Chapter I

In the Beginning

We may place the beginning of technology with the first human-like creatures making simple stone tools. Homo erectus, who emerged in Africa some 1.8 million years ago, is considered as the earliest toolmaker[1]. Modern humans, known as Homo sapiens, also originated in Africa some 100,000 or more years ago and came to Europe roughly 40,000 years ago. The first hominid in Europe was Homo heidelbergensis, from about 700,000 years ago, followed by Homo neanderthalis, who disappeared some 30,000 years ago. Hominids that pre-dated the first toolmakers undoubtedly used natural objects as tools, but Homo erectus was the first to make tools. Many primates and other animals use natural objects as tools, for example sticks as weapons or stones for cracking nuts; and even occasionally modify such objects, by chewing or other manipulations, to make them more suitable for the task in hand. The modifications, however, are never very substantial and tools are not made for future use, but only for an immediate purpose. Man, on the other hand, perceives of possibilities of using natural raw materials to make objects that are very different from the original materials, though even in the late Stone Age some natural objects were used as tools, such as antlers for pickaxes and bovine shoulder blades for shovels, though not without a considerable amount of cleaning and preparation. Only humans appear to have the imagination necessary to plan major modifications of natural objects for particular practical purposes. Only humans appear to have the foresight to make tools for future use, for occasions that might arise at some future time. Foresight and imagination are part of the tool-making process. Humans have two further abilities that, in contrast to animals, enable them to make intricate artefacts. One is a superior ability of coordination between visual and tactile sensations or, in other words, superior coordination between eyes and hands. Human dexterity, controlled by vision, far surpasses that of any other creature. The second ability is concentration. The concentration span of humans exceeds that of animals and thus humans are able to produce artefacts that require a great deal of effort, sustained over long periods. Remarkable as some feats of animal construction are - we may think of the elaborate dams built by beavers or of birds' nests – they are no match for the human facility of producing artefacts.

Tools are means to an end. Indeed technology may be defined as *the material ways and means to achieve some human purpose*. The prime purpose of all living creatures is survival, and humans are no exception in this respect. Thus the needs that arise directly out of the primary purpose of survival are primary needs and consist of:

a. the need for food and water, may include hunting;
b. the need for protection from cold, be it by clothing or by shelter. The latter may consist of natural caves or of man-made objects;
c. the need for protection from predators and, possibly, fellow humans.

The earliest technologies addressed the primary needs and were an essential aid to the survival and development of the human race.

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[1] Homo habilis is a slightly older form of hominid that made tools, but is generally regarded as less important. The pre-history of humans is very complex, ill-documented by fossil finds, and somewhat controversial. The matter is not central to our arguments and will not be discussed in detail.

Throughout the Lower Palaeolithic period, from about 2.5 million years ago to roughly 200,000 years ago, only these categories of purpose played any role. In the Upper Palaeolithic, Mesolithic and Neolithic periods, covering from 200,000 years ago to something like 3,000 BC, further purposes gradually gained in significance. Present day technology, although incomparably more extensive, complex and sophisticated, still fulfils our basic needs, though with much greater complexity and variety than ever before. And, of course, modern technology serves many more categories of purpose and enables vastly increased numbers of humans to survive.

Palaeolithic societies consisted of small groups of hunters and gatherers who lived a nomadic life and used tools merely as aids to survival. Technology was born out of the need for survival. Hominids - and humans - are physically ill equipped to survive unaided in hostile environments. They are neither fast, nor powerful, nor endowed with effective natural weapons. Their only equipment for survival, or competitive advantage, is their intelligence and their ability to make and use tools. Tools to help them gather food, scavenge and hunt for meat, build shelter and tame fire, and to produce clothing. Only with the help of these early technological achievements could they survive and thrive against the odds of being eaten by predators and of starving or freezing to death. Technology assisted hominids in their struggle for survival since the days when they first made their appearance on earth. Indeed this aspect of technology, to assist humans in their struggle for mere survival, is a vital part of technology to this day, even though this task has been overshadowed by many other functions of contemporary technology. Need was the mother of early technology and imaginative dexterity was its father.

In the beginning was the use of natural objects as tools; the manufacture of tools was a crucial next step. It is this step that humans alone have taken. Many animals use, and sometimes slightly modify, natural objects as tools – man alone makes tools. Man is a toolmaker or, to put it the other way, tool-making makes man. It is easy to imagine that some of the more intelligent of these early hominids would first look for sharp stones in nature that could scrape, dig and cut more effectively than blunt stones; they would then hit upon the idea that sharp stones can be obtained by hitting blunt ones with another stone. Gradually they would perfect the manner of producing such sharp stone flakes that constitute early stone tools. They would learn how to select the best raw materials, such as flint, and would learn how best to hit it to produce sharp flakes. For many millennia the development of technology was very slow. It was not till Neolithic (new Stone Age) times, about 10,000 years ago till about 3,000 BC that technological development accelerated, the techniques of producing stone tools were perfected and the variety and quality of the tools improved greatly.

Palaeolithic man was a nomad who moved in cycles determined by the seasons. He had to follow the migrations of game herds and the ripening of edible plants in various locations. He used caves for winter shelter and simple temporary shelters during his migrations. It is known, for example, that many sites in the British Isles, where human remains and other traces of human presence were found, were not continuously occupied. If no caves were available, he was forced to build more permanent shelters from what materials he could find. Occupation of different territories depended on the state of glaciation. Humans were nomads in two senses – the usual sense of having no permanent abode but wandering from place to place in search of food; and also in the sense that climatic conditions limited the regions in which humans could survive and forced them to move with the ebb and flow of the ice. We might speak of short period and long period wandering. During periods of greatest glaciation many northern parts of Europe became uninhabitable, while milder interglacial periods allowed habitation of more northerly regions. The fauna and flora, and even the landscapes, changed dramatically with climatic changes and all that contributed to enabling, or not enabling, humans to occupy a region. Climatic conditions were a major determinant of the way humans lived and what food was available to them. Their spread through the world was similarly dictated by geographic and climatic conditions. It is thought, for example, though disputed by some, that humans reached America when that continent was practically connected to Siberia. Similarly, humans first inhabited Britain during a period when it was still firmly part of continental Europe.

We have said that humans survived in hostile environments by using their intelligence and their hands, equipped with natural tools at first and artefacts later. It was only with the use of artefacts, however, that humans managed to survive in large numbers and, eventually, to spread across the world. Tools allowed them to dig for edible roots, to scavenge efficiently for meat, to use sticks, branches, stones, grass and hides to produce

temporary shelters. Intelligent cooperation enabled them to outwit their prey and hunt for large animals and, in the fullness of time, to kill not only weak animals but also those in their prime. Early on the ability to produce tools and to plan ahead and to cooperate in common endeavour were the most important uses of human intelligence. Planning enabled hominids to arrange their days so as to reach suitable shelter when needed, to plan the hunting of small and, later, larger animals, to obtain water at times and in places where they avoided excessive danger from predators. At some time they learned to make arrangements to keep their fires going. It is likely that very early on they depended on natural ignition by lightning, though later they learned not only to tend, but also to light fires. This had two effects: they learned to cook food and this, over many generations, caused their digestive apparatus to shrink and their brains to grow. Cooking replaces part of the digestive process and thus, indirectly, advances intelligence.

The second effect was that fire enabled humans to survive in colder climates. It is likely that the mastery of fire was a pre-condition for human migration into most parts of Europe. The Cro-Magnons certainly spent their winters in caves warmed by fires during the coldest period of the last ice age. They could venture out only in properly tailored warm clothing made of animal skins.

Nobody knows exactly when language developed, but undoubtedly some form of communication was part of pre-human society from very early on. After all, apes communicate, even if they have nothing that we recognize as language. Gestures, shrieks and grunts and facial expressions must have become ever more complex and over thousands of years the first simple languages emerged. No doubt anatomical development of the larynx and pharynx was a pre-condition for articulate speech. It is thought that Homo erectus developed the anatomical potential for speech roughly 300,000 years ago.

We must stress the great uncertainty involved in all our knowledge of pre-history. The only certainty is our uncertainty. Stories and theories are conjectured on the basis of very few finds and experts disagree over many interpretations. Though lithic artefacts can be identified with some confidence, methods of dating very ancient sites and finds are inaccurate and often contradictory. As far as this book is concerned, I am trying to tell a more or less coherent story based on as much consensus as I can find, but it is not my ambition, or within my competence, to provide an authoritative detailed account of the development of the human race. My ambition is to tell a consistent tale of technological developments and correlate these with reasonably well-founded facts on human society.

The road from producing crude stone flakes to the production of sophisticated tools made of stone, wood, horn, bone or antlers is a very long one and is intimately connected with the development from Homo erectus to Homo sapiens. One of the many problems in studying archaeological artefacts is that most of them have not survived to the present. In fact almost anything made of hide, wood, bone or antlers and other biological materials has long since disappeared. What remains are stone tools and even they pose problems. It is difficult to distinguish with certainty between natural stone flakes and artefacts and also difficult to know what the ravages of moving ice sheets, volcanic eruptions, flowing rivers and other forces of nature have done to the shapes and locations of lithic artefacts.

We must use our imagination to conjecture what uses the earliest tools were put to. Whereas small animals could be killed with sticks, and nuts or bones could be crushed with pebbles, a sharp instrument was needed to separate the skin from the flesh and the meat from the larger bones and to cut the meat into manageable portions. Thus scrapers and knives became an essential item in the tool-kit of early humans. Some form of axe was needed for chopping down trees or shrubs, whether for the production of weapons, or for firewood, or for the construction of simple shelters. The hand-axe, a ubiquitous tool of a slightly later period, represents a combination of scraper, knife and axe. For killing larger animals, and possibly fellow humans or predators, a spear was needed. Early spears were made of wood, with the tip sharpened with an axe; later stone tips were fixed to a wooden shaft by various methods.

During this early period of technological development there was neither specialisation nor standardisation. Everybody made their own tools as best they could and each tool was slightly different from all others. More standardised and more specialised tools became prevalent later, when small bands of humans merged into something approaching society and the knowledge of making and using tools became social knowledge, shared by members of a given social group.

The earliest stone artefacts consisted of naturally sharp-edged flakes broken off a larger stone, either by hitting a pebble with another stone or by hitting it on a stationary larger stone or rock, an anvil. We call this very earliest stone technology Oldowan technology because the first examples were found in the Oldovai Gorge in East Africa. These early tools might have helped with gathering wild crops, but their main utility was in scraping skin and bones off meat and perhaps cutting meat, hides, and wood. Meat was probably obtained mainly by scavenging, though the tools, coupled with the use of sticks, may have helped to kill and butcher small animals.

Homo erectus spread from Africa into Eurasia. It is estimated that the first such humans reached Europe about half a million years ago by way of North Africa and the Middle East. The stone technology they left behind is known as Acheulean technology, named after St. Acheul, near the Somme river in Northern France, where the first archaeological finds were made. The principal tool of the period is the hand-axe. It has been found in many regions of the world and comes in many sizes and slightly different shapes. Essentially it is made from a natural piece of stone and first hammered roughly into shape, then shaped more accurately with a lighter hammer, perhaps made of bone. Hand axes were the principal universal tools over a very long period, supplemented mostly by sharp stone flakes used for cutting and scraping meat and skins.

The Acheulean technique was later refined into the so-called Levallois technique. In this method a stone core was carefully trimmed in such a way that a final well-placed and angled blow would detach a large flake directly usable as an implement. The core was discarded. Such tools are known as unifacial tools because one surface was flat. They could be large and wedge-shaped with a straight edge, to be used as choppers or cutters, or they could be pointed for use as burins or borers. Tools with serrated edges, an early form of saw, have also been found. It is thought that these tools were used to cut and shape wood, but also to prepare skins for clothing or temporary shelter. The Neanderthals used assemblages consisting of hand axes and various tools made by the Levallois technique and their technology is collectively known as Mousterian. If we regard hunting as a technology, it certainly developed during this period. Neanderthals learned to hunt large game such as reindeer, mammoth, bison and wild horses. This shows that the Neanderthals lived in somewhat larger groups and were able to cooperate in hunting and other activities. Presumably they were able to communicate by speech. Neanderthals became adept at survival in cold regions, which means that they must have mastered the art of keeping, and probably lighting, fires.

We should not be surprised that it took so many millennia to develop the Levallois technique. We must remember that human intelligence and innate skills, especially eye-hand coordination, needed to develop and that this is a very slow biological process. Another important factor is the very small size of groups that formed human society and the very limited interaction between groups. As most learning is social learning – we learn from each other and develop or discover very little for ourselves – limited social intercourse puts a considerable brake on technological development. Learning requires interaction and communication between many individuals and if such interaction is rare and limited, learning proceeds but slowly.

Tools found in different locations, dating from the same period, are similar, but somewhat different. This fact can be used to argue either the case of a simple technological determinism or the case of social learning. It could be argued that the logic and possibilities of using stones for practical tasks determines, to a considerable extent, what shapes shall be prepared. We shall return to this discussion later, when more advanced technology and more coherent societies form a better basis for discussion. At this early stage it is clear that the technological options were pretty limited, as was social intercourse. Nevertheless, the fact that regional differences are discernible tends to show that some social learning was involved even in these early stages, although the technological determinism was probably stronger than the social forces.

Early Palaeolithic society had a very limited range of social interactions, let alone institutions. These early humans probably lived in bands of gradually increasing size, though below about 100 members. They had no known rituals and interaction between bands was limited to occasional chance meetings. Even these limited occasions were probably enough for some exchange of technical know-how and, thus, to social learning. Within a band, social learning probably played an important role as each member could observe all other members in their daily tasks and the naturally more talented stone-workers passed some of their skills to younger members of the group. Whenever a group uses a technology, this passes into the ownership of the group and be-

comes social knowledge. Shared knowledge is social knowledge. Throughout the Palaeolithic period social life increased and by the time the Cro-Magnons took over, groups had increased in size, had developed some forms of social institutions and had more intense contact with more distant populations.

The Cro-Magnons, who succeeded the Neanderthals as the main Europeans, made substantial contributions to technological progress. One of the great advances made by them was hafting. Attaching a stone tool to a wooden shaft would increase the available kinetic energy considerably and thus enable the user to cut and shape much larger trees and timbers. Attaching smaller tools to some form of handle or holder would render their use much more convenient. Many new varieties of tools were introduced to serve specialised purposes. The Cro-Magnons produced spear-points from stone or bone and were able to attach these to wooden shafts. The surface finish of the tools improved, as they were retouched with light hammer blows and by grinding and polishing. The Cro-Magnons developed burins, which enabled them to produce eyed needles from slivers of bone or antler. This enabled them to produce clothing from animal skins and furs. Remembering that the Cro-Magnons survived the coldest periods of the last ice age, their clothing must have been very well made.

It is possible to scavenge for meat, but in order to obtain undamaged skins for the production of clothing, it is necessary to kill animals. They could either be driven toward some precipice and the carcases collected at the bottom, or they could be trapped in deep holes adequately disguised, or they could be killed with lances, spears and axes. Both for hunting and for the preparation of meat and of clothing suitable tools had to be developed. But tools were not enough; to trap or hunt large animals cooperation between several hunters is necessary. Thus a pre-condition for the production of effective clothing was the development of effective social organisation. If you have only very simple tools, you have to cooperate with others in order to kill large animals. Fishing also provided an important source of protein. Fishing was carried out either with the aid of rouses, or nets made from natural fibres, or fishhooks that were made mostly of bone.

The Cro-Magnons were biologically modern humans and it is thought that they may be the remote ancestors of some humans living today. They flourished in the Upper Palaeolithic, from about 35,000 years ago to about 10,000 years ago. Both Neanderthals and Cro-Magnons buried their dead, though it is impossible to know whether the reasons for this were ritual or hygienic. The Cro-Magnons almost certainly developed some form of faith and of ritual.

Cro-Magnons were the first humans to be known to have produced art. They produced cave paintings, depicting mostly hunting scenes and found mainly in France and Spain. The cave paintings provide many clues to the life of these societies. Hunting scenes are an important feature and show some of the weapons and techniques used, as well as the animal species hunted. We do not know for certain whether these pictures were associated with rituals, perhaps incantations to the spirits or gods to provide good hunting, or whether they were purely the result of artistic impulses. In any case, they provide proof of considerable facilities for abstract thought. The Cro-Magnons obviously had aesthetic feelings, shown in decorations engraved on tools and weapons. They also carved small sculptures, mainly of big-breasted pregnant women. One assumes that these were used in some form of fertility rites.

Perhaps the most famous, though not the oldest, of these cave paintings are those of Lascaux, in the Dordogne region of France. The vast cave contains a large array of wonderful paintings, mainly of animals such as aurochs (wild cattle), horse and deer. They are dated to about 15,000 BC. It is obvious that by this time humans in this region had not only the capacity for abstract thought and a desire for artistic expression, but also had a set of techniques that enabled them to produce these spectacular images. They needed pigments, pestles and mortars, brushes, lamps and scaffolding, quite apart from great skill and sufficient time, presumably available during the long cold winter. It is possible that some of the paintings served a ritual designed to influence the outcome of hunts. Apart from the realistic images, the paintings also contain a number of abstract geometric patterns, whose significance is not understood. Was it an early script or early abstract art?

The cave paintings are an early instance showing technology serving a class of purpose that falls outside primary needs. Such classes of purpose include art, ornamentation, ritual, play and religion. From their beginning with cave paintings, engraved ornaments and simple sculptures, this class of cultural needs served by technology expanded hugely from the Stone Age to our modern days. One might conclude that as the daily struggle for survival became more successful and no longer occupied all the time and energy available to hu-

mans, their minds turned to other things, to a different direction of their creative abilities. Homo faber is not only a maker of tools, but also a maker of artistic artefacts. We do not know whether these activities originate from a desire to enlist the help of spirits in practical endeavours, or whether they were created just for the pleasure of creation and contemplation.

The Upper Palaeolithic, with Homo sapiens the dominant and probably the sole human species, saw the introduction of further new improved technologies. Stone tools were now made in two stages. The first stage consisted of producing long slender blanks, or blades, that could then, in a second stage, be worked into all kinds of specialized tools. The long flint blades were of trapezoidal cross-section. This method of producing stone tools was the culmination of the development of lithic technology and is known as the blade-tool industry. It could produce long slender knives or small tools, known as microliths. Both knives and microliths could be attached to handles made of bone, wood or antler, using resin as glue. It is probable that by this time some degree of specialisation had developed and it is possible that both blades and finished tools were manufactured by specialists and traded.

The Neolitic age took developments in lithic technology even further. One of the hallmarks of Neolithic stone tools is the superior quality of their surface finish. They were well finished by light hammer strokes and then ground and polished, either on a rock or with abrasive powder, so that their appearance was smooth and their cutting edges sharp and even. The smooth finish not only made these tools into more desirable objects, it also increased their efficacy and ease of use by sharper edges and reduced friction. A further hallmark of Neolithic tools was the use of superior materials. Whereas previously the materials used came mostly from the immediate surroundings, in Neolithic times superior flint was traded over quite long distances and much of it came from flint mines. This required the development of mining techniques and the transportation of the mined products to different places for knapping and use. A further excellent and rather rare raw material for tools, obsidian (a volcanic glass) appears to have been obtained from quite faraway places, either by exploration, by exchange with travellers, or by trade.

A major invention of this period was the bow. The bow may be looked upon as a device that stores and accumulates the energy of the archer's muscles and, on release, imparts greater momentum to the arrow than the archer could impart unaided. The bow and arrow were destined to become one of the principal weapons for a very long period, probably more than 10,000 years, until the 15th century AD. The bow and arrow proved as useful in hunting as in combat. It spread rapidly to all populated regions, showing that by then contacts between different populations were well established, thus enabling a superior technology to diffuse quite rapidly.

Throughout the millennia that we have described, albeit briefly, natural selection worked in favour of higher intelligence and of greater prowess in making and using tools and weapons. More intelligent individuals stand a better chance of living longer, and of producing more offspring, than their less intelligent contemporaries. This is the classical evolutionary pressure toward the development of higher average intelligence of a population. The less able have lower chances of survival and of procreation than the more able and thus the species evolves toward greater ability. In particular, it is technical prowess, superior tool making, which improves the chances of survival, though undoubtedly physical prowess was of great importance for survival under harsh conditions. Growing average intelligence causes greater average chances of survival and, thus, leads to an increase in population. Improved tools, which help to provide more food, lead to the demand for ever more food and thus to a demand for ever better tools. A feedback loop between better technology, growing populations and the need for ever improved tools evolves. Man the advanced toolmaker could survive in places and in numbers that were inaccessible to humans without good quality artefacts.

Though the technology reached by the end of the Palaeolithic, or even the Neolithic, was still very simple when viewed with modern eyes, the development of technology up to this period already demonstrates three principles of the development of technology that have remained valid to this day.

1. All technologies and technological products improve with further development. They become more effective and efficient, more comfortable to use, more streamlined. We can define one or more figures of performance for technologies, and these figures increase with the development of the technology. The improvement continues until the particular technology becomes obsolete, either because a superior type of technology re-

places it, or because the need it had served disappears. Stone technologies largely disappeared because they were replaced by superior metal technologies. An interesting figure of performance for lithic technology is the length of cutting edge that can be obtained per unit weight of raw flint or similar material. The increase throughout the life of the technology is quite spectacular (Table 1.1)

Length of cutting edge produced from 500g of flint or similar material	Years ago	Human Species	Type of Technology
80 mm	2,000,000	Homo habilis	Oldowan
300 mm	300,000	Homo erectus	Acheulean
800 mm	100,000	Neanderthal	Mousterian
9,000 mm	10,000	Homo sapiens	Blade

Table 1.1 Figure of performance of lithic technology (Source: B. M. Fagan, 1998, p. 87)

2. Technology becomes able to satisfy ever more human needs, or serve ever more human purposes. At first it only helped with the provision of food gathered or scavenged. Later it helped with hunting and with the better utilisation of food by making cooking possible. It helped with the provision of shelter, clothing, warmth and light. Technology provided weapons not only for hunting, but also for defence against predators and, soon enough, for inter-human warfare. Before long, at least as early as 16,000 years ago, technology became instrumental in producing symbolic, ritual and decorative objects. This shows clearly that needs expanded as possibilities to satisfy them became available. At first technology was driven only by elementary biological needs. Later, further needs were added and this addition of needs has expanded and accelerated to the present day.

The need for symbolism and ritual arose because the small scattered bands of humans had grown into an early form of society. Technology helped more people to live longer and thus their numbers increased and the small hordes became larger communities. Ritual is an expression of cohesive forces in society and technology made its contributions to ritual when it became able to do so.

3. As the purposes served by technology become more varied, so technology becomes specialised. Whereas the original stone flake served as a universal tool and the Acheulean hand axe served most purposes, later tools were made for specific uses. Scrapers, cutters, choppers, saws, diggers, needles, borers, spears, fishing hooks and nets, boats, huts, fireplaces, lamps, and so forth.

By Upper Palaeolithic times, the categories of purpose served by technology had increased to at least four, albeit all served at a rather elementary level, not much beyond mere survival. In addition to the previously listed purposes, technology now also provided artefacts in support of decorative, symbolic and ritual purposes.

The new Stone Age, the Neolithic age, began and ended at different times in different regions. Generally it was preceded by the Mesolithic, a transition from the Palaeolithic to the Neolithic, and succeeded by the metal ages – copper, bronze, iron. To give a rough idea, we can place the Neolithic between, say, 8,000 BC and 3,000 BC, though this may be out by a couple of thousand years in some places. By the beginning of the Neolithic, Homo sapiens had spread to most parts of the world, including Southeast Asia, New Guinea, Australia, Siberia and America. Most of the places could be reached either by land or by quite short sea routes. The intriguing question is what drove humans to roam all over the world. I suppose the main factor was competitive search for food and changing climatic conditions, but curiosity and the challenge of the unknown may have played a role.

The Neolithic brought about the most momentous change of all. The two major innovations defining the age were pottery and, above all, agriculture. Man learned to grow crops and to domesticate animals. This changed his world from one in which he had to roam to find food, into one in which he could settle into permanent settlements and produce food. The process was very gradual, with nomadic lifestyles co-existing with sedentary

ones for a long period. The development of agriculture changed the economy from one in which everything that each human produced was consumed more or less instantly, into one where surpluses could be produced, thus enabling human society to create an infrastructure of specialised workers, including artisans, administrators, priests, and rulers. As long as each person instantly consumes the food that he/she finds, it is impossible to sustain people who are fully engaged on pursuits other than gathering or hunting for food. Specialists who do not produce food have to be fed by the surpluses of food producers.

As an aside, we may indulge in an interesting, though gruesome, speculation. If people who consumed all the food they could produce made a prisoner in any kind of war, the only sensible thing to do with the prisoner was to kill and, preferably, eat him or her. If, on the other hand, prisoners could produce more food than they needed to consume, then it was worthwhile to keep them as slaves. Thus slavery was born, and with it some of the darkest chapters in human history.[2] It is not known when the first wars were fought, or when hunting weapons were first used against fellow humans. It is likely that Cro-Magnons and Neanderthals fought over resources and equally likely that different later tribes of Homo sapiens, alias Homo bellicosus, fought each other for reasons of greed, lust for power, envy or some such.

How agriculture initially developed can only be surmised. The most likely explanation is that people observed that the seeds they gathered from wild oats or wheat and other grains could be sown and thus grown in greater densities for easier gathering. They probably also observed that some seeds can be harvested more easily than others, because they stay on the stalk for a while when already fairly ripe. Undoubtedly they also found that some seeds are larger than others and thus provide better food value. Such observations may have caused them to start selecting seeds for sowing and a long chain of development of cultivated crops may thus have started. Perhaps the first seeds were sown by accident, when some dropped on the ground and were observed to sprout. Perhaps people observed how plants seed themselves in nature and hit upon the idea to emulate this process. After all, they collected seeds and must have accumulated quite a lot of knowledge about them.

Apart from wheat and barley, a variety of other edible and useful plants were of importance in Neolithic times; with some of them growing wild, others coming under cultivation. Green vegetables, such as cabbage, lettuce, nettles, cress, beans and peas were planted, albeit in forms much closer to their natural forms than to the vegetables we see on modern market stalls. Carrots and radishes were among the root vegetables; and beans, peas and lentils among the pulses. Apples, pears, plums and cherries were important. Vegetable oils were obtained from walnuts, linseed, poppy-seed, rape and olives. Rye, oats, millet and rice were gradually added to the earliest cultivated cereals. A variety of plants served as raw materials for the production of artefacts: timber, palm trunks and reeds for building; gourds for vessels; flax, hemp and cotton for fibre. Boats and paddles were constructed from much the same materials.

The knowledge gathered by individuals soon began to circulate and became enriched in the process. Different people exchanged their knowledge and experience and thus spread, enhanced and refined it. Communal knowledge grew out of a large number of individual observations. By the time of the Neolithic, language was quite well developed and exchanges between people within and between communities had become widespread. Knowledge about planting deliberately for crops gradually accumulated and, at the same time, knowledge about cultivation must have advanced. Special implements, such as a variety of digging sticks and hoes, were developed as predecessors to the plough. Sickles with stone blades and wooden handles were developed and used for harvesting.

Eventually, knowledge about crop rotation and about fertilisation and the use of grazing animals became part of agriculture. The latter presupposed animal husbandry that developed at about the same time as planting and cropping methods. Again, we can only speculate how animals were first domesticated. Perhaps people hit upon the idea that herd animals could be driven into pens and thus made more accessible for meat, for wool and for milk. Wool was gathered by plucking and it is obviously much easier to do this with penned or tethered animals than with freely roaming ones. It is also much easier to preserve meat on the hoof, rather than preserve surpluses accumulated in a successful hunt. The production of milk and milk products was realised later as an added bonus.

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[2] V. Gordon Childe, Early Forms of Society, pp. 43–44 in Singer et al., 1954

We may ask why agriculture developed at all. Was it simply a result of newly recognised opportunities, of factual observations, of inventions based on the study of nature? Or was there some pressure, perhaps of increasing populations, an increasing number of mouths to fill, which forced people to seek ways and means of increasing food production? Or did humans attempt to free themselves from the vagaries of weather and climate, to obtain not only more abundant, but also more secure and regular food supplies? I think the answer must be a bit of each. A constellation of circumstances in which a problem – increasing population and insecure supplies of food – and a possible solution – intensification of food production – came together. A need and a possibility to satisfy it are the fundamental ingredients of technological innovation. We cannot say which was the egg and which the chicken, all we know is that agriculture increased food supplies and this enabled the population to grow, but whether agriculture or growth came first we cannot say.

The fundamental reason for wishing to grow crops and domesticate animals is the need to obtain larger and, of equal importance, more stable and secure food supplies; to gain some independence from the whims of nature. The reasons why agriculture developed much earlier in some regions than in others are hotly disputed. The reasons may be either greater need or better opportunities in some regions compared to others, or a combination of both. It may be unusual pressure of population, or particularly difficult ecological and climatic conditions that render traditional food supplies inadequate or unstable. On the other hand, it may be that natural conditions were particularly favourable to the development of agriculture in particular regions.

It is generally agreed that the process of domestication of farm animals – initially goats and sheep – started in southwestern Asia in roughly 8,000 or 8,500 BC. The process of 'domestication' of wild plants, especially of wheat and barley, is thought to have started in the same region at about the same time. The valleys of the rivers Jordan and Euphrates were among the first regions of grain cultivation. In a sparsely populated world, with extremely slow and erratic communications, technological revolutions were spread out over a long period. It took about 8,000 years from the beginnings of farming to a virtually complete conversion of the world's population from hunting and gathering to farming. The dog forms a separate case and was domesticated long before the rise of agriculture. We must assume that the dog proved its utility by helping hunters and by guarding households. No doubt the bond of friendship between humans and dogs was forged in very early times.

The consequences of these developments are obvious and far-reaching. People who have fields and animals to tend lose their mobility. They have to settle near their fields and can build more permanent shelter. Thus the first permanent settlements with proper huts became the forerunners of recognisable villages with various communal arrangements. Apart from leading to a development of building techniques, using timber, earth, grass and hides, there were other far-reaching consequences. Or were they consequences, rather than parts of a jigsaw that formed a new picture? May we speak of causes and effects, or must we seek to describe constellations of circumstances that gave rise to a different society with different technologies?

We can be certain, though, that increased food production and the settled way of life led to entirely new and far-reaching social developments. It became possible to accumulate surpluses of food and either gather these as wealth or exchange them for other forms of wealth. As soon as wealth was created, it became possible for some families to accumulate more of it than other families. Even more important, land acquired a value and could be appropriated, either by communities or by individuals. Nomads roam and do not lay individual claims to land. During nomadic times, land was communal and did not have any wealth or ownership implications associated with it. It was the advent of agriculture that created the concept of land ownership. Once ownership claims were made, the foundation was laid for hierarchies. Ownership and hierarchies lead to disputes and to the need to settle them, thus some rudimentary form of a legal system had to be established. Wealth, hierarchies, and laws in their turn are the foundations of power and of political systems. In further consequence, power and wealth become incentives for conquest and war, thus creating a new constellation in which weapons become the technological aspects of military-political systems. However, the true development of hierarchies and all their consequences did not happen till the metal ages, though the Neolithic period was one of accelerating social and technological change.

It may be appropriate to formulate another fundamental law of technological development at this point, albeit in a preliminary form to be refined later. Whenever social change occurs, whether primarily because of changes in technology or for other reasons, new needs arise for technology to satisfy. A sedentary agricultural

society requires new technologies, such as agricultural implements and permanent shelter.[3] Technological and social changes go hand in hand and fundamental social changes, however caused, require the implementation of technological change. We can turn this round and say that fundamental technological change needs to be accompanied by social changes.

One of the major technological innovations of the Neolithic period was the development of pottery. Clay pots of various shapes and sizes were produced by the technique of coiling snakes of clay in a spiral and smoothing over the joints. The pots were fired either in open fires or, preferably, in a rudimentary kiln consisting of a fire in a pit covered with turf. The pots could be used for storing grain or fats or for carrying water. They could also be used for drinking or eating from and for cooking. Some vessels were ornamented in a variety of ways, either by scratching ornaments into the wet clay or by attaching them to the pot. Here is an early instance of technology serving the need for ornament. It is likely that some ornaments had a ritual meaning, while others were simply regarded as beautiful. Clay pots themselves can be things of beauty and soft clay puts great opportunities and temptation for creativity in the way of the potter. Technological opportunity and human need combine in ways that cannot be disentangled.

We may view the Neolithic revolution either from the point of view of technological determinism or from the point of view of social choices. Neither viewpoint can be proven and neither is totally satisfactory. In my view, we have to regard the social and technological changes as interdependent, as concomitant, as a constellation of circumstances that cannot be separated into cause and effect.

Technological determinism would mean that once the technical possibilities of agricultural production had been discovered and experimentally shown to be feasible, society had to adopt agricultural production and adapt to its requirements and consequences, such as abandoning the nomadic, foraging way of life in favour of settled communities. This deterministic view of the rule of technology over society contains some truth, but it cannot be the full truth. It is true that technology exerts a considerable influence, but it cannot cause society to do things that it does not wish to do. In present-day circumstances, with powerful corporations and powerful public relations and advertising, we may be closer to technological determinism (perhaps commercial determinism would be a more fitting description) than in the days when technology had to win or lose on its merits, without the backing of powerful advocates. In the days of the first tentative steps toward sedentary communities it would seem most plausible that technology opened up new avenues and society was willing to explore and develop these.

It takes generations to develop the full potential of a complex technological system, such as agriculture. In the early days the new technology can do no more than show the practical feasibility of the new ideas and demonstrate the initial advantages. At least some degree of social commitment is necessary for further development to be undertaken. A few individuals must be willing and able to have a go. If the majority of people were unwilling to settle into permanent settlements and abandon their foraging way of life, it would have been difficult to overcome their resistance. Even so, the two types of society, sedentary and nomadic, co-existed for a long period. There were no powerful corporations that had the ability to dictate patterns of consumption; no powerful advertising machinery to convince people of the advantages of one technology over any other. All that the first steps toward cultivated plants and domesticated animals could do was to show the feasibility of producing more food with decreased need to travel over long distances. As this possibility was perceived to give substantial social advantages in the form of increased and more reliable food supplies, society was willing to give it a try. Perhaps they would not have adopted agriculture in the full knowledge of its ultimate consequences, but in the absence of such knowledge the advantages seemed too great to be ignored. Though it is possible that some saw a connection between the adoption of agriculture and sedentariness, the full range of consequences of agriculture certainly was neither foreseen, nor desired, from the outset.

We can imagine the other extreme of the theoretical possibilities, the case in which the technology was developed entirely in response to social desire. We can imagine hunters and gatherers, and more especially their women with infants, becoming tired of trekking all round the countryside, never knowing where they will find shelter or food or water. They may have felt a strong desire to stay in some nice place in a decent hut, near a

[3] Some scholars argue that a few permanent settlements, e.g. Jericho, pre-date the rise of agriculture. See Henry Hodges, p. 30, Technology in the Ancient World, 1970

good supply of water and of basic food, and go out hunting from such a base. But as long as they were totally dependent on gathering wild plants and following roaming herds of wild animals, they had no option but to lead a nomadic life. The desire for a more settled way of life could not be satisfied on command, but may well have played a role in the gradual introduction of domesticated plants and animals. Technology does not simply produce what society orders, but potential inventors certainly keep society's desires in mind.

Neither social nor technological determinism make complete sense, only interplay between technological possibilities and social desire produces technological innovation. Technology and society are interlinked, with neither of them a free agent, an independent variable. When dealing with such complex phenomena as the development of technology and its adoption by society, the separation into cause and effect becomes very problematic and largely futile. Instead, we have to consider a description in which technological invention and social change interact with each other to bring about a change from one socio-technical state to another. And even that is too simple, for everything is in flux and the stable states that we imagine are not very stable and take a long time to achieve. We must think of the Neolithic revolution to have taken many hundreds of years for its completion in any locality. Indeed technical and social change are never completed, all that happens is that there are times of more rapid change that we call revolutions, and times of less rapid change that we call development. And if the development is slow, we call it stability.

It took hundreds of years for sedentariness to become fully established in the sense that the majority of the population had settled in permanent settlements and the accumulation of wealth had led to the establishment of hierarchies and fully-fledged rituals. It was a period in which spectacular feats of engineering produced megalithic monuments and elaborate burial chambers and other feats of construction. So vast are these monuments and so great was the required input of labour that the population of a single village could not possibly have built any of them. They must be the result of regional cooperation, with workers from far and wide participating in the construction and, probably, in the planning and use of the monument. Only cooperation on a large scale or dictatorship over a large region would have been able to achieve constructions of such grandeur.

The case of Neolithic monuments is a very special case of the interaction between technology and society. First and foremost, there must have been a mechanism to express a social desire in a practical form. This mechanism could have been democratic, i.e. some form of regional meetings must have discussed the issue and reached a decision. Alternatively, there may have been a ruler powerful enough to command large resources and take major decisions either single-handed or in concert with a small number of dignitaries. Secondly, there must have been sets of beliefs that required some form of ritual. These beliefs may have included a belief in democracy and a need for regional assemblies, and/or they may have been religious beliefs that became ritualised in some way, as is the wont of religions. One way or another, there must have been a mechanism for reaching a decision on what was required and a further mechanism to negotiate the requirements with the technicians of the day to see what possibilities there were to fulfil the social desires. After all this, a plan for major works must have become established.

The next stage, the stage of execution, required a great deal of organisation, coordination and what we would now call logistics. The right number of people and the right tools and materials had to be available at the right time in the right place. Was that achieved by the ruler or rulers directly, or was there some sort of technical committee or a chief engineer? We cannot know how it was done, but we do know the fact that it was done.

We shall briefly look at one example only - Avebury in southern Britain, built between roughly 3,600 and 2,200 BC. Though this northwestern corner of Europe was among the last to adopt agriculture, it is blessed with some of the most spectacular Neolithic monuments.

The main features of the Avebury site are long mounds (barrows) for burials; enclosures for assemblies and ceremonies (so-called henges); and a very large artificial hill that served no known purpose. The artificial hill, called Silbury Hill, stands nearly 40m high and it is estimated that it took about 18 million man-hours to build. Its purpose is an unsolved mystery, but must have seemed very important to its builders. Perhaps it served spiritual purposes similar to those served later by the great cathedrals, as a communal act of worship, striving to reach into a sphere outside that of living humans.

The second most remarkable structure is a huge henge, i.e. a large circular area surrounded by an earth wall and an inner ditch, with 98 huge sarsens erected along its inner periphery. It is thought to have served needs for

ceremonial and assembly. The ditch was up to 10m deep and it is estimated that about 200,000 tons of chalk had to be removed during its excavation. A total of about 200 stones, each weighing up to 50 tons, had to be dragged from a site about 2km away. The stones were probably transported on rollers and erected with the aid of leather ropes and wooden props.

Finally, there are eight long barrows on the Avebury site, the most famous of which is known as West Kennet. It contains five stone chambers at the eastern end; two each side and one at the end of a passage. The chambers contained human bones, though no complete skeletons. A variety of grave goods were found, such as pottery vessels of different periods; flint tools; bone, stone and shell beads; and some animal bones.

The construction of such large earthworks, containing tunnels and chambers supported by timber or stone walls and roofs, is a remarkable feat of civil engineering achieved with stone-age tools. Enormous effort was put into a construction that served purely social and ritual purposes. Technology had become a servant of social desires that went well beyond bare survival, and yet did not appear to serve a commercial purpose, except perhaps as a marketplace. Technology did not provide profits; it served purely social and biological needs. There can be no doubt that these huge monuments were built because of social 'need' and not just because they were technologically feasible. To the contrary, technological and social resources had to be developed, stretched and mobilised to make the project possible. The technology involved is indeed remarkable, but the social aspiration and social organisation involved are more remarkable still. Was it faith that moved the stones?

It is almost certain that some of the rituals involved supernatural, or religious, beliefs, including a belief in an after-life. Perhaps it was thought that the spirits of the dead were able to protect the settlements and had to be kept happy. No sooner was pottery invented than figurines were produced for purposes that cannot be ascertained, but certainly fall into our category of decorative, ritual and symbolic needs. It was not long before bracelets and necklaces and other ornaments were made of stone or clay beads. Neolithic Man attempted to comprehend the meaning of life and death and conjectured some kind of afterlife. And Neolithic Man felt the need for ornament, to bring beauty and pleasure into a life of toil. Improved efficiency of food production made time available for the production of desirable artefacts that had no practical utility.

One of the remarkable features of technology is the way it spreads – diffuses - over vast geographic regions. There are several ways in which diffusion of technology – and of social organisation - can take place. Migration of people is one way, and plenty of migration there was from the very dawn of humankind right into the Neolithic age. Trade is another way in which novelty diffuses. The traders brought with them the latest fashions in tools, artefacts and ornaments and were instrumental in describing new techniques and new ways of life observed elsewhere. Finally, occasional meetings between migrating people, or people settled in a particular region, took place and information was exchanged during such meetings. Toward the end of the Neolithic period, some larger centres were established and people travelled from far and wide to attend ritual or other meetings. Stonehenge and Avebury were such sites in England; other countries had their equivalents. Different researchers emphasize different mechanisms of diffusion and all the mechanisms are likely to have played their part.

During the latter parts of the Neolithic period, experimentation with the extraction, smelting, alloying and use of copper began. At first the metals were rare and were used solely for precious ornaments. Later they started replacing stone in some applications, though it was only when bronze came into use that metal offered a substantial advantage over stone for spearheads, arrowheads, sickles, knives and so forth. The metal ages saw the development of what is known as civilizations, and these are the subjects of the next two chapters.

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