LECTURE 1

Origins and Prospects

Life on the Planet

From a remote vantage point, our local star would be seen as a small speck of light two-thirds of the distance from the centre of the galaxy which we know as the milky way. It is situated in the Orion spur which stretches between two of the spiral arms of the galaxy. The width of the galaxy is estimated at 100,000 light years, which is so vast a distance that it would take a jumbo jet 100 billion years to make the crossing; yet the galaxy is one of many in a galactic cluster which resembles similar clusters which are scattered sparsely throughout the universe.

Eventually, the thermonuclear processes of our star the sun will abate with the consequence that life on this planet will cease. However, the event is so far in the future that, in terms of human prospects, it is barely worth contemplating. In a much shorter time, our species may have vanished, as have the majority of vertebrate species which have lived on this planet to date. Nevertheless, the time scale which encompasses the birth of our planet and the extinction of the sun can seem momentary in the context of the evolution of the galaxies.

Within the local time scale of the history of life on this planet, there have been some cataclysmic changes. In contemplating these events, we are bound to feel that humanity is impermanent and that its present circumstances are liable to be temporary. The characteristic feature of our own times is an unprecedented rate of change in human ecology and in the environment in which we live and die. An insistent theme of this course is that it is impossible for the human population and its consumption of physical resourses to continue to grow at their present rates for more than a human lifetime or two.

Before we embark on an account of these circumstances, we should tell of the major changes which life on this planet has experienced. A debate still rages over the origins of life. Thirty year ago, a simple opinion was widely accepted. It had been show in the chemistry laboratory that, by subjecting a mixture of water, methane and carbon dioxide to a bombardment of electrical discharges and of ultraviolet light, a rich brew of amino acids could be produced. These acids resemble the very building blocks of life which are present in the genetic codes of all animals. It seemed that, if the early oceans were of such a consistency, then self-reproducing organisms that lived off this broth were bound to evolve in due time.

Since the sixties, the debate over the origins of life has raged. There have been numerous conflicting hypotheses, some of which place the inception of life in quite a different environment. Perhaps, for the layman, the most interesting question concerns whether there was any inevitability in the emergence and the survival of life forms; but, on this issue, informed opinion is divided.

Whether we regard life as fragile and permanently threatened or as resilient and capable of survival in the most adverse of circumstances seems to be more a consequence of our individual emotional dispositions than of our scientific knowledge. It is important to recognise the role of our emotions in this discourse and in the debate concerning our own prospects for survival. Some people have a profound and unshakable belief in the ability of humanity to survive the impending environmental crises. Others insist that the prognosis is dismal. There is little point in trying to influence such deep-seated attitudes which must be allowed to coexist. Moreover, once we begin to study the scientific questions in detail, a consensus of knowledge and analysis emerges which makes attitudes which are based on emotions seem less worthy of debate.

Regardless of their precise nature, it seems certain that, to the extent that they were capable of propagating themselves, the early forms of life must have posed a threat to their own survival. At the inception, the resources which these life forms had learned to harness were virtually limitless. After several hundreds of millions of years, the resources would have begun to deplete. At this point, organisms of a more self-sustaining nature must have gained an advantage. The organisms in question were the blue-green algae or cyanobacteria which use photosynthesis to convert the energy of sunlight into the chemical energy which sustains them.

At length, these algae wrought a fundamental change in the earth's atmosphere. We imagine that the original atmosphere was composed primarily of carbon-dioxide with a small percentage of nitrogen and traces of other gasses, but with no free oxygen at all. The effect of the algae was to convert this to an atmosphere which was abundant in oxygen. Today's atmosphere, which is their legacy, contains 77 percent nitrogen, 21 percent oxygen and 1 percent water vapour and only 0.03 percent of carbon dioxide.

Eventually the very success of the algae precipitated an environmental crisis. The oxygen which they released combined with the materials in the earth's surface which were readily oxidisable. Iron is one of these materials. However, the concentration of the free oxygen in the atmosphere increased steadily and, at the same time, the ozone layer, which shields land-based life against damaging ultra-violet light, was formed.

At length, the atmosphere, which had been depleted of the greenhouse gasses of methane and carbon-dioxide, would have cooled. At the same time, the excess of oxygen must have killed many of the original methanogenic bacteria which give off the greenhouse gasses of methane and carbon dioxide. Of course, the latter are still with us. They survive in wetlands and swamps and in the guts of animals. What came to the rescue and what eventually restored the temperature and the atmosphere to an equable condition were the plants and animals which breathe oxygen and give off carbon-dioxide.

The history of land-based life, which occurs in a period characterised by the present atmosphere, has been punctuated by crises and mass extinctions. The first explosion of life that left a fossil record occurred in the Cambrian period between 600 million and 500 million years ago. The wave of biological creativity 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 extinctions, there was another great wave of biological diversification. Then, at the end of the Cretaceous period, 65 million years ago, there was a mass of extinctions which killed 60–75 percent of the species. This entailed the demise of the dinosaurs.

The causes of the Cretaceous extinction are still debated, but one of the clues which is widely acknowledged consists of a thin and uncommonly uniform layer or iridium which separates the Cretaceous strata from subsequent Tertiary Cenozoic strata. Such iridium is usually found only in meteorites; and the consensus of modern opinion is that a massive meteorite impact was the prime cause. 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 deviod of biological activity.

Human Origins

In terms of the geological time-scales which we have been considering so far, the origin of man is very recent. The first hominids appeared in Africa around 5 million years ago. These were the Australopithecenes or southern apes which were distinguished from other primates not so much by the size of their brains as by their upright stance and their omnivorous diet.

A modern gorilla has a cranial capacity of 500 cc whilst the southern ape had one of perhaps 600 cc. After 2 million years, the cranial capacity of our ancestors had increased to the 900 cc of the *Pithecanthropus* or *Homo erectus*. The current average for *Homo sapiens*, which appears to have been constant for the past 100,000 years is 1,450 cc. Surprisingly, this is slightly less than the cranial capacity of the much-maligned *Neanderthal* man.

The upright stance of early man is, by universal consent, the characteristic which stimulated his physical and intellectual development. For it freed his hands from the role of bearing his weight and made them available for any task to which his intelligence might direct them. Gorillas and chimpanzees, who support part of their weight on their knuckles as they move about, have not had this advantage.

It is worth remarking that a bipedal stance on its own does not lead to the use of the upper limbs for purposes of manipulation. Unless there is a brain that can exploit their potential, these limbs are liable to atrophy as, invariably, they did amongst the bipedal dinosaurs. Amongst mammals, the kangaroo, which has a small brain, is a testimony to this phenomenon. However, in the case of the primates, the increasing use of the upper limbs was virtually assured, as it has been since their prosimian ancestors took to the trees.

The second feature which is supposed to have set the hominids apart from the other primates was their diet. Unlike the chimpanzee and the gorilla who are vegetarians, the hominids were omnivorous scavengers. This freed them from the constraints of a specialised habitat and allowed them to spread far and wide. The population density of the hominids however, must have been rather less than those of the gorilla and the chimpanzee in their natural habitats. The density of the gorillas in the rain forests of Rwanda is estimated at about 1 per square kilometre. That of the chimpanzee is probably 3 per sq. km. It is estimated that the hominids had a density of only 1 in 10 square kilometres.

The reason for the relative sparseness of the omnivorous hominids has to do with their position in the food chain which stretches from plants to carnivores. Animals derive their sustenance ultimately from the chemical energy which is provided by the photosynthesis of plants. Those animals which consume plants have direct access to this energy and can become numerous. Those which prey on other animals must rely upon that small portion of the energy which is stored in the flesh of their victims. It follows that carnivores, who are positioned at the end of the food chain, require a vastly greater area of land for their sustenance that do herbivores. A familiar instance of this fact is provided by the relative numbers of lions and wildebeest in the African Savanna.

In supposing that the hominids had a population density of 1 per 10 sq. km. of habitable terrain, we are attributing to them the same density as the human hunter gatherers of today. This may be overestimating their density, since we must assume that they were less adept than humans in satisfying their needs.

The fossil record suggests that the *Autralopithecenes* were confined to Africa. The remains of their successor *Homo erectus* have been found from Europe to Indonesia. If we assume a density of 1 per 10 sq. km., then we get a population estimate for *Homo erectus* for 1.7 million.

It was only when *Homo erectus* was superseded by *Homo sapiens*, or modern man, that men came to occupy the entire globe. At some stage during last ice age, which began at about 75,000 BC, man crossed the Bering straights and penetrated North America. The date may have been as early as 25,000 BC or as late as 10,000 BC; but, when the crossing had been made, it would have taken only a few centuries for man to spread into south America. The crossing of the Bering straights presupposes that man had acquired the habit of protecting himself from environmental extremes; and with this accomplishment there were few limits to his range. When the ice finally retreated at around 12,000 BC, the population of mankind may have been in the region of 4 million.

The Agricultural Revolution

An increase in the global population of humanity beyond the 4 or 5 million which it had reached twelve thousand years ago could only be achieved by increasing its density in the areas of settlement. The limits to the numbers which could be sustained by hunting and gathering had been reached. At this stage a fundamental change of human ecology occurred which is know as the neolithic revolution or the agricultural revolution.

The means by which this revolution was achieved are nowadays subject to intense debate. It is no longer believed, as it was in the past, that the revolution began uniquely in the valleys of Mesopotamia and spread from there. Nowadays it is commonly supposed that agriculture began in several centres at much the same time. As well as in the near east, it began in the Andes, Central America, China and South-East Asia. Moreover, a wide variety of crops were subject to the processes of domestication as were several species of birds, ruminants and ungulates. Nevertheless, it is the emergence of agriculture in the valleys of the Tigris and the Euphrates in the area covered today by Iraq and Syria which remains the best-documented and most widely studied instance.

One does not have to postulate an act of invention to account for the emergence of agriculture. One can imagine instead that people began to congregate in areas where wild cereals were abundant with only the intention of harvesting them. The gathered grain would be transported to the settlements, to be consumed and stored. Seeds which had spilled would germinate; and, in doing so they, would provide a limited but accessible supply of the cereals which was close at hand. Gradually the unintentional spillage of grains which had resulted in a small boon would have given way to a systematic scattering and then to a regular routine of sowing. Often the sown cereals would have proved easier to harvest than their wild counterparts, if only because of their greater concentration; and, eventually, their yield would have been enhanced significantly by the processes of selection which, for the most part, have been an automatic and largely unconscious concomitant of agriculture.

Over a long span of time, there has been a gradually increasing consciousness of the factors which favour agricultural productivity which has culminated in the modern sciences of agronomy and genetics. As the skills of farmers have developed, the land has been called upon to sustain ever-increasing numbers of people. At times, these numbers have outstripped the capacity of the land, and they have been held in check by famine and by the diseases to which malnourished people are prone. With far less frequency, there have been "pudding days" or times of plenty such as the brief period of agricultural affluence in Britain on the eve of the Industrial Revolution. Almost invariably a brief hiatus of this sort has been followed by a surge of population growth.

Thus there is a remarkable way in which improvements in agricultural techniques have gone hand in hand with rising populations densities. A detailed account of this concomitance was provided thirty years ago by the Danish economist Ester Boserup in a monograph which is widely quoted and which has been subject to conflicting interpretations. According to Boserup, technical, economic and social changes are unlikely to take place within primitive agriculture unless the rural community concerned is exposed to the pressure of population growth. Thus it is argued that population growth is the main force by which agrarian change is brought about.

According to one reading of this thesis, technical innovations will always occur in time to avert the crises which are threatened by population growth. This notion, which is refuted by many historical instances, is too optimistic. Indeed, the proposition that increases in population density are necessary conditions for technological change does not imply that they constitute sufficient conditions as well.

The main effect of agricultural innovations, prior to the age of mechanisation, has been to increase the intensity of human labour with an accompanying worsening in the quality of life. It may be confidently asserted, for example, that the quality of life of the peasant farmer or the landless labourer in Bangladesh compares most unfavourably with that of the aboriginal Malayans who are some of the few remaining primitive hunters and gathers. In the same vein, we might reasonably imagine that the lives of the neolithic farmers of Mesopotamia compared favourably with those of the medieval European peasants on the eve of the bubonic plague, known as the black death, which struck its first blow in 1347. We are certainly inclinded to hold this view if we identify the once-fertile valleys of Mesopotamina with the garden of Eden, which is described in the biblical book of Genesis.

The question which is uppermost in the minds of many economists and scientists is whether or not the technologial innovations which are now at our disposal will enable mankind to steal a march upon the relentless pressures of population growth and move beyond the reach of the plagues and crises which have culled our numbers in the past. The pessimists would have us believe that the modern developments in agriculture, industry, medecine and transport which seeemed, only a generation ago, to promise access to limitless resources, are now posing a threat to our very survival by unleashing an unsustainable growth in our numbers and by facilitating the irreversible spoliation of our environment.