CLIVE PONTING

A GREEN HISTORY OF THE WORLD

The Environment and the Collapse of Great Civilizations
These movements are manifested in the natural disasters that have punctuated human history—volcanic eruptions such as Thera, which may have overwhelmed Minoan society on Crete, the eruption of Vesuvius that destroyed Herculaneum and Pompeii or major earthquakes such as that in Shensi province in China in 1556 that killed over 800,000 people or those affecting Lisbon in 1755 and Tokyo in 1923 that killed tens of thousands. The impact in the long term is even greater. About 400 million years ago the earth had two supercontinents Laurasia (north America, Europe and Asia) and Gondwanaland (south America, Africa, India, Australia and Antarctica) divided by the Tethys Sea. When this massive land mass broke up, the southern continents were situated over the south pole, causing glaciers in what is now Brazil and South Africa, and Laurasia was in the tropics. What is now North America broke away from Europe about 200 million years ago although the major drift apart to form the Atlantic ocean has only occurred in the last 80 million years, Gondwanaland began to break up into separate continents about 160 million years ago but the formation of most of the Indian Ocean and the break between Australia and Antarctica occurred in the last 60 million years. Africa and South America split apart 180 million years ago.

The drift of the continents across the globe has had a profound impact on human history. It has determined the distribution of resources and it accounts for the differing flora and fauna of the continents. Material welling up from the earth’s core formed part of the continental land masses and determined the location and concentration of the world’s mineral resources. The position of the continents at an earlier stage of their history explains the distribution of fossil fuel reserves in the modern world. Coal, oil and natural gas come from the decomposition of the vast tropical forests present about 250–300 million years ago. Continental drift has also been a major influence in determining the current distribution of plants and animals. Some have evolved in isolation and others been driven to extinction by competitors suddenly brought into contact with other parts of the world. For example, marsupial mammals had a worldwide distribution about 80 million years ago. As the continents drifted apart marsupials were replaced in Eurasia by placental mammals. They survived in South America until it joined North America about 30 million years ago and they live on in Australia, which has remained isolated. The evolution of animals in different parts of the world has also had major effects on human history. The isolation of the Americas from the Eurasian landmass meant that animals domesticated in Europe and Asia such as
sheep, goats, cattle and horses were not present. This influenced both
their agriculture and their transport — domesticated animals were
relatively unimportant and, although societies in the Americas were
aware of the principle of the wheel, they could not utilise it because no
draught animals were available.

Climate has been a fundamental force in shaping human history. Year
to-year variations in the weather influence crop yields but more
significantly major, long-term trends have affected the ability of
humans to settle parts of the globe, influenced the way plants and
animals are distributed and placed limits on the crops that can be
grown. The distribution of the continents has also been one of the
factors determining climate. The ice ages, which have dominated the
world’s climate for the last two-and-a-half million years, depend for
their effect on the current distribution of the land masses of the
northern hemisphere. Large scale ice sheets could not develop, and
move further south when the climate deteriorated, without the con-
tinents clustering towards the north pole and the formation of a land-
locked Arctic Ocean about three million years ago.

The position of the continents is only one factor influencing the
world’s climate. Apart from the steadily increasing energy output of the
sun and the levels of gases such as carbon dioxide and methane in the
atmosphere, the major factor determining climate is a series of astro-
nomical cycles affecting the earth and its orbit round the sun. In the
1920s a Yugoslavian scientist, Milankovitch, put forward this theory but
he was largely ignored. Only in the last thirty years, with the scientific
analysis of cores taken from ocean sediments and ice sheets giving
information on climate stretching back over hundreds of thousands of
years, have his theories been accepted. Over a period of 90–100,000
years the earth’s orbit varies from being nearly circular to more
elliptical. At present the orbit is becoming more circular and reducing
the difference between the times when the heat from the sun falling on
the earth is at its maximum and minimum. The second cycle, the
timing of the earth’s closest approach to the sun, is completed every
21,000 years. At the moment the earth is nearest to the sun during the
northern hemisphere winter. This reduces the impact of seasonal climatic
change in the north whilst increasing it in the southern hemisphere.
The third cycle affects the ‘tilt’ of the earth, which varies
over a period of about 40,000 years. At the moment the tilt is decreas-
ing, which again reduces the difference between the seasons. Although
there are other short-term cycles, such as minor variations in the sun’s
output over a 22–23 year period (linked to sunspot activity and
reversals of the solar magnetic field), it is the combination of the three
long-term cycles that largely determines the earth’s changing climate.

The long term cycles alter the distribution of the sun’s energy falling
on the earth. The current closeness of the continents in the northern
hemisphere to the pole is of crucial importance because only a 2 per cent
drop in heat from the sun during the northern summer can initiate
glaciation. Cool summers allow winter snow and ice to survive to the
next winter and the growing snow cover causes further cooling by
increasing the reflectivity of the earth’s surface. This further reduces
the temperature in the northern hemisphere leading to a rapid increase
in the extent of ice sheets and glaciers. The same process cannot work in
the southern hemisphere when changes in the earth’s orbit produce cool
summers there. Apart from Antarctica there is insufficient land near to
the pole and too much water (which moderates the temperatures) to
allow continental ice sheets to form. For the last two-and-a-half million
years a cycle of ice ages has affected the earth’s climate; the interglacial
periods have normally been short, a total of about 250,000 years out of
the last two million. The warmest interglacial was the one about
120,000 years ago (with temperatures about 2°C warmer than today).

The various forms of life on earth, including humans, do not exist
independently, they are part of ecosystems — a term which is used to
refer to a community of organisms and their environment. There are
many different types of ecosystem such as a tropical forest, a grassland
prairie or a coral reef but the foundation of all of them, and therefore
the basis for all life on earth, is photosynthesis — the process by which the
energy of sunlight is used by plants and certain types of bacteria to
create the chemical compounds essential for life. It is the only way that
energy is introduced into the system. Very little of the sun's energy is, in fact, converted into matter (often as low as 0.2 per cent) and there is no way in which this efficiency can be improved since it depends on the amount of light falling on the earth, the laws of physics and the amount of carbon dioxide in the atmosphere. (Selective breeding of plants does not increase the efficiency of photosynthesis, it simply makes plants put more of their effort into producing those parts that humans find useful at the cost of other parts).

Within an individual ecosystem photosynthesisers (such as plants, trees and grasses) provide the basic energy input. They are at the bottom of a food chain which links together all the different organisms. When, photosynthesisers die they are broken down in the soil by decomposers such as funguses and their essential elements become available for other plants to use. (The pattern is similar in a marine environment.) Photosynthesisers are also eaten by animals (herbivores) which are able to extract essential nourishment from the plant. Herbivores are in turn eaten by other animals (carnivores) which are capable of extracting their food from animals. Some animals, known as top carnivores, can eat both herbivores and other carnivores. When all these animals die their carcasses rot and the essential elements are recycled. Most ecosystems have complex food chains with numerous interrelationships between the various parts. However behind this complexity there is an iron rule. The higher an animal is in the food chain, the rarer it will be. Each step up the food chain is further removed from the primary production of the photosynthesisers and therefore less energy efficient — consequently the numbers that can be supported get smaller. A cow for example is only able to store 0.6 per cent of the primary production of the grass in a field. This is why only a very small number of carnivores can exist within an ecosystem compared with the number of primary producers. In the case of a deciduous wood in southern England, 88 per cent of the primary production by photosynthesisers (in this case trees, plants and grasses) eventually falls to the ground and decomposes on the woodland floor and another 8 per cent is stored as dead wood, which eventually decomposes. Only about 3 per cent is available for herbivores to eat and even less for the carnivores who have to live off the herbivores.

Ecosystems are not static. Over time they develop through an orderly and predictable series of changes resulting from the modification of the environment by the plants and animals themselves to culminate in a climax system which has the maximum possible number of plants and animals for the available energy input. It takes thousands of years to move from bare rock through lichens and mosses to ferns, plants and eventually trees to create a climax forest that can survive for very long periods — provided there is no human interference. The original pioneer species that colonise the rock are adapted to coping with poor soils or with none at all. Slowly, as decayed matter is accumulated, a better soil is created, capable of sustaining annual plants and successively perennials, grasses, shrubs and trees. As the ecosystem develops and changes, so do the plants and animals that can be supported. This
development of an ecosystem has occurred countless times during the
earth's history — for example the retreat of an ice sheet after a glacial
period exposes bare rock, which within a few thousand years is con-
verted into a climax temperate forest. Where a climax ecosystem is
destroyed (as is often the case through human intervention to clear
forests) then the subsequent process of change is speeded up because
good soil already exists. For example arable land (the result of forest
clearance at an earlier stage in its history) left uncultivated in England
will, through a succession of arable weeds, grasses, and shrubs such as
hawthorn and mixed scrub, revert to an oak and ash forest within 150
years.

The different types of ecosystem depend to a large extent on the
temperature and level of rainfall. They are therefore found in broad
bands between the poles and the equator. Changes in the earth’s climate
cause these bands to change location, often by hundreds of miles over a
period of several thousand years, as well as producing major local
variations. At present, near the poles, low rainfall, low temperatures
and permafrost produce tundra (poorly drained, acidic soils covered in
low scrub). Further away from the pole in the northern hemisphere
(though not in the southern because there is no land in the right place)
are the great coniferous forests known as the taiga. Further away still
from the poles are the temperate forests with their rich secondary flora,
better soils, high leaf drop and a correspondingly large quantity of
decomposers. Then there are the grasslands, which have less rain than
the temperate forests and where the soils are poorer. In two bands sited
about 30°N and 30°S of the equator are large areas of desert — a product
of the global weather system which concentrates large masses of very
dry air in these latitudes. Finally in the tropics, around the equator,
with both high rainfall and temperatures, are the vast, tropical rain-
forests. There are of course many local variations within this overall
picture such as the tropical savannas of grassland with scattered thorny
trees and the temperate rain forests of north-west America and southern
New Zealand.

The productivity of the different ecosystems varies greatly. In the
tundra the level of primary production is low because of the cold and
lack of sunshine. This means fewer species can be supported and then
not in large numbers. The food chain is therefore short and relatively
simple. The open oceans are virtual deserts whereas coral reefs and
estuaries teem with life, reaching levels equivalent to the most pro-
ductive of all terrestrial systems — the tropical forests. These forests,
which cover about 6 per cent of the world’s land surface, produce about
40 per cent of all terrestrial primary plant production and contain about
half of all the plants and animals on earth. Rainforests are remarkable
not just for the quantity of life found there but also for the diversity. A
typical four square mile patch of forest will contain the following
species (not individuals) — 1,500 flowering plants, 750 trees, 125
mammals, 400 birds, 100 reptiles, 60 amphibians, 150 butterflies and
probably over 50,000 insects. (In total in the tropical forests there are
probably 20 million species of insect). Tropical forests are, however,
very different in their structure from temperate forests, which have rich
soils. Three-quarters of all the nutrients are held in the plants and trees
and only 8 per cent in the soil. Very little rain water runs off into the soil
— over half is evaporated and most of the rest absorbed directly by the
plants and trees. The soil itself is thin, acidic and of poor quality with
very little humus. If the ecosystem is destroyed through forest clear-
ance most of the nutrients are destroyed too; there is little available in
the soil to support crops or grass and the exposed ground can quickly
turn into a hard, baked clay.

Soil is the product of an ecosystem — it has been created by living
plants and animals and it continues to rely on them to remain fertile and
productive. Before the earliest forms of life emerged from the sea there
was no soil; all the land on the earth was bare, eroded rock and deserts.
Soils build up over thousands of years through physical, chemical and
biological processes as rock is weathered into minute fragments and
incorporated together with the remains of dead plants and animals to
form a medium that supports bigger plants and trees as the ecosystem
develops to a climax. Fertility is built up and maintained as an active
process through the interaction of the plant cover, the existing soil, the
work of decomposers and other environmental factors such as rainfall
and temperature. All of these processes make the various types of soil
found in different parts of the globe one of the most complex living
systems on earth. Just one acre of good soil from a temperate region will
contain about 125 million small invertebrates, and thirty grams of that
soil will contain 1 million bacteria of just one type, 100,000 yeast cells
and 30,000 fungus mycelium. Although soils are created over time this
process is, on a human timescale, so slow that the soil is in effect a non-
renewable resource. It is also a highly fragile one. Ecosystems develop
naturally in a way that protects the soil on which they depend. On the
dry grasslands it is the roots of the grass that hold together a poor soil
and in the temperate forests it is the whole process of extensive leaf drop
in the autumn, combined with a large number of decomposers living off
the dead material, which maintains a highly fertile soil. In tropical
forests, where the soils are generally poor in nutrients and potentially vulnerable to the high rainfall and temperatures, the ecosystem has developed in such a way as to protect the soil. Once the trees and plants of an ecosystem are destroyed or badly damaged then the underlying soil is very quickly subjected to severe strain and can be easily destroyed or eroded away by wind and rain leaving only a degraded remnant.

To fully understand the individual parts of an ecosystem, it is necessary to see them as part of a bigger whole. All the parts of an ecosystem are interconnected through a complex set of self-regulating cycles, feedback loops and linkages between different parts of the food chain. For example, the fertility, stability and texture of a soil depend on an interaction with the other parts of the ecosystem which have produced it. If one part of an ecosystem is removed or disrupted there will be knock-on effects elsewhere in the system. The extent of the reverberations will of course vary depending on the nature, scale and duration of the initial disruption; on the relative significance of the part or parts affected; and on the resilience of the ecosystem. For example, if one species of animal is wiped out (by disease or by being hunted to extinction) then there will be ramifications up and down the food chain. The population of those plants and animals that formed its diet will increase, while those that previously hunted it for food will decrease, and these changes will then bring further secondary disruption at other levels in the food chain. A form of disruption which destroys the primary producers (as with a forest fire or deliberate clearance) will constitute an attack on the base of the food chain and it will have disastrous effects on all parts of the chain.

Just as the plants and animals in an ecosystem are part of a greater whole so ecosystems themselves are part of a greater whole – the earth itself. For all practical purposes the earth is a closed system. Although sunlight gets in to provide the necessary energy for life all the other resources are finite. The fact that the earth is a closed system also means that nothing can get out. All waste products must go somewhere. This fact, combined with the limited resources available to all living things, means that the recycling of the materials necessary for life is an essential function of all ecosystems and the other physical and chemical processes on earth. Problems can arise though when artificial wastes are ‘disposed of’ in ecosystems, for example by dumping at sea or discharging into the air. Many of these products cannot be recycled at all by natural systems or not in the concentrations in which they are found as a result of human activity and they remain as pollutants somewhere in the system. All pollution is, therefore, bound to affect natural processes and ecosystems, whether on land, in the oceans or in the atmosphere.

Humans too are part of the earth’s ecosystems; whether or not they are always conscious of this fact and its implications. All plants and animals tend to modify the environment as they compete and cooperate with others to survive and flourish. In their relationship to the ecosystem, two factors distinguish humans from all other animals. First, they are the only species capable of endangering and even destroying the ecosystems on which they depend for their existence. Second, humans are the only species to have spread into every terrestrial ecosystem and then, through the use of technology, to have dominated them. (They have even been able to develop ways of heavily exploiting marine ecosystems too.)

The most important task in all human history has been to find a way of extracting from the different ecosystems in which people have lived enough resources for maintaining life – food, clothing, shelter, energy and other material goods. Inevitably this has meant intervening in natural ecosystems. The problem for human societies has been to balance their various demands against the ability of the ecosystems to withstand the resulting pressures.
NINETY-NINE PER CENT OF HUMAN HISTORY

For all but the last few thousand years of their two million years existence humans have obtained their subsistence by a combination of gathering foodstuffs and hunting animals. In nearly every case people lived in small, mobile groups. It was without doubt the most successful and flexible way of life adopted by humans and the one that caused the least damage to natural ecosystems. It enabled them to spread across the face of the globe into every terrestrial ecosystem and to survive not just in favourable areas with easily obtained food but also in the rigorous conditions of the Arctic, the tundra of ice-age Europe and the marginal dry lands of Australia and southern Africa.

The origins and earliest development of humans and their immediate ancestors have to be deduced from scanty evidence, usually the fossilised remains of partial skeletons, sometimes as little as a jaw bone or a tooth, and therefore interpretation is difficult. Not surprisingly, the topic arouses great controversy between experts and numerous conflicting schemes have been put forward to explain the nature of particular fossils and their relationship to each other. The fact that the remains have, so far, only been found in a few areas of the world, mainly east and south Africa, has naturally heavily influenced explanations of the likely geographical origins of human ancestors and their development.

Fossils found from about 2-1.5 million years ago and called Homo erectus are recognised as being the direct ancestors of modern humans. But much earlier fossil remains reveal evidence of certain 'human traits', notably upright posture (as early as 3.5 million years ago) and toolmaking linked to the first stone tools about 2 million years ago. The distinguishing characteristic of Homo erectus is a large brain size of about 1,100cc (about three-quarters of modern human capacity). They probably emerged in Africa, although if a skeleton from Java is correctly dated at about 1.9 million years ago this theory might need to be revised and it is certainly the case that far less archaeological work on human origins has been done in south-east Asia than east Africa. The available archaeological evidence suggests that they survived until about 100,000 years ago when the first anatomically modern skeletons, named in a piece of immense self-flattery Homo sapiens, are found in east and southern Africa. By about 30,000 years ago fully modern human types (Homo sapiens sapiens) were widespread throughout the world.

The earliest humans appear to have inhabited a variety of habitats within a belt of tropical and semi-tropical country stretching from Ethiopia to southern Africa. The population was small, thinly spread, living in groups which probably depended mainly on the gathering of nuts, seeds and plants, which they would have supplemented by scavenging dead animals killed by other predators and perhaps the hunting of a few small mammals. It was this basic form of subsistence - gathering and hunting - that was to last as the human way of life until the development of agriculture about 10,000 years ago.

Gathering and hunting as a way of life is now restricted to a handful of groups in the world such as the Bushmen of south-west Africa, some pygmy groups in the equatorial forests of Africa, the Hadza of east Africa, a few groups in India and south-east Asia, some Aborigines in Australia, some Inuit in the Arctic and the native inhabitants of the tropical forests of South America. These groups now occupy essentially marginal habitats, having been gradually pushed aside by the advance of agriculture. Two-thirds of the Inuit originally lived in a much more benign climate south of the Arctic Circle, while the Aborigines used to live mainly in the productive regions of eastern Australia not in the central and northern deserts. The commonly accepted view of gathering and hunting is that it produces a life which is, to quote Thomas Hobbes, 'nasty, brutish and short'. In the last thirty years new anthropological studies of existing gathering and hunting groups have provided a fascinating insight into how humans lived for the overwhelming majority of their history and how they were integrated into the environment. These studies have emphasised the relatively easy way in which sufficient food could be extracted from what would have been much more productive ecosystems than those now occupied by such groups. In parallel with these findings there has been a revolution in archaeological thinking and techniques for investigating early human remains. Instead of collecting large numbers of stone tools and trying to classify them into different 'cultures' on the basis of marginal differences in the way in which they were made or by comparing the different types of tools found at different sites, archaeologists have adopted a much more sophisticated approach. This emphasises trying
to understand, often using contemporary groups as examples, what tools were made to do, what activities were carried out at the different sites, how human groups exploited their environment in different ways, to obtain food and how their seasonal movements were integrated into this overall pattern.

What emerges from these new approaches is a much more positive view of gathering and hunting groups. In general, gatherers and hunters do not live under the constant threat of starvation. Rather they have a nutritionally adequate diet selected from a wide range of the available food resources. This wide variety of food is normally only a small proportion of the total amount of food available in the environment. Obtaining food and other forms of work take up only a small proportion of the day, leaving a large amount of time free for leisure and ceremonial activities. Most groups survive with very few goods because their wants are few and because they would find extra goods a hindrance to their mobile way of life. Items such as hunting tools or cooking utensils have no great value because they can be easily replaced from locally available materials. The pattern of life varies during the year depending on the seasonal availability of different types of food. Most of the time they live in small groups of about 25–50 people and come together in larger groups for ceremonial purposes, marriage and other social activities at a time when food supplies allow a larger population to gather in one place. Within the group there is no concept of food ownership and food is treated as available to all. Food is not stored because that would interfere with mobility and because their experience dictates that some food will always be available even if certain items are occasionally in short supply.

The bushmen of south-west Africa illustrate how easily gathering and hunting groups can obtain sufficient food. The mainstay of their diet is the highly nutritious mongongo nut obtained from a drought-resistant tree. It is a very reliable source which keeps for over a year. It contains 5 times the calories and 10 times the amount of protein of an equivalent amount of cereal crops and half a pound (about 300 nuts) has the calories of two-and-a-half pounds of cooked rice and the protein of almost a pound of beef. In addition 84 different species of food plants are available although the bushmen normally only use twenty-three of them. There are 54 edible animals available although only 17 are hunted regularly. Compared with modern recommended levels of nutrition the diet of the bushmen is more than adequate: calorie intake is higher, protein consumption is about a third higher and there are no signs of any deficiency diseases. The amount of effort required to obtain this food is not very great — on average two-and-a-half days a week. The work involved is steady throughout the year (unlike agriculture) and apart from at the height of the dry season the search for food rarely involves travelling more than six miles in a day. Women and men devote about the same amount of time overall to obtaining food but the women, who are responsible for gathering, bring in about twice as much food as the men are able to hunt. The women tend to work about one to three hours a day and spend the rest of the time in leisure activities. Hunting, which is carried out by the men, is more intermittent involving perhaps a week of hunting followed by no activity at all for two or three weeks. About 40 per cent of the group play no part in the work of obtaining food. About one in ten are aged over sixty and treated as honoured members and the young are not expected to provide food until they marry at about the age of twenty for women and twenty-five for men. Similar patterns have been found amongst the Hadza of east Africa and the Aborigines of Australia.

All of these groups have now been pushed into marginal subsistence areas and so it is safe to assume that when similar groups were able to live in locations with more abundant resources food gathering would have been even easier. Indeed many contemporary groups fail to see the attractions of agriculture with its much greater workload. As one bushmen told an anthropologist, 'Why should we plant when there are so many mongongo nuts in the world?' Leisure time is valued very highly and preferred to increasing food supplies (which are already more than adequate) or producing more material goods (which can be a hindrance). Earlier this century the Siane tribe in New Guinea adopted modern steel axes instead of their traditional stone tools. This reduced the amount of time needed to provide an adequate level of subsistence by about a third. The new spare time was not spent in increasing output but was devoted to ceremonies, leisure and warfare. Similarly in sixteenth-century Brazil the Portuguese found that the Indian tribes, if not enslaved, would only work for them until they had earned enough to buy metal tools and then they wanted to enjoy their extra leisure.

In general, gathering and hunting groups live largely by gathering. Hunting is a difficult and hazardous activity with only intermittent rewards at best. Studies of top carnivores in ecosystems (which is the role humans are trying to adopt when hunting) show that they only make a kill about once in every ten attempts. Humans, even with some help from technology, are much less well adapted to this role than lions or tigers and are likely to achieve even lower rates of success. In early gathering and hunting groups, operating with fairly primitive spears
and bows and arrows, most of the meat in their diet is likely to have come from scavenging animals killed by other predators. In the equatorial and tropical areas hunting rarely contributes more than a third of a group’s diet. Ecosystems further away from the equator are less productive and therefore the available plant food needs to be supplemented—often through the more time-consuming task of fishing. The great grasslands pose major problems for these groups in finding food because of their lack of suitable plants for human consumption and the difficulty of hunting the large herds of grazing animals. It is only in the Arctic areas, with their almost total lack of suitable plant food, that hunting dominates subsistence. In these areas finding sufficient food is not easy and survival requires a great deal of skill and effort to make use of the limited resources available.

In order to obtain the necessary subsistence, gathering and hunting groups depend on a deep knowledge of their local areas and in particular an awareness of what types of food will be available at different places and at different times of the year. Their way of life revolves around major seasonal changes in methods of subsistence and patterns of social organisation are integrated into these changes. Contemporary gathering and hunting peoples again illustrate how historical groups would have adapted to their particular conditions. The bushmen of southwest Africa live in a relatively homogeneous environment, moving camp about five or six times a year but never moving on more than about ten or twelve miles a time and making longer trips only for social occasions such as marriage. The Gidjingali Aborigines of northern Australia have a clear seasonal round of varying exploitation. In the wet season, when the swamps are full, they eat waterlilies—the stalks are eaten raw, the seeds made into unleavened cakes and the corms cooked. In the early dry season they move to an area where large yams are found since the tubers are easy to locate at this time of the year when the tendrils are still green. Later they move to the edge of the wetlands where the men hunt geese and the women dig up spike rush corms. At the height of the dry season subsistence depends on cycad nuts which, although difficult to prepare, are plentiful and can support the large groups of people who gather together at this time for ceremonial, religious and social events. Only in a brief period before the rainy season is there any shortage of suitable food when subsistence depends on less favoured roots and plants.

An example of an extreme form of adaptation to a harsh environment influencing all forms of economic and social life is provided by the Netsilik Inuit living north and west of Hudson’s Bay in Canada, who were studied in the 1920s before they had any real contact with modern technology. Their way of life depended on careful exploitation of every part of their environment. Houses and storage facilities were made from the snow and ice. Clothing, kayaks, sledges and tents came from the skins of animals and the bones provided tools and weapons. Cooking utensils were made out of stone. The seasonal round of subsistence activity was highly varied. In the winter the Netsilik were totally dependent on seal hunting. A huge number of hunters had to cover the numerous holes in the ice used by the seals for breathing. This was therefore the time of the year when extended social groups gathered together in great igloo communities and took part in the major religious and ceremonial activity of the year. The large winter camps broke up into small groups living in tents from June when it was possible to hunt the seals on the ice. By July the groups moved inland fishing and occasionally hunting caribou. In August they constructed stone weirs across streams in order to catch the plentiful supply of salmon trout moving upstream to spawn. At the end of the month they again came together in large groups for the communal activity of hunting from kayaks as the caribou crossed the rivers during their annual migration. In October smaller groups of Inuit would fish for salmon before reassembling in larger groups for the winter seal hunt. In each of the phases of communal hunting there were social customs to ensure that everybody was fed and that nobody was penalised because of poor luck or lack of skill.

These modern examples of gathering and hunting groups tell us a good deal about the way in which historical groups would have operated in the various environments they inhabited around the world. All gathering and hunting groups, both contemporary and historical, seem to have tried to control their numbers so as not to overtax the resources of their ecosystem. This was achieved through a number of accepted social customs. The most widespread was infanticide involving the selected killing of certain categories such as twins, the handicapped and a proportion of female offspring. (Studies in the 1930s showed that Inuit groups killed about 40 per cent of their female children.) In addition, protracted weaning of infants probably provided a form of birth control and some of the old people may have been abandoned if they were ill and a burden on the group. In such ways the demand for food and, therefore, the pressure that gathering and hunting groups placed on their environment was reduced. Population densities were generally low (although the numbers would vary according to the type of environment and its natural level of productivity). The best estimate for
the total population of the world about 10,000 years ago, just before the adoption of agriculture in a few areas, was not more than about four million and in earlier periods it would have been considerably less than that. The gradual development of human societies and the spread of settlement across the globe into different environments can be traced to four basic traits that distinguish humans from other primates. Fundamental to all advance was an increase in brain size. A bigger brain seems to have been important in achieving the power of abstract thought so vital in the development of technology. A second vital breakthrough (made as early as three-and-a-half million years ago) was the ability to stand fully upright on two feet. This was important not just in increasing mobility but also in freeing the hands to undertake other tasks such as using and making tools. The third trait was the use of speech. Not surprisingly there is absolutely no evidence as to when speech was adopted but it is generally assumed to have been at an early date and the ability to communicate would have opened the way to increased group co-operation and more elaborate social organisation in general as well as aiding the spread of different cultural advances. The fourth trait was fundamental to the human settlement of the world—the adoption of technological means to overcome difficulties imposed by hostile environments. Although other animals use tools, humans are the only ones to make them. Stone toolmaking began about two million years ago with the first crude stone choppers from pebbles, although other less durable tools that have not survived would probably have been used earlier.

Apart from stone tools, the artefacts and technologies used by the earliest humans were wooden spears (about 400,000 years ago), bolas stones for entangling animals (about 80,000 years ago), the use of wood and skins and also fire. Since fires also happen naturally, the exact date at which fire was first deliberately used is a matter of considerable controversy. There are ambiguous indications from the site of Chesowanja in east Africa dated to about one-and-a-half million years ago but the first definite, and widely accepted, evidence comes from about 500,000 years ago. Traces of the use of fire are first found in association with animal kill sites, suggesting that it was brought to the sites in order to cook the meat, as well as at camps where it would have been used for heat and light and possibly protection. At this early stage, it is unlikely that it was used to drive animals into suitable killing sites, although this technique certainly was used at much later dates. But for at least two million years the principal technology used by humans was the stone tool. For about the first one-and-a-half million years of tool
making the dominant types were a chopper like tool made from pebbles and a hand axe with a working edge round most of the perimeter. These tools were relatively easy to make and are found in huge quantities. For example, the disarticulated skeleton of a hippopotamus found at Olduvai Gorge in East Africa was surrounded by 459 blunted hand axes and choppers.

It was with this primitive tool kit that the first humans were able to move from Africa into the frost-free zones of the Middle East, India, south China and parts of Indonesia, although the use of clothing from the skins of animals would have been necessary too. The exact chronological framework is difficult to establish because of the lack of archaeological work in many areas, but it is clear that Homo erectus had spread outside Africa by about one and a half million years ago, very soon after the first skeletons of this direct ancestor of modern humans were found. But the areas occupied were still restricted. With the skills that they possessed at this time humans could only adapt to those ecosystems found in the semi-tropical areas where there was a considerable variety of vegetable material that could be gathered easily and a wide range of small and easily hunted animals to supplement this diet. The equatorial rain forests were not penetrated and the settlement of Europe posed formidable difficulties. These problems were not solved for a very long time and so the settlement of Europe is a comparatively late phenomenon in human history despite its relatively easy access from the Near East and Africa. European ecosystems made it very difficult, even in interglacial periods, to extract enough subsistence with only a limited technological base: the plant life was less rich and the scope for gathering more limited. The hunting of medium and large-sized game was therefore vital, but difficult. Even if they were only scavenging and killing the sick and old members of the herds the groups would have needed to move over large areas when following the seasonal movements of the animals and they would have found it difficult to keep in touch for social and cultural activities. The first evidence of human occupation is dated to about 750,000 years ago and most areas of Europe had seen human settlement by about 350,000 years ago. But this settlement was intermittent and confined to interglacial periods when the climate of Europe would have been equable enough to support gathering and hunting with a limited tool kit. The conditions during glacial periods, when the great northern ice sheets advanced and the climate of even southern France deteriorated into semi-arctic conditions producing a type of tundra, would have been too severe.

It was not until the last, long, glacial period that began about 80,000 years ago and lasted till about 12,000 years ago that the first permanent occupation of Europe took place. It marked a major advance in the ability of humans to adapt to a harsh ecosystem. During this period the whole of Scandinavia, north Germany, Poland, north-west Soviet Union and most of Britain were covered in ice and at the height of the glacial period, about 20,000 years ago, the ice sheets moved even further south. The area to the south of these ice sheets was one of permafrost and a tundra type vegetation. But this tundra was richer than that now found in northern Europe because of the longer summers. It supported a wide variety of animal life dominated by large herds of reindeer, woolly mammoth, bison and wild horse together with smaller numbers of woolly rhinoceros, giant elk and saiga antelope. Given the low level of plant life and therefore the limited role that gathering could play in the subsistence base, humans were dependent on these large animal herds for their existence. This challenging environment produced a highly developed and sophisticated culture to control the available food supply and it stimulated a much greater degree of social integration than ever before achieved by human groups.

The conventional picture of the ice-age inhabitants of Europe is that they were hunters preying randomly on the herds of reindeer and other large animals. But pure hunting is a high risk strategy: the rate of success is very low and continual hunting only frightens the herds, making them more difficult to follow and attack. A much more sophisticated approach to obtaining subsistence in a difficult environment was in fact employed. This was based on managing the herds with the minimum of disturbance. In eastern and central Europe it involved following the migrating herds between their winter ranges on the Hungarian plain and the edge of the Black Sea to their summer grazing areas in the Jura, southern German highlands and the Carpathians. Human habitation sites are found along the natural migration routes and on the edges of the natural grazing grounds of the reindeer. The herds were not hunted at random but culled on a selective basis to remove the sick and the old. Enough animals to provide meat for the season were herded away from the main group, driven to areas such as natural basins and killed as required. The numbers of humans that could be supported in this way though were very small. A herd of about 1,500 reindeer would perhaps be sufficient for only about three families or fifteen or so individuals. These groups would also have been forced to be highly mobile, coming together in larger numbers, essential for ceremonial and social activities, for only short periods of the year.
A very different way of life developed in south-west France and northern Spain at the height of the last glaciation about 25–20,000 years ago. When the climate was at its most severe, northern Europe seems to have been partially abandoned and a relatively dense population developed further south. Subsistence was based on the large herds of reindeer and red deer that passed through the Dordogne area and northern Spain. Within this region it was possible for a moderately dense human population to sustain a reasonable level of food supplies without undertaking long migrations following the herds. They were able to utilise different parts of the area at different times of the year and food from the herds was supplemented by a plentiful supply of salmon and other fish in the rivers. In these semi-settled conditions a highly integrated society emerged that produced the great cave paintings found at sites such as Lascaux in south-west France and Altamira in northern Spain (roughly contemporary paintings and rock art have also been found at the Apollo cave in South Africa and in Australia). The exact function and meaning of the European cave paintings is still unclear but their religious and ceremonial nature is not in dispute and there was almost certainly some magical element involved in seeking to control the herds on which the way of life of the community depended. When the ice slowly retreated the herds gradually moved north. They fell in size as the increasing bands of forest also moved north, eliminating the tundra as the climate improved. The whole subsistence base of the humans in the area slowly collapsed and a series of major adjustments was required in order to obtain food from a radically different environment. There was a greater emphasis on gathering from the richer ecosystem produced by the milder climate, and on the use of smaller animals living in the wooded conditions, on fishing and on marine resources such as shellfish.

Europe was also one of the areas to see a significant development in human technology involving the development of new techniques in the production of tools and also the use of new materials. They constitute one of the most significant changes made by humans and the greatest burst of innovation before the invention of pottery and the use of metal. They began about 40–30,000 years ago and appear to be linked to the spread of fully modern humans, Homo sapiens sapiens. The number of different types of stone tools manufactured rose from six to eighty and the nature of the tools changed significantly. Before about 40,000 years ago tools tended to be large—mainly hand axes or flakes from a prepared core—with only a minimal investment of time and effort in their preparation. After this date the emphasis changed to the production of very thin, parallel-sided blades from the core and later still, after about 20,000 years ago, small light blades used as points for projectiles. These new tools required different and more complicated manufacturing techniques involving heat treatment and pressure flaking from the core. Mastery of these techniques not only needed higher motor abilities and co-ordination but also greater mental skills to cope with the number of separate stages needed to manufacture these artifacts.

For the first time, previously available materials such as bone, antler and ivory were worked into tools, some of them extremely complex to make, such as barbed harpoons. Spears were improved through the use of bone or ivory points to replace stone and by the use of the spear thrower to increase range. Hunting was also made easier and less manpower intensive by the invention, about 23,000 years ago, of the bow and arrow and the likely use about this time of snares, traps and nets, which would have widened the resource base available for human exploitation. Although clothes had been made from skins for hundreds of thousands of years, life in Europe, at the height of the last glaciation, required major improvements in survival techniques. Hoods, gloves and foot mittens were produced and by 20,000 years ago eyed needles and fine thread (a product of fur trapping) were being used. Good insulation from the cold provided by warm clothing meant that the level of caloric intake necessary for survival in the harsh conditions was kept low enough to be extracted from the environment. The development of new techniques was probably accompanied by a greater degree of specialisation within the gathering, hunting and herding groups and the use of increasingly high quality materials that could only be found in a small number of locations led to the creation of regional networks for their exchange.

The permanent settlement of Europe at a time of extremely severe climatic conditions was a major human achievement and a sign of increasing human control over the environment. It was made possible by a combination of the adoption of new technologies and more sophisticated animal management. The settlement of Australia did not require such elaborate adaptations because of the relatively benign climate in the eastern part of the continent and the ease with which gathering and hunting groups could find food. It could only have come about, however, after one major invention—the boat—because Australia, although joined to New Guinea at the height of the glaciation, was never linked to the Asian mainland. Australia was settled about 40,000 years ago at a time when sea levels were at their lowest and when a voyage of about sixty miles would have been needed. Tasmania
was linked to Australia until about 15,000 years ago (it was settled about 20,000 years ago) and New Guinea became an island about 8,000 years ago. The initial settlement was probably by a small group, perhaps as few as twenty-five people, but the population grew rapidly in what had been an undisturbed environment to reach about 300,000 – the same level as when Australia was first reached by Europeans. The society which developed in Australia did not lead to the development of more complex social organisations as happened in almost every other area of the world.

The settlement of America was almost the last stage in the movement of humans across the globe. This was because it depended on the ability of human groups first to survive in the harsh climate of Siberia and then to advance eastwards to the Bering Strait. The crossing to Alaska was made at the height of the last glaciation when the reduced sea levels turned the Bering Strait into a land bridge. The climate in the area is likely to have been less severe than now with reasonable opportunities for hunting and herding the large animals of the area. But movement south out of Alaska could only have taken place at a slightly warmer stage when the two major ice sheets of north America, centred on the Rocky mountains and the Laurentian shield, would have retreated and separated enough to open up the passes to the south east. This could have taken place at one of two periods – either 30–23,000 years ago or about 13,000 years ago. Although this is a matter of great controversy in early American archaeology, the latter date is the more likely. Once the first human settlers were able to move through the passes to the south they found an enormously rich environment that provided plenty of opportunities for relatively easy subsistence. The human population multiplied rapidly and within a few thousand years had spread to the tip of South America.

A whole series of adaptations were required in order to extract food from the wide variety of ecosystems found in the Americas. On the plains of North America, given the lack of a large variety of plants for gathering, subsistence depended on exploiting large herds of bison and other animals. These were often killed in a crude and highly wasteful way by driving them into narrow canyons or over cliffs. At Caspar in Wyoming about 10,000 years ago a single kill involved at least seventy four animals and in a roughly contemporaneous kill in south-east Colorado hunters appear to have set off a stampede into a canyon and ended up with about 200 corpses most of which could not be used because they were squashed at the bottom of a large pile of bodies. In eastern North America the spread of the forest after the ice sheets retreated changed the ecosystem and removed most of the large animals suitable for hunting. Societies adapted to these new conditions in much the same way as those in post-glacial Europe – by exploiting smaller animals such as deer, by fishing, by placing a greater emphasis on gathering. Further north in the Arctic areas settlers were attracted by the abundant meat from caribou, arctic foxes and hares and only later moved on to exploit marine resources, especially the seals. The deserts of the south-west required a different adaptation with the emphasis on mobility so as to exploit a wide range of plants and animals in a difficult environment. In the tropical areas of central and south America a way of life based on the widely available plant resources supplemented by a small amount of hunting was possible.

Perhaps the most extraordinary development though took place on the north-west Pacific coast with its abundant marine resources of seals, sea lions, sea otters and in particular the salmon that came to spawn in the rivers. This relatively plentiful supply probably involved more effort in storage than in procurement. The various animals were dried during the summer or smoked in the autumn and the fat was rendered down to oil to provide sufficient food for the winter. Although there were, naturally, fluctuations the supply of food was sufficiently reliable to avoid the need for mobility and this area produced one of the few examples of a settled society not based on agriculture. Villages developed each with a population of about 1,000 living in long, communal houses with village chiefs, considerable social stratification and specialisation of labour together with complex mechanisms for barter and gifts of food as a way of obtaining prestige and ensuring adequate subsistence was available for all. This complex society even produced a hereditary caste of slaves. Extensive food storage meant that winter was a time when the effort required for subsistence was minimal and elaborate ceremonial activities took up most of the spare time. This proved to be a highly stable way of life that survived until Europeans arrived in the area.

By about 10,000 years ago, with the movement of the human frontier through the Americas, nearly all parts of the globe had been settled. The final phase in the human settlement of the world took place relatively late in the Pacific and Indian Oceans. This settlement was carried out not by pure gatherers and hunters but by groups that obtained their subsistence through a primitive form of agriculture although they still relied on stone tools and supplemented their diet through occasional hunting. In the Pacific, the Micronesia people settled islands such as the Marshalls and Carolines but it was the
Polynesians who carried out the most extensive voyages. From New Guinea they reached Tonga and Samoa about 1000 BC and moved further east to the Marquesas about 300 AD. From there they sailed to Easter Island and Hawaii about a century or two later. The last two major islands of the world were settled by humans about 800 AD in the Pacific and the Indian Oceans at a time when Charlemagne’s empire was at its peak in western Europe and the Vikings were beginning their epic voyages, when Islam dominated the Mediterranean and the Near East and China was ruled by the T’ang dynasty. The Polynesians reached New Zealand and people moving west from Indonesia settled the small island groups in the Indian Ocean together with Madagascar.

Every major area of the world (except Antarctica) had now been settled by humans. Gathering and hunting groups had, over hundreds of thousands of years, adapted to every possible environment in the world from the semi-tropical areas of Africa to ice-age Europe, from the Arctic to the deserts of south-west Africa. The subsistence techniques used in these differing environments varied widely from dependence on gathering and the hunting of small animals to the herding of reindeer, hunting of bison and the highly complex mixture of strategies required in the Arctic. It is often assumed that these groups lived in close harmony with the environment and did minimal damage to natural ecosystems. The gathering of food did require very detailed knowledge and considerable understanding of where resources could be found at different times of the year so that the annual round of subsistence activity could be organised accordingly. The herding and hunting of animals similarly required close study of their habits and movements. There is also evidence that some of these groups did try to conserve resources in the interest of maintaining subsistence over a long period. Totemic restrictions on hunting particular species at certain times of the year or a pattern of only hunting an area every few years would have helped to maintain population levels in the hunted animals. Some groups had sacred areas where hunting was forbidden and others, such as the Cree in Canada, used a form of rotational hunting, only returning to an area after a considerable length of time, which allowed animal population levels to recover from the bounts of slaughter. Apart from specific cultural restrictions one of the main reasons why gathering and hunting groups, in many instances, avoided over-exploiting the available natural resources was that their numbers were small and therefore the pressure they placed on the environment limited.

However, gatherers and hunters are by no means passive in their acceptance of ecosystems and many of their activities do alter the environment considerably and cause damage. The modern Hadza of east Africa are known to destroy wild beehives in order to obtain a small amount of honey and other groups often destroy many of the wild plants on which they depend by carelessly uprooting large numbers. Moreover, gathering and hunting groups do alter the conditions in which wild ‘crops’ grow, intervening in order to benefit some favoured plants at the expense of others that they do not require. One of the most effective ways of doing this is by burning and the use of fire for such purposes was widespread among gathering and hunting groups. Fire alters the habitat significantly, by favouring annual plants that grow well in new ground and by increasing nutrient recycling. The Aborigines used fire regularly to encourage an edible bracken on Tasmania and the Maoris on New Zealand used the same technique to increase the spread of an edible bracken the rhizome of which formed a substantial part of their diet. In New Guinea from about 30,000 years ago, not long after it was first settled, there is widespread evidence of forest clearance by felling, ring barking and the use of fire. This opening up of the forest cover was to encourage food plants such as yams, bananas and taro to grow and to provide room for the sago tree. In post-glacial Britain patches of woodland were cleared by burning in order to encourage the growth of forage for red deer. Most groups also tended wild plants by transplanting and sowing in their natural habitats and by removing competing plants. Some even used techniques such as irrigation on a small scale to improve the habitat of favoured plants. Although these interventions in a natural ecosystem are very different from agriculture, which involves replacing the natural system with an artificial one, they reveal humans modifying the environment if only on a small scale and in limited locations.

The most dramatic impact that gathering and hunting groups had on their environment though was through hunting animals. It is much easier to damage this part of an ecosystem because the numbers are smaller, and populations, particularly of larger animals or carnivores at the top of the food chain, usually take a long time to recover from any over-hunting. Although there is some evidence of attempts by groups not to overhunt, there is far more of uncontrolled hunting and even the extinction of species. We have already seen how the great bison hunts on the plains of north America could kill hundreds of animals in one drive even though only a few were required. The bison population was huge (about 50–60 million) so that even a large number of kills a year on this scale would not significantly reduce numbers. Smaller populations
though could be badly affected. The effect of hunting was made worse by the tendency of hunters to concentrate on one species to the exclusion of others. On the Aleutian Islands in the north Pacific the population concentrated on killing the sea otter for over a thousand years after the settlement of the islands about 500 BC until it was virtually extinct and the subsistence base of the community destroyed. Then the islanders had to alter their way of life substantially and accept a lower level of subsistence from the diminished resources that remained.

The impact humans could have on animal numbers is well illustrated by the examples of Madagascar, Hawaii and New Zealand, previously isolated islands with unique fauna suddenly subjected to severe stress. Because no large mammals had been able to reach such isolated spots large flightless birds had evolved, in the absence of major predators, to become the dominant animals. They were defenceless against human predation. Within a few hundred years of the settlement of Madagascar many of the larger animals, including a big flightless bird and a pygmy hippopotamus, were extinct. On Hawaii within a thousand years of human settlement thirty-nine species of land birds had become extinct. In New Zealand the Maoris were faced with a temperate environment where many of their traditional crops such as banana, breadfruit and coconut from the sub-tropical Polynesian islands could not be grown and even yams and taro could only be grown on the North Island. This forced a radical shift in their normal subsistence pattern towards wild plants such as bracken fern and the leaf heads of the cabbage tree together with marine resources. Hunting also became more important. The large number of flightless birds such as the kiwi, weka and the many species of moa (most of them about six feet high though one type was over twelve feet tall) were hunted ruthlessly and their eggs were eaten too. Within 600 years of the first settlement twenty-four species of moa were extinct together with twenty other types of bird.

Gathering and hunting groups could even have had an impact on animal populations on a continental scale. A number of species became extinct around the end of the last glaciation at a time when climatic change and the consequential shift in vegetation types were adversely affecting the large mammals that had inhabited the tundra of northern and central Europe. In Eurasia five large animals - the woolly mammoth, woolly rhinoceros, giant Irish elk, musk ox and steppe bison - together with a number of carnivores became extinct within a period of a few thousand years as the ice sheets retreated and the tundra was replaced by forest. The changing environment put the greatest strain on these large animals but hunting by humans would have had a devastating impact on a population already in decline and may have tipped the balance between extinction and survival.

The extinction of species in Eurasia was on a relatively small scale. Elsewhere in the world it was massive. In Australia, over the last 100,000 years, 86 per cent of the large animals have become extinct in an area where the climatic impact and therefore the effect on animal habits of the ice ages was minimal. The most likely explanation is hunting by Aboriginal groups in the last 40,000 years. Even if the largest animals were not themselves hunted on a large scale, disruption of the ecosystem as a result of human intervention - by destroying habitats or killing the smaller herbivores on which the carnivores depended - could easily lead to extinction. Equally remarkable is the 80 per cent loss of large animals in South America and the 73 per cent loss suffered in the north of the continent. Unlike Eurasia, where only the animals on the steppe tundra were affected, the extinctions in the Americas involved every type of ecosystem. Although some occurred at the end of the last glaciation, climatic changes had not produced such massive extinctions in the past and there is little doubt that they were the outcome of human intervention in some form. As the first settlers in America moved south out of Alaska and the Rocky Mountains they would have found a rich, undisturbed environment and their number would have risen quickly, thanks to the easily obtained resources. These first American settlers left a trail of destruction across the continent. Two-thirds of the large mammals present when humans first arrived were driven to extinction. Some of these were archaic types, such as the plains camel (found only in North America because of its isolation), others were giant species particularly sensitive to both climatic change and overhunting. Overall the extinctions included three genera of elephant, six of giant edentates (armadillos, anteaters and sloths), fifteen of ungulates and a large number of giant rodents and carnivores.

By about 10,000 years ago humans had spread over a period of about two million years from their original area of southern and eastern Africa to every continent. The slow expansion of human settlement depended upon a number of linked developments. Growth in brain size gave increased capacity for abstract thought and conceptualisation and an ability to provide increasingly sophisticated cultural and technological solutions to the challenges posed by a wide range of difficult and even hostile environments. These solutions included the use of fire and clothing to enable humans to live in harsher climates and the adoption of increasingly elaborate subsistence strategies. In the benign sub-
tropical areas gathering and hunting groups could rely mainly on the wide variety and large quantity of plant food available supplemented by only a small amount of hunting. As human groups moved away from the tropics this way of life had to be drastically modified and a whole variety of different techniques adopted. These ranged from more intensive hunting to herding of large animals to the highly complex seasonal round of activities practised by the Inuit of the Arctic. Technological changes were vital in allowing human settlement around the globe and they occurred on several different fronts, starting with the production of increasingly sophisticated stone tools and the introduction of new weapons such as the bow and arrow but also including the use of furs and skins for clothing, the construction of shelters from a wide variety of materials and the adoption of more complex food processing techniques - cooking in pit hearths rather than open fires and grinding nuts and seeds.

The rate of development was of course very slow and also patchy. Not until about 40,000 years ago did the pace of technological change increase rapidly, at least in comparison with earlier periods. But taken together, these developments were of fundamental importance for the rest of human history and the future of the earth. Humans had become the only animals to dominate and exploit every terrestrial ecosystem. Yet at this stage the overall impact of the gathering and hunting groups on the environment was small because of the low, thinly spread population and their limited technology. Even so they were already making their presence felt as a number of animals were hunted to extinction and the environment was modified in subtle ways. The gathering and hunting way of life was highly stable and very long lasting. For hundreds of thousands of years it was the only way in which humans were able to extract the necessary subsistence from the environment. The number of people that could survive in any one area was constrained by their position at the top of the food chain. Only in exceptional cases such as the Pacific coast of North America were resources so abundant that settled populations could develop in sizeable villages.

Then, about 10,000 years ago, after two million years of a highly stable and well-adjusted way of life, the methods humans used to obtain their food began to change in a number of locations across the globe. The pace of change was still slow but far faster than in the past. Its consequences were far more radical than anything that had gone before. It brought about the most fundamental alteration in human history - and one which made possible all the subsequent developments in human society.

4

The First Great Transition

For about two million years humans lived by gathering, herding and hunting. Then in the space of a few thousand years a radically different way of life emerged based on a major alteration to natural ecosystems in order to produce crops and provide pasture for animals. This more intensive system of food production was developed separately in three core areas of the world - south-west Asia, China and Mesoamerica - and it marked the most important transition in human history. Because it was capable of providing much greater quantities of food it made possible the evolution of settled, complex, hierarchical societies and a much faster growth in human population. About 10,000 years ago, before the evolution of agriculture, the population of the world was approximately four million and rose very slowly to about five million by 5000 BC. Then, in the crucial period as settled societies developed on a major scale after 5000 BC, it began doubling every millennium to reach 50 million by 1000 BC and grew to 100 million within the next 500 years and to 200 million by 200 AD. The upward trend has continued ever since, though not at a steady rate and often interrupted by the consequences of famine and disease, so that agriculture now supports a world population of just over five billion.

The combined phenomena of the transition to agriculture, the growth of settled societies, the emergence of cities and craft specialisation and the rise of powerful religious and political elites, are often referred to as the 'Neolithic Revolution'. However, although the consequences of all these changes were clearly revolutionary - both in their impact on the way of life and on the environment - it is misleading to describe the process itself as a revolution. The timescale over which these changes took place was long, at least four or five thousand years, and the contribution of any one generation would probably be very small. Moreover the idea of a revolution implies action undertaken with the aim of bringing about change, and what we can see in retrospect as a
'process' would not have been embarked on in such a self-conscious or deliberate way. Human societies did not set out to invent 'agriculture' and produce permanent settlements. Rather a series of marginal changes were made gradually in existing ways of obtaining food as a result of particular local circumstances. The cumulative effect of the various alterations was important because they acted like a ratchet. Adjustments in subsistence methods to a more intensive form enabled a larger population to be supported but meant that it became impossible to go back to a gathering and hunting way of life because the larger number of people could not then be fed. Over this long period there was no straight line of development from 'gathering and hunting' to 'agriculture'. Many different ways of obtaining food from plants and animals would have been tried in various permutations and with changing balances between plant and animal foods. Some of these strategies would have failed and others would only have been partly successful. Only slowly and unconsciously did a radically new solution to the human problem of extracting food from different ecosystems emerge.

This long transition can best be understood by abandoning any idea of a clear distinction between gathering and hunting on the one hand and agriculture on the other. They should be seen as parts of a spectrum of human activities of different degrees of intensity designed to exploit ecosystems. Gathering and hunting groups are not passive in their acceptance of the environment: they carry out a wide variety of activities that involve interfering with natural ecosystems for the benefit of humans. In terms of animal exploitation there is a clear gradation between random hunting of a herd, controlled predation, herd following, loose herding, close herding and finally modern intensive factory farming. Gathering and hunting groups carry out the first three or four processes but not the last two. In utilising plants there is a range of intensity from foraging of wild plants, tending wild plants through cultivation, domestication of genetically distinct crops some of which can only propagate through human intervention and finally genetic engineering to create new species known to nature. Gathering and hunting groups did practise certain forms of cultivation (and some still do): they alter habitats by burning to clear ground and improve nutrient recycling, they engage in replanting and sowing plants in the wild, weeding and even small-scale irrigation. Preparing artificial habitats specifically for growing and tending plants and gradually selecting and domesticating certain types is only an intensification of this process of intervention.

Gathering and hunting groups in glacial Europe had already demonstrated an ability to exploit herds of reindeer and deer in quite sophisticated ways in order to extract subsistence from a hostile environment. Such relatively intensive exploitation of animals does not require settled agricultural communities, as is demonstrated by present day groups of nomadic herders such as the Sami (reindeer), Masai (cattle), or various peoples of central Asia (horse). There are other examples too of varieties of exploitation techniques that adopt some but not all of the processes that are to be found in modern agriculture. In the Levant as early as 18,000 BC humans were herding gazelles in a semi-domesticated environment: at sites such as Abu Hureyra in Syria and Nahal Oren in Israel over 80 per cent of the animal bones recovered were those of gazelles even though many other species were available to both herd and hunt. At the same time these groups were also harvesting wild forms of plants such as einkorn, emmer and barley that were to be domesticated 10,000 years later. The use of wild grains was not necessarily an inferior way of obtaining food. Recent experiments using stone sickles to harvest the large stands of the wild ancestors of current crops that still grow in the Near East have shown that such techniques could be highly productive and the wild grains are often far more nutritious than the domesticated varieties. Wild emmer in Israel has produced yields of 2,500-4,000 pounds an acre, a rate as good as that of wheat in medieval England. In Mexico, teosinte, a wild form of maize, has been found to be highly productive with three-and-a-half hours' gathering providing enough food for one person for ten days. The effort involved in obtaining food from these wild 'crops' is also far less than with domesticated crops since no sowing, weeding and tending is required.

The identification of domesticated plants and animals from archaeological remains is very difficult. It is for, example, impossible to tell the difference between the remains of plants and grain gathered in the wild and those that come from the same plants and grain in fields where they have been planted and cultivated by humans. It is usually possible to distinguish the characteristics of plants during the domestication process as they gradually alter from their wild progenitors to fully domesticated varieties but the changes take place over a considerable period of time. The difficulties encountered by archaeologists are compounded by the problems associated with tropical and semi-tropical sites, where plant remains are rarely well preserved in the warm, wet climate. Many plants, particularly roots and tubers such as yams and potatoes, and also trees such as coconut and sago, show almost no changes when domesticated and therefore pose immense
problems in trying to date changes in subsistence techniques. Similar problems apply to working from animal bones. It is almost impossible to identify directly from the archaeological record whether wild animals were being herded. The best indirect method is to look for findings such as a large percentage of bones from young animals, which suggests that highly selective predation techniques were being used. The morphological changes that take place on domestication are subject to dispute although it is generally agreed that animals become smaller and retain more of their juvenile characteristics. But this process again can only take place over long periods of time, which makes it very difficult to use changes in physical characteristics to identify changes in animal husbandry techniques in the short term.

There is also no clear distinction, and a great deal of continuity, between the tool kits and artifacts of gathering and hunting groups and the first agricultural communities, particularly in south-west Asia (the area where the earliest moves towards agriculture took place). The first grinding slabs and stones are found in the Near East about 15,000 BC and were probably used to crush nuts (particularly acorns) and berries but possibly gathered seeds as well. Other tools such as mortars and sickles, which would seem to be 'agricultural' are found among the remains of groups that did not practice agriculture. Conversely, many tools associated with gathering and hunting groups (such as burins and scrapers) are also found in the deposits of settled communities that practised agriculture. Villages are not solely associated with agriculture as the Indian settlements of the north-west coast of North America demonstrate with communities of 1,000 people dependent mainly on fishing and other marine resources. Neither is pottery confined to agricultural societies. The Jomon culture in Japan made pottery for thousands of years before the adoption of agriculture.

This more complex picture reinforces the view that a fundamental distinction between agriculture and gathering, herding and hunting should not be drawn. No radically new techniques or relations between humans and plants and animals developed in the period beginning about 10,000 years ago. Humans had been involved in obtaining subsistence from the various ecosystems of the earth for many hundreds of thousands of years. Over that time the methods adopted had evolved. The techniques available to a group living in late glacial Europe or at a similar period in the Near East were far in advance of anything used by the earliest hominids in East Africa. Previous subsistence strategies had used different solutions depending on what was economically favourable at the time, including intensive reliance on selected plants, dependence on one type of animal or a broad spectrum of resource use involving both gathering and hunting. Each of the methods that characterise agriculture had been adopted by one or more groups at some time in the past, though usually in isolation. What was new was the combination and intensification of techniques that began to emerge in a few areas of the world about 10,000 years ago. It was here that the methods adopted by humans to obtain their food slowly amounted to more than just a variation on the theme of gathering and hunting.

It is difficult to explain why agriculture was adopted. Gathering and hunting groups had developed an extensive repertoire of methods for obtaining subsistence, in most cases, and in all but the most marginal areas, without needing to expend large amounts of time and effort. By exploiting a wide range of resources they were also able to reduce the risks involved by guarding against the failure of any one plant or animal. Agriculture is most definitely not an easier option than gathering and hunting. It requires far more effort in clearing land, sowing, tending and harvesting crops and in looking after domesticated animals. It does not necessarily provide more nutritious food, nor does it offer greater security because it selects and depends on a far smaller range of plants and animals. The one advantage agriculture has over other forms of subsistence is that in return for a greater degree of effort it can provide more food from a smaller area of land.

Many of the earliest explanations for the adoption of agriculture were based on the view that agriculture offered such obvious advantages that it was adopted as soon as human knowledge and cultural achievements had reached a sufficiently advanced level. This approach, following recent research into the way gathering and hunting groups operated and obtained their food, has now largely been abandoned. Another theory has linked the adoption of agriculture to the climatic changes taking place at the end of the last glaciation. Improvements in the climate would certainly have produced major changes in vegetation belts and therefore in the resources available for humans to exploit. In north-west Europe the replacement of the tundra by temperate forest completely destroyed the subsistence base of the reindeer herders and forced a shift to radically different methods of obtaining food. But climatic changes had happened before without producing any fundamental alterations in subsistence patterns and they were spread over thousands of years giving plenty of time for humans to adopt alternative gathering and hunting strategies. The effects of climate change in the three core areas of south-west Asia, China and Mesoamerica would also have been very different and therefore unlikely to elicit a similar response. In addition
the plants and animals that were eventually domesticated had existed in the same areas for thousands of years, and had often been utilised short of full domestication.

The explanation that best fits modern knowledge is based on increasing population pressure. Although gathering and hunting groups take a number of measures to limit their population to a level the environment can support without strain, they are not always successful. The usual solution is for the excess population that cannot be supported by the existing territory of the group to separate, form a new group and exploit a new area. If, in the case of prehistoric groups, this process continued over a long time then eventually all the suitable territories would be occupied. It is possible that a human population of around four million (the level reached about 10,000 years ago) or even less, was about the maximum that could readily be supported by a gathering and hunting way of life. If population growth continued beyond this point, especially in areas that were relatively crowded, groups would be forced into ever less favourable habitats where they would have to depend on lower quality plants and animals or where ecosystems were less rich and therefore more effort would be required in order to obtain sufficient food. Over thousands of years a continuation of this displacement process and the need for more effort in obtaining food would drive groups towards much more intensive and time-consuming ways of exploiting the environment, eventually resulting in what is now recognised as full-scale agriculture. Once some of these groups had reached a point where they were prepared or had no alternative but to adopt agricultural techniques, they would have been subject to a ratchet effect. Food production would rise and more people could be fed. In the absence of population control, this higher population would then increase the pressure towards even more intensive cultivation. The changes from one generation to the next would have been slight but the cumulative effects would have been great.

The changes now acknowledged as the emergence of agriculture, took place initially in south-west Asia, China and Mesoamerica over a period of several thousand years. The similarities between the three areas are such that a common process can be identified but the end results showed significant differences. The crops that could be cultivated and the animals which could be domesticated were determined by the local ecosystems which, in their turn, were determined by the climate and the way continental drift had separated the various continents and allowed plants and animals to evolve in isolation. The different forms of agriculture that emerged were to have a profound effect on the development of human societies in these different areas and therefore on the course of world history.

The first area to experience these changes was south-west Asia, a crescent-shaped region stretching from what is now Palestine and Syria through the southern parts of Anatolia to the Zagros mountains of Iran. This area had long been occupied by gathering and hunting groups and there is no major discontinuity between them and the later agricultural communities. The wild progenitors of the crops that were domesticated in the area have now been clearly identified. Wheat comes from two wild forms still found in the region - emmer and einkorn - and barley from a wild form of the plant. Wild forms of legumes such as lentils, chickpeas, and peas have also been found. These wild plants still exist in the region in large stands and their distribution gives a good indication of where domestication is likely to have taken place. Although their ranges overlap, emmer has a very limited distribution in the wild (largely confined to the upper Jordan valley), whereas einkorn and chickpeas are found in south-east Anatolia and wild barley is fairly widely distributed in Palestine and the Zagros mountains. Recent experiments have shown that emmer and wild barley can be easily cultivated but genetic studies suggest that modern wheats, peas and lentils come from only a very limited part of the wild stock and that domestication may therefore have occurred on only a small number of occasions. The way in which wild characteristics such as seed dispersal mechanisms have been lost again points to only a limited number of domestications. These biological considerations suggest that domestication may have happened only because a small number of groups were forced to exploit what were seen at the time as less favourable resources.

Other characteristics of these early cultivated plants influenced the course of domestication. The wild ancestors of the plants domesticated for their seeds tend to be weedy types well adapted to growing in disturbed and open sites. Before cultivation they survived in poor thin soils in areas lacking much competition and subject to marked wet and dry seasons. They produced large seeds, were able to germinate easily, grow quickly and survive dry summers - all characteristics which would have been useful to human cultivators. Continual harvesting would unconsciously select those seeds with less effective dispersal mechanisms because they would be easier to gather and this process would lead to a slow loss in natural dispersal ability. Deliberate sowing of specially selected seeds would increase this selection pressure. Both wild and
cultivated wheats and barley are predominantly self-pollinating (unlike the majority of plant species which are cross-pollinated). The advantage of this characteristic for human cultivators was that the cultivated forms would easily have become independent and not subject to swamping by the more numerous wild plants. Occasional cross-pollination would provide just enough genetic flexibility for the cultivated forms to spread, adapt and produce new characteristics.

In parallel with the increasing cultivation and domestication of wild plants the relationship between humans and animals was also becoming more intensive. The first fully domesticated animal was the dog. The Aborigines of Australia and New Guinea domesticated it possibly earlier than anywhere else in the world and the same process took place over most of the northern hemisphere from North America to Japan in the late glacial and early post-glacial periods, although the Near East was comparatively late in this development. Its agricultural significance was slight — it seems to have been done mainly for reasons of companionship and possibly protection rather than to add dog meat to the diet. The first animal to be domesticated and exploited economically was the sheep. This occurred in south-west Asia about 1,000 years before the first fully domesticated crops of einkorn, emmer and barley and it raises the intriguing question of whether some of the first seed plants were gathered as feed for animals and only later transformed into human food. Certainly wild lentils grow in thin, small stands and have a low number of seeds per plant, which would make them uneconomic to harvest for their seeds but by using the whole plant they could still be suitable for animal feed. The great advantage of animals such as sheep and goats (which were domesticated about 8,000 BC) and later cattle is that they do not compete directly with humans for food. Indeed they convert what would otherwise be material unsuitable for human consumption such as grass into usable products such as meat and therefore greatly extend the range of food available to humans. Animals such as pigs do compete directly for human food sources and they were not domesticated until 6,500 BC at the earliest, when food supplies would probably have been more extensive.

It is possible to trace the gradual transformation of human subsistence, and as a consequence human society, across the south-west Asian region as new techniques were adopted. Again there is no clean break or sudden shift from gathering and hunting to agriculture but an evolving mix of strategies with a slow transition towards more intensive forms of exploitation over a long period of about 3,500 years after 10,000 BC. In Khuzistan on the slopes of the Zagros mountains in the earliest semi-agricultural phase people fed themselves by a combination of hunting (mainly for gazelle and onager), the herding of goats and a few sheep and the extensive reaping of a wide variety of wild plants. This pattern supported a mixture of settlements — small villages of about 100 people (but not necessarily occupied permanently) to exploit the wild cereals and legumes, together with seasonal camps and caves for hunting. In the next phase, plant gathering became much less important and was overtaken by cereal cultivation combined with herding of goats. This more intensive system allowed bigger houses and villages to be built. By 8,500 BC, in the Zagros mountains, sheep were being herded (but probably not domesticated in this region), wild grains reaped and hunting remained important. By 7,500 BC the inhabitants of Jarmo, a village of about 25 houses, depended on a fairly intensive system of mixed farming, growing domesticated barley, emmer and peas combined with herding sheep and goats while hunting provided only about 5 per cent of their total food. In Palestine and Syria the Natufian culture, which flourished in the 1,500 years after 9,000 BC, was based originally on a combination of harvesting wild grains and herding gazelle and goats without full domestication but again with hunting playing only a minor role. The domestication of emmer and einkorn and some legumes enabled them to produce a much higher food output and led to the first large settlement of about 2,000 people at Tell
es-Sultan but it was probably only inhabited for part of the year when crops were being harvested. At the end of this long transition a fundamental change had occurred - subsistence now depended on cultivating domesticated varieties of wild plants in special fields and controlling herds of domesticated animals.

By about 7000 BC, as settled agriculture was slowly adopted, there were a series of small farming villages scattered across the south-west Asian region. Communities across the whole of south-west Asia were becoming increasingly sedentary as intensive exploitation of a small area for growing crops and feeding animals meant that a seasonal round of mobile camps was no longer necessary. Then, when food production in some areas was sufficient to sustain a larger, permanent population, the first towns appeared. By 6500 BC, at Jericho, a small town, surrounded by a defensive wall, and covering almost ten acres, had developed. A larger town spreading over about thirty-two acres grew up at Çatal Hüyük in southern Anatolia. It was dependent on the cultivation of wheat and other cereals together with domesticated sheep and goats although hunting for ox, pig and deer remained important. Most of the villages contained only a few hundred people with perhaps a handful of craft specialists but otherwise little social differentiation. Pottery was invented about 6000 BC but technology remained, as with gathering and hunting groups, based on stone tools with metals such as copper only utilised for ornamental purposes. Neither Jericho nor Çatal Hüyük were true cities in that they lacked significant social stratification and both were dependent on particular local conditions - the well at Jericho and the exploitation of obsidian deposits at Çatal Hüyük, which were traded over a large area - for their expansion. The development of true cities did not begin for another 1,500 years.

By 6000 BC the first stage of the transformation of human society in south-west Asia was complete and settled life was becoming the norm. All the region's major crops and animals had been domesticated and no major new types were added for thousands of years. The crops and animals domesticated in this region were crucially important because they formed the basis for the adoption of agriculture in other areas. The great transition that had occurred in south-west Asia was transferred to other regions, spreading by a combination of new groups adopting agriculture and settlers who already practised it moving into new areas. A way of life based on domesticated wheat and barley and herds of sheep and goats (and later cattle) spread to central Asia and the Nile valley almost unchanged and then also to Europe, where difficult adaptations were necessary. Apart from one type of einkorn all the plants used in the formative stages of European agriculture came from south-west Asia as did the animals - sheep and goats were not native in post-glacial Europe. Even the European reaping knife and the quern (hand-mill) were of the same design as those in Asia. Despite these common features it is not necessary to visualise a wave of agricultural settlers spreading across Europe. In many places agriculture was clearly taken up by existing gatherers and hunters although central Europe was undoubtedly colonised by new groups of agriculturists. In the eastern Mediterranean the adoption of agriculture posed few problems because the climate was not very different from that of south-west Asia and between 6000-5000 BC Greece and the southern Balkans shifted their subsistence base to agriculture. Cattle were probably first domesticated here at this time and then spread back into south-west Asia (although they were not milked for about another 3,000 years).

The movement of agriculture into central and north-west Europe took about three millennia after its adoption in Greece, and this long period gives an indication of the difficulties involved in adapting what were originally crops and techniques suited to long hot dry summers to the different ecosystems and climates found in the region. By 4000 BC agriculture was predominant in coastal zones round the whole of the Mediterranean, though not in a continuous band, and had moved onto the easily worked soils of central Europe in the Rhine/Danube and Vistula/Dnestr areas. Between 3000-2000 BC it had been adopted in north-west Europe and a thousand years later it reached Denmark and southern Sweden. Beyond this area gatherers and hunters continued their old way of life. Over most of Europe fields and pasture could only be created by clearing parts of the climax temperate forests, which was still a difficult task with the resources available - stone axes and burning. (In the Near East much of the land would have been covered by a more open type of vegetation.) After clearing the trees, crops were planted in the newly exposed, ash enriched soil until yields began to fall. In a form of 'slash and burn' or swidden agriculture new areas would then be cleared and the abandoned plots allowed to revert to grass and through secondary succession to brambles, shrubs and woodland for further clearance decades later. Because of the difficulty of sustaining fertility with the limited amount of manure available it was not until population pressure increased still further that permanent fields and pastures would be cleared and maintained. Other changes were also induced by the different conditions in Europe. The climate forced a shift in crops. Oats and rye originally grew as weeds in the first cultivated cereal fields of south-west Asia but they flourished in the
cooler, wetter climate of north-west Europe and became crops in their own right. Apart from such changes the early European agriculturalists adopted much the same pattern as in south-west Asia - small villages of peasant farmers obtaining their subsistence from mixed farming.

A few extra crops and animals were domesticated in southern Europe and Asia after about 6000 BC. In the Mediterranean, olives, vines and figs were cultivated by about 4000 BC but only the vine moved into northern Europe and then quite late, being introduced into many areas by the Romans in the first centuries AD. The dromedary and the Bactrian camel were domesticated between 2000–1500 BC but the most important new animal to be introduced was the horse shortly after 3000 BC. Use of the horse not only revolutionised warfare in the Near East by changing the role of the chariot and developing cavalry, it also enabled a whole new culture to develop on the plains of central Asia. Thereafter for thousands of years the history of the Near East, China, India and Europe was to be heavily influenced by successive waves of nomadic horsemen such as the Huns and Mongols descending on settled societies.

The second core area that saw the development of agriculture was China. The modern picture of farming in China is of wet rice production in paddy fields but the origins of agriculture lie in a very different environment among the semi-arid loess plains of the north of the country. Loess is a wind-borne soil of fine particles that is very easy to work even with primitive digging sticks. The soils in this area were thick and not heavily weathered and therefore had a high mineral content. There was only a light wood cover and although the area is semi-arid most of the rain falls in the summer, which makes crop cultivation possible. The area also originally contained a large number of wild grasses, some of which would have been suitable for cultivation and domestication. The crops domesticated in China differ markedly from those of south-west Asia. Wheat and barley are not indigenous (they need some winter rain): wheat was not introduced until about 1300 BC and barley slightly later. Instead agriculture was based on millet and rice grown as a dry land crop rather than in special paddy fields. For a long period millet remained the primary crop and the basis for peasant agriculture with rice a luxury food for the elite. It was only later that rice was adapted to growing further south in wet field conditions. The earliest millennia of Chinese agriculture differed from both south-west Asia and Mesoamerica in one important respect. In the other two regions a nutritionally balanced agricultural regime based on a starchy cereal seed and legumes rich in protein developed. Although soybeans are native they were domesticated very late - about 1100 BC on the north China plain - and then spread rapidly but until then Chinese agriculture was dominated by seed crop production. Pigs and poultry were the main animals to be domesticated followed much later by sheep and goats.

The earliest habitation sites are found not in the flood plain of the Yellow river, an area of very dense settlement later, but on elevated terraces and mounds along tributaries of the river. Millet was first domesticated about 6000 BC and the first settled communities developed at about the same time. Within a thousand years a number of small villages practising agriculture had developed in the same way as in south-west Asia but the process took place some three or four thousand years later and developed independently. Farming further south in the Yangtze valley, using rice and clearing ground through the swidden system, was known by shortly after 5000 BC and again was soon followed by the development of small villages. China was not the only area of the world where rice was domesticated. It seems to have been subject to multiple domestication (of more than one type) in India and across south-east Asia in a broad belt from the southern foothills of the
Himalayas through upper Burma, north Thailand to Vietnam and the far south of China.

Mesoamerica (an area that encompasses the modern states of Guatemala, Belize, parts of Honduras and San Salvador and, most important, Mexico south and east of 24°N) was the last of the three core areas to develop agriculture. Most of the evidence about the process comes from the highland areas of Mexico – Tehuacan and Oaxaca – where the climate is dry enough to preserve plant remains. As late as about 6000 BC (when agriculture was widespread in south-west Asia) the area was still occupied by groups dependent on a very wide variety of food sources. They hunted small game such as rabbit and deer, harvested nuts and beans and collected wild grasses, an early type of maize and various squashes. These groups still led a mobile life utilising seasonal resources and a wide variety of animals such as grasshoppers, snails, mice, lizards and snakes. During the dry season they lived in small groups but came together in larger groups of about a hundred in the wet season when food was more plentiful. About this time, or a little earlier, the first steps towards agriculture were taken, not with the cultivation of wild cereals but by creating small garden plots to grow a wide variety of plants that had previously been gathered from the wild (although the work involved in tending these plots did not involve them giving up their mobile way of life). About thirty plants were grown not just for food but also for dyes, medicines and (in the case of gourds) as containers. The list included chili peppers, tomatoes, avocados, papaya, guava, five types of squash, gourds and beans. Some of the earliest of these plants may have been domesticated about 7000 BC but many such as maguey, prickly pear and mesquite show no changes on domestication and so dating is particularly difficult. The uses of the plants also changed over time. Pumpkins were originally grown for their seeds but cultivation gradually changed their bitter flesh into a sweet, more palatable variety.

Development of full scale agriculture in Mesoamerica was delayed by two factors. The first was a lack of suitable animals for domestication. The geographical isolation of the Americas meant that unlike Europe and Asia there were no sheep, goats or cattle. This meant that hunting animals remained a vital activity in order to provide sufficient meat in the diet. Of even greater importance though was the role of maize, the main grain to be domesticated. The exact origins of maize are still a matter of great dispute, especially its relationship to a wild grass called teosinte. It may be descended from teosinte, or from a different but unknown ancestor, or it may be of hybrid origin possibly involving teosinte. Maize was being cultivated from about 5000 BC but it was still a very small grain. The earliest cobs were no bigger than a human thumb and for at least 2000 years they were chewed rather than being ground into flour. For genetic reasons it was difficult to cross maize with other wild grasses and produce better, higher yielding varieties. The earliest cultivated maize was virtually identical with wild material and was only slightly bigger in size because of better growing conditions. Not until about 2000 BC were the first higher-yielding varieties developed and modern maize cobs are about seven times the size of the earliest domesticated varieties. This low productivity during the early stages of Mesoamerican agricultural development meant that for a long time it was more economic to gather food from wild plants than depend on maize. Even after 2000 years of domestication cultivated plants made up only about a quarter of the diet. Not until about 2000 BC was productivity great enough to support village life, which then developed fairly rapidly across Mesoamerica. But this long transition to settled communities had a profound effect on world history. It meant that the evolution of complex societies in Mesoamerica began some 4000 years after Europe and Asia. Thus when the first Europeans arrived in the Americas in the sixteenth century they found a society that was in many ways comparable to those of Mesopotamia in about 2000 BC.

A subsidiary area to Mesoamerica in the development of agriculture was Peru which, in archaeological terms, includes large parts of present day Bolivia and Ecuador. Maize spread south from Mesoamerica to reach the Andean highlands about 1000 BC and the coastal regions about 150 years later. Other plants such as chili peppers and beans were domesticated in both areas but from different wild progenitors. A major
Peruvian crop, which was unique to the Andean highlands until the sixteenth century AD, was the potato. The exact date of domestication is unknown but it could only have taken place when selection of tubers had reduced the naturally high, poisonous, glycoalkaloid levels. Selection of wild tubers for greater size is likely to have helped. In the Andean highlands the potato was the central element in a food complex that included oca, ulluco, anu, and a grain – quinoa.

The development of agriculture in other parts of the world is much more difficult to trace, partly because far less archaeological investigation has been carried out but also due to the fact that plant remains are not well preserved in the sites and because many of the plants show few changes when domesticated. Domestication of roots and tubers may well have taken place in south-east Asia and New Guinea by about 7000 BC using taro and yams, which would have needed little more than the cultivation of wild varieties in specially tended-plots. Taro and yams formed the basis for agriculture in this area and were normally combined with other plants such as breadfruit, bamboo, coconut, bananas and sago and associated with animals such as poultry and pigs, which were independently domesticated in the region. This agricultural complex also formed the agricultural basis for the Polynesian people as they spread out across the Pacific. Yams were also domesticated in the tropical areas of west Africa but the date is unclear. In the period between 7000–3000 BC the lowlands east of the Andes produced a different tropical complex from the plants available in the area – manioc, sweet potato and arrowroot (and possibly peanut). These then spread into other tropical areas of south and central America and the Caribbean.

By about 2000 BC all the major crops and animals that make up the contemporary agricultural systems of the world had been domesticated. However, for thousands of years there were separate streams of agricultural development as a result of lack of contact between Eurasia and the Americas and even between different parts of Europe and Asia. Then, in two waves, the various separate systems were brought together. From the seventh century AD Islamic traders brought many of the semi-tropical crops of south-east Asia to the Near East and the Mediterranean. Then, much later, in the sixteenth century American crops were brought to Europe (and eventually Asia) and European plants and animals were taken to the Americas and Australasia.

The adoption of agriculture was the most fundamental change in human history. Not only did it produce settled societies for the first time, it also radically changed society itself. Gathering and hunting groups were essentially egalitarian, but sedentary communities, almost from the beginning, resulted in increasing specialisation within society and the emergence of religious, political and military elites and a state with the power to direct the rest of society. At the root of these social
changes was a new attitude to the ownership of food. Gathering and hunting groups generally regard plants and animals not as things ‘owned’ by individuals but as available to all. Plants and animals are taken from the wild and there are normally strong social conventions on how food must be shared between all members of the group. Agriculture introduced the idea of ownership of food either by individuals or larger organisations. The move to growing crops in fields and the practice of herding and breeding flocks of animals opened the way to viewing the resources used and the food produced as ‘property’ and the far greater degree of time and effort involved compared with gathering and hunting encouraged this trend.

The main advantage of agriculture as opposed to gathering and hunting is that in return for greater effort it enables a much higher output of food to be obtained from a smaller area. Once that greater effort has been made there is normally a surplus of food over and above the immediate requirements of the cultivator’s family. This surplus can then be used to support and feed individuals not engaged in the production of food. The first non-farmers were probably craftsmen producing pottery, tools and other specialised items for the community. But ruling groups, probably religious at first and then political, took over the distribution functions. Societies emerged with large administrative, religious and military elites able to enforce the collection of food from peasant farmers and organise its distribution to other parts of society. In parallel, unequal ownership of land, and therefore of food, rapidly emerged.

In its broadest sense human history in the 8,000 years or so since the emergence of settled agricultural societies has been about the acquisition and distribution of the surplus food production and the uses to which it has been put. The size of the surplus available to a particular society has determined the number and extent of other functions – religious, military, industrial, administrative and cultural – that the society can support. Without a food surplus it would be impossible to feed priests, an army, industrial workers, administrators and intellectuals. The link may have been more obvious in earlier, simpler societies but it is still present in contemporary societies. In medieval Europe, and many other feudal and quasi-feudal societies, there was a direct relationship between the amount of land owned and the provision of military service and the church obtained food either through the direct ownership of land or through the extraction of tithes. The redistribution of food has occurred both within individual societies and between societies. All societies have to have a mechanism for the allocation of the food surplus to non-farmers. This may be through direct ownership of land by rulers, elites and religious organisations, as in most pre-industrial societies, a market mechanism (aided by huge subsidies); as in modern western industrialised countries, religious mechanisms, probably backed up by the threat of force, as in many ancient societies; or by the use of naked force as the Soviet Union demonstrated in the early 1930s during the collectivisation and industrialisation drives. The development of larger states and empires made it possible to extract a surplus of food from dependent territories by inducing them, by various means, to grow crops intended for the dominant power. The Roman empire achieved this in the Mediterranean region by turning Egypt and North Africa into grain producing areas for Italy and Rome in particular. European states carried out much the same policy from the sixteenth century in their colonial territories and spheres of influence by introducing new crops and production methods and making the dependent territories turn from subsistence farming to large scale production for the European market.

The development of widespread and effective mechanisms for the extraction of surplus took time to emerge. The first settled communities in south-west Asia, China and Mesoamerica were small villages made up almost entirely of peasant farmers with only a limited amount of specialisation. But the pressure of rising population, which had slowly forced the adoption of more intensive food production did not cease with the evolution of agriculture and settled communities; indeed it intensified. This forced the development of even more intensive forms of food production from less favourable environments as groups of people were edged into even more marginal areas.

The earliest agriculture in south-west Asia was dry farming – it depended on rainfall for crop production. The emergence of irrigation, about 5500 BC in south-west Khuzistan (on the eastern fringes of Mesopotamia), is another illustration of the same combination of pressures that produced agriculture. The advantage of irrigation is that in return for even more effort than dry farming (in digging and maintaining irrigation channels) it enables a higher output of food to be obtained from an even smaller area. Between 7000 and 6000 BC the agricultural population of south-west Asia was confined primarily to the highland zone but in the next thousand years or so population seems to have increased rapidly so that nearly every area suitable for dry farming was occupied. It was at this point that some communities were forced to exploit the more difficult environment of Mesopotamia – an area lacking adequate rainfall, stone and timber and which required the
The adoption of irrigation techniques. At first, settlement was confined to the easily worked areas of northern Mesopotamia and only slowly did it move into southern areas where more extensive irrigation works were necessary. The land was initially fertile and produced abundant crops and high levels of surplus food. However only a small part of the available land could be irrigated because of technical problems in building and maintaining the canals and therefore considerable organisation and control was required to ensure the most productive use of limited resources. As population continued to rise, settlements became more dense because of the limited room available for expansion. All of these factors had important effects on developments in Mesopotamia.

In the period after 5000 BC Mesopotamia was occupied by communities with a fairly uniform culture; people established settlements along river banks so that irrigation was confined to relatively small scale, simple schemes. These settlements were nearly all small towns or villages scattered at roughly equal distances across the landscape. Although agriculture was vital for basic subsistence, hunting and fishing in the surrounding marshes were still important sources of supplementary foods. Archaeological investigation of the very earliest towns has revealed a considerable degree of internal social organisation from the beginning of settlement in the area. Nearly all had large temples as the focus of urban life and they played a fundamental part in the redistribution of resources among farmers, the religious elite and specialist craftsmen, by controlling food production and distributing rations to all members of the community. An intensification of this process of developing control within society took place in the south of Mesopotamia from about 4500 BC. At Uruk huge temples were constructed (including one 225 feet long, 200 feet wide and 40 feet high) and they were regularly rebuilt. This would have required the organisation of large amounts of labour and illustrates the degree of control already exercised by the main religious organisations. By 3500 BC Uruk was already a substantial ceremonial centre with only small settlements in the surrounding region. Five hundred years later the population of Uruk had grown rapidly to about 50,000 and the number of local settlements had fallen from 146 to 24 in what appears to have been a process of increasing political control and forced resettlement in the chief town of the area. Similar processes, though on a less drastic scale, can be detected at other cities in the region such as Ur, Kish, Lagash and Umma, all of which had populations of about 10-20,000. In parallel with this major burst of urbanisation, irrigation works became more extensive, complex and remote from the rivers; canals were built over large areas which had no natural watercourses in order to increase the area available for food production as population continued to grow.

By about 3000 BC the southern area of Mesopotamia known as Sumer was dominated by eight large cities. Within these cities major social changes were taking place. Producing a surplus of food involves far more than merely growing an excess above the needs of the cultivator. The surplus has to be transported, stored and re-allocated and this requires institutions able to organise the process. Control of the surplus also involves determining who owns and works the land and who has rights to the food. From the start the temple played a key role in the organisation of society in Mesopotamia. In the earliest settlements the temple seems to have owned all the land and its priests and administrators were responsible for collecting food, storing it and then distributing it, often in uniform rations. Other agricultural resources were also held centrally – at Shuruppak the temple owned and accounted for 9,660 donkeys – and ploughing was organised through labour gangs. The amount of power wielded by the religious elite was not static and large scale feedback mechanisms operated. Those in authority sought to increase control and extract a greater surplus and achieve more power through their ability to direct more resources. A bigger surplus created the ability to maintain more non-farmers, and the longer this process continued the greater the degree of social differentiation until separate classes with markedly different access to wealth and power emerged.
This more powerful state structure offered religious benefits in return for the bulk of the population providing food, labour and eventually military service as the rivalry between the city states mounted.

Within the cities of Sumer, by about 3000 BC, strongly stratified class societies had developed: there were slaves at the bottom of the hierarchy, the bulk of the population were peasant farmers and above were craftsmen and then an administrative, religious and military elite. Growing rivalry between the cities led to increasing militarism, fortifications and the organisation of militias. Uruk built a huge city wall about six miles in circumference, twelve to fifteen feet thick with large defensive towers. The increasing importance of war led to the emergence of temporary military leaders, who rapidly transformed themselves into permanent, hereditary, secular rulers. Large palaces with staffs of several thousand (plus large numbers of slaves) rose alongside and then replaced the temples as the main buildings in the city. The increased importance of warfare reinforced trends to greater internal control and direction over society. By about 2500 BC, land was owned not by the temple or the city but by private individuals, thereby completing the full development of a class society with ruling families wielding political power and controlling large estates with their dependent labour force. At a later stage, by 1800 BC when southern Mesopotamia was part of the Babylonian empire, there were legally separate classes of nobles, commoners and slaves.

In parallel with these developments, and increasing the pressure for greater specialisation and stratification within society, were a number of technological advances which occurred in the early stages of the settlement of Mesopotamia. Smelting of copper had begun in Anatolia shortly before 6000 BC and was in use in Mesopotamia about a thousand years later, and the wheel was first developed for making pottery about 4500 BC. Both of these new processes required trained specialists, who had to be fed by other members of society. Although metal tools were more durable than stone tools, they were not much more effective and much of the earliest metal work took the form of luxury items for the elite. The wheel was soon adapted for vehicles drawn by domesticated animals. But the most important development of all was the invention of writing, stimulated by the need to keep accounts in the temples of all the complex transactions involved in obtaining, storing and redistributing the food surplus. The first baked clay tablets using a fully developed script come from the Eanna sacred precinct in Uruk, where over 4,000 have been found dating from about 3100 BC. They form part of the temple’s administrative archives and 85 per cent of them deal with economic matters such as allocating resources for agriculture and providing food to the population in what appears to be a fairly strict rationing system. These tablets illustrate once again the overwhelming importance of centralised controls within a society attempting to wrest subsistence from a difficult environment.

The first steps towards stratified, hierarchical societies with a large degree of state control were taken in Mesopotamia from about 5000 BC. Similar but independent developments took place in Egypt, only slightly later than in Mesopotamia, and then were repeated in the Indus valley, China, Mesoamerica and Peru. Like Mesopotamia, the Nile valley was not one of the original core areas for the domestication of plants and animals: both took over the agricultural system that had evolved in south-west Asia and adapted it to meet their local conditions. The Nile valley had been occupied by gathering and hunting groups existing on a plentiful supply of wild foods and game for some 20,000 years before the first agricultural settlements appeared about 5500 BC. Agriculture based on sheep, cattle and emmer wheat had been well established in North Africa for hundreds of years before farmers moved into the Nile valley. The long, narrow and fertile valley provided an excellent environment for agriculture – much better than Mesopotamia. The annual flood came at the right time of the year for crop growing and was normally sufficient to provide a crop over two-thirds of the immediate valley area. Artificial irrigation was only necessary on a small scale and this could be accomplished by dredging the river’s natural overflow channels, making small breaches in natural levees and creating small earth dams to retain water. These measures helped even out a very variable natural flood level, retained water in basins for later use, and allowed planting on newly irrigated ground at the edge of the flood plain and the cultivation of a second crop in intensive garden plots.

Egypt developed in different ways from Mesopotamia. The easier environment and the lower intensity of irrigation meant that there was less pressure on land compared with Mesopotamia and therefore highly structured cities did not emerge. The two great Egyptian cities of Memphis and Karnak-Luxor were essentially local markets, cult centres and the residence of officials rather than populous cities on the scale of Uruk (which had a resident population of nearly 50,000). Most Egyptians were peasants living in villages and the system for regulating the annual Nile flood remained a local rather than a central state responsibility. Nevertheless an elite class of priests, administrators,
warriors and rulers did emerge, as in Mesopotamia, through the appropriation of the agricultural surplus. This strongly centralised political superstructure continued though to rely on a much more decentralised administration of agriculture and flood control based on the ancient nomes or divisions of the valley. The unification of Egypt into a single state is conventionally dated to about 2950 BC and the emergence of the First Dynasty. This is roughly contemporary with the period in Mesopotamia when secular rulers had become dominant, although Egypt was probably unified for about ten rulers before the First Dynasty. This dynasty seems a radically new departure only because it is contemporary with the emergence of writing, invented independently of Mesopotamia and a few hundred years later. Here too the function of writing was essentially administrative – allocating resources and food – and it did not feature in a continuous text for another 300 years.

The Indus valley was settled by migrating farmers, almost certainly moving eastwards from south-west Asia, about 3500 BC, cultivating wheat and barley in the comparatively dry climate of the area and relying on domesticated sheep and goats together with a few humped cattle. As in Egypt the water control system was essentially small scale but the appropriation of the food surplus to feed non-producers led to the emergence of a highly stratified society by about 2500 BC. The main characteristic of Indus valley society was its cultural uniformity over a very wide area. There is little evidence of the sort of organic growth of settlements and the evolution of cities that took place in Mesopotamia. The two main cities – Harappa and Mohenjo-Daro – though nearly 400 miles apart were built to similar plans and were dominated by huge citadels (1,200 feet long and 600 feet wide built on artificial platforms 40 feet above the flood plain) where all the major public buildings were situated. All of the cities had large central granaries for the storage and redistribution of food. It is not known whether the central authority in society was religious or secular but what is clear is that it was authoritarian and capable of mobilising a large amount of labour and imposing a more rigid uniformity across a bigger area than the first two complex societies to emerge in the world.

The development of such societies in China was a much slower process than in Mesopotamia, Egypt and the Indus valley. The exact reasons are not clear but they may be linked to the slow development of irrigation systems and consequently the longer period before substantial food surpluses emerged. The precise sequences and chronology of early Chinese cultures is difficult to establish. The earliest farming communities following the domestication of millet about 6000 BC were small villages of about 200 people with only very limited social stratification and the farmers followed a swidden system of cultivation, clearing fields for a few years and then abandoning them when fertility levels declined. As population grew and the amount of unused land declined, settlements became permanent with farmers adopting a form of rotation and fallowing in an attempt to maintain fertility. The use of the potter’s wheel and other craft techniques led slowly towards a more stratified society. Irrigation though remained on a very small scale and millet was still a far more important crop than either wheat or rice. The first urban, stratified society emerged from this background about 1750 BC at the beginning of the Shang period when the whole of the north China plain came under a single secular ruler. In the two main cities – Cheng-Chou and An-Yang – a central ceremonial and administrative area was surrounded by a massive defensive earth wall. Unlike Mesopotamia secular rulers appear to have dominated from the beginning of settled communities although they were strongly supported by the religious elite whose functions helped to integrate society. Both written records and archaeological investigations confirm that the Shang period saw the development of distinct classes. Burials show a huge range in wealth between different parts of society and while the rulers lived in large palaces the peasants lived in semi-subterranean huts. Like similar complex societies in Mesopotamia, Egypt and the Indus valley there were central mechanisms for storing grain (in this case in huge pits) and redistributing it. There was also strong central control of labour not just for agriculture but also for other state work such as constructing palaces and temples.

The development of a highly organised society in Japan came extremely late in world terms. Japan was partly dependent on external developments in China but the history of its social changes clearly demonstrates how changes in food production were necessary preliminaries for the emergence of stratified, specialised societies. Although hand-pressed pottery making began about 10,000 BC (the earliest in the world), for a long period settlements were small, about fifteen huts, with the population dependent on hunting deer and pigs and on fishing. Not until about 1400 BC did the Japanese begin to cultivate their first crops (barley and rice, probably from Korea, which itself obtained them from China). However the scope for farming on a large scale in Japan was limited because over three-quarters of the land was unsuitable for cultivation. In its earliest form agriculture, as in many other areas of the world, was based on a swidden system and population...
densities were low. Animals played little part because the shortage of land meant that priority had to be given to crop production and fish remained a major source of protein. Not until rice became the main basis for subsistence in north Kyushu about 300 BC and spread gradually over the whole of the western half of Japan was there a basis for higher levels of food production. Increased food supply brought more craft specialisation including pottery (now made using wheels) and bronze production. With more intensive cultivation a more complex society could be supported yet development remained slow until the emergence of a recognisable Japanese state after the adoption of writing, introduced from China in the sixth century AD.

In the Americas the historical development of this type of society was heavily influenced by a number of environmental factors. The difficulty, for genetic reasons, in producing high-yielding varieties of maize compared with the relative ease with which domesticated wheat and barley could be crossed with other types to improve output, meant that settled communities did not emerge in Mesoamerica till about 2000 BC. The Americas also lacked animals suitable for domestication (apart from the llama and the alpaca in Peru). Although the principle of the wheel was known it was not developed for transport because there were no draught animals available. Metal working was also restricted mainly to gold and silver goods for the elite because of the lack of easily worked deposits and stone tools remained the norm until the European conquest. Despite these handicaps, sophisticated, hierarchical societies did develop and achieve significant, cultural progress equal to, and in some areas in advance of, developments in similar societies elsewhere in the world. Indeed the astronomical knowledge and calendrical systems of the Maya in the sixth to eighth centuries AD were probably the most advanced in the world at that time.

The development of more productive varieties of maize about 2000 BC was the basis for the first settled Mesoamerican communities. These were still small and people depended for part of their food on gathering from the wild and hunting. Within a thousand years the first small towns and ceremonial centres emerged as maize became an increasingly important part of the diet. As in Mesopotamia, huge temples were a feature of these settlements from the start and they acted as centres for redistributing the food surplus to a growing number of craftsmen, priests and administrators. Large ceremonial centres developed such as La Venta on the Gulf coast of Mexico (a major Olmec site) with pyramids 400 feet long, 200 feet wide and 100 feet high. Such ambitious architectural projects would have involved the direction of vast quantities of human labour. The pace of development was heavily influenced by a further leap in the productivity of maize about 400–300 BC when the length of the cob doubled. This formed the basis for the huge increase in social complexity and organisation found in the Classic Period in Mesoamerica lasting from 300–900 AD.

The centre of this development was the city of Teotihuacan. Situated in the valley of Mexico, it covered an area of about ten square miles with a population of about 100,000 and with its enormous pyramids, ceremonial avenues and large plazas was far grander in conception than any city in Mesopotamia. Its rise illustrates yet again the way in which increases in food production led to highly structured societies organised around strong central institutions responsible for food production and distribution. The city was highly planned, there was no clear distinction between political and religious authority and the population lived in strictly separate areas. The elite lived near the temples and the adjacent parts were occupied by craftsmen and traders making or dealing in goods for the elite. Large numbers of peasants lived in densely settled compounds, probably organised on a clan basis, within the city. The highly concentrated population was supplied with food (fruit and vegetables as well as the ubiquitous maize) from diverse sources. Irrigation in the valley and a system of highly productive chinampas, or ‘floating’ gardens, in the swamps and on the lakes, provided a highly intensive system of agriculture. Further away from the city, but still under its political control, more peasants produced yet more food from the terraced hillsides in a semi-intensive system while on the borders of the territory farmers still relied on low-intensity swidden agriculture. The overwhelming impression of Teotihuacan is one of an immense central power able to develop and dominate a highly unified city and also enjoying strong powers of direction over the whole of a rigidly organised society. The Teotihuacan empire, which, at its height, influenced all of Mesoamerica, collapsed about 700 AD. It was replaced, in much the same way as Sumer was conquered by the Akkadians, by the military empire of the Toltecs based on Tula (also in the valley of Mexico) and they in their turn were supplanted by the Aztecs with their capital at Tenochtitlan (the current Mexico City). These later societies were dependent on the same sort of agricultural base, especially the chinampas, and structurally, apart from their greater military element, were remarkably similar to Teotihuacan and exercised equally strong central control.

The way in which, across the world, increasing food production and growing population gradually gave rise to more highly organised
societies is illustrated on a smaller scale in the islands of Hawaii. Because the islands were settled comparatively late, social developments were still at an early stage when the first Europeans arrived in the eighteenth century and wrote accounts of what was happening, noting down oral traditions about the recent past. These accounts give an idea of how other societies in the world might have developed in their early stages. The Hawaiian islands were first settled about 500 AD by the Polynesians, probably by a group no more than fifty strong. They brought with them the normal Polynesian social organisation based on hereditary chiefs who monopolised religious rituals and received offerings from those under their authority. In Hawaii it was the position of the chiefs that was to change as numbers rose and society became more complex. By about 1100 all the islands in the group had been settled, although the villages were almost entirely confined to the coasts, and the population had grown to about 20,000. But society remained simple and largely unstratified. The situation began to change after 1700 with a more rapid rate of population growth, accompanied by the expansion of settlement inland, so that by about 1400 all the available land on the islands had been taken up and had come under the control of the various chiefs. This situation produced major social problems. In the past, conflict within chiefly lineages had been resolved by younger sons splitting off from the main group and setting up their own groups in the unsettled areas. This was no longer possible and so conflict increased, with disgruntled members of the chiefly families leading revolts of commoners.

The response to these growing social and political problems, exacerbated by crop failures as agriculture was forced on to ever more marginal land as numbers rose to around 300,000 by the end of the eighteenth century, was increasing central control. By about 1440 on the island of O‘ahu individual chiefdoms were replaced by a single ruler and other islands rapidly followed the same path. This central, political control brought social changes as the chiefs drew further away from the rest of society (marrying only into the families of chiefs from other islands), enforced tribute to themselves rather than the traditional gods, took over what had previously been commonly-held land and made the peasants into their tenants. Warfare broke out as chiefs tried to control more territory so as to exact more tribute. The result was growing inter-island warfare until in 1795 the islands were conquered and united under a single ruler. Not long afterwards the society and culture of the islands began to disintegrate as Europeans started to exploit the Pacific.

The development of agriculture, bringing with it intensive forms of food production and settled societies, had essentially the same effect all over the world. Surplus food was used to feed a growing religious and political elite and a class of craftsmen whose main role was to supply and service that elite. The redistribution of surplus food required extensive control mechanisms for transport, storage and reissue leading to powerful central institutions within society. These processes became self-enforcing as the elites with political and social power took an ever greater degree of control and imposed greater discipline through enforced labour and service, first in labour gangs for major social projects such as temples or irrigation works and then in the rapidly growing armies. Societies that were broadly egalitarian were replaced by ones with distinct classes and huge differences in wealth. These changes had two further consequences of great significance, one generally seen as positive and the other as negative, but both have helped to shape the rest of human history.

The development of organised societies and the increasing ability, as agriculture became more productive, to support a growing number of people not engaged in the direct production of food formed the basis for all subsequent human cultural and scientific advances. The demands of the religious and secular elites produced the great temples, palaces, state buildings, theatres and other structures that make up the great ancient sites of the world and are the main memorials of past societies. At the same time, craftsmen produced exquisite works of art that are still admired. Settled societies also made possible the great developments in religious and spiritual thought. Gathering and hunting groups, certainly in their later stages, seem to have had systems of religious belief to integrate humans into their environment — as is still the case with the Aborigines of Australia for instance. Indeed religion acted as one of the main motivating and organising forces behind the development of complex societies, particularly in areas like Mesopotamia, as humans moved to exploit new and difficult environments. The development of writing and its evolution into the highly flexible modern scripts was fundamental for all the later advances in human knowledge. The earliest societies also quickly developed extensive astronomical knowledge, notably among the Babylonians and the Maya and many sites from Mesoamerica to China and bronze age Britain are aligned towards significant solar, stellar and lunar positions. None of the major human cultural and intellectual achievements would have been possible without the development of agriculture, and a food surplus capable of supporting artists, builders, architects, priests, philosophers and scientists.
The other side of the coin is the parallel development of increasing coercion within society and warfare. The great buildings and monuments of ancient societies could only be constructed using huge amounts of human labour. The ability to mobilise labour on this scale demonstrates very clearly the enormous power and authority wielded by the religious and secular elites. Although there may have been, particularly in the early phases of organised societies, a degree of voluntary participation in a common endeavour, this was replaced fairly rapidly by coercion. One of the reasons why internal organisation and discipline within society grew was the developing external threat and increasing warfare. The place of warfare in the earliest phases of human history is controversial but there is evidence of fighting between gathering and hunting groups about 20,000 years ago with the development of the bow and arrow, a far more effective weapon than the spear. Some of the cave paintings in France and Spain from the last glaciation appear to show humans under attack and evidence from cemetery 117 at Jebel Sahaba in Nubia from the pre-neolithic Qadan culture gives an idea of what this sort of fighting might have involved. Of the fifty nine burials over forty per cent had extensive wounds caused by arrowheads and one young adult female was found with twenty-one arrowheads in her body including several shot into the mouth.

The development of settled societies undoubtedly increased the reasons and the potential for warfare by instituting defined territories and clear ownership of resources. From the start the earliest settled communities had to defend themselves. By about 7500 BC Jericho was surrounded by a wall almost half a mile long, ten feet thick and over thirteen feet high, with a least one tower thirty-three feet in diameter and twenty-eight feet high. Çatal Hüyük in Anatolia was built as a series of interconnected houses with common walls accessible only through a hole in the roof and a series of blank walls facing outwards from the village to provide some protection. Hacilar was constructed on similar principles with an outside wall as well. Societies rapidly became militarised and formed their own armies. In pre-dynastic Egypt there was continual warfare between the cities and the unification of upper and lower Egypt was accomplished by force. In Mesopotamia battles between Lagash and Umma lasted for 150 years over a dispute about fields along the boundary between the two cities. The development of metal technologies was quickly followed by the use of metal battle axes, arrowheads, shields and helmets. The invention of the wheel led to the development of the chariot about 2800 BC in Mesopotamia, originally drawn by asses until the domestication of the horse.

Armies and militias increased in size and by 1285 BC Egypt was able to deploy an army 20,000 strong (larger than many in Europe before the eighteenth century) at the battle of Kadesh. The development of new weapons, first used by the Assyrians in the early part of the first millennium BC, only increased these trends towards more destructive and extensive warfare. It frequently involved mass killing and the destruction of crops, animals, villages and cities. In the 300 years of the militaristic Assyrian empire about four-and-a-half million people were forcibly deported in the Near East in an attempt to establish political control. Such inhumanity was easily exceeded by the gruesome record of the Aztecs of Mesoamerica, who ritually slaughtered huge numbers of prisoners of war (sometimes 20,000 at a time) by ripping out their still beating hearts on the steps of the great temple at Tenochtitlan.

By about 3000 BC in Mesopotamia and Egypt, a few hundred years later in the Indus valley, a millennium or so later in China and another two millennia later in the Americas, hierarchical, militaristic societies ruled by religious and political elites with immense powers of control over their populations were established. Despite the development of more sophisticated metal technologies in Eurasia there was no fundamental change in the human way of life for several thousand years. The overwhelming mass of the population remained peasants, landless labourers or slaves, and subject to extensive expropriation of their produce, forced labour and the risks of highly destructive warfare. Only a very small minority within each society could be supported in a more affluent or more intellectually rewarding, style of life. Various states and empires rose and fell (often as a result of changing fortunes in warfare, revolts or the unexpected deaths of rulers but also because of important changes in their vital agricultural base) without fundamentally altering this way of life.

Despite the variations in cultural achievements, none of these empires and states altered the way in which humans obtained their subsistence once settled agriculture had been adopted. Nevertheless their impact on their immediate environment was often far-reaching. They provide the first examples of intensive human alteration of the environment and of their major destructive impact. They also provide the first examples of societies that so damaged the environment as to bring about their own collapse.
5

DESTRUCTION AND SURVIVAL

The adoption of agriculture, combined with its two major consequences – settled communities and a steadily rising population, placed an increasing strain on the environment. That strain was localised at first but as agriculture spread so did its effects. Some areas such as the temperate forest ecosystem of north and west Europe with its moderate temperatures, high rainfall and rich soils, were able to withstand the strain reasonably well. Other areas, with more easily damaged ecosystems and with a higher population density began to be affected within a thousand years of the adoption of agriculture and a settled way of life.

Agriculture involves clearing the natural ecosystem in order to create an artificial habitat where humans can grow the plants and stock the animals they want. The natural balances and inherent stability of the original ecosystem are thereby destroyed. Instead of a variety of plants and permanent natural ground cover a small number of crops make only part-time use of the space available. The soil is exposed to the wind and rain to a far greater extent than before, particularly where fields are left bare for part of the year, leading to much higher rates of soil erosion than under natural ecosystems. Nutrient recycling processes are also disrupted and extra inputs in the form of manures or fertilizers are, therefore, required if soil fertility is to be maintained. The adoption of irrigation is even more disruptive since it creates an environment that is even more artificial than dry farming, which relies on rainfall. Adding large amounts of water to a poor soil may allow the farmer to grow his preferred crop but it can have catastrophic longer term effects. The extra water drains into the underlying water table and will, over differing lengths of time depending on local conditions, cause water levels to rise until the soil becomes waterlogged. The additional water also alters the mineral content of the soil: it increases the amount of salt, and may eventually, especially in hot areas with high evaporation rates, produce a thick layer of salt on the surface which makes agriculture impossible. The only way in which this process can be avoided is by very careful use of irrigation, not overwatering, and leaving the ground fallow for long periods.

The spread of sedentary societies also increased pressures on the environment in other ways. The overall impact of gathering and hunting groups, with their mobile way of life and low level of demand for goods, had been light and comparatively diffuse. But the emergence of villages and towns (and an increasing population) meant that the demand for resources was now more concentrated, and efforts to increase supply would inevitably impose significantly greater strains on smaller areas. New demands arose, especially for construction materials for permanent houses and also for new and more varied goods. Forests suffered most as the requirement for wood to build houses, heat homes and cook food rose steadily. Local deforestation leading to increased soil erosion became a problem around settled areas. Recent evidence from central Jordan suggests that as early as 6000 BC, within about a thousand years of the emergence of settled communities, villages were being abandoned as soil erosion caused by deforestation resulted in a badly damaged landscape, declining crop yields and eventually inability to grow enough food.

The creation of artificial environments to grow food and the rise of communities not only concentrated the environmental impact of human activities but also meant that it was far more difficult for human societies to escape the consequences of their actions. In particularly sensitive ecosystems and where the impact of human modifications to the environment was particularly concentrated in its effects, the foundations of society could be so damaged as to cause its collapse. These early societies were dependent on the production of a food surplus in order to feed and support the growing number of priests, rulers, bureaucrats, soldiers and craftsmen. If food production became more difficult and crop yields fell, and with them the surplus available for distribution within society, then the very basis of the early city states and empires was undermined. It is perhaps not surprising that the first signs of widespread damage emerged in Mesopotamia, the area where the most extensive modifications to the natural environment had first been made.

When, in 1936, one of the excavators of the earliest cities of Sumer, Leonard Woolley, wrote a book about his work entitled Ur of the Chaldees he was puzzled by the desolate, largely treeless landscape of contemporary southern Mesopotamia.
‘Only to those who have seen the Mesopotamian desert will the evocation of the ancient world seem well-nigh incredible, so complete is the contrast between past and present... it is yet more difficult to realise, that the blank waste ever blossomed, bore fruit for the sustenance of a busy world. Why, if Ur was an empire's capital, if Sumer was once a vast granary, has the population dwindled to nothing, the very soil lost its virtue?’

The answer to Woolley's question is that the Sumerians themselves destroyed the world they had created so painstakingly out of the difficult environment of southern Mesopotamia.

The valley of the twin rivers, the Tigris and Euphrates, posed major problems for any society, especially in the south. The rivers were at their highest in the spring following the melting of the winter snows near their sources and at their lowest between August and October, the time when the newly planted crops needed the most water. In the north of Mesopotamia the problem was eased by the late autumn and winter rains but rainfall was very low, and often non-existent further south. This meant that in the Sumerian region water storage and irrigation were essential if crops were to be grown. However, a combination of local conditions meant that these processes involved both costs and benefits. At first the advantages would have outweighed the disadvantages but slowly a series of major problems would have become apparent. In summer, temperatures were high, often up to 40°C, which increased evaporation from the surface and as a consequence the amount of salt in the soil. Water retention in the deeper layers of the soil and hence the risk of waterlogging was increased by two factors. The soil itself had very low permeability. This was exacerbated by the slow rate of drainage caused by the very flat land, itself made worse by the amount of silt coming down in the rivers, probably caused by deforestation in the highlands, which added about five feet of silt every millennium and caused the delta of the two rivers to extend by about fifteen miles a millennium. As the land became more waterlogged and the water table rose, more salt was brought to the surface where the high evaporation rates produced a thick layer of salt. Modern agricultural knowledge suggests that the only way to avoid the worst of these problems is to leave land fallow and unwatered for long periods to allow the level of the water table to fall. The internal pressures within Sumerian society made this impossible and brought about disaster. The limited amount of land that could be irrigated, rising population, the need to feed more bureaucrats and soldiers and the mounting competition between the city states all increased the pressure to intensify the agricultural system. The overwhelming requirement to grow more food meant that it was impossible to leave land fallow for long periods. Short-term demands outweighed any considerations of the need for long-term stability and the maintenance of a sustainable agricultural system.

About 3000 BC Sumerian society became the first literate society in the world. The detailed administrative records kept by the temples of the city states provide a record of the changes in the agricultural system and an insight into the development of major problems. In the Early Dynastic period, which lasted just over six hundred years until 2370 BC, the major city states—Kish, Uruk, Ur and Lagash—were militaristic, organised societies using the food surplus produced by irrigation to feed both the bureaucracies that ran the states and the armies with which they continually competed for domination of the area. All these states were dependent on their agricultural base for the large-scale production of wheat and barley and that was being slowly undermined by environmental degradation brought about by irrigation. About 3500 BC roughly equal amounts of wheat and barley were grown in southern Mesopotamia. But wheat can only tolerate a salt level of half a per cent in the soil whereas barley can still grow in twice this amount. The increasing salinisation of the soil can be deduced from the declining amount of wheat cultivated and its replacement by the more salt tolerant barley. By 2500 BC wheat had fallen to only 15 per cent of the crop; by 2100 BC wheat production and overall it had declined to just 2 per cent of the crops grown in the Sumerian region. By 2000 the cities of Isin and Larsa no longer grew wheat and by 1700 BC salt levels in the soil throughout the whole of southern Mesopotamia were so high that no wheat at all was grown.

Even more important than the replacement of wheat by barley was the declining yield from crops throughout the region. In the earlier phases of Sumerian society when areas went out of production because of salinisation they were replaced by newly cultivated fields. Rising population, and the demand for a greater food surplus to maintain an army as warfare became more frequent, reinforced the demand for new land. But the amount of new land that could be cultivated, even with the more extensive and complex irrigation works that were becoming common, was limited. Until about 2400 BC crop yields remained high, in some areas at least as high as in medieval Europe and possibly even higher. Then, as the limit of cultivable land was reached and salinisation took an increasing toll, the food surplus began to fall rapidly. Crop
yields fell 42 per cent between 2400 and 2100 BC and by 65 per cent by 1700 BC. Dating from 2000 BC there are contemporary reports of the earth turned white, a clear reference to the drastic impact of salination. The consequences for a society so dependent on a food surplus were predictable. The size of the bureaucracy, and perhaps even more important, of the army that could be fed and maintained, fell rapidly, making the state very vulnerable to external conquest. What is remarkable is the way that the political history of Sumer and its city states so closely follows the steady decline of the agricultural base. The independent city states survived until 2370 BC when the first external conqueror of the region – Sargon of Agade – established the Akkadian empire. That conquest is contemporary with the first serious decline in crop yields following widespread salination. For the next six hundred years the region saw the Akkadian empire conquered by the Guti nomads from the Zagros mountains, a brief revival of the region under the Third Dynasty of Ur between 2113–200 BC, its collapse under pressure from the Elamites in the west and Amorites in the east, and about 1800 BC the conquest of the area by the Babylonian kingdom centered on northern Mesopotamia. Throughout this period, from the end of the once flourishing and powerful city states to the Babylonian period, crop yields continued to fall making it very difficult to sustain a viable state. By 1800 BC, when yields were only about a third of the level obtained during the Early Dynastic period, the agricultural base of Sumer had effectively collapsed and the focus of Mesopotamian society shifted permanently to the north, where a succession of imperial states controlled the region, and Sumer declined into insignificance as an underpopulated, impoverished backwater of empire.

The artificial agricultural system that was the foundation of Sumerian civilisation was very fragile and in the end brought about its downfall. The later history of the region reinforces the point that all human interventions tend to degrade ecosystems and shows how easy it is to tip the balance towards destruction when the agricultural system is highly artificial, natural conditions are very difficult and the pressures for increased output are relentless. It also suggests that it is very difficult to redress the balance or reverse the process once it has started. Centuries later, when the city states of Sumer were no longer even a memory, the same processes were still at work in Mesopotamia. Between 1300–900 BC there was an agricultural collapse in the central area following salination as a result of too much irrigation. Around Baghdad in the seventh and eighth centuries AD, both before and after the Arab conquest, the area was flourishing with high crop yields from irrigated fields supporting a wealthy and sophisticated society. But the same pressures seem to have been apparent as in Sumer over 3,000 years earlier. To boost food production four major new irrigation canals were dug between the Tigris and Euphrates, which, in turn, led to waterlogging, a rapidly rising water table and salination. At this time the population of Mesopotamia was probably about one-and-a-half million but the agricultural collapse brought about through intensive irrigation and the Mongol conquest in the thirteenth century caused a massive decline in population to about 150,000 by 1500 and brought about the end of the sophisticated society that had survived in the area for centuries.

Many of the same forces that brought about the collapse of the first settled societies in Mesopotamia seem to have been at work in the Indus valley too, although it is not possible to identify the trends in such detail because the script used by the inhabitants has not been deciphered. As in Mesopotamia what was once a flourishing society and a rich and productive area has been turned into a desolate region through over-exploitation of a delicate environment. The complex, hierarchical, highly centralised society which emerged about 2500 BC lasted less than 500 years. The settlers in the Indus valley faced one major problem – the tendency of the river to flood over wide areas and change its course. Extensive works were built to contain the river and to irrigate the fields to produce the food that supported and fed the ruling elite, priests and the army. In the hot climate of the valley, irrigation would have had the same effect as in Sumer – raising the water table, increasing waterlogging, producing rapid salination of the soil and eventually a layer of salt on the surface, which would have led to the gradual decline of crop production.

The other factor undermining the environment of the Indus valley was deforestation. The area that attracted the first settlers was richly forested country with a plentiful supply of wildlife. Part of this forest was cleared to provide fields for agriculture. More important though was the construction technique used by the inhabitants. To build their huge temples and palaces Mesopotamian societies used mud bricks dried by the sun. The people of the Indus valley also used mud bricks but they dried them in ovens, and the process required enormous quantities of wood. Very rapidly the trees in the area were cut down. This exposed the soil to the elements and caused rapid erosion and decline in soil quality. About 1900 BC the Indus valley society came to a sudden end. The immediate cause was probably external conquest following a period of internal decline. The extent of the environmental
degradation through salinisation and deforestation suggests a substantial reduction in the available food surplus may have led to a reduction in the size of the army and increased vulnerability to external conquest—much in the same way that Sumer collapsed.

Extensive deforestation has been a problem for a number of societies throughout history. A larger human population put an increasing strain on local environments generally and in particular supplies of wood—the one readily available resource for heating, cooking and in many cases construction. Forests were cleared to make room for fields to feed the steadily growing number of people. It is the slow, steady, and in many ways unappreciated, destruction of the woods and forests around all settled communities that forms the backdrop to the development of human societies. These early societies lacked the technology for large-scale clearance but between them the metal axe, ring barking and fire would have been very effective ways of obtaining wood or clearing a section of the forest. No one generation would have been conscious of making any dramatic changes. Generally people seem to have accepted the process as a natural way of obtaining the resources needed. As settlements moved into new areas so the whole process of attrition would start again. There is little evidence of any attempt at major planting or replanting, although coppicing was practised in many parts of Europe as a way of obtaining a sustainable crop of wood. Over hundreds of generations the scale of destruction could be massive. Huge areas that had once been dense forests would become treeless or retain only isolated pockets of woodland in the least accessible places.

In China the development of agriculture and the rise of the first settled societies had been based on the cultivation of millet on the easily worked loess soils in the north of the country. Although the soil was rich it was very easily eroded once the natural grass cover had been removed in order to make way for fields of millet. Very rapidly huge gullies and canyons developed as the soil was blown away by the wind or washed away by the rain. At the same time hill slopes were cleared of trees for fuel and construction. Steadily the deforested area increased until, by about two hundred years ago, nearly all the original forests of China had been cleared. The wholesale loss of trees in the highlands of China was one of the main causes of the often disastrous flooding of the Yellow river (so-called because of the amount of soil it carried from erosion upstream), which regularly resulted in major changes of course by the river in the lowlands and huge loss of life. The same sequence of events can be seen in Japan. The scale of forest destruction, particularly following the great rebuilding of castles and towns at the beginning of the Tokugawa period (shortly after 1600 AD) was such that it led to the imposition of strict government controls in the form of licences for further tree felling. The same problems can be identified in the great medieval Christian kingdom of Ethiopia. The original centre of the state was in the northern area—Tigre and Eritrea. Continual deforestation produced a badly degraded environment of poor soils and eroded hilltops, some in such a ruined state that they could no longer support shrubs or even grass. By about 1000 AD the damage was so great that the local point of the state had to shift to the south and a new capital in the central highlands. However, the same process was repeated, again leading to major environmental damage in this area. Just how quickly and completely people could transform the area surrounding a new or expanding settlement is illustrated by what happened around Addis Ababa after it became the capital of Ethiopia in 1883. Within twenty years a zone stretching for 100 miles around the town had been devastated—stripped of its trees by charcoal burners producing fuel for the capital.

The effects of the steady and continual cutting down of trees can be seen at their clearest in the Mediterranean region. Modern visitors regard the landscape of olive trees, vines, low bushes and strongly scented herbs as one of the main attractions of the region. It is, however, the result of massive environmental degradation brought about not by the creation of an artificial system such as irrigation but by the relentless pressure of long-term settlement and growing population. The natural vegetation of the Mediterranean area was a mixed evergreen and deciduous forest of oaks, beech, pines and cedars. This forest was cleared bit by bit for a variety of reasons—to provide land for agriculture, fuel for cooking and heating, and construction materials for houses and ships. Other activities ensured that it did not regenerate. Overgrazing by sheep, cattle and particularly goats meant the young trees and shrubs were eaten before they could grow and mature. Gradually the flocks of animals reduced the vegetation to a low scrub of largely inedible plants. Removal of the tree cover, especially on steep slopes, led to large scale soil erosion which ruined agricultural land (already short of manure because the farmers practised transhumance, moving the flocks of animals to different areas for summer and winter) and the large amount of silt brought down in the rivers blocked water courses and caused large deltas and marshes to form at river mouths.

This process of long-term environmental decline can be traced around the Mediterranean and the Near East in every area. Overall it is now
estimated that no more than ten per cent of the original forests that once stretched from Morocco to Afghanistan even as late as 2000 BC still exist. One of the first areas to suffer was the hills of Lebanon and Syria. The natural climax forests here were particularly rich in cedars, and the cedars of Lebanon became famous throughout the ancient Near East for their height and straightness. They were prized by the states and empires of Mesopotamia as building materials and control of the area or trade with its rulers was a high priority. Later the cedars became one of the mainstays of Phoenician commerce and were traded over a wide area. Gradually the trees were cut down until the renowned cedars of Lebanon were reduced to a pathetic remnant in a few places – there are now just four small groves of cedars left in the region – maintained as a symbol of former glory.

In Greece the first signs of large-scale destruction began to appear about 650 BC as population rose and settlements expanded. The root of the problem here was overgrazing on the eighty per cent of the land that was unsuitable for cultivation. Although the Greeks were well aware of techniques for preserving soil such as the use of manuring to maintain the structure of the soil and of terracing to limit erosion on hillsides, the pressure from a continually rising population proved too great. The hills of Attica were stripped bare of trees within a couple of generations and by 350 in Athens the great reformer of the constitution, Solon, was arguing that cultivation on steep slopes should be banned because of the amount of soil being lost. A few decades later the tyrant of Athens, Pisistratus, introduced a bounty for farmers to plant olives, the only tree that would grow on the badly eroded land because it had roots strong enough to penetrate the underlying limestone rock. Many of the writers of ancient Greece such as Herodotus, Xenophon and Aristotle were aware of the problem but the most graphic description of the effects of deforestation and soil erosion was left by Plato in his Critias:

‘What now remains compared with what then existed is like the skeleton of a sick man, all the fat and soft earth having wasted away, and only the bare framework of the land being left. . . . there are some mountains which now have nothing but food for bees, but they had trees not very long ago . . . there were many lofty trees of cultivated species and . . . boundless pastureage for flocks. Moreover, it was enriched by the yearly rains from Zeus, which were not lost to it, as now, by flowing from the bare land into the sea; but the soil it had was deep, and therein it received the water, storing it up in the retentive loamy soil, and . . . provided all the various districts with abundant supplies of springwaters and streams, whereof the shrines still remain even now, at the spots where the fountains formerly existed.’

The same problems can be identified in Italy a few centuries later as population rose and Rome grew from a small city into the centre of an empire encompassing the Mediterranean and most of the Near East. About 300 BC Italy and Sicily were still well forested but the increasing demand for land and timber resulted in rapid deforestation. The inevitable consequence was much higher levels of soil erosion, and as the earth was carried down in the rivers, the gradual silting up of ports in the estuaries. The port of Paestum in southern Italy silted up completely and the town decayed while Ravenna lost its access to the sea. Ostia, the port of Rome, only survived by constructing new docks. Elsewhere large marshes developed around river mouths built with the soil eroded in the hills. The Pontine marshes were created about 200 BC in an area which had supported sixteen Volscian towns four hundred years earlier.

The creation of the Roman empire increased the pressure on the environment in other areas of the Mediterranean as the demand for food increased. Many of the provinces of the empire were turned into granaries to feed the population of Italy, particularly after 58 BC when the citizens of Rome started to receive free grain for political reasons. North Africa, for example contains a whole series of impressive Roman remains, such as the great city of Leptis Magna in Libya, from what were once some of the most flourishing and highly productive provinces of the empire. But they now lie surrounded by vast deserts, a memorial to widespread environmental degradation brought about by human actions. The area continued to flourish even after the final destruction of Carthage in 146 BC but the growing Roman demand for grain pushed cultivation further into the hills and onto vulnerable soils that were easily eroded when deforested. There is no single date that marks the decline of the North African provinces – it was a long drawn-out process of increasing strain and deterioration in the environment as soils eroded and the desert slowly encroached from the south. The process was intensified after the fall of Rome as tribes such as the Berbers moved into the cultivated areas bringing with them their large flocks of grazing animals, which completed the work of removing the remaining vegetation cover. Similar pressures can be identified in Asia Minor where the interior of the old Roman provinces of Caria and Phrygia was completely deforested by the first century AD. A few decades later the emperor Hadrian had to restrict all access to the remaining forests of
Syria because of the amount of deforestation. Some regions in the area were less seriously affected and continued to prosper as food exports to the main imperial cities and towns such as Antioch and Baalbek flourished until the early Byzantine period. But both are now ruins, some of the limestone hills of the area have lost up to six feet of soil and Antioch is under twenty-eight feet of water-borne silt from hillsides ravaged by deforestation.

The causes of the decline and fall of the Roman empire are still a subject for debate by historians. But most would agree that it was the result of the interaction of a number of factors causing internal political decay and vulnerability to external pressure. It would, therefore, be too simple to see environmental degradation as the single, or even the main, cause, of the decline and fall. But there is no doubt that it was an important contributory factor and that the difficulties in extracting the food surplus needed to feed both the population of Rome and large standing armies was one of the causes of internal weakness in the empire. The deterioration of the environment of the Mediterranean region did not end with the fall of Rome. Freed from some of the demands of the imperial system some areas may have recovered enabling secondary forests to develop as population fell. The recovery in population levels by around 1000 AD followed by a steady rise, meant that deforestation continued until the present day. As more forests were cleared, more soil is eroded away. The same trends can be identified in Spain where overgrazing by the huge flocks of sheep kept by the Mesta, the most powerful of the medieval guilds, permanently degraded the environment of large parts of central Spain, in particular La Mancha and Extremadura, producing vast expanses of poor quality grass and scrub.

The development of settled societies in the Americas produced the same sequence of events as in Eurasia – the clearance of land for agriculture, deforestation and soil erosion. There is a strong suspicion that the collapse of the great city of Teotihuacan in the valley of Mexico and some of the early city states in the coastal area of Peru in the first centuries AD were linked to problems arising from the overuse of irrigation and the consequent failure of the agricultural base leading to an inability to maintain the superstructure of the state. But the clearest case of environmental collapse leading to the demise of a society comes from the Maya – who developed in what are now parts of Mexico, Guatemala, Belize and Honduras – one of the most extraordinary societies of its type found anywhere in the world. Some of the first explorers to find the 'lost cities', the Americans John Stephens and Frederick Catherwood in the late 1830s, were as much at a loss as Leonard Woolley in Mesopotamia to explain what had happened. At Copan and Palenque they mused on a vanished society:

'We . . . strove in vain to penetrate the mystery by which we were surrounded. Who were the people that built this city? . . . architecture, sculpture, painting, all the arts which embellish life, had flourished in this overgrown forest; orators, warriors and statesmen, beauty, ambition, and glory, had lived and passed away, and none knew that such things had been or could tell of their past existence. . . . In the romance of the world's history nothing ever impressed me more forcibly than the spectacle of this once great and lovely city, overturned, destroyed and lost; discovered by accident, overgrown with trees for miles around, and without even a name to distinguish it.'

The main obstacle to understanding what really happened is that the Mayan script has still been only partially deciphered. However archaeological research since the sites were rediscovered and the use of increasingly sophisticated techniques in the last three decades or so have brought new insights.

Mayan society was a remarkable achievement in that it developed in dense lowland tropical jungle. The earliest settlements in this area, which posed major problems for human exploitation in terms of obtaining enough food, date from about 2500 BC. Population rose slowly and settlements grew in size and complexity so that by about 450 BC it is possible to identify separate ceremonial areas and buildings within the settlements. Two hundred years later at Tikal in Guatemala a complex, hierarchical society had emerged (easily identified by the large differences in status between the burials of different groups) and steep pyramids over 100 feet high with temples on their summits were being built out of the local limestone rock in the north acropolis of this major centre. Over the next two or three centuries this process was repeated throughout the area until a whole series of major settlements had developed with a remarkably uniform culture displayed in the architectural styles and common script. The considerable intellectual achievements of the Maya were reflected, in particular, in their astronomy (where they made detailed and accurate calculations not just about the phases and positions of the sun and moon but also planets such as Venus) and in their highly complex and extremely accurate calendar,
based on a fifty-two year cycle counting from a fixed date in the past equivalent to 3114 BC (although the significance of this date remains unknown). All the Mayan sites have a large number of stone stelae inscribed with a series of dates, which can be translated, and texts, which, very largely, remain undeciphered. The main phases of Mayan history though are clear. By the first centuries AD a large number of elaborate ceremonial centres had developed throughout the region. For about a couple of centuries after 400 there was strong influence from the city of Teotihuacan in central Mexico but when that declined after 600 the Maya entered their most spectacular period. Huge pyramids, often aligned towards significant astronomical points, were built at all the centres and large numbers of stelae erected. Then, within a few decades after 800, the whole society began to disintegrate. No stelae were erected, the ceremonial centres were abandoned, population levels fell abruptly and the cities were soon covered by the encroaching jungle.

Until the 1960s it was believed that the Maya were virtually unique in the world in that they were peaceful and governed not by secular rulers and a military elite but by a religious caste obsessed by the intricacies of their calendar and astronomical observations. Since only the dates on the stelae could be understood it was assumed that these recorded various events associated with astronomical and calendrical cycles. The way in which the Maya obtained their food and supported the priestly elite in a lowland jungle environment remained a puzzle. Studies of the twentieth century Maya suggested that the only viable strategy would have been a swidden system, involving clearing a patch of jungle with stone axes during the dry season between December and March and then setting fire to the area just before the start of the rainy season when maize and beans would have been planted with a digging stick to be harvested in the autumn. The cultivated patch would have been abandoned after a couple of years as weeds reinvaded and made clearance too difficult. This agricultural system is widely used in tropical areas and highly stable in the long-term but it can only support a small population in any area because of the need to have a large amount of land for each farmer—the cleared patches cannot be re-used for about twenty years or more until the jungle has regrown (the task of clearing jungle is far less laborious than that of clearing grass and scrub). It was, therefore, assumed that the Maya lived in small, shifting settlements scattered throughout the jungle only coming together at the ceremonial centres, where the small priestly caste lived permanently, for part of the year.

In the last thirty years these assumptions about Mayan society have been abandoned and a radically different picture of the Maya adopted which helps to explain why the society collapsed so abruptly. The most important change has stemmed from a new understanding of the texts engraved on the stelae. It is now clear that these do not represent religious texts but rather they are monuments to the different secular rulers of the cities, setting out the dates of their birth, accession and death together with the major events of their reign. All the rulers at Tikal between 376 and about 800 when the site was abandoned have now been identified, as have the rulers of Palenque from 603–799 and those of many other cities. The signs on the stelae indicating the different cities have been deciphered and, although the texts still cannot be read in full, the conquest of one city by another, and hence the existence of warfare, can be deduced. The picture of a peaceful, religious society has been replaced by a view of Mayan society as dominated, in the same way as other early societies, by a secular elite supported by armies and engaged in fairly continuous warfare between the different cities. Recent archaeological work has also made the nature of these cities much clearer. They were not merely ceremonial centres occupied by a small elite but true cities with a large permanent population. At the centre were the huge ceremonial areas with magnificent temples and palaces built around a plaza. Beyond were complexes of thatched huts on platforms grouped around courtyards where most of the people lived in extended family groups. They provided the labour force that constructed the public buildings and residences for the elite. Excavations in the outer areas of Tikal suggest that, at its height, the population was at least 30,000 and possibly as high as 50,000 (of the same order as the great cities of Mesopotamia). Other cities, though not quite so large, would have followed the pattern of dense urban settlements and it seems likely that the total population in the Maya region at its peak might have been near to five million in an area that now supports only a few tens of thousands.

This new knowledge about the nature of Mayan society has been complemented by new information about the way the Mayans obtained their food. Obviously a swidden system could not be productive enough to support such a large population. Not enough land was available between the cities, which in some cases were no more than about ten miles apart, to make this feasible. Hunting and fishing would have provided no more than useful supplements and although the ramon, or breadnut tree, whose nuts can be ground to make flour, grows in profusion in the Mayan area, studies of the current day Maya suggest that it would only be used as a food of last resort. Archaeological
fieldwork in the 1970s discovered that a much more intensive agricultural system was in fact used by the ancient Maya. On the hillside they would clear jungle and make fields using extensive terracing to try to contain the inevitable soil erosion. Equally important though was the construction of raised fields in swampy areas. These followed the same principle as the chinampas of central Mexico except that they were not built out into lakes. Grids of drainage ditches were dug in the swamps and the material from the ditches was used to form raised fields. Traces of the huge areas once covered with those fields have now been found in the jungle from Guatemala across to Belize. In the fields crops such as maize and beans were grown for food together with others such as cotton and cacao.

This intensive cultivation system was the foundation for all the achievements of the Maya. However, when too much was demanded of it, it could not withstand the strain. The crucial period came after the waning of Teotihuacan influence about 600. It was marked by increasing warfare between the Mayan cities and a much greater emphasis by the elite on the construction of more and larger ceremonial buildings taking up huge amounts of labour. Population continued to rise steadily and a higher proportion lived in the cities where they were available to man the armies and work on construction projects. Cultivation became more intense. However the ecological basis to support such a massive superstructure was simply not there. The soils in tropical forests are easily eroded once the tree cover is removed. Mayan settlements clustered, not surprisingly, around the areas of fertile soil but three-quarters of the fertile soil in the area occupied by the ancient Maya is today classified as highly susceptible to erosion. Around Tikal for example 75 per cent of the soil is classed as highly fertile but nearly 60 per cent is highly vulnerable to erosion once it is cleared of trees. Clearing the forest, therefore, ran the risk of bringing about soil deterioration and declining crop yields and this would be exacerbated by the lack of domesticated animals to provide manures to maintain soil structure and fertility. The forest was cleared not just to provide land for agriculture but also for fuel, construction materials and for making the huge amounts of lime plaster that coated the ceremonial buildings. Population pressure pushed fields and terraces into ever more marginal areas which were even more vulnerable to erosion. Across the Maya area the vulnerable soils were increasingly exposed to the wind and the rain and eroded away.

Soil erosion caused by deforestation would have reduced crop yields in the affected areas and the associated higher levels of silt in the rivers would have seriously damaged the extensive raised fields in the marshy areas by altering the delicate balance between water levels and the fields and making the ditches much more difficult to keep clear. The first signs of declining food production are evident in the period before 800, when the skeletons from burials of the period show higher infant and female mortality and increasing levels of deficiency diseases brought about by falling nutritional standards. A reduction in the food surplus on which the ruling elite together with the priestly class and army depended would have had major social consequences. Attempts were made to increase the amount of food taken from the peasantry cultivators, leading to internal revolt. Conflict between the cities over the declining resources would have intensified, leading to more warfare. The fall in food supplies and the increasing competition for what was available led to very high death rates and a catastrophic fall in population, making it impossible to sustain the elaborate superstructure the Maya had built upon their limited environmental base. Within a few decades the cities were abandoned and no more stelae were erected to commemorate rulers. Only a small number of peasants continued to live in the area. The deserted fields and cities, buried under dense jungle, were not found again until the nineteenth century.

By using the natural resources readily available to them, by finding ways of exploiting these more fully and, in some cases, by creating artificial environments, the Maya were able to build a complex society capable of great cultural and intellectual achievements, but they ended up destroying what they had created. Perhaps the more complex the superstructure, the more difficult it was to retain an awareness of the connections or to alter course. But success or failure also depended to a large extent on the resilience of the ecosystem concerned. Some ecosystems, such as those in the temperate climate of north and west Europe, were better able to withstand continued human occupation. The ecosystems themselves were less easily disrupted and continued human occupation (though at a lower population density than in the Mediterranean or China) and partial clearance of the forests resulted in only a low level of environmental damage during the first millennia of settled, agricultural societies. In this area none of the societies came under the threat of a major environmental collapse.

The most striking example of a society establishing a sustainable balance between the natural environment and its demand for food is Egypt. For about seven thousand years after the emergence of settled societies in the Nile valley about 5500 bc the Egyptians were able to
exploit the annual flood of the river as the basis of a succession of states from the various dynasties of the Pharaonic era, through the Ptolemies to the period of the Roman empire, and under the Arabs and the Mamluks, until new technology in the nineteenth century began to undermine the system.

Each year the river Nile would flood the vast length of its lower valley depositing huge quantities of silt from its twin sources in Ethiopia and Uganda. To some extent the Egyptians happened to be the beneficiaries of somebody else's environmental problems. Much of the silt was the result of deforestation and soil erosion in the highlands and although, at present, it is estimated that the Nile carries about a hundred million tons of silt a year, it was probably less in earlier periods. The heaviest rainfall in the highlands occurred in June and the flood reached Egypt, nearly 2,000 miles away, in September. Here it spread out over the narrow valley (no more than twelve miles wide in places) through natural overflow channels into flood basins to produce the rich, permanently renewed soil of Egypt. The flood ended by November but this short period was exactly right for the sowing of autumn crops.

The great stability of the agricultural system originally adopted by the ancient Egyptians and used (without major changes) by their successors lay in the fact that what they did was to exploit a natural process, with only minimal human interference, and then only at a low technological level. The whole water control system was built upon regulating the natural flow of the river to provide the right amount of water at the right time together with the silt to fertilise the land, rather than producing an artificial environment. In some places they breached natural levees to ensure that the water reached the maximum possible area and in others they built artificial banks to provide semi-natural basins to enable water to be retained for longer. The natural irrigation of the flooded area made it both impractical and unnecessary to build artificial canals. Because of its underlying geological structure and essentially natural irrigation system the Nile valley suffered none of the problems and unwanted and damaging side-effects of Mesopotamia’s artificial irrigation system. Within a month of the flood the water table was more than ten feet below the surface and so waterlogging was not a problem and there was no build-up of salts in the surface layers. This eliminated the need for the long, fallow periods essential, but not adopted, in Mesopotamia if the twin disasters of waterlogging and salinisation were to be avoided. The silt, rich in nutrients and regularly renewed, also eliminated the need for heavy manuring and ensured the continuing fertility of the soil. The level of this fertility can be judged by the fact that in the eighteenth century AD crop yields in the Nile valley were about twice as high as in France. The absence of salinisation is demonstrated by the increasing importance in Egyptian agricultural output of wheat, a crop more sensitive to salt levels, compared with barley – the exact opposite of what happened in Mesopotamia.

Although there were some changes in the agricultural system over the centuries, it showed a remarkable degree of continuity. In the Pharaonic period Egyptian farmers planted wheat, barley, beans and chick peas as their main winter crops together with flax, the main textile fibre, in the flood basins. Vegetables, particularly onions, lentils and also fodder crops, were planted in those areas where water was still available in the spring. On the higher land date palms flourished. Sorghum, which was resistant to semi-drought conditions, was introduced as a main summer crop in the Ptolemaic period and crops such as sugar, cotton and rice were cultivated for the first time in the Islamic period. The technology involved in utilising the annual flood was, like the rest of the system, basically simple. For the first four thousand years or so the fields were watered from the channels by buckets moved by hand. About 1340 BC the shaduf (or bucket and pole system) was brought into use and its greater efficiency increased the amount of cultivated land by about ten per cent. A similar increase was again achieved about 300 BC when the animal-drawn water wheel was introduced. After that there were no technological changes of importance until the nineteenth century.

The long term stability of the Egyptian agricultural system was maintained as long as there were only limited modifications to the natural flood regime. However, there were problems stemming from the fact that there could be major fluctuations from year to year in the flood level of the Nile and from a tendency for there to be sustained periods of especially high or low floods. In the short term the results for both Egyptian farming and society could be disastrous and these fluctuations had a major influence on the course of Egyptian history, particularly under the Pharaohs. Very high floods destroyed many settlements and the artificial works for containing water. Very low floods left some areas dry and lacking in silt. For example, although the 1877 flood was only about six feet below normal, it still left about a third of the valley without water and silt. Either extreme reduced crop yields with severe social implications.

In general the overall trend has been towards a fall in flood levels, probably caused by declining rainfall in the highlands that are the source of the Nile, but with major fluctuations within that trend. After
about 3000 BC flood levels fell by about a quarter but it was the long series of extremely low floods in the period from 2250–1950 BC that brought about major social disruption and the end of the Old Kingdom in Egypt. These low floods drastically reduced crop yields, leading to mass starvation, death of livestock, lack of seeds for the next planting season and abandonment of marginal land. This happened at a time when the demands of the state (huge construction projects and support of a growing bureaucracy, army and priesthood) were imposing an even heavier burden on a weakened agricultural base. The result was the political and social collapse of the Pharaonic state in the wake of a full-scale revolt by the peasantry. There followed two centuries of disunity before Egypt was reunited at the beginning of the so-called Middle Kingdom. This period was marked by a series of very high floods (those between 1840 and 1770 BC were nearly thirty feet higher in places than the modern average) which, although destructive, at least ensured adequate water and silt for crop production. A substantial decline in flood levels after about 1550 BC again caused major political and social problems. The fall in food production made it more difficult to support a large number of non-producers, especially the army, at a time when the Egyptians were under considerable external pressure, from a wave of what their records refer to as 'sea-peoples', attempting to settle in the Nile delta. The powerful Egyptian state under the Ramessid dynasty that had built the great temples at Abu Simbel collapsed. Egypt was once again disunited and was only reunited about two hundred years later under external conquerors.

Despite these vicissitudes that had such a major impact on Egyptian history, the Nile flood continued to provide a stable way of supporting a large population and a complex society in Egypt until the nineteenth century. Only then were major changes made which, within a relatively short space of time, began to have widespread effects. In the 1840s the first artificial irrigation systems were built to provide more irrigated land to grow extra crops, not for food but other items such as cotton for sale in Europe. Within a few decades permanent irrigation had produced widespread salinisation and waterlogging in the newly cultivated areas. In 1882 the British agricultural expert Mackenzie Wallace described the 'white nitrous salts covering the soil and glistening in the sun like untrodden snow'. In the early twentieth century the first attempts were made to control the flow of the Nile by building a dam at Aswan on the upper Nile so as to be able to release water as required, thus avoiding flooding or water shortages downstream. It was the construction of the present high dam, which began in the 1950s, that

was finally to undermine the long established Egyptian agricultural system. Although it solved one problem by regulating flood levels, it undermined the real secret of success by retaining the silt behind the dam. As a result the natural fertility of the Nile valley was destroyed and had to be replaced by expensive artificial fertilizers. It constituted a forcible entry into the modern agricultural system of high input farming but many of the peasant cultivators were unable to afford the expensive new artificial fertilizers.

Many of the earliest settled societies were unable to strike a balance between their need for food for the populace as well as for the rulers, bureaucrats, priests and soldiers and the ability of the environment to sustain intensive agriculture over a long period. Some overreached themselves in the end, although for a considerable period, often many centuries, they appeared to be highly successful. In Mesopotamia, the Indus valley, the jungles of Mesoamerica and other areas too, a fragile environment collapsed under pressure. The demands of an increasingly complex society began to overstretch the capacity of the agricultural base of the society to support the large superstructure that had been erected. In the end, the unwanted, and unexpected, side effects of what at first appeared to be solutions to environmental difficulties became problems themselves. The result was falling food production and increasing difficulty in supporting a large number of non-producers. Attempts to increase the proportion of the declining amount of crops going to the elite often produced internal revolt and the strain of provisioning a sufficiently large army often led to conquest by enemies. Only in a few cases, like the Maya, was there a dramatic collapse of an entire society or wholesale abandonment of land as no longer fit for agriculture. In the Mediterranean and China there was long-term degradation which seriously damaged the resource base of these societies. The struggle to provide enough food was to be one of the central features of nearly all the rest of human history. It remains acute for the majority of the people in the world.