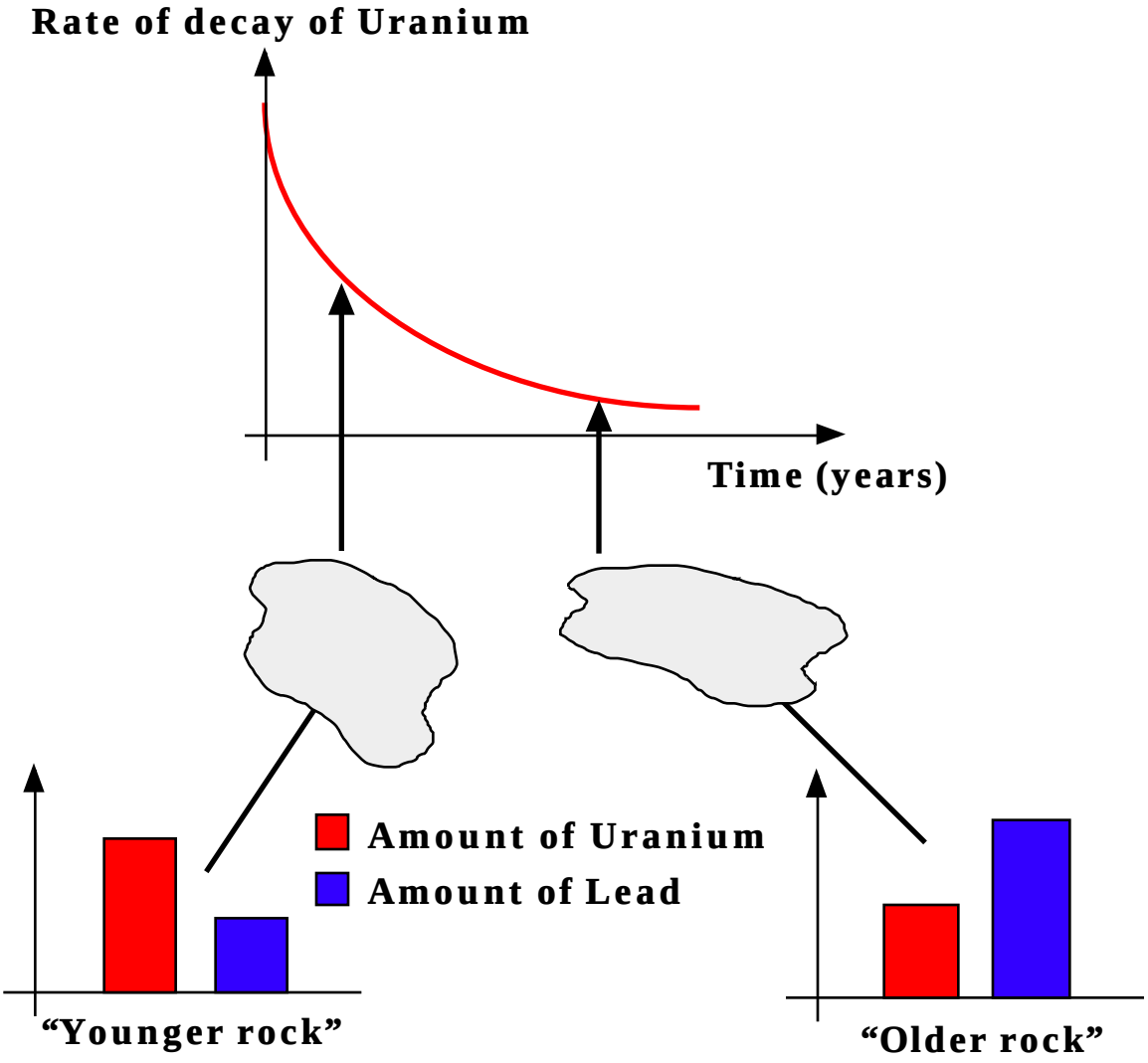

FIGURE 13: By measuring the ratio of the amount of lead to the amount of uranium in a rock sample, it is possible to determine the age of the rock. The greater the ratio, the older the rock.