ENVIRONMENTAL ECONOMICS: Introduction 2002

Mans's Place in the Environment

This course is concerned with man's place in the environment. In the last 250 years or so, mankind's impact upon the environment has increased beyond all previous measure, and it has been increasing most rapidly during the last century.

In recent times, there has also been a growing awareness of the extent to which our reproductive behaviour and our instincts of territorial aggression, as well as many other aspects of human behaviour, are in thrall to our animal nature. These tendencies were developed in circumstances quite different from those in which we now find ourselves, and we seem to be ill-adapted to cope with an environment which is increasingly of our own making. We seem unable to adapt our social organisation quickly enough to respond to the problems that we ourselves are creating.

In preindustrial times, that it to say, as recently as 300 years ago, there was little consciousness amongst Europeans of any processes of historical change or of technological evolution. Man's history was supposed to be bounded by the date of creation and the date of doomsday; and, between those limits, the human condition was not expected to change greatly. The dates of creation and doomsday were remote; and to try to determine the latter with any exactitude would have been regarded as a presumptuous divination of God's will. This is notwithstanding the occasional bouts of Milleniarist enthusiasm, which foresaw the imminent second coming of Christ and an ensuing thousand years of happiness on earth.

Within Christian theology, there was a definite view of man's place in the natural order of things. According to the biblical book of Genesis, man is at the centre of creation. It was supposed that, having created heaven and earth and all of the animals and plants in a period of six days, God rested on the seventh day. On the eight day, he created Adam, and from Adams's rib he created Eve. Thus, all of creation, including women, had been placed on earth to serve the purposes of God and man.

A better understanding of the environmental impact of our present-day industrial and agricultural activities can be achieved if we also understand the processes of biological and geological evolution that have created our world. In order to understand the problem of global warming, for example, which has arisen over the period of 250 years since the beginning of the industrial revolution, it is helpful to understand how the peculiar and essentially unstable atmosphere of the earth evolved over aeons of time.

In order to understand the successes in the 20th century in warding off the diseases to which humans are susceptible, and to understand the limits to this process and the potential for its reversal, we need to understand how the bacteria and the viruses that discomfort us have evolved over similar periods of time.

It is within my own lifetime that we have reached accurate reckonings of such measures as the age universe, the age of the earth, the likely date for the emergence of life on earth and the date for emergence of our own species. None of these dates was know with any certainty thirty years ago; and yet, nowadays, we can make confident assertions in every case except, perhaps, for the date of the origin of life on Earth.

The Age of the Earth

The geological dates that are the products of recent scientific research can be see in the accompanying diagram which is described as the stratigraphic column. It is very hard indeed to grasp some of the durations that are involved and to make comparisons between them and the intervals of time that we experience in our own lives.

The first figure to gasp is the date that has been given for the Earth's formation. This can be quoted as 4.6 times 10 to the power 9 years before present. 10 to the power 9 is an American billion i.e. a thousand million. There are, for example, 6 billion people currently on this earth, whilst the population of this country is perhaps 60 million and that of India one billion.

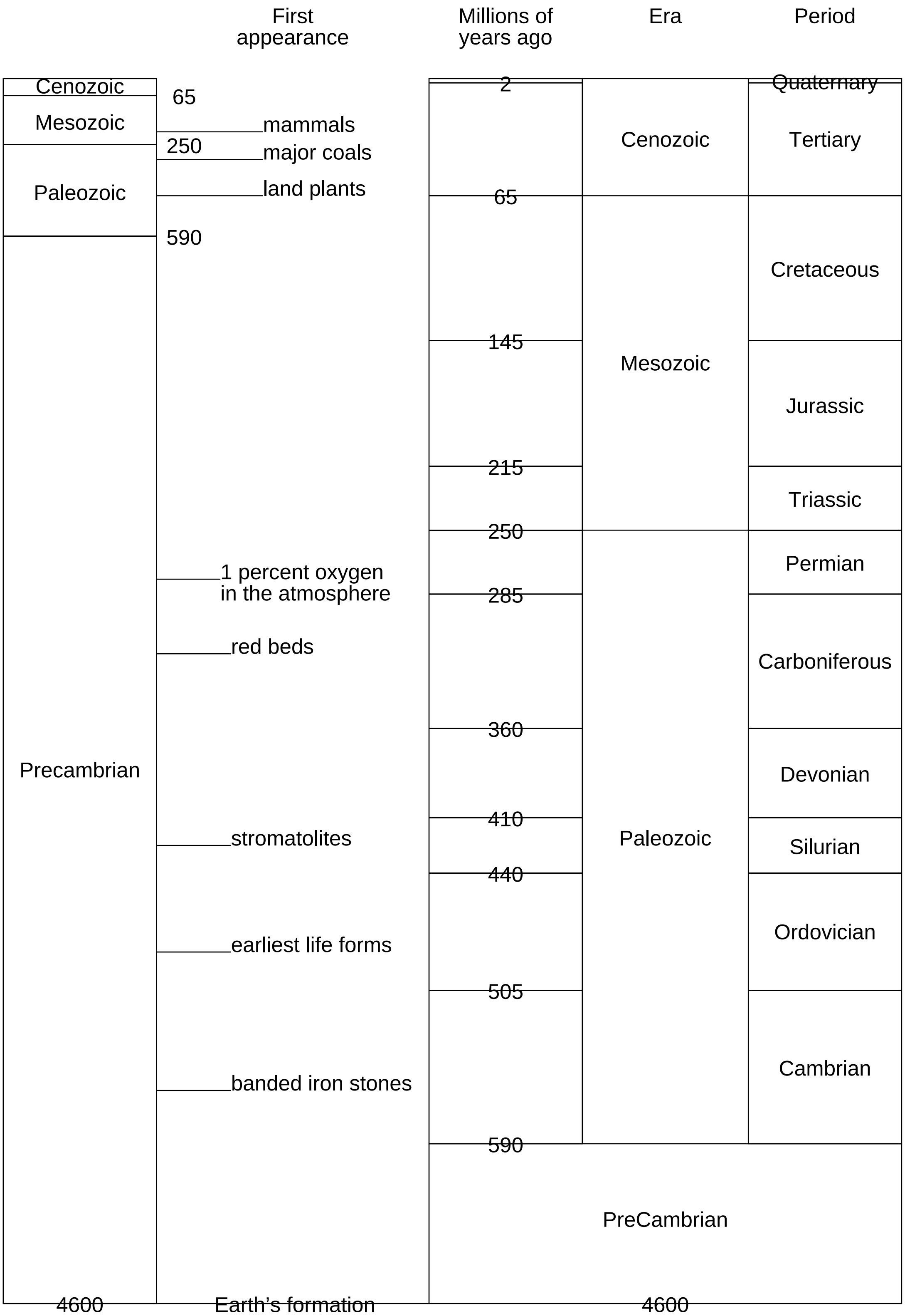
In seeking to express these time spans in a way that is intuitively intelligible, it is customary to compare them to the length of the day. There are $24 \times 60 \times 60 = 8,6400$ seconds or 1440 minutes in the day. Life was present on earth at least 2.7 billion years ago, which corresponds to 10 o'clock in the morning. The dinosaurs met their end in a fiery cataclysm that occurred at 20 minutes to midnight at the end of the Cretaceous period.

The hominid apes, which were the progenitors of our own species, emerged in Africa at most 5 million years ago, which is at 93.9 seconds or one and a half minutes to midnight. Our own species, Homo Sapiens, dates from between 100,000 and 150,000 year ago. 0.15 million years is equivalent to 2.8 seconds.

Another way of measuring relative times is by the pages of a book. I have a version of the King James Bible that is printed on fine Indian paper. There are altogether 1,000 pages. Most of the first page of the bible, which is the first page of the book of Genesis, can represent the 5 million years of the hominid species, and the rest of the book can represent the age of the Earth.

On the first page of this Bible, at the top of the middle column, is a scholarly estimate of the age of the Earth, which was published in the year 1654 by James Usher (1581–1656), the Bishop of Armagh and the Primate of all Ireland. The date of creation is given as 4004 BC, which would make the Earth some 6,000 years old. I am reminded of this because I have been sitting only recently in the Usher Lecture Theatre of Trinity College in Dublin, where I was attending a conference.

We might find Usher's estimate laughable, but I propose that we should take it seriously. It was the product of the research of a celebrated biblical


First appearance
Millions of years ago
Era
Period
Cenozoic
Mesozoic
Paleozoic
Precambrian
65
250
590
4600
mammals
major coals
land plants
1 percent oxygen in the atmosphere
red beds
stromatolites
earliest life forms
banded iron stones
Earth's formation
2
65
145
215
250
285
360
410
440
505
590
4600
Cenozoic
Mesozoic
Paleozoic
PreCambrian
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian

scholar who based his calculations upon the genealogical records of the bible. What he achieved was a fairly accurate estimate of the age of the nation of Israel.

Another reason that we should not be too scornful is that, until quite recently, modern scholars were also making estimates that were in error by large factors. One of the early modern scientific estimates was that of William Thompson who became Lord Kelvin. In the 1860's Thompson began to speculate that he could determine the age of the earth by the extent to which it had cooled since its fiery formation. He imagined that the only possible source of the Earth's heat was the energy released by the impact of the rock bodies from which it had been formed.

Kelvin observed that, as one penetrates below the earth's surface, the rocks get hotter, and he was able to determine the temperature gradient. Assuming that the initial temperature of the earth had been uniform throughout its mass and that it had been at some 1,100 degrees centigrade, which is the temperature of molten lava, he was able to estimate that the age of the Earth was between 20 million years and 40 million years, and somewhat nearer to the former.

Kelvin had failed to take account, in his calculations, of an internal source of energy, which is the radioactivity of the earth's core. In 1902, the New Zealand born physicist Ernest Rutherford, working with the British chemist William Soddy, began to question Kelvin's calculations.

In 1904, Rutherford visited England and gave talks on the newly discovered radioactivity to the Royal Society and the Royal Institution. Some 800 people including Kelvin attended the meeting at the Royal Institution. Rutherford describes the meeting in these terms:

> I came into the room, which was half dark, and, presently, I spotted Lord Kelvin in the audience and realised that I was in for trouble at the last part of the speech dealing with the age of the Earth, where my views conflicted with his. To my relief Kelvin fell asleep, but as I came to the important point, I saw the old bird sit up, open an eye and cast a baleful glance at me! Then a sudden inspiration came, and I said that 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 considering tonight, radium. Behold, the old boy beamed at me.

The important thing here is not the estimate that Rutherford supplied. Instead, it is the role that radioactive processes have played in the dating of the Earth's minerals. As you know, radioactive elements undergo a gradual process of transmutation as they emit particles and rays. Their rate of decay is measurable. From the assumption that, at the time of their formation, the minerals contained the pure radioactive substance and from an assessment of the extent of its decay, we can accurately calculate the age of the minerals. It is from this source that we have derived our modern estimate of the age of the earth, which is accurate to within a few percentage points.

A Brief Look at the Stratigraphic Column

It is worth our while to look briefly at the stratigraphic column to pick on some of the salient dates and to consider some of the events. The fullest detail is in the final eighth of the column after the Precambrian period has ended. The word Cambrian refers to the county of Cumbria in England to which much of the attention of the geologists of the early 19th century was directed. Above a certain stratum of Cambrian rock, there can be found a profusion of fossils. Below that stratum, there is little if any direct geological evidence of complex life forms, or indeed of life itself.

Nevertheless, we know for certain that life emerged long before the period in question. In fact, the photosynthetic bacteria had already wrought a massive change in the composition of the earth's atmosphere by the time that it took to progress halfway up the column i.e. by circa 2.5 billion years before the present. The evidence is seen in the oxidisation of iron ores to form red beds. The red beds replaced the banded ironstones of earlier geological strata. However, as I have already indicated, there is modern evidence of bacterial remains from as long ago as 2.7 billion years before present.

We can imagine that we are watching the globe from afar during the entire process of its evolution from its fiery beginnings 4.6 billion years ago, when it coalesced from stellar debris, up to the present moment. In the first quarter of its lifetime, we see the swirling opaque atmosphere gradually changing to the lucid blue atmosphere that clothes the earth today.

During this period, we can see the effect of the processes of tectonic drift at work, which bring the landmasses into ever-changing configurations; and we can witness the successive advances and the retreats of the polar ice caps. Punctuating these gradual processes are episodic events such as the eruption of major volcanoes—which are themselves the effect of the tectonic processes—as well as the occasional impacts of large meteorites, which become rarer as time passes.

According to modern geological analysis, an extraordinary event occurred at the end of the Precambrian period. The earth froze over, and even the tropics were covered in ice. The reason for this event was a concentration of landmass in the Northern Hemisphere, which served as a platform of the ice and which prevented the global circulation of warming waters. Only when the burden of carbon-dioxide in the atmosphere had increased sufficiently through volcanic emissions did the globe warm enough for the ice to disperse.

After the great freeze was over, there was a proliferation of complex life forms. The sea abounded in life and soon, in the mid Palaeozoic period, land plants began to clothe the earth. Forests appeared, and, in the Carboniferous period, the great resources of fossil fuel were created, which have been exploited intensively over the past 250 years. It is at this stage that the earth began to resemble, at least to casual inspection, the globe that has been familiar to us since the mid-sixties from satellite pictures and from pictures taken during return journeys from the moon.

Crises and mass extinctions have punctuated the history of land-based life, which occurs in a period characterised by the present atmosphere. The wave of biological creativity that began in the Cambrian period peaked about 450 million years ago, at the end of the Ordovician period. Then, 250 million years ago, the great Permian extinction wiped out 75–95 percent of all extant species.

After the Permian extinction, there was another great wave of biological diversification. Then, at the end of the Cretaceous period, 65 million years ago, there was a mass extinction, which killed 60–75 percent of the species. This entailed the demise of the dinosaurs.

The boundary that separates the Cretaceous strata from subsequent Tertiary Cenozoic strata contains a uniform layer or iridium. Such iridium is usually found only in meteorites; and the consensus of modern opinion is that a massive meteorite impact was the prime cause of the extinction.

Huge dust clouds would have been raised which darkened the sun and lowered global temperatures. The photosynthesis of plants, impaired by the lack of sunlight, would have slowed or ceased, cutting off food supplies; and the vegetation might have been poisoned as well by the debris in the atmosphere. Eventually, in consequence of the death of plankton and plants, the level of carbon dioxide in the atmosphere would have increased, causing temperatures to rise. When the atmosphere had cleared, the sun shone upon wastelands almost devoid of biological activity. The scene was set for the emergence of mammals as the dominant land-based creatures.

The Emergence of Mankind

If we watch the processes of earthly evolution for the remaining 65 million years, we will witness the spread and the diversification of the mammals and the emergence of a world which is recognisably our own. If we listen quietly, then, at 5 million years before the present, we can hear the sound of a muffled crack as the continent of Africa is rent from top to toe by the rift valley. At the same time, by casting our eyes to the east we will be able to see the uprising of the Himalayan plateau as the hard core of the Indian subcontinent pushes into the soft underbelly of Asia.

The radical climatic changes that these events brought forth were the cue for the emergence, on the east side of the rift valley, of the hominid apes who were our progenitors. They pursued a precarious existence on the open savanna to the east of the rift in separation from their cousins, the chimpanzees, who remained within the forest canopy of the verdant upland to the west.

These small hominid apes gained their living opportunistically by scavenging the remains of animals slain by the larger African predators including the lions and leopards, for which they were also prey. They sustained themselves, as well, on nuts, roots and tubers by grubbing in the undergrowth. The story of how they were transformed into the dominant predator is a long and complex one. Eventually, a remarkable transformation was wrought which was accompanied by the hypertrophic development of one organ of the body, which was the brain.

As recently as 1.5 million years ago man ventured forth for the first time from the African continent in the form of Homo Erectus. This human ancestor, who knew the use of fire, spread all the way across Southeast Asia. Indeed, the first discovery of the so-called Pithecanthropus, which was the early terminology for Homo Erectus, was by a Belgium citizen named Eugene Dubois working in Java for the Dutch East India Company.

Our own species, Homo Sapiens Sapiens, is thought to have emerged out of Africa between 100 and 150 thousand years ago. Sometime during the last ice age, which began 77,000 years ago and ended 12, 000 year ago, Homo Sapiens crossed the Bering Straight and penetrated North America. With that event, the spread of the human population became truly global. When the ice finally retreated at around 12,000 BC the population of mankind may have been in the region of 4 million.

The Human Explosion

Since the dawn of the agriculture revolution 8,000 years ago, there has been an extraordinary increase in the numbers of human beings. For much of this time, the human population has bumped along on an upward path, which has been beset by the pitfalls of famine and plague and accompanied by warfare and occasional mass migrations. It has been estimated that, by 1750, at the dawn of Britain's industrial revolution, there were 720 million people in the world, and the numbers were increasing rapidly.

The current population stands at something like 6 billion, which is more than an eightfold increase in the numbers since 1750. However, the growth has been virtually exponential, with the result that more than half the increase has come in the last 50 years.

If we resume our vantage point from afar to watch the evolution of the globe, we will find that the effects of the modern changes are highly visible. At the start of the modern period, we see nothing more that a slight clouding-over above the landmasses of the northern hemisphere, which is the consequence of the coal burning that is providing increasing amounts of energy to power the processes of industrialisation. (The particles of sulphur that are emitted form nuclei around which the water vapour in the atmosphere can readily condense as the droplets that form the clouds.)

Had we been observing southern Britain over the previous 200 years, we would, perhaps, have noticed the precursor of the industrial revolution in the stripping of the tree cover from the Sussex Weald and in the wisps of smoke rising from the many iron smelting furnaces buried in the thinning forests.

In the 250 years following 1750, the clouds thicken in the Northern Hemisphere. The tree cover gradually thins and the forests recede at an increasing rate. The patchwork of green and brown, which is evident at certain times of the year and which denotes agricultural activity, spreads. The acute observer will notice that the appearance of the patchwork is changing as fewer fields are left to fallow. Cities and conurbations spread across the land like virulent bacterial growths. There are unfilled interstices, which persist for a while, but, eventually, they are quickly covered over when seemingly separate urban growths coalesce.

Our attention is arrested by something that alters the night sky in early part of the 20th century. Suddenly, pinpoints of light erupt all over the globe. Where there was once a dull glow, we see clusters of lights, which we identify with the great urban conglomerations. By the middle of the century, we can see lights in motion passing from one light cluster to another in orderly processions. What we are seeing are the traces of the airline travel that is carrying increasing numbers of people hither and thither at the cost of a great expenditure of fossil fuel energy.

It is at this point that we should look at what is happening elsewhere on the globe. The atmospheric level of carbon dioxide rises to its highest level from 220,000 years. Great plumes of nitrous oxide and toxins rise from forest fires in South America and Africa and settle in the upper troposphere. In South America, the central rain forests begin to sicken and peel back to reveal patches of brown and yellow earth. In Africa, the margin of the Sahara desert is seen to be slowly advancing and encroaching further upon the once fertile land. The haze of dust that hangs over some parts seems to thicken and to hang in the air for longer periods. We see Southeast Asia and then Australia erupting in fire and smoke in successive summers. Holes are opening in the ozone layers aboved the poles. The Antarctic hole being much the larger.

The water of the Indian ocean becomes murky from the quantities of silt that are being carried down to the sea by the great Asian rivers, the Indus, the Ganges the Irriwaddy and the Mekong. We look up river and we see that the cause is the loosening of the soil brought about by the destruction of the trees that once covered the upstream areas thickly. We aslo notice that the seasonal flooding in the river deltas, particularly in the delta of the Ganges, has worsened and become longer lasting.

The appearance of the coastlines of Southeast Asia is strangely altered, and we perceive that the reason is the clustering of increasing numbers of people on these narrow margins. We have been concerned for the health of the coastal fish stocks on account of the increased burden of silt and sediment and effluent carried by the rivers. Now we begin to fear that the activities of the coastal fishermen might finally destroy the sickening marine ecology.

Where are these Changes Leading?

Having witnessed some of the widespread environmental changes of recent years, we ask ourselves what their eventual consequences are likely to be. One thing is quite certain. The rate of growth of the human population cannot be sustained for much longer. Never before in the history of the globe has one species accounted for such a large proportion of the total biomass. Surely, the limits have been reached.

Nor has any other animal preempted, directly or indirectly, such a large proportion of the earth's renewable resources or made such inroads into its non-renewable resources. It has been estimated, for example, that man appropriates between 20 and 40 percent of the sun's energy that would otherwise be fixed into the tissues of natural vegetation. In our relentless search for more food, we have reduced the animal life in lakes and rivers and now we are exhausting the stocks of wildlife in the oceans and threatening some of them with extinction.

Animal populations do occasionally increase in numbers rapidly and break out of their natural habitats. This is described by ecologists as the phenomenon of swarming. It is a usually symptomatic of a fundamental ecological imbalance and it is almost invariably followed by massive mortality in the swarming population. (Think of a plague of locusts.) The question that we need to ask ourselves with some urgency is whether these same ecological principles apply to the human population.

Perhaps the human species is so exceptional that the basic principles of animal ecology do not apply to it. Many times, in the face of threatened crises, humans have devised technological innovations that have carried them to higher levels of welfare and prosperity and of control over their environment. Why should we doubt that the present environmental crises should lead likewise to a favourable outcome? Such a lack of concern is an optimistic attitude.

My own prognosis, which I shall be expounding during this course, is less optimistic. We are faced with unprecedented problems of planetary overload. The destructive impact of the human species is all too evident. Hitherto, our environmental depredations have been on a scale small enough to be overcome by the resilience of the natural ecosystems. Now it looks as if thresholds are being been passed and that such resilience can no longer be relied upon. I fear that we have overstepped the limits and that we are facing disaster.

We shall be facing up to some of these real or imagined threats during the course; and we shall be asking what scope there is for favourable outcomes. Each of you will reach you own judgment on the basis of the evidence that we shall uncover.