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Introduction

The material culture of our earliest hominid ancestor who inhabited northeast Africa some four million years ago was probably on about the same level as that of the modern apes. The first identifiable hominid, *Australopithecus afarensis*, was a small primate, less than a metre and a half tall, with a brain about the same size as a chimpanzee's. This hominid probably made use of only slightly modified natural objects, much as apes do today. Unmodified objects such as rocks used to crack a nut are sometimes called *naturefacts* (Oswalt 1973:14), and their use is by no means limited to the primates. On the Galapagos Islands Charles Darwin observed a species of ground-dwelling finch (now named after him) that used a cactus spine or twig held in its beak to pick insects out of crevices in tree trunks. Many animals also purposely modify natural objects for immediate use in a task – for example the Darwin Finch modifies a twig by shortening or trimming it (Beck 1980:24–5). However impressive animal tool-use may be, it is the range, complexity and sophistication of modified objects, or *artifacts*, that is the hallmark of humanity.

The first evidence of a material culture appeared some two million years ago with the stone artifacts of *Homo habilis* (literally, 'handy man'). As hominids evolved so did their material culture. Early technology was simple, but with the evolution of *Homo erectus* and the emergence of modern man, *Homo sapiens*, these species spread to populate even the most challenging environments. The human species is the most adaptable and successful of all the higher animals and its ability to develop sophisticated and complex material culture seems almost boundless.

Invention and diffusion

Culture is a shared body of learned knowledge transmitted from one generation to the next. It is through culture – material and otherwise – that humans adapt to different environments, though not all such learned behaviour is adaptive (Huffman 1984). Innovations in the form of local inventions or ideas derived from outside the social unit can be added to the pool of learned knowledge. While land animals other than humans learn little from individuals outside their social units, they can also make innovations. For example one group of macaques on the Japanese island of Koshima learned that unhusked rice scattered on the beach for them by scientists could be separated from sand if thrown into a rock pool and collected from the surface of the water. This and other innovations were made by a three-year-old female, who was perhaps the macaque equivalent of a Marie Curie, and quickly learnt by other members of her group (Kawai 1965).

Today almost all the world's societies are linked by a sophisticated communication network so that most changes in a region's material culture occur by diffusion. It is only a rare society, like the Jarawa of North Sentinal Island in the Andaman group, that is almost entirely cut off culturally from the rest of the world, and even in this case the Jarawa accept gifts of mirrors and metal basins left by the Indian government patrols. Although there has always been some communication between social units in the form of trade, the speed by which innovations could be diffused must have been comparatively slow in prehistoric times. Hence innovations in the form of simple artifacts such as most stone tools, or artifacts suggested by nature itself, like cords and ropes, would be more likely to occur by invention than by diffusion. There is less possibility of inventing a relatively sophisticated and complex artifact, such as the rotary quern, and these kinds of artifacts are more likely to have appeared in a particular area because of diffusion rather than independent invention. Today when independent inventions are made in more than one place they are more likely to have come about because of the topicality of the subject; for example many researchers around the world are currently attempting to invent a material that will be superconducting at higher temperatures. In today's industrial societies a high value is placed on useful innovation which, to varying degrees, is in contrast to the cultural values held by prehistoric and non-industrial societies. Nevertheless even in the most conservative societies innovations were possible when material and social prerequisites were in place.

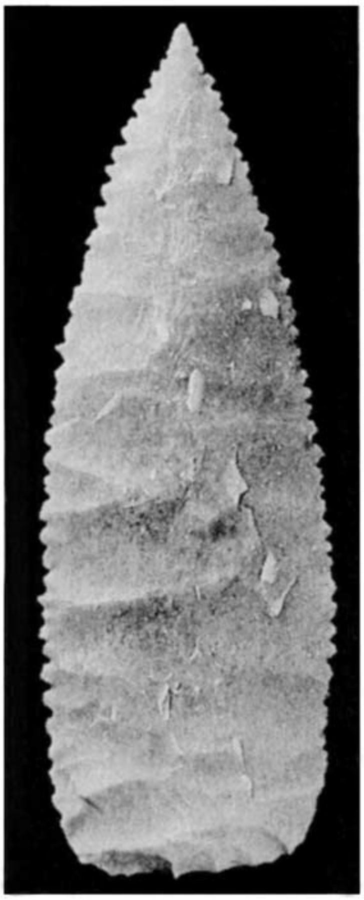
Very little is known about invention and diffusion in prehistoric and non-literate societies because evidence such as reliable oral traditions is sparse. The archaeological record can reveal the presence of a new artifact in a particular time or place, but the process of how it occurred and the reasons why it was adopted and developed in a particular direction is usually open to different interpretations. Much of what is written about culture history is concerned with just this problem. One topical example is the origin and development of the Lapita cultural complex in the western Pacific that is associated with the ancestors of the Polynesians. The Lapita complex belongs to recent prehistoric times; when one proceeds further back in time the evidence for resolving problems of this kind becomes even more scarce and tests the strengths of archaeological theory.

The innovation by macaques discussed earlier had immediate application and reward in the food quest and one can see why it became established as a group norm, but certain other apparently beneficial innovations that were also seen to occur were not acquired by the rest of the macaque group (Kawai 1965). Many factors operate to condition the response of individuals or groups to changes in material culture. Whether a change is seen to be beneficial to an individual or group is in part a subjective opinion of the observer. Thus not all innovations are adopted, be it in macaque or human society. For an innovation to be accepted there must be an appropriate social, political, technological and economic environment. It is a common observation that people tend to resist cultural change because it often requires shifts in established cultural values. Resistance to change is not limited to non-industrial societies, and indeed a warning about this aspect of human nature is often sounded to aspiring engineers early in their university training (e.g. Beakley and Chilton 1973).

It is worthwhile to review a number of historical case studies to grasp the context of change in material culture. The importance of religious factors in the response to some innovations cannot be overemphasised. One outstanding example of religious proscription is that of the Old Order Amish community in the United States which bans its members from using automobiles and electricity. There are also economic, technological and other cultural factors to consider. For instance the wooden screw press, which we discuss in Chapter 4, was not used by the peasant farmers of Corfu because they were unable to make the capital investment (Sordinas 1974). While this machine had been invented by the Alexandrian Greeks in the first or second century BC, and was therefore well known to the inhabitants of Corfu, the crushing of olives continued to be done by the technically less-efficient and truly antiquated direct beam press. While most people think that the jet engine is a modern invention, the original concept can be traced to Heron of Alexandria, an avid inventor of the first century AD, who made a toy steam jet engine. In 1791 a British patent for a gas turbine was granted to John Barbar, but it was not to be until the late 1930s that the first practical jet engine was produced. The earlier attempts to develop this artifact failed because a strong heat-resistant material needed for the turbine blades still had to be developed. When suitable materials became available, the first practical jet engines were produced independently within a year of one another by Sir Frank Whittle in Britain and Hans von Ohain in Germany. This example highlights the need for an appropriate technological environment for change to occur. A more personal and contemporary example of an unsuitable environment for the acquisition of new material culture is provided by a group of Agta Negritos which one of us recently studied in an isolated part of the Philippines. While gin and cigarettes were seen as appropriate and affordable purchases from trade stores, items of Western medicine that were highly desired were uncommon purchases because they were perceived as being too expensive (though comparable in price to the gin and cigarettes) and could not be administered because no one was able to read the instructions about dosage.

In the cases cited the reasons for an innovation not being exploited are known because there are sufficient historical records available, but there are also many instances where the evidence allows only speculation. One of the most notable of these cases is the absence of wheeled vehicles in the New World. While the Incas had more than 3000 km of made roads with suspension bridges for pedestrian traffic, and llamas for carrying loads, they failed to develop wheeled vehicles. Similarly the absence of the bow and arrow among the Australian Aborigines is difficult to explain when the materials for making them were certainly available, and when these artifacts were in common use among their neighbours in New Guinea and the Torres Strait islands. In contrast to this evident disinterest in certain new subsistence technology, the Australian Aborigines copied the outrigger canoe from New Guinea and were unhesitating in their acceptance of the steel hatchet and other artifacts brought by white settlers, such as blankets and glass bottles.

Fig. 1.1. A Kimberley point.



The appearance in the archaeological record of a new type of artifact or a design change does not necessarily imply a novel invention, but may simply reflect a technological or social change that promotes or allows the general adoption of an obvious idea. An invention can be conceived countless times before it becomes established as a cultural norm. Making stone tools by grinding rather than flaking is a low order innovation about on par with making simple flaked stone tools; it has direct correspondence to observable processes in nature and the phenomenon of abrasion and grinding must have even been within the experience of hominids – our old friends the macaques rub pebbles together as a form of play (Huffman 1984:726). Yet ground stone technology did not appear in the archaeological record until as recently as 20 000 to 30 000 years ago. Among the Australian Aborigines the primary use of ground stone tools was to extract small game hidden in tree trunks and to process the new and important food resource of grass seeds, while the first appearance of ground stone tools in the Middle East and Europe was as an element of farming technology.

Some changes in material culture that occurred in prehistoric time were due entirely to fashion, just as today many changes in the shape of automobiles have little to do with improving their aerodynamics. In the Kimberley region of northwest Australia the Aborigines made delicately shaped stone spear heads called Kimberley points (Fig. 1.1) that were the finest examples of flaked stone implements made on the continent. Much time was spent in their execution, and they were highly regarded in adjacent regions where the process of their manufacture was not understood and where they acquired a new status as ritual objects (Davidson and McCarthy 1957:435; Tindale 1965:155). Yet the most aesthetic specimens appear not to have been particularly efficient because they frequently broke on impact, and their popularity may well have been due to social factors of status and fashion.

Theories of cultural evolution

In the eighteenth and nineteenth centuries navigators, adventurers and colonial officials were returning to Europe with artifacts from many different traditional societies. In the light of Darwin's theory of biological evolution parallels between these artifacts and ancient ones were quickly drawn and grand schemes of cultural evolution began to be defined. One of the most popular early theories of material culture development was conceived by Augustus Henry Lane Fox (1906), who later changed his name to Pitt-Rivers and became Britain's first Inspector of Ancient Monuments. Lane Fox was a military man and his conception of cultural evolution emerged from his observation of the changes in bullet design and their effect on the rifle's accuracy and range (Lane Fox 1858). His proposition was that the most 'primitive' or basic types of artifacts had prototypes evident in natural objects and that material progress followed a path of increasing specialisation and complexity.

The models of cultural evolution proposed by Lane Fox and other scholars such as Otis T. Mason (1895), a curator of the US National Museum, and Henry Balfour, curator of the Pitt Rivers Museum in Oxford (see Rogers 1962), relied to a large extent on the mechanism of diffusion – an innovation would appear in one place and, if it was useful, be conveyed into distant regions where it was subject to modification to make it more suitable for local conditions. In describing how these evolutionary schemes worked one of the best examples one can cite is that of stringed musical instruments. It was reasoned that the simplest stringed instrument, the one-string musical bow, must have evolved from the hunter's bow. The next postulated evolutionary step or advance on the basic design was the addition of a resonator, as it appears on traditional African musical bows (Fig. 1.2). Further postulated design modifications were thought to have led to the development of the whole family of modern stringed instruments.

While the diffusion of ideas from single sources was emphasised, it was recognised that similar forms could and sometimes are known to have evolved independently of one another in quite different regions. For instance there is no evidence to indicate that the material cultures of the complex societies of Central and South America derived in any way from those on other continents. However the degree to which cultural evolutionists accepted independent development as a major factor in culture change varied considerably.

The emergence of the 'historical method' in ethnology at the turn of the century marked a reaction to the extremes of grand theories of cultural development and promoted an appreciation of material culture in its local context. The most prominent proponent of the new approach was Franz Boas (1858–1942). Today there is no robust theory of evolution of material culture. Certainly the grand theories of the nineteenth century were too simplistic. What appears to have happened is that material culture began in a simple form over 2000000 years ago with the hominid ancestors of modern humans. In time, possibly relatively recently, the general material culture inventory of the species grew larger and the artifacts became progressively more complex in form and more efficient overall. World prehistory is framed in terms of evolutionary phases that are based on a combination and predominance of subsistence modes (hunter-gatherer, agricultural and pastoral, industrial) and the type of material for hardware artifacts (stone, bronze, iron and steel). The general changes in subsistence mode and metal technology are

Fig. 1.2. Gubu player.

evolutionary, but they did not occur uniformly throughout the world; nor did all material cultures develop in the same direction. In Australia the hunter-gatherer way of life and stone technology lasted for over 40000 years into the nineteenth century, and in more isolated parts of the continent until the late twentieth century, when the traditional Aboriginal material culture was superceded by an industrial material culture with a technology based on steel and other metals and a range of diverse synthetic materials. In the New World flaked and ground stone technology continued as a major part of indigenous technology until the colonial era, though in some regions the soft metals – copper, silver and gold – were exploited, while in remote Greenland the Eskimos made iron implements from a huge 30-tonne meteorite they called Abnightito (Weaver 1986:410).

Cultural, environmental and geographic factors have combined to cause the development of material culture to be diverse within the context of broad global changes, so that the material culture increased in complexity even in hunter-gatherer groups like the Australian Aborigines (Lourandos 1983; Kamminga 1985:20–1). The various material cultures were often specific to the physical environments in which they operated. For instance the artifacts possessed by the inhabitants of cold temperate and Arctic lands made possible the human settlement of those inhospitable parts of the world. Likewise the artifacts of the Aboriginal tribes who inhabited the deserts of the interior of Australia fulfilled the essential needs of people who were required to travel as unencumbered as possible over long distances; for this reason their artifacts were often multipurpose – their spearthrower was not only used to cast spears but also used in firemaking, and a small stone flake fixed on one end served as a chisel. Thus it is virtually meaningless to compare artifact inventories from different parts of the world as if they represent development stages in one progression towards the material culture of the Industrial Age as was the common belief of the grand theorists. In Australia hunter-gatherer technology developed over tens of thousands of years in relative isolation. A developmental sequence is evident from the archaeological record, certainly in the stone technology (Kamminga 1985:21). Other developments in material cultures in different parts of the worlds are also clearly indicated by the archaeological record. However material cultures are not always accumulative. Innovations are sometimes discarded by societies when, for one reason or another, they no longer suit the physical and cultural environment. Cultural loss can come about by proscription due to social or political change, but in most documented cases the causes are cultural isolation or environmental change.

It has been suggested that the Tasmanian Aborigines, who had one of the least complex material cultures in the world (Jones 1977; Oswalt 1976:189), became culturally pauperised because of geographic isolation. Only 8000 years ago the island was part of the Australian continent and its inhabitants at that time are presumed to have shared some of the material culture of their more northern neighbours. However at the time of first contact with Europeans they had no idea of how to make fire (like the Andaman Islanders), and they had no stone tools hafted with wooden handles, such as hatchets and adzes, and no boomerangs or spearthrowers. One pundit has proposed that the Tasmanians suffered a 'slow strangulation of the mind' (Jones 1977), but the mechanisms responsible for this simplification of material culture are yet to be fully understood.

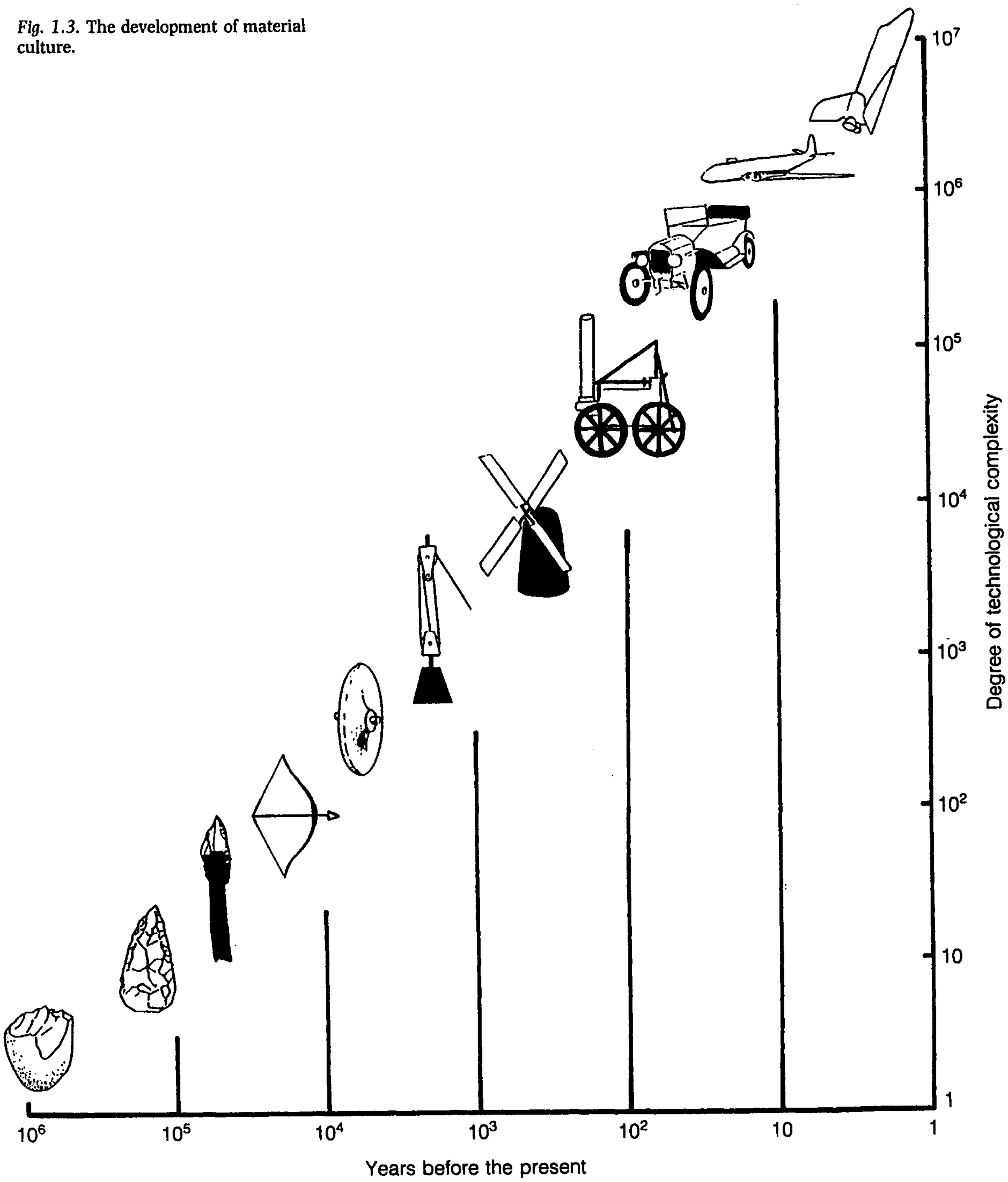
A second example of material culture loss is provided by the Polynesians, the descendants of coastal Asian people who had pottery and possibly knew about metal when they began their odyssey eastwards into the Pacific. These Asian seafarers brought fine pottery with distinctive decoration, and pottery technology remained in the material culture of Polynesian descendants in the western Pacific. But further east, on islands like Hawaii and Easter Island, pottery is completely absent. Again, while geographic and cultural isolation must have played a part in material culture change, the precise causes of this artifact loss are as yet unknown.

An example of material culture loss due to a change in the environment is provided by the Polar Eskimos of the Thule District of northern Greenland. In that high Arctic latitude the subsistence technology is largely concerned with ice-hunting since the ice remains practically throughout the year. When this Eskimo group was discovered in 1818 the normal summer-hunting technology had disappeared and the kayak and umiak were unknown to them. It was not until the beginning of the 1860s that the forgotten elements of Eskimo material culture were restored in the Thule District through the immigration of some families from northern Baffin Island (Gilberg 1974).

Artifact sophistication and complexity

Attempts have been made to gauge the technological complexity of artifact inventories (e.g. Oswalt 1976; Satterthwait 1980) to enable general statements to be made about change in different material cultures. One such gauge is based on the structural complexity of artifacts, that is, their interrelated parts, patterns or elements (Oswalt 1976:42). In this system each individual part of an artifact is called a technounit, and the number of technounits that comprise a complete artifact is a measure of the artifact's complexity. Defining artifact complexity in terms of the diversity of its parts or structural units is a very simple gauge of an artifact's status. Although the measure of technological complexity depends on how one defines complexity, whatever definition is used it is obvious that on a worldwide scale artifacts have increased in complexity with time, especially since the end of the Pleistocene period about 12 000 years ago (Fig. 1.3). However increased complexity can be considered an evolutionary progression only if it reflects greater efficiency. While artifacts are becoming more complex in the contemporary world, improved efficiency can also be gained by structural simplification.

Fig. 1.3. The development of material culture.



There are three main regions of the world where complex societies and material cultures developed as an outcome of the adoption of farming, animal domestication and the process of urbanisation – in East Asia, the Middle East, and Central America. With the advent of the Industrial Age many elements of the material culture of complex societies in Eurasia and North America were exported, through political and technological dominance, to most other regions of the world. In the last two centuries much of the traditional material culture of non-industrial societies has been swept away and replaced by both simple and complex artifacts of American, European or Japanese design – for instance the Coca-Cola can must now be one of the world's most widely recognised artifacts.

The exponential increase in material culture occurred because of the development of highly organised economic structures that enabled tasks to become highly specialised, ideas to be communicated easily and the cooperation of large workforces. Today new artifacts or modifications to pre-existing designs that come into common usage are the product of the cooperative efforts of sometimes countless thousands of humans drawing on, and contributing to, a common pool of knowledge (Altshuller 1984:3). The pace of research is increasing at such a phenomenal rate that in some areas, like computing technology, obsolescence of artifact types occurs within only a few years.

In the contemporary world, many artifacts are both complex and sophisticated in design. Artifacts of earlier times were on the whole much less structurally complex, though not necessarily unsophisticated. Let us examine the wheel as a way of demonstrating these qualities. The basic conceptual sophistication of the wheel is the idea of rotary motion about a fixed axle. Obviously a wheel is more distant from a natural object than a roller is, and it is therefore more sophisticated. The earliest wheels were solid timber discs, less complex than a wheel constructed from a number of separate pieces of wood. As well as being structurally more complicated, a spoked wheel has the added design sophistications of lightness and resilience. The fitting of an iron tyre introduces further mechanical sophistication by strengthening the wheel, and structural complexity by adding an artificial material, iron. The early Chinese wheelwrights learned to dish their wheels so that the spokes formed a shallow cone; this increased the strength of the wheel and is therefore an additional design sophistication. The wheel is just one example and obviously it does not show all the possible kinds of complexity and sophistication an artifact can possess.

The sophistication and complexity of an artifact must be judged against its efficiency. Mechanical efficiency will be discussed in Chapter 4, but we must first consider the broader aspects of efficiency which relate to an artifact's fitness for purpose and cost effectiveness in all the activities for which it is used, as