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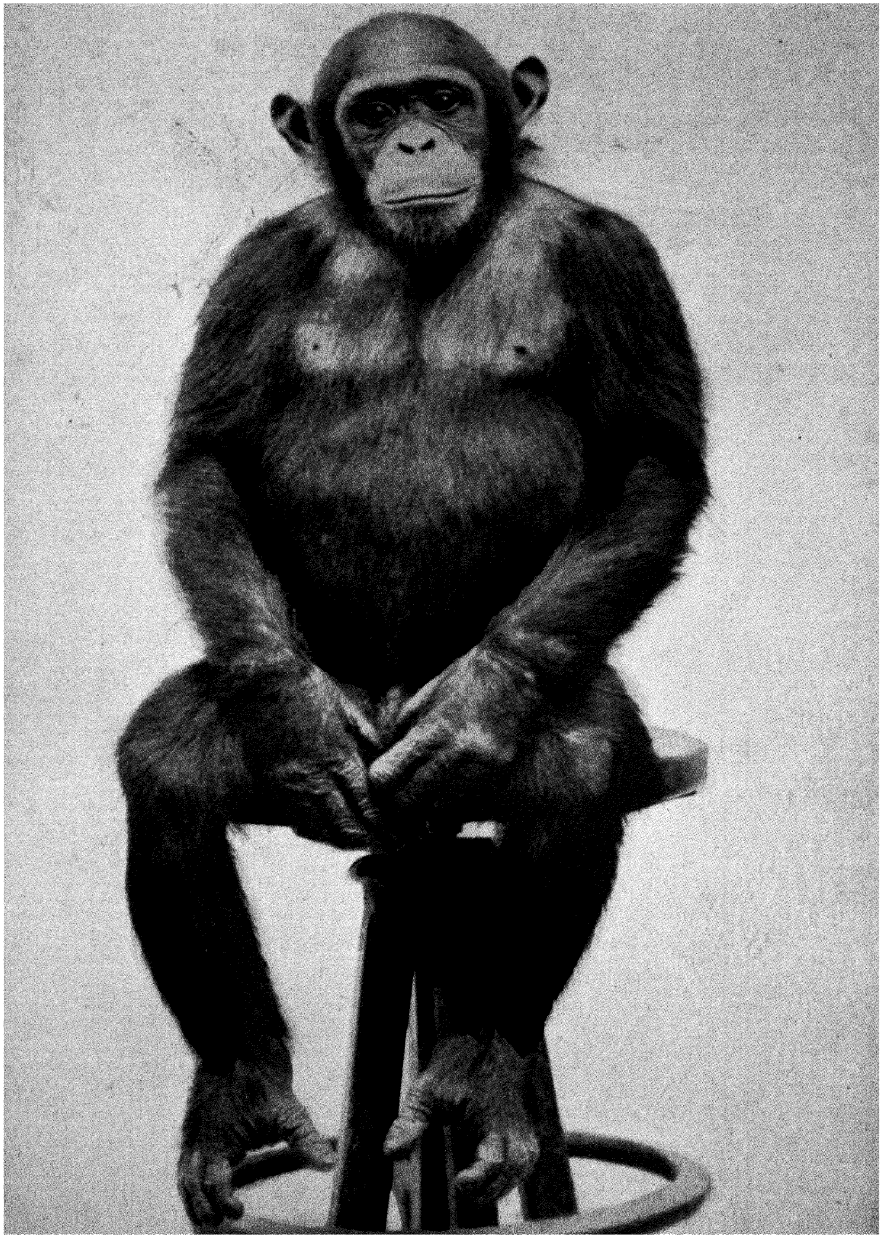
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Title Man's journey through time. 1957

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MAN'S JOURNEY THROUGH TIME



The Chimpanzee (*Pan troglodytes*)

MAN'S JOURNEY THROUGH TIME

A first step in Physical and Cultural Anthropochronology

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HUTCHINSON
SCIENTIFIC AND TECHNICAL
London

HUTCHINSON & CO. (*Publishers*) LTD
178-202 Great Portland Street, London, W.1
London Melbourne Sydney
Auckland Bombay Toronto
Johannesburg New York

★

First published 1957

Set in eleven point Garamond one point leaded
and printed in Great Britain by
Taylor Garnett Evans & Co. Ltd
Watford, Hertfordshire

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PREFACE

IT may, at first sight, seem surprising that one who has studied and taught Physics should now be writing a book on what may well be called "Anthropochronology". On the other hand, it is perhaps not inappropriate that a physicist who thinks automatically in graphs and who has spent much of a lifetime reading about and excavating the relics of prehistoric man should now combine these diverse disciplines in an attempt to depict the fascinating story of the development of man in a graphical and quantitative manner. Palaeoanthropology can hardly be classed as an exact science, but when biometrical data are combined with chronological evidence, certain aspects of man's evolution can be depicted graphically and quantitatively in a way that has not hitherto been practicable. Deductions made from such a method of approach should be of value in supplementing the conclusions derived from what Professor Sir Wilfred Le Gros Clark calls the "total morphological pattern".

The graphical or quantitative aspect of the subject is the underlying theme of this book. It has grown from a seed planted over thirty years ago when the Author had occasion to address the Bristol Naturalists Society on "The Influence of Environment on the Development of Prehistoric Man". A summary of that paper appeared in 1921 in Volume V of the Society's Proceedings. Graphs were drawn which purported to show how man had developed physically and culturally during the past half a million years. At that time comparatively little skeletal material was available for study, the precise antiquity of the available bones was problematical and there was no recognized method by which anatomical indices or cultural criteria could be compared quantitatively. The graphs were, in fact, little more than visual indications of the very different and distinct ways in which man seems to have developed physically and culturally. The production of more reliable graphs to depict these two separate aspects of human development is one of the main objectives of this present work.

The desirability of studying man's morphological development quantitatively has been emphasized recently by Sir Wilfred Le Gros Clark and also by Professor J. B. S. Haldane. In "A discussion of time-rates in evolution" (Proceedings of The Linnean Society of London, Session 162, 149–50, Part 2, 16th March, 1951) Professor F. E. Zeuner states, "More important fossil hominids have been found in the last decade than in any preceding one, and it is to be hoped that in the not too distant future it will be possible to apply some chronological method to the investigation of the Hominoidea." Dr. F. Weidenreich, using the "darwin" as a unit of evolution, has already made one calculation of man's rate of physical development. His result is 0·62 darwins; a surprisingly rapid rate when compared with that of most other animals. It thus seems probable that the time is ripe for more calculations of this kind. In fact it is desirable to obtain graphs by plotting against time in years B.C. the values of all anatomical indices

of taxonomic significance. These indices would have to be obtained from measurements made on a whole series of skeletons each of which must be datable. It has only been possible to do this, and even now only to a relatively small extent, since the discoveries of prehistoric skeletons in China, Java and Africa during the past twenty years.

Assuming sufficient skeletal material is now available, there are still three other difficulties to be overcome before rates of evolution can be measured and compared. One difficulty was the fact that, until quite recently, there was no recognized unit of evolution. This has now been overcome by the suggestion of Professor J. B. S. Haldane who recommends that, when any dimension changes by one-thousandth of its original value in one thousand years, then this rate of change should be called a "darwin". Thus for the measurement of rates of evolution or of morphological changes the "darwin" has been adopted as a convenient unit in this book.

The second difficulty will be appreciated when it is realized that anatomical indices have not been developed with the particular objective of measuring evolutionary changes. For example, the ratio of the volume of the skull to the area of the palate may usefully distinguish the juvenile from the adult, but it gives much less information concerning the antiquity of a skeleton. Again some indices have relatively large values for primitive features whilst others have large values for more recent characteristics. It is obviously desirable that all numerical values should vary in the same way with the antiquity or modernity of the skeleton.

The third difficulty arises because there is no particular skeleton that has been recognized as a standard by which others could be compared.

These problems concerning the quantitative or metrical treatment of skeletal material are discussed fully in the second chapter where methods of overcoming them are outlined. Without some solution to these problems it is obviously impossible to compare rates of evolution of different parts of the human body as they have gradually changed morphologically with time. The particular methods advocated here enable the "percentage humanity" of a given skeleton to be measured. This is not a new conception because Westoll when comparing the characteristics of Permian fishes allocated the figure 100 to one particular Devonian ancestor and then gave smaller numbers to later genera. He thus determined what may be called the "percentage primitiveness" of any particular fish.

Assuming therefore that the value 100 be allocated to a given anatomical index as measured for a particular bone of an average modern adult European male, then it is at least theoretically possible to determine the comparable value of this particular index for any other similar bone of an earlier type. This bone, for graphical purposes, must be datable in years B.C. The variation with time of the percentage humanity, as indicated by the variation with time of the particular anatomical index, can thus be determined.

It is realized that such a quantitative treatment can only indicate the rate of development of one particular aspect of a skeleton; the aspect determined by the chosen index. Consequently in order to compare the quantitative results deduced from this graphical treatment with the qualitative conclusions derived from the overall morphological pattern, it is desirable, and in fact necessary, that graphs for as large a number of different

anatomical indices as possible be obtained. Furthermore, only indices of taxonomic significance should be considered. The practical difficulties which these limitations create is discussed in Chapter II where the available skeletal material is reviewed.

It has been recognized for a very long time that man's cultural development has proceeded in a manner quite different from his physical development. This is to be expected because the two rates are not determined by the same factors. Cultural development is initially determined by the skill, knowledge and personal efforts of an individual and subsequently by the ability of others to adopt ideas and to copy techniques. This process would be repeated by successive generations who might therefore be expected to reach the same state of development in the same length of time. But when the propagation of ideas was facilitated by articulate speech, cultural development was accelerated. A son could by verbal instruction inherit the products of his father's experience and commence his development more or less at the stage where his father left off. For this reason a cultural development/time graph would not be rectilinear but logarithmic. When ideas could be preserved in written form, a given generation could inherit the accumulated knowledge of its forefathers, and the cultural development/time graph would be still more rapidly accelerated. These verbal and written means for accumulating knowledge will lead to a steeply rising graph when some measure of culture is plotted against time.

Chapter III is devoted to the difficult problem of the quantitative measurement of culture. Certain criteria are selected which can be subjected to quantitative treatment, and which are believed to be directly dependent on cultural development. But such criteria will only indicate the development of that particular aspect of culture to which they refer. They will consequently have definite but limited cultural significance. For example, the number of different substances which man used at any given time is some indication of his command over his material environment at that time. His ability to utilize different substances increases with his cultural development, so that the number of substances at his command is a quantitative measure of this particular material aspect of his culture. It is not possible to treat numerically all aspects of his culture. His ethical standards and his appreciation of beauty have so far defied quantitative treatment.

Anatomical indices and cultural criteria would be useless for graphical purposes unless the skeletons or artifacts to which they respectively refer can be dated with reasonable precision. That this is now possible is very largely due to the work of Professor F. E. Zeuner whose recent book on geochronology—*Dating the Past*—has put the dating of prehistoric remains on a sound and scientific footing. As more and more evidence accumulates, the actual numerical values in years B.C. (or B.P.) of skeletons and artifacts may be modified, but the methods employed and dates already determined, especially those obtained by radioactive methods, have been adopted in Chapter IV where the Time Factor is discussed.

Professor Zeuner has done for geochronology what Professors Sir Wilfred Le Gros Clark and J. B. S. Haldane have done for palaeoanthropology. This book merely combines their results in an attempt to depict them in graphical form so that extrapolations both backwards and forwards in time may be possible. Such extrapolations do in fact

lead to new conclusions which are not without interest to the present generation, and may well indicate the lines of man's future development. Furthermore, the possibility of depicting in a graphical form the temporal changes in man's physical or morphological condition and in his cultural or intellectual status enables one to visualize and therefore to appreciate the two distinctly different rates at which these respective aspects of man's make-up have developed. It is felt that development graphs will convey more information in an easily comprehended manner than can be conveyed by the somewhat more cumbersome and less precise method of verbal descriptions. It is easier to understand what is meant by "a spiral staircase" when confronted with a picture than when presented with a technical specification.

Finally, it is hoped that this book, and in particular the discussion in Chapter V of Figures 53 and 54, will convey the story of man's past and the trend of his future in a manner which is both comprehensible to the layman and student and acceptable to the anthropologist and prehistorian.

Were it not for the encouragement and help I have received from many friends and colleagues who have specialized in the many fields covered by a work of this kind, it would not have been possible to attempt this book. To all of them I tender my grateful thanks and in particular to Professor F. E. Zeuner of the Institute of Archaeology, University of London; to Professor G. H. R. von Koenigswald of the Institute of Mineralogy and Geology, University of Utrecht; to Dr. L. D. Brongersma of the Natural History Museum, Leiden; and to Professor E. K. Tratman, late of the University of Malaya; with all of whom I have had much helpful discussion.

For the early encouragement and generous help which I received from the late Professors Sir Arthur Keith and Edward Fawcett I shall always be grateful.

The production of this book has been facilitated by the patient work of Miss Ruth Champeney who succeeded in transcribing my difficult manuscript into legible type, and I am particularly indebted to Dr. R. J. G. Savage of Bristol University, who has made many valuable suggestions and kindly assisted with the onerous task of proof reading.

Finally I would like to give additional thanks to my brother—Mr. E. B. Palmer—who has prepared all the line drawings. The half-tone blocks have been taken from various sources and I am grateful to the following who have kindly given me permission to reproduce copyright figures:

Figures	*Author*	*Source*	*Publisher*
Frontispiece	Professor M. F. Ashley Montagu	*An Introduction to Physical Anthropology*	Charles C. Thomas, New York
14			
7	Professor Sir Wilfred Le Gros Clark and Dr. L. S. B. Leakey	*The Miocene Hominoidea of East Africa*	British Museum (Natural History)
8	Professor Sir Wilfred Le Gros Clark	*History of the Primates*	British Museum (Natural History)
9, 10, 11	Professor G. H. R. von Koenigswald	University of Utrecht	—

Figures	*Author*	*Source*	*Publisher*
13, 21	Dr. L. S. B. Leakey	*Adam's Ancestors*	Methuen & Co. Ltd.
15, 16	Dr. T. D. McCown and Sir Arthur Keith	*The Stone Age of Mount Carmel* II	Oxford, Clarendon Press
17, 18	A. H. Broderick, Esq.	Photos by Professor H. V. Vallois in *Early Man*	Hutchinson & Co. Scientific and Technical Publications
19A	Professor A. C. Blanc	Istituto Italiano di Paleontologia Umana, Rome	—
20, 22	Professor H. V. Vallois	Musée de l'Homme, Paris	—
23		Procds. University of Bristol Spelaeological Society	J. Wright & Sons Ltd.
24, 26	The Trustees	Wells Museum, Somerset	—
25	Dr. L. D. Brongersma	Rijksmuseum van Natuurlijke Historie, Leiden	—
27, 28, 29, 30	H. St. George Gray, Esq.	*Glastonbury Lake Village*	The Glastonbury Antiquarian Society

In a new topic of this kind there will be unavoidable errors for which I am alone responsible, but if this book stimulates others to develop the subject and to increase the range and accuracy of the data, then I shall be well satisfied.

L.S.P.

Wells

CHAPTER I

The Problem

NORMAL men are essentially conscientious reasoning animals, and frequently show a special interest in information which helps them to understand something of their past history. Many are particularly stimulated to hear or read about their very remote ancestry. Instinctively one compares the past with the present and may well speculate on the future—a tantalizing occupation. But whereas material remains yield undeniable evidence of the past, the future can only be mentally visualized with more or less uncertainty. It is believed that a greater knowledge of the past will enable the future to be predicted with much greater certainty than is at present possible.

1. Changes with time

When we read a railway time-table and proceed to a railway station with the object of meeting a given train, there is a reasonable hope that the train will arrive more or less on time. A railway time-table is, in fact, a book of prophecies. When a tank of water springs a leak, it is not difficult to predict the time when the tank may be expected to be empty. On a rather bigger scale and in a very different field, almanacs are published which predict the phases of the moon or the times of the tides with a certainty that would have amazed a medieval philosopher and would have credited the author with the title of prophet had he lived two thousand years ago.

All these predictions and the many others that can be called to mind are no longer marvellous nor mysterious when we consider and analyse the nature of the processes involved. There are three stages in each example. First a starting point is fixed. Second, a regular law relating the changing event with time is discovered, and finally it is assumed that the law will hold good in the future. The probability of any prediction being fulfilled is obviously increased when the time to the predicted event is short. This naturally follows because the opportunity for the occurrence of any abnormal circumstance which could upset the continuity or regularity of the law will be reduced. Any prediction is thus only a probability; but in given cases it may almost amount to a certainty—at least a certainty for all practical purposes and for a not too distant future.

In the first example the initial time at which the train starts is known, the distance to travel is known and the velocity of the train can be controlled so that the arrival at a given destination is more or less on schedule. Thus the certainty of the prediction, in this case, depends on the human element—the driver—and on such uncontrollable and unpredictable occurrences as accidents. The law relating the location of the train with time is regular and is known. Consequently the time-table can be used with

reasonable reliability assuming the driver does not fall asleep or become unconscious and that no other unforseen event occurs to disturb the anticipated speed of the train.

In the second example the initial amount of water in the tank can be determined. The rate of leak can be measured over a short interval of time and, with a little knowledge of the physical laws concerning water escaping through a hole, it is relatively easy to predict the time when the tank should be empty. Again, no unexpected accidents must upset the regularity of the law after it has once been determined by experiment. No speck of rust must obstruct the hole and no unknown person must bale out the water.

The third example is similar to the other two in that some initial condition must be known—the phase of the moon and the condition of the tide now. Then at any time in the future, the phase of the moon or the time of the tide can be calculated from a knowledge of the natural laws concerning these two particular phenomena. To obtain a knowledge of these laws many years of experimentation and the gradual accumulation of astronomical data has been necessary. Here too it must be supposed that no untoward happenings upset the natural cycle of events upon which the predictions depend. Man cannot change the operation of these natural laws and consequently the probability of the correctness of the almanac is much greater than the probability of a train's punctuality. Furthermore the almanac is likely to be correct for a much longer time.

It is well known that man himself has changed with time and many anthropologists and prehistorians have studied these changes. Such a study is the objective of this book. Geologists, physicists, astronomers and others have considered the question of time and most of them now agree that this earth and all the changes through which it has gone commenced between 2,000,000,000 and 4,000,000,000 years ago. Before we can consider the changing events which preceeded the advent of man and those changes through which he has lived and which he is still experiencing, it will be desirable to consider a little more fully the best method for linking together the two aspects of the subject. These are the changing events (including the changes in man himself) and the time period during which these changes have occurred. Perhaps, as in the three examples quoted above, there may be a regular law relating human changes with the time. If so such a regular law might well be called the law of human development. That such a law is not improbable and is even suspected follows from the not uncommon use of the word "progress" when referring to man's changes with time. This is obviously a matter for further discussion, but before such a discussion can take place it will be very desirable, in fact necessary, to define our terms very carefully.

2. Definitions

Man's journey through time has been one of continuous development. The purpose of this book is to study this "development" of the human animal we call "man". Then to determine the path along which he has travelled and the present state of development that he has reached after the first million years of his journey. From this it may be possible to foresee the not-too-distant destiny towards which he appears to be moving.

2.1 *Man*

What do we mean by "man" and how is "development" to be defined? Recent discoveries in the Far East (near Pekin), in Java, in Palestine and in Africa have led to the now generally accepted conclusion that man has gradually developed from early Primates (one of the mammalian orders) into the human beings represented by the many races now inhabiting this world. During the period of man's development other branches have sprung from the same trunk and the apes and monkeys have also gradually evolved throughout approximately the same period of time. Apes and monkeys may be more or less our remote cousins but they are not our ancestors. Whereabouts on the human branch does the earliest creature become a man—the genus *Homo*? Several authorities have constructed "trees" to show these several branches developing from the primary trunk. One of the earliest trees was drawn by Sir Arthur Keith in his *Antiquity of Man*. Professor E. A. Hooton's wire tree in the revised edition of *Up from the Ape* is probably one of the most recent attempts at solving this complicated and difficult problem. Fortunately much new evidence has been discovered during the past twenty years and a detailed study of the anatomy of the several skulls in particular and skeletons in general has thrown a great deal of light on the changes through which man-like apes and ape-like men have passed. The changes have been gradual but by no means simple. For example the very early ape-like man from Java (*Pithecanthropus*)[1] and the man-like ape from Africa (*Australopithecus*)[2] walked upright yet in all probability could barely speak, whilst men from more geologically recent deposits in Germany (Neander Gorge) and from France (Le Moustier Rock Shelter) walked or waddled more like apes but from existing anatomical evidence seem to have had articulate speech and certainly controlled fire. Some authorities prefer to think of the former as closer to man than the latter. This brings us to the crucial point. Is man to be defined by his physical (anatomical) characteristics or by his attainments or by what other criteria? If we choose to define man by reference to his erectness of posture as determined from his skeletal remains, then we must be prepared to accept as man creatures from Africa about whose cultural attainments we know little or nothing and exclude the "animal" from the Neander Gorge who controlled fire and made tools. Similarly if we judge not by uprightness of gait and straightness of limb but by the absence of (say) large canine teeth, then we should include in the genus *Homo* the more ape-like skeletons (as judged by posture) from Germany and France.

Again there seems to be a general increase in cranial capacity as the geological age of skulls decreases. Many early skulls do not exceed in capacity the size of large apes, about 500 c.c., whilst more recent skulls may be more than three times as large. Although this criterion appears to be helpful it is too dangerous to generalize from it. It would not, in fact, be safe to decide that all skulls, the capacity of which exceed some fixed arbitrary volume, shall be classed as the skulls of men. Such a simple test would exclude some races of modern men—and many individuals of our present race. On the other hand, as Sir Arthur Keith points out, there appear to be no truly human crania with very

[1] Meaning "Ape-man".
[2] Meaning "Southern ape".

small capacities. If man is defined as a big-brained biped who walked upright, then the southern men-apes from Africa (the *Australopithecinae*) who walked upright but had small brains and also the Neanderthal men from Germany who had relatively large brains but walked with a stooping gait would both be excluded.

In fact there is no one definite anatomical criterion by which man can be defined satisfactorily. This is unfortunate because skeletal remains obviously yield the most direct evidence about the morphological changes in man's appearance which have taken place throughout the period of his existence on earth. Presumably therefore we cannot judge by appearances if such appearances are to be deduced from skeletal remains, and there is no other means of finding out what our ancestors looked like. The oldest known "portrait" is probably the remarkable carved and coloured head and shoulders of a man who looks rather like a blue-eyed black-bearded Eskimo. This engraved limestone figure was recently discovered by Mlle. de St. Mathurin and Dr. Dorothy Garrod at l'Angle-sur-l'Anglin in France. But the carving cannot however be much more than 20,000 years old and we know that very intelligent creatures, whom we must certainly class as men, existed long before this time.

We are now forced to seek some other test. The test must, if possible, conform to three requirements. Firstly, any selected criterion or characteristic must be of sufficient permanence to have been preserved throughout the ages. Secondly, it must be of such a nature that it is definitely acceptable as pertaining to man and to man alone, and thirdly, it must be capable of differentiating between various types of men. If these requirements could be satisfied then the test would be of greater value than any comparative anatomical features which, as we have seen, do not show any very distinct or sharp change by which man could be irrefutably differentiated from his ape-like cousins. The criteria we must now examine are man's cultural attainments which have arisen from his superior knowledge. In fact we must turn to the products of his mind rather than to the structure of his body. Here there is a choice, although limited, from the permanent material relics which man has left behind him. Such relics will, of course, be quite useless unless they can be associated with the men who produced them. The association may be quite direct as when skeletons and artifacts are found buried together. Alternatively the association may be indirect, as for example when a stone implement and a human skull are found in different but geologically contemporary deposits. With this indirect association it is essential that both the implement and the skull should have been found *in situ*. They must not be "derived" fossils. That is, they must not have been washed into, and therefore be earlier than, the deposit in which they were found. It is not often easy to be certain that such remains are *in situ*. Indirect methods of dating must therefore be used with due caution. Several examples of the works of man may be considered as potential criteria. For instance, his use of fire is indicated by the ashes of his hearths, by burnt bones and by stone lamps. In Europe collected heaps of iron pyrites and flints and in Australia hard wood friction drills and bark tinder are other indications of the control of fire by those whose remains are associated with such relics.

Such cultural achievements as the making of clothes or houses would not be satisfactory diagnostic material because of their perishable nature. Any definition of

man based on such remains would date man as no older than the clothes found in Danish and Irish peat bogs, or the houses found in crannog and lake village sites. Balfour suggested that man might be defined as the animal who first produced and appreciated works of art. The engravings, sculptures and paintings to be found in the caves of France and Spain and in the rock-shelters of Scandinavia and Africa are certainly the works of man. From other evidence, the European art can be dated about 70,000 to 20,000 B.C. but the African paintings are almost certainly more recent. Of all the foregoing evidences of man's culture, the use of fire is the oldest and dates back to at least the middle of the penultimate phase of the most recent ice age—usually known as the Riss epoch. This would date man as not older than about 200,000 years ago.[1]

The least perishable of man's works have yet to be considered, namely his implements made out of stone—usually flint. Undoubted man-worked implements are found in deposits which from other evidence are pre- or inter-glacial and are associated with a warm climate fauna. They can be dated with reasonable accuracy to at least 300,000 years ago, whilst the crude pebble industry of Africa in all probability dates back to twice that time. If we accept certain crudely chipped flints—the so-called eoliths—as the work of man then such implements would mean that man was a tool-maker in England over 500,000 years ago. This date depends on the geological evidence for the age of the Ipswich and Norwich Crag deposits in which the implements of this kind have been found.

The deliberate fabrication of a stone implement is as characteristic of man as is his art or the making of clothes. No animals clothe themselves with artificially made garments and no animals shape stones in order that they might more effectively fulfil some specific purpose. The maker of a stone axe must have first of all mentally visualized a pointed or chisel-shaped stone and appreciated the advantage of such an implement for the purpose he had in mind. In fact he used his brain before proceeding to use his hands. This sequence of events is definitely peculiar to man and has never been observed in the lower animals. Obviously it is necessary to distinguish such a deliberate mental operation by man from the instinctive acts which result in birds building nests, rabbits digging burrows and beavers constructing dams.

Thus of all man's cultural achievements only the making of stone implements would seem to fulfil all the requirements mentioned above: stone implements are not easily destroyed, they are not made by any animals we may wish to exclude from the human family, and different types of implement can, as will be shown later on, be associated with different types of men.

Before finally deciding on a definition of man based on his ability to make implements, it may be worth while to consider whether or not any better criteria are available to distinguish man from the so-called lower animals. Man appears to be a complete trinity—a body, a mind and a spirit. Permanent remains indicative of his superior mental ability are his large skull and the many and diverse artifacts which he has made. There is however no material evidence indicative of his spiritual make-up. It is generally accepted that the possession of a conscience and the ability to do what is considered

[1] In the far east Pekin man used fire possibly 250,000 years ago (see page 79 and Table VIII).

right without being influenced by the external stimuli of pleasure or pain are characteristics peculiar to man. It is true that some people attribute an appreciation of our ideas of right and wrong to animals. It is not appropriate here to discuss the evidence for and against such an hypothesis. It must suffice to say that it is not generally acceptable and any apparent appreciation of right and wrong in animals is more correctly explained as the consequence of a pleasurable habit rather than as a deliberate mental decision dictated by conscience. Hence if any animal *has* left any permanent concrete evidence indicative of a conscience, then this might well be taken as a safe diagnostic characteristic of man. One corrollary of a conscience is the practice of some form of religion. This in turn leads to the worship of unknown gods who are held responsible for familiar but inexplicable events such as the weather. To placate the gods or solicit their help magic practices have arisen. Cannibalism may well be a ceremonial act by which those who practised it could thereby absorb some of the virtues of their ancestors, whilst other magical ceremonies may serve as mimic rehearsals designed to influence the course of future events. The one-time practice in Africa of ceremonially spearing an ant-hill or other object imagined for the time being to represent a lion was intended to ensure success in the hunt. Similar magical practices undoubtedly took place in the painted caves of France where drawings and models of animals are often covered with engraved arrow-heads or spear holes. Similarly, the sun chariot from Meare Lake Village in Somerset and the phallic carvings from the "altar" in Grimes Graves in East Anglia are clear indications of religious practices which can only be associated with man. A consequence of such practices is the anticipation of the future and a belief in life after death. There is a great wealth of evidence for deliberate ceremonial burials in caves and tumuli; the latter often enclosing "houses", food, weapons and even chariots and ships. There is thus considerable material evidence for man's religious activities and beliefs, but unfortunately such criteria of humanity suffer from the same defects as the evidence for his appreciation of art. That is, any definition based on religious practices would exclude many remains which, when judged by skeletal evidence, would certainly be included in the genus *Homo*. In a way this comment "begs the question", because if we decide to define man as the animal with a conscience, that leaves evidence of religious beliefs and that ceremonially buries its dead, then we must perforce dismiss the skeletal evidence and limit the range of humanity accordingly.

A survey of the foregoing facts leads to the conclusion that anatomical evidence alone does not show any marked or abrupt change by which man could be defined. Cultural evidence is more satisfactory in that the making of stone implements entails a technique and requires an ability well beyond the capacity of any non-human animals. Finally, although the appreciation of art and the practice of religion are essentially human attributes, such criteria are not satisfactory for defining man because of the too severe limitations which any such definition would impose.

Consequently Man may now be defined with some confidence as a tool-making animal. This definition may cover and include other criteria which are not by themselves diagnostic. These additional characteristics may include an erect posture, a big brain, articulate speech, relatively small canine teeth, marked canine fossae (the depressions

below the occipital orbits) and other affiliated anatomical peculiarities. It is unfortunate that no material evidence, contemporary with the earliest stone implements, has been preserved which would enable one to conclude that man the tool-maker also had a conscience. Were this so, man would indeed be separated from his animal forbears by an interesting hiatus which would be very difficult to explain. It seems more probable that those characteristics diagnostic of man's spiritual make-up were gradually disclosed as his body equally gradually developed its peculiarly hominid or human features. The hiatus therefore, even if present, cannot be discerned from a knowledge of the material remains of his skeleton or culture. The foregoing definition of man as a tool-making animal is, of course, not new. The analysis of other possible criteria for defining man is not without interest because it places the definition on a sound and acceptable basis. Having come to this conclusion, it is interesting to compare it with the comments of Professor Zuckerman who in *Functional Affinities of Man, Monkeys and Apes* states, "Man is a big-brained Primate with the power of articulate speech. He walks erect and uses his hands—emancipated from the task of carrying his body—to work with artificially fashioned tools. His teeth and correspondingly his face are small relative to those of the apes." These remarks would differ from the conclusions reached above if all the characteristics mentioned by Zuckerman are to be considered as essential to man and of equal diagnostic value. In fact if this interpretation of Zuckerman's statement is correct, then Neanderthal man would have to be excluded. This would lead to the unfortunate result that the ability to fashion an artificial implement would no longer be a characteristic peculiar to man. It is better therefore to retain the simple definition of man as a tool-making animal, and treat the other factors as supporting and confirmatory evidence if and when they are applicable. Zuckerman's definition is however acceptable if limited to our own species—*Homo sapiens*. Some authorities prefer to place Neanderthal man in a different genus and call him, not *Homo neanderthalensis* but *Palaeoanthropus*[1] *neanderthalensis* in spite of his undoubted ability to make implements, to control fire and to have articulate speech. For these reasons it is felt desirable to retain the older and simpler definition and thereby to include Neanderthal man in the genus *Homo*. This decision will force us to include the *Australopithecinae* of Africa in the same genus if and when artificial tools can be definitely attributed to them, and so far this has not been done. It would not be difficult to transfer the *Australopithecinae* to the *Hominidae* (see Fig. 4) should the necessity arise; because, although these "near-men" (as Leakey[2] calls them), have very small brains and probably no articulate speech, yet they do walk and run with the erect posture of modern men. However, their inclusion in the genus *Homo* does not yet arise. We can therefore with renewed confidence accept the definition of man as "The tool-making animal".

2.2 *Development*

Turning now to the continuous development which man has undergone during his journey through time; it is intended that the use of the particular word "development"

[1] Meaning "Ancient man".
[2] In *Adam's Ancestors*.

shall here indicate a succession of changes, each change being dependent on the preceding ones and leading to the succeeding ones; thus resulting in a temporal sequence of associated changes. Hence it follows that the changes which have taken place in man throughout his existence on the earth are not random changes unrelated to each other. The nature and extent of the successive changes will determine the way man has developed. It would not be appropriate to use the word "Evolution" because it is not intended here to give a biological study of those early forms of primates from which the human animal is believed to have descended. The theme of this book is limited to a study of the changes both physical and cultural which have taken place in man from his first appearance on the earth to the present day. When considering these changes it will be necessary to keep in mind their chronological order so that their variation with time can be readily appreciated. Whether or not the development is one of progression or of retrogression is a matter for later consideration after the relevant physical and cultural changes have been discussed. However at this stage it is appropriate to consider how it is proposed to see whether or not man's development has been progressive or retrogressive or whether the employment of such terms is meaningless until a standard of judgment has been agreed. The usual genealogical "trees", to which reference has been made, are not intended to give any solution to the problem of the direction in which man has developed. They only show by their several branches how it is thought that one type of ape or man is genetically related to the other types. Sometimes the time succession is indicated by a series of horizontal lines across the "tree" indicating the time limits of the several geological epochs. But there is no way of determining from such trees whether one type of man is better or worse than his predecessor or successor. If he can be said to be better than his predecessor and worse than his successor, then he can be said to have progressed. This follows if we accept the usual definition of progress as "an advance to a better and better condition".

But how are we to judge whether a man's state of development is better or worse than it was at some earlier time, and hence whether he has progressed or retrogressed since that time? Our standard of judgment must depend on (i) the extent to which man has physically adapted himself to his environment, and (ii) the extent to which he has been able to adapt his environment to suit himself.

To adapt himself is a slow process depending on inherited tendencies; as for example, when he gradually released his arms from the task of helping to support his body and adapted them for other purposes—a physical or anatomical development.

To adapt his environment to his own purposes is a much more rapid progress depending on his knowledge of the material world around him. For example, he has not been able to fly by gradually growing wings, but his rapidly increasing knowledge of aerodynamics and mechanics has enabled him to adapt the forces of nature so that he can fly with artificial wings—a cultural development without physical adaptation.

Thus man's development must be considered from two quite separate points of view. The first is his physical development depending on anatomical changes and the second is his cultural development depending on his acquisition of knowledge.

3. Graphical treatment

In order to compare either man's physical or his cultural states of development at any two given times it is preferable that they should be compared not qualitatively, but quantitatively. Unless the latter can be done it will not be possible to determine any law of development—this is one of our main objectives. Therefore it is now necessary to see in what way quantitative measurements can be made of these two aspects of man's development. This is comparatively easy in the case of his physical development because the various numerical indices which specify his several anatomical characteristics at any time can be quantitatively compared with their values at some earlier or later time. Both the time in years and the anatomical indices in figures enable a pictorial or graphical method of comparison to be carried out with considerable ease and with a degree of precision depending on the accuracy of the measurements. But it is not so easy to obtain quantitative measurements indicative of man's cultural development. For the moment let it be supposed that some figure could be obtained which was a measure of man's cultural attainment at any given time. Then a graph of such data plotted against the time in years would depict the time-rate of change of this particular aspect—the cultural aspect—of man's development.

Before considering whether such cultural data are available, it is desirable to anticipate what kind of graphs may arise and how they could be interpreted.

It will only be necessary to consider at this stage one of the two aspects of man's development. The interpretation will be applicable to either his physical or his cultural development depending on which series of figures or measurements have been plotted against the time. In Figure 1 the time in years has been plotted horizontally (abscissae) with the origin at B.C./A.D.; the time scales being measured off in both directions as shown. The ordinates (vertical scale) considered here are those which we have chosen

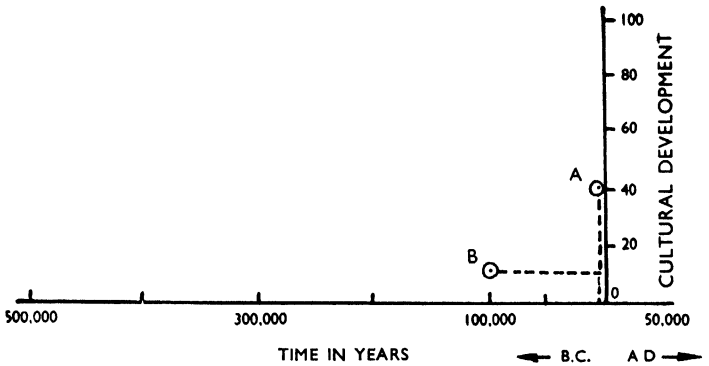


Fig. 1. Graphical representation of cultural measurements.

to be a measure of man's cultural development. Furthermore it will be assumed that the figure representing his cultural attainment at any given time is, in some way yet to be determined, directly proportional to his knowledge of the forces of nature and of the material world around him.

Culture is usually considered to include more than a knowledge of the physical universe. It has been defined as "a trained and refined state of the understanding, manners and tastes". It does not seem possible to measure quantitatively the degree of refinement in manners and tastes, but it is possible to measure the extent of man's knowledge and understanding of his physical environment (see also pages 15 and 154). Thus it will be necessary to keep in mind the fact that the measurements we are able to make will only lead to information about this somewhat limited and materialistic aspect of culture. Nevertheless, in spite of this short-coming, it will be found that such measurements do lead to some interesting information concerning man's cultural development. For convenience one hundred may be chosen as an arbitrary upper limit within which all the measurements will fall. It will be appreciated that so far we have not considered how such measurements are practicable. But for purposes of this preliminary discussion it is supposed that man's knowledge and resultant culture can be quantitatively determined and numerically represented by figures ranging from 0 to 100.

Within the past fifty years many human remains and artifacts such as ornaments, grave furniture, weapons, implements, pottery, etc., have been excavated from geological deposits (for example, river terrace gravels and cave deposits), from tumuli (or other forms of burial), from habitation sites (lake villages, hut circles, etc), and from similar locations. If it be found possible to assess man's knowledge and cultural attainment from these remains and artifacts, then here would be the data for the ordinates in Figure 1. Furthermore if these remains were found *in situ* and consequently were known to be contemporary with the deposits in which they were found, then the necessary time data for the abscissae in Figure 1 would also be known as soon as the age of the particular deposits was determined in years B.C. or A.D. How this dating can be done will be discussed in a later chapter. As an example, suppose it was known that a particular beaker had come from and was contemporary with a tumulus that had been constructed about 1800 B.C. and if by some means yet to be determined the beaker corresponded to a degree of cultural attainment represented by the figure 40 (say), then these two figures will, when plotted as in Figure 1, be represented by the point A. Similarly, a particular type of stone axe found in a deposit laid down some 100,000 years ago would be represented by the point B, if the cultural attainment figure applicable to the particular axe was 10. In this way, with the vast amount of information now available, hundreds of such points could be placed with varying degrees of accuracy in Figure 1. What can be deduced from such a mass of points? Before any deduction can be attempted the points must be joined in chronological order by a line commencing with the point at the earliest date and finishing if possible with a point at the present day. What can now be determined from the resulting graph depends entirely on the form of the graph. If the graph took the form of a zigzag line oscillating along from left to right, then we could conclude that man's cultural attainments also fluctuated with time in this way. He would be extremely knowledgeable at one period and be very ignorant at the next and so on. This we know is definitely not the case and so we may dismiss as entirely improbable an erratic graph of this kind. It is much more likely that

the graph would be regular rather than fluctuating. The regularity of the graph would represent the regularity of man's cultural development with time—in fact it would represent the law of man's cultural evolution during the span of time covered by the graph. Some forms of graph representing different kinds of laws are indicated by the several curves in Figure 2. Obviously there is an infinite variety of graphs but the general method of interpretation can be understood from the five imaginary or hypothetical graphs shown in the figure. Graph 1 indicates that man has steadily declined in his

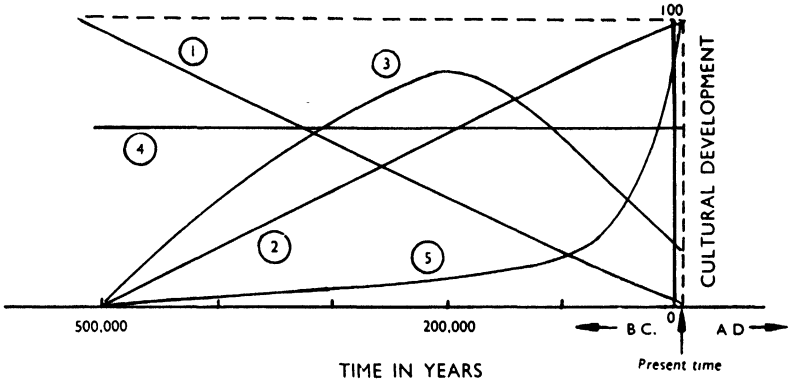


Fig. 2. Graphs showing hypothetical variations of cultural development with time.

cultural attainments from a state of very high development 500,000 years ago to one of zero knowledge today. This we know does not represent the true state of affairs. It means that the law of evolution of man's culture is one of steady retrogression. Graph 2 in a similar way represents a law of steady progress. Graph 3 indicates a rapid initial progress during the first 300,000 years of man's existence reaching a climax about 200,000 B.C. and then followed by a more rapid decline to a very low state at the present time. This too is not believed to approximate to what has actually happened during man's existence. Graph 4 illustrates the unlikely case that man's culture has remained unchanged for all time. Finally, Graph 5 is to be interpreted as representing a very slow progress for hundreds of thousands of years followed by an ever accelerating progress culminating in the highest state of culture at the present time. The regularity of all these laws during the last 100,000 years means that, as long as no unforeseen events upset the continuity of the law, then man's future cultural state could be predicted with reasonable confidence at least during the next 10,000 years. Thus we see that, with the exception of Graph 4, the form of the graph indicates the nature of man's ever-changing cultural development with time.

Similar hypothetical graphs could be drawn for man's physical development.

We have seen that the form of the graph enables us to determine what was the state of man's physique or cultural attainment at any given time or how much it changed during a given interval of time. It will also be appreciated that the slope of the graph at any particular point or time is a measure of the *rate* at which man is developing at

that particular time. As the slope is zero in Graph 4, the rate at which man's knowledge was changing is also zero. This is merely repeating our previous deduction from this graph but deducing it from a slightly different standpoint. His rates of change are constant but not zero in Graphs 1 and 2, and a retrogression can therefore be looked upon as a negative rate of change whilst progress is a positive rate of change. Both these occur in Graph 3, whilst the rate of change in Graph 5 is always positive but it increases with time.

It is generally accepted that man's cultural development, at least in Europe, has, in fact, proceeded more rapidly in recent times than in pre-Roman times and therefore it may well be that a graph similar to 5 represents the true state of affairs. It would be interesting to be able to verify this possibility, to study the underlying causes and to see how such a graph compares with the graph of his physical development.

It has already been suggested that anatomical indices from skeletal remains would provide figures for the ordinates of a physical development graph. Such figures would, of course, be useless unless the time (the abscissa) associated with a particular bone was also known. Obviously without both sets of figures it would not be possible to locate a point with reference to the two axes.

3.1 *The Ordinates*

(*a*) *Physical Data.* Anatomical indices have been devised in order to be able to compare similar parts of different skeletons. Variations in the value of a given index are due to many factors such as age, sex, race, time, etc., but for our immediate purpose only variations due to the relative antiquity of the skeletons, that is changes due to time, need be considered. Furthermore the only significant changes are those which have magnitudes greater than the relatively small range of variations which normally occurs between similar parts of contemporary skeletons.

It will be convenient for our present purpose if the value of every index could be indicated by a number which progressively increased to (say) 100 or 1,000 as the type of skeleton more nearly approaches that of the normal present-day adult European. But anatomical indices were not devised with the present objective in view. For the purposes of comparative anatomy it does not matter whether the index increases or decreases with increase of hominid (i.e. human) characteristics. Neither does it matter whether any particular number represents the average modern European. Consequently, some of the orthodox indices will need to be modified if they are to serve the graphical purpose now under consideration.

As an example of a measurement which increases with time, the cranial capacity, to which reference has already been made, may be cited. The skull capacity of the earliest forms of men or ape-men, such as the *Australopithecinae* of Africa, is about 500 to 600 c.c. These proto-men lived perhaps half a million years or more ago. The volume of the skull of an average modern European is of the order of 1,480 c.c. The change has not always been a steady increase. Cro-Magnon men of 30,000 years ago and some early Neanderthal men of 100,000 years ago had larger skulls than the average men of today, but apart from these anomalies the general change has been an increase of volume with time.

As an example of an anatomical index which decreases with time we may consider the length of the arm compared with the length of the leg or in more technical language the pectoral/pelvic limb index. This inter-membral index is greater than unity in the chimpanzee and gorilla but less than unity in man. Thus a value exceeding one is indicative of brachiating habits (i.e. swinging by the arms) and a fractional value shows greater adaptation to a bipedal method of progression. The sequence of changes is represented by a series of decreasing numbers as the posture becomes more erect and as more hominid characteristics are developed.

In order to modify anatomical indices such as the foregoing to suit our present purpose, the following procedures will be adopted. When the index figures increase with time, as in the first example, all that is necessary is to reduce them all in the same proportion so that the maximum value of the new series is 100 or any other suitable figure, e.g. Z.

Thus if X be any figure in the series and X_0 is the maximum value, and Y the required new figure corresponding to X, then

$$Y = 100X/X_0 \text{ or in general } Y = ZX/X_0 \quad . \quad . \quad . \quad (1)$$

The new values Y are the ordinates to be plotted against the time (abscissae) in years. This process merely adapts the graph to our requirements by effectively altering the scale of ordinates.

Thus if the cranial capacities of skulls dated 500,000 and 50,000 years ago and the present day were 500 c.c., 950 c.c. and 1,300 c.c. respectively, then the ordinates corresponding to the three times would be, approximately 38, 73 and 100.

When a series of indices decreases with increase in the hominid characteristics of the skeleton, then two processes are necessary. First the indices are plotted against the corresponding time. The resulting graph is then reversed so that it becomes the mirrored image of the original graph. Such a procedure reverses the slopes without affecting the shape of the graph in any way. To do this each figure X of the series must be subtracted from the sum of the first and last figures. The new series of figures (Y^1) may therefore be expressed as follows:

$$Y^1 = (X_1 + X_n) - X \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where X_1 and X_n refer to the first and last members of the original series. Of this new series in Y^1, suppose Y^1_0 is the term of maximum value. Then, in order to compress (or expand) the graph so that $Y^1_0 = 100$ or in general any number Z, we calculate the final numbers Y of the new series as before, namely:

$$Y = 100\ Y^1/Y^1_0 \text{ or } ZY^1/Y^1_0 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

In this way each value X of a given anatomical index is first transformed to the "mirrored" value Y^1 and then finally modified to Y. These last values are plotted as the ordinates against the time corresponding to the particular value X. For example, suppose the pectoral/pelvic limb indices of the three skeletons mentioned above are 1·22, 1·01 and 0·69 corresponding to the same times as before. Then the "mirrored" indices Y^1 will be 0·69, 0·90 and 1·22, leading approximately to 56·5, 74 and 100 for the final values of the ordinates Y.

In this way the graph for each index is made to increase up to the desired arbitrary maximum number of 100 or 1,000 or in general Z. Such an increase is an indication of the development of man's skeleton towards that of modern man, for whom all indices will be equal to 100, or 1,000 or Z as the case may be.

It might be thought that in the second case it would have been simpler merely to take the reciprocal of the decreasing indices. The resulting series would certainly increase with time, but the shape of the curve would be entirely changed and distorted. The procedure would amount to initiating a new index. The present objective is to modify existing indices, and this is achieved by calculating the figures of the graph for the undistorted mirrored image as suggested above. If, as may be the case, some indices of a series happen to be negative, all numbers should be made positive before applying the above formulae. This can be done by adding the biggest negative value to every number of the series. All numbers will then be positive, the lowest one being zero.

When indices are modified so that 100 is the value for man, they give directly the "percentage humanity" of the skeleton in so far as the particular index is a measure of hominid characteristics; that is, in so far as the index has taxonomic significance.

When all the available data comprising both anatomical indices and corresponding time factors have been collected and appropriately modified, it should then be possible to depict graphically and to interpret quantitatively the story of man's physical development. This task will involve the collection of existing data, the making of many new measurements and a survey of the evidence from which the corresponding time factors can be deduced. It is proposed to select some of these data and measurements in the following chapter; sufficient it is hoped to enable results to be deduced with reasonable accuracy. But the complete task is obviously quite beyond the capacity of this book, and will take many years to complete even with the limited data now available.

(*b*) *Cultural Data.* The next matter for consideration is the much more difficult problem of man's cultural development. If we are to treat the subject graphically and quantitatively as in the case of his physical development, then, again two sets of data must be obtained; one concerning cultural measurements pertaining to a given type of man and the other concerning the date or time factor of the period when he lived on the earth. The determination of the time factor of his remains and artifacts will be considered below after the quantitative assessment of his cultural attainments has been discussed. But how is his cultural attainment to be measured? One obvious and direct line of attack on this problem is to see if there is any clear relationship between man's brain and his cultural development, and then to study endocranial casts made from his skulls. There are, however, two serious objections to such a procedure. First, although a higher mental capacity, but not necessarily a higher culture, is generally associated with a greater complexity of the brain convolutions, there is little if any quantitative relationship between the sulcal markings on brain casts and mental ability, and still less relationship to man's cultural attainment or knowledge. Second, evidence of this kind is so scarce that there would not be sufficient data to make a reliable graph. A more indirect method must therefore be devised.

It is believed that a solution to the problem may be found from the following

considerations. It will be readily appreciated that as time advances so man has come to understand more and more about the natural forces in action around him and the laws by which they operate. As a consequence of this he has slowly but surely increased his mastery over his material environment and he has been able to utilize and direct the forces of nature to his own ends and for his own betterment. In fact man's mastery over matter might safely be taken as one criterion of his cultural attainment. If we accept this thesis, the problem reduces to one of measuring quantitatively man's control over natural forces and his utilization of the world's material resources. There are certain inevitable results which follow from this ability of man to mould his environment to suit his requirements rather than to adapt his physique to conform to its dictates. Man makes clothes and builds houses much more effectively than he could grow a thick coat of hair. Similarly he can make aeroplanes more easily than he could grow wings and he can carry an atmosphere with him beneath the surface of the sea or above the stratosphere more readily than he could develop gills or learn to live in a vacuum.

His cultural development is, in fact, largely the consequence of his mental ability and is characterized by many factors, three of which are chosen because they can be assessed quantitatively. These factors are: (1) The variation in the number of materials at man's disposal; (2) the variation in the number of his occupations; and (3) the variation in his speed of movement by mechanical means. Without specifying any numbers it is obvious that all these particular factors have increased with time. Consequently if numbers are allocated to them representing the maximum attainment at given times, graphs can be drawn which will show the development of man's culture with time and the increase in his mastery over matter. The reliability of any conclusions that may be deduced from such graphs will naturally depend on the accuracy with which numbers can be allocated to the varying factors and also upon the extent to which the factors are truly representative of man's cultural attainment. It will be shown later that the allocation of numbers can be carried out most accurately where the number is small and least accurately where the number is large. This is fortunate because it means that the overall percentage of accuracy will be more uniform. In other words when considering times of the order of 100,000 years, errors of 1,000 years may be permissible, whilst it will usually be possible to date a piece of Iron Age pottery of 2,000 years ago to within 20 or 50 years. Similarly when dealing with a hundred different artifacts or kinds of materials it will not matter if we are unable to determine the correct figure to within, say, half a dozen.

Consequently this method of quantitatively assessing cultural attainment looks as if it may be a solution to the problem with which we were originally faced—namely, how can man's culture and his ever-increasing knowledge of his environment be measured? Each of the three criteria will yield a culture/time graph from which the rate of development can be judged. Naturally, if the criteria are truly representative of man's cultural attainments, the three graphs should be similar in shape.

The actual data for these graphs will have to be obtained from a knowledge of man's ever-changing life in prehistoric times. This is the theme of Chapter III.

Some years ago another method of obtaining a culture/time graph was attempted.

The results were of some interest even though they were not strictly quantitative but only a statistical survey of educated personal opinions. About two dozen members of a class in prehistory were asked to allot a number varying from 0 to 100 to indicate what in their opinion was a measure of the standard of culture necessary to enable a man to make any one of a series of prehistoric and historic artifacts. The articles chosen could be dated and were selected so as to cover the whole range of time during which man had developed. They varied from the earliest form of stone implement to an aeroplane. The maximum mark of 100 was allotted to the latter. The details of this and of a similar experiment and the results obtained will be discussed later when the other three culture/time graphs have been obtained.

So far attention has been concentrated on the possibility of obtaining data representing the condition or state of man's physical growth and cultural attainment. That is, we have concentrated on the ordinates of our graphs. It is now necessary to consider how the appropriate values on the time scale (abscissae) may be obtained. Without such information no graphs could be plotted and we should only be able to visualize man's physical and cultural development in a vague and qualitative way. In fact we could not get any reliable idea or true mental picture of changes in the rates of development. In a superficial manner we are conscious of the fact that, for example, ancient Egyptians, African natives, Australian aborigines and Eskimos developed physically and culturally at different times, with different rates and eventually reached quite different heights of cultural attainment. But any rigorous comparisons are impossible without some means of measurement such as those discussed above together with a knowledge of the time in years associated with each stage of development.

3.2 *The Abscissae*

Time. Professor F. E. Zeuner's book *Dating the Past* is the standard work on this subject of geochronology. Only a brief outline of the more common methods of dating need be attempted here. More detailed information will be given in Chapter IV before graphs are plotted. It is convenient to divide the methods into two classes.

(*a*) Indirect methods based upon the characteristics of the environment in which the skeletal remains or artifacts were found, and

(*b*) Direct methods based upon the particular characteristics of the relics themselves.

(*a*) Indirect methods of dating skeletal remains and artifacts may be sub-divided into two: those which rely upon a knowledge of the date of the contemporary deposit, and those which depend on a knowledge of the date of associated remains. In these two statements the important words are "Contemporary" and "Associated". The word "Contemporary" is used to indicate that the bones or other remains are *in situ* and can be treated in the same way as the contemporary fossils which date the deposit. In other words, the remains were laid down along with the other geological constituents of the deposit, and are not derived fossils.

Similarly it is appropriate to use the word "Associated" when a given artifact is part of a hoard or collection or when it is obviously connected with other datable remains.

Thus, if in an undisturbed cave deposit unabraded flint blades are found along with carved reindeer antlers and the same deposit also yields a mammalian fauna found elsewhere with reindeer bones and other evidence of a cold climate, then it is reasonably safe to assume that the flint blades were made and used when the reindeer and the other "cold" climate animals were living in the locality. Other evidence will then have to be obtained to enable the time of the particular cold period to be determined. The dates for the successive cold epochs and their approximate duration have now been agreed by most authorities. These are indicated roughly in Figure 3 where the corresponding geological divisions are shown along the top line. (See also Fig. 46.)

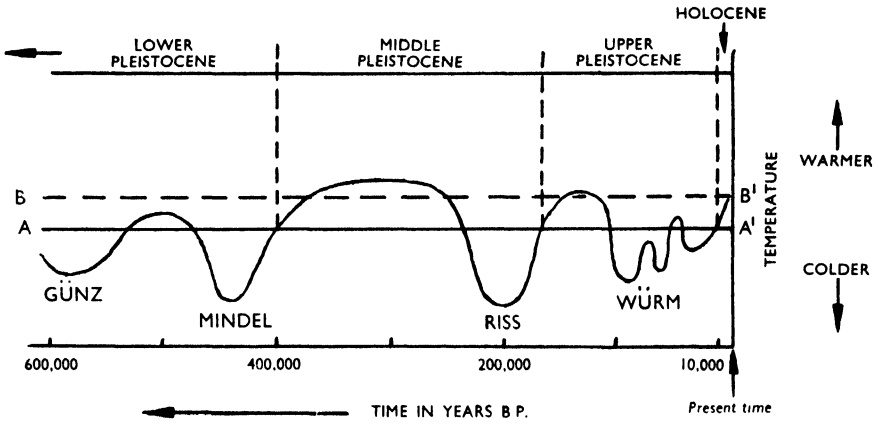
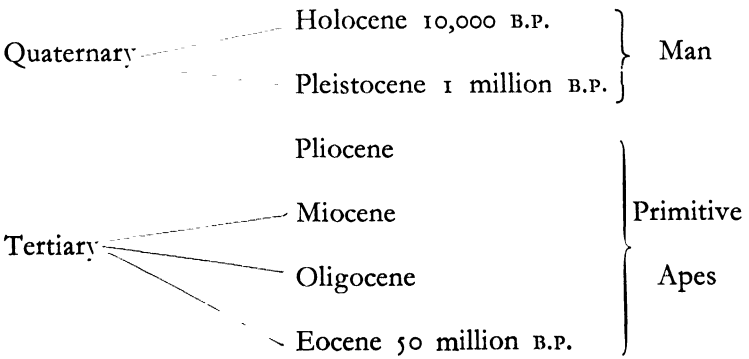


Fig. 3. The Ice Age: graph showing variations of temperature with time (*after* Penck *and* Brückner).

Digressing for a moment it may be stated here that we are only interested in the last two geological periods (the Pleistocene and the Holocene). This follows because there is no evidence that man existed before the beginning of the Pleistocene period which was about a million years before the present (B.P.). The whole of geological time is conveniently divided into Primary, Secondary, Tertiary and Quaternary periods, the sub-divisions of the last two being:



Returning to Figure 3 the line AA' represents the situation in the latitude of south France and Switzerland where Penck and Brückner[1] first demonstrated the existence of four glaciers. In more northern latitudes these phases are less distinct and the interglacial periods considerably shorter or even missing. This condition is indicated by a line similar to that at BB'. For example, in Yorkshire it is possible to detect two interglacial gravels separating three different glacial boulder clays, and only one of these gravel layers is continuous and clearly marked.

Thus it is apparent that dating of skeletal remains and artifacts by indirect methods can only be carried out with confidence if the remains can be treated as contemporary fossils.

On the other hand, abraded flint implements in river gravels or secondary burials in an Early Bronze Age tumulus cannot be dated from a knowledge of the geological horizon of the gravel or from the fact that the tumulus is characteristic of those built between 1800 to 1600 B.C. In the former case the implement must be older than the gravel and in the latter case the burial must be more recent than the tumulus.

Thus the problem resolves itself to that of dating the material of the site in which the remains are *in situ*. In the majority of cases the site is a geological deposit either in the open or in a cave. The dating of geological deposits is a difficult matter and will be discussed in more detail in Chapter IV. Suffice it to say in this introductory chapter that the various methods may be conveniently divided into two classes. Methods depending on the condition and nature of the deposit and methods depending on the contemporary foreign constituents of the deposit. The problem will be restricted here to the consideration of deposits in which the remains of man occur. Such deposits, as may be seen in Figure 3, are relatively recent—not more than 1,000,000 years old—and cover the last two geological epochs; the Pleistocene and the Holocene. The Pleistocene period extends from about 1,000,000 years before the present (B.P.) to 10,000 B.P. and the Holocene or recent period extends from the close of the Pleistocene to the present day. The former period covers the several phases of the last ice age in Europe and the pluvial periods of Africa. The Holocene period covers the post-glacial and post-pluvial periods. The oscillations of temperature in Europe which resulted in the advance and retreat of glaciers coincided more or less with the oscillations of humidity in Africa and are different consequences of the same causes. The causes for these oscillations will be discussed later (see page 114). Preceding the Pleistocene period was the Pliocene during which there is no definite evidence for the appearance of man as here defined. No doubt his immediate ancestors lived in Europe and Africa and were already differentiated from the general primate stock—the *Hominoidea*—from which both the apes (the *Pongidae*) and man (the *Hominidae*) have descended. In discussing this matter G. G. Simpson in his book *The Major Features of Evolution* says: "In the immediate ancestry of man, the whole population crossed the thresholds of upright posture and cerebral expansion, but the result can also be represented as splitting of the families *Hominidae* and *Pongidae*." It is generally believed that this differentiation took place in Miocene times, the geological period which preceded the Pliocene. It is

[1] "Die Alpen im Eiszeitalter"—Leipzig 1909.

probable therefore that some primitive form of man-ape or ape-man existed during these remote times some twenty to thirty million years ago. *Proconsul africanus*, a primitive ape discovered in East Africa in 1933, may be an example of such a creature. These ideas are embodied in Figure 4 where the tentative position of the *Australopithecinae* (the southern ape-men) is shown. The times in millions of years are drawn to scale,

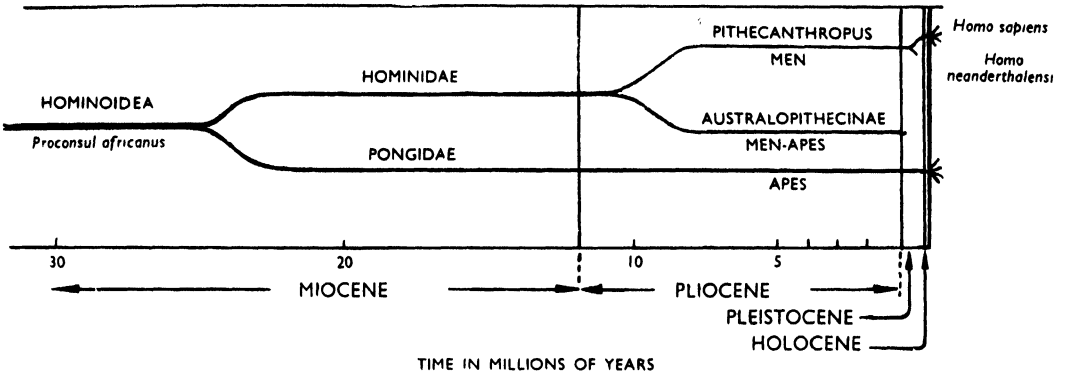


Fig. 4. "Tree" showing time of divergence between Men (*Hominidae*) and Apes (*Pongidae*).

except that the ten to fifteen thousand years of the Holocene period should be less than the thickness of a line. This is an extremely simplified "tree". The monkeys—the *Cercopithecidae*—do not appear in this diagram because they diverged from the *Hominoidea* over ten million years before the left-hand end of the diagram; that is early in the Oligocene period. Neither is it possible to show details of species, sub-species or races in a diagram in which the Pleistocene period of a million years is represented by a small fraction of an inch on the time scale. To appreciate the time scale in its true perspective, it is interesting to realize that the diagram would have to be about one hundred times as long if it were to include the beginning of the earth about three thousand million years ago.

Another indirect method for dating is that which involves the counting of layers or varves as they are called which have been deposited periodically. Alternatively, the analysis of pollen in peat beds enables the latter to be dated relative to the climate at the time of their formation. Pollen spores may then be looked upon as type-fossils for dating peat-beds. Again the nature of an ice-borne erratic rock in a boulder clay and the locality of its origin may serve to identify the particular phase of the ice age in which the boulder clay was laid down.

These and similar indirect methods of dating geological deposits will be discussed more fully in Chapter IV where detailed consideration will be given to the particular dates of given skeletal remains and cultural relics.

(*b*) In the same way that Geology is the most important indirect method of dating, so Typology is the most important of the direct methods.

By Typology is meant the identification of a skeleton or artifact by its similarity to other skeletons or artifacts which have already been dated. That is, the type of the new

specimen is recognized and therefore the time of its occurrence or manufacture is known. Thus an experienced archaeologist will at once date a piece of highly glazed well-made cherry red pottery found in Kent as Roman; probably imported from Southern Gaul about the first century of the Christian era. Similarly a twisted ovate stone hand-axe found in Hampshire would be dated as contemporary with the penultimate inter-glacial period of some 300,000 years ago. Dating by typological comparisons is useful especially when isolated finds are submitted for identification without any knowledge of where they came from or whether they were associated with any other objects. But obviously it is desirable whenever possible to check any dating by more than one method. It is highly improbable that two methods would both give the same incorrect date and practically impossible for three methods to lead to the same wrong conclusion.

Recently three other direct methods have been developed which are of considerable use with certain substances and for limited periods of time. All three methods are physical. One depends on the relative amount of radioactive to non-radioactive carbon in the substance and the other two methods depend on the time taken for the substance to absorb fluorine or uranium salts. Details of these methods will be discussed in Chapter IV.

4. Summary

To summarize the content of these introductory pages, it may be said, firstly from the skeletal remains of man it should be possible by anatomical measurements to follow quantitatively the course of his physical development. Secondly, from the vast evidence of his cultural remains, it should be practicable to study quantitatively his cultural development by allocating numerical values to his artifacts and to other evidence of his mental attainment. Thirdly, both these series of figures (ordinates) may be dated in years B.P. (abscissae) by some or all of the many different methods briefly cited above.

The aim of the following chapters is to collect, to measure and to arrange chronologically enough evidence, physical and cultural, to enable man's development to be seen graphically and thus to be more clearly appreciated than is possible from qualitative descriptions of his physical appearance and cultural status.

CHAPTER II

Anatomical Evidence

THE number of discoveries of prehistoric human skeletal remains has increased enormously during the past twenty years. It will be appreciated that the more datable bones there are for measurement, the more points it will be possible to plot on a graph. But for the present purpose it is only possible to compare like bones of different ages. It will, in fact, obviously be impossible to compare for example measurements indicative of the primitive features of a femur or thigh bone with measurements made on the area of a palate. But similar measurements on each of a series of femora taken from sites which extend over a long period of time may well lead to definite conclusions concerning the changes that have taken place in this particular bone with time.

1. Available skeletal material

Unfortunately the bones recovered from one site belonging to one man may be quite different from the bones of another person found elsewhere. Because of this only a very small percentage of the thousands of bones now available can be of any use for determining the morphological changes that have taken place during the past half a million years or more. It so happens that that portion of the skeleton which seems to have been most effectively preserved is the skull, and it is fortunate that more can be learnt from an examination of a skull than from any other bones of the skeleton. This is especially so if the mandible (lower jaw) and teeth have also been preserved.

The latest discoveries have been made in Africa, China and Palestine together with further remains from Java and Europe. Those from Africa include more than a hundred specimens of the very ancient men-apes—the *Australopithecinae*—whilst the Chinese evidence comes from a series of about forty skeletons found in caves near Pekin—the now-called *Pithecanthropus pekinensis* originally known as *Sinanthropus pekinensis*. In Palestine remains of twelve individuals have been excavated from caves in Mount Carmel. These men are of the type known as *Homo neanderthalensis*. Some of them conform to the now well-recognized somewhat ape-like and highly specialized[1] type originally found in the Neander Gorge near Dusseldorf and later at Le Moustier in the Dordogne district of France. Others of the Mount Carmel remains are less ape-like in appearance and conform more closely to the earlier Neanderthal remains from Ehringsdorf (Weimer) and Steinheim (Würtemberg). These less specialized skulls from Germany come from deposits containing the warm climate fauna of the last inter-glacial epoch. The more specialized men were contemporary with the last or Würm glaciation and are associated with mammoth,

[1] Meaning well adapted to the existing environment.

woolly rhinoceros and the other "cold" animals characteristic of those times. At Mount Carmel both types of Neanderthal men seem to have lived together. Near Trinil in Java an ape-like skull cap was found by Dr. E. Dubois towards the end of the nineteenth century and was for many years the sole representative of the most ancient of our ancestors. The calotte (or brain pan) came from mid-Pleistocene deposits and undoubtedly belonged to an "erect ape-man" who was therefore aptly called *Pithecanthropus erectus*. For many years this specimen was the only one known from this locality although Dr. Dubois had some long bones and a jaw fragment which he did not describe until forty-five years later in 1935. From 1935 and onwards Drs. G. H. R. von Koenigswald and Franz Weidenreich discovered many other bones and some more skulls from a site near Sangiran north of the Solo River in Java. One of these skulls was almost identical with though more complete than the *Pithecanthropus erectus* discovered by Dubois. This particular skull has therefore been called *Pithecanthropus erectus II* and is shown in Figure 10. Eight other skull caps were found together at a higher level, and the damage they have sustained suggests the relics of a brain feast or the victims of prehistoric head-hunters. These *Pithecanthropus soloensis* remains, as they are now christened, are more recent than the original *Pithecanthropus* from Trinil because they came from the *upper* Pleistocene river terrace deposits known as the Ngandoeng beds. The type of man is comparable in some respects with the classical Neanderthal skulls from Germany and France, but has still closer affinities with the skull discovered in Rhodesia in 1929 (*Homo rhodesiensis*). (See Figs. 11 and 17.) From beds *older* than the Trinil deposits—the Djetis beds of the Lower Pleistocene—Weidenreich discovered the skull of a Pithecanthropus child about two years old, together with some remains of a large ape-man. (Fig. 9A.) These have been called *Pithecanthropus modjokertensis* from the village of Modjokerto near to which they were found. Weidenreich originally named the species *P. robustus* because of the large size of the adult bones. He considered them to be the most primitive form of man yet discovered. The most modern relics from Java were found in 1889 by Mr. van Rietschoten and Dr. E. Dubois near Wadjak and, from their geological horizon, are generally considered to be of Neolithic date. All together there are now fifteen skulls or parts of skulls from deposits of four different ages in the island of Java.

In Europe less startling discoveries have been made and very few since 1930. One early paedomorphic[1] form of Neanderthal man was discovered in 1933 at Steinheim, near Würtemberg, and in 1935 a gerontomorphic skull of the classical Neanderthal type was found in a cave in Monte Circeo near Rome. This skull, like the skulls from Ehringsdorf in Germany, Krapina in Croatia, Choukoutien in China and the skulls of the Solo men in Java, was evidently a relic from a cannibal feast of human brains—a possible ritualistic habit of Neanderthal man. He and his contemporaries may therefore be credited with the adaptation of the skull as a salad bowl or soup tureen, in addition to his other accomplishments such as controlling fire, fabricating new forms of stone implements and having articulate speech.

In this brief résumé of the more important discoveries during the past twenty years

[1] Paedomorphic and gerontomorphic refer to skeletons which retain generalized child-like or juvenile characteristics and specialized adult or more mature characteristics respectively.

the number of skulls far exceeds the number of bones of the other parts of the skeleton. The long bones, particularly femora, come next in quantity—a fact that might be expected because they are the strongest of the limb bones.

These conclusions concerning discoveries since 1930 also apply to the many more remains that have been unearthed before that date. The earliest finds are probably the long bones of a male skeleton discovered in the Paviland Cave in Gower, South Wales, in 1822. Then come the Neanderthal remains from Gibraltar (1848) and in 1856 the type specimen from the Neander Gorge near Dusseldorf.

This survey now enables us to come to some decision concerning what anatomical indices are likely to be of most use for obtaining data to meet our graphical requirements. The two outstanding desiderata are firstly, there must be a reasonably large number of similar bones from localities of different periods; and secondly, the approximate antiquity of the remains must be known in years B.P. These rather rigorous requirements restrict our choice considerably. For instance, we can rule out as impracticable the pectoral/pelvic limb index referred to on page 13 because all these bones are very seldom found with the earlier skeletons. In fact the best if not the only course is to confine our attention to the skulls from which, as was mentioned above, a very fair idea of the man as a whole can be deduced. There are dozens of measurements that can be made on a skull and dozens of ratios (indices) by which different skulls may be compared. For our present purpose it will suffice if only three or four indices are selected, as long as they are chosen with the present objective in view. That is, we must decide which indices vary most conspicuously with increasing hominid characteristics, or, what amounts to the same thing, with decreasing simian characteristics. In other words, they must have taxonomic significance.

To this end and with the above limitations in mind, the following four indices have been chosen:

1. The Nuchal Area Height Index.
2. The Condylar Position Index.
3. The Cranial Capacity.
4. The Lower Dental Arcade Convergence Angle.

These indices and the reasons for their selection will now be explained. In the first place it will be obvious that if three or four indices all show the same kind of variation with time, then it will be reasonably certain that their general indications will apply to man as a whole. Clearly a complete picture of man's development can only be obtained if and when there is enough skeletal evidence to obtain a graph of each and every index. But this will not be possible for many, many years at the present rate of accumulation of datable human bones. Neither must it be supposed that man developed his various hominid characters at the same time or at the same rate.

2. Some criteria of humanity

In order to see why these indices have been chosen it will be desirable to consider two aspects of the subject. Firstly, what anatomical or skeletal criteria are indicative

of human or hominid status; and secondly, how are the above four indices obtained and in what way do they measure the extent or degree of development of these criteria.

Three criteria, which are considered to be the most characteristic, will be considered; namely, (i) an erect walking posture, (ii) a large brain and (iii) articulate speech.

It should be emphasized here that according to our discussion on page 4 leading to the definition of man as a tool-maker, no single anatomical criterion can be strictly diagnostic of the humanity of a skeleton. The present reference to characteristic criteria is therefore essentially restricted to the anatomical point of view and only the fulfilment of all three criteria by any given skeleton enables it to be classed as human. This follows because there is no known erect big-brained speaking animal that does not make tools. The reverse proposition does not of course necessarily hold good. There may well be a tool-maker and therefore by our definition a man, who either is not erect or not big brained or has not the gift of articulate speech. For instance, the classical geronto-morphic form of Neanderthal man was by no means fully erect, the small-brained African *Australopithecinae* may have made stone tools and it is by no means certain that Rhodesian man had articulate speech.

These three anatomical criteria are, in fact, the first three of the "additional characteristics" mentioned on page 6.

2.1 *An Erect Walking Posture*

Let us first consider the question of an erect walking posture. This is probably the most important morphological characteristic of man. It automatically involves the development of several other hominid skeletal features, which can therefore be included with or be considered as corollaries of the attainment of an erect posture when walking. For example, an erect posture is accompanied by a basin-like pelvis in which the abdominal viscera are supported when the trunk is vertical. Again the freedom of the arms and hands from the task of helping to support the body leads to the retainment of an opposable thumb. The loss of opposability of the great toe also follows the erect posture because the foot becomes more specialized for its sole purpose of bi-pedal loco-motion. Other skeletal modifications such as the S-curvature of the spine or the pillastric buttress, or ridge down the posterior (rear) side of the femur, need not be considered in detail here because not enough remains are available from which a graph could be produced. There is no doubt that the attainment of an erect posture when walking is one of the most important criteria of humanity, and incidently it seems to have developed before the enlargement of the brain.

2.2 *A Large Brain*

The size of the brain is the next most important human characteristic. Sir Arthur Keith states[1] that "In every known instance where the human brain has fallen below the 900 c.c. level, the owner of that brain has been idiot or imbecile. In no case has the anthropoid capacity been found to rise above the 650 c.c. level." So that a relatively large skull to contain a big brain is a definite requirement of normal human beings.

[1] *New Discoveries Relating to the Antiquity of Man*, p. 67.

Additional information arises from the shape and complexity of the brain. These details can often be studied from endocranial plaster casts, when the skeletal remains are sufficiently complete and clean to enable such casts to be made. The degree of complexity is not however subject to precise measurement and therefore can only be used as qualitative corroborative evidence of human status.

That the size of the brain is not an infallible criterion of humanity is apparent from the enormous variations that normally occur in any community. This applies to prehistoric communities as well. In the *Pithecanthropus* remains from the upper cave at Choukoutien the skull capacities ranged from about 800 c.c. to 1,300 c.c. almost overlapping the range from modern apes to modern man. But this is rather exceptional and the community itself varied from an old Ainu man to a young Melanesian girl.

Nevertheless, as Sir Arthur Keith points out, apes have not big brains and normal men have not small ones. In actuality there has been a steady increase in man's brain size up to about 100,000 years ago after which time the average volume has dropped to the present European mean of 1,480 c.c.[1] But this is just one of the facts of man's development about which we are seeking information.

2.3 *Articulate Speech*

The question of whether articulate speech is possible can only be settled by the study of rather indirect, but none the less reliable, skeletal features. The essential difference between articulate speech and inarticulate noises is that, whilst both originate from air vibrations produced by the lungs and larynx (the vocal chords), speech vibrations are modified by resonance effects arising in the mouth cavity. In man the cavity is relatively large and the tongue, by its movement, can vary both the shape and size of the cavity. Inarticulate noises are practically unmodified after the air vibrations leave the larynx.

It is said that the chimpanzee can produce slight modifications of timbre and frequency so as to be able to express different emotions by distinctive noises. The "vocabulary" however is limited to about ten or fifteen monosyllabic "words".

Normal articulate speech can only be produced in a large unrestricted mouth cavity. This involves two major differences between the jaws of man and ape. Firstly, the two horizontal sides of the jaw bone or mandibles of man are splayed apart from before backwards with the result that, whereas in the ape the mandibles are practically parallel, in man they converge towards the front and if produced forwards would intersect at some very definite angle. (Fig. 5.)

This divergence of the posterior ends of the mandibles with a consequent increased distance between the rami (the vertical ends of the jaw) leads to an increased width between the condyles at the upper ends of the rami. These condyles act as hinges where the jaw articulates with the glenoid fossae or concavities in the temporal (the lower side) bones of the skull. Thus the angle between the mandibles of the human jaw is partly the natural consequence of the increased width of the skull itself.

[1] The world mean cranial capacity is usually taken to be 1,350 c.c. but, from measurements made by the London Medical School, 1,480 c.c. is a better mean for modern adult male Europeans.

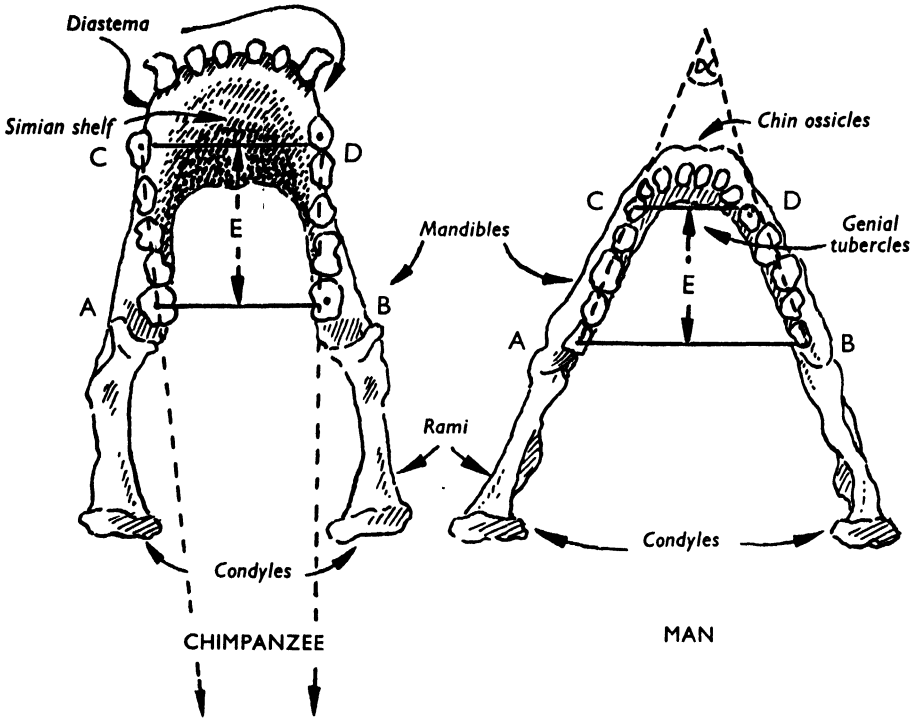


Fig. 5. The occlusal aspect of the lower jaws of the chimpanzee and of man showing the convergence angle α; and, in the case of the chimpanzee, the diastemata or simian gaps and the simian shelf and in man the chin ossicles and genial tubercles.

This convergence angle is referred to by several anatomists (e.g. Professors Sir W. E. Le Gros Clark and E. A. Hooton), who point out that the smallness of the angle in modern apes (the teeth series being almost parallel) is probably due to a specialized development of the canine and incisor teeth necessitating an increased width between the pre-molars. As a consequence of this, lines joining the third molars to the first pre-molars tend to become parallel. This view is supported by the fact that the convergence angle for primitive Miocene apes is intermediate between that of modern man and that of modern apes: men and apes having become specialized in opposite directions. Apes require large canines and incisors for use as weapons of attack and defence and consequently this necessity tends to inhibit their ability to speak.

On the other hand man's free use of his hands released his canines and incisors from the function of defence thereby leading to an atrophy of his front teeth. This, coupled with a wide skull, resulted in the development of ample space for the free movement of the tongue, thereby facilitating articulate speech.

Thus an increase in the convergence angle of the dental arcade above that of the Miocene apes is a human characteristic whilst a decrease, with consequent inability to speak, is a simian feature.

The second difference between the jaws of apes and men may be appreciated by considering the so-called "simian shelf". This is a bony ledge connecting the anterior or front ends of the mandibles of the jaw of the ape. The shelf fulfils two functions. It strengthens the junction of the mandibles in the symphyseal region and serves as an attachment for the tongue muscles (the "Genio-Glossus" or chin-tongue muscles). Both the parallel mandibles and the simian shelf limit the volume of the mouth cavity of the apes and seriously hamper the free movement of the tongue. In man the junction of the splayed sides of the mandibles is strengthened outside in the symphyseal region by two bony ossicles which fuse together and form the human chin. The tongue muscles attachment is a series of small bony tubercles (the genial tubercles) projecting backwards from the interior of the chin. (Fig. 5.) They take up little room and so leave the tongue perfectly free to move about in the enlarged space formed in the angle between the splayed mandibles.

A further indication of potential articulate speech is the extent of the development or degree of convexity of the "orbital cap"—a projection of the frontal lobe of the brain, which is associated with the speech function. This may be apparent from the size of a corresponding concavity in the cranium or may be seen more readily on an endocranial plaster cast. But this "cap" has not yet been subjected to precise measurements.

Having considered three skeletal characteristics which enable us to differentiate between the hominid or simian features of skeletal remains, it is now desirable to examine the four anatomical indices enunciated above in order to see how they give quantitative evidence in the form of precise numerical values for (i) the degree of erectness of posture, (ii) the size of the brain and (iii) the potentiality for articulate speech.

3. Anatomical indices

The first two indices are related to erectness of posture, the third deals with brain size and the fourth refers to the ability for articulate speech.

3.1 *The Nuchal Area Height Index* (I_1)

In order to appreciate the relationship between this index and erectness of posture it will be necessary to consider the mechanism by which erectness of posture is maintained. In order to make corresponding measurements on different skulls, some agreed but arbitrarily fixed plane is necessary from which all measurements can be made. That which is most convenient and which has been used by Sir Wilfred Le Gros Clark,[1] who established this particular index, is the Frankfort plane. This is the plane passing through the base of the eye sockets or lower orbital margins and the top of the ear passage or meatus. The skull is oriented so that this plane—the plane E A C D in Figure 6—is horizontal. The skull articulates with the spinal column on two fulcrums or pivots called the occipital condyles. They are situated one on either side of the hole (the foramen magnum) in the base of the skull through which the nervous system of the spinal column

[1] *New Palaeontological Evidence bearing on the Evolution of the Hominoidea*, Q.J.G.S., Vol. 105, p. 225, also *Essays on Growth and Form*, D'arcy Thompson presentation. Oxford Press, 1945.

communicates with the brain. In quadruped animals with a horizontal spine the foramen magnum is situated well to the rear or posterior portion of the skull which, in consequence, is more or less suspended from the end of the spinal column. In the anthropoid apes and still more so in man the foramen magnum is more centrally situated so that the skull is almost balanced on the occipital condyles, upon which it can rock or tilt up and down.

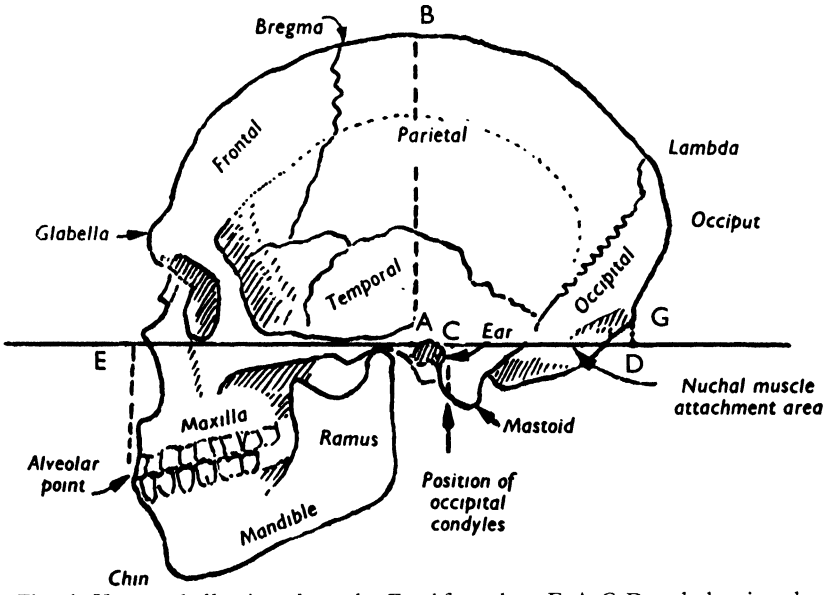


Fig. 6. Human skull oriented on the Frankfort plane E A C D and showing the principal bones.

The occipital condyles being on the base of the skull are not seen in Figure 6, but their position is indicated by the point C on the line E D. Point A is vertically below the highest point B of the skull, so that A B is the height of the vault. Point E is the projection on the Frankfort plane of the alveolar point—the most forward point of the maxilla or upper jaw. Thus with the prognathous jaws of the ape, the distance E C is longer in these animals than it is in man. It is now obvious that the degree of unbalance of the skull increases with the distance E C, or with the distance A C for a fixed A B, or with the distance A B for a fixed A C and in either case the face tends to tilt or drop downwards. To counteract this the nuchal muscles pull downwards on the posterior part of the skull where they are attached over an area shown shaded in Figure 6. Obviously they will be most effective the farther back the points of attachment are from the pivot C. Consequently the farther forward the face is or the farther back the occipital condyles are, so will the point G (the most posterior point of the nuchal muscle attachment area) need to be shifted farther backwards. With a large value of A B there will be a bigger volume of skull to be supported and this is compensated by a bigger distance D C and a correspondingly greater height D G—which obviously increases

with backward extension of the nuchal muscle area. Thus, for a given amount of unbalance measured by the distance A C, a big-sized skull (large value of A B) will require a correspondingly big value of D G to maintain the erect posture about the point C. In fact the ratio DG/AB will get smaller and smaller as the distance AC gets less, and the foramen magnum becomes more central in the base of the skull—a hominid characteristic. From another point of view, the same forward movement of the foramen magnum will necessitate less muscular effort at the point G, with the result that the point D can be closer to C and the height DG correspondingly small. Thus the degree of erectness of posture and therefore the degree of "hominidity" of the skeleton is measured by the *smallness* of the ratio DG/AB.

The index (I_1) is thus given by the formula

$$I_1 = DG/AB \quad . \quad . \quad . \quad . \quad . \quad (4)$$

It can be measured for a large number of datable prehistoric skulls and consequently has been selected as a suitable formula for obtaining points on a physical development/time graph. It will be obvious that the values as measured will need to be modified by the use of equations (2) and (3) on page 13 in order that the plotted figures shall increase up to 100 with increasing erectness of posture.

3.2 *The Condylar Position Index* (I_2)

From the foregoing discussion it will be obvious that a measure of the degree of balance will be given by the ratio DC/EC (Fig. 6) which will progressively increase as the pivot point C moves forward; and will equal unity when the two distances are equal. This does not mean that the skull will then be balanced and no nuchal muscles required, because the ratio is not one of mechanical moments about C but only of distances; the values of the forces acting at E and D have not been considered. Neither would this be practicable because it would involve measurements of the effective mass operating at E and of the effective muscular force operating at D. Nevertheless the ratio is, as its name applies, a measure of the position of the fulcrum upon which the skull rotates, and it is the forward position of this fulcrum which distinguishes man from the lower primates. This second index

$$I_2 = DC/EG \quad . \quad . \quad . \quad . \quad . \quad (5)$$

is also due to Sir Wilfred Le Gros Clark.

Formula (5) can therefore be used to obtain a physical development/time graph which will be independent of that obtained from equation (4). For our present objective it need only be modified by the use of equation (1) on page 13.

3.3 *The Cranial Capacity* (I_3)

The relationship between brain size and human status has already been mentioned and it would appear a relatively simple matter to equate the volume of the brain to the capacity of the skull. Experimentally the skull capacity in c.c. can be measured by filling the skull cap with mustard seed or peas and weighing the former or counting the latter.

It would then only be necessary to carry out a calibration experiment in order to know the weight of seed in grams per c.c. or the number of peas per c.c. This direct method is not always practicable and consequently various formulae have been proposed which purport to give the skull capacity from measurements of its external dimensions. In particular the general Lee-Pearson formula for the index I_3 is

$$I_3 = P + Q(L \times B \times H) \text{ c.c.} \quad . \quad . \quad . \quad . \quad (6)$$

where L and B refer to the maximum length and breadth of the skull in millimetres and H is the auricular height in millimetres; that is the height of the highest point of the skull above the level of the top of the meatus or ear-holes—approximately the distance AB in Figure 6. P and Q are constants which have different values according to the sex of the skull. Their values are P is $3{\cdot}5934 \times 10^2$ and $2{\cdot}9640 \times 10^2$ and Q is $3{\cdot}65 \times 10^{-4}$ and $3{\cdot}75 \times 10^{-4}$ for male and female respectively.

Formulae such as these are obviously very empirical and incorrect theoretically for two reasons. Firstly if one dimension is zero the skull still has the minimum volume given by the particular value of P and this is palpably absurd unless P is some extra-cranial volume. Secondly, they ignore variations in the skull wall thickness. This is a serious error when applying such formulae to prehistoric skulls in which the wall thickness usually increases with the more primitive and ape-like types. In such cases the formulae would obviously over estimate the internal volume and lead to crediting the early types of men with brain capacities to which they were not entitled. Professor Hooton[1] suggests adding 50 c.c. to the calculated result when the wall thickness is less than 4 mm. and subtracting 50 c.c. if the wall thickness exceeds 6 mm.; the wall thickness being that of the left parietal bone.

Probably a more satisfactory method of attack would be to use a semi-spheroidal formula for dolichocephalic skulls (that is, skulls for which the ratio of B/L[2] is less than 0·75) and to use a semi-spherical formula for brachycephalic skulls (for which B/L exceeds 0·8), and then to modify the theoretical formulae by an empirical shape factor designed to take account of peculiarities due to race, sex, etc. In any case, great accuracy (and certainly not the accuracy assumed by the five significant figures for P and Q in the Lee-Pearson formulae) cannot be claimed for skull capacities when calculated from external dimensions. However, for our present purpose great accuracy is not required. An accuracy of 5 per cent would be quite sufficient to enable the general trend of skull development to be determined from a graphical treatment of the data.

Skull capacity is not strictly an anatomical index. Anatomical indices usually compare two dimensions and give the ratio (or percentage ratio) of one in terms of the other. They are thus "shape factors" or morphological indices and indicate differences in the shape of different parts of the skeleton. Thus the ratio of the anterior-posterior depth of a bone to its width at a given cross-section is a definite measure of the shape of the particular section. Similarly the ratio of arm length to trunk length indicates the appearance of this aspect of the skeleton; the ratio being small in man and large in the apes. In spite of the fact that I_3 is not strictly an anatomical index, the absolute capacity

[1] *Up from the Ape*. Revised Ed. Macmillan, 1946. [2] The ratio B/L is known as the cephalic index.

of a skull in c.c. is a valuable diagnostic measurement which will enable a third physical development/time graph to be obtained.

Perhaps the index palate area/skull capacity might have been a more useful one to have chosen than skull capacity, but upon studying the available material it was apparent that many fewer points on such a graph would have been possible. Consequently the skull capacity/time graph was considered preferable.

Furthermore, the palate area/skull capacity index is a much better criterion of maturity than of antiquity. The ratio steadily increases with age and was originally devised by Sir Arthur Keith as a measure of bodily growth rather than as an indication of morphological development. However, it could be used for the latter purpose as is evident from the fact that its value for the African ape-men (the *Australopithecinae*) is 1/27 which is almost twice what it is for modern man, namely 1/55.

3.4 *The Lower Dental Arcade Convergence Angle* (I_4)

Although many measurements on lower jaws and teeth have been made and various indices devised to indicate primitive features, there do not seem to be any specific measurements of the angle between the mandibles in the symphyseal region. This feature, as has been indicated above, is extremely diagnostic and of considerable value when comparing, for example, the specialized jaw of the modern chimpanzee with that of modern man as in Figure 5. Qualitative differences are referred to in most text-books and the parallel form of the two sides of the dental arcade of the apes is often contrasted with the forward convergence of the teeth series in the human arcade, or with their somewhat parabolic curvature. In the words of Sir Wilfred Le Gros Clark this is one of the factors which has "been established to have a high degree of taxonomic relevance". The angle between the two sides of the dental arcade is easily calculated from simple measurements, but the curvature of the arcade is less susceptible to metrical treatment. Consequently it is suggested that, although the value of the convergence angle, like the colume of the cranial capacity, is not strictly an anatomical index, it is nevertheless a useful diagnostic measurement by which the hominid characteristics of different species may be compared. Such measurements from datable specimens will therefore yield another physical development/time graph for comparison with the three other graphs given by equations (4), (5) and (6).

To measure the convergence angle all that is necessary is to divide the difference between the separation of the first pre-molar teeth and the separation of the last molar teeth (either the 2nd or 3rd) by the perpendicular distance between the two lines joining respectively these pairs of teeth. In Figure 5 this angle α can therefore be calculated from the formula:

$$I_4 = \alpha = \frac{AB - CD}{E} \text{ radians or } 180\,\frac{(AB - CD)}{\pi \times E} \text{ degrees} \quad . \quad . \quad . \quad (7)$$

where AB is the separation of the two 2nd or 3rd molars, CD is the separation of the two 1st pre-molars and E is the perpendicular distance between AB and CD.

There may be a few, very few, exceptional cases where the above method for

measuring the angle α could not be applied. For almost circular arcades it sometimes happens that the lines joining the first pre-molars to the last molars are almost parallel. The resultant very small value of α would not, in such cases, have any meaning. In fact, with a circular arcade there is no convergence angle to be measured. In general the convergence angle increases from zero (or a small negative value) in the lower jaw of the chimpanzee to as much as 50 degrees in man. Consequently it will only be necessary to use formula (1) to adapt the measurements for graphical purposes. Of course the figures will not then be in degrees any more than the modified data for skull capacities are in cubic centimetres.

The values of α given in Table II on page 67 have been obtained from measurements made on original jaws whenever possible. But as the availability to the writer of original material was naturally limited, some of the figures were obtained from casts and also from photographs of the occlusal aspect. (See Figs. 5 and 9.)

4. Factors influencing measurements

Before examining the actual material now available with a view to collecting data for the four physical development/time graphs, consideration must be given to all the factors which may influence the figures. So far we have assumed that the four indices will give numerical values which will vary with the humanity of the specimen, and we are satisfied that this is so. But obvious difficulties will arise if other hitherto unconsidered factors also influence or affect the value of the indices. There are four such additional factors which must now be considered, namely (i) sex, (ii) age, (iii) race, and (iv) the existence of some morphological abnormality. These factors may well influence the measured values of the four indices I_1 to I_4. They can only be neglected if their influence on the measurements is small compared with that resulting from the antiquity of the specimen. If their effect is not negligible then some correction or modification must be made to the value of the index as calculated from the appropriate formula.

4.1 *Sex*

The effect of the sex of a skull will not seriously alter the erectness of posture as calculated from formula (4). In other words, at any given time or with any given species both male and female skulls give practically the same numerical values. This might be anticipated because, although the height of the vault of the female skull is less than that of the contemporary male, so also is the height of the uppermost point of attachment of the nuchal muscles. That is, a smaller skull requires less muscular effort to prevent it from tilting forward. This constancy of the value of I_1 with change of sex also applies to I_2. In fact one reason for using ratios as anatomical indices is to minimize the effects due to the absolute values of the dimensions. In other words, relative measurements relate to shape or form; absolute measurements relate to size.

When the index I_3, which is not a ratio, is considered, then the sex of the skull will appreciably affect the value of the index calculated from equation (6). It is to remedy

this that the different numerical values for the constants P and Q have been introduced into the Lee-Pearson formula.

Finally, let us consider the effect of sex on I_4, the value of which is based on a measurement of the angle between the mandibles. In general, the female jaw is thought to be slightly more developed than the male jaw. In other words the value of α for a female jaw is slightly larger than that for a contemporary male jaw of the same age and race. Perchance this is not unrelated to the proverbial tendency of women to talk more than men!

Although the necessary correction to formula (7) will be quite small, it cannot be easily evaluated. In practice it means that calculated points on the I_4-time graph for men would lie somewhat below those for women. It would make an interesting exercise to establish this as a method of sexing jaws by measuring α and for a large number of contemporary specimens all of the same age and race but of different sexes. If, as may well be the case, the test is not sufficiently sensitive, then the effect of sex on formula (7) could be neglected. This has been assumed to be the case in the data given in Table II and no correction has therefore been attempted for any variation due to sex.

4.2 *Age*

The effect of age on the values calculated from equations (4) to (7) is more difficult to assess than the effects of sex. This arises because it is not always easy to distinguish youthful from primitive characteristics especially with indices which are ratios. With absolute values, such as skull capacity, there can be little confusion between a modern juvenile skull and a primitive adult skull which exhibits youthful characteristics—that is a paedomorphic skull. The extent of the ossification of the sutures would readily distinguish between immaturity and paedomorphism.

The difficulty becomes serious when, for example, the values of the ratio for the nuchal height index for a baby chimpanzee and for the primitive adult Miocene ape—*Proconsul africanus*—are both equal to 42. This figure must be interpreted quite differently in the two cases. With the young chimpanzee the relatively high dome of the vault and slight prognathous character of the jaw are youthful features which will change rapidly with age. With the adult Proconsul ape the value arises from the fact that this ape had not become highly specialized in Miocene times like the apes of today. The values for the posture index I_1, as calculated directly from measurements and before modification, are—baby chimpanzee and *Proconsul africanus* + 42, modern man −9. The maximum value is +70 for the gorilla. (See Table I, page 38.) Thus the degree of maturity of any skeleton must be judged before interpreting or making any deductions from the numeral values of this particular index. The determination of the approximate stage of growth of a bone is generally possible especially with very young specimens. This is all that is necessary because the major changes arising with increased maturity happen within the first decade of growth, that is, within the first three or four years with apes and before the age of fourteen with man.

The effect of age on the angle of the dental arcade is quite noticeable. The effect is a reduction in the angle with increase of maturity. This does not lead to any

ambiguity in the interpretation of the index I_4 because the effect is only really appreciable before the permanent teeth have erupted; that is before ten years in the case of the chimpanzee and before eighteen years in man, by which time the third molars or wisdom teeth will usually have appeared if they are going to.

Furthermore, any measurements based on milk teeth will necessarily be very inaccurate because there will only be two milk molars on each side between which measurements can be made. In fact the index is strictly only applicable to an arcade of permanent teeth.

4.3 *Race*

The effects of racial differences depend on what is meant by "race". It is outside the objective of this book to discuss the precise definition of "race" or of "species". That is best left to the professional taxonomist. In dealing with prehistoric peoples conspicuous or significantly different anatomical characteristics usually justify classification as a distinct species. The number of distinct prehistoric species which are contemporary is very limited. Only when two or more different species occur at the same period of time is there going to be any difficulty in interpreting the anatomical index/time graphs. In the same way that the sexes have slightly different graphs, so the graphs of one species will differ somewhat from those of another. In fact, the occurrence of two or more values for a given anatomical index for contemporary skeletal remains (of the same sex and age) can only mean that we are dealing with bones belonging to two different types or varieties. For example, two types of Neanderthal man were found together in Mount Carmel, and both long-headed and short-headed Late Palaeolithic men were found together in Aveline's Hole in Somerset and at Ofnet in Bavaria. In the upper cave near Choukoutien an old man (*Pithecanthropus pekinensis*) with Ainu features lived (or died) with six others, one of whom had Melanesian characteristics and another seemed to be not unlike an Eskimo. Differences in the values of anatomical indices for contemporary skeletons means that two or more points—vertically above each other—will occur on man's physical development/time graphs. Their interpretation leads to no ambiguity as long as the differences in question do not arise from sex or age. Such groups of points might lead to valuable information concerning the presence of different types of men living at the same time, whether or not in the same locality. With very early forms of man as in China, such variations as these may be due to a general morphological instability during man's earlier stages of evolution. With later groups, such as those at Aveline's Hole in Somerset, the presence of long- and short-headed men together is probably due to the intermixing of stable racial types.

Obviously racial differences will, in general, affect all four of the anatomical indices with which we are now concerned, but there is no question of "correcting" the indices to eliminate these variations arising from racial peculiarities. Such variations are, in fact, precisely what anatomical indices are designed to disclose.

4.4 *Morphological Abnormalities*

Physical abnormalities may quite well vitiate any conclusion based upon anatomical indices. The only course is to recognize the presence of abnormal conditions or patho-

logical defects and to ignore the values of any indices calculated from measurements made upon such exceptional specimens. As an example, the condition known as acromegaly may lead to giantism and to overgrowth of the jaws and extremities accompanied by a thickening of the brow ridges—some of these effects are reminiscent of the classical Neanderthal men.

Excessive secretion of the pituitary gland which causes acromegaly may well be a defect not restricted to modern times. Similarly, diminished pituitary activity causes a dwarfing of the stature and a retention of infantile characteristics.

Rhodesian man may well be an example of prehistoric acromegaly leading to gerontomorphism, whilst modern African pygmies may be due to inherited defects in the functioning of the ductless glands leading to a form of permanent paedomorphism.

A somewhat different kind of abnormality arises from rheumatoid arthritis. Osseous growths on bones will lead to false values for anatomical measurements but this disease will not seriously affect the particular indices of the skull now under consideration.

The foregoing conclusions may be summarized by saying that, as long as the effects of sex, age, race and disease are kept in mind and taken into consideration if and when necessary, then the four chosen anatomical indices will give reliable information concerning bodily posture, brain size and dental arcade convergence. Also the time sequence of the numerical values will, when plotted, show graphically how these anatomical features have changed with time, and consequently, how man has gradually acquired his hominid characteristics throughout the Quaternary period during which he has been developing.

5. Selection of skeletal material

Before proceeding to obtain data from which to calculate indices it will be necessary to select all skulls and jaws for examination. The second step will be to determine whether the remains can be approximately dated from a knowledge of the geology of the site and/or from associations with other datable remains such as contemporary animals or artifacts. Only skulls and jaws which pass this test will be of any use for our purpose. Fortunately over sixty specimens, including most of the recent finds, can be dated with reasonable and sufficient accuracy. The third step is then to eliminate all material which is not sufficiently complete to enable at least one of the four selected indices to be measured.

This rigorous sifting reduces the acceptable remains to just over twenty specimens. There may be, and no doubt are, others which have been missed in going through the literature on the subject, but twenty specimens will give enough points to enable satisfactory graphs to be drawn.

The final result of this process of selection is a series of skulls and jaws which fortunately extend from the remotest ape-men of Africa (the *Australopithecinae*) to modern man. For comparative purposes the modern chimpanzee and a recent Australian aborigine have been included. When the working out of the data had proceeded far enough to make a rough graph, it was at once apparent that all the figures tended (with certain notable exceptions) to approach assymptotically to definite minimum values. It

was natural to wonder if these minima corresponded to the values of the indices for man's remote primate ancestor. To check this idea the data were also obtained (as far as possible) for the Miocene ape (*Proconsul africanus*) which had already, by several authorities, been discussed as a possible ancestral type from which modern man may have descended. With these additions the total list of skulls and jaws is as indicated in the left-hand columns of Table II (page 66). The specimens have been arranged in what is believed to be chronological order, the most recent being at the top. The evidence for this order will be discussed in Chapter IV, where the absolute time in years appropriate to each specimen is fully considered. This chapter will be restricted to a discussion of the skulls and the anatomical indices which have been obtained from measurements made directly or indirectly on them.

6. Methods of measurement

Before considering this material in detail a word about the methods used for making the measurements may not be without interest. When the skull itself (or a cast) is available, it should be set up on the Frankfort plane (see Fig. 6) and measurements can then be made directly with appropriate vernier calipers. This obviously was not possible with many of the skulls listed in Table II. Another but indirect method is to take a photograph of the skull from the particular viewpoint desired, such as that shown in Figure 6, for example, or directly from above (for measuring the cephalic index[1]). The required photograph can then be projected on to a screen already ruled in measured squares like a large sheet of graph paper. This projection must be done with a good epidiascope free from spherical aberrations; that is, one which does not distort the picture when enlarged. It is now easy to adjust the size of the image and the orientation of the photo so that the Frankfort plane coincides with one of the horizontal lines—the zero line. The measurements necessary for indices I_1 and I_2—the poise indices—can then be read off from the scale of squares. Absolute measurements in millimetres are of course not necessary for indices which are non-dimensional ratios. The only difficulty with this method is that of locating the precise position of the occipital condyles when measuring I_2. But after a study of photographs of other aspects of the particular skull, their required position can be satisfactorily located and in practice this difficulty does not lead to serious error. In fact it is much easier to use a large two-dimensional projected photographic image than to manipulate calipers around a three-dimensional skull or model. Consequently, the accuracy of the projection method can be greater than for the direct method and quicker as long as "suitable" photographs are available.

Photographs of three-dimensional objects intended for measurement purposes will only be "suitable" if they are taken from a distance of at least a dozen feet in order that light rays coming from the object shall be practically parallel. The fact that the photograph may be very small is immaterial because the final image can be projected to any convenient size. If an ordinary close-up photograph is used, the full or maximum area of the object will not be visible. This will be obvious if one tries to see the top of a skull by observing it from a very close-up lateral position.

[1] See footnote 2 on page 30.

Direct methods for obtaining the value of I_3—the cranial capacity—have already been mentioned. They can be accurate to within 10 per cent given an internally clean skull. Otherwise measurements as made as for I_1 and I_2 will be necessary and a Lee-Pearson or other formula used to calculate the internal volume in cubic centimetres. With the projection method, since the I_3 index is not a ratio, it will be necessary to calibrate the squares on the screen in equivalent millimetres. This can be done in two ways. Either a centimetre scale can be included in the original photograph of the skull or two points or lines a known distance apart (e.g. 1 centimetre) can be marked on the skull before it is photographed. Alternatively, one particular distance on the skull, for example that along the Frankfort plane between the lower margin of the orbit and the upper edge of the ear passage or the width of an orbit, must be known in millimetres and this distance used as a standard of measurement on the projected image. With the capacities of the skulls given in Table II this difficulty of calibration did not arise because accepted values are available in the literature and have therefore been used in the Table.

When using the projection method for I_3, it is advisable to use photographs of three mutually perpendicular aspects, so that check measurements are possible for each of the dimensions L, B and H. The appropriate aspects are the side view or profile (norma lateralis), face or back view (norma frontalis or norma occipitalis), and the top or bottom view (norma verticalis or basilaris).

For I_4—the dental arcade angle—the most accurate method was found to be a projection method using either a photograph or preferably the jaw itself. The screen should be ruled with a circular grid consisting of a large graduated circle with radial lines every five degrees. The photo or jaw can then be manipulated on the stage of the epidiascope until one of the radial lines passes through the centre of the first pre-molar (or its socket) and the centre of the posterior molar on the same side. The jaw is then moved along this radial line towards or away from the centre until the two corresponding points on the other mandible lie along another radial line. The required angle α can then be read off the degree scale round the circle.

Otherwise the lengths AB, CD and E (Fig. 5) must be read on a squared screen and the value of α calculated by use of equation (7). Obviouly in this case it will be desirable, before taking readings, to orient the jaw so that one line of a rectangular grid passes through the pair of first pre-molars. The pair of posterior molars will then lie along or be parallel to another line of the grid.

7. Selected Skeletal Material

The material selected for measurement will now be considered. No comments are necessary with regard to the present-day skeletons—modern man, Australian native and the chimpanzee (*Frontispiece*)—except perhaps to mention why the chimpanzee has been included rather than one of the three other members of the ape family. Most authorities agree that the chimpanzee has closer affinities to European man than have either the gorilla, the orang-utan or the gibbon. This however does not apply to Asiatic peoples in general or to Mongoloids in particular because these people have characteristics more in

keeping with the orang than with either the gorilla, the chimpanzee or the gibbon. Similarly in some respects the negro races are possibly more allied to the gorilla. This only means that the apes and races respectively may have diverged from the common primate stock slightly earlier than they had diverged from each other. But, of course, this is as yet pure conjecture. It does however give the reason why the chimpanzee was included in Table II. The indices I_1 and I_2 clearly show that the chimpanzee is nearest the human poise; but if the index I_3 be alone considered, then the gorilla with its relatively large brain would have been a better standard of comparison. Some approximate values of these three indices are given in Table I.

TABLE I

	I_1		I_2		I_3	
	Measured	*Modified*	*Measured*	*Modified*	*Measured*	*Modified*
Gorilla . . .	+70	1·25	24	30	550	37
Orang-utan . .	+60	13	19	24	420	28
Chimpanzee . .	+50	24	26	32	400	27
Man (European) .	−9	100	80	100	1,480	100

The remaining skeletons listed in Table II (pages 66-7) will be considered from the bottom (the oldest) upward.

7.01 *Proconsul Africanus*

During Miocene times which extended approximately from twelve to thirty million years ago, Africa and India were nature's experimental breeding grounds for the development of many forms of animals ancestral to modern men, apes and monkeys. In particular from the region of the great lakes (Kenya) in central Africa three genera including at least six species of fossil apes have been discovered. Dr. H. L. Gordon found the first jaw in 1922, and by 1948 several hundreds of identifiable fossils had been discovered mainly due to the untiring efforts of Dr. and Mrs. Leakey.[1] Of the various species, *Proconsul africanus* is of special interest here because the completeness of the remains (in particular, most of a skull and the whole of the associated jaw) has enabled Sir Wilfred Le Gros Clark[1] to draw some important conclusions concerning the relation of this species to man.

It is unfortunate that the rear portion of the skull of *Proconsul africanus* is missing. The cranial capacity is therefore not known, but the skull is definitely smaller than that of the modern chimpanzee. The value may be, from restorations, of the order of 300 to 350 c.c. Perhaps the most interesting feature of the skull is the absence of a continuous bony ridge or torus across the brow. The forehead is rounded and curves evenly upward

[1] *The Miocene Hominoidea of East Africa*, W. E. Le Gros Clark and L. S. B. Leakey, British Museum (Natural History). Pub. 1951.

and backward from the root of the nose. A somewhat similar smooth rounded forehead occurs with the baby chimpanzee. *Proconsul africanus* is thus somewhat paedomorphic and has not developed the specialized brow ridges of the modern apes. It may be noted in passing that the classical Neanderthal skull, such as the type specimen from near Dusseldorf, shows a well-developed torus, whilst skulls of the earlier Neanderthal forms such as those found at Steinheim and Ehringsdorf, are more comparable to those of *Proconsul africanus* and modern man in this particular respect.



Fig. 7. The Miocene ape *Proconsul africanus*.

No measurements of indices I_1 and I_2 are possible owing to the absence of the occipital parts of the skull, but from a study of limb bones it is evident that this small ape progressed on the ground using all four limbs and had not specialized in brachiating habits in trees. It was probably relatively fast and agile on the ground. From Figure 7 it is obvious that the eye socket is somewhat rectangular and low-set in contrast to the high and round sockets of the living great apes. This is, like the rounded forehead, a hominid rather than a simian feature.

The jaw is of particular interest because it shows a curious mixture of unspecialized and specialized characteristics. The convergence angle instead of being very small or zero as with the modern apes is about sixteen degrees. It is interesting to compare this with the smallest value for man, namely about twenty-six degrees for *Pithecanthropus*

modjokertensis and the Heidelberg jaw. The canine teeth are prominent but not as much as in living apes. Nevertheless a diastema or gap (Fig. 5) appears to be necessary so that the upper and lower canines may interlock when the jaws are closed. Diastemata are generally but not necessarily simian characteristics. Another simian feature also arises from this locking of the jaws by projecting canines, namely, the inability of the animal to chew after the manner of modern man. This is indicated by the "sectorial" character and pointed cusp of the first pre-molar teeth. Such teeth are designed for cutting rather than chewing. On the other hand the Proconsul jaw has no simian shelf (Fig. 5), the absence being a hominid feature comparable with the forward convergence angle of the teeth series. Finally, the molars increase in size from before backwards—this is usually considered to be a simian trait. Dr. E. K. Tratman in discussing the teeth of Mongoloid peoples (*Dental Record*, LXX, p. 36, Feb. 1950) points out that this reduction of the third molar is not *necessarily* a hominid characteristic. For example, it occurs quite frequently in the large "primitive" jaws of modern Eskimos, whilst large third molars are also to be found in modern Mongoloid groups. This grading in the size of the molars must therefore be interpreted with caution. It is, in fact, fairly safe to say that when the third molar is the largest, then the jaw exhibits a simian feature; but it is less reliable to say that a reduced third molar is a hominid characteristic. It is thus apparent that *Proconsul* might ultimately specialize either along the line taken by the great apes or along the less specialized directions taken by man. For these reasons Sir Wilfred Le Gros Clark, when commenting on the possibility that the actual ancestors of the human stock were one of the early Miocene apes, states, "There is some reason to suppose that this may actually be so." It will be seen later that the graphical treatment of this problem lends support to this possibility.[1]

7.02 *Australopithecinae* (Southern Apes)

In 1925 Professor R. Dart[2] announced the discovery of an immature ape skull which had certain peculiar hominid characteristics. From geological considerations he thought it was late Pliocene or early Pleistocene in date.

The skull was embedded in a limestone matrix from a cave at Taungs in Bechuanaland, South Africa. The ape was named *Australopithecus africanus*. Now the remains of over thirty individuals are known mainly from the Transvaal locality. Dr. R. Broom[3] discovered one group in a cave near Sterkfontein about two hundred miles north-east of Taungs. The fact that sabre-tooth tigers and a Pliocene form of extinct hyaena were found at Sterkfontein tends to confirm the Pliocene date originally suggested by Dart. It is however now generally thought that an early Pleistocene date is more probable, and that the earlier forms of contemporary fauna were late survivals into the Pleistocene period; a time characterized by rather dry arid semi-desert conditions with the land lacking in forests.

[1] Here might be considered *Oreopithecus bambolii* from the Lower Pliocene of Tuscany, but whether this beast is ancestral to man is still under discussion. (See also note on p. 147.)

[2] *Australopithecus africanus*, Nature, 115, 1925.
Recent Discoveries bearing on Human History in South Africa. Journ. Roy. Anthrop. Inst., Vol. 70, 1940.

[3] *On Australopithecus and its Affinities*—Early Man Conference, Philadelphia, 1937.
The Sterkfontein Ape-men, with J. T. Robertson, Pretoria.

The general anatomical features of the *Australopithecinae* (Fig. 8) are as follows: The cranial capacity is similar to that of the larger modern apes, namely about five or six hundred cubic centimetres. The most important feature is the almost erect posture of the creature when walking and running. In fact we must picture a fairly erect pygmy



Fig. 8. An *Australopithecine* skull.

with an ape-like head and moderately prognathous jaws. But even the ape-like head shows many hominid characteristics when studied more closely. The supraorbital ridges although present do not form a continuous shelf of bone as in living apes. Endocranial casts (natural ones from the limestone caves) suggest a slightly more convoluted brain than is possessed by the apes of today and the nuchal crest in the occipital region of the skull is much less marked and lower down on the skull. This suggests the necessity for less powerful neck muscles. The foramen magnum (the hole in the base of the skull) and the occipital condyles are both situated relatively well forward. These are in keeping with the high values of the nuchal area height index (I_1) and the condylar position index (I_2) both of which indicate a relatively upright posture with the head more balanced on the spinal column than it is in the apes. This is completely confirmed by the discovery of a basin-like pelvis in direct association with skull remains.

The dentition and jaw are even more remarkable because of their extremely hominid characters. There is a complete absence of a simian-shelf and diastemata (Fig. 5) and the convergence angle of the teeth (I_4) is approximately equal to that of modern man. This strongly suggests that these Australopithecoid pygmys might have been able to

speak. Other hominid features are the decrease in the size of the molars from before backwards and the bi-cuspid (i.e. non-sectorial) form of the lower first pre-molars. This is in keeping with the small canines permitting human chewing action. In spite of all these hominid characters these pygmys cannot be classed as men until it can be proved that they made tools. That they *used* stones as tools is suggested by the collection of artificially bashed-in baboon skulls from caves in the Taungs area. On the whole it certainly looks as if the *Australopithecinae* are representatives of primitive men-like apes who, even if they do date from Pliocene times, cannot be called our ancestors. It will be seen later that from a graphical standpoint they occupy an extremely curious position in the story of man's development.

7.03 *Pithecanthropus modjokertensis* (Modjokerto Ape-man)
7.04 *Pithecanthropus erectus* (Erect Ape-man)
7.05 *Pithecanthropus soloensis* (Solo Ape-man)

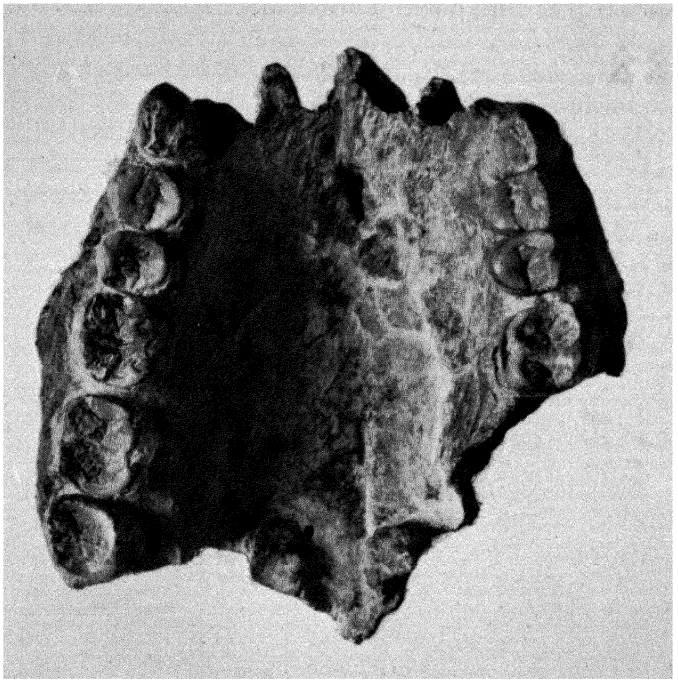
Reference has already been made on page 22 to the discoveries in Java from the three horizons of the Solo River terraces—the lowest or Djetis beds, the middle or Trinil beds and the uppermost or Ngandoeng beds. These beds, from their fauna, may be classed as lower, middle and upper Pleistocene respectively. Man seems to have left worked stone implements of a very early type in deposits in Java older than the Djetis beds. They would presumably be of Pliocene date but so far they have not been associated with any human bones.

The oldest human remains come from the Djetis beds and are considered to be of lower Pleistocene date, that is, at least 500,000 years old.

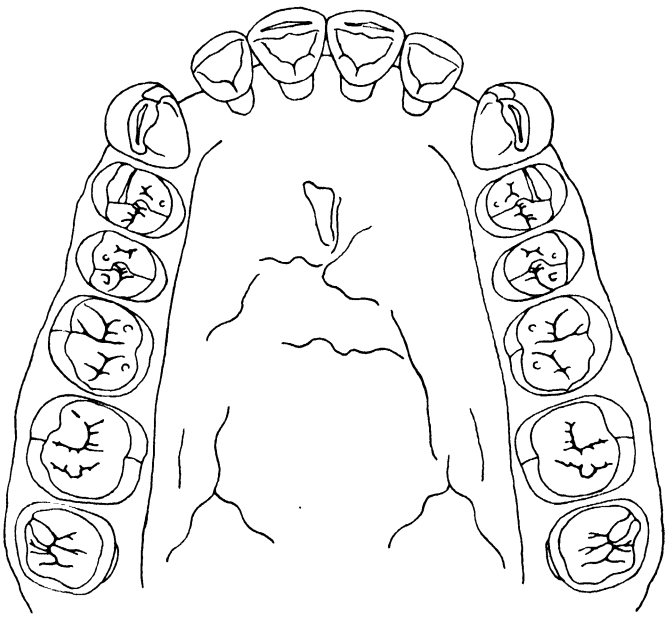
Apart from the skull of a small baby, the most interesting relics are the maxilla and the right mandible of a large adult. The maxilla is shown in Figure 9A and Figure 9B is the drawing of a reconstruction by Professor G. H. R. von Koenigswald, who found the remains near Sangiran. It will be observed that there is a curious mixture here of hominid and simian features. The convergence angle of $25\frac{1}{2}$ degrees is practically identical with that of the Heidelberg jaw (paragraph 7.06 and Figure 12) and the formation of the entrance into the nose and the roughness of the palate are distinctly human in character. Opposed to these aspects is the surprisingly primitive but not very wide simian gap or diastema indicative of fairly large but not tusk-like canines, one of which is clearly visible in Figure 9A. Although the third molar is smaller than the second, the second is larger than the first—a mixture of human and ape-like characteristics. It should be remembered, however, that this sequence is sometimes found in modern Mongolian peoples. It will be seen later that the value of the I_4 index is such that this maxilla fits extremely well on the I_4 graph in Figure 53. This supports the conclusion reached by Professor von Koenigswald[1] that the maxilla does belong to a member of the human family in spite of its simian features.

The next oldest human remains are those from the mid-Pleistocene beds of Trinil.

[1] *Ein fossiler Hominidae aus dem Altpleistocän von Java.* Ingen. Ned.—Indie IV, Mijuingen 3, 1936.
Fossil Hominids from the Lower Pleistocene of Java. Internat. Geol. Cong. 18th Session, Pt. IX, 1950.
The Discovery and Study of the earliest known Human Fossils and their place in the history of Man's Development. Eighth Pacific Science Congress, Vol. 1, pp. 377-86, 1955.



A



B

Fig. 9 (A). The ape-man from Modjokerto, Java (*Pithecanthropus modjokertensis*).
(B). Reconstruction by Professor G. H. R. von Koenigswald.

The first skull cap together with a femur and other bones and a small portion of lower jaw were discovered by Dr. E. Dubois in 1891. A more complete skull was found by Dr. von Koenigswald[1] about 1935. It was handed to him deliberately broken into many pieces in order to obtain a monetary reward for each piece. Fortunately it was possible to restore practically the whole calvaria and the result is shown in Figure 10. The capacity of this skull is about 775 c.c. which is somewhat smaller than the volume estimated for the example discovered by Dubois. The skulls when seen from above are almost identical and because of this and also because they both came from a mid-

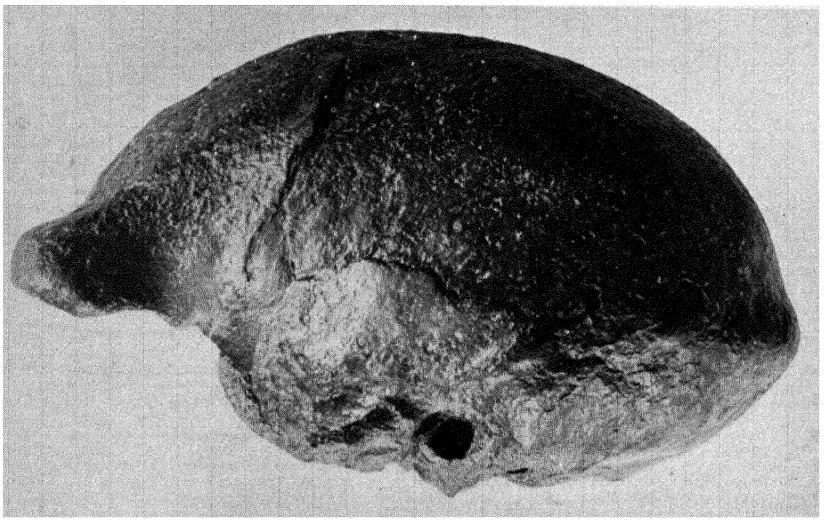


Fig. 10. The erect ape-man from Sangiran, Java (*Pithecanthropus erectus II*).

Pleistocene horizon, von Koenigswald has christened the more recent find *Pithecanthropus erectus II*. The temporal parts of the skull show affinities with the recently discovered Chinese specimens (see paragraph 7.07 and Figure 13). In other respects they are similar to the skull caps found in the Upper Pleistocene beds of the Solo River—the Ngandoeng beds; but whereas the average volume of the Solo skulls (Fig. 11) is about 1,100 c.c. that of the Trinil skulls is of the order of 850 c.c.

Both *Pithecanthropus erectus* and *Pithecanthropus soloensis*[2] have prominent supra-orbital brow ridges. Their skulls show evidence of a moderately erect posture; somewhat less than that of the *Australopithecinae* of Africa. The species from Java and Africa are similar in that their dental characteristics are partly hominid and partly simian. A common hominid feature is the absence of the simian shelf, but the Javanese and African men differ in that the former show an ape-like gradation in the size of the molars, the third being the biggest, whilst the order of magnitude is reversed in the *Australopithecinae*. Nature seems to have produced moderately erect men in both continents but with rather

[1] *Neue Pithecanthropus Funde*, Wetenschappelijke Mededuligen No. 28.
[2] Anthropological Paper of the American Museum of Nat. History—N.Y. 1951. Vol. 43, Pt. 3.

different mixtures of hominid and simian details. The giant forms in Java, *if* they can be classed with the Pithecanthropoids, are also not paralleled in Africa. On the other hand, giant apes (*Paranthropus*) do occur amongst the many species to be found in Africa. Perhaps the most important difference lies in the fact that stone implements are definitely associated with the Java ape-men but none have been found with the African man-apes. There are crude implements from the mid-Pleistocene Trinil beds and an early Palaeolithic bone industry from the Upper Pleistocene Ngandoeng beds. These Upper Pleistocene "solo" men used the bolas and made harpoons.[1] They are more or less contemporary

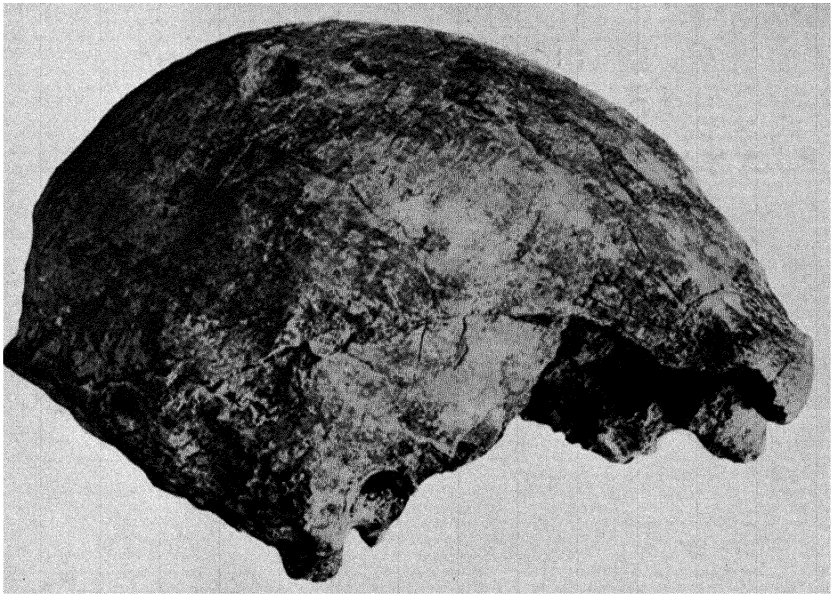


Fig. 11. The ape-man from the Solo River, Java (*Pithecanthropus soloensis I*).

with the Neanderthal men in Europe and with the Neanderthal-like skeleton from Rhodesia (*Homo rhodesiensis*)—all three types have marked brow ridges and somewhat prognathous jaws which suggest specialized off-shoots (gerontomorphism) leading to reduced adaptability and possibly ultimate extinction. There is, however, some evidence to be discussed in Chapter V which suggests that these specialized types may be ancestral to the modern Australian native.

7.06 *Homo heidelbergensis* (Heidelberg man)

Near the little village of Mauer about six miles to the south-east of Heidelberg is a very large sand pit which had been watched for many years by Dr. Otto Schoetensack. In 1907 his patience was rewarded by the discovery of a human jaw at a depth of 82 feet

[1] W. F. F. Oppenoorth, *Een prehistorisch cultuur-centrum langs de Solo Rivier*. Periodical of the Royal Dutch Geographical Society, Vol. 53, 3, May 1936; and *Homo* (*Javanthropus*) *soloensis*, Scientific Communications of the Mining Service in Dutch Indies, No. 20, 1932, Batavia.

beneath both the newer and older loess sands. (See Fig. 49.) The jaw was associated with some worked bone objects and with a warm fauna which included a straight-tusked smooth-skinned elephant (*Loxodonta antiquus*), a smooth-skinned rhinoceros (*Diceros leptorhinus*), a very early type of horse, etc.

It is generally believed that Heidelberg man lived during the middle inter-glacial period between the Mindel and Riss glaciations (Figs. 3 and 46).

The jaw (Fig. 12) is remarkable for its massive proportions and for the width of the ascending rami (60 mm. compared with 35 in modern man). But the dimensions are

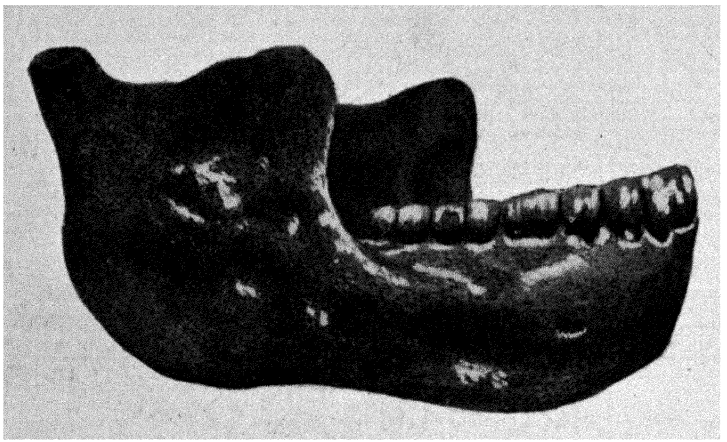


Fig. 12. The jaw of the ancient man from Heidelberg, Germany (*Homo heidelbergensis*).

much less impressive when compared with the Java giant (*Meganthropus*) besides which the Heidelberg jaw appears to be quite slender. The jaw is human if judged by the absence of a simian shelf, but simian when seen in profile because of the absence of a chin prominence in front. The jaw is, in fact, so massive that it requires no strengthening ledge inside and no bony re-enforcement outside. The most interesting feature is the extremely modern appearance of the teeth, all of which have been preserved. The canines are small, there are no diastemata, the third molar is the smallest and the incisors are erect and do not protrude forward. All these are definitely hominid characteristics. Also the lines joining the first pre-molars and third molars converge forward at an angle of 25·7 degrees. This may be compared with 48 degrees for modern man and about 3 degrees or less for the chimpanzee. It is generally supposed that Heidelberg man is of the Pithecanthropoid type, whilst in some respects he shows kinship with the classical Neanderthal men.

7.07 *Pithecanthropus pekinensis* (Pekin ape-man)

Pekin man was first known from a single molar tooth. Now over forty individuals can be recognized mainly from skulls, jaws and teeth. Care must be taken to distinguish

those remains (chiefly skulls) from a cleft in the rock near Choukoutien from the much more recent skeletons found in the so-called "Upper Cave" close to the rock cleft. The former show some evidence of being the relics of a cannibal brain feast whilst the latter group were probably just murdered and their brains were not eaten. The two distinct horizons are reminiscent of the middle and upper Pleistocene levels in Java. The respective ages of the levels in China and Java are approximately the same, but on the whole the Pekin remains are probably slightly more recent. The dating is based mainly on the fauna, but this will be discussed in Chapter IV.

Concerning the skeletal remains themselves—nearly half are skulls of children under fourteen. Of the six adult skulls the cranial capacities of which could be measured, one probable adolescent measured 915 c.c., three adult males varied from 1,030 to 1,225 c.c.,

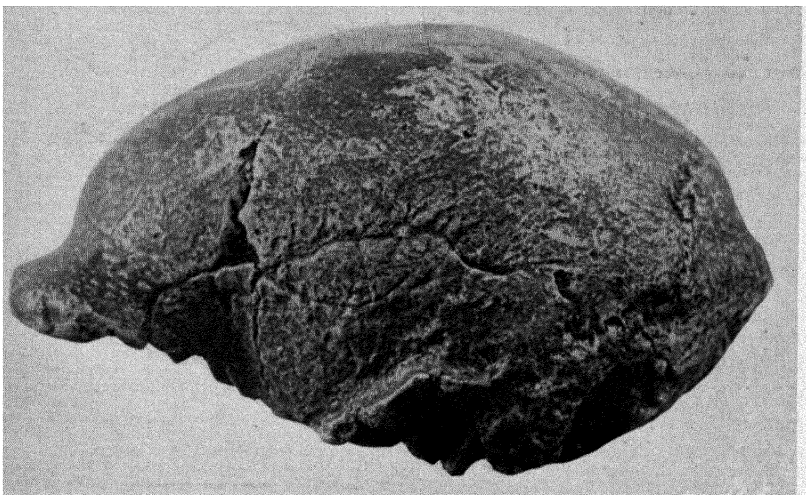


Fig. 13. The ape-man from Pekin, China (*Pithecanthropus pekinensis*).

one female skull was 1,015 c.c. and one not sexed was 1,030 c.c. Weidenreich[1] calculates the overall average to be 1,075 c.c. (Table II) which is considerably larger than the Trinil men for whom the corresponding figure is 850 c.c. Although the Pekin man's forehead is receding (Fig. 13), there is a distinct frontal bulge when compared with the Javanese skull shown in Figure 10. The indices I_1 and I_2 both indicate that Pekin man was more erect than the Java man—the respective values being $I_1 = 58$ and $I_2 = 69$ for the former compared with $I_1 = 35$ and $I_2 = 54$ for the latter. Like both the African and Javanese ape-men, the jaw of Pekin man shows a mixture of hominid and simian features. The convergence angle is appreciable, being 29 degrees, and the molars decrease in size from before backwards—a hominid feature (but see page 40). The canines are small requiring no diastemata but they are not as small as those of Heidelberg man. Like

[1] *Sinanthropus pekinensis and its position in the line of Human Evolution*, Pekin Nat. Hist. Bull. X, Pt. 2, 1936.
"The Trend of Human Evolution," *Evolution I*, p. 221, 1947.
The Skull of Sinanthropus pekinensis, Palaeontologia Sinica., No. 127 (Nat. Geol. Survey of China).

Heidelberg man the jaw has no simian shelf and no chin prominence. Pekin man, as judged from the relatively few limb bones, was of short stature and stood almost five feet—slightly taller than the *Australopithecinae*.

On the whole *Pithecanthropus pekinensis* was a man of some intelligence, could probably speak and certainly worked course quartz tools. Remains of numerous hearths and charred animal bones show that he had learnt to control fire.

It has been suggested that the predominance of skulls together with the fact that they were much broken open round the foramen magnum is an indication that cannibalism was practised. This has already been mentioned when referring to other groups of skulls that had been similarly treated. (See page 22.)

The group or family of rather mixed types of people from the upper cave at Choukoutien are not characteristic of Upper Pleistocene times, and have therefore not been included in Table II.

7.08 *Homo neanderthalensis* (Steinheim) *or Homo steinheimensis* (The Neanderthal man from Steinheim)

So-called Neanderthal men include two types which, although similar in some respects, are quite different in others. Some authorities like to separate the types by classifying them as separate species. The earlier type appeared during the last interglacial period immediately preceding the Würm glaciation. The later type straddled the Würm glaciation and seemed to disappear from Europe when the climate ameliorated.

For our present objective one of the earliest skulls, namely that from Steinheim near Würtemberg, will be discussed, and one of the later ones—the fairly complete skull from La Chapelle aux Saints in the Corrèze province of France. This later classical type is in many respects similar to and is more or less contemporary with both *Pithecanthropus soloensis* and *Homo rhodesiensis*. The former has already been discussed (page 44) and Rhodesian man is considered below.

The first Neanderthal remains were found in a Gibraltar cave in 1848, but it was not until the discovery of similar relics from the Neander Gorge near Dusseldorf in 1856 that the real importance of these creatures was appreciated.

In 1925 and 1933 skeletal remains were found in a limestone quarry at Ehringsdorf near Weimar and from gravel deposits at Steinheim respectively. Although they were recognized as types of Neanderthal men, it was realized that they were in many respects more primitive in that they were less specialized than the later classical forms. That is, they were paedomorphic. The fact that they were associated with a warm climate fauna including *Loxodonta antiquus* and *Diceros leptorhinus* indicates that they were interglacial in time. They are usually placed in the last interglacial period between the Riss and Würm glaciations. The Steinheim skull (Fig. 14) has even been considered as contemporary with Heidelberg man of the Mindel-Riss interglacial period, but this view is not now generally accepted. It is however agreed that the Steinheim remains are earlier than those from Ehringsdorf. They comprise the right side of the skull vault and most of the face. The skull is quite small (1,070 c.c.) and probably female. The main interest lies in the more dome-shaped character of the vault compared with that of the later classical

Neanderthal remains. There is no marked "bun" or projecting part of the occipital bone and the forehead is not so flat and receding as in both the earlier *Pithecanthropoids* and later *Neanderthaloids*. There are also distinct dents (the canine fossae) below the cheek bones which are definitely hominid features. The heavy torus or ridge above the orbits is however characteristic of all Neanderthal skulls.

That the more modern types of Upper Pleistocene men are the result of cross-breeding between the two types of Neanderthal men is a possibility. This idea is the more probable because both forms lived together (or rather in adjacent caves) at the same period in Mount Carmel. (See below.)

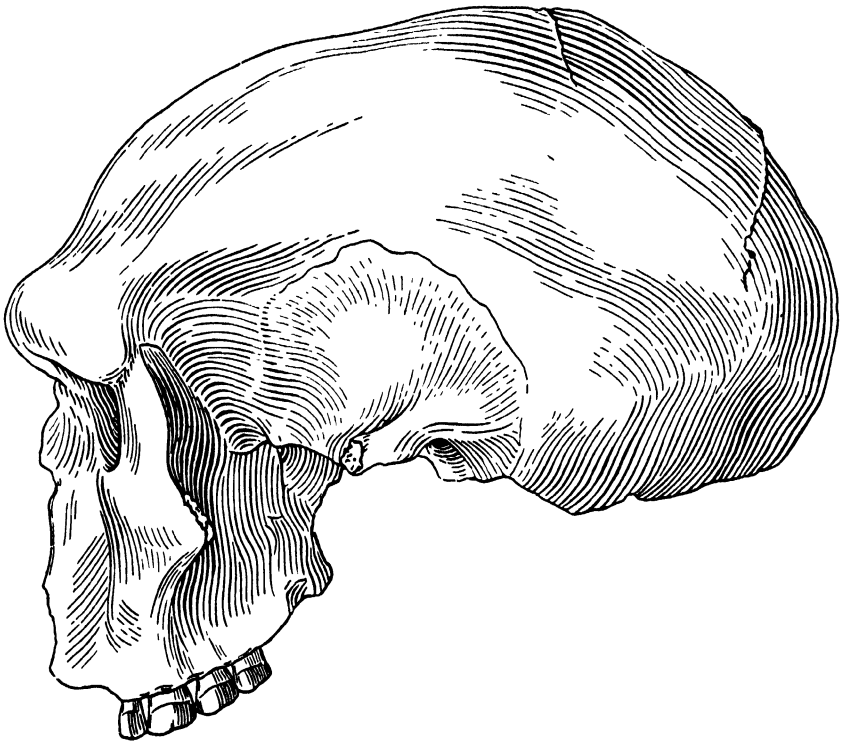


Fig. 14. Neanderthal man from Steinheim, Germany (*Homo neanderthalensis*-Steinheim).

Again in Croatia the Krapina skulls are all Neanderthaloid but are not uniform. In this case too they may have inter-bred, but from the damage in the region of the foramen magnum it would appear that they were all the victims of a cannibal feast.

Be that as it may, the later Upper Pleistocene forms of *Homo sapiens* might well be descendants of the early non-specialized Neanderthal type. (See page 58.) They certainly were not descendants of the later and highly specialized Neanderthal forms who became extinct at least in Europe after the Würm glaciation.

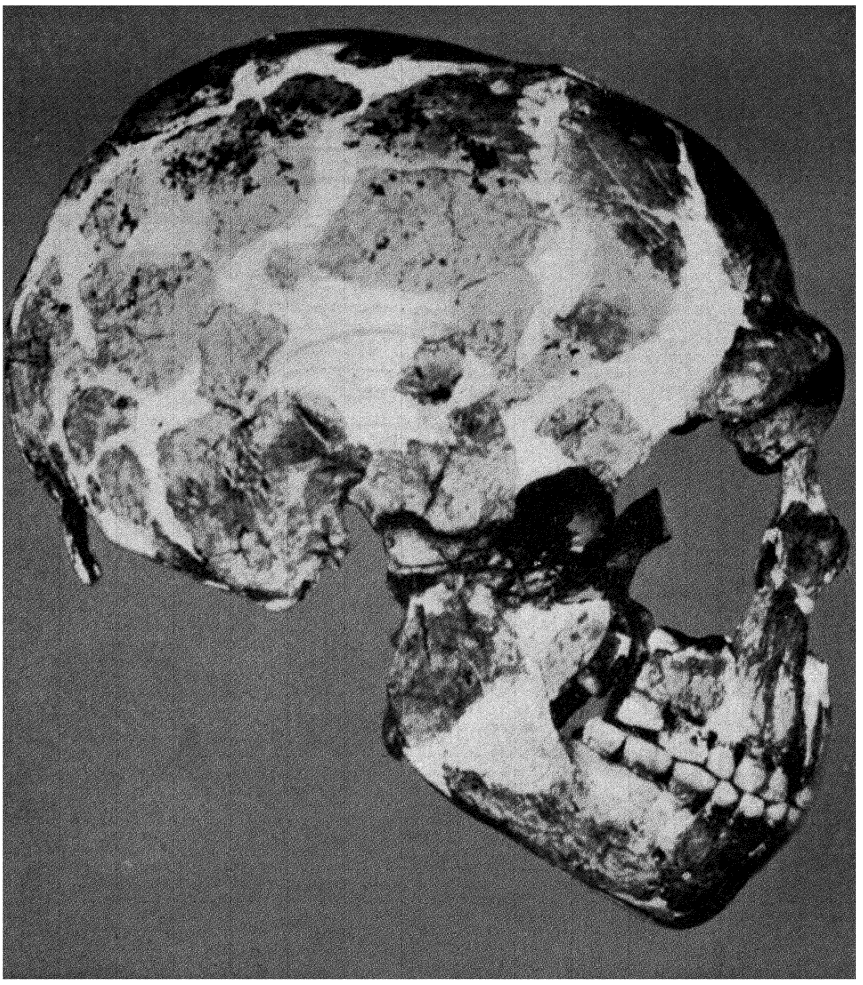


Fig. 15. Neanderthal woman from the Tabūn cave, Palestine (*Homo neanderthalensis*—Tabūn I).

7.09 *Homo neanderthalensis* (Palestine)

In 1931-32 the joint expedition of the British School of Archaeology and the American School of Prehistoric Research investigated some of the n merous caves in the "Valley of Caves" which runs from the western slopes of Mount Carmel towards the Mediterranean Sea. The excavations were under the direction of Dr. Dorothy Garrod.[1] The two particular caves of interest were the Skhūl cave and the Tabūn cave. In the former were found about ten skeletons of very varied Neanderthaloid types and in the latter

[1] *The Stone Age of Mount Carmel I*, Oxford, 1937; also *The Stone Age of Mount Carmel II*, by McCown and Keith, Oxford, 1939.

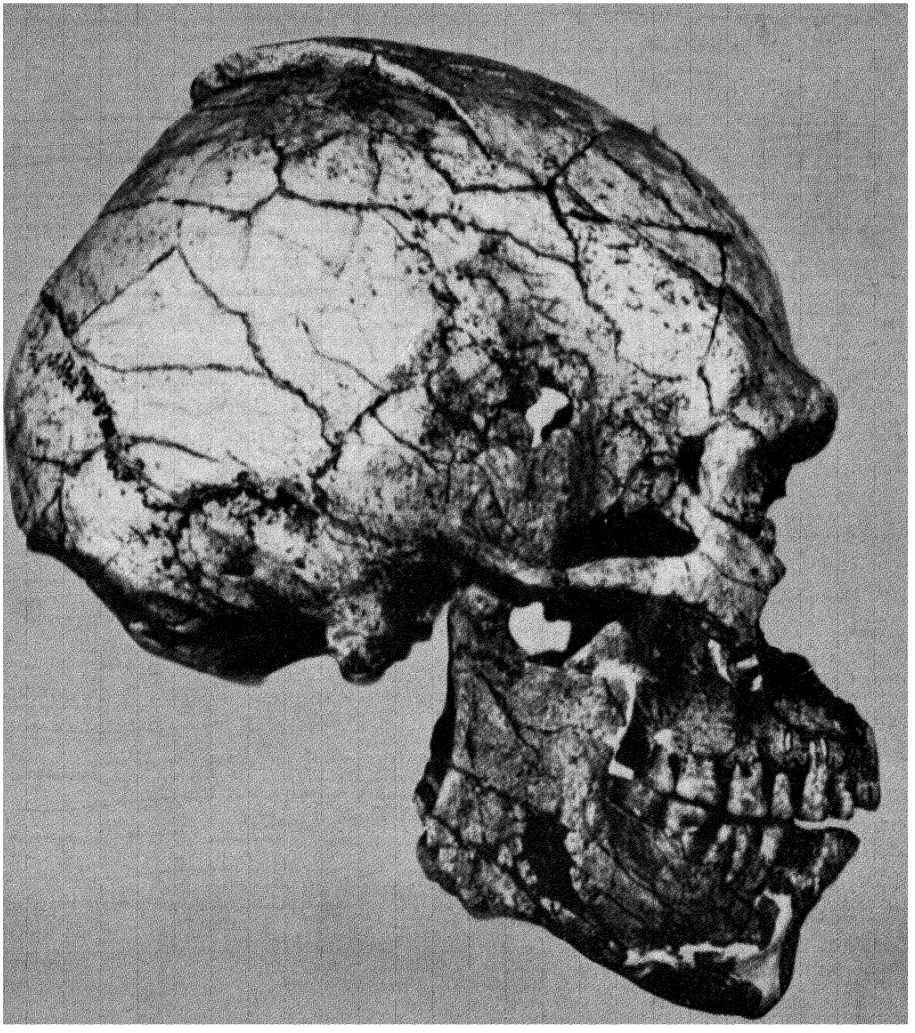


Fig. 16. Neanderthal man from the Skhūl cave, Palestine (*Homo neanderthalensis*, Skhūl V).

was found a woman's skeleton of the more classical or gerontomorphic type together with two lower jaws. The Tabūn female skull (Fig. 15) is low vaulted, of small capacity (1,270 c.c.) and has a prominent supra-orbital ridge. The lower jaw is chinless and prognathous and the convergence angle is practically the same as for the classical Neanderthal skull from La Chapelle aux Saints. The pelvis is peculiar and not clearly indicative of the posture. However the foot bones do suggest the erect posture when

walking. Thus the Tabūn woman seems to have a curious mixture of a Neanderthaloid skull with the walking gait of modern man. The two jaws from the cave are also mixed in that one has a marked chin whilst the other is chinless.

In the Skhūl cave the mixture of Neanderthaloid and modern features is even more remarkable. The "modern" type of adult male from Skhūl (Fig. 16) is tall and erect. The skulls are high-domed and are larger than those of modern men being on the average about 1,550 c.c. There are however marked brow ridges with both types. This feature in the more modern type may be contrasted with quite modern lower jaws exhibiting prominent chins. The dentition is also comparable with that of modern man and the convergence angle of the lower jaw is identical with that of Cro-Magnon. These two types of people were living in Palestine during the last inter-glacial period. The time (approximately 150,000 B.P.) is insufficient for later and more modern forms of men (e.g. Cro-Magnon man) to have descended from the somewhat paedomorphic Neanderthal man from Skhūl. It is, however, quite probable that modern Europeans may owe many of their characteristic features to the hybridization of these different types who occupied adjacent caves at the same time on the slopes of Mount Carmel some 150,000 years ago.

7.10 *Homo rhodesiensis* (Rhodesian man)

The next three skulls in Table II are from widely different localities—Rhodesia, Java and Europe. They are more or less contemporary and possess some of the same morphological characteristics. From geological considerations it is not yet possible to decide their order of antiquity. They all lived during the last ice age or its equivalent pluvial phase. Solo man has already been described and a classical Neanderthal man from La Chapelle aux Saints is described below.

The Rhodesian remains were taken from a quarried cave in Broken Hill, Northern Rhodesia, in 1921. Other parts of the cave had already yielded vast quantities of animal bones and crude worked quartzite implements, but these were not directly associated with the human remains. The animal bones, with the exception of one extinct form of rhinoceros, were of species still living in Africa, such as elephants, hippopotami, zebra, etc. The human remains were found ninety feet from the surface and one hundred and ten feet from the cave entrance. They rested below a cleft down which they may have fallen from the surface. They were highly mineralized by the minerals which were the object of the mining operations, but they were not much fossilized. Consequently it is almost impossible to date the skeleton geologically. A recent investigation by Mr. Desmond Clark[1] leads to the conclusion that the remains (including the artifacts) belong to the Gamblian Pluvial period which is more or less contemporary with the Würm glaciation and with the later Palaeolithic period in Europe.

Physically Rhodesian man (Fig. 17) looks very similar to the specialized classical Neanderthal man, only the brow ridges of Rhodesian man are more massive and continuous than for any other known human skull. In fact the large face and wide palate are more like those of the gorilla except that the palate is not smooth as it is in all the

[1] *The Stone Age in Northern Rhodesia* South Africa Arch. Soc. Handbook Series. 1950.

anthropoid apes. The length of the face from the root of the nose to the alveolar point (see Fig. 6) is 95 mm. whereas it is only 70 mm. in modern man, 87 mm. in the long-faced classical Neanderthal man from La Chapelle and over 100 mm. in the gorilla. The eye sockets on the other hand are rectangular—a hominid feature. The absence of canine fossae which are replaced by slight convexities, is a typical simian feature. The temporal lobes of the brain are far less human than they are in Neanderthal man and it is doubtful whether Rhodesian man could speak. He is certainly mentally inferior to

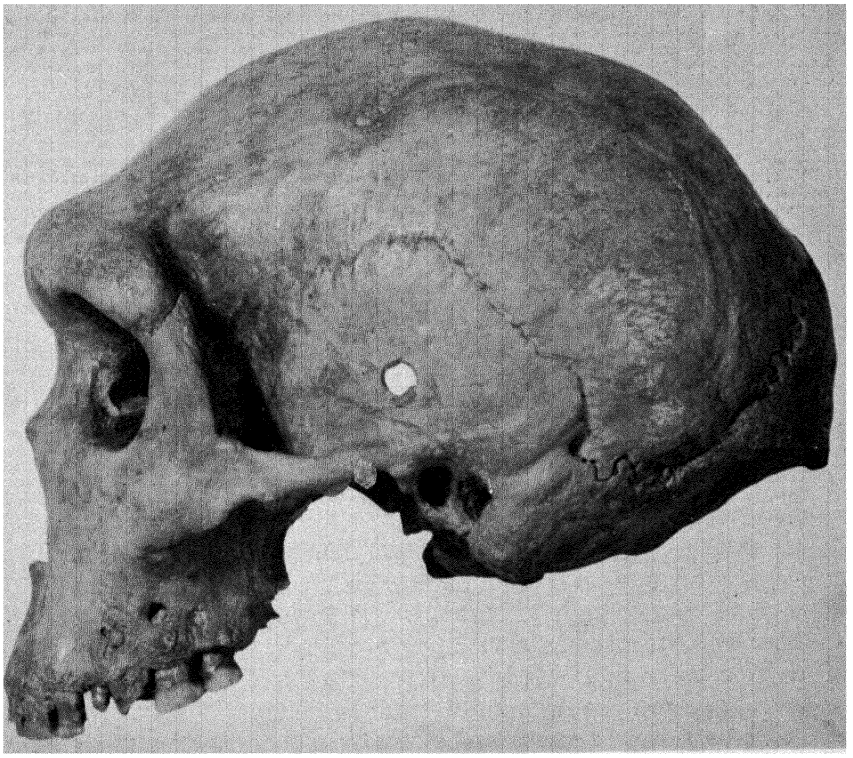


Fig. 17. The man from Broken Hill Mine, Rhodesia (*Homo rhodesiensis*).

Neanderthal man, which accords with the relatively small capacity of his skull—about 1,280 c.c.

The associated limb bones and the forward position of the foramen magnum indicate that Rhodesian man was much more erect in his posture than Neanderthal man and therefore in this respect rather more reminiscent of the *Australopithecinae*. The corresponding values of the posture indices I_1 and I_2 are, respectively:

	I_1	I_2
Rhodesian Man	76	63
Neanderthal Man (La Chapelle aux Saints)	70	56
Australopithecus africanus . . .	78	62

Rhodesian man therefore did not shuffle along with head forward as did the classical Neanderthal man.

The dentition of Rhodesian man is definitely human but curiously enough he must have suffered severely from dental caries and abscesses—a state of affairs not seen in any other early skull of this type. This, together with the freshness of the bones which are but little fossilized, tends to suggest a much later date for this man than Upper Pleistocene. If he was pathologically abnormal and suffered from acromegaly as some authorities have suggested, then perhaps the remains may not be Palaeolithic at all but relatively recent. However, Hooton[1] points out that certain details associated with his glands are quite normal, and therefore do not support any theory of pathological abnormality.

7.11 *Homo neanderthalensis* (La Chapelle aux Saints)

The remains of the type specimen from the Neander Gorge are fragmentary and of much less use for measurement than the almost complete skeleton that was buried in a cave at La Chapelle aux Saints. Incidentally a great many of Neanderthal remains were deliberately buried—a significant fact when considering their cultural development. The body was buried in a flexed position surrounded with a ring of stones and provided with a leg of beef for the journey into the next world. The associated fauna were characteristic of the last ice age and the flint implements were equally characteristic of this period.

As we are here concerned with his skeletal features, the associated finds will be discussed later when considering his culture and the period of his burial.

The volume of the skull (Fig. 18) was exceptionally large (1,600 c.c.) compared with 1,450 c.c., the average for Neanderthal males according to M. Boule.[2] The supra-orbital ridges are enormous but show a slight depression in the glabella region which lies immediately above the nose. The forehead is flat and receding and the jaws prognathous. The occipital area is almost buried in the neck by the powerful nuchal muscles necessary to support the very unbalanced head with its prognathous jaws. The degree of unbalance is indicated by the index I_2 which is only 56. The distal attachments for these nuchal muscles are the spines on the neck vertebrae. These are almost as prominent as those of the gorilla. The mastoid processes—the conical bony projections behind the ear to which the muscles are attached that turn the head—are almost rudimentary, and not much bigger than they are in the apes. The lower jaw has no simian shelf and the tongue muscles are attached to genial tubercles in the symphyseal region as in modern human races (Fig. 5). The convergence angle of the teeth series (26·4 degrees) is slightly bigger than in Heidelberg man but considerably less than in modern man. The canines are small, there are no diastemata and the third molars are the smallest—all features characteristics of modern man. Boule does suggest however that the chewing action of Neanderthal man was a to and fro motion of the lower jaw as distinct from the side to side motion of modern man. This accords with the large postglenoid process which

[1] *loq. cit.*, p. 346.
[2] *Les Hommes Fossiles*, 3rd Ed. Edited by Vallois, 1946.

is only rudimentary in modern man. The postglenoid process is the back wall of the "hinge" in which the condyles of the lower jaw articulate. This "hinge" (the glenoid fossa) is well marked in man but is replaced in the apes by a "plateau" backed by the postglenoid process. The values of the indices I_1 and I_2, namely 70 and 56 respectively, indicate a poise more comparable with that of the chimpanzee than with the erect posture of modern man. This conclusion receives support from a study of the leg bones.



Fig. 18. Neanderthal man from La Chapelle aux Saints, France (*Homo neanderthalensis*—La Chapelle).

The forward curve of the thick short femora is most ape-like. There is no rough ridge or linea aspera down the posterior surface of the shaft. This indicates an absence of attachments for the extensor muscles concerned with maintaining the erect posture. The heel bone or calcaneum is smaller than in modern man and leans over outwards. These details all point to the fact that Neanderthal man shuffled along on the outer sides of his feet with bowed knees like a modern chimpanzee. He also retained a prehensile great toe, but on the whole the foot was adapted more for walking than for handling objects. These conclusions have been confirmed recently in a striking fashion by the discovery in the Basua Cave, near Toirano, Savona, Italy, of fossilized footprints

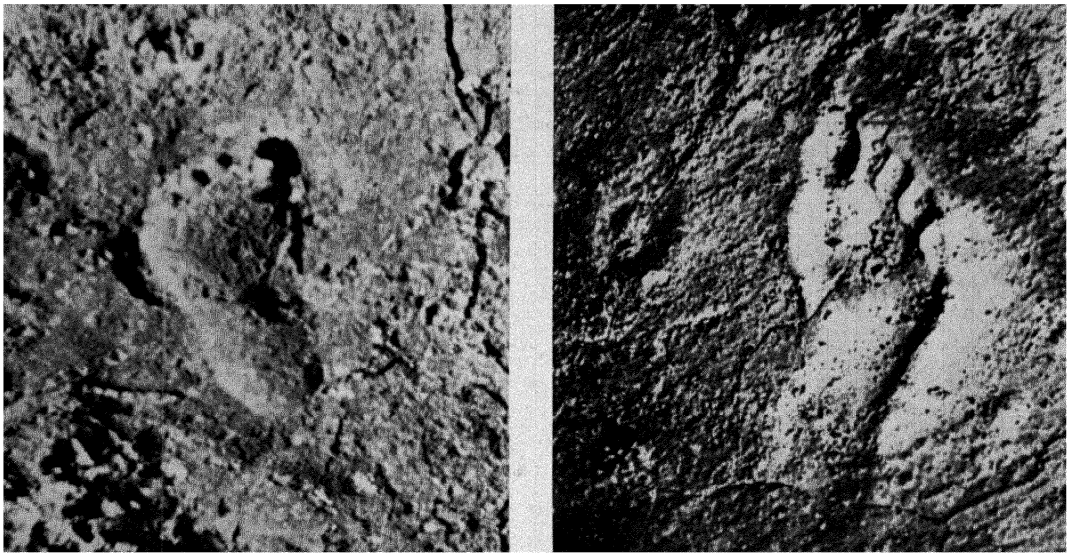


Fig. 19 (A). Fossilized foot-print of Neanderthal man from the Basua Cave, Toirano, Italy. (B). Fossilized foot-print of Magdalenian man from the Grotto of Aldene, France.

(Fig. 19A) which accord completely with impressions that would result from a foot such as that attributed to Neanderthal man. Nevertheless in spite of his ape-like gait, he could make tools, control fire, had some belief in life after death, and in all probability had some form of articulate speech.

Incidentally many Neanderthal skulls, including that from La Chapelle, are asymmetrical with the left half of the skull larger than the right. This indicates a right-handedness never found in the anthropoid apes.

7.12 *Homo sapiens* (Cro-Magnon)

Towards the end of the fourth and last glacial epoch *Homo sapiens*, already separated into several racial types, appeared in Europe. His remains have been found in practically every country including England. There is little to distinguish his skeletal remains from those of modern men and racial peculiarities could easily be matched from the many different types of modern Europeans.

A great many skeletons have been found in France and Germany. The classical examples come, in particular, from the caves along the Vezère River in the Dordogne district of France. Perhaps the best known remains are those of Cro-Magnon man discovered in 1868 at Les Eyzies. Here in a small rock cavity both male and female skeletons had been buried. The man (Fig. 20) was tall and muscular with a large long head (some of this race had skulls of over 1,600 c.c.) and a short broad face; a combination known as disharmony. The cheek bones were prominent and the chin

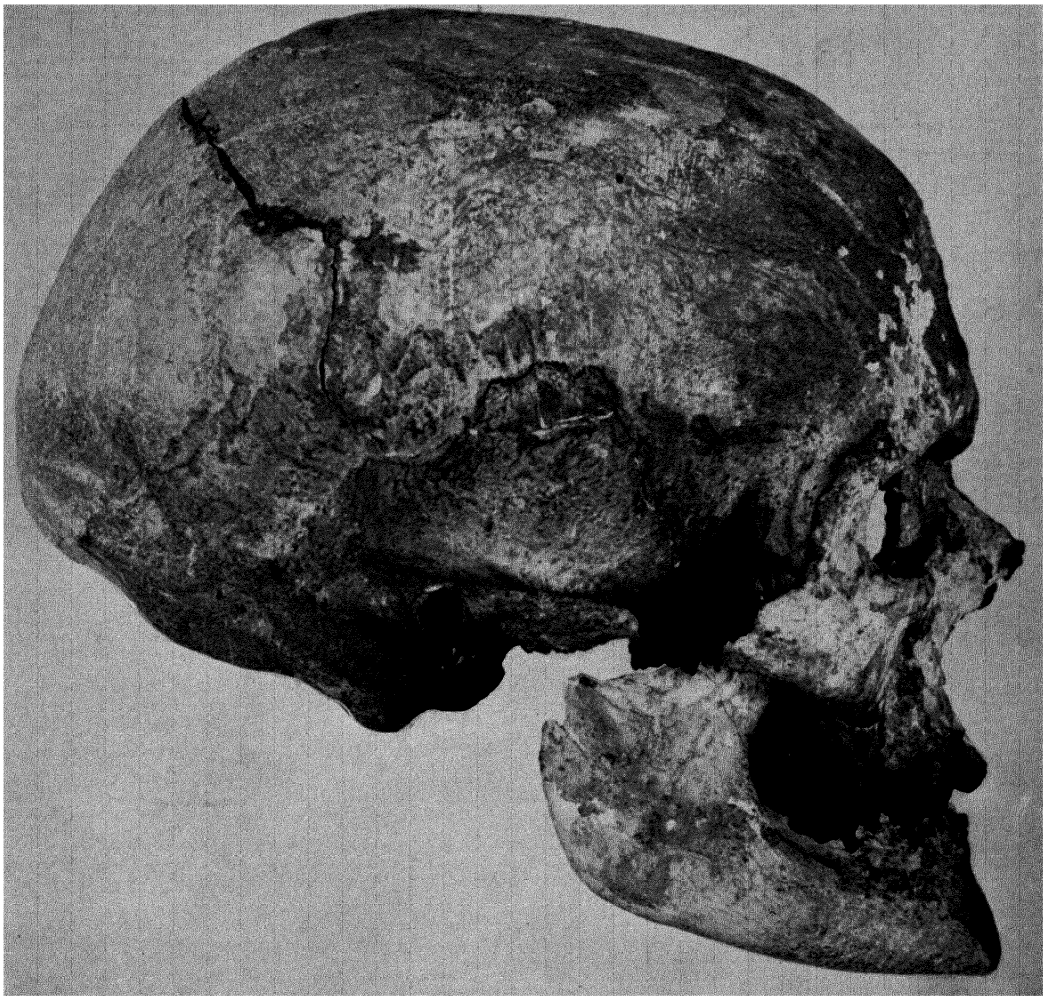


Fig. 20. The Cro-Magnon man, Dordogne, France.

jutted well forward. Brow ridges were not conspicuous and teeth were quite modern. The marked pilastering of the posterior surfaces of the thigh bones (femora), their fore-and-aft flattening (platymeria), the side-to-side flattening (platycnemia) of the shin bones (tibiæ), the prolongation of the articulating surfaces of the condyles on the lower or distal ends of the femora all point to athletic men capable of leaping about on rough surfaces and of squatting with bent knees. His modern-looking footprint from the French Grotto of Aldene is shown in Figure 19B. There is no evidence

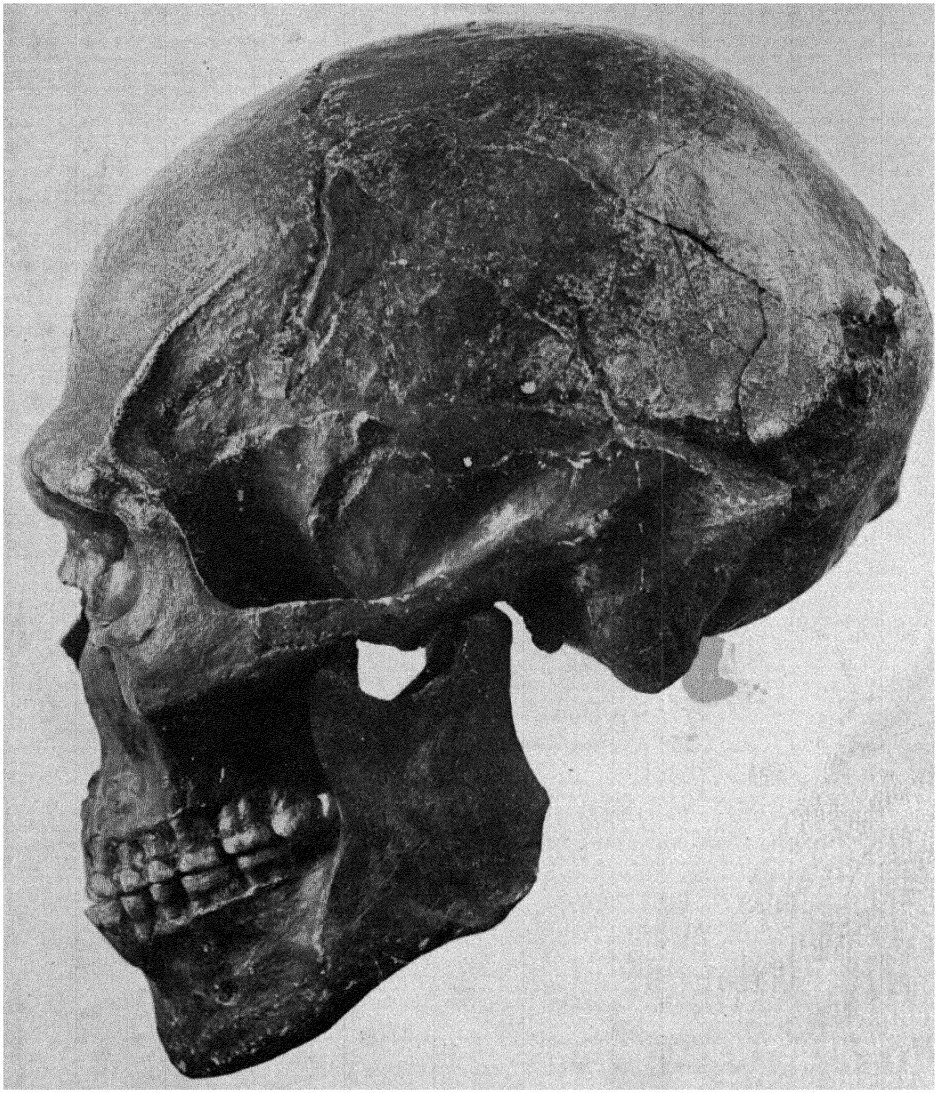


Fig. 21. The Predmost man, Brunn, Czechoslovakia.

to show that these men migrated into Europe and it may well be that they developed directly from their paedomorphic Neanderthaloid forbears, perhaps hybridized with immigrants from the near east and north Africa.

Their stone implement techniques, their burial customs, and other cultural characteristics together with associated animals will be discussed in the following chapter.

7.13 *Homo sapiens* (Combe Capelle and Predmost)

Contemporary with Cro-Magnon man was a shorter narrow-faced man whose remains are even more widely distributed than those of the Cro-Magnon type. They are represented by the Combe Capelle skull from the Perigord district of France and the many skeletons from Predmost, Brunn, Vestonice and other sites in Moravia and Czechoslovakia.

Apart from their shorter stature and less facial disharmony, these men had more prognathous jaws and lower and flatter skull vaults (Fig. 21). Their brow-ridges were more conspicuous than in Cro-Magnon men, but much less than in the classical-Neanderthaloids. They were not far removed in appearance from the so-called Mediterranean people of today. It is perhaps significant of their ancestry that all four anatomical indices recorded in Table II are less than the corresponding ones for Cro-Magnon man.

At least, in Moravia, they were great mammoth hunters, and left behind much evidence of their advanced cultural development—a matter for later consideration.

7.14 *Homo sapiens* (Chancelade)

When the ice had finally retreated from England, possibly about 25,000 years B.P., the climate in N.W. Europe must have been very similar to what it now is in Siberia, Iceland, North Norway and Finland and what it may well be in Greenland in a hundred years' time if the present rate of warming up continues. This vigorous but ameliorating climatic period was marked by the extinction of the mammoth and woolly rhinoceros. Later the bear, reindeer and wolf also disappeared from this country; although wolves in England and reindeer in Scotland persisted until Roman and Saxon times.

The men who inhabited England and N.W. Europe immediately after the recession of the ice were different from the Cro-Magnon and Combe Capelle men, who are often referred to as Aurignacian men. This term is used, in particular, for the type of flint implement culture with which their remains are associated. The cultures following the Aurignacian are known as Solutrian and Magdalenian.

Human skeletal remains are scarce. They are comparable physically with those from Combe Capelle and seem to be limited to the lowland areas of Hungary, France and Spain. More or less contemporary with Solutrian man were the Magdalenian folk. The Magdalenian "blade" culture is different from the flint "leaves" of Solutrian man. These long blades were originally identified at the rock shelter of La Madeleine in the Dordogne district of France. There are many human skeletal remains associated with this blade culture from various places in N.W. Europe and the name "Magdalenian Man" has been applied to those men whose remains are associated with this long-blade technique. Other cultural details of these men of the "Reindeer age", as these times are often called. will be discussed in Chapter III. Magdalenian man seems to have some affinities with the modern Eskimo, both in physical appearance and in cultural practices. But, on the other hand, there are also distinct differences. A type skull (Fig. 22) is that found at Chancelade in the Dordogne. Other specimens come from Duruthy (Landes), Placard (Charente), Laugerie-Basse and Cap Blanc (Dordogne) and from Obercassel in Germany.

In England the skulls from Aveline's Hole, Somerset, are of the late Magdalenian period and are discussed below.

The Chancelade skeleton[1] was discovered in 1888. It was evident that the man had been buried, because the skeleton was crouched and covered with red ochre—a custom associated with other late palaeolithic burials. The skull volume has been estimated as

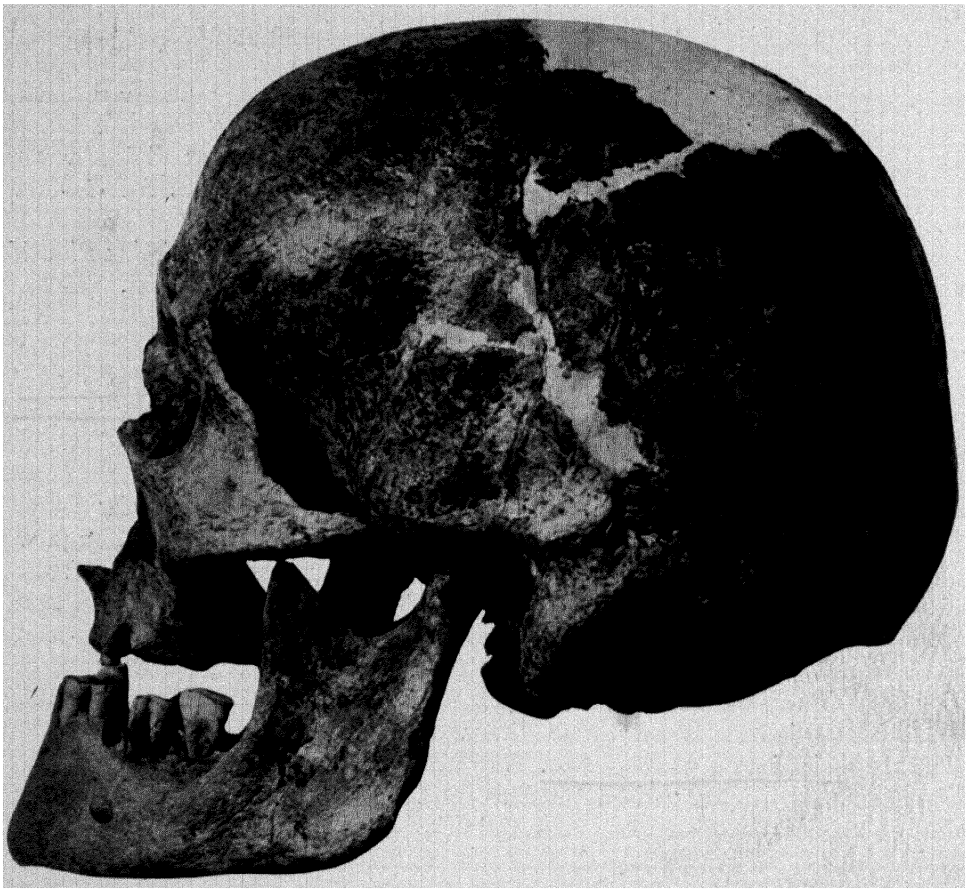


Fig. 22. The Chancelade man, Dordogne, France.

1,530 c.c. by Keith and as 1,650 by Pearson. A mean capacity of 1,590 c.c. has therefore been used in Table II. The skull is dolichocephalic with a very high-pitched vault. The cheek-bones are prominent and the jaw has a protruding chin—features not uncommon in the Eskimo. But the large volume of the skull and the relatively long leg bones are more reminiscent of Aurignacian man.

The lower jaw of Chancelade man is particularly interesting. From a photograph of the occlusal aspect kindly supplied by Professor H. V. Vallois it is evident that the angle

[1] H. V. Vallois; *L'anthropologie* 50, p. 165, 1941–6.

of the convergence of the teeth series is intermediate in value (38 degrees) between that of Cro-Magnon man and Magdalenian man; and this provides an important and crucial point on the I_4 time graph. (See Table II and Fig. 53.)

7.15 *Homo sapiens* (Aveline's Hole and Cheddar, Somerset)

It is usual to consider that the Palaeolithic or Old Stone Age came to a close at the end of Magdalenian times. It was separated from the Neolithic or New Stone Age by

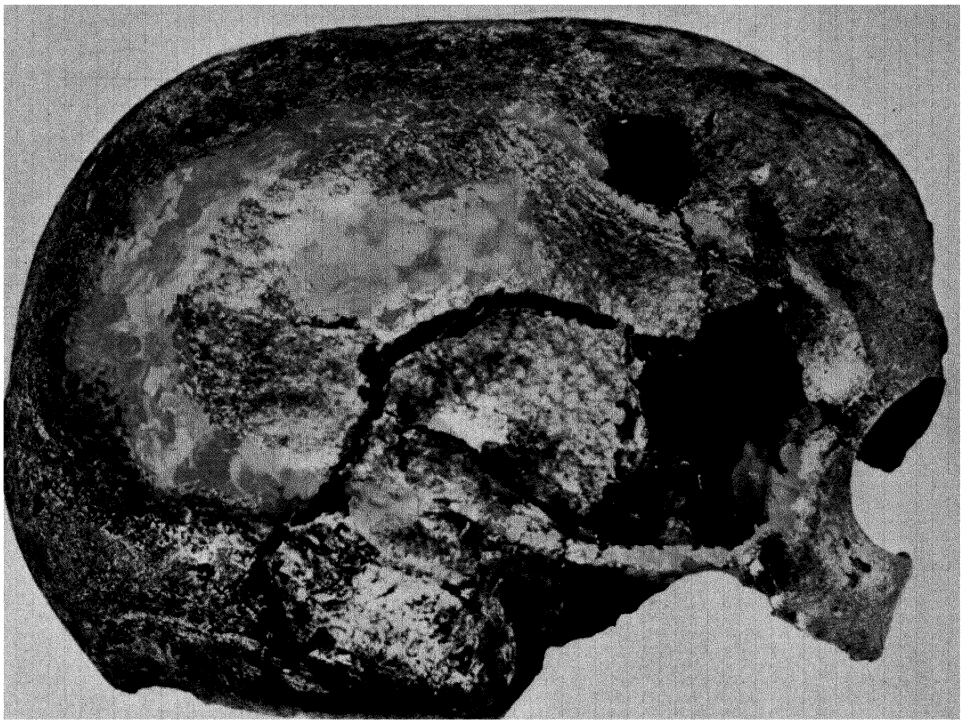


Fig. 23. Long-headed man from Aveline's Hole, Somerset.

a transitional period which extended from about 8000 to 2500 B.C. This period is sometimes called Mesolithic and is characterized by blade and microlithic flint cultures, bone harpoons, a birch bark industry, etc. The flint cultures are given various names depending on the district in which the artifacts are found—Creswellian (Derbyshire), Azilian (South France), Tardenoisian (North France), Capsian (Near East and North Africa), Stillbay (South Africa), Magosian (East Africa), etc.

The human remains are not as numerous as might be expected considering that they are relatively recent in time. They mark the end of the Pleistocene and the beginning of the Holocene geological periods.

The skeletal remains with which we are here concerned were discovered in 1913 and further remains were excavated by the Bristol University Spelaeological Society between 1919 and 1924. They were all found in the cave known as Aveline's Hole which is situated towards the lower end of Burrington Coombe, Somerset. Skeletons from this cave were reported at the end of the nineteenth century, but the present

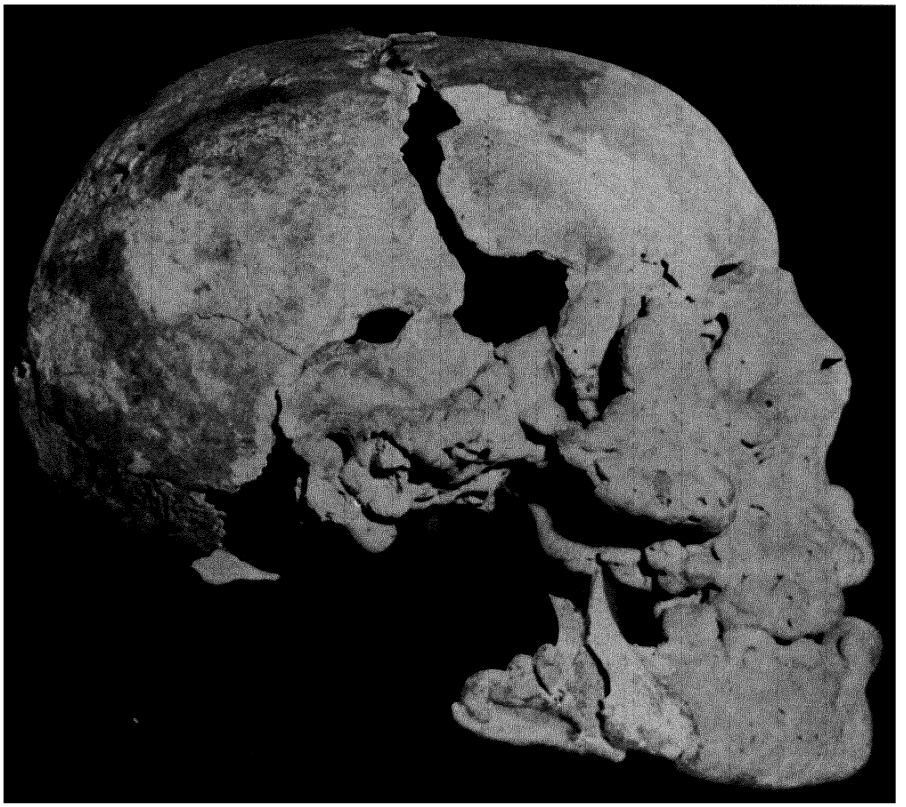


Fig. 24. Broad-headed man from Aveline's Hole, Somerset. (Face coated with stalagmite.)

location of these earlier finds is not known. The bones (chiefly parts of skulls) were cemented in hard stalagmite, but three skulls were sufficiently complete to yield interesting information concerning their size and shape. One was a long skull (dolichocephalic) (Fig. 23) and two were short skulls (brachycephalic) (Fig. 24). This association of long and short skulls in the same place at the same time is comparable with similar mixtures of long- and short-headed men at Ofnet in Bavaria, at Furfooz in Belgium and at Grenelle near Paris. It is probable that the short-headed men spread from the near east and intermingled with the long-headed descendants of the earlier palaeolithic inhabitants of Europe. The remains from Aveline's Hole represent their farthest point of migration.

The long-headed men had powerful jaws operated by well-marked temporal muscles. The skulls resemble those of modern types of men and the teeth show no peculiarities which could be considered as characteristic of men living 10,000 years ago. Over a hundred different faunal species and dozens of characteristic flint implements, a double-barbed engraved harpoon of red-deer antler, shell ornaments, etc., were associated with these skulls.

A skeleton found in Gough's Cave, Cheddar, was quite similar to the dolichocephalic skulls from Aveline's Hole. The cultural remains were typical of the same period—Azilio-Tardenoisian, but rather more varied in that they included a good example of a carved *bâton de commandement* and other bone artifacts.

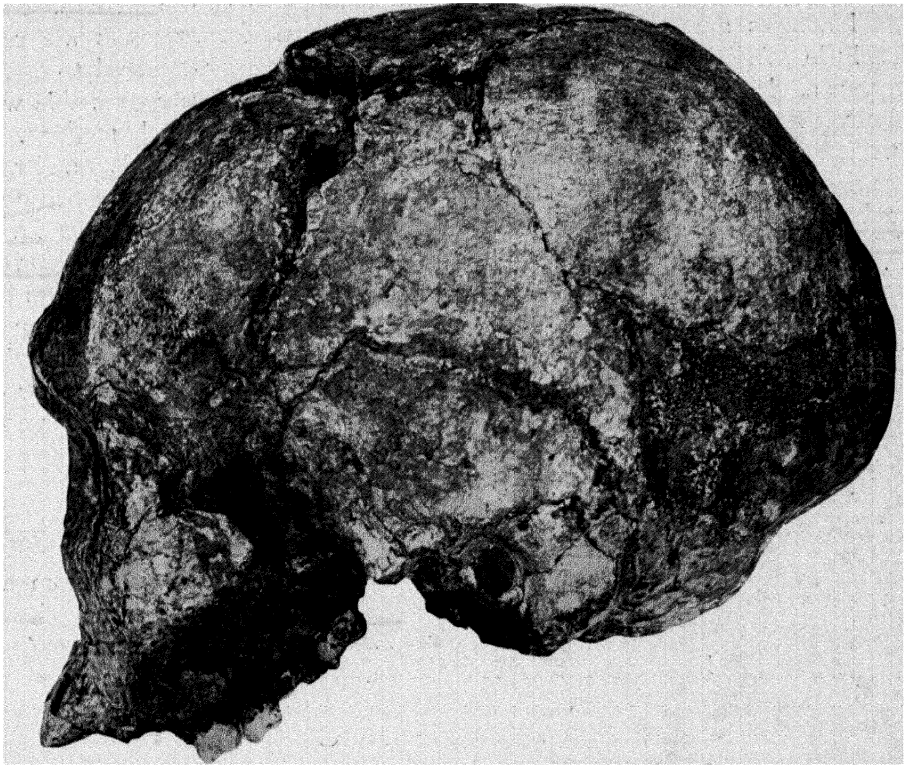


Fig. 25. Proto-Australoid man (Wadjak I) from Java

7.16 *Homo sapiens* (Wadjak) *or Homo wadjakensis*

In many respects the least ancient of the Java skulls proves to be the most inte
The Neolithic (or possibly Mesolithic) remains from the neighbourhood of Wadjak in the centre of Java present many interesting problems. The almost complete skull (except for the lower jaw) is known as Wadjak I (Fig. 25) and presents a large-domed modern-shaped cranium which is more like that of the Cro-Magnon men than the skulls of the more ancient men from Java. The volume is of the order of 1,550 c.c. and is thus

somewhat larger than most other skulls of post-glacial times. Unfortunately the skull is filled with a very heavy breccia material and so far it has not been possible to remove this without danger of smashing the skull. The skull is dolichocephalic and the bones are more fossilized than might be expected for a relatively recent skull—if such it is. Dubois was inclined to think the skull was Pleistocene rather than Holocene, but the opinion of most modern authorities[1] is that the Wadjak remains are not older than Mesolithic. The morphological characters suggest a closer affinity with modern Papuans than with modern Javanese, and the skull is generally considered to be that of a proto-Australian. This is an important point when the dental arcade is considered.

The remains of Wadjak II consist mainly of a large part of the maxilla and most of the lower jaw together with a few loose teeth and fragments of the calvaria. It is when the dental arcades are studied that the chief primitive characteristics are revealed. Fortunately in Wadjak I there is sufficient of the teeth series preserved to enable the convergence angle to be measured. It is 24 degrees and therefore comparable with the oldest known human jaws. In spite of this the chin region is relatively modern.

With Wadjak II the molars are preserved and all the first pre-molars and the convergence angle is found to be 28 degrees. These low values are quite surprising when compared with the relatively modern features of the skull. On the other hand, the second and third molars, especially with Wadjak I, are definitely reduced. Both Boule and Keith point out morphological similarities between the massive primitive jaws of the Wadjak folk and the jaws of the present Australian aborigines. They also compare them with those of the classical Neanderthal men. When the measurements of the I_4 index are graphed (Fig. 53) they practically bridge the gap between these two types of men. This is to be contrasted with the skull index I_3 which places these people on the branch of *Homo sapiens*.

This interesting and anomalous situation is discussed in the last chapter.

7.17 *Homo sapiens* (Chelm's Combe)

Of the many Neolithic remains available for study, those excavated from a rock shelter and a tomb in Chelm's Combe, near Wells, Somerset, are some of the few Neolithic skeletons not buried in long barrows. The Chelm's Combe remains (Fig. 26) consist of skulls and long bones together with typical early Neolithic pottery. The average volume of three skulls is 1,533 c.c. which happens to be identical with the mean value for twenty-five Neolithic skulls measured by Dr. G. M. Morant.[2] They are dolichocephalic and not very different from the long-headed men from Aveline's Hole. The jaws are less robust and the skulls somewhat flatter and thinner than the Burrington remains. Apart from some dental caries, the teeth show no abnormal characteristics, whilst the convergence angle of the lower jaw is practically the same as for modern man, namely 47 degrees. All the measurements correspond more closely with those of the modern Englishman than do any of the others recorded in Table II.

[1] Pinkley, G.: *The Significance of Wadjak Man. a fossil Homo sapiens from Java* Pekin Nat. Hist. Bull., Vol. 10, pp. 183-200, 1935-6.

[2] Biometrika XVIII, 1926.

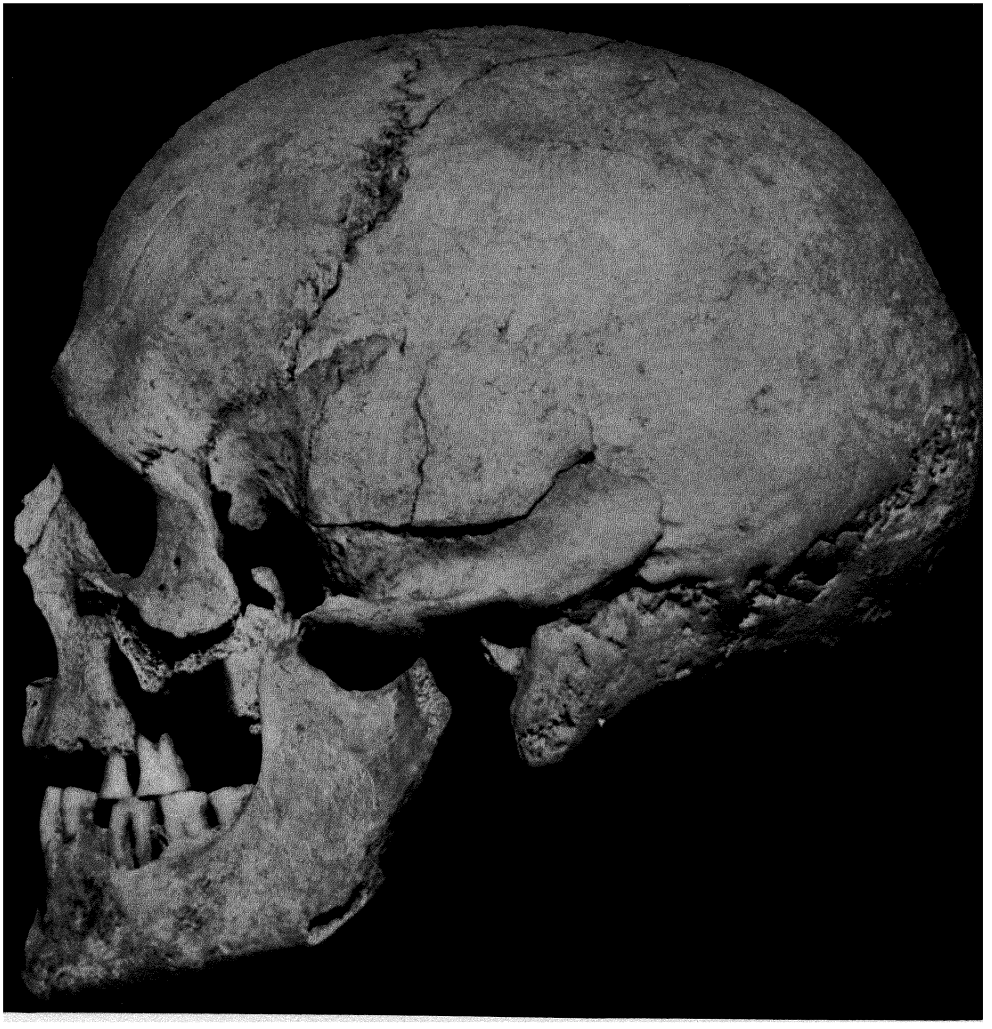


Fig. 26. Neolithic man from Chelm's Combe, Somerset.

The remains were excavated by Mr. H. E. Balch in 1925–26 under the auspices of the Somerset Archaeological and Natural History Society. The measurements in Table II were made on the skulls now in Wells Museum.

7.18 *Homo sapiens* (Glastonbury)

The Early Iron Age remains from Glastonbury Lake Village include several male skulls, some of which were found outside the palisade enclosing the village. Some were damaged by sword cuts and no doubt the men were killed defending their village from

TABLE II

Skull		Anatomical Indices			
		I_1 Nuchal Area Height		I_2 Condylar Position	
Name	Location	*Ratio Measured*	*Modified*	*Ratio Measured*	*Modified*
Modern Man	England	−9·0	100	80	100
Aboriginal	Australia	+23	60	62	78
Homo sapiens	Glastonbury (Somerset)	−5·7	96	77	96
	Chelm's Combe (Somerset)	−8·4	99	81	100
	Wadjak I and II (Java)	—	—	—	—
	Aveline's Hole and Cheddar (Somerset)	—	—	—	—
	Chancelade (Dordogne, France)	—	—	—	—
	Predmost (Czechoslovakia)	−2·9	91	68	85
	Cro-Magnon, Coombe Capelle (Dordogne, France)	−8·0	98	75	94
Homo neanderthalensis	La Chapelle aux Saints (Corrèze, France)	+14	70	45	56
Pithecanthropus soloensis	Solo River (Java)	+25	57	40	50
Homo rhodesiensis	Broken Hill Mine (Rhodesia, Africa)	+10	76	50	63
Homo neanderthalensis	Mount Carmel	−1·6	91	81	100
	Skhūl Cave	+4·6	83	76	95
	Tabūn cave (Palestine)	+8·7	77	66	83
	Steinheim (Würtemburg, Germany)	+17	67	57	71
Pithecanthropus pekinensis	Choukoutien (Pekin, China)	+24	58	55	69
Homo heidelbergensis	Heidelberg (Germany)	—	—	—	—
Pithecanthropus erectus I and II	Trinil and Sangiran (Java)	+30	51	43	54
Pithecanthropus modjokertensis	Modjokerto (Java)	—	—	—	—
Australopithecus africanus	Sterkfontein (Africa)	+8·9	78	49	62
Proconsul africanus	Kenya (East Africa)	+42	35	33	41
Chimpanzee (Pan troglodytes)	Africa	+50	24	26	32
			○		×

(Table II, *continued*)

Anatomical Indices				
I_3 Cranial Capacity		I_4 Lower Dental Arcade Convergence Angle		Authority
C.C. Measured	*Modified*	*Degrees Measured*	*Modified*	
1480	100	48	100	Gladstone, Cameron
1200	81	25	52	Shellshear
1,468	98	—	—	Bulleid and Gray
1,533	103	47	98	Balch, Morant
1,550, 1,650	104, 110	24, 28	50, 58	Dubois, von Koenigswald
1,450	97	45	94	Keith, Fawcett
1,590	106	38	79	Keith, Pearson, Vallois
1,590	106	—	—	Maška, Absolon
1,440	95			Matiegka
1,660	111	34	71	Boule, Keith,
1,580	106			Verneau, Morant
1,600	107	26·4	55	Boule
(1,450	97 mean)			
1,100	74	—	—	Weidenreich
				Oppenoorth
1,280	86	—	—	Keith
1,550	104	34	71	McCown and Keith
1,270	85	27	56	
1,070	73	—	—	Weinert
				Berckhemer
				Boule
1,075	74	29	60	Weidenreich
				Black
—	—	25·7	54	Schoetensack
917, 775	61, 52	—	—	Dubois, von Koenigswald and Weidenreich
—	—	25 5	53	von Koenigswald
450	30	38 8	81	Le Gros Clark and
to 600	to 40			Leakey, Broom
(350)	(25)	15·2	32	Le Gros Clark and Dart
400	27	3 2	6 7	Yerkes
				Schwultz
	△		⊡	

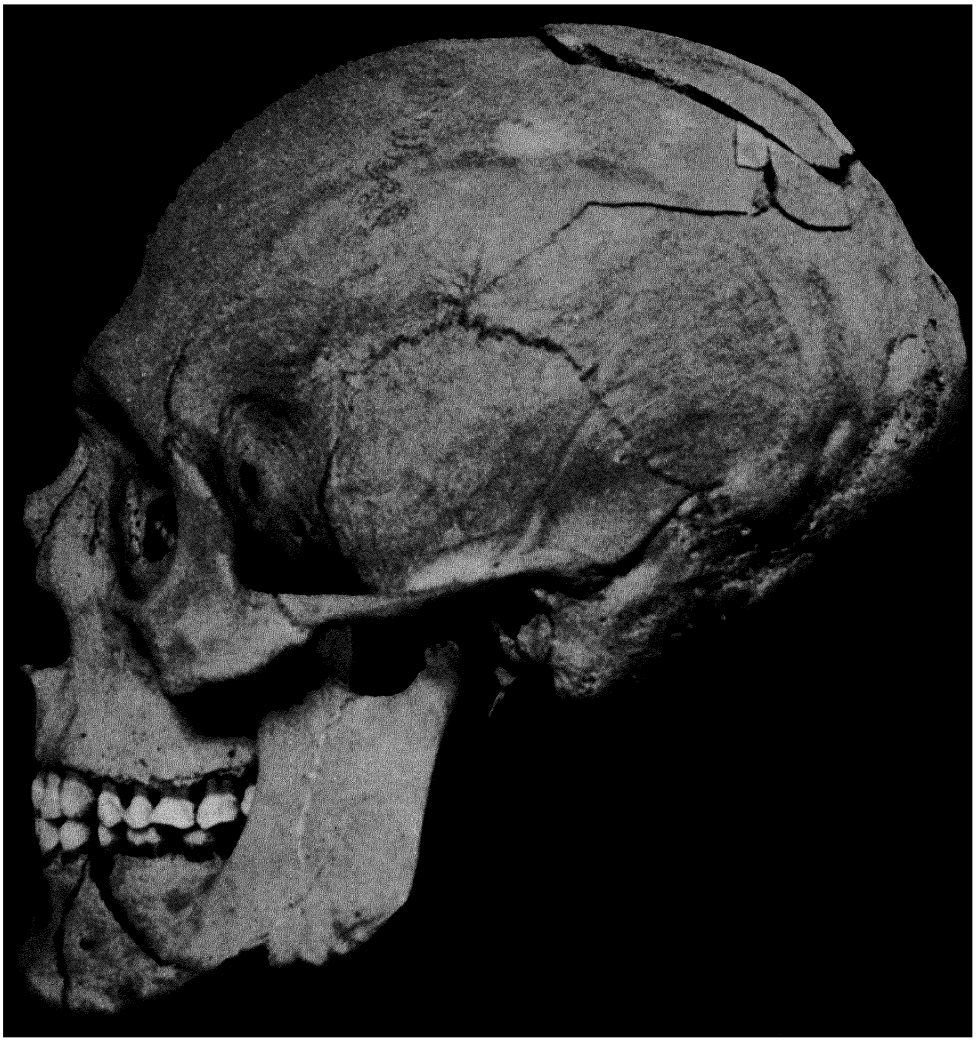


Fig. 27. Early Iron Age man from Glastonbury Lake Village, Somerset.

German invaders who had landed probably near Selsey and had crossed the River Test as they spread towards the north-west under pressure from Roman legions advancing from farther east. They constituted the second and last Belgic invasion of this country. (See also page 73.)

The skulls (Fig. 27) are quite modern in every respect and have been described by Dr. E. G. Bulleid and Mr. H. St. George Gray in their monograph.[1] The general form

[1] *The Glastonbury Lake Village*, The Glastonbury Antiquarian Soc., 1917

of the skulls, as seen from above, is long and oval. The measurements given in Table II were made on the skulls now in Glastonbury Museum and the values of the indices are all slightly less than for the modern Englishman. Cameron found the decrease in skull capacity to be a general feature with a large number of skulls of this period which he measured.

8. Summary

In this chapter consideration has been given to the available skeletal material and it was concluded that human skulls would be the most suitable and most plentiful material from which to determine some of the physical changes that have occurred in man's skeleton throughout the course of time.

It was realized that certain features distinguished men from apes and that the degree of "humanity" could be deduced from certain anatomical indices associated with the skull and lower jaw.

The particular features considered were erectness of posture, large brain and articulate speech. The state of development or "percentage humanity" was then deduced from the numerical values of four anatomical indices which all equalled one hundred for the modern adult male European.

Factors, other than the antiquity of the skull, which could affect the measurements and so lead to incorrect interpretations were considered. These factors are sex, age, race and morphological abnormalities.

Then follows brief descriptions of the skulls selected for measurement and an account of the methods of measurement which have been employed.

The use of photographs not taken specially for measurement purposes and the inability to measure original skulls in some cases means that the values of the indices given in Table II are only approximate. It is, however, believed that the errors are not such as to vitiate the general conclusions which can be made when the data are plotted against time.

The measurements of the four indices for twenty-three specimens, including the chimpanzee, are summarized in Table II. The order is chronological but the evidence for this will be considered later. (Chapter IV.)

In Table II the last column needs some amplification. The publications of the Authorities are those which contain information, data, photos or diagrams that have been used in obtaining the values of the indices in the preceding columns. Only in the case of the index I_3 (cranial capacity) are the figures taken directly from published texts. The indices I_1, I_2, and I_3 are relatively new; the first two being due to Professor Sir Wilfred Le Gros Clark. The index I_4 is one introduced as a useful method of recording numerically one of the characteristics of the lower (and upper) dental arcade which is believed to have taxonomic significance. As it is possible to measure this index in more than 50 per cent of skeletons, it was felt that it would be interesting to see if the figures (I_4) would lead to graphs and consequent conclusions comparable to those from the other three established indices.

CHAPTER III

Cultural Evidence

On page 15, when discussing the problem of how it might be possible to obtain a graphical or quantitative pictorial representation of man's cultural development, it was suggested that at least three criteria of culture could be assessed numerically and would therefore be suitable for the ordinates of a cultural development/time graph—time being the abscissae. These three criteria are: (1) the number of different materials utilized by man; (2) the number of different occupations with which man is engaged; and (3) the speed at which man can move by mechanical means.

A fourth method for obtaining a cultural development/time graph is to plot against time an arbitrary numerical cultural value which could be assigned to each of a series of datable artifacts—a cultural "grading" process depending on such factors as complexity of design and skill in production.

1. Some criteria of culture

When obtaining data for the ordinates of a physical development/time graph certain particular datable skulls were chosen which covered as effectively as possible the half to one million years during which man has been living and developing on the earth. This is not a suitable procedure when studying his cultural development because the cultural evidence associated with any one particular skeleton is seldom typical of all the many aspects of his culture. Even such a fragmentary skeleton as a broken skull may give sufficient evidence to enable the type of man to be determined. This is not the case with his cultural evidence. For example, whereas man's walking posture can be judged from a study of his pelvic bones, his ability to make clothes could not with certainty be deduced from the fact that he made bone needles. Only by the gradual accumulation of a knowledge of all the many associated links in the chain of evidence can an overall picture of man's cultural attainment be obtained. When, for example, it is known that at a given time man made bronze axes, woollen clothes, particular types of pottery, circular log huts, dug-out canoes, wooden push ploughs and so forth, only then can his cultural standard be fully visualized. The links in the chain are usually scattered and have to be collected from many different sites by the efforts of many excavators in different countries. Man's cultural status at a given time and in a given locality may often be known without any skeletal remains having been found. This is particularly the case with the oldest types of flint implements. The kind of men who made and used certain forms of primitive hand-axes are as yet unknown, whilst in a similar way the cultural attainments of the oldest types of men—the *Australopithecinae*—are still matters

of speculation. Consequently, the cultural data will be studied independently of the men who may ultimately be associated with them. However, when it is known that a particular cultural standard can definitely be attributed to any one of the types of men listed in Table II, then it will obviously be both of use and of interest to associate the two together. Such cross-linkages will usually be based on the fact that the particular culture and the given skeletons were found together. Discoveries of skeletons directly associated with some artifacts are not infrequent especially in post mid-Pleistocene times. A natural consequence of such direct associations is the possibility of superimposing the physical development/time and the cultural development/time graphs one upon the other. Such a process of comparison may well lead to possible associations of men and cultures which have not yet been proven by actual excavations. (See Chapter V sub-section 5.1.) The evidence concerning the time factor (the abscissae of our graphs) will be the main topic of discussion in Chapter IV.

For convenience the three cultural criteria will be denoted by C_1, C_2, and C_3 and the "grading" method will be C_4. Thus the criteria may be abbreviated to Materials C_1, Occupations C_2, Speed C_3 and Grading C_4. In the same way that the four anatomical indices I_1 to I_4 can give four independent physical development/time graphs, so the four cultural criteria can be plotted against time in years to give four cultural development/time graphs.

Before considering each of these criteria in detail, a superficial survey at once discloses certain distinctive differences between the preceding physical data and the present cultural data. It is easily appreciated that the variations of the anatomical indices during the last few thousand years of the Holocene period are very small. An examination of skulls of Bronze Age, Early Iron Age, the Romano-British period, Anglo-Saxon times and through the last 900 years of history reveals certain minor fluctuations in the indices I_1 to I_4, but they are not of such magnitude as to affect the general trend of the figures recorded in Table II. But when the cultural data are similarly considered, a marked difference is at once realized. Whereas the numbers representing criteria C_1 to C_3 will be relatively small up to the end of the Stone Ages about 2000 B.C. they will obviously increase considerably on passing into the metal ages and the increase will be even greater in historic times. In fact, the changes in the cultural values will, unlike the changes in the physical values, have to be considered in much greater detail as the period of time approaches the present day.

The four cultural criteria will now be examined in order to assign appropriate numbers to them. These numbers will then be the ordinates of the cultural development/time graphs.

2. The number of different materials utilized by man, C_1

Some consideration must here be given to the meaning of the phrase "different materials". For our purpose, it is not proposed to count, say, oak and beech as different materials. Nor is it possible to determine when either was first utilized by man; although from a knowledge of the climatic conditions at given times, it is possible to know when

oaks or beeches were growing. The general term "wood" will be used and counted as one material. On the other hand "bark" and "withies" will be counted as materials different from wood, because they were used and adapted for specific purposes for which wood in bulk was quite inappropriate and unsuitable. Similarly "skin" and "leather" will be considered as two materials, whilst "flint" and "quartz" would count as one, namely, "stone". This is justified as long as they were used for the same purpose. Slate and sometimes shale, on the other hand, could not be used as chopping tools like flint and quartz but were used as pot covers, roof tiles, etc. Slate and shale will therefore count as different materials from flint and quartz.

In order to determine the number of materials used by a given type of man or during a given period of time, it will be necessary to have a knowledge of the materials associated directly with a given skeleton or located *in situ* in a particular geological deposit of known date. Obviously the number of materials for which there is direct evidence will be limited to those which are sufficiently durable to have withstood the ravages of time. If cloth was used 200,000 years ago it is very unlikely that it can ever have been preserved. On the other hand, imperishable materials used in the manufacture of cloth should be found if cloth had been used in so remote a period. Thus if such accessory implements as loom weights, weaving combs, etc., are found, it will be fairly safe to assume that cloth was made. Difficulties of this kind must necessarily arise with perishable materials, and to this extent numbers of materials can only be approximate minima. However, in spite of this possible but not serious source of error, the small values of the criteria for the more remote periods and for the earlier types of men will be more accurate than the very large numbers that will have to be allotted to the materials and other criteria used in more recent times and by more modern men. It has already been pointed out on page 15 and is discussed in Chapter V that least absolute accuracy is required where the numbers are large—a fact that makes a graphical treatment practicable.

It will be obvious that attention will have to be restricted to one region or country at a time because of the different standards of cultural attainment that have been reached by different peoples in different localities. For example, any cultural development/time graph for the peoples of north-west Europe will be quite different from that for, say, the Australian native. For this reason the development of north-western European culture will be considered first. The graphs for other localities can then be compared with those for this particular region. This procedure is adopted because it is believed that the north-western European people have developed to a higher standard as measured by our criteria than the peoples of other regions.

When considering the number of different materials at the disposal of the prehistoric peoples of Europe, it is perhaps surprising to realize how very few materials were utilized as recently as three or four thousand years B.C. and even the most highly civilized folk of a few hundred years B.C. (Early Iron Age times) could only muster about a score of different substances which were at their disposal. It is therefore perhaps simplest to consider these Early Iron Age people first and then to see, if possible, when the different materials used by them were first introduced.

2.1 *Early Iron Age Materials*

Evidence for the standard of civilization or cultural status of Early Iron Age people can best be found from a study of their habitations, in particular their Lake Villages. Of these the pile dwellings of Switzerland and France, the crannogs (artificial mud and log islands) situated from Belgium and Germany to Scotland and Ireland and the intermediate type of crannog-huts at Glastonbury and Meare in Somerset are typical of the various forms of European Early Iron Age lake village settlements.

A brief description of the Glastonbury Lake Village will suffice to indicate the materials available to its inhabitants. Between eighty and ninety huts on built-up crannog-like floors covered a rough triangular area of about 8,500 square yards. The village was enclosed in a log palisade and had a wharf or landing stage near which was found a dug-out canoe about eighteen feet long. An artificial causeway connected the village to the landing stage and another causeway linked the village to higher ground in the vicinity. The contents of the huts indicated that they were occupied by families who specialized in different forms of industry, such as weaving, carpentry, baking, pottery making, etc. The presence of a bronze hand mirror, a dish of rouge and bronze tweezers in the annex of one hut is very suggestive of a ladies' boudoir, whilst the presence of four-sided dice and dice-box has other equally interesting implications. Specialized industries necessitate a form of currency and this was supplied by iron bars (currency bars) of specific denominations or weights. Iron agricultural implements (Fig. 28) such as bill-hooks, choppers, reaping-hooks, hoes, spades (wooden blades bound with iron), push ploughs were much more plentiful than iron spears, swords and daggers. The knowledge of metallurgy was indicated by crucibles, tongs, ladles, furnaces and bellows together with heaps of slag and metals such as tin, lead, copper and iron.

Hand-made pottery food vessels (Fig. 29), looms, shuttles, combs and spindle whorls, lathe-turned wooden bowls together with axes, hammers, pull-saws, adzes, gouges and chisels all indicated a highly civilized community of peaceful farmers. Glass beads, bronze, amber and jet ornaments, dress pins (fibulae), pennanular brooches, buckles, bracelets and finger rings (Fig. 30) are decorative artifacts indicative of the tastes of the womenfolk of the village. Wheels, axles and horse harness suggest that carts and probably chariots were used as means of transport on the higher lands bordering the marshes.

The end came after probably 200 years or more of peaceful existence. The Roman advance on the Continent drove Belgic tribes across to Kent at the end of the last century B.C. Other Belgic invaders landed on the south coast towards the middle of the first century A.D. It seems probable that these invaders, who advanced at least as far as Gloucestershire, were responsible for the raiding of Glastonbury Lake Village somewhere between A.D. 30 and 50.

The village was sacked and burnt. The defenders were slain with the sword as is evidenced by the head wounds in the skulls of men found both inside and outside the palisade. The precise circumstances leading to the sacking of the Lake Village may never be known. The absence of skeletons, except skulls, and the fact that the sword cut on the skull shown in Figure 27 is also accompanied by a fracture which may well have

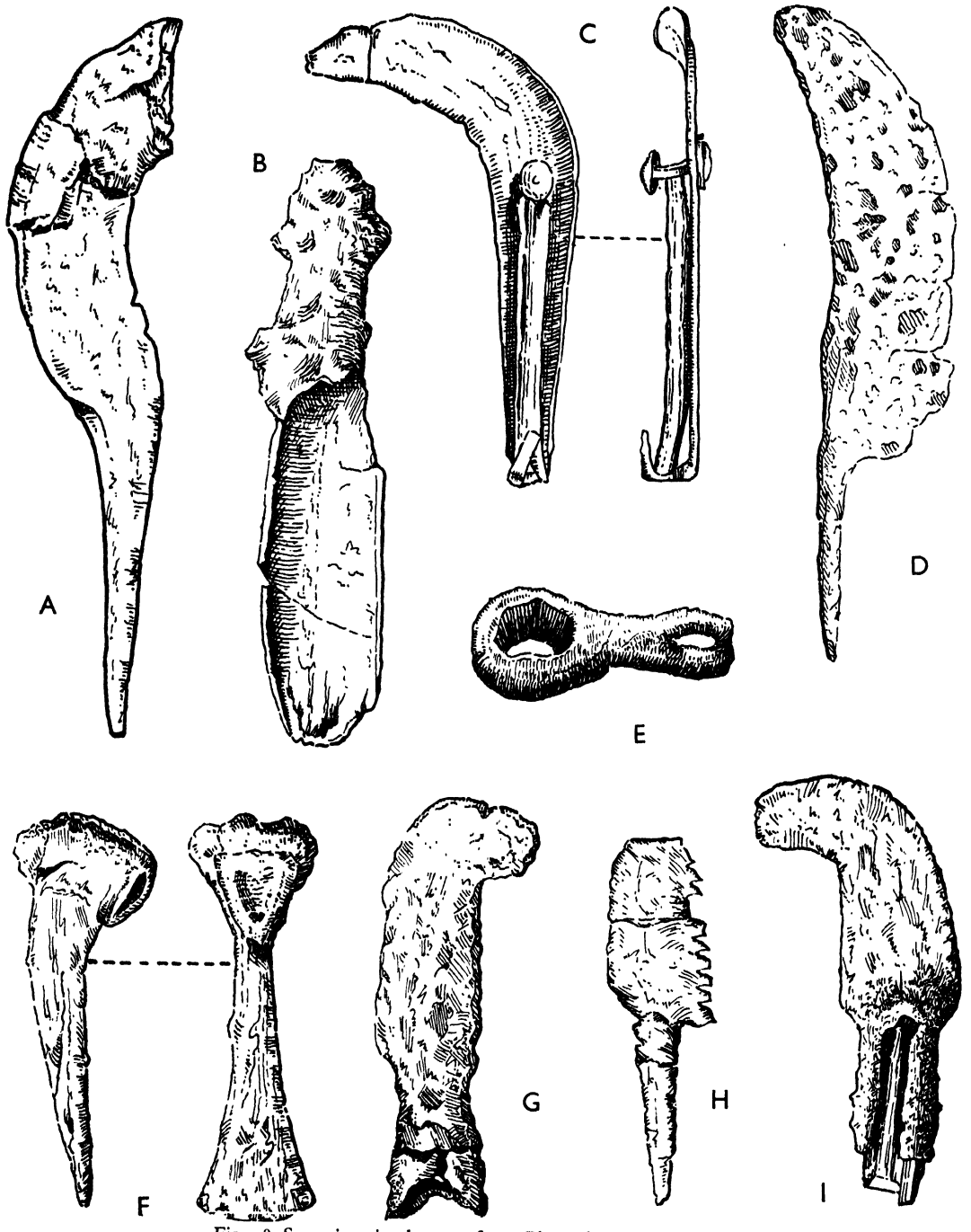


Fig. 28. Some iron implements from Glastonbury Lake Village.



Fig. 29. Typical pottery from Glastonbury Lake Village.

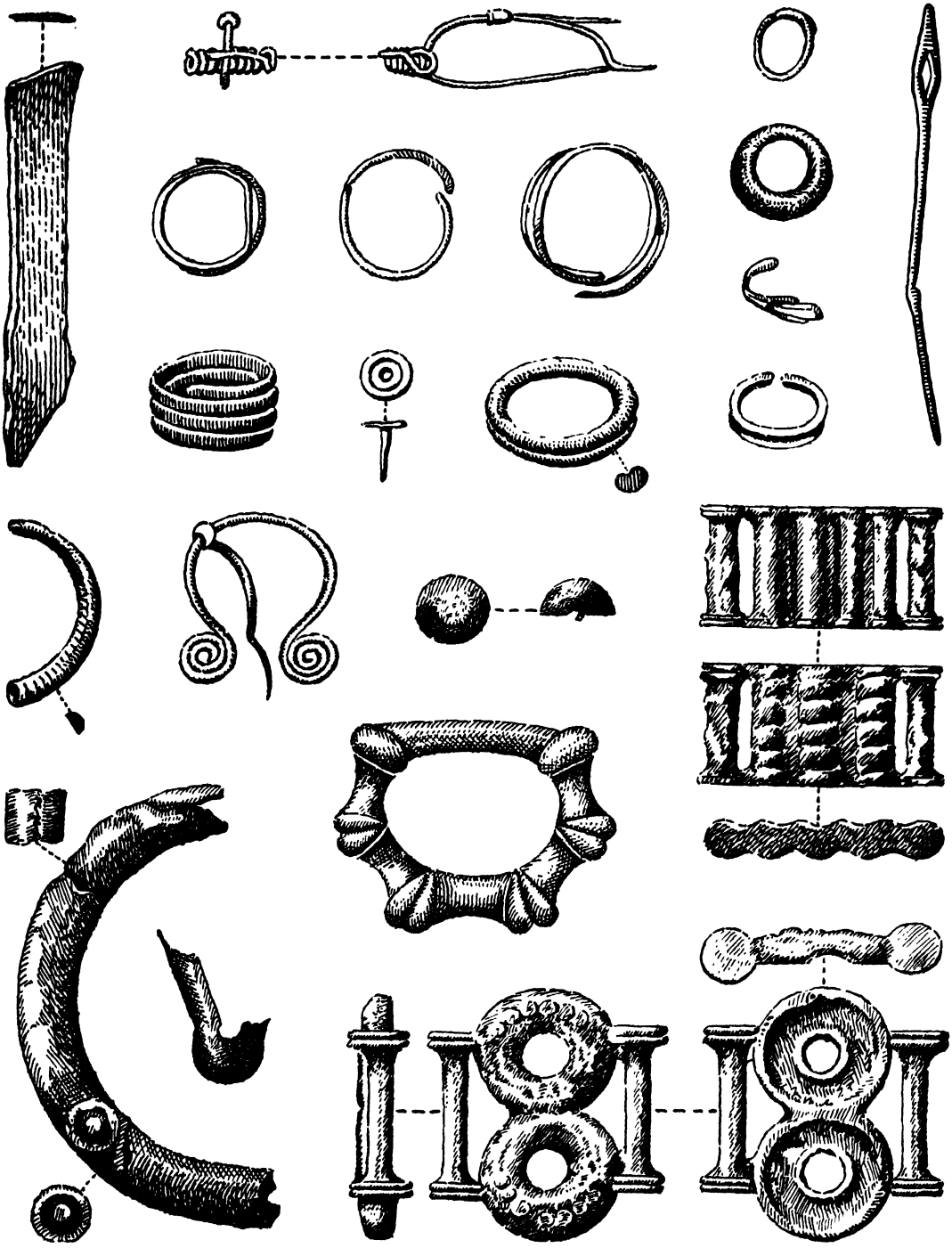


Fig. 30. Bronze ornaments from Glastonbury Lake Village.

been produced by sticking the decapitated head on a spike, tends to suggest that the skull belonged to one of the attackers whose head was stuck on the palisading as a warning to others. Before the attack many women and children fled to the Mendip Hill and took refuge in a large rock-shelter under Dolbury Hill near Burrington. Some time later the overhanging rock fell and sealed up these Glastonbury refugees before the Romans themselves inhabited the district. This rock-shelter was opened up and excavated in 1919–24 and the last tragic episode in the life of the Glastonbury Lake Villagers was revealed. Here were found quantities of domestic pottery, implements, bronze ornaments, etc., characteristic of the Glastonbury culture. Unique iron slave shackles (Fig. 31) and four decorative bronze hub-bands from chariot wheels added further details to our knowledge of these peoples. The picture of their economic and social life is fairly complete thanks to the thorough and patient work of Dr. Bulleid and Mr. St. George Gray at

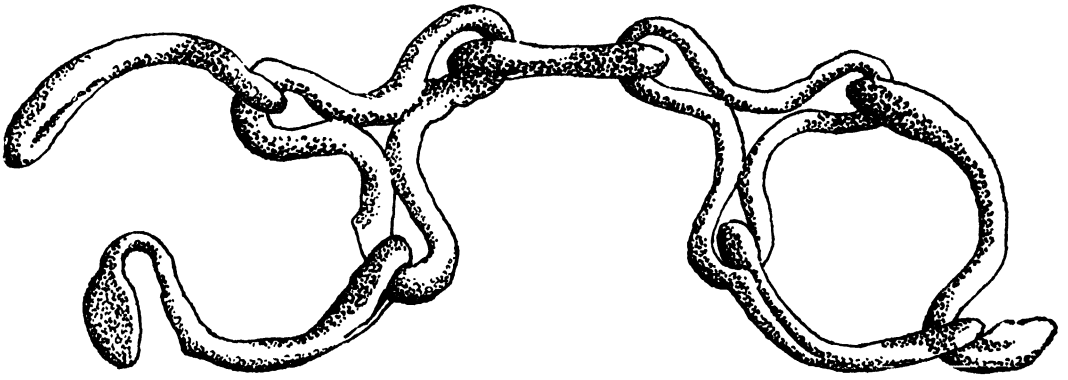


Fig. 31. Iron slave shackles from Read's Cavern, Somerset.

Glastonbury from 1892 to 1907 and to the work of the University of Bristol Spelaeological Society at the cave now known as Read's Cavern under Dolbury Hill.

We are now in the position to review the materials that have been discovered. Not all have been mentioned in the above brief account but the following list is based on the detailed monographs which have been published on the village. There are nineteen materials as follows:

Stone (flint), shale, bone, horn, wood (hafts, wheels, bowls, ladders, looms, canoes, lathes, etc.), withies (basketry and hurdles), skins, leather, wool, flax, pottery, glass, colouring matter, amber, jet, bronze, iron, lead and tin. To these from other Early Iron Age sites must be added shells, enamel, ivory, silver, gold, bark, wax and glue making a total of twenty-seven materials which have been utilized for different specific purposes during the Early Iron Age extending from about 500 B.C. (on the Continent) to the Roman era. Only one of these twenty-seven materials (namely glue) is strictly a synthetic material; the others were used either in the form in which they were obtained or were processed to meet specific requirements. Examples of processed materials are leather, wool, pottery, glass, enamel and metals. It is fairly certain that by this time bronze was processed and the proportions of copper and tin deliberately controlled.

The particular period during which Glastonbury Lake Village flourished was from about 150 B.C. to A.D. 40.[1] and the culture is usually called Iron Age B or "La Tène" (meaning "the shallow place") after the classic site at the northern end of Lake Neuchâtel in Switzerland. The earlier iron-age culture (from 1000 to 500 B.C. in Europe) is called Iron Age A or "Hallstatt" from the place of this name about thirty-five miles from Salsburg where a rich variety of grave-goods including pottery, weapons, ornaments, etc., was discovered. Iron Age C covers the most recent culture, namely that of the Belgic tribes who imported much Arretine (Italian) ware, introduced the potter's wheel and minted coins immediately prior to the Roman occupation of southern Britain. This cultural phase reached its zenith about A.D. 10 to 20 but no new materials were introduced.

Thus only just over two dozen different materials were available to the most recent of prehistoric peoples.

We now are in possession of information for one point on the Materials/Time graph, namely the number 27 as ordinate corresponding to an abscissa value extending from 500 B.C. to A.D. 50 or to an approximate mean value of 250 years B.C. or 2200 years B.P.

2.2 *Early Palaeolithic Materials*

To obtain other ordinates it is necessary to seek evidence for the first appearance of these two dozen materials. It is certain that stone (Fig. 32) was used at least as early as any other material and, because it is relatively imperishable, stone implements have even out-lasted the skeletons of the men who made them. This cannot be said with certainty of any other material, so that the number 1 is an ordinate corresponding to an abscissa value of the order of 500,000 years and more. Probably the earliest recognizable implement (the eolith) dates back to a million years but the geological evidence for this date is not conclusive, neither is the "humanity" of many so-called eoliths.

The earliest man directly associated with crude stone or pebble implements (Fig. 32A) is the *Pithecanthropus erectus* from the Trinil beds of Java. This enables us to place the fabrication of stone at least as early as 400,000 years ago. The pebble choppers of Africa (Kafuan) are not directly associated with any particular type of man.

Worked bone was not found in the older beds at Java. The earliest evidence for worked bone is from the Mauer sands from which the Heidelberg jaw came. These deposits date back to the Mindel-Riss interglacial period of some 350,000 years ago. (See Chapter IV.) Animal jaws and pieces of antler were also used by Pekin man 100,000 years later.

Although there is naturally no direct evidence that wood was shaped and used by man as early as 350,000 years ago, yet it is highly probable that he used sharpened sticks as soon as he was capable of sharpening them with a stone chopper. The pebble cleaver or chopper implements of Africa and Java could have been used for this purpose as effectively as they could be used for cutting up meat or skinning an animal.

[1] It has been suggested recently that the Glastonbury Lake Village was occupied only for a relatively short time extending from about 60 B.C. to A.D. 50; but there is evidence at Wookey Hole and at Worlebury Camp (Weston-super-Mare) that the La Tène or Iron Age B culture existed in Somerset for at least 200 years. We are not here concerned with the precise period when Glastonbury Lake Village flourished but with the more general problem of the duration of the Early Iron Age in Europe.

Charcoal layers and charred bones associated with Pekin man at Choukoutien suggest that fire was controlled in China as long ago as 250,000 years (Chapter IV). In warm climates fire is usually generated by primitive peoples by using a hard wood hand twist drill (as in Australia) or by rubbing a hard wooden stick in a long groove cut in another piece of wood, but in colder climates (as at Taubach in Germany during the last ice age) flint and iron pyrites were collected together and fire made with tinder and spark. There is no evidence of the latter method in Choukoutien. The climate, as judged from the associated fauna, was warm; the time being towards the end of the main interglacial period—the Mindel-Riss. Hence it is probable that Pekin man made fire by using some

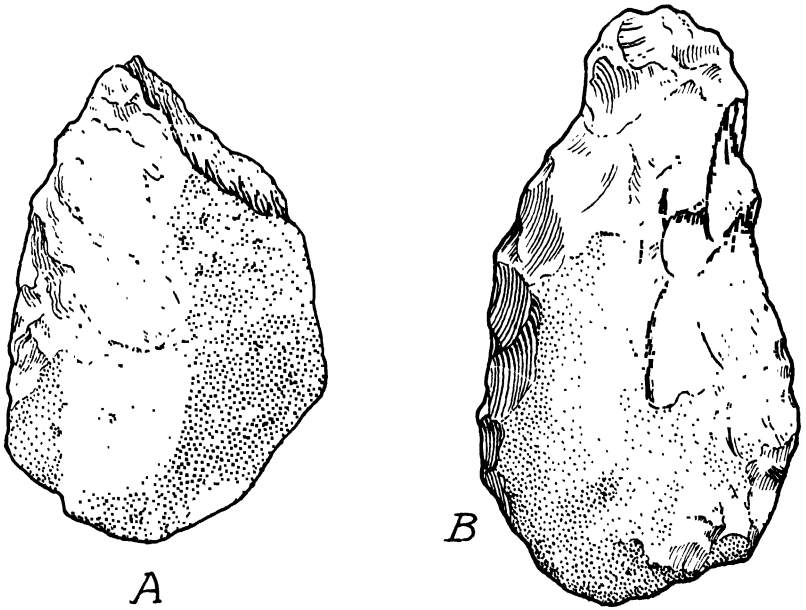


Fig. 32. Early Palaeolithic pebble cleaver and flint hand-axe (Oldowan or Pre-Chellian and Acheulian).

form of wood drill. If this indirect evidence is acceptable, then the charred remains at Choukoutien indicate that wood was used and drills were fabricated 250,000 years ago. Professor Dart thought that one of the Australopithecinae used fire and consequently named him *Australopithecus prometheus* but the evidence for this is somewhat uncertain. Neanderthal man from Steinheim is also associated with charcoal hearths as well as with stone implements but his remains are considered to be more recent than those from Choukoutien, although still in the Mindel-Riss interglacial period.

Less indirect but much more recent evidence for the use of fabricated wood is provided from the Skhūl cave at Mount Carmel. There was a severe hip-wound in the Skhūl V skeleton. This wound was not made with a stone or metal weapon but with some sharp perishable material such as hardened wood. The hole in the broken femur and pelvis had become fossilized as the decaying head of a broken-off spear was gradually

replaced with stalagmite. It seems therefore highly probable that wooden spears were used at least 150,000 years ago.

For these remote periods there is no definite evidence for the use of any other materials by man. The cultural evidence considered so far may therefore be summarized as follows:

1. Stone was definitely worked and used by the Java man from the Trinil Beds—*Pithecanthropus erectus*—400,000 years B.P.
2. Stone and bone were worked and used by Heidelberg man—*Homo heidelbergensis*. The evidence is direct for bone but only indirect for stone. Stone implements are known from contemporary deposits—350,000 B.P.
3. Stone, bone and wood were worked and used by Pekin man from Choukoutien —*Pithecanthropus pekinensis*—250,000 B.P. Here the evidence for wood is deduced from his use of fire. More direct evidence for the use of wood comes from the wounded Palestinian man from Mount Carmel—*Homo neanderthalensis* (Skhūl)—150,000 B.P.

Thus cultural evidence for man's use of materials indicates that the values of the criterion C_1 are 1, 2, and 3 respectively for the times 400,000; 350,000 and 250,000 to 150,000 B.P.

The evidence for the dates is given in Chapter IV, but by anticipating the figures here the nature of the early part of the C_1 or number of materials/time graph can be appreciated.

From the foregoing discussion it appears that twenty-four new materials were brought into use by those who followed the early Neanderthal men of Steinheim and Palestine.

2.3 *Middle Palaeolithic Materials*

The first of these men were the classical Neanderthal men of Africa (Rhodesia), Java (Solo River) and Europe (Chapelle aux Saints and others), all of whom were more or less contemporary with the last cold period—the Würm glaciation—of about 100,000 to 75,000 years ago. There is no definite cultural evidence associated with *Homo rhodesiensis* although stone implements were found in the Broken Hill cave into which Rhodesian man had probably fallen. With Solo man stone weapons and tools fashioned from bone and antler were found. Their bone harpoons simulated the spines of the ray-fish which they collected. A bolas stone (see page 45) has also been associated with the Solo River men. There is much more evidence of Neanderthal man's cultural standard to be obtained from the many skeletons which have been found in Europe and from deposits which are known to be contemporary with the Würm glaciation. This evidence must now be considered.

We have already seen that there were two different types of Neanderthal men: the earlier had relatively large heads, walked erect and had less receding foreheads than the later "classical" forms. The later men were more highly specialized along the lines which must have been followed by the apes than in the direction which ultimately led to the neanthropoids (new men) of post-glacial times. This statement will be considered later when the anatomical indices/time graphs are discussed (Chapter V). Both types were

found together at Mount Carmel and at Krapina in Croatia where they lived towards the end of the last interglacial period. Then at the beginning of the last cold phase (the Würm) the paedomorphic form seems to have disappeared from Europe whilst the gerontomorphic form persisted through the last ice epoch only to become extinct in Europe as the climate began to ameliorate. Coincident with this disappearance of the classical Neanderthal men there was the appearance of Cro-Magnon man and other new modern types. These newcomers are usually supposed to have followed the retreating ice from the south-east or south. It is tempting to suggest that these modern immigrants represent merely the reappearance of the paedomorphic Neanderthaloids after a period

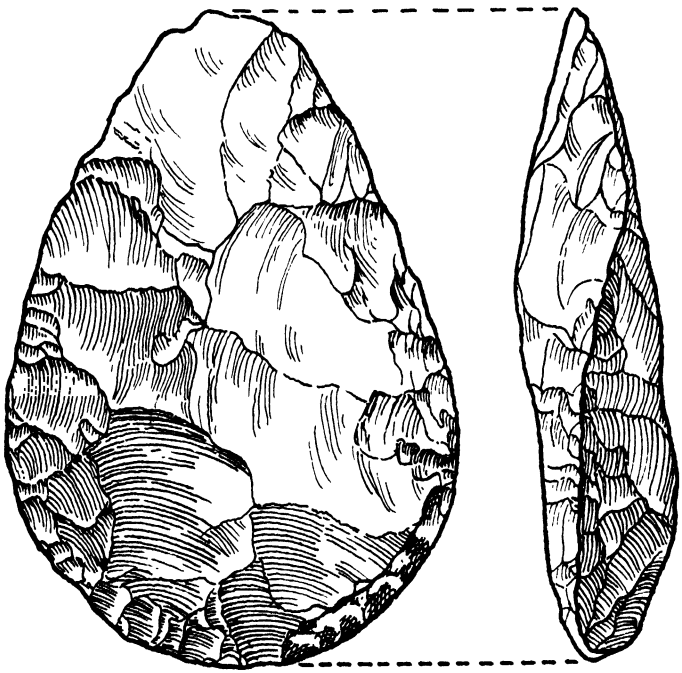


Fig. 33. A twisted ovate flint implement (Mid-Acheulian).

of development in Africa during the Gamblian pluvial period which coincided roughly with the Würm glaciation in Europe.

That such a migration from and return to Europe may have occurred immediately before and after the Würm glaciations is supported by evidence for a similar but reverse movement of peoples before and after the Mindel-Riss Interglacial period. Leakey[1] has pointed out that the stone hand-axe culture (known as Mid-Acheulian) in Europe during the Mindel-Riss interglacial was derived from or imported by men from Africa advancing with the retreating ice as the Mindel glaciation ameliorated. Then later, the stone culture involving the so-called "twisted-ovate" implement (Fig. 33) with a cutting edge all round was brought into Africa by people who retreated from Europe with the advancing

[1] *Adam's Ancestors*, p. 77

cold of the on-coming Riss glaciation. Whether the new modern men arriving in Europe after the passing of the Würm ice were or were not descended from the paedomorphic Neanderthalers must be left until further evidence becomes available.

Skeletal remains of the classical or gerontomorphic Neanderthal men who remained in Europe during the Würm glaciations have been found dispersed over a wide area which includes Belgium, France, Germany, Spain, Portugal, Italy, Czechoslovakia (Moravia), Gibraltar and Jugoslavia (Croatia). All together parts of over seventy skeletons have been discovered. The cultural status of these people can be established with some detail. It was influenced by the rigorous climate of the time. The cold temperature stimulated them to invent new techniques and to bring into use new materials. Most of the evidence comes from the caves and rock shelters in which whole families lived and

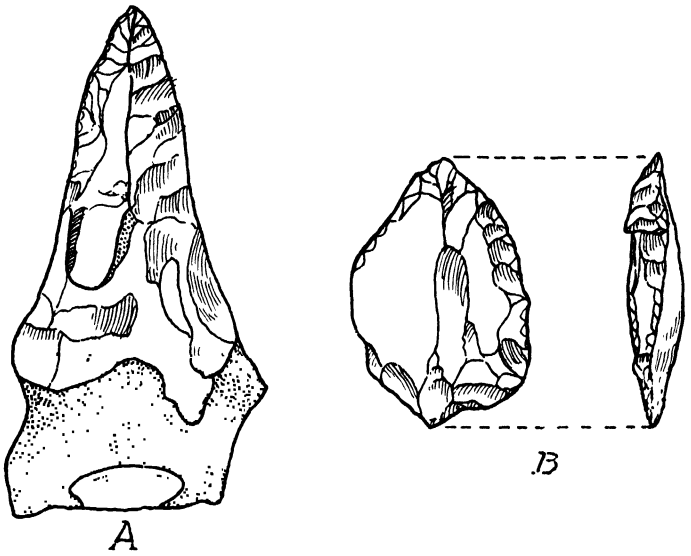


Fig. 34. Mid-Palaeolithic hand-axe and side scraper (Late Acheulian and Mousterian).

from which they made their hunting raids and food gathering expeditions. Probably the former were carried out by the men and the latter by the women folk.

From the great variety of their stone (flint) implements (e.g. Fig. 34) it is clear that they carried out more specialized tasks than was possible with the ubiquitous stone hand-axe; the main weapon-cum-implement of the preceding 300,000 years. In particular Neanderthal man developed a technique for making side scrapers (Fig. 34B) from flint flakes. This was a new process compared with the trimmed blocks of flint which formed the basic material from which hand-axes were shaped. There is little doubt that this new side scraper was used for cleaning the flesh from skins in order to make skin clothes to help withstand the rigours of the climate. Pointed flaked implements were also common together with hand-axes and large thin triangular implements obviously to be hafted and used as spearheads. End scrapers were also present but less common.

The whole flint industry is called "Mousterian" after the rock shelter of that name in the Dordogne district of France where the industry was first identified.

In addition to worked flint, Neanderthal man made limestone balls which were too big for use as sling stones. These were found mainly at La Quina in the Charente district of France. They were of different sizes. Two large and one small stone ball when connected together with long leather thongs form a bolas as used by the Patagonians today. The Eskimo tribes use bolases with six or seven thongs for catching birds on the wing. Similar roughly shaped spherical stones have been found in Kenya, East Africa, sometimes in groups of three. Other stone balls have been found in Portugal and with the Solo men from Java. Their method of use is fairly obvious. With three balls the smallest ball or the centre knot of three thongs is held in the hand and the balls whirled round and round at high speed. When released so as to fly in the direction of an animal, they entangle the legs and effectively bring the animal to the ground so that it can be overtaken and despatched with other weapons. The bolas stones (if such they be) at La Quina are the earliest occurrence of this weapon in Europe and add a new material (limestone) to those already fashioned and utilized by man. Limestone is not suitable for making pointed or flaked implements in the way that flint and quartz can be used and therefore, like the shale lid of a clay pot, limestone must be classed as a new material now at man's disposal.

On some sites where Neanderthal man made his flint implements cut bones have been found. They were mainly the foot bones of bison and horses. The metatarsal and metacarpal bones (the longest foot and hand bones nearest to the ankle and wrist respectively) were apparently used as cylindrical hammers in the manner described by Leakey and the first phalanges (the longest bones of the toes and fingers) were used as anvils.

At Taubach in Germany the heaps of broken flint and iron pyrites collected together with the ashes of hearths leaves little doubt that Neanderthal man made and controlled fire to add to his comfort and warmth. The charred skull of a mammoth with the holes plugged with clay and containing the remains of cooked food is evidence of some culinary proficiency to which can be added the use of human skulls as food vessels and drinking cups.

Although there is no evidence that Neanderthal man ever made pottery, Dr. R. R. Marett did find at St. Brelade Cave in Jersey pieces of curved burnt clay which may or may not have indicated an attempt to simulate the curved and cracked "saucers" of sun-baked mud often seen on the edges of tidal rivers at low tide. The geological evidence is not sufficient to associate those pieces of burnt clay with the Neanderthal horizon in the cave. Consequently even the crudest of pottery cannot be credited to Neanderthal man. A further reason against this possibility is the fact that there is evidence to indicate that pottery was evolved from skins held by four corners and lined with soft unburnt clay.

Another point of interest relative to Neanderthal man's cultural status is the fact that in many instances his body was deliberately buried. Reference has already been made to this in the case of the remains from La Chapelle aux Saints (page 54). The expectation of a life after death or of a journey to the next world first arises with these degenerate

(specialized) ape-like men whose physical appearance would therefore seem to belie their cultural and spiritual attainments.

Whether they became extinct because of their physical specialization and consequent less adaptability to environmental changes or whether they were exterminated by faster and more effectively armed neanthropic invaders is a matter of interesting speculation. A third possibility that they interbred with the Cro-Magnon and similar types was suggested by Hooton who said, "When Cro-Magnon met Neanderthal, one or the other may occasionally have bled but I think that they surely bred."

Yet another and fourth possibility is that Neanderthal men moved eastwards and southwards and so contributed to certain peculiarities recently recognized in Mongolian peoples (see page 152). This hypothesis receives support from the forward extrapolation of the graphs in Figure 53, where the idea is again discussed.

This brief survey of some details of the life of Neanderthal man enables a list of the materials at his disposal to be made. They amount to only seven, namely: flint or quartz, limestone, bone, wood, skins, pyrites and vegetable fibre or animal sinew thongs.

Thus the next point on our C_1 graph is the ordinate 7 corresponding to a mean abscissa value of about 90,000 years B.P.

2.4 *Late Palaeolithic Materials*

With the passing of the Würm glaciation some 30,000 years ago and the advent of neanthropic man in Europe, the cultural ordinate might be expected to increase more rapidly towards the number 27 which corresponds to an abscissa value of 250 B.C. or nearly zero (B.C./A.D.). In fact although the new men had much greater skill in making flint implements and probably introduced the bow and arrow, the spear thrower, the throwing stick, fish harpoons (Fig. 36), etc., yet the materials involved were still stone, bone and horn (antlers), wood and grass or sinew rope or string.

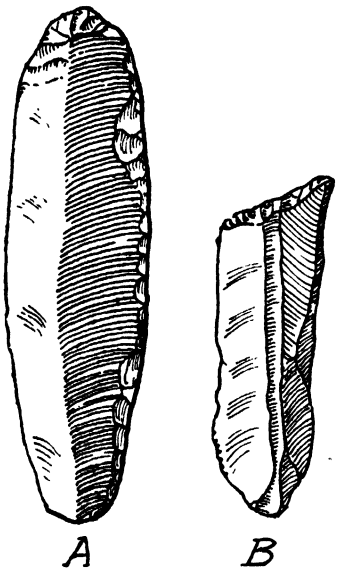


Fig. 35. Late Palaeolithic scraper and awl (Aurignacian).

Their flint culture (Fig. 35) is named Aurignacian from the type station at Aurignac forty miles from Toulouse where seventeen skeletons were ceremonially buried. The site has now been quarried away. The later cultures are known as Solutrian, Magdalenian, Azilian, etc. (Fig. 36), from various sites where specific types of implements were first discovered. It is not, however, our present purpose to study the typology of flint implements, but merely to consider materials.

Throughout this period cave-art flourished in the form of engraved, painted or modelled animals. The earliest were simple but life-like line engravings on rock or on bone. Colours, chiefly brownish red and black, followed a few thousand years later and at the height of the art in

Magdalenian times (*c.* 20,000 B.P.) white and yellow colours were also introduced. Stone lamps, some containing traces of fat, have been found in the French caves. The brownish-red colours were produced from iron ores, the black from carbon and pyrolusite (MnO_2), the white from kaolin and the yellow (and also red) from ochre. Besides representations of contemporary animals such as the mammoth, rhinoceros, reindeer, ibex, bear, horse, bison, wolf, lion, etc., there were paintings of what might well be huts together with magic symbols and ritualistic impressions of hands with amputated fingers and "medicine men" dressed in masks with antler head-dresses and tails.

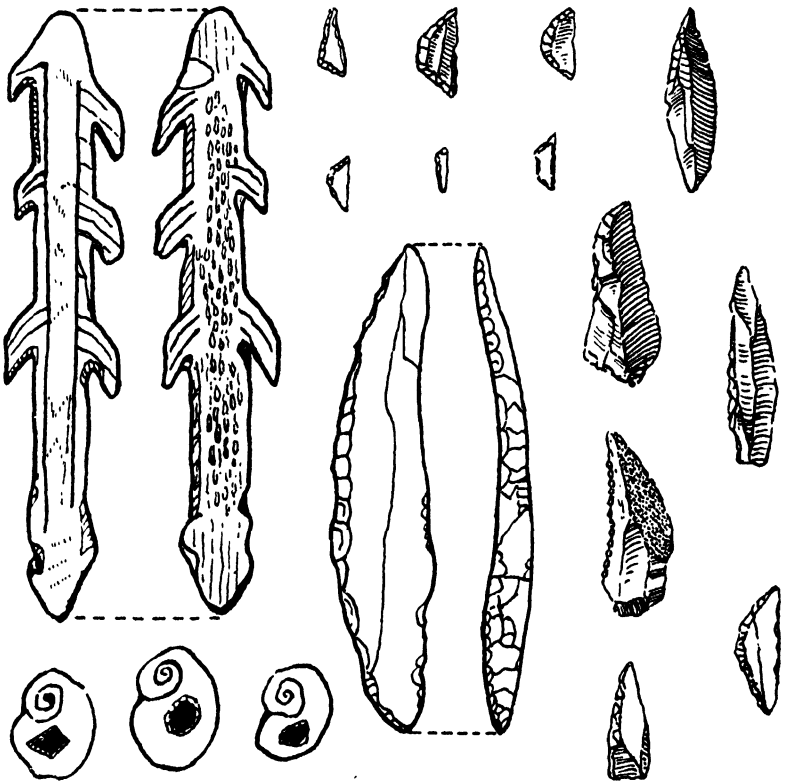


Fig. 36. Transitional harpoon, bored shells, flint blades and microliths (Magdalenian and Mesolithic).

That these people used shells is evident from the perforated shells buried with the Combe Capelle skeleton (50,000 B.P.) and onwards to the skeletons in Aveline's Hole (10,000 B.P.) where pierced shells (Fig. 36) and teeth were used as necklaces. The teeth were usually the canines of pigs or wolves.

It is interesting to realize that such a practice and also the use of spear throwers and throwing sticks persisted in Papua and Australia until modern times. Was this the result of divergent migration from a central location like that possibly undertaken by Neanderthal man at the close of the Ice Age?

Further evidence of the culture of these times is to be found from a study of the Moravian mammoth hunters, the Predmost men. These men left behind in the loess deposits round Predmost and Vestonice not only many of their own skeletons and piles of sorted mammoth bones but literally thousands of relics of their culture. These varied from flint weapons, bone ornaments, toilet outfits, needle cases, spoons, pigments, palettes, ivory carvings of animals to sculptured and moulded clay figures of women. The wonderful pre-war collection at Brunn from the excavations by Karl Absolon seem now to have disappeared or to have been destroyed. A human skull trimmed and used as a drinking cup and a wolf's skull conveniently adapted as a lamp were among the interesting relics of these people.

Even as recent as 10,000 B.P., the remains from Aveline's Hole and Cheddar Cave in the Mendip Hills add no more to the list of materials used throughout this late Palaeolithic period.

Thus the total count for the end of the old stone age is only 10 namely—flint, limestone, bone, antler, ivory, skin, sinew throngs, wood, pigments, and shells. This groups together all the pigments. By separating them into red and black for Aurignacian times and into red, black, yellow and white for the Magdalenian period the numbers become 11 and 13 respectively. But this distinction has not been made when considering the many pigments used in Early Iron Age enamels. The number 10 will therefore be taken as the ordinate value throughout this late Palaeolithic period with a mean abscissa of about 30,000 years B.P.

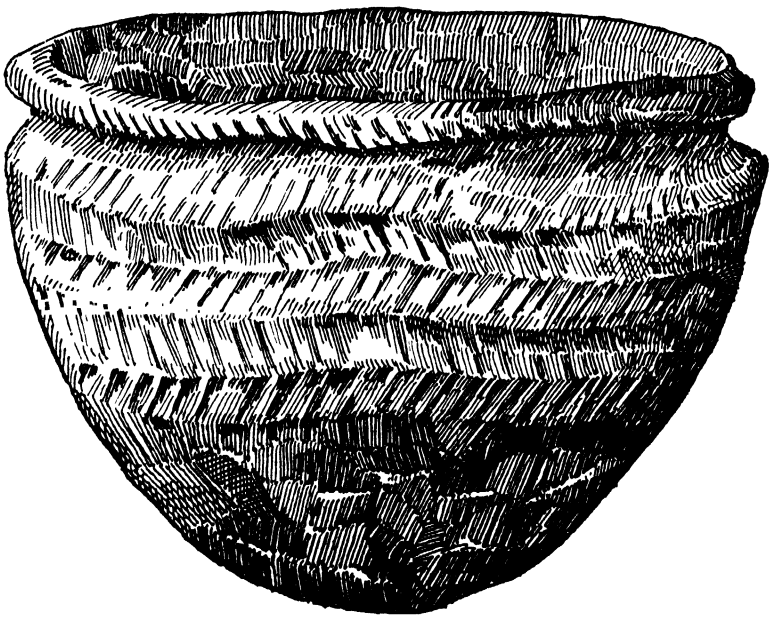


Fig. 37. Neolithic B round-bottom pottery bowl (Peterborough type).

2.5 *Mesolithic and Neolithic Materials*

Very little is known about Mesolithic life and times in this country (8000 to 2500 B.C.). A few fish-harpoons (with barbs along one edge) have been found from time to time—mainly in East Yorkshire. Recently a settlement or living site was excavated at Star Carr Plantation near Seamer (Scarborough) to which reference is made below. It is surprising so little is known about so relatively recent a period. More is known about the Neolithic invaders of about 2500 B.C.

New stone age times are characterized by the invention of pottery (Figs. 37 and 52) and the use of hafted chipped and polished stone axes (Celts) (Fig. 38). The standard of living was much advanced compared with that of the most recent of the old stone age peoples. The dog had become domesticated; covered trench and pit houses and early lake dwellings indicate a more static existence compared with the earlier hunting folk who had to follow the animals (particularly the reindeer and horse) upon which they lived. The walled and gated enclosure surrounding twenty-four circular stone-walled huts at Grimspound on Dartmoor is probably one of the best Neolithic villages to be seen in this country. A similar village has been excavated and preserved in Anglesea. An isolated trench dwelling was discovered in Holderness and the remains of a dog together with some crude bone implements indicated a habitation of early Neolithic date. Similar bone implements were found in an early crannog site near Ulrome also in Holderness.



Fig. 38. Neolithic chipped and polished stone axes.

Neolithic man had become a herdsman which he could not have done were it not for the domestic dog. There is evidence that he made leather from cow-skins long before he made fabrics from sheep's wool. His main object in keeping herds of cattle and flocks of sheep and also pigs and goats was to use the animals for food instead of hunting for it.

The feeding of his cattle in winter must have become a serious problem when pasture was limited to the areas around his habitations. The solution came when he commenced farming and cultivated crops. It is uncertain when the horse[1] was first made to work for man in this country but probably not in Neolithic times. Consequently turning the soil would have been undertaken with spades made from the shoulder blades of oxen. Remains of antler picks and wooden push ploughs have also been found on Neolithic sites. His crops, reaped with flint sickles, consisted mainly of wheat, some barley and possibly flax. He was particularly skilled in hafting his flint knives, arrow and spear heads and stone axes. Remains of hafting sinews and bone glue have been preserved in peat beds and there is little doubt that the string and glue methods still used by modern primitive peoples in Australia were also employed by Neolithic man. There is no definite evidence of Neolithic date to show that he made baskets, trays, bags, etc. But the recent

[1] Some Late Palaeolithic cave paintings of horses look as though they had some form of head harness or halter.

discovery of a Maglemosian[1] settlement near Scarborough with rolls of birch bark, deer antler harpoons, knives, etc., indicates a birch bark industry similar to that practised in Finland today. That this use of bark preceded the Neolithic invasions of this country is certain but whether or not the industry continued into Neolithic times or was adopted by Neolithic people is doubtful. However birch bark must certainly be included as a material used for very specific purposes in Mesolithic times. In point of fact pine, oak and hazel were more common in England than birch by the time Neolithic tribes reached this country which was not before 3000 B.C. (See Fig. 50.) Other characteristic relics of Neolithic peoples are their hill forts or camps, their long chambered tumuli, their megalithic monuments and cromlechs including the earliest phases of Stonehenge. Finally, the introduction of hand-moulded round-bottomed pottery bowls is perhaps (along with the polishing of stone celts) their most outstanding achievement from a technical standpoint.

We may now conclude from the story of Maglemose (Mesolithic) and Neolithic man the fact that a very great advance in culture and an enormous increase in the standard of living was accomplished with comparatively few more materials than those available to Late Palaeolithic men.

The materials that by about 2000 B.C. were available to man were therefore: flint, shale, bone, horn, ivory, skin, leather, wood, bark, withies, pigments, pottery, shells and glue—a total of 14 or only 40 per cent more than were used by Late Palaeolithic man.

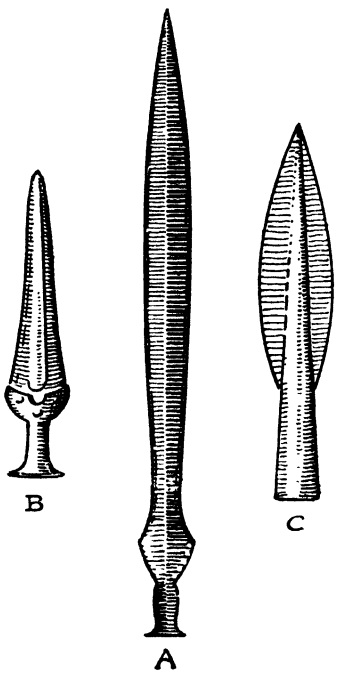


Fig. 39. Bronze sword, dagger and spearhead.

2.6 *Bronze Age Materials*

Bronze was used in Mesopotamia and Egypt when this country was still in the Neolithic stage of civilization (Fig. 55). But by about 2000 to 1800 B.C. invaders came to Britain by sea armed with bronze swords, daggers, palstaves, spears and axes. (Figs. 39 and 51.) With them came two other cultural improvements—the art of spinning and weaving and the knowledge of elementary metallurgy.

In a Yorkshire bronze-age tumulus were found traces of a linen shroud. Pieces of woollen fabrics have been found in other burials of this time. In the peat bogs of Denmark whole garments have been preserved and the nature of the tailoring and workmanship can be readily seen. Restorations and originals are well depicted by Shetelig and Falk in their book *Scandinavian Archaeology*.

Although shale cups and jet ornaments were turned on some form of lathe, pottery was still hand-made but much improved in variety and decoration. Bronze objects included weapons (e.g. daggers, palstaves and swords), personal ornaments, such as bracelets, finger rings,

[1] Called after Maglemose or "The Great Bog"—Zealand, Denmark.

brooches, etc., and large curved and flared horns or luren.[1] Horse trappings and solid wheels (Fig. 42) mark the beginning of horse-drawn vehicles none of which have been preserved intact in this country. Open-fronted chariots used for mobile infantry are described by Julius Caesar, but these were of Early Iron-Age date. No doubt two-wheeled carts and four-wheeled wagons were in use before Early Iron Age times but the exact time of their introduction during the Bronze Age is uncertain in this country. Perhaps the two ceremonial four-wheeled wagons from Dejbjœrg, Jutland, are the finest Bronze Age vehicles known. Reconstruction was fortunately possible from the broken pieces preserved in the bog into which they had been thrown. It is worthy of note that oxen and not horses were used for ploughing, but this was probably due to the temperamental differences between the two animals and their consequent suitability for different tasks.

Besides the jet bracelets mentioned above, jet beads have often been found in Bronze Age tumuli. Amber and dark brown or black glass beads also occur. Although little gold has been found in British Bronze Age sites it does occur as decorative additions to Danish horse harness, and the gold ceremonial cape from Mold in north Wales is now considered to be of Middle Bronze Age date.[2]

On the whole, it therefore appears that during the Bronze Age nine new materials were added to the fourteen available to Neolithic man. These additional materials are wool, flax, gold, copper, tin, bronze, jet, amber and glass making a total of twenty-three. Thus the Early Iron Age peoples, in order to reach their total of twenty-seven materials, only added five new materials (iron, lead, silver, enamel and wax) and ceased to use copper by itself in the relatively short period between the middle of the Bronze Age—say 1200 B.C.—to the middle of the Iron Age about 250 B.C.

2.7 *Post-Roman Materials*

It will be apparent that after the Roman occupation and during the interval preceding the Norman Conquest some more materials could have become available. But even in the medieval period of history the ordinate for cultural materials does not show any very marked increase. The development of world-wide commerce certainly made available several additional materials, but it is difficult to name more than a score of really new materials by, say, 1500 A.D.

For example, there is silk and cotton, brass and nickel, clay or tiles and bricks, china, glaze, paper, ink, resin, hemp, cork, various chemicals and drugs—and so on until the total might reach 50 or 60 (say 55).

Today with 92 different stable elements at our disposal and an ability to make synthetic materials such as modern plastics, the ordinate corresponding to the present time must be in the neighbourhood of several hundreds. The exact number does not matter for our present purpose and, in any case, it is not practicable to attempt to determine it.

[1] *Die Luren von Daberkow,* Prahistorische Zeits. vii, p. 85, 1915. by H. Schmidt.

[2] *The Gold Ornament from Mold, Flintshire, N. Wales.* Procs. Prehistoric Soc. New Series. Vol. xix, p. 161, 1954 by T. G. E. Powell.

The ordinate values for the cultural criterion C_1 are now complete. They are summarized in Table IV in the third column. Before it is possible to decide whether or not they require to be scaled up or down, the other criteria C_2, C_3, and C_4 must be examined. It will then be possible to decide how to make the four sets of figures comparable as was done with the anatomical indices.

3. The number of different occupations with which man was engaged, C_2.

The data for this criterion can be deduced readily from the foregoing section on C_1. But before doing so the precise meaning of "Different Occupations" must be considered. It is desirable to define "occupations" in such a way that cooking, sleeping, swimming, eating, and similar necessary personal daily activities are excluded. The word "Occupations" is intended to include the arts and techniques associated with man's daily work and also the more abstract activities of the doctor, teacher, lawyer, etc. Thus the making of flint implements or ship-building would both be included as "occupations" along with the activities of the modern professional man, the medieval farmer, the neolithic fisherman and the palaeolithic hunter.

A further decision is necessary concerning such specialized industries as those of carpenter, joiner and turner. Similarly, is a farmer to include a ploughman? Are weavers and spinners, millers and bakers to be considered as one or two industries respectively. With the earlier periods there is little doubt that a woodworker was both carpenter, joiner and turner. Similarly the maker of cloth both spun and wove, and the miller supplied bread or flour direct to the housewife. Therefore in determining numbers of industries the smaller number will be used until the degree of specialization justifies the separation of the industries. That did not happen until historic times. Then glass-makers were distinct from glaziers, stone-masons from builders, millers from bakers, joiners from cabinet-makers and so on.

In the previous section on "materials" it was found to be convenient to consider the Early Iron Age first and then to deal with the other periods chronologically from the early Palaeolithic to the Bronze Age and finally to consider what additional materials became available during historic times. In this section this procedure will not be necessary because the foregoing brief surveys of the different periods together with the summaries of the particular materials available will enable the number of industries appropriate to each period to be determined quite readily and in chronological order.

3.1 *Early Palaeolithic Occupations*

Australopithecus: As it is not known for certain that the Australopithecinae made stone implements, they cannot be credited with that particular industry. In fact hunting is the only activity that can be recorded here as their "occupation".

Pithecanthropus erectus scores two; hunting and making flint implements.

Homo heidelbergensis, having been associated with worked bone, can have the "occupation" of bone-working added to his activities, making a total of three.

From the discussion on page 79 Pekin man must be the first to be credited with the

wood-working industry. No doubt the earlier men fabricated wooden clubs but, except possibly for a fossilized wooden spear (?) from Clacton-on-Sea, there is not even any indirect evidence to support this suggestion however probable it may be. No doubt many would like to have more evidence for Pekin man's use of wood, but indirect evidence has been accepted here because the perishable nature of wood precludes direct evidence until Neolithic times. Decayed and charred wooden hafts have been found with perforated stone axes and charred marks in clay sometimes show the position of an arrow or harpoon shaft. Pekin man will therefore have the ordinate four as indicative of the number of occupations upon which he was engaged.

3.2 *Middle-Palaeolithic Occupations*

Neanderthal man undoubtedly occupied himself in making skin clothing in addition to the four activities credited to Pekin man. We can hardly call the collecting of iron pyrites and flint an "occupation" and by our definition "cooking" cannot be included even though there is much evidence that Neanderthal man ate cooked food. Consequently the five occupations for *Homo neanderthalensis* are hunting, flint, bone and wood working and the making of skin clothing.

3.3 *Late Palaeolithic Occupations*

When considering the activities of Cro-Magnon men, Magdalenian men and other post-glacial men of the so-called "Reindeer-age", it is difficult to add many new occupations to their daily tasks. The practice of magic, fishing and carving, engraving, modelling and painting can, however, now be included. The last four can hardly be separated into different occupations or rather "arts" and are therefore counted as one. Hence the *Homo sapiens* of Late Palaeolithic times could spend his time on three additional "occupations" making a total of eight.

3.4 *Neolithic Occupations*

There is a very big jump in the number of occupations when we consider Neolithic man. He could employ himself with flint mining, pottery making, glass making, basketry, farming, milling (with saddle-backed querns), herding cattle, shepherding sheep, building huts and constructing boats; a total of ten new occupations.

We possibly should deduct one of the previous occupations because Neolithic man's skill as an engraver and modeller was restricted to pottery decoration and a crude clay figure of a woman from Northern Ireland.[1] As these hardly justify the term "occupation" when compared with the superb carvings, engravings and paintings of Late Palaeolithic man, it is better to make the total of Neolithic man's occupations $8 + 10 - 1$ or seventeen.

3.5 *Bronze Age Occupations*

Although it is probable that Neolithic man processed skins before using them for clothes, he could not be called a "tanner". It is better to credit the art of tanning and the trade of cordwainer to Bronze Age man. Evidence from Danish peat bogs justifies this and enables us to add the following six additional occupations to the men of this

[1] W. Jackson. *The Antiquaries Journal*, Vol. 14, p. 180, 1934.

period (approximately 2000 to 500 B.C.); namely, tanner, cordwainer or cobler, weaver and spinner, bronze metal worker, wheelwright and farrier, making a total of twenty-three occupations.

3.6 *Early Iron Age Occupations*

The one additional occupation characteristic of this period is, of course, that of the blacksmith or iron-worker. If we distinguish between the farrier and the charioteer, the total number of early iron-age activities becomes twenty-five and it is difficult to raise this number any further. Although there may have been brewers, bee-keepers and milkmen it is more likely that these tasks were carried out in each household and were not specialized occupations in prehistoric times. We may now profitably collect and summarize the twenty-five occupations associated with Early Iron Age man. They are: hunting, fishing, farming; the working of stone, bone, wood, bronze and iron; the making of glass, pottery, clothing, baskets, huts and boats. Then there is the medicine man, the herdsman, the shepherd, the miller, the skinner, the miner, the farrier, the wheelwright, the tanner, the cordwainer and the charioteer.

3.7 *Post-Roman Occupations*

By medieval times it is almost impossible to list the occupations that have sprung up because of the ever increasing standard of living. All "occupations" taking up man's time are some measure of his cultural development, hence the new occupations of merchant, teacher, banker and so forth must now be included in our ordinate. Although these more abstract occupations do not deal with materials as such, they are necessary tasks in a community, the individuals of which are becoming more and more specialized. Our picture of man's cultural development would not be correct unless we adhere to our original definition of "occupation" which includes new activities of this kind. But the consequence of this is that the number of occupations increases very rapidly (more so than the number of post-Roman materials). It is comparatively easy to list, say, twenty new occupations such as: doctor, lawyer, teacher, merchant, banker, apothecary, money-lender, clerk, shopkeeper, surveyor, printer, stonemason, glazier, papermaker, jeweller, whitesmith, tailor, seaman, brewer, and such a list is obviously far from complete. Thus in medieval times the total number of occupations must be of the order of, say, seventy.

When we consider the number of occupations of the present day perhaps the best indication of the order of our ordinate is to think of the headings in a London Trade Telephone Directory. The number of occupations must be well over a thousand. However, the precise number is quite immaterial as will be evident when the C_2/time graph comes to be plotted.

3.8 *Occupations of the Chimpanzee*

When considering the C_1 ordinates, zero was allocated to the Chimpanzee because it was thought that the utilization of materials for the building of a nest was comparable

with the nest-building of a bird. That is, it is not a deliberate mental decision demanding intelligent thought for its execution but it is an instinctive reaction to environment or an inherited habit. With the C_2 ordinates it is necessary to decide whether "hunting" (that is, food gathering with the apes) be classed as an "occupation" in the present use of the word or is it to be considered an instinctive reaction to hunger. It is easy to imagine man deciding on and deliberately preparing for a hunting or food gathering expedition. But does an ape premeditate on the desirability or otherwise of undertaking such an expedition or is the hunting carried out as a daily habit at times regulated by the sun or is hunting carried out as opportunity arises or as hunger dictates? Nissen, in his book *A Field Study of the Chimpanzee*, states that chimpanzees gather fruit early in the morning, sleep during the midday, build tree-nests in the evening and retire at dusk. The writer is not qualified to decide whether the food-gathering occupation is the result of an instinctive habit or a thoughtful and deliberate action. But on seeing two chimpanzees in Africa go up to a tree, look up at it, obviously meditate together on the situation and then decide to go on to a more desirable tree, he is inclined to credit them with at least some deliberate and thoughtful action. The chimpanzee is therefore given one mark for his hunting occupation, but none for his nest-building. Possibly this is an unfair distinction. If so, then it is felt that two zeros would be more justifiable than two units.

The final values for the C_2 ordinates are therefore as listed in Table IV.

4. The speed with which man moved by mechanical means, C_3

The fact that the two foregoing criteria only yield information about one aspect of man's cultural development has already been considered (page 15). The present criterion is even more open to such criticism. Nevertheless the continual increase in the speed with which man can transport himself by mechanical means is a measure of his increasing control of the materials and forces of his environment. To this extent his "artificial speed" is a measure of his command over nature and this command is an aspect of his culture. It is unfortunate that this seems to be the only aspect subject to quantitative measurement.

Whether or not conclusions that can be made from a quantitative study of this physical or material aspect will be equally applicable to other aspects of culture, such as artistic appreciation or refinement of taste, is a matter for later consideration. What is certain is that mechanical speed is a definite measure of man's knowledge of and control over the physical world in which he lives.

The word "mechanical" has been chosen deliberately to exclude the domestication and use of horses. The reason for this is obvious because man cannot improve the speed of a horse or his own speed of running except by the slow process of selective breeding—a process which is not a measurable criterion of culture.

When considering speed in miles per hour (m.p.h.) normal or usual speeds capable of being maintained for reasonably long periods will be given and not maximum speeds possible for short times under abnormal circumstances. For example, a man's speed

will be that of walking three or four m.p.h. and not his maximum of one hundred yards in under ten seconds or about twenty m.p.h.

It is fairly certain that the earliest mechanical transport would have been man-propelled, and probably operated on the principle of a sledge. That sledges were used in Late Palaeolithic times is highly probable because at least one of the drawings in the cave known as Hornos de la Peña, Spain, may well be interpreted as a sledge (Fig. 40).

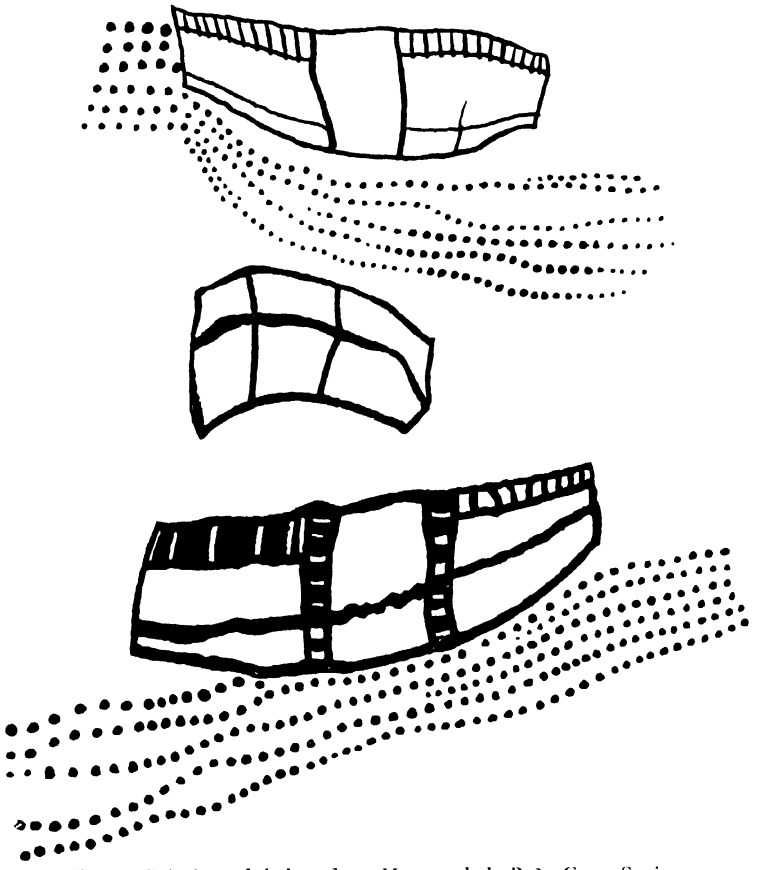


Fig. 40. Painting of sledges from Hornos de la Peña Cave, Spain.

Over ordinary rough ground a speed of two to three m.p.h. might be usual. No real advance on land speed was possible until the wheel had been invented, but a dug-out canoe (Fig. 41) might well be credited with a speed of five m.p.h. in still water when propelled by one man. There is no evidence for dug-out canoes before Neolithic times in this country, but the Maglemose folk who came over to the East Riding of Yorkshire would have arrived by sea if they came towards the end of the Mesolithic period. By this time (probably about 5000 B.C.) England had become an island for the last time. Before that time England was part of the Continent. This is confirmed by the fact that

a Maglemose harpoon has been dredged up in a lump of peat from the bed of the North Sea. A pollen analysis (page 125) of the peat shows that hazel and oak forests existed where the Leman and Ower banks are now covered with nineteen fathoms of



Fig. 41. A Neolithic dug-out canoe.

water. Consequently it is perhaps safer not to date back the canoe much before 3000 B.C. in England, in spite of the fact that relatively large ships were sailing in the Mediterranean Sea at this time. When allocating speed ordinates to given times

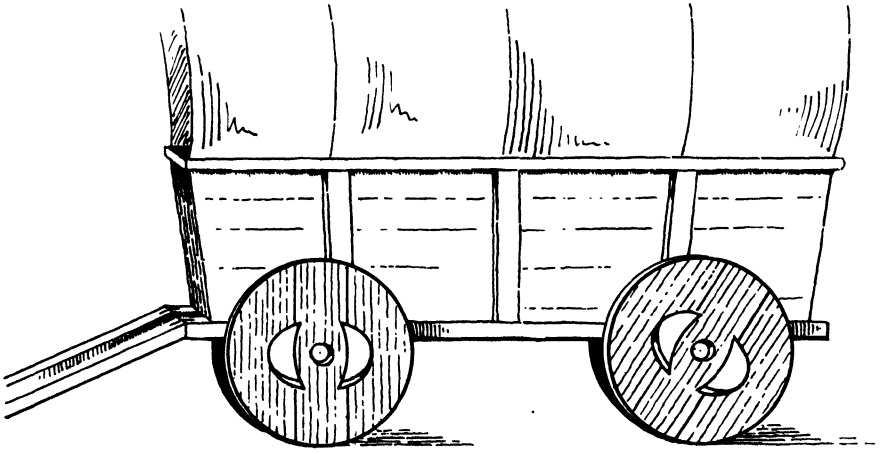


Fig. 42. Wagon wheels of the Bronze Age (Jutland).

(abscissae) our data will be limited to events in this country. It will be easy to adjust graphs for other countries when the time interval between the attainment of similar stages of culture in the two countries is known. (See Fig. 55.)

There are now three points on a speed/time graph, namely:

(i) 0 m.p.h. for Lower and Middle Palaeolithic man who, as far as we have evidence, had no means of mechanical transport;

(ii) Two to three m.p.h. for the Late Palaeolithic men who painted sledges in caves about 25,000 years B.C.; and

(iii) Five m.p.h. for canoes about 2000 or possibly 3000 years B.C.

It may well be that in Neolithic times men used rollers (tree trunks) to aid them in transporting the stones of Stonehenge, and that the invention of the wheel followed

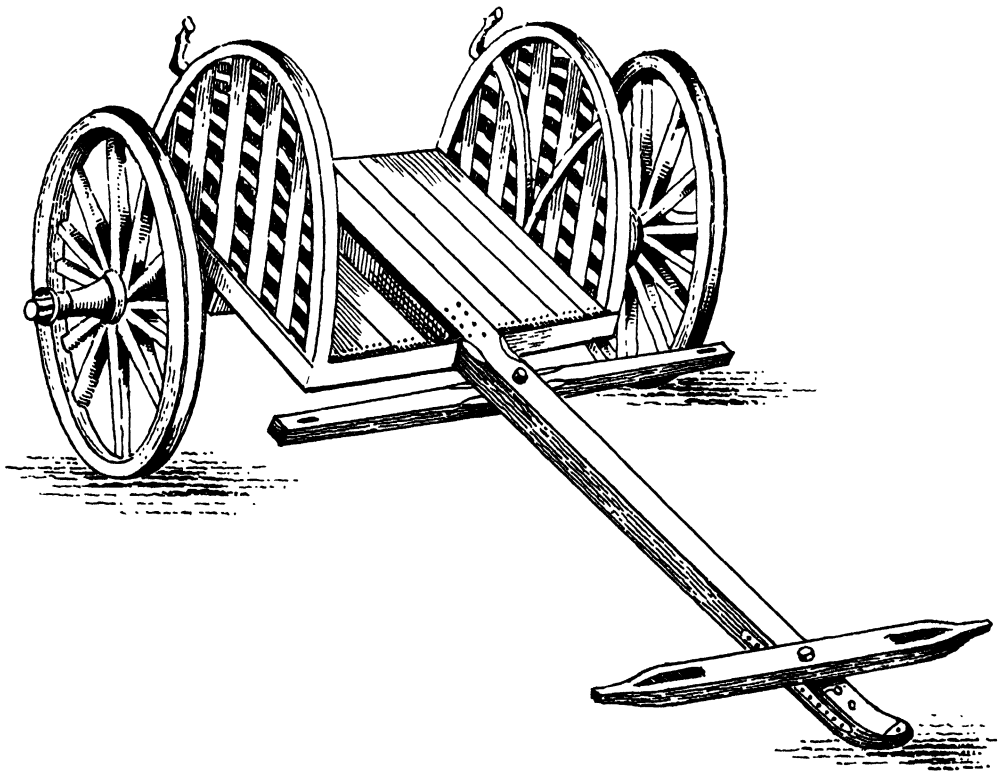


Fig. 43. A type of Early Iron Age or Celtic chariot.

soon after. But as wheels have been depicted on Sumerian vases long before this time in the Mediterranean, it is more probable that the knowledge of the wheel (Fig. 42) was imported into this country by visiting traders or invaders. By whichever method it came, it was certainly in use in Bronze Age times. Ox-wagons and horse-drawn carts were undoubtedly made at least a thousand years B.C. in this country. A light horse-drawn cart would be capable of six or eight m.p.h. over open country, but four or five m.p.h. is a more likely speed before the days of Roman roads.

In Early Iron Age times the war chariot (Fig. 43) with two or more horses would be capable of speeds up to possibly ten or even fifteen m.p.h. for a short while.[1]

[1] See, for example, *L'Attelage le cheval de selle*, Lefebvre des Noëtte, 1931.

This gives us two more points on the speed/time graph; namely, not more than six m.p.h. for a cart in Bronze Age times of a thousand years B.C. and ten m.p.h. for an Early Iron Age chariot of one or two hundred years B.C.

It is apparent that further advances in land transport did not come until the steam engine had been invented, but on the sea a full-rigged ship would be man's fastest means of mechanical transport. Under favourable conditions as much as 12 or even 15 m.p.h. could be maintained by the nineteenth century tea clippers.

Finally, in the twentieth century there is the express railway train at 80 m.p.h. or more and the jet propelled aircraft at 800 m.p.h. Possibly the next point on the graph will arise when man travels in a rocket.

5. Cultural "Grading" of man-made objects, C_4

The subject matter of this section records the results of two experiments which were undertaken with the object of testing statistically educated opinion on man's cultural development as judged by (*a*) the complexity of a man-made object, and (*b*) the degree of knowledge required to produce the object.

It is fully realized that a survey based on such material evidence can only give information on this particular limited aspect of man's culture. Preliminary tests on objects which were thought to have artistic merit or aesthetic value showed that no numerical grading was possible because standards of judgment differed so widely with different peoples. This is obvious from the extreme opinions of professional art critics on one and the same work of art. Not only does opinion differ from critic to critic with no apparent relationship to their educational background, but opinion also differs from generation to generation. Fashion cannot, in fact, be subjected to any quantitative measurement. For these reasons the inquiries now to be considered were limited to certain material aspects of objects which, from experience gained by preliminary tests, could be assessed quantitatively by ordinary men and women with a modern education. It was in fact surprising how closely opinions agreed and for this reason (and also because of the extremely interesting and unexpected results obtained) that a record of the experiments is included here.

The test consisted of evaluating sixteen man-made objects of very varying complexity. A hundred marks was arbitarily allotted to the two most complex objects. Marks less than 100 were to be allotted to the other fourteen objects by comparing them with the two most complex objects from two points of view. Comparison was to be made first with regard to the complexity of the object and second, with regard to the knowledge required in order to produce the object. Emphasis was laid on the fact that the objects were to be considered without reference to any personal knowledge of their historical date and without reference to their social value to the community who made and used them. Each object was, in fact, to be considered as entirely isolated and to be judged purely from the two aspects stated above.

The sixteen selected objects were tabulated in the following order and a blank column added in which to record marks.

Radar-controlled automatically fired anti-aircraft gun battery.
Supersonic jet-propelled aeroplane.
Animal snare or pit-fall.
Iron (not steel) sword in enamelled scabbard.
Chipped flint hand-axe.
Coarse hand-made clay pottery bowl.
Spoked-wheel horse-drawn chariot.
Bronze dagger.
Bow and arrows.
Cannon, powder and shot.
Loom-woven woollen fabric.
Full-rigged sailing ship.
Bone needle in carved bone case.
Untanned skin-cloak.
Hafted polished stone axe.
Flint-tipped spear.

The first two objects were given 100 marks and were the standard of reference for the other fourteen. The test was carried out with:

(*a*) an adult-education class studying prehistory; and
(*b*) individuals interested in the experiment.

On collecting the marks from thirty-two members of the prehistory class and from thirty other individuals, two facts emerged. First, the divergence of opinion on any one object determined by the various numbers allocated to it usually followed a kind of probability curve; second, the consensus of the opinions of the class-members was practically the same as that of the isolated individuals. There seemed to be no bias in one direction or the other due to specialized instruction in Prehistory. This is to be expected if the mark allocated was judged strictly and solely from the two aspects—complexity and knowledge—as requested when the lists were circulated. Consequently the sixty-two results have been taken together when computing the final values.

In Table III the columns headed M (or mark) list all the different grading marks that were allocated by one or more recorders to one particular object indicated at the head of the column. In the column headed N, opposite each mark is given the number of times it was recorded.

It will be noticed that none of the columns headed N adds up to 62. This arises because marks were not always allotted by some of the Recorders to all of the fourteen objects and there were also six "spoilt" returns due in most cases to a misunderstanding of the questionnaire. There are several different methods for handling data of this kind. The one adopted here is as follows. On the assumption that each opinion is of equal value, the sum of the products of the two columns for any object is the total number of marks of equal value allotted to the object. The total number T of Recorders who allotted these marks is given by the sum of the numbers in the second column. Therefore the ratio of these two summations gives the average mark for the object or the mark

which best represents the average opinion concerning the merit of the object judged by its complexity of design and by the knowledge required for its production. These optimum marks A have been calculated and are recorded at the base of the columns. In many cases they correspond very closely with the peak mark allocated by the largest group of people. These marks (to the nearest whole number) giving the average or optimum are recorded under the C_4 column in Table IV (page 101). The general run of the figures when the objects are arranged chronologically is surprisingly similar to the figures for the other cultural criteria.

The loom-woven fabric seems to be an exception. Apparently the optimum opinion was that the spinning of wool, the making of a loom and the weaving of cloth is a more complicated process requiring more knowledge than the smelting of iron, the forging of a sword and the enamel work involved in decorating the scabbard.

The time (abscissae) corresponding to these ordinates will be discussed in the following chapter, but it may be stated that the sixteen objects were chosen in such a way that they represent in pairs the following eight cultural periods: namely the Early Palaeolithic, Middle Palaeolithic, Late Palaeolithic, Neolithic, Bronze Age, Early Iron Age, recent historical times and the present day. These periods were not, of course, disclosed to those who provided the data in Table III. The jumbled group of objects in the order given on page 98 was alone presented for assessment. With the exception of the Bronze Dagger and Woven Fabric, the calculated ordinate values for a given pair of objects do not differ significantly from one another. This fact alone seems to give some confidence in the ultimate outcome of this experiment.

6. Comparison of cultural data

When dealing with the physical or anatomical data in the previous chapter it was fairly easy to modify existing anatomical indices so as to be able to compare readily one with another. This was done by making them all increase with increase of hominid characteristics in such a way that 100 (or any arbitary number) represented each of the indices of the modern European.

With the cultural data the figures for the modern Englishman are so very big and vague (see Table IV) that they are quite unsuitable to reduce to 100 and then to modify the remaining figures accordingly. But on inspecting Table IV it is apparent that the values for the second period—"Recent History"—are all definite and more or less numbers of the same order. Hence, in order to make the sets of figures comparable, it will be most convenient to modify them in such a way that 50 represents each of the four cultural values for the period of "Recent History". No modification should or need be undertaken for the criterion C_4, the figures for which have been determined statistically. Also one of the C_4 figures happens to be 50 for the "Recent History" period without any modification. The final figures for the C_1, C_2 and C_3 criteria are shown in the columns headed "Modified". These "modified" values will form the ordinates of cultural development/time graphs that will coincide at the point (Recent History, 50). Their subsequent shapes will, of course, depend on the other ordinate values.

Table III

Record of Grading Marks

Columns M = Value of *Mark* allocated to given Object.
,, N = *Number* of Recorders who allocated the particular Mark.
Line T = Total number of Recorders.
,, A = Average value allocated to the particular Object by the T Recorders. That is A is the sum of all the products M × N divided by T.

OBJECTS

Full rigged sailing ship		*Cannon, powder and shot*		*Spoked-wheel horse-drawn chariot*		*Iron sword in enamelled scabbard*		*Bronze dagger*		*Loom-woven woollen fabric*		*Hafted polished stone axe*		*Coarse hand-made pottery bowl*		*Bow and arrows*		*Bone needle in carved bone case*		*Flint tipped spear*		*Untanned skin cloak*		*Chipped flint hand-axe*		*Animal snare or pitfall*	
M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N	M	N
15	1	15	1	10	2	10	3	5	2	10	2	3	1	4	1	2	4	3	3	2	3	0	2	2	5	1	4
25	1	20	1	15	2	12	2	8	4	12	1	5	4	5	4	5	6	5	10	3	7	1	5	3	7	2	8
28	1	25	2	19	1	14	1	10	9	15	2	6	2	6	2	6	9	7	7	4	5	2	19	4	3	3	10
30	2	30	1	20	9	15	4	12	8	18	5	8	7	7	5	7	10	8	5	5	10	3	2	5	12	4	10
35	3	35	6	22	2	18	7	13	1	20	7	10	5	8	10	8	8	9	4	6	5	4	6	6	14	5	7
40	4	40	3	25	5	20	9	15	13	22	8	12	8	9	8	13	7	10	12	7	7	5	7	8	2	8	3
44	1	42	1	28	7	22	7	18	8	25	6	15	8	10	4	15	5	12	5	10	12	7	2	10	8	10	4
45	2	45	8	30	9	24	8	20	6	28	4	20	3	11	2	17	1	15	3	12	4	8	5	12	2	12	2
50	4	48	4	32	6	25	4	25	1	30	5	22	5	12	4	18	1	17	1	15	1	10	4	15	1	15	1
55	8	50	7	37	1	28	4	30	1	32	6	25	1	14	2	20	1	18	1	20	1	12	1	20	1	25	2
60	6	55	8	40	2	30	2	35	1	35	4	28	3	15	6	25	1	20	2			20	1			30	1
62	7	56	4	45	2	35	1	40	1	40	2	30	4	17	3			45	1								
65	4	60	3	46	1	40	2			42	1	40	2	18	4												
70	5	70	2	50	2	46	1			45	2	45	1	20	1												
75	1	75	3	55	1	50	1			50	1																
80	4	80	1																								
83	1	85	1																								
85	1																										
T→																											
	56		55		52		56		55		56		54		56		53		54		55		54		55		52
A→																											
55·9		49·6		28·6		22·6		15·1		26·4		16·2		10·6		8·9		9·8		6·9		4·3		6·3		5·9	

Note.—When the extreme complexity of the two standard objects is compared with any of the fourteen test objects, the highest allocated mark should probably be less than unity. This aspect was mentioned by some Recorders who felt that the number given to the jet-plane and gun battery should have been 10,000 or even 100,000 in order to justify the marks generally recorded. Only one Recorder actually allocated marks less than unity. These small decimal marks are not included in the above table because they would not appreciably affect the results, whilst their inclusion would unnecessarily complicate the figures.

TABLE IV

Cultural Period	*Type of Man*	Cultural Criteria							
		C_1 Number of Materials		C_2 Number of Occupations		C_3 Speed of Mechanical Transport		C_4 Grading of Man-made Objects	
		Number	*Modified*	*Number*	*Modified*	*M.P.H.*	*Modified*	*Object*	*Grading*
Present Day	Modern Englishman	300 or 200	275 or 180	1000+	700÷	Plane 800	2000	Jet Plane	100
						Train 80	200	A.A. Battery	100
Recent History	Merchant Citizen	55	50	70	50	Sailing Ship 15	50	Sailing Ship	56
								Cannon, etc.	50
Early Iron Age	Glastonbury Lake Villager	27	25	25	18	Chariot 10	33	Chariot	29
								Sword in Scabbard	23
Bronze Age	Round Barrow Man	23	21	23	16 5	Cart 6	20	Bronze Dagger	15
								Woollen Fabric	26
Neolithic	Long Barrow Man	14	13	17	12	Canoe 5	17	Polished Axe	16
								Hand-made pottery	11
Late Palaeolithic	Neanthropus	10	9	8	6	Sledge 3	10	Bow & Arrows	9
								Bone Needle and Case	10
Middle Palaeolithic	Homo neanderthalensis	7	6 5	5	3 5	0	0	Flint-tipped Spear	7
								Untanned Skin Cloak	4
Early Palaeolithic	Pithecanthropus pekinensis	3	2·5	4	3	0	0	Chipped Stone axe	6
	Homo heidelbergensis	2	1·8	3	2			Animal Pitfall	6
	Pithecanthropus erectus	1	0·9	2	1·5				
	Australopithecus	?	?	1	0·7				
Miocene	Proconsul africanus	0	0	1 ?	0·7 ?				
Present Day	Chimpanzee	0	0	1	0·7				

The curves will be given in Chapter V after the abscissae have been discussed in the next chapter.

7. Summary

From a discussion on the possible criteria of culture it was realized that quantitative values could only be obtained for a very limited aspect of man's culture—the material aspect or that aspect which indicates his knowledge of and control over the materials of the earth and the natural forces of the universe. Consequently with full realization of its limitations, this material aspect was accepted as some indication of man's cultural development. Four "cultural criteria" are considered: the number of materials utilized by man at different times, the number of different occupations with which man was engaged, the speed with which man could move by mechanical means and a "grading test" of man-made objects.

These four criteria are then evaluated for the various cultural periods from the earliest Palaeolithic times to the present day. The resulting figures are reduced to comparable scales and summarized in Table IV on the previous page.

CHAPTER IV

The Time Factor

A BRIEF survey of methods of dating prehistoric remains and geological deposits was given in the first chapter. In the present chapter it is desirable to consider this subject, usually called Geochronology, more fully in order to determine the time in years before the present (B.P.) or before Christ (B.C.) during which a given type of man lived or during which a given artifact was made. These times will then be the abscissae for the anatomical indices I and the cultural criteria C—the subject matter of the two previous chapters.

Before considering how time in years can be measured, the main events which prepared the stage for man's debut will be discussed. It is not easy to realize how long has been the period of preparation compared with the very short interval during which man has existed and developed (see page 19).

Many independent sources of evidence all lead to approximately the same time interval since the earth was formed and its crust began to solidify.

1. Motion of the sun and planets

The sun and its planets, of which our earth is a relatively small member, are moving rapidly and spirally away from the centre of that galaxy of stars known as the Milky Way. From a knowledge of our speed and present position, it is possible to determine when the "explosion" took place that initiated the present motions of our sun and of all the other stars of this galaxy. The time, when calculated from these known facts, is of the order of three thousand million years. A period of this duration can also be deduced from independent physical and geological evidence.

2. Orogenic rhythms and drift

As the earth cooled and shrank, its crust crumpled and cracked. The main effects were "orogenic"; that is, mountain building accompanied by a fracturing and drifting apart of broken land masses. There is much evidence to show that the mountain building effect took place periodically or rhythmically, as though an internal compression gradually built up until, by eruptive explosions and terrestrial upheavals, the pressure was reduced. Volcanoes would thus act as safety valves. A periodical renewal of this process would account for the periodic orogenic activity that is known to have occurred.

Just prior to and coinciding with the last upheaval (known as the "Alpine"), the

main mass of solidified rock seems either to have split into several blocks or to have become submerged in definite areas. This occurred not necessarily all at the same time but at intervals during and not very remote from the Alpine period. As a result of this "catastrophy" the several blocks or continents continued to move or drift on the fluid core of the earth—the magma—in which the solid crust is floating. This hypothesis, usually attributed to Wegener, is not fully satisfactory, and like all hypotheses will need to be modified in due course. One modification due to Dr. A. L. du Toit pre-supposes there were initially two land masses separated by the Tethys Sea. Such a supposition helps to solve some of the difficulties which arise with the somewhat simpler theory of Wegener. Before the last upheaval there is evidence that at least eight and probably more periods of orogenic activity had occurred at intervals of roughly 200,000,000 years. The first one would therefore have occurred more than 1,800 million years ago. The oldest rock that has been measured by radioactive methods is a piece of pegmatite from Northern Rhodesia and the age is 2,640 million years. (See page 109.) Recognized geological formations which constitute the upper layers of the crust of the earth date back to a period—the Cambrian—which is only 500 million years old and consequently this interval just straddles the last three orogenic upheavals. It may be mentioned in passing

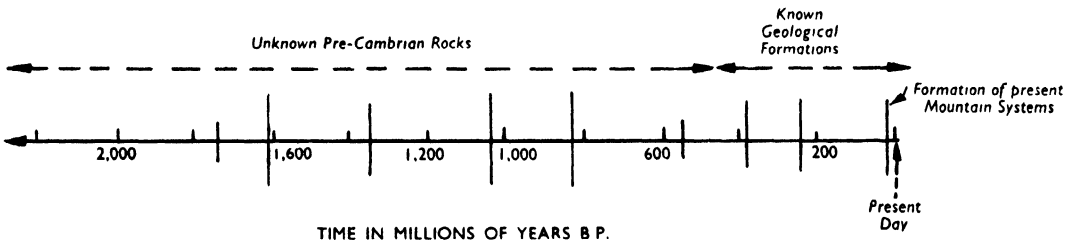


Fig. 44. Periods of orogenic activity.

that the earliest evidence for life on the earth occurs in the Cambrian rocks where trilobite fossils are first found. No doubt more primitive creatures allied to the jelly fishes existed before these times, but their soft bodies left no fossil evidence of their existence. The older and deeper layers of the earth's crust are formed of pre-Cambrian rocks. The foregoing may be summarized graphically by plotting the periodic upheavals on a time scale as in Figure 44 in which the lengths of the vertical lines are very rough indications of the severity of the upheavals.

The present mountain systems of the earth were formed during the period of continental drift associated with the Alpine orogenic upheaval. This occurred about Miocene times in the middle of the Tertiary geological period (see "Tree" on page 17 and Figure 45). The later portion of Figure 44 is magnified in Figure 45 and drawn, not with time as the abscissae, but with time as the ordinates in order that the geological deposits may appear as they normally do in the earth's crust; that is, with the oldest at the bottom. In this figure more detail is possible and a second graph is added to show roughly fluctuations of temperature. From a comparison of the two graphs it is apparent that terrestrial upheavals were accompanied by periods of abnormally cold climate.

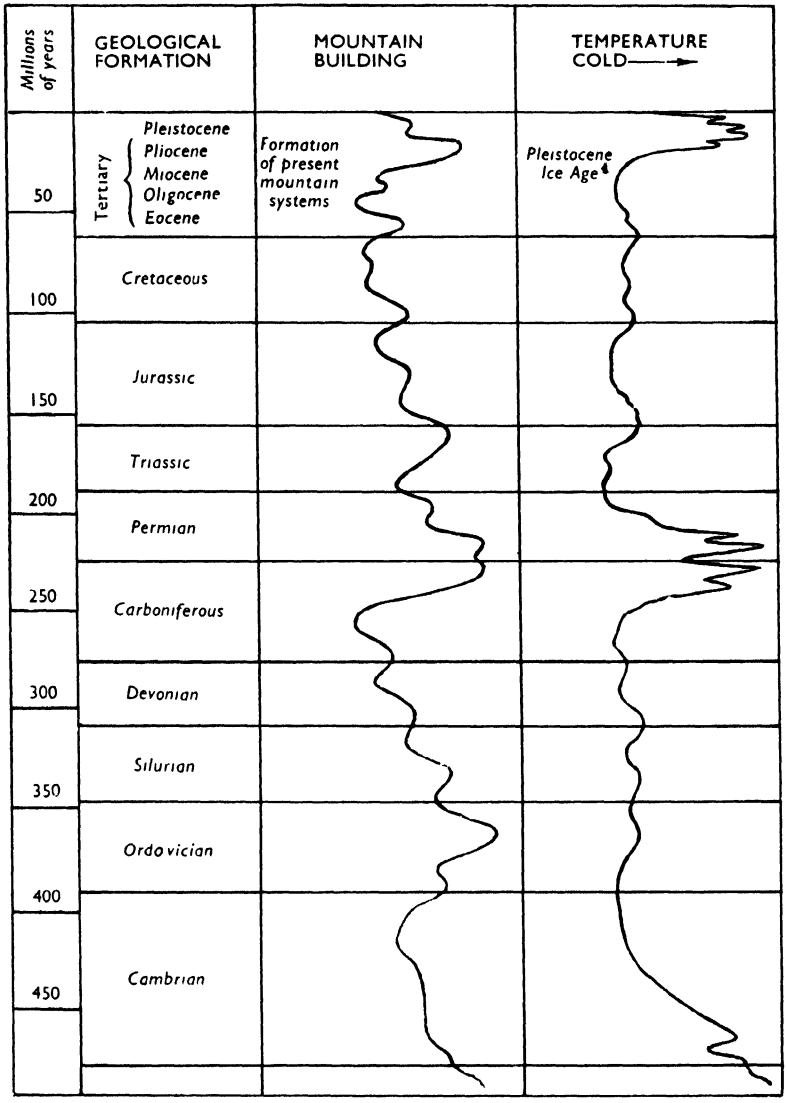


Fig. 45. Approximate ages of [illegible] formations and climatic fluctuations (*after* [illegible] Umbgrove).

Reasons for these temperature fluctuations will be discussed when dealing with the climate oscillations of the Pleistocene period. (Fig. 46.)

The theory of continental drift was put forward by Taylor and independently by Wegener whose book *Die Entstehung der Kontinente und Ozeane* was republished in 1915.

From radioactivity measurements of the age of similar geological formations in countries now separated by known distances of sea, it is possible to calculate (using known rates of movement) the relative rate of drift between two land masses. A few centimetres a year is the order of magnitude of these movements.

For example, the distance between Newfoundland and Ireland is 2400 kilometres and the time of separation as measured radioactively is early Pliocene about 15 million years ago. The rate of drift is therefore about 15 to 20 cms. per year. The time of the last orogenic activity was about 30 million years ago; so that the Atlantic rift and the formation of the mountain ranges along the western coast of North America would be, according to these figures, more recent occurrences than, or delayed effects from, the terrestrial upheavals of Miocene times. It is by no means certain that the radioactive rocks which led to the early Pliocene date were the oldest rocks in the Newfoundland and west Irish sections. Consequently the time interval is in all probability, far too short. Furthermore the speed of 15 to 20 cms. per annum is much faster than that measured for any other continents and should probably be at least halved. This would result in doubling the time interval to 30,000,000 years and would bring the event well in the Miocene epoch. This is much more satisfactory because it is probable that the Alpine period of activity was responsible for the original rift or sinking between these two land masses.

Although these major disturbances occurred millions of years before the advent of man, they do have their repercussions in the Pleistocene and Holocene periods during which he lived. The last Ice Age with its several cold phases and the continued movements of land masses both affect the climate and environment of the present day. England is still tilting downwards along the east and south coasts and is rising along the north and west—Hornsea on the east coast of Yorkshire is losing its shore-line at the rate of several yards annually, whilst from Southport on the west coast, the sea is steadily retreating. Furthermore the passing of the last Ice Age is resulting today in a gradually ameliorating climate accompanied by a slow retreat of the ice from Greenland and an advance up the English Channel of a warm marine fauna.

In order to appreciate more readily the enormous time the earth has existed compared with the relatively short time during which man has appeared on its surface, a digression is justified to introduce a method of comparing time intervals which has proved to be very useful in discussion.

A 500-page octavo novel with 400 five-letter words on a page will contain a million letters and would be, say, two inches thick. Let it be supposed that every letter represents one year. Then such a book would contain a million years of history. Three thousand such volumes on a shelf 500 feet long would therefore suffice to record the history of the world since its formation three thousand million years ago. It would be necessary to pass by the first 2,500 volumes before any reference to life on the earth would be found. The coal forests of the Carboniferous Age would be in the 250th volume from the end or the 2750th volume from the beginning. The first reference to man would not occur until the very last volume. This follows because there is no evidence of man more than a million years ago. The use of fire would be first mentioned on about page 375.

The whole of history would occupy less than the last page, and the last two words on this page would undoubtedly be "Atomic Energy".

Man has indeed only just appeared on the world stage, and he is, in fact, only just commencing his journey through time.

3. Radioactivity dating method for rocks

Reference has been made to dating rocks by radioactivity measurements. As such methods provide absolute values in years B.P. they are particularly important. The principles underlying radioactivity measurements are as follows. All substances are built up from different numbers and different arrangements of one or more of 92 different elemental atoms—the 92 stable elements of our land, sea and atmosphere. The atoms differ from one another because they are made up of different numbers and different arrangements of three different elemental particles. These fundamental "bricks" are known as the "neutron" with no electrical properties, the "proton" with positive electricity and a much lighter "electron" with negative electricity. Each atom has a core or nucleus of neutrons and protons which determine whether or not the atom is stable or whether it tends to break up; that is whether or not the atom is radioactive. The electrons form a kind of planetary cloud surrounding the nucleus and do not affect the radioactive disintegrating tendency or property of the nucleus. The 92 stable atoms differ from each other in that they have from 1 to 92 protons in their nuclei. The lightest—hydrogen—has one proton and the heaviest—uranium—has 92. Along with these protons there are various numbers of neutrons. The important word in this statement is the word "various". These neutrons merely add weight to the atomic core but do not affect the chemical properties by which the different atoms can be identified. Thus an atom of oxygen has eight protons and may have eight or nine neutrons. Ordinary oxygen has eight neutrons but heavy oxygen has nine. Similarly hydrogen has normally one neutron along with its one proton, but heavy hydrogen may have two or even three neutrons. Atoms with the same number of protons but different numbers of neutrons are called isotopes. The heavier the isotope the more unstable it becomes and eventually the isotope becomes too unstable and automatically breaks up or disintegrates. In other words it is a radioactive isotope. It is comparatively easy to bombard any atom with a neutron source and bury an extra neutron in its nucleus. It then becomes an artificial or man-made radioactive isotope of the particular substance. Sometimes this bombarding process results in an artificial radioactive atom of a different kind. For example, if aluminium is bombarded with neutrons it turns into radioactive unstable magnesium which at once commences to disintegrate and after two or three days half of it has returned to normal aluminium again. Every one of the 92 elements can now be obtained in an unstable radioactive form. These artificial isotopes when disintegrating give off various particles and rays which are being used more and more in the medical and industrial world. Besides these artificial top-heavy elements, the three heaviest of the natural elements, namely uranium, actino-uranium and thorium, are also steadily disintegrating and have been doing so since they were formed along with the other

oldest rocks of the earth's crust. It so happens that the disintegration of any radioactive material takes place at a measurable unalterable rate; at least unalterable by any of the natural forces normally experienced on the earth. Each of these natural radioactive substances ultimately disintegrates to form an isotope of lead or bismuth. These can be identified by their different atomic or nuclear masses.

Obviously if the rate of disintegration be known and the amount of end-product (e.g. uranium-lead) compared with initial uranium could be measured, then the time during which disintegration had been proceeding could be calculated. This is the basis of the radioactive method for measuring the age of rocks—assuming of course they contain radioactive constituents. Fortunately most of the oldest rocks are more or less radioactive and their ages can therefore be determined. Incidentally, radium is one of the intermediate products formed as uranium disintegrates to uranium-lead.

It is now necessary to consider this rate of disintegration a little more closely. The rate is determined by and is proportional to the amount of the original substance still remaining at any given time. Consequently the amount of new material formed per second gradually decreases as the amount of parent substance gets less and less. This means that the process gets slower and slower, but the time at which it has decayed to half its original value is always constant. This time interval is known as the "half-life" of the radioactive substance. This is the constant which enables the radioactive rocks to be dated by measurements of the ratio of the amounts of parent to daughter products. For example, any given mass of radium will disintegrate to half its original amount in 1590 years and in another equal period it will be only one quarter of the amount that it originally was. This time interval is the fixed unalterable half-life of radium. As a further example, uranium is so stable that in one year one million grams of uranium will only produce approximately 0.13 milligram of lead. Pitchblende from Bohemia gives a lead/uranium ratio of 0·03. Consequently the age of the pitchblende is $\frac{0{\cdot}03 \times 1{,}000{,}000}{{\cdot}00013}$ years or $\frac{{\cdot}03}{{\cdot}00013}$ million years; that is 230 million years approximately. This is somewhat larger than the corrected figure given in the table on page 109. Half-life periods vary from millions of years to fractions of a second according to the stability of the disintegrating atom. As uranium disintegrates to lead, helium gas is evolved along with powerful invisible radiations and high-speed electrons. If the gas could be collected and measured this would give as accurate a time period as would a measurement of the amount of lead formed in the same time. But a gas tends to escape from the rock and so measurements of the helium/uranium ratio are liable to be less accurate than measurements of the lead/uranium ratio.

The foregoing is a very simplified account of the general principles underlying time measurements by radioactive methods. All the many technical difficulties and various corrections have purposely been omitted in this survey.

Some of the more important results are given in Table V.

TABLE V

Mineral	*Locality*	*Geological period*	*Age in millions of years*
Pitchblende	Colorado	Tertiary	58
Pitchblende	Bohemia	Carboniferous	215
Cyrtolite	New York	Ordovician	350
Kolm	Sweden	Cambrian	440
Bröggerite	Norway	Pre-Cambrian	860
Uraninite	Manitoba	Pre-Cambrian	1,980
Pegmatite	Rhodesia	Pre-Cambrian	2,640

These ages and other similar ones provide the time scale in Figure 45.

The use of heavy carbon as a means of measuring relatively short time periods—less than 70,000 years—will be discussed below when dealing with the age of late Pleistocene materials. (See page 136.)

4. The phases of the Pleistocene Ice Age

4.1 *Geological Considerations*

It was in 1909 that Penck and Brückner published their now famous work *Die Alpen im Eiszeitalter* in which, from a study of glacifluvial gravel terraces and "spreads" coupled with terminal moraines in upper Swabia, north-east of Lake Constance, they announced their conclusions that the Pleistocene Ice Age could be divided into four separate epochs. These they named from the earliest to the most recent, Günz, Mindel, Riss and Würm—the Mindel-Riss interglacial period being about four times as long as either of the other two. Furthermore the Würm epoch could be sub-divided into three minor oscillations of which the Bühl—the largest—was preceded by what is now called the last or Eemian Interstadial. In a similar way studies along the peripheral edges of the Scandinavian ice sheet have been made by Wahnschaffe and Schucht and by Zeuner who again found evidence for at least four major advances of the ice. These have been named respectively Teylian, Elster, Saale and Warthe with the Weichsel corresponding to the Bühl. This nomenclature is still in a state of flux. The farther north evidence is sought, the more difficult it naturally becomes to identify separate phases.

In England, for example, two phases are clearly marked by the two curved ridges of moranic debris convex to the south marking terminal snouts of glaciers in the Vale of York. The most southernly is the famous Escrick moraine and the more northerly passes almost across York City. These are accompanied by two major and distinct superimposed layers of boulder-clay covering the Holderness plain. The interglacial period is marked by gravel deposits which, at a depth of about 50 feet, separate the two boulder-clays. Above these there is another but less marked boulder-clay—the Hessle or purple boulder-clay—which indicates a third and more recent phase of the Ice Age. From evidence based mainly on animal remains, the lowest boulder-clay is usually considered

to be contemporary with the Mindel epoch, the upper with the Riss and the Hessle boulder-clays with the Würm epoch. On the other hand some authorities prefer to consider all the clays as more recent and to coincide with the Riss, Early Würm and Bühl phases respectively. The Mindel might then be identified with the patches of boulder-clays to be found at high levels on the chalk wolds of the East Riding. In any case, three and not four phases can be distinguished at this latitude in England. Pleistocene glaciers did not reach further south in England than an undulating line joining South Wales to south of the Wash. South of this line coombe-rocks take the place of boulder-clays. Coombe-rocks are cemented sub-angular flint or limestone gravels mixed with sandy lenticular seams without any marked signs of stratification. They are the products arising from alternate or seasonal freezing and melting of screes on the slopes of chalk downs and limestone hills. The whole process is generally termed "Solifluction". When exposed by quarrying, the sections usually show two distinct layers separated by seams of sand or fine gravel. The upper coombe-rock is often covered with a stoney brick-earth. From the remains of contemporary animals and occasional un-worn flint implements, the three deposits can be correlated with the Riss, Early Würm and Bühl glacial oscillations.

In countries south of the ice cap, excessively wet periods occur which exhibit four major fluctuations. In Africa these are usually named Kageran, Kamasian, Kanjeran and Gamblian pluvial periods—beginning with the earliest. That these African pluvial periods were more or less contemporary with the European glacial epochs is generally agreed, but the physical explanation is as yet very uncertain. The fact that when there is much cloud the earth is screened from the sun's radiation and therefore becomes cooled whilst the clouds precipitate more rain is a much too simple an explanation even though the statement is correct. In the north the result would be snow and ice and an advance of the northern glaciers, whilst in the south where the average temperature would be too high for freezing at ground level, the result would be a pluvial period.

Another related factor is the periodical variation in the shore-line and the formation of raised beaches as the sea retreats or the land is elevated. Presumably the sea would retreat when the waters became locked up as ice and the shore-line would become lower (glacial eustasy). On the other hand when the land becomes covered with ice, the weight would tend to depress the land and the shore-line would become higher (glacial isostasy). In other words as ice begins to accumulate, is the lowering of the shore-line due to the lack of water greater than the elevation of the shore-line due to the depression of the land? By studying the fauna and unabraded flint implements in the gravels of raised beaches and river terraces, correlations have been established between the beach levels and glacial and interglacial epochs. For example, the Würm glaciation with its mammoth, reindeer, certain arctic voles and shells and a mousterian flint culture is correlated directly with the 50 foot raised beach. Other similar correlations have been obtained for the 15 foot, 100 foot and 150 foot beaches; these with the 50 foot beach being the four clearly recognized raised beaches around the southern shores of this country.

The general conclusion has been reached that with a glacial period there is an

exposure of the beach or a lowering of the sea-level and the beach becomes habitable by man and animals. Conversely, an interglacial period is accompanied by a rise in the sea level relative to the land. From these conclusions it follows that the increase in ice formation is more effective in withdrawing and locking up water from the sea thereby lowering the sea level, than is the weight of ice in pressing down the land and thereby raising the sea level. There is also a time lag between these two effects. The complications and difficulties of the whole problem of the relationships between glacial periods and raised beaches—the problem of glacial eustasy and isostasy—can only be appreciated by detailed studies of several localities. Such studies are as yet only in their infancy.

In general, therefore, there are three interrelated phenomena—glacial epochs, pluvial periods and raised beaches. Before considering possible causes and, in particular, specific datings for these fluctuating events, some further important results of recent detailed investigations must be considered. For many years geologists had recognized the fact that in relatively recent times there has been a great ice age—this fact becomes obvious after a walk in the Lake District, in the Holderness plain or in Scotland. But it was not until 1909 that the four main divisions with the three interglacial periods were generally accepted as a better picture of what happened in northern Europe than the original idea of one long ice age. Still more recent and detailed studies have led to the recognition that all the three cold epochs which preceded the Würm are themselves divisible into two cold periods separated by what are generally known as interstadial phases. Evidence for this fine resolution of the glacial oscillations is only to be found in countries which, by virtue of their relatively southern latitudes, quickly experienced the effects of minor climatic variations. Consequently such finer gradations cannot be seen in the boulder-clays or coombe-rocks of this country. However, during the past thirty years and with the help of more specialized and refined techniques, the present idea of the fluctuations of the Pleistocene Ice Age may be summarized by saying that there were four major cold epochs each broken by a warmer interstadial period with the exception of the last which had two interstadials, whilst the main cold periods were separated by interglacial periods of which the middle one was about three to four times as long as the other two. These conclusions are based entirely on geological field studies without reference to any possible physical causes. They are graphically depicted in Figure 46 which may be compared with Figure 3.

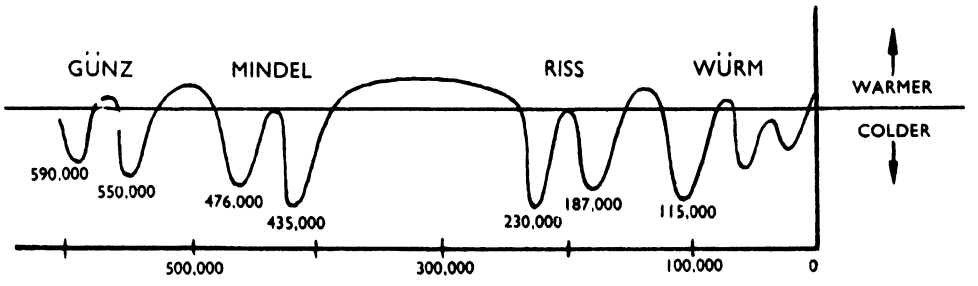


Fig. 46. The climatic fluctuations of the Pleistocene period as deduced from geological evidence.

In these figures the time scale has yet to be considered. It is based on calculations from radioactivity and astronomical measurements.

4.2 *Astronomical Considerations*

There is no evidence to suggest that the internal temperature of the earth has fluctuated as it has cooled. Causes of fluctuations in the earth's climate must therefore be sought in possible changes in the amount of radiation received from the sun. There are three astronomical phenomena which taken together might effectively explain the climatic variations deduced above from geological considerations. These phenomena are: (i) the path or orbit of the earth round the sun, (ii) the tilt of the earth's axis relative to the plane of its orbit, and (iii) the variation in the tilt of the earth's axis. These three phenomena are known as perturbations and their values at any given time can be determined. Because they vary with time, they change the amount of radiation falling on any given part of the earth's surface. Consequently, superficial and temporal changes in the earth's climate are produced. It is only very recently that Milankovitch[1] and others have succeeded in calculating the combined effects of all three perturbations. As a result it is now possible to see how the constant radiation from the sun has been received in varying amounts by a given part of the earth's surface during the past million years of the Pleistocene period. In order to appreciate the complicated and difficult nature of the problem, it is necessary to say a little more about the three perturbations.

(i) The orbit of the earth round the sun is not circular but elliptical with the sun at one of the foci. Consequently the distance of the earth from the sun varies from a minimum when at the perihelion to a maximum at the aphelion. At the former the intensity of the sun's rays would be greater than when the earth was farthest away at the aphelion. A seasonal variation of temperature will therefore result. The difference between the minimum and maximum distances of the earth from the sun varies with the eccentricity of the orbit and this changes periodically with a frequency of 92,000 years. Consequently the relative duration and temperature variation of the seasons changes accordingly: the summer being shortest and hottest when the perihelion distance is smallest, and vice versa.

(ii) The tilt of the earth's axis relative to the plane of its orbit is not at the present time 90 degrees, but is about $64\frac{1}{2}$ degrees. The angle between the earth's equatorial plane and the plane of its orbit is known as the obliquity of the ecliptic. The axis at the present time is tilted in such a way that the northern hemisphere is leaning towards the sun when the earth is farthest away, that is when the earth is at the aphelion. The sun's rays will be most effective on that part of the earth's surface which is facing or tilted towards the sun. Consequently, the northern hemisphere does not at present benefit from the earth's position when at the perihelion as it otherwise would. That is, the variation of temperature between summer and winter in the northern hemisphere will be relatively small whilst the seasonal variation in the southern hemisphere will be more extreme. The value of the obliquity determines the position of the thermal equator relative to the geographical equator and so affects the latitudes of the various temperature zones. The obliquity changes with a period of almost 40,000 years.

[1] *Astronomische Mittel zur Erforschung der erdgeschichtlichen Klimate.* Handb. Geophysik 9. pp. 593–698. 1938.

(iii) Besides the variation in the obliquity with time, the earth's axis rotates with a conical movement known as the precession. Its effect is to alter the cardinal points very slowly. This means that the north or pole star is not quite fixed in the sky as seen from the earth but has a small circular movement with an effective period of about 21,000 years. Because of its effect on the apparent positions of the perihelion, the aphelion and the equinoxes, this perturbation is known as the Precession of the Equinoxes. The spring and autumn equinoxes are the positions on the earth's orbit where the earth passes from aphelion to perihelion and from perihelion to aphelion respectively. They are fixed at the ends of the line passing through the sun at right angles to the major axis of the earth's elliptical orbit.

It is now apparent that the three perturbations, eccentricity of orbit, obliquity of ecliptic and precession of equinoxes with their different periodical variations will continue to give very curious and complicated temporal variations of the earth's climate. At times they may all combine to increase or reduce the radiation received at a given latitude; at other times they may partly reinforce or partly interfere with each others effects. Because of the obvious difficulties of combining mathematically the effects of these perturbations, further details will not be considered here. Approximate results for places on latitude 65° N. are depicted in Figure 47. In this graph minor fluctuations

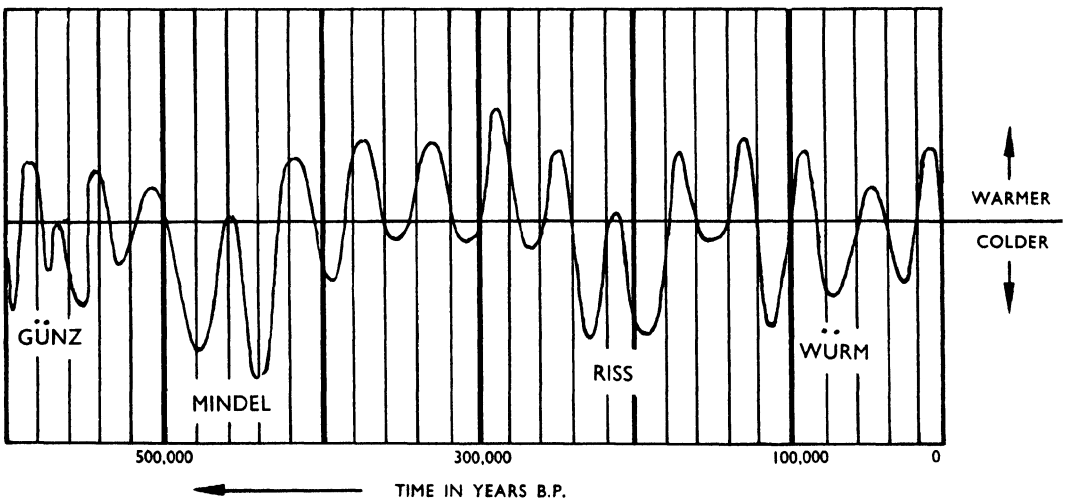


Fig. 47. Variatons in received solar radiation at latitude 65° N during the Pleistocene period according to astronomical evidence.

have been omitted for clarity. Nevertheless the figure gives a correct impression of the major climatic variations that have occurred during the Pleistocene period as calculated from perturbation theory. It is however important to realize that quite small changes in the relative phases of the three perturbations can produce large changes in the relative intensities of the several peaks of the resultant oscillation. It is easily possible, for example, to introduce a glacial peak in, say, the middle of the Mindel-Riss interglacial period.

4.3 *Comparison of Geological and Astronomical Results*

The first thing that strikes one on comparing Figures 46 and 47 is their truly remarkable similarity. The several phases—two cold oscillations for the Günz, Mindel and Riss glaciations and three for the Würm with a long Mindel-Riss interglacial period—as determined by the geologists are completely supported by the astronomical evidence as calculated by the mathematicians. Here then is our time-scale with which to measure the abscissae values of the human skulls and artifacts discussed in the previous chapters. Our problem is reduced to determinations of the climatic conditions which prevailed when the particular man was alive or when the artifact was made. The problem is complicated by the fact that it will be necessary to distinguish between the several cold and warm periods. How this can be done will be discussed below.

The comparison of the geological results with the radiation calculations is sufficiently close to imply a casual connexion between the two. If this conclusion is justified, the astronomical calculations when extended beyond 600,000 years B.P. should yield evidence for the absence of any very marked Ice Age since early Permian times. (See Fig. 45.) Unfortunately the calculations become more and more unreliable as the time gets longer, and conclusions beyond a million years based on perturbations are not yet possible. Furthermore, although the effects of perturbations may be and are sufficient to account for relatively recent climatic variations, other and more potent causes would have to be taken into consideration when attempting to determine the general periodicity of the major Ice Ages. That they are mainly related to periods of orogenic activity and probably less to fluctuation in received solar radiations seems to follow from Figure 45. However this may be, the agreement between Figures 46 and 47 provides us with the time scale we require for abscissae measurements covering the relatively short time of man's existence on the earth.

How to place prehistoric relics on the time scale will now be considered.

5. Indirect methods of dating

If it can be established that a bone or artifact has been in a given geological horizon since the beginning of its history, then the age of the deposit and of the bone or artifact can be considered to be the same. Similarly, if the bone or artifact is found with other bones or artifacts under circumstances which show that they have always been together in close association, then it is fairly safe to conclude that all the objects were deposited together. There are thus two different indirect methods for dating bones and artifacts:

5.1—to determine the date of the deposit in which they were found *in situ* and

5.2—to determine the date of closely associated remains.

5.1 *The Dating of Geological Deposits*

Geological deposits may have (*a*) a structure which indicates that they have varied rhythmically or periodically with time or (*b*) they may have changed continuously at irregular intervals with time. Seasonal layers in a lake bed which filled in winter and dried up in summer would be an example of the former, whilst a cave deposit which

gradually accumulated with time would be an example of the latter. The stratigraphy of the deposits is thus different in the two cases and the methods of dating such deposits varies accordingly. Most deposits are mixtures of these two extremes. That is, the sequence of layers is neither periodic nor continuous, but like the boulder-clays of the north or the gravel terraces along river valleys, the deposits show a series of layers of unequal thickness each with different characteristics. Their nature and order in a given sequence is often the clue to their date.

(*a*) *Rhythmic Deposits.*—The layers of a periodic deposit are generally known as "varves", and varve analysis is rapidly becoming a powerful weapon for dating geological deposits which are not older than 10,000 years. The idea of counting varves occurred to Baron Gerard de Geer[1] in 1878 when he was studying the Swedish glacial deposits, some of which were laminated. Such laminations are called "varves" in Swedish. He assumed the layers were due to the alternation of summer melting and winter freezing with a subsequent deposition of fine sandy particles from the melted ice. It was, of course, necessary to have a situation such as a quiet lake or very slowly running stream for the deposition of the particles. This occurs in the waters ponded between a glacial snout and its terminal moraine and sometimes in the waters of a deep pothole in the bed of a slowly moving intermittent cave stream. Laminated clays are formed in both these situations and by counting the laminations, *if* they have been continuously forming to the present day, the age in years of a layer at any depth in the deposit can be determined. If the deposit ceased forming at any time, then obviously the age of a given layer can only be determined prior to the cessation of deposition.

In some cases the date of the overlying deposit may be known, in which case the absolute dating of the varves is also known. For example, at Meiendorf in Holstein a well recognized and datable Magdalenian settlement containing worked reindeer antlers and typical flint implements is overlain by a peat which can be dated by pollen analysis (see below). Immediately underlying the Magdalenian settlement is a glacial varved clay. The approximate date of the top varve is therefore just pre-Magdalenian. A count of the varves then enables the bottom varve and therefore the commencement of climatic amelioration to be determined.

The problem of comparing the varves at one site with those at another site perhaps in another country is not easy. Nevertheless successful cross-references have been made by a comparison of occasional abnormalities. These may consist of peculiarities common to a group of varves or as Sauramo calls them "varve series", when referring to Finnish deposits. By carefully matching slight irregularities in varve thicknesses, colour, coarseness, etc., he has succeeded in obtaining cross-references to the deposits in various localities. He has, in fact, been able to get a time sequence from the present day to nearly 10,000 years B.P. Antev in North America has continued the work, and between them they have been able to verify most of de Geer's datings in spite of several mistakes in his original publications. As a result of this work a time in years has been obtained for

[1] *A Geochronology of the last* 12,000 *years.* C.R. XI. Congr. Geol. Inst., Stockholm, 1910, and also Geol. Fören. Stockholm Förk., 46, p. 493, 1924, and Geochronologie Suecica Principles, K. Svensk Vet. Akad. Handb. Stockholm 1940.

certain recent but major glacial phenomena. These times, such for example as 7900 years B.C. for the drainage of the lake ponded by the Central Swedish Moraine, or 8200 B.C. for one of the well-marked Finnish moraines, indicate that the final melting of the ice in these latitudes occurred about 8000 B.C.

Again the Maglemose (Mesolithic) culture—named after Maglemose, a peat bog near Mullerup in Denmark—belonged to a hunting and fishing folk who lived when the pine was the predominating tree. The period is usually known as the "Boreal" period which, by a combination of varve and pollen dating, is placed at from 7000 to 5000 B.C. Following this came the kitchen-midden people with the Ertebölle culture characterized by refuse mounds of the shells of oysters and other edible molluscs. These mounds occur along the sea-shores and lakes sides. The date has been determined as about 4000 B.C. to perhaps as recent as 2500 B.C. The period is generally called the "Atlantic" period during which the pine gave place to mixed forests of oak, elm, lime and hazel. (See Fig. 50). Professor Gordon Childe[1] points out that at the end of this period the incoming Neolithic farmers (food producers) overlapped with the last of the food gatherers or kitchen-midden folks.

Antev's work[2] in America has led to the conclusion that man was living in North America with extinct forms of bison and with the mammoth sometime between 10,000 and 20,000 years ago.

These conclusions all assume that the varves are annual. In some cave deposits in Yorkshire (e.g. Victoria Cave) and also in terrestrial deposits at Ipswich the periodic layers are probably due to weather or seasonal changes and are not all annual variations. Furthermore, varves in much older geological formations sometimes show periodicities which can be linked with astronomical changes. For example, Upper Devonian and Lower Carboniferous shales in Thuringia show cycles every 11 to 12 years, 23 years, 56 years and 21,000 years. The first is clearly related with the 11·4 sunspot cycle and the last with the precession of the equinoxes. The other two cycles have been noted in meteorological studies. Similarly in the Eocene formations of Colorado cycles of about 12, 50 and 21,500 years have been recorded throughout the six million years during which the deposits were being laid down. It is extremely interesting to realize that varve layer counts in deposits so different in age (see Fig. 45) and so far apart in space should both lead to the same cycles. This is extremely important when comparing geological with astronomical evidence and tends to give confidence in the two independent methods of attacking the chronological problem. Incidentally it also shows that the length of the astronomical year has remained practically constant since pre-Carboniferous times.

(*b*) *Continuous Deposits.*—Pleistocene deposits, which are characterized by a more or less continuous sequence or series of non-periodic layers, may for convenience be classified as (i) cave deposits, (ii) river terrace and raised beach deposits and (iii) general terrestrial and fluviatile deposits. Typical examples of each case will be given to show how such deposits can be dated.

(1) As an example of a cave deposit, one of the best in this country is that excavated

[1] *Prehistoric Communities of the British Isles,* Chambers, 1940.
[2] *Climate and Early Man in North America,* Early Man Conference, Philadelphia, 1937, pp.125–132.

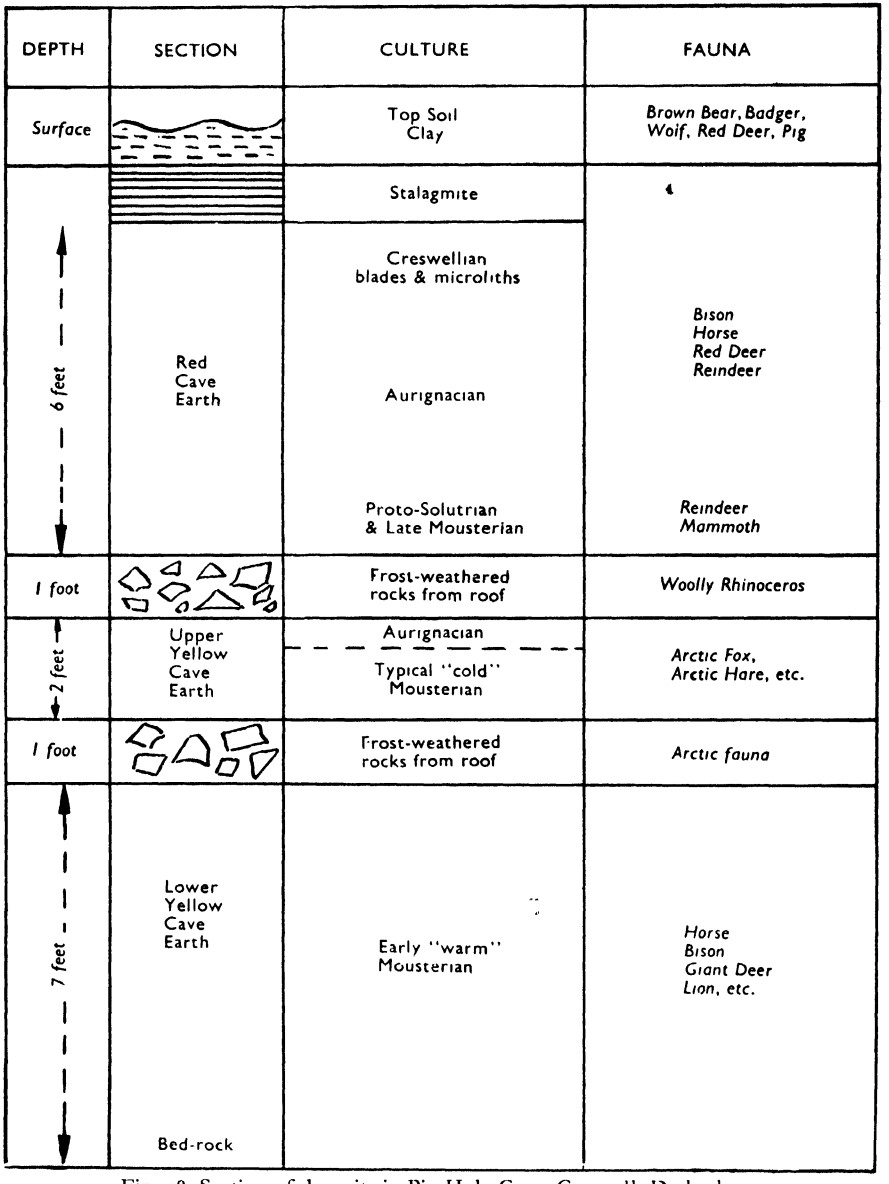


Fig. 48. Section of deposits in Pin Hole Cave, Creswell, Derbyshire.

by Leslie Armstrong[1] in the Pin Hole Cave near Creswell, Derbyshire (Fig. 48), where 17 feet of deposit disclosed a continuous series of layers straddling the Würm glacial

[1] *Excavations in the Pin Hole Cave, Creswell Crags, Derbyshire*, Proc. Prehistoric Society of East Anglia, 6, pp. 330–334, 1931.

epoch. The basal deposit consists of yellow cave earth divided into two by a layer of rocks which had fallen from the roof as a result of frost weathering. A second layer of rocks separates this yellow cave-earth from an upper red cave earth. This is sealed by a stalagmite layer which is covered by a superficial clayey deposit of relatively recent date.

The bottom layers contain horse, bison, lion, giant deer, etc., together with an early Mousterian flake industry of massive somewhat crudely made flakes similar to the early Mousterian flakes from Clacton-on-Sea. The whole fauna is comparable with that found elsewhere in the later stages of the last interglacial period. The lower layer of broken rocks contains an arctic fauna and represents a cold phase. It is followed by another relatively temperate zone. This however differs from the lowest temperate cave-earth in that the Mousterian implements are typical scrapers showing a more developed technique than the crude flakes of the basal deposits. The most interesting fact is the intermixing of this flint culture with some worked bone (including a bull-roarer) characteristic of the Aurignacian culture of the Cro-Magnon and later races. Zeuner points outs that this overlap of Mousterian and Aurignacian cultures has also been noted from deposits in the Rhine Valley.

The second or upper rock layer and the lowest foot or so of the overlying red cave-earth contain reindeer, mammoth, woolly rhinoceros, arctic hare and arctic fox indicative of another cold phase. Some late Mousterian with proto-Solutrian implements come from these cold layers. Then come animals of a more temperate climate such as red-deer and bison but reindeer antlers are also present together with a typical Aurignacian flint flake culture. Above this the climate again becomes colder and the flint culture is a blade and microlithic industry together with worked bone artifacts characteristic of Magdalenian times. It is usually called Creswellian from the fact that the Pin Hole Cave is situated in the Creswell Gorge. This industry is practically identical with some of the flints from Aveline's Hole in Somerset. The whole of these deposits are sealed with stalagmite (as is the culture in Aveline's Hole). This stalagmite probably indicates the advent of a more humid although still cold climate. If this stalagmite layer is contemporary with the last oscillation of the Wü-m epoch, then the substitution of stalagmite for frost weathered rocks is in keeping with the fact that the last cold oscillation is known to have been the least severe, a fact that is apparent from Figure 46. This correlation is justified by the fact that the earthy deposit above the stalagmite contains a relatively recent fauna including brown bear, wolf, badger, red-deer, pig, etc. Armstrong supposes that the two layers of broken rocks coincide with the first two cold peaks of the Würm epoch. This also agrees with Zeuner's interpretation which places the whole of the series from bed-rock to the stalagmite layer within the last main cold phase—the Würm.

It is interesting to compare the Pin Hole Cave with Aveline's Hole, where only one cultural horizon seems to have existed. A barren yellowish loamy clay (probably of aeolian origin) was covered with red cave-earth containing not only about 120 different faunal species but hundreds of typical late Magdalenian flints together with a necklace of perforated shells and teeth and the bone harpoon made from red-deer antler previously mentioned on page 85. In addition there were the long- and short-headed human skulls.

Throughout the deposits were scattered many broken rocks from the roof, but they did not form any defined layer separating the upper from the lower cave-earth. All these bones and artifacts were unfortunately destroyed in 1942.

As a further example of a cave deposit, the classical rock shelter near Le Moustier on the Vézère River in the Dordogne region of France may be cited. About 80 to 90 feet above the river are two rock shelters one above the other. The total sequence of cultural layers commences with the bottom stratum in the lower shelter where the bones of a warm climate fauna are mixed with large crude flake implements generally called the Levallois industry. They mark the very earliest phases of the Mousterian culture. Above this material are layers of more typical early Mousterian forms; in particular side scrapers and some small hand-axes somewhat reminiscent of the late Acheulean types from La Micoque. This typical Mousterian material is accompanied by the remains of mammoth, giant deer, woolly rhinoceros, cave-bear, bison, horse and towards the top reindeer. At the top of the lower shelter were found some disc scrapers and a few end scrapers. These are usually classed as mid-Mousterian. The upper rock shelter extended the sequence through upper Mousterian to (and including) early Aurignacian cultures. These were found in eight layers of which the Aurignacian worked bone and flints (end scrapers, awls, and some blades) were only found in the top or eighth layer. There were no hand-axes in the upper layers. These became fewer and fewer towards the more recent layers, whilst reindeer bones and antlers became more and more plentiful.

It was here that Hauser in 1908 found the ceremonial burial of a Neanderthal man.

This type station gives the complete story of the gradual development of the Mousterian flint culture accompanied with contemporary animals. The whole series of deposits straddles the Würm glacial epoch from the Riss-Würm interglacial to the Reindeer Age when Late Palaeolithic man arrived with his Aurignacian culture. The total span in years is approximately from 125,000 years B.P. to 50,000 B.P. A column of the deposits was roofed over and left standing so that visitors could examine the section and marvel at the great quantities of implements which have been left sticking out all over each horizon.

(ii) River terraces are formed when the land rises relative to sea-level. On such an occasion the river cuts a new and deeper channel leaving its original banks high and dry in the form of a terrace. This terrace can then be occupied by man and animals. It is eventually covered by superficial debris washed from the older and higher river banks or by fluviatile spreads of deposits as the terrace becomes flooded when the land again sinks. Along most of the rivers of England two or three such terraces may be seen. The lowest was formed when the land reached its maximum elevation and is now covered with recent fluviatile deposits through which the modern river has cut a new bed. Thus below the present rivers are usually to be found this lowest terrace appropriately termed the "buried channel". Reference has been made to these terraces and beaches on page 110 when discussing eustasy and isostasy. The submergence and burial of the lowest terrace is, of course, contemporary with the submergence of coastal areas once covered with forests. Remains of these buried forests can be seen at many places; for example, off Saint Audries in Cornwall and Saint Anns in Lancashire where the water recedes

sufficiently at low tide to expose the remains of broken tree trunks and decayed roots. That these submergences were post-Neolithic follows from the Neolithic and Maglemose artifacts sometimes found at low tide or by chance dredging operations. The upper river terraces are naturally older—the oldest being the highest. This is the reverse of cave deposits where the oldest is the lowest. In the course of time, the terrace platforms became covered with gravels, coombe-rocks, aeolian sands, brick-earths, etc., of which the lowest is the oldest. The basal gravels on the 100 foot terrace of the Thames and of other rivers in the south of England often contain remains of *Loxodonta antiquus*—the warm climate elephant—together with unabraded hand-axes of Acheulian man. This suggests that the 100 foot terrace gravels were first exposed as the waters became ice-bound during the Mindel glacial epoch. This lowering of the water level allowed Acheulian man of the Mindel-Riss interglacial period to live on the newly exposed banks formed as the river was cutting its deeper channel to the sea.

This correlation of the major Pleistocene interglacial with the basal deposits on the 100 foot terrace containing the artifacts of Acheulian man and a warm fauna is one of the important links which date this culture with a period somewhere between 250,000 years and 350,000 years ago. (Figs. 45 and 46.) When Acheulian hand-axes are found on the 50 foot terrace they are always more or less abraded indicating that they are "derived fossils" from an older deposit—the 100 foot terrace—from which in all probability they have been washed. In such a circumstance they are of course quite useless for correlating or dating purposes. Occasionally Mousterian implements occur on the 100 foot terraces. They are not however found in the basal deposits but usually in the lower coombe-rocks which were formed on the 100 foot terrace during the later cold phase of the Würm when the river was at the 50 foot level.

(iii) As an example of an ordinary terrestrial deposit, the section of the Mauer Sand Pit from which the Heidelberg jaw came will be considered. (Fig. 49.) The section is not simple. Its interpretation in terms of climate is more or less straightforward but the allocation of the cold phases to the four main glaciations and their sub-divisions has been and still is a matter of some controversy. The section is over 80 feet thick. The upper portion is 18 feet thick and comprises three layers of the Younger Loess separated by signs of weathered surfaces. The Younger Loess is a wind-blown sand characteristic of the cold blizzard conditions of a glacial epoch. Animal bones are scarce but shells and a few rodent bones are typical of the last (Würm) ice epoch. It is therefore natural and probably correct to assume the three distinct layers represent the three phases of this cold period. (Originally the lowest layer was classed as the upper layer of the Older Loess.) The lowest weathered surface of the Younger Loess is followed by 17 feet of the Older Loess which is separated into two layers by a weathered surface. These Older Loess deposits cover a fluviatile and sub-angular gravel characteristic of the solifluction conditions associated with coombe-rocks. This Older Loess and its basal gravels are usually considered to be contemporary with the phases of the Riss or third major glaciation. Finally, overlain by these Loess deposits is about 50 feet of stratified sands—the Mauer Sands—at the base of which the Heidelberg jaw was discovered. There is no evidence of a cold climate throughout these sands and they therefore fit into position

as representative of the long Mindel-Riss interglacial period. Thus the Heidelberg jaw belonged to a man who lived just after the second or Mindel Ice Age. He therefore lived possibly as long as 400,000 years ago (see Figs. 46 and 47), but probably 350,000 years is a more reliable figure.

As a second example of a terrestrial deposit, that banked against the southern slope of Brean Down at Weston-super-Mare in Somerset will be considered. This deposit links up with that at Mauer and extends the story up to recent times. Against the southern slopes of Brean Down a series of terrestrial gravels, sands and clays have been banked to a depth of over 80 feet. The surface slopes steeply downwards towards the south

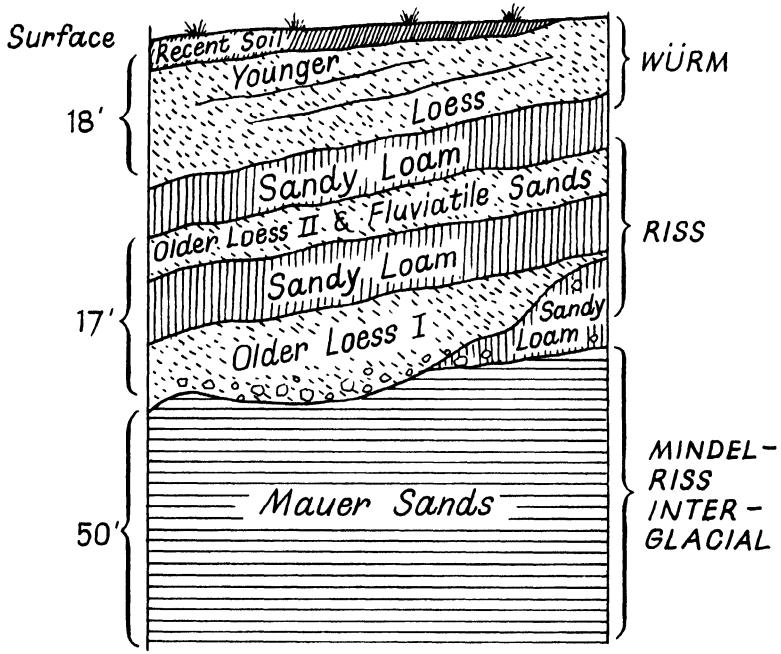


Fig. 49. Section of the Mauer Loess deposits, near Heidelberg, Germany.

where the deposits disappear below the present beach level. The section is exposed from top to bottom where the sea encroaches. The basal layer is a sub-angular limestone breccia; a product of solifluction but hardly a coombe-rock for the deposit is not cemented to any extent. This is covered with aeolian sands which constitute the major part of the section. These sands or loess are about 70 feet thick where they abut on to the Down and extend southwards for a distance of 500 yards from the foot of the hill where they pass beneath the present beach. Overlying these sands is about four to five feet of stony brick-earth with some lenticular sandy seams. These, in turn, are covered with a variable amount of humus and top-soil. The fact that all these layers dip down at a steep angle and disappear beneath the present beach indicates that the earlier shore line was much lower and the Bristol Channel dry land when these

deposits were being formed. Between the aeolian sands and the basal gravels and in the top of the gravel itself are to be found large quantities of shed reindeer antlers together with a few bones of the small horse characteristic of the last phases of the Würm Ice Age. The sands (from an analysis of their mineral content) were evidently blown from the south because they contain materials peculiar to Dartmoor. They no doubt were piled up on the southern slopes of the Down during the dry blizzard conditions which marked the close of the Ice Ages. They can be correlated with the Newer Loess of the Mauer section. Dug into the surface of the brick-earths was found a Bronze Age burial with characteristic beaker pottery. Some Iron Age sherds came from the overlying humus, together with several burials possibly of Saxon origin.

If the brick-earths represent a moderately cool period after which present day climatic conditions prevailed, then the aeolian sands must be representative of one of the interstadial periods of the Würm ice epoch. The basal gravel or pseudo coombe-rock would therefore have been formed either during the first or second cold oscillations of the last phase. There is no exposure of a lower coombe-rock to enable this point to be settled. But the usual occurrence of two coombe-rocks one overlying the other suggests that this condition may also occur here below the present beach level.[1] At a quarry further inland near Bleadon village there is a typical limestone coombe-rock formation which has yielded woolly rhinoceros teeth. The section is not sufficiently extensive to see whether a second and distinct coombe-rock is present. In any case the fauna below the loess is sufficient to date that particular horizon as approximately 10 to 15,000 years B.P.

The foregoing examples have been selected from many hundreds of sections available. It was felt desirable to avoid the more complicated and controversial sections such as those in East Anglia or the many sections of boulder-clays to be found in the northern half of England. The examples cited do however indicate how the nature of the climate can be deduced from the character of the geological deposits. Reference in passing has also been made to intrusive or "foreign" constituents such as animal bones. It will be recalled that our present objective is to determine the age of man and his artifacts by the indirect method of studying the nature of the deposit in which the remains were found *in situ*. Thence, from the nature of the deposit, to deduce the climate and finally with the help of Figures 46 and 47 to fix the date of the skeletal or material remains.

5.2 *The Dating of Associated Remains*

The second indirect method (page 114) for dating skeletons and artifacts is to determine the date of other closely associated remains. By "closely associated" is meant usually one of two things: either the skeleton or artifact is found along with other remains of known date or else the skeleton or artifact can be bracketed above and below by other remains of known date.

[1] During the past year the present exposure of the basal gravels has been re-examined by Dr. H. Taylor and Mr. A. M. ApSimon of the University of Bristol Spelaeological Society, and they have found evidence of a lower breccia separated by a sandy layer from the "basal" gravels originally exposed. This confirms the expectation that the main loess would be underlain by two separate deposits of limestone breccia.

With old geological deposits the "other remains" are usually characteristic fossils by which the particular geological horizon can be recognized. But with relatively recent geological deposits, such as the Pleistocene with which we are here concerned, the "other remains" may not have had time to become fossilized. They can be classified as (*a*) faunal remains—animal bones and molluscan shells; (*b*) floral remains—pollen micro-fossils; (*c*) "erratic" constituents.

(*a*) *Faunal Remains.*—To date a human skeleton or artifact by reference to other datable remains found in close association needs much caution. Care is necessary because the two objects to be compared may not both be *in situ* and because there may be difficulty in establishing close association. For example a skeleton in a tumulus may be contemporary with the beaker found along with it or the skeleton may be of a secondary burial of later date. Similarly a skeleton found in the gravels of a river terrace may be much more recent than a rolled and abraded palaeolithic hand-axe which was within a few inches of the skeleton. The hand-axe being a derived "fossil" could obviously not be used for dating the skeleton; and vice versa if the date of the skeleton were known by other means it could not be used for dating the palaeolith. Closeness of association is important in cases where two objects, although only a few inches apart, may nevertheless be in adjacent geological horizons of different date. This, of course, is more likely to happen with objects displaced vertically above one another than with objects separated by a horizontal distance. It is in cases of this kind that a radio-carbon or fluorine test of contemporaneity is useful. (See pages 136 and 137.)

Indirect dating by comparisons usually determines limits rather than specific or absolute dates. This follows because the dates of first appearance or of extinction of a given species of animal may be known and these dates may cover a long period of time.

We may consider for example one of the very earliest known fossils—the Trilobites. Trilobite fossils are to be found in most of the older rocks from the Cambrian to the early Permian. They lived in the seas during the interval of time which extended from the Ice Age of 450 million years ago to the penultimate Ice Age which occurred just over 200 million years ago—a period of approximately 250 million years (Fig. 45). Again, winged insects appeared in the Carboniferous geological period of 225 million years ago and have existed ever since. Similarly the earliest flying, as distinct from gliding, birds appeared in Upper Jurassic times about 130 million years ago. Primitive man-like apes occur in the late Miocene period only 20 to 30 million years ago. These apes gradually, very gradually, developed into ape-like men whose remains may yet be found in the Pliocene.[1] The earliest of such creatures recognized so far are the *Australopithecinae* who have already been discussed.

The foregoing are just a few typical examples of fossils which can be used for limited dating purposes. They are, however, of no use for dating materials contemporary with man who has only existed for about a million years. More recent fossils must therefore be sought which have very fixed and limited ranges in time if they are to be useful for dating skeletons and artifacts less than a million years old. A few of these will now be considered.

[1] See footnotes on pp. 40 and 147.

The date of an object associated with, for instance, the mammoth (*Mammuthus primigenius*) cannot be later than 15,000 to 20,000 B.P. when that animal became extinct. On the other hand, the date of an object cannot be earlier than 400,000 B.P. if associated with the warm climate elephant (*Loxodonta antiquus*). This straight-tusked smooth-skinned elephant had not definitely evolved from the unspecialized upper Pliocene *Mammuthus meridionalis* until the Mindel-Riss interglacial period.

Occasionally some species may have definite lower and upper temporal limits in a given locality either because of its migratory movements stimulated by climatic changes, or because of its limited period of existence before becoming extinct.

From whichever cause the time-limit arises, such animals are of particular value for dating purposes. It so happens that *Loxodonta antiquus* is a case in point. This creature was adapted to woodlands and a temperate climate. It survived during the Mindel glaciation because it had not become too specialized; flourished throughout the long Mindel-Riss interglacial, migrated southwards during the Riss glacial, and after becoming most prolific during the Riss-Würm interglacial disappeared from Europe before the last cold phase.

The mammoth (*Mammuthus primigenius*) also evolved from the unspecialized *Mammuthus meridionalis* and reached its highest degree of specialization by the time of the Würm epoch after which it became extinct. It became adapted to the cold steppe and tundra country. By 200,000 B.P. both species had become fully specialized and distinct—an interesting example of divergent evolution. One became adapted so that it was characteristic of the middle and upper Pleistocene interglacial phases and the other was adapted to the glacial periods.

Thus *Loxodonta antiquus* appears about 400,000 B.P., disappears from Europe during the Riss glacial epoch from 250,000 to 175,000 B.P. returns during the Riss-Würm interglacial and finally disappears about 120,000 B.P. The elephants occurring in the last interglacial can usually be distinguished from those living during the long middle interglacial by the fact that their molar teeth laminae are slightly more compressed and have more laminae per unit length of tooth.

With each of these elephants there was a contemporary rhinoceros, the teeth and bones of which are therefore equally valuable for approximate dating purposes. The *Diceros leptorhinus* or smooth-skin rhinoceros is often found in "warm" deposits along with the *Loxodonta antiquus* and the woolly rhinoceros—*Coelodonta antiquitatis* (=*tichorhinus*) frequently accompanies the mammoth.

On an entirely different scale from the elephant molars are the minute molars of the rodents known as Hensels' banded lemming (*Dicrostonyx henseli*, Hinton) and the extinct English vole (*Microtus anglicus*, Hinton). Both these voles are characteristic of the Upper Pleistocene 50 foot terrace gravels and therefore of the Würm epoch. Their limited sojourn in England makes their remains extremely valuable for dating purposes.

Another interesting example is that of the British Red Deer (*Cervus elaphus scoticus*) to which Zeuner calls attention in "Dating the Past". Remains found in this country which do not have the bez-tine cannot (as a rule) be earlier than the time of severance of this country from the Continent. That is, the antlers must be later than about 5000 B.P.

This follows because this particular peculiarity was developed since England became an island.

The ibex (*Capra ibex*, Linn) is another useful animal for dating purposes. It is now mainly confined to mountainous regions, such as the Himalayas, Alps, Pyrenees and the mountains of Abyssinia. In Late Pleistocene times it was to be found at low altitudes practically all over Europe.

As final examples shells are often characteristic of specific deposits and times. The very small barrel-like shell *Pupilla muscorum* is to be found in loess deposits and is most common in Upper Pleistocene times. On the other hand *Corbicula fluminalis* occurs in many deposits throughout the Pleistocene. The earlier forms can be distinguished by the fact that they are relatively thick-walled. The main diagnostic value of a shell of this kind is its limitation in time. It does not occur in the Pliocene or earlier periods in this country.

(*b*) *Floral Remains.*—It will be obvious that plant remains will be preserved only under abnormal circumstances. Plant fossils found in coal beds were buried before they had time to decay—a process requiring a supply of oxygen. Any circumstances which prevent the access of oxygen to fallen vegetable matter will tend to preserve the plants in recognizable form. This occurs in relatively recent times with plants which become constituents of peat beds or which become incorporated in the muds of lake bottoms. The Swedish geologist Lennart von Post first called attention to the presence of fossil tree-pollen in Quaternary deposits and how their identification can lead to a knowledge of the climatic conditions prevailing when they were blown or had fallen from the trees. The hard relatively resistant walls of pollen grains can be preserved for thousands and even millions of years. By modern techniques these grains can be isolated from the mineral matrix which has preserved them. They can then be identified under a microscope. Different kinds of pollen grains are counted and their percentage of the total is a useful method of recording their relative abundance.[1]

In this way pollen analysis has developed until it is now a powerful dating method for late glacial and especially post-glacial deposits. The method is not limited to these recent periods. Its extension to Tertiary, Jurassic and older deposits is rapidly progressing now that it has been found possible to identify these micro-fossil grains in such relatively old deposits. The most valuable evidence has however so far been obtained for peat and lake deposits dating back to not much earlier than about twenty or thirty thousand years. The main objective in pollen-analysis is to study the *changes* in the predominant trees and grasses, and so to deduce the kind of climate which has caused the decrease or increase of a given species of pollen grain. From other "foreign" inclusions such as animal skeletons or human artifacts it is comparatively easy to link up given climatic phases with distinctive cultural periods. From such a chain of evidence it is now possible to date the successive layers of a peat bed by studying the varying sequences of pollen grains.

As an example of the use of this method, the work of H. Godwin[2] on the Pickering Vale glacial lake deposits in East Yorkshire and on the peat moors of Somerset

[1] Owing to its prolific quantity of pollen, the hazel is usually excluded from the total and treated separately.
[2] *Pollen Analysis.* New Phytologist 33, pp. 278–305, 325–358, 1934, and other papers in later volumes.

are of considerable interest. Pollen analysis has provided the earliest known date of the Maglemose settlers in this country. Godwin was able to fit the pollen data from a Maglemosian lake settlement into the whole series obtained from the ancient Pickering lake bed. The position is shown in the lower portion of Figure 50. The upper post Bronze Age deposits have been washed away from the Pickering Vale, but these missing sections appear in the Somerset peat beds. The Somerset section (from Decoy Pool Wood)

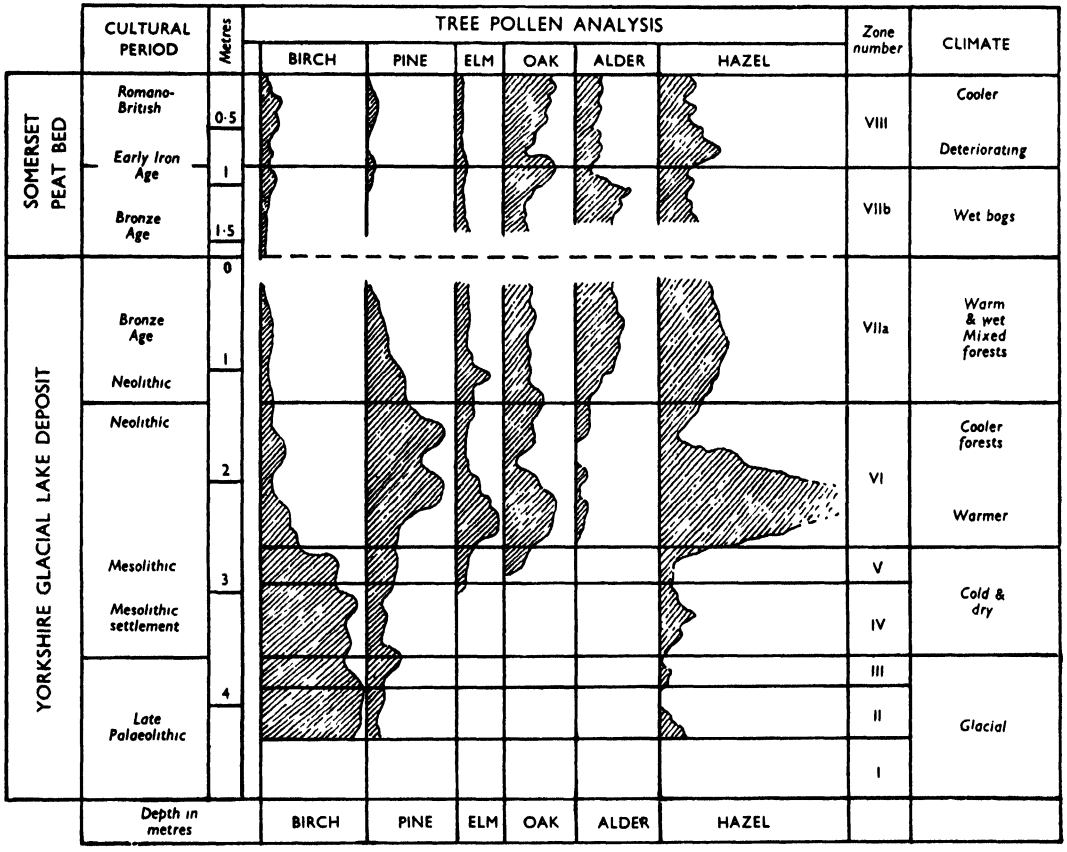


Fig. 50. Pollen analyses—Pickering Vale lake deposit and Somerset peat beds (*after* H. Godwin).

is therefore added at the top of Figure 50 to the same vertical scale as for the Yorkshire deposits. Several other points of interest follow from this figure. The sudden disappearance of birch together with an increase in the elm and oak forests and a very marked increase in hazel indicates a decided amelioration in the climate as the glacial epoch passed away. The increase in pine forests with a decrease in elm, oak and hazel shows clearly a minor cold oscillation. This is followed by warm and wet conditions and an abundance of trees of most kinds. Confirmation of this growth of forests arises from the increase in forest animals such as deer of all kinds, pig, beaver, forest horse, ox, etc. A similar

sequence of deposits is to be found in the Holderness "carr" lands, where the upper peats in the neighbourhood of the River Hull contain enormous blackened tree-trunks and roots. They are so plentiful as to effectively prohibit ploughing. The trees are mainly oak intermixed with alder and hazel and a few elms—a closed forest group which is indicated by the upper part of the Pickering Vale section and by the Somerset peat beds. (Fig. 50.)

The upper Somerset section is most noticeable for the marked deterioration of the climate at the transition between Bronze and Early Iron Age times—a deterioration which occurred all over Europe. It defines the boundary between zones VII and VIII at about 500 B.C. or somewhat later in England.

Besides the value of pollen analysis for fixing climatic zones, it can also be used to determine man-made changes in the distribution of trees. Iversen, working in Denmark, was able to show artificial forest clearances in Neolithic times. He detected ashes from the hearths of Neolithic shore settlements accompanied by a sudden and local disappearance of tree pollen coupled with an increase in cultivated cereal grasses and plantains. The ashes were from burnt oak trees which were replaced by hazel and alder when the locality was abandoned by the Neolithic settlers. For these relatively recent times the radiocarbon method of absolute dating is also very effective. This method is discussed below.

Before leaving the method of pollen-analysis, mention must be made of the important discovery that the last interglacial was accompanied in Europe by an increase in the number of hornbeams in the deciduous forests. This fact was recently used to check the suggestion that certain Cambridge gravels were of the Riss-Würm interglacial period. The strictly limited time during which hornbeams were plentiful makes the pollen-count a valuable dating method for this particular interglacial period.

(*c*) "*Erratic*" *constituents*.—The name "erratic" is applied to rocks which have become incorporated with a deposit and are not a constituent part of the deposit itself. In this sense all fossils are "erratic", but the term is usually confined to rocks which have been conveyed by and in glacial deposits as the glaciers moved from one location to another. The occurrence of erratics is therefore usually limited to the boulder clays—the "boulders" being the erratics in question. Erratics are seldom found in the coombe-rocks because these solifluction deposits have not travelled appreciable distances and consequently have not had an opportunity of collecting "foreign" materials. Occasionally, however, erratics are to be found in river terrace gravels but their original location is not farther away than the upper reaches of the river. They are not of much use for dating purposes.

Referring back to the boulder-clays, it has already been pointed out that there are at least two well marked and distinct boulder-clay deposits. In the north-east of England the lower boulder-clay often contains erratics from Norway such as syenites, gneisses, etc. They are to be found in greatest quantities in the lowest parts of the clay. The upper boulder-clay contains rocks from the north of England and from Scotland. These rocks have not only travelled a shorter distance than those from Norway but have come from a more northerly direction. Amongst the erratics from the upper boulder-clays of the Holderness Plain are to be found such rocks as volcanic sills from Whitby, granite from Shap, limestone from the Pennines and Yorkshire Moors together with occasional lumps

of chalk from the local Wolds. Chalk is the chief erratic constituent of some of the East Anglia boulder clays, as a consequence of which they are generally known as the Chalky Boulder Clays.

Many of the harder erratic rocks show parallel scratches and a high polish characteristic of ice action. The polish is quite distinct from that caused by wind-blown sands or by running water.

Thus the identification of erratic constituents enables the deposit (and other remains *in situ*) to be dated. This follows because it is known which particular glacial phase is responsible for transporting the given erratics. For example, Shap granite and limestone erratics are often found with walrus tusks and mammoth teeth all characteristic of the Würm glaciation. On the other hand teeth of the warm climate elephant (*L. antiquus*) are occasionally found in the intervening gravels which usually separate the two lower boulder clays. Other similar warm faunas occur on the 100 foot raised beaches which, like these particular interglacial gravels, are usually considered to be contemporary with the Riss-Würm interglacial epoch.

Erratics are occasionally to be found at the base of aeolian or loess deposits. They take the form of small wind-blown polished rocks (wind-pebbles). They are here classed as erratic rocks, not because they have been transported by the wind-blown sands, but because they have become buried and incorporated with the sand particles. These erratics often have very smooth (but not sharp) edges, which meet to form wedges or tetrahedral angles. The sides are highly polished when the rock is fairly hard and homogeneous, but sometimes becomes pitted when the rock is composed of grains of varying hardness, as, for example, a granite. Erratics of this type are often to be collected from the tops of old glacial moraines. They are—like the most recent or Younger Loess deposits—characteristic of the closing phases of the Würm epoch when dry blizzard conditions prevailed about ten to fifteen thousand years ago.

At Clevedon in Somerset and along the south coast of Hampshire and Sussex sandy layers of this nature with occasional wind-blown erratics overlie the upper coombe-rocks. Bones of horse and wolf sometimes accompany the wind-blown erratic rocks in loess deposits, whilst in Moravia the remains of men, artifacts and animals were completely buried by many feet of the Younger Loess. (See pages 59 and 86.)

6. Direct methods of dating

Occasionally prehistoric bones and artifacts become isolated from their original surroundings and may have to be dated without reference either to the deposit from which they came or to any other closely associated remains. Abraded flint hand-axes that have been washed into a recent brick-earth or animal bones from a cave in which the sequence of deposits has been upset by badgers or by earlier (or present) untrained and unguided excavators cannot be dated by any of the indirect methods discussed in Section 5 above. Such objects are virtually or actually separated from just those very locations and materials by which they might have been dated. In such cases the article or bone must be dated entirely from its appearance or type. It has to be compared with

other similar articles or bones of the same type, the date of which has already been determined by one or more of the indirect methods. The study and identification of an object by comparative methods of this kind is known as Typology. When an undated article is found to be similar to or identical with a type specimen, then any information deduced about the former obviously depends on just how much is known about the latter. Typology is the first of the Direct Methods by which isolated objects may be dated. The method is discussed more fully in Sub-section 6.1 below.

A second direct method for dating depends on whether or not the article to be dated has any physical characteristics which change in a known or measurable way with time. For example, the colour of flint implements often changes (due to burial) from the dark blue of newly broken flint to the yellowish ochre colour seen on many old palaeoliths from river gravels. Alternatively, relatively recent flints, when subject to exposure on the surface, usually change to a dirty white colour. These colour effects are known as "patina" and the process is one of "patination". Unfortunately flints do not patinate in a regular measurable way and consequently this physical change can only be a qualitative guide—and an unreliable one at best.

Many artifacts and all bones and vegetable matter contain radio-carbon, and they may also have absorbed other materials (in particular fluorine and uranium) from their surroundings. The quantities of radio-carbon and absorbed materials usually change with time in a known and measurable way. Consequently appropriate measurements of these substances should enable the date (absolutely or relatively) of the artifact or bone to be determined. Some physical dating methods of this kind are discussed in sub-section 6.2 below.

6.1 *Typology*

It is obviously necessary to consider the typology of skeletal material separately from that of artifacts.

(*a*) *Typology of bones.*—Two problems are presented when a bone is submitted for identification; namely, to what animal does it belong and from what part of the body does it come? To answer these questions a wide knowledge of anatomy is necessary together with much experience. It is quite beyond the scope of this book to deal with so vast a subject. Even when the bone has been identified, there still remains the difficult problem of dating it. This involves the whole subject of comparative anatomy. Some indication of the necessary procedure has been given in Chapter II where some anatomical indices were discussed. Dating depends on the identification and measurement of selected indices which are known to have changed with time. To do this easily and readily a whole set of anatomical or physical development/time graphs similar to those given in Chapter V would be necessary. From them or rather from the particular graphs appropriate to the bone under identification, the time in years could be read off directly given the measured value of the ordinate; that is, the measured value of the particular index or indices. Hitherto there has not been enough data to enable such graphs to be drawn and consequently measured indices have had to be compared with isolated examples of similar bones. The date can then usually be computed from a knowledge of the dates of

the specimens used for comparison. Qualitative, in addition to quantitative, comparisons are also desirable to check and verify first conclusions.

As an example of the process involved, suppose one was given a few broken laminae from a mammoth's tooth. That it was part of an elephant's molar would probably be fairly obvious with very little experience. It would then have to be compared with modern African and Indian species and finally with prehistoric examples. The closeness of the laminae (probably over thirty to a foot) and the absence of marked nicks or V-shaped notches at the middle of the grinding surfaces of the laminae would differentiate the tooth from those of very early elephants. It would then probably be possible to identify it as a mammoth's molar and to date the specimen to perhaps the beginning or end of the Würm glacial epoch but not more precisely than that. Additional experience and comparisons would enable one to say whether the tooth was from the upper or lower jaw and possibly how old the elephant was; but these additional facts would not help towards dating the specimen.

In a similar way a human femur could be differentiated from that of an ape and then dated by comparison with other prehistoric specimens of the same sex. The platymeric index (see page 57), the general curvature and other morphological peculiarities would all help to determine the species.

The date could then either be read directly from an anatomical index/time graph for femora or could be determined from any graph or table connecting dates and species.

Additional tests such as the degree of fossilization, the amount of residual fat (if any), the presence of a stalagmite coating, the inclusion of identifiable foreign matter or minerals will all assist in checking the date deduced by other methods.

(*b*) *Typology of Artifacts.*—Methods of dating isolated artifacts will vary with the nature of the artifact. Most artifacts to be dated will be identified either by the material from which they are made or by the function they were designed to fulfil. Thus we may refer back to Chapter III and think of the materials used by man or of the occupations upon which he was engaged. In all probability both aspects of a given artifact will instinctively be considered together in the process of identification. For convenience it will be assumed that the material is identified first. In most cases artifacts will be made from one or more of the following: stone, bone (including ivory), wood, bronze, iron, other metals, glass, pottery, fabric. This preliminary identification may serve to put certain limits to possible dates for the use of the particular material in a given country. For example, any bronze article made in England cannot be older than about 1900 B.C. but of course may be of any age later. Other dates for the first appearance of these materials are given in Chapter III.

Having identified the material, the function of the article can next be considered. It is here that a detailed typological knowledge is necessary—especially with such substances as stone, the use of which has extended over hundreds of thousands of years. As stone gradually became used for different purposes, so the type of implement changed. The typology of stone implements is a study in itself; a fact that is readily appreciated by comparing Figures 32 to 38 (excluding Fig. 37). The nomenclature of flint implement typology is both complicated and changing. Originally the main distinctive types were

named after the French sites at which the type was first recognized. Later, when similar but slightly different forms were found in other countries, new names were given to the type found in the particular country. Perhaps the simplest way to deal with this problem is to tabulate the different cultural names relative to the Ice Ages with which they are associated. (See Table VI.) Thus, for convenience of tabulation, the four European Ice Ages and four African Pluvial Periods have been treated as though they were contemporary, although this is not yet proven. Examples of the cultures printed in italics are depicted in the six figures in Chapter III to which reference has been made above.

Bone implements were probably used at least as early as Mousterian times and bowls from human skull caps have been found where Neanderthal man has indulged in a cannibal feast. But any skilled work in bone did not develop until late Aurignacian and Magdalenian times. The ability to execute life-like carvings of animals on bone and to make double-edged barbed harpoons from reindeer and red-deer antlers seems to have declined during the transitional period between the old and new stone ages. Maglemosian men certainly made long single-sided barbed harpoons and bone needles and fish-hooks but left behind no evidence of the artistic ability shown by the Magdalenians. Later the Neolithic peoples only used crudely sharpened bone points and wedges such as those found in the lowest layers of Ulrome Lake Village in East Yorkshire. Although Bronze Age tribes undoubtedly worked bone, there is little evidence of any great skill or specialized techniques. In early Iron Age times there was a revival of bone artifacts of all kinds including weaving and hair combs, beads, buttons, needles, potters' tools, antler hammers, toggles, bobbins, etc. With comparatively little experience it is therefore possible to date bone artifacts with reasonable precision.

This cannot be said of wooden implements and weapons because of the perishable nature of the material. Wooden articles preserved in bogs and lake beds may be of Mesolithic date but are generally not much older than 2000 or 3000 years B.C. Early Iron Age wooden articles are more plentiful and show evidence of skilled turning and joinery with iron carpentry tools of comparatively modern design. The dating of wooden objects is consequently a relatively simple task.

Bronze weapons and implements, although limited to a period not older (in England) than 1900 B.C., have been classified by Peake and others into types with fixed time limits for their manufacture and use. For example the development of the bronze axe has been traced from the Neolithic polished stone counterpart through successive stages to the highly developed hollow or socketed axe with a side loop for tying it on to a haft. (Fig. 51.) The earliest flat bronze copy of the stone axe appeared at the beginning of the Bronze Age and was still used until about 1700 to 1600 B.C. when, in the middle Bronze Age (1600 B.C. to 1000 B.C.), it was replaced by a winged axe or palstave. This weapon had a stop-ridge against which the split ends of the bent haft could press when the axe was used. As the wings became wider and bent further round the haft so the centre portion lying between the split halves of the haft became less useful. The introduction of a side-loop together with the enveloping wings eventually led to the omission of the centre portion (the body of the original flat axe) and did away with the necessity of splitting the haft. Thus by about 1000 B.C. the hollow or socketed axe with a solid haft evolved.

TABLE VI

Stone Implement Cultures

Geological Periods →	Pleistocene								Holocene
Ice Ages →	Günz		Mindel		Riss			Würm	Post Glacial
Europe	—	Eoliths	—	Abbevillian or *Chellian* / Clactonian / *Acheulian*	—	Levalloisian / Late Acheulian / Micoquian / Early Mousterian	*Mousterian* / *Aurignacian* / Solutrian / *Magdalenian* / Azilian		Maglemosian / *Neolithic* / Bronze Age / Iron Age
Asia	—	—	—	Early Soan / Choukoutien	Soan	Tayacian / Acheulian / Micoquian	Mousterian / Aurignacian / Atlitian / Capsian		
Pluvial Periods →	Kageran		Kamasian		Kanjeran			Gamblian	
Africa	Kafuan / Oldowan		Chellian / Early Acheulian	Middle Acheulian	Early Levalloisian / Late Acheulian / Hope Fountain	Fauresmith / Sangoan / Tayacian	Late Levalloisian / Mousterian / Still Bay / Capsian / Magosian		
Approximate Time in Years →	600,000		450,000		200,000		100,000		20,000

It had the advantage of a stronger haft and an economy of metal. This type of axe was accompanied for the first time with a striking rather than a thrusting sword—a possibility arising from the manufacture of a more flexible and less maleable bronze. These improvements were characteristic of the Late Bronze Age of 1000 to 500 B.C. The chronology of the bronze axe was worked out by Peake and others in England and by Montelius in France. They naturally differ because the Bronze Age invaders to England

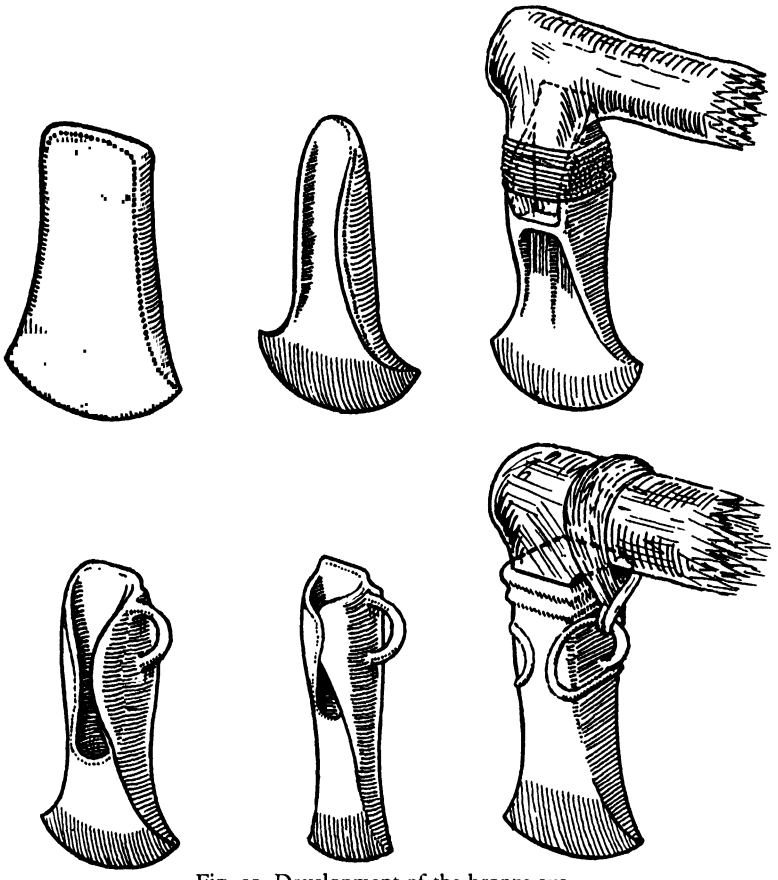
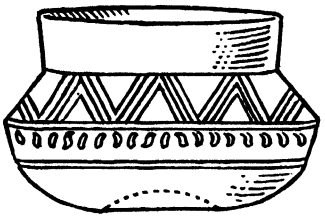


Fig. 51. Development of the bronze axe.

introduced improvements in East Anglia and Kent which were already in use on the Continent. The time lag is between one and two hundred years.

Iron objects in this country have already been discussed briefly in Chapter III and the chronological problem for the relatively short period prior to the Roman invasions is not a difficult one. The common divisions into Hallstatt, La Tène and Belgic cultures are sufficiently adequate for most purposes; the dividing lines being about 220 B.C. and A.D. 20 in England. Sub-divisions of these main periods have been undertaken by various authorities some based on the typology of the iron sword, some on pottery and one on

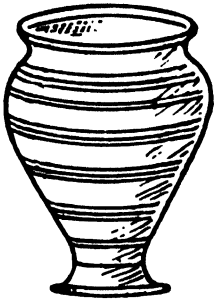
EARLY IRON AGE



Hallstatt A

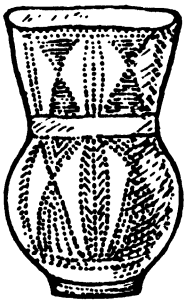


La Tene B



Belgic C

BRONZE AGE



Early

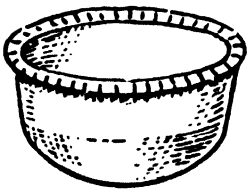


Middle



Late

NEOLITHIC



Windmill Hill A



Peterborough B

Fig. 52. Various types of prehistoric pottery.

the development of the bronze fibula. These specialist studies certainly enable more precise dating to be made when the sword, pot-sherd or pin is presented for identification but associated articles in such relatively short periods of time may well have been made in an earlier period. Consequently, it is not safe to date articles in this way however close the association.

In England pottery appears for the first time about 2500 B.C. and recognized changes in paste, form and technique enable dating to be carried out with some precision. As with all artifacts, experience gained by handling many different examples gives an appreciation of significant but inconspicuous details which can never be conveyed by word or picture. One of the chief practical difficulties when attempting to date a pot-sherd is the variation from one locality to another of both materials and workmanship during the same period of time. An outstanding instance is the coarseness of texture and crudity of workmanship of Early Iron Age pottery from the lake villages of Yorkshire compared with the artistic merit and skilful manufacture of the contemporary ware from Glastonbury Lake Village in Somerset. It is convenient and sufficiently exact for

TABLE VII

Characteristics	*Period*	*Date B.C.*
1. Bucket-shaped vessels and pedestal foot vases. Wheel-turned with horizontal ring markings. Imported Arretine red ware.	Early Iron Age C. Belgic	B.C./A.D.
2. Rose-bowl shaped vessels with Celtic curvilinear and scroll ornament. Black ware bonded with crystalline grit.	Early Iron Age B. La Tène	220
3. "Duck" stamped or finger impressions on rough hand-shaped pots with flattened rims. Red haematite coated ware. Omphalos bases. Angular profiles.	Early Iron Age A. Hallstatt	500
4. Barrel and bucket shaped urns. Deverel-Rimbury type urns.	Late Bronze Age	1000
5. Food-vessel collard-urns and small perforated "incense" cups.	Middle Bronze Age	1600
6. Beaker with chevron and straight-line decorations. Herring-bone pattern and dotted line markings.	Early Bronze Age	1900
7. Round bottomed flanged bowl. Possibly thumbnail or cord pattern markings.	Peterborough or Neolithic B	2200 (?)
8. Round bottomed straight edged bowl. Hand moulded.	Windmill Hill or Neolithic A	2500

most purposes to divide the prehistoric pottery of this country into eight main classes which correspond, not surprisingly, to eight invasions by peoples from the Continent. Characteristic pots together with the name and date of their period are listed in Table VII, and examples illustrated in Figure 52.

Besides the few general characteristics outlined above, there are masses of other details connected with the kind of paste, baking technique and peculiarities of ornamentation which justify sub-divisions of the later main periods. Most of these recognized sub-divisions, particularly of the La Tène period, are not however based on pottery characteristics but mainly on variations in bronze ornaments, particularly brooches.

6.2 *Physical Measurements*

The three physical methods which will be discussed here for the absolute dating of artifacts are the radio-carbon method, the fluorine method and the uranium method. These will now be considered in this order.

(*a*) *The Radio-carbon Percentage.*—The fundamental principle underlying all radioactive dating methods is the constancy of the half-life period of all disintegrating atoms. This was discussed in section 3 on page 107. Dr. W. F. Libby[1] in America realized that all vegetable and animal matter contained carbon and that all carbon in nature consisted mainly of a mixture of two isotopes—one stable and one radioactive or unstable. Consequently old dead vegetable and animal matter would have a smaller amount of the unstable isotope per unit weight of stable carbon than new live matter, which would have the same percentage of radio-carbon that is normally found in the air. This follows because live vegetable matter absorbs carbon from the air in its "breathing" process, and animals feed on vegetable matter either directly or indirectly. Consequently all live matter contains carbon with the ratio of radio-carbon to stable carbon equal to the ratio normally found in the atmosphere. It happens that the half-life period of radio-carbon is 5570 years according to the most recent measurements. Hence any given initial amount of radio-carbon will be halved in this number of years, and reduced to one quarter in twice this time, to one eighth in four times 5570 years or 22,280 years and so on. It is difficult to measure the very small quantity of radio-carbon compared with stable carbon after about 40,000 years. This is because of present technical difficulties in measuring very small percentages of a radioactive isotope in a mixture in which the major constituent is stable. Consequently the radio-carbon method of measuring the age of a bone of an animal which lived 50,000 years ago will not be very accurate. However, for shorter times the method is proving extremely valuable and improved techniques will, in due course, no doubt extend the method up to periods of perhaps 100,000 years.

Before considering some recent results, the reason for the persistent existence in the atmosphere of radio-carbon—an *unstable* isotope—will be explained. In Section 6 of this chapter it was stated that one of the three constituent particles of all atoms was the neutron. High speed isolated or free neutrons are always present in the atmosphere of this earth especially in the upper reaches of the stratosphere. They are part of the cosmic rays which exist in the "empty" spaces of the universe. When these high-speed neutrons

[1] *Radiocarbon Dating*, 1952.

strike an atom of atmospheric nitrogen they bury themselves in the nucleus of the atom and so turn the normal nitrogen atom into a heavy radioactive isotope. This atom at once commences to disintegrate or break down into a heavy isotope of carbon and a normal atom of hydrogen. An atom of normal carbon in the atmosphere contains six neutrons and six protons in its nucleus. Radio-carbon contains eight neutrons and six protons, and is therefore known as carbon-fourteen or ${}_6C^{14}$, where the upper figure refers to the total number of nuclear particles and the lower one refers to the number of protons (the nuclear electric charge). There is therefore a continual increase of ${}_6C^{14}$ due to its creation from disintegrating radio-nitrogen atoms and a continual decrease due to its own disintegration. In the course of time a steady balance or equilibrium is reached resulting in a constant or fixed amount of radio-carbon in every cubic foot of atmosphere. As a result of this equilibrium there is a constant but extremely small ratio of radio-carbon to stable carbon in the atmosphere. The ratio is about one billioneth (10^{-12}). Therefore this same ratio also occurs in all live matter which absorbs directly (as vegetable) or indirectly (as animal) atmospheric carbon in the process of living. As soon as plants and animals die, the process of absorbing carbon ceases but the disintegration of the radio-carbon in the plant or animal continues. Thus, because the disintegration process takes place with a known constant half-life period, it is possible to measure the percentage of radio-carbon to stable carbon and so calculate the time in years since the death of the plant or animal; presuming of course that at least a few grams of the plant or animal still remain for analysis. Peat bog plants may exist for several thousands of years and animal bones for periods much longer than the 50,000 years for which the radio-carbon method of dating is at present suitable.

The method has been applied with considerable success to such diverse objects as cotton cloth from Peru; wood from a Ptolemaic Egyptian coffin, from old Sequoia trees in California and from a Maglemose settlement in Pickering Vale, Yorkshire; burnt bone from La Madeleine rock-shelter, charcoal from Lascaux caves in France and a piece of mammoth tooth from an arctic plant bed at Ponder's End near London. The approximate dates[1] for these seven examples are as follows:

	Years B.P.
1. Peruvian cloth	1550 and 1850 (different sample)
2. Egyptian coffin	2200 (Ptolemaic—2280)
3. Sequoia tree	2720 (mean) (Tree Ring count 2928)
4. Maglemose wood	9000 and 10000
5. Magdalenian bone	11100
6. Lascaux cave charcoal	15500
7. Mammoth tooth	> 20000

All these values are subject to plus or minus corrections of a few hundred years.

(*b*) *Relative Fluorine Content.*—The fluorine method depends on the fact that bones and some artifacts absorb fluorine at a more or less regular rate when buried in deposits containing fluorine. The material—hydroxyapatite—of the bone combines with fluorine to form fluorapatite, the amount of which can be determined per gram of bone. Because

[1] Zeuner—*Dating the Past.* 3rd Ed., pp. 329 and 344-5.

different deposits contain different amounts of fluorine, the method is unreliable for comparing measurements on bones from one site with measurements made on bones from another site. Consequently, fluorine tests are only useful for comparing the ages of different bones from the same site. However, if fluorine is present (as is usually the case with most Pleistocene deposits) then the percentages of fluorapatite present are approximately:

2 to 3 per cent for Lower and Middle Pleistocene bones,
0·5 to 1·5 per cent for Upper Pleistocene bones, and
0·05 to 0·3 per cent for Holocene bones.

For example Dr. K. P. Oakley[1] obtained values of the order of a few per cent with bones from the interglacial gravels on the 100 foot terrace of the River Thames but only one twentieth of this amount with bones from post-glacial gravels.

When this order of difference arises between two bones both from the 100 foot terrace gravels, then it is fairly safe to conclude that the bone with the smaller fluorine content is a post-glacial or secondary inclusion. Similarly if the two bones had come from a post glacial gravel deposit, then the bone with the higher fluorine content would, in all probability, be a recently derived fossil washed from an older gravel.

To this extent the fluorine test can be of considerable value in deciding whether or not closely associated bones are in fact contemporary or otherwise.

(*c*) *Relative Uranium Content.*—In the same way that buried bones absorb fluorine when conditions are suitable, so they will also absorb uranium when exposed to water containing uranium salts. The absorption process is in all probability a chemical one, and takes place more readily in bones buried in sand or gravel than in bones which have been preserved in limestone breccias or clay deposits. Also the waters in some localities contain uranium salts in much greater quantities than the waters from other sites. Consequently there is a great variation in the radioactivity from absorbed salts in bones of the same age that have been derived from different localities. Absolute dating is therefore impossible, but relative dating of bones of different ages from the same locality is a useful method of checking conclusions based on fluorine absorption tests. Dr. C. F. Davidson and S. H. Bowie, who developed the uranium assay technique, state that in spite of the large variations in radioactivity of contemporary bones, there is a "marked and progressive build-up in the average radioactivity of the fossils from the older strata". This is shown very clearly by the following figures taken from their paper.[2]

RADIOACTIVITY OF BONES FROM SANDS AND GRAVELS

Deposit	*Average count*
Old Red Sandstone	1250
Cretaceous	800
Miocene and Pliocene	225
Lower Pleistocene	60
Middle Pleistocene	32
Upper Pleistocene	11
Holocene	< 1

NOTE—The "average count" depends upon the rate of disintegration of the uranium and on the amount of uranium absorbed. This, in turn, depends on the time of exposure to the uranium contaminated water.

[1] *Fluorine and the relative dating of Bones.* Adv. Sci., London. 4 (16) pp. 336–7.
[2] Procs. Geol. Soc. of London—Vol. CXVI, Sept. 15, 1954.

This uranium method is as yet in its infancy but is likely to prove most valuable for confirming tentative dates based upon geological evidence. The method has the advantage over the fluorine method in that no material is consumed or destroyed in the process of measurement.

7. Summary

In this chapter some general considerations concerning geochronology are followed by a discussion on the formation of the earth's crust in remote times and the climatic

TABLE VIII

Cultural Period		Name of Skeleton		Location	Geological Period Time in Years A.D. or B.C.	
Present Day		Modern European	*Homo sapiens*	England	20th Century	Holocene
Recent History		Merchant citizen		England	18th Century	
					A.D.	
					B.C.	
Early Iron Age		Early Briton (Celt)		Glastonbury	250	
				Lake Village, Somerset	500	
Bronze Age		Round Barrow Man		S.W., N.E., S.E. England	1900	
Neolithic		Long Barrow Man		Chelm's Combe, Somerset	2500	
Mesolithic		Wadjak		Java	8000	
Late Palaeolithic	Azlio- Tardenosian	Aveline's and Cheddar Man		Aveline's Hole, Burrington Coombe Cheddar, Somerset	15,000	Upper Pleistocene
	Magdalenian	Chancelade		Dordogne, France	30,000	
		Predmost		Czechoslovakia		
	Aurignacian	Cro-Magnon Combe Capelle		Dordogne, France	50,000	
Middle Palaeolithic	Mousterian	*Homo neanderthalensis*		La Chapelle aux Saints, Correze, France	70,000 to 100,000	
	Tayacian	*Pithecanthropus solensis*		Solo River, Java		
	?	*Homo rhodesiensis*		Broken Hill Mine, Rhodesia, Africa		
	Levalloiso-Mousterian	*Homo neanderthalensis*		Mount Carmel, Skhūl	150,000	Middle Pleistocene
	Early Levalloisian			Tabūn, Palestine		
	Late Acheulian			Steinheim, Würtemberg, Germany	200,000	
Early Palaeolithic	Clactonian	*Pithecanthropus pekinensis*		Choukoutien, Pekin, China	250,000	
	Acheulian (?)	*Homo heidelbergensis*		Heidelberg, Germany	350,000	
	Abbevillian	*Pithecanthropus erectus*		Trinil, Java	400,000	Lower Pleistocene
	?	*Pithecanthropus modjokertensis*		Sangiran, Java	500,000 (?)	
	?	*Australopithecus africanus*		Sterkfontein, Africa	>600,000	
—		*Proconsul africanus*		Kenya, East Africa	*c.*30,000,000	

changes which accompanied it. An account is then given of the method of measuring the ages of rocks by their radioactive properties.

Discussion is then restricted to the Pleistocene period. The geological evidence for the detailed phases of the Pleistocene Ice Age are next considered and compared with the conclusions deduced from astronomical evidence. The main fluctuations of temperature are then dated in years by reference to the variations in received solar radiation.

Methods of dating skeletons and artifacts are divided into Indirect and Direct. The former include a study of stratigraphy (varves, cave deposits, river terrace deposits, etc.) and the use of fauna (elephants, voles, shells, etc.,) and floral remains as dating fossils. Pollen analysis is outlined in connexion with floral micro-fossils. The Direct method of dating deals with the typology of bones and artifacts and then discusses radio-carbon measurements, the fluorine test and the uranium method. In Table VI the nomenclature used in the typology of flint implements is accompanied by approximate dates in years B.P. for the different classes of implements. Table VII on page 135 gives the eight main classes of pottery together with dates B.C. Some results from the three physical methods of dating are given in sub-section 6.2.

Finally the table on page 139 collects together the skeletons listed in Table II on pages 66–67, the cultural periods of Table IV on page 101 and tabulates them in Table VIII with reference to the dates in years that have been the subject matter of the present chapter. Table VIII provides the abscissae for the ordinate values given in Tables II and IV for anatomical indices (I) and cultural criteria (C) respectively. The three tables can now be used together to produce the physical development/time and cultural development/time graphs; the subject matter of the next and last chapter.

CHAPTER V

Changes with Time

1. The data

THE position has now been reached when four particular anatomical indices have been determined for about twenty skulls and an estimate has been made of the antiquity of each skull in years. Similarly four cultural criteria have been obtained for eight different periods, the approximate dates of which have also been determined. Because the skulls in Table II and the cultural periods in Table IV have been arranged for convenience in chronological order, it has already become apparent that the two sets of measurements vary in quite different ways as the years have progressed. That there is a marked difference between the rates of physical and cultural development has been realized for a long time and has been discussed by many anthropologists and prehistorians; especially by Professors J. B. S. Haldane and F. E. Zeuner in England and by Professor M. F. Ashley Montague in America. But such discussions must of necessity be somewhat limited by the difficulties inherent in the measurement of time rates of change. Until the past few years there has been a great paucity of skeletal material and a lack of knowledge of the rates and causes of geological changes and associated climatic fluctuations. The first difficulty has been overcome to a considerable extent by the many recent discoveries of the skeletons of early man in Africa, China and Java, and the second difficulty has been enormously reduced by the recent geochronological investigations of Professor Zeuner.

It seemed therefore that the time had come when it might be possible to undertake measurements of evolution; the quantitative study of which has been advocated by both Haldane[1] and Zeuner.[2] The collection of data summarized in Table IX from the foregoing chapters has been carried out with the object of depicting graphically and quantitatively how man has evolved. Even with these figures before us, it is not possible by merely looking at them to see clearly their many implications, nor is it easy to make deductions directly from them. But graphs disclose at once the rates and changes of rate in man's development in a way that no tabulated data could possibly do.

2. The graphs—accuracy

The four graphs of physical development are given in Figure 53. The ordinates are the figures in Table II and the abscissae have been obtained from Table VIII. These are reproduced in columns 2 to 5 and column 1 respectively in Table IX.

[1] *Suggestions as to the quantitative measurement of rates of evolution.* Evolution 3, pp. 51–56, 1949.
[2] *A discussion of time-rates of evolution*—Procs. Linnean Soc. of London, Session 162, Pt. 2, pp. 124–130, 1951.

TABLE IX

ABSCISSAE	ORDINATES							
YEARS B.C. (Table VIII)	ANATOMICAL INDICES from Table II				CULTURAL CRITERIA from Table IV			
	I_1	I_2	I_3	I_4	C_1	C_2	C_3	C_4
Present Time M	100	100	100	100	180 or 275	700+	2000	100
Present Time A	60	78	81	52	—	—	—	—
Present Time C	24	32	27	6·7	0	0·7	—	—
Recent History	—	—	—	—	50	50	50	56, 50
500	96	96	98	—	25	17	33	29, 23
1,900	—	—	—	—	20	16	20	26, 15
2,500	99	100	103	98	13	11·5	17	16, 11
8,000	—	—	104, 110	50, 58	—	—	—	—
15,000			97	94	—	—	—	—
30,000	—	—	106	79	9	5	10	10, 9
50,000	98, 91	94, 85	111, 106 106, 95	71	—	—	—	—
75,000	70, 57, 76	56, 50, 63	107 74, 86 97	55	—	—	—	—
100,000	—	—	—	—	6·5	3·5	0	7, 4
150,000	91 77 83	100 83 95	104, 85	71, 56	—	—	—	—
200,000	67	71	73	—	—	—	—	—
250,000	58	67	74	60	—	—	—	—
350,000	—	—	—	54	2	2	0	6, 6
400,000	51	54	61, 52	—	—	—	—	—
500,000	—	—	—	53	—	—	—	—
600,000	78	62	30 to 40	81	?	0·7	—	—
20,000,000 P	35	41	(25)	32	0	0·7 ?	0	—
	← Fig. 53 →				← Fig. 54 →			

M = Man, A = Australian aborigine, C = Chimpanzee
P = Proconsul africanus

Figure 54 shows the four cultural development graphs plotted from the figures in Tables IV and VIII, which are reproduced in columns 6 to 9 and column 1 respectively in Table IX.

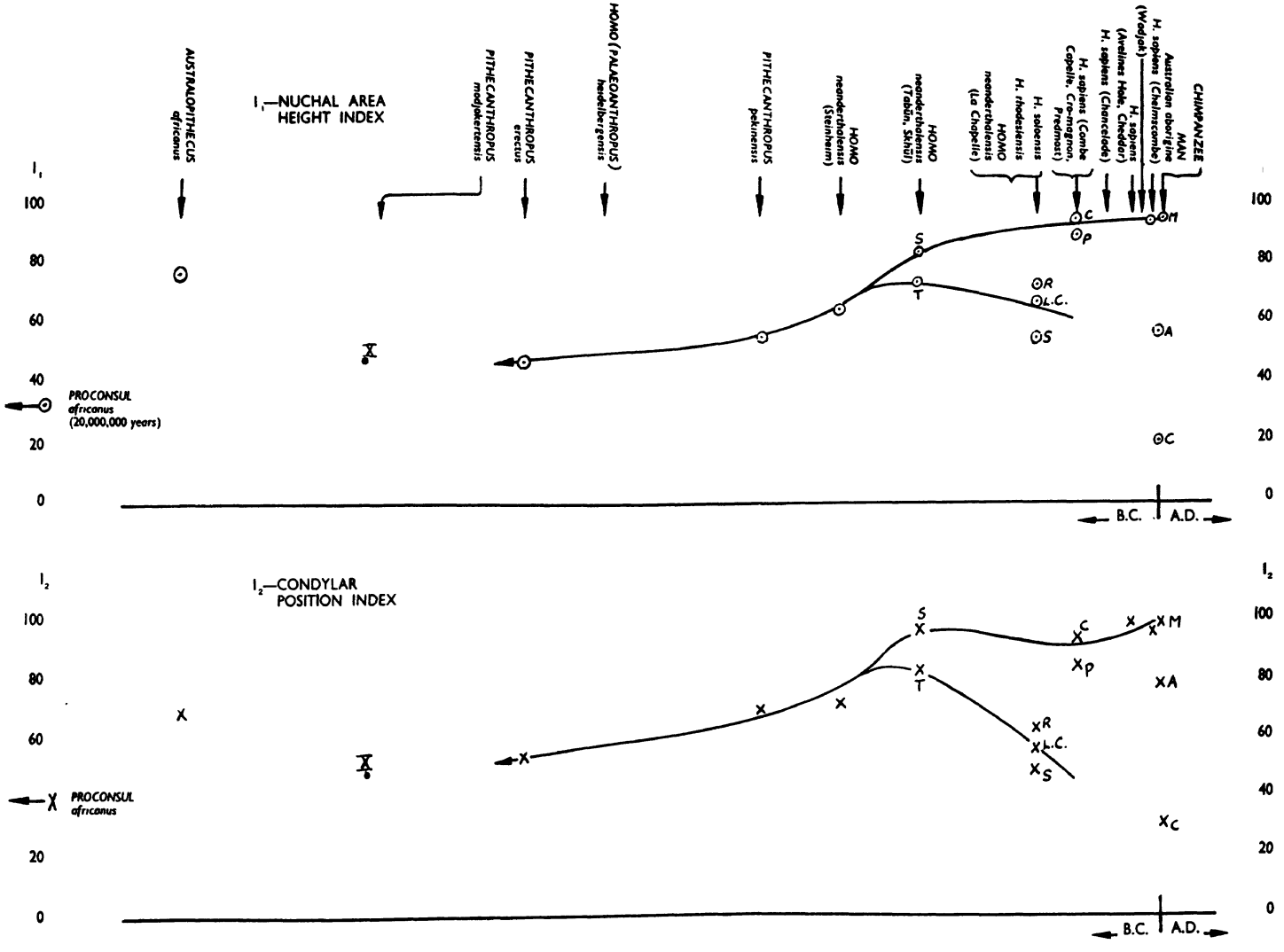
Before discussing these eight graphs, the question of their accuracy and reliability will be considered. Referring first to the physical development/time graphs, in spite of the obvious difficulties in obtaining measurements of the anatomical indices (or I ordinates), it was felt desirable to obtain the data in the best way available even though it was realized that no great accuracy could be claimed for the resulting figures. These difficulties were discussed in section 6 of Chapter II. Furthermore it is felt that, although greater accuracy of measurement in the future would move the points on the graph up or down, their positions relative to each other would be changed but little. Consequently deductions based on the absolute values (single ordinates) may need modification but deductions based on relative values in general and on gradients (or slopes) in particular will be reliable. This is important because by far the most valuable and interesting deductions are dependent only on relative values and gradients.

The determination of the abscissae value in years is a less serious source of error, because of the fact that the graphs in Figure 53 all run more or less parallel to the abscissae axis. Thus if, for example, *Pithecanthropus erectus* should have been plotted at 500,000 or 300,000 B.C. instead of at 400,000 years as indicated in Figure 53, then the gradient of the graphs would have been slightly decreased or increased respectively without affecting the general deductions which can be made from them. As will be seen, this point has much more important implications in the cultural development/time graphs now to be considered.

In the case of the ordinate and abscissa values of the cultural development/time graphs, the position of any point can be allowed to vary very considerably if by so doing the point is only moved *along* the graphs. This arises because of the kind of curve that has resulted by plotting the data from Tables IV and VIII.

In Figure 54 all four graphs are almost horizontal for the more remote times and are almost vertical for recent times when plotted to scales similar to those used in Figure 53. Thus a "point" for the Early Palaeolithic period could be almost anywhere between 600,000 B.C. and 200,000 B.C. during which time the ordinate values hardly vary at all. This means that the accuracy of the big values of the abscissae is a matter of little concern. Fortunately it is just these big values that can be obtained only very approximately. The ordinate values for these remote periods must be more accurate. But because they vary only between 0 and 3 for times up to 200,000 years and only reach 5 by 50,000 years, this requirement is easily fulfilled by the very small values of the ordinates involved.

These arguments are reversed for the vertical part of the graph. That is, it matters little whether the *ordinate* values are only approximate, but the abscissae must be more accurately obtained. Again this is precisely what can be done. The very large cultural ordinate values for historic times could vary from a hundred or so to a few thousand without affecting arguments based on the steepness of the graph. Also it is for the more recent times that the figures in years B.C. can be most accurately obtained. These


I1—NUCHAL AREA HEIGHT INDEX
I2—CONDYLAR POSITION INDEX
AUSTRALOPITHECUS africanus
PITHECANTHROPUS modjokertensis
PITHECANTHROPUS erectus
HOMO (PALAEOANTHROPUS) heidelbergensis
PITHECANTHROPUS pekinensis
HOMO neanderthalensis (Steinheim)
HOMO neanderthalensis (Tabūn, Skhūl)
HOMO neanderthalensis (La Chapelle)
H. rhodesiensis
H. soloensis
H. sapiens (Combe Capelle, Cro-magnon, Predmost)
H. sapiens (Chancelade)
H. sapiens (Ehringsdorf, Cheddar)
H. sapiens (Wadjak)
H. sapiens (Chelmscombe)
Australian aborigine
MAN
CHIMPANZEE
PROCONSUL africanus (20,000,000 years)
B.C.
A.D.

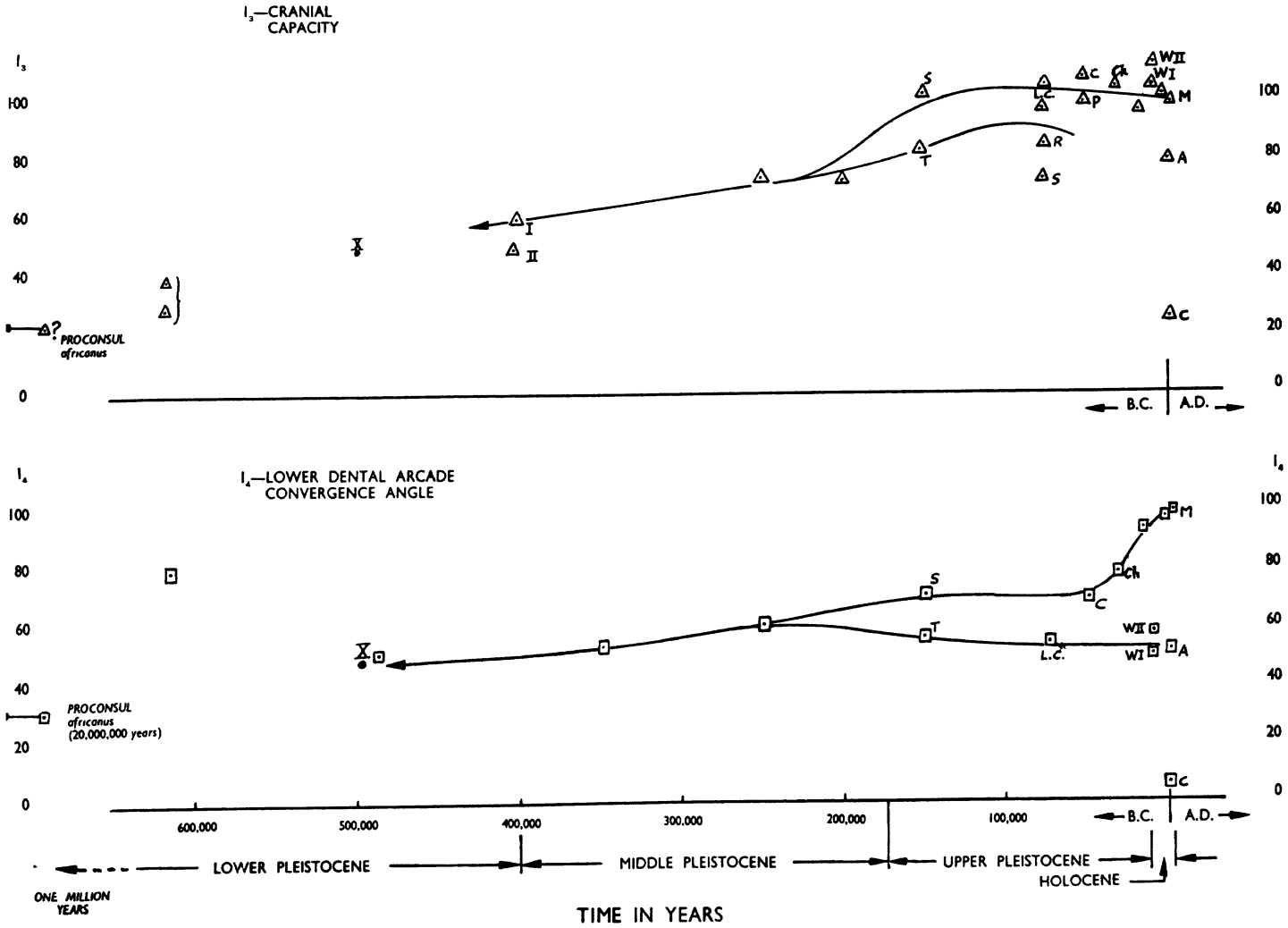


Fig. 53. Physical development/time graphs.

considerations were pointed out in the previous chapters, but it is only after the graphs have been plotted that their real importance can be readily appreciated.

It is also for this reason that it was believed that the grading experiment used for obtaining the last curve in Figure 54 would probably be successful. When times were allocated to the statistical values obtained by analysing the figures obtained from educated opinions, it was found that where opinions varied most the variation mattered least. That this belief was justified seems to follow from the fact that the C_4/time graph is quite similar to the other three cultural development/time graphs—a fact not without considerable psychological interest.

It is therefore with some confidence that we can proceed to interpret the graphs in spite of the short-comings in the absolute value of the ordinates and abscissae.

3. Man's physical development

3.1 *Limitations of the Graphs*

The first point to emphasize is that the joining of a series of points which relate to different skeletons and species does *not* imply a genetic relationship between the several skeletons. The graphs are not genealogical "trees" but merely a time-sequences of certain anatomical indices. The fact that all the graphs are initially (for remote times) only single lines does not therefore enable one to deduce any ortho- or mono-genetic theory for Man's evolution. Ideally graphs of this kind are required for each separate genus or branch of a genealogical tree, but there are not enough skeletons to provide the data for such graphs. Only when a very large number of skeletons from many localities becomes available will it be possible to decide whether man has descended from one form of early Primate (the Monogenetic Theory) or from several different Primates (the Polygenetic Theory). In the latter case separate physical development/time graphs will be necessary. In other words, the single line graphs for the earliest periods in Figure 53 do not disprove Klaatsch's Digenetic Theory because they are not related to that particular problem. When sufficient skeletons become available it may be possible to obtain separate graphs for the orang-utan—Asiatic and for the gorilla—Negro lines both possibly originating from different primitive apes in different localities. But this cannot yet be accomplished.

3.2 *Major Deductions—rate of Physical evolution*

There are three major and four minor deductions which follow from Figure 53. The first major deduction follows from the remarkable and unexpected similarity of the graphs; the second is based upon the extrapolation of the graphs backwards through time and the third deduction concerns the gradual increase in ordinate values with time (apart from several small but important deviations discussed below).

(1) The first point—the similarity of the graphs—is particularly interesting especially when it is realized that of the four indices chosen, three of them relate to quite different hominid characteristics. The interpretation of this general similarity seems to be that man developed his hominid characters (or at least his erect posture, large brain and

ability to speak) more or less contemporaneously although not all at the same rate in recent years. This very general deduction needs qualifying when more detailed variations, such as the very early erect posture of the Australopithecinae, are considered. Such details are discussed in the paragraphs on minor deductions in sub-section 3.3 below.

(2) Secondly, the steady rise in all four graphs is the graphical representation of some law of development. Assuming as a first approximation that the graphs are rectilinear, then man's humanity, as judged from the four chosen indices, seems to have increased by about 1 per cent per 10,000 years during the past half a million years. This applies to each of the graphs since they are roughly parallel. But in view of the difficulties of the measurements, it is surprising that all the graphs should so closely approximate to this same result. Assuming this constant rate for half a million years, it follows that the values of each of these anatomical indices of humanity would be 50 per cent at 500,000 B.C. These points are marked x in Figure 53 and they all lie very close to their respective graphs produced backwards to this date—an interesting confirmation of the fact that this law can be applied as a rough measure of evolution throughout the past 500,000 years. The slight convexity of the graphs towards the axis of abscissae means that this rate of development gets less and less as the time gets more remote.

Consequently, the foregoing law of physical development will need to be modified for periods exceeding 500,000 years. The curvature of the graphs as determined by only a few points does not justify any more exact analysis. But it is certain that a reduction of humanity by a further 10 per cent would take several millions of years and the next 5 per cent many more millions of years as the curve begins to get more and more horizontal. An estimate of the order of 20 million years all together may not be far wrong. The percentage of humanity would then be 35. This is about the mean value of the indices ($I_1 = 35$, $I_2 = 41$, $I_4 = 32$) recorded in Table II for the primitive ape *Proconsul* which lived perhaps 20 to 30 million years ago in the Miocene period.

It is therefore very tempting to extrapolate the graphs backwards in the direction of the arrows and find that they would pass very close to the ordinate values of the *Proconsul africanus*. These values are shown for reference on the left-hand edge of the graphs.

This does not mean that man has ascended (or descended) from this primitive Miocene ape, but it does mean that he could have done.[1]

(3) The third major deduction concerns the slopes of the graphs.

The value for the rate of evolution obtained above on the assumption that the graphs are straight lines sloping upwards to 100—the ordinate value for modern man—is of course only justified because all the four graphs are more or less parallel. The value obtained of 1 per cent per 10,000 years is curiously enough the value of a unit suggested by Professor J. B. S. Haldane (see footnote 1 on page 141) as an appropriate one for measuring evolutionary rates. He suggested the name of a "*darwin*"

[1] In this connection it is interesting to note that the I_4 value for *Oreopithecus bambolii* of the Lower Pliocene is very close to that of *Proconsul* as far as can be measured on the much distorted jaw of the former. This suggests that men and apes had not greatly diverged, even ten or twelve million years ago. But according to Hürzeler's reconstruction of *Oreopithecus*, I_4 would be only about 20; thus making this beast a link between *Proconsul* and the apes and definitely not ancestral to man. (See Figure 4 and p. 40.)

and defined it as a rate of evolution in which the measured characteristic changes by one thousandth in 1,000 years. This is the same rate as 1 per cent in 10,000 years which seems to be about the value for man. Put in a slightly different way the lines joining the points X to M on the graphs of Figure 53 all have a gradient of one darwin. To justify this statement and the calculations made from these graphs some ancestral relationship between *Pithecanthropus erectus* and modern man must be assumed. This condition is more easily satisfied for very remote skeletons rather than for more recent ones where the chance of a divergent form with a different evolutionary rate is greater. Weidenreich made this same assumption when calculating the evolutionary rate of man from the skulls of *Pithecanthropus pekinensis* (then called *Sinanthropus pekinensis*) and modern man. He obtained the value of 0·62 darwins for the index skull length/skull height. He also assumed that Pekin man lived 500,000 years ago. This figure is now generally thought to be too big and *Pithecanthropus pekinensis* (with Clactonian type implements in association with a warm interglacial fauna) is not thought to be much earlier than 300,000 years. Accepting this as a maximum value and using Weidenreich's measurements, the re-calculated rate of evolution becomes 1·03 darwins as a minimum value. This compares very favourably with the figure of 1.0 darwins obtained from Figure 53. The rate is extremely rapid compared with that for most animals which have existed on the earth for a much longer time than the million years during which man has been developing. For example, Haldane measured the increase in tooth length of the Mesohippus compared with the Hyracotherium—two extinct primitive horses. He calculated the evolutionary rate as 0·036 darwins assuming the interval of time was sixteen million years. Haldanes's calculations (and those of Weidenreich) are based on the assumption that the dimensions or values of the index vary exponentially with time. That is, the curvature of the time graphs is taken into account. If some dimension L is being measured, Haldane assumes that $L_2 = L_1 e^{\alpha t}$ where L_1 is the initial value, L_2 the final value and t the interval of time during which the value L_1 increased to L_2. α is then the evolutionary rate. For example, suppose we take the figures in Table II for the skull capacity of modern man (1480 c.c.) and that for *Pithecanthropus pekinensis* (1075 c.c., Weidenreich) and the time interval of 300,000 years. Then we have:

$$1480 = 1075\ e^{\alpha\, 300{,}000}.$$

This gives

$$\alpha = \frac{\log_e 1480 - \log_e 1075}{3.10^5} \text{ or } 1{\cdot}06 \text{ darwins.}$$

Similarly taking the figures for *Pithecanthropus erectus* and modern man with a time interval of 400,000 years, the evolutionary rate works out to be 1·2 darwins. This indicates that man is evolving physically at an extremely rapid rate according to measurements on his skulls and jaws. Zeuner calls it "explosive" evolution. Such a rapid evolutionary rate is a characteristic of new species. The rate begins to slow up after 50 million years as judged from ancestral lines of fossils, and then dies down gradually as the species tends towards extinction. Whether or not this process applies to man is a matter for speculation. The possibility of determining a law of evolution by graphical

means was one of the objectives we hoped to achieve. The approximate equation for the graphs of Figure 53, assuming them to be rectilinear, is:

$$H = 100 - \alpha t \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where H is the "percentage humanity", α the evolutionary constant expressed in per cent per annum (1 per cent in 10^4 years or 10^{-4} per cent per annum for man) and t is the time in years. Thus for *Pithecanthropus erectus* the percentage humanity is given by:

$$H = 100 - 10^{-4} \times 400{,}000 = 60\%$$

The measured values in Table II are $I_1 = 51\%$, $I_2 = 54\%$, $I_3 = 61\%$ and I_4 (extrapolated) $= 50\%$. This means that the value of α needs to be somewhat larger than 1 darwin for calculating the indices I_1 and I_4.

A similar calculation has already been done when discussing the points x. The present calculation is therefore merely a repetition using this algebraic equation connecting the rate of evolution with the "percentage humanity" and the time.

Haldane's law of evolution seems to fit the graphs of Figure 53 less well. Using the above nomenclature we have:

$$H = 100\, e^{\alpha t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where α is now expressed in darwins $(= 10^{-6})$

$$\text{i.e. } \log_e 100 - \log_e H = 10^{-6} \times 400{,}000 = 0{\cdot}4,$$
$$\text{Hence } \log_{10} H = (4{\cdot}6 - 0{\cdot}4)/2{\cdot}3, \text{ from which } H = 66\%.$$

However, Haldane's law has a better theoretical basis. It assumes the time rate of change of any dimension or index is proportional to the initial magnitude of the dimension or index; that is $dH/dt = \alpha H$, where α is the evolutionary constant. Haldane's exponential form of the evolutionary law will therefore be more suitable for long periods of time during which evolution cannot be represented by a straight line graph. The law expressed in equation (8) is however simple to use for calculating the "percentage humanity" for periods less than 500,000 years and seems to be sufficiently accurate for this purpose.

It is conceivable that as methods for the absolute measurement of time become more precise, the time scale deduced from Figures 46 and 47 and used in Figures 53 and 54 may need modifying. For example, some recent carbon 14 measurements[1] on samples of peat taken from the reclaimed Eem Sea in Holland led to the conclusion that the beginning of the Würm cold phase was only 40,000 years ago. This seems hardly probable in the light of much evidence to the contrary, and it may well be that the samples chosen were contaminated from more recent superficial deposits or that their typical fossil plant (*Brasenia purpura*) flourished in the interstadial periods of the Würm epoch as well as at the end of Riss-Würm interglacial times. There are also very considerable technical difficulties with C^{14} measurements which tend to reduce their accuracy for materials much older than 20,000 years.

Such a decrease in the time scale would, of course, increase the measured value of the rate of man's evolution, but would not affect the general deductions that can be made from this graphical treatment.

[1] A. W. Barendsen: *Ouderdomsbepaling met Radioactieve Koolstop*. Doctorate Thesis, Gröningen University, 1955.

3.3 *Minor Deductions*

Besides the three foregoing major deductions from Figure 53 there are four others of less generality but of some interest.

(1) First, it follows from all the graphs that after about 200,000 B.C. the non-specialized paedomophic characteristics of the Neanderthal man from Steinheim appear in the Skhūl man and in the Late Palaeolithic man and may account for similar characteristics in modern man. At the same time, by an interesting example of divergence, the specialized gerontomorphic Neanderthal man was evolved. These two types developed independently; the flexibility of the former leading to continuity of the species and the rigidity of the latter leading to extinction (at least in Europe) as soon as the environment changed to which the classical specialized Neanderthal man had become adapted. This divergence seems to have occurred somewhere about the time of the Riss glaciation. Although something of this kind has been suggested before, it is not without interest to see graphically how the whole problem can be linked up with the skeletons from Palestine, the classical Neanderthal men of the Würm Ice Age and the men of Late Palaeolithic and post glacial times. The fact that it is not yet possible to arrange chronologically the classical Neanderthal skeletons from La Chapelle aux Saints in France, from the Solo River in Java and from Rhodesia in Africa does not affect this conclusion. This follows because for these three skeletons a variation of the abscissae within reasonable limits would not alter the divergence between the two branches of the graphs. Because of this inability to date these particular skeletons accurately, they have all been given the same abscissa value (75,000 years B.C.) as for the French specimen which certainly belongs to the Würm epoch somewhat between 115,000 and 30,000 B.C.

(2) The second minor deduction concerns the cranial capacity ordinates I_3 which exceed 100 for the more generalized paedomophic forms of man during the period from 150,000 B.C. to 25,000 B.C. After gradually rising to 108 they decrease towards 100 commencing at 50,000 B.C. Even the cranial capacity index of the classical specialized Neanderthal man from La Chapelle aux Saints is 107 (1600 c.c.) although the mean capacity for these men is about 1450 c.c. ($I_3 = 97$). Similarly the Wadjak skulls both exceed 1500 c.c. This might mean that during the last interglacial period man's skull was expanded by the internal pressure of the cerebro-spinal fluid. Such a process was made possible by the reduction of muscular compression of the skull when strong nuchal muscles were no longer required by men of erect posture. Thus an erect posture may have led to an expanded skull. These events are clearly shown by the increased gradients in the three relevant graphs for the indices I_1, I_2, and I_3. The change seems to have commenced about 200,000 years ago. The expansion of the skull was followed in turn by an increased complexity in the lobes and fissures of the brain and a consequent absorption of cerebro-spinal fluid in the increased volume of the fissures. This would lead to a release of fluid pressure in the skull and a reduction in its expansion. Whether or not this sequence of events is a correct explanation of the measured variations in the skull capacity is a moot point, but it is a sequence of events which would explain the I_3 graph where it exceeds 100 and the whole process might well have taken 125,000 years to complete.

(3) This curious variation in skull capacity may possibly be related to the changes in speech faculty—the third point to be considered. It is an interesting coincidence that marked changes of speech potentiality occurred in 50,000 B.C. just when the skull capacity was beginning to decrease. It is not possible to say how articulate man was with an I_4 index equal to about 70 per cent—the value throughout the Würm Ice Age—but his ability to speak seems to have *increased* very rapidly after that time and during the period when the volume of the skull was gradually *decreasing*. In this connection it is particularly interesting to see that the very large volumed Wadjak skull is accompanied by an exceptionally small value of the I_4 index. It is unfortunate that so far it has not been possible to see the inside of this skull and consequently the degree of complexity of the brain convolutions is unknown. Judging from the average intelligence of the Australian aborigines it is not likely to be very great, so that a poor speech potentiality is not surprising with these abnormally large skulls. This question is discussed again below when considering the extrapolation of the graphs. Whether or not these two changes (in skull capacity and speech potentiality) can be linked anatomically (or physiologically) is a matter for professional anatomists to consider. If, for instance, it could be shown that the left hand side of the brain associated with speech function developed in excess of the right hand side at and after 50,000 B.C., then this would establish the link between the I_3 and I_4 graphs. On the other hand, an asymmetrical brain must have developed thousands of years before this if we are to judge from right-handed workmanship on flint tools—particularly on the twisted ovate implement of Acheulian times. (Fig. 33.)

(4) The fourth point that needs special consideration is concerned with certain specific values. These are the values of the ordinates (indices) for *Australopithecus*, Wadjak man, the Australian aborigine and the Chimpanzee.

i. The values of the indices for *Australopithecus* are plotted just beyond 600,000 years B.C. The skull capacity index I_3 which varies from 30 to 40 fits in with the general picture and indicates the small cranial capacity to be expected for men-apes of this remote period. The other indices are however quite exceptional. The I_1 and I_2 indices indicate a moderately erect posture, somewhat better than that of *Pithecanthropus erectus* but less erect than the Skhūl men of Palestine. The possibility of speech, as determined by the convergence angle of the lower dental arcade, seems to have been better than that of all subsequent men up to about 30,000 B.C. These curious divergences from the law given by equation (8) need careful consideration. One obvious solution is that the *Australopithecinae* are not men and never became men, and so should not appear on these graphs. Sir Wilfred de Gros Clark has come to this conclusion from a study of the first milk molars and states that the process of "molarization" suggests, "that the *Australopithecine* represent a collateral branch of the *Hominidae* which could hardly be ancestral to *Homo*." This conclusion has, in fact, already been anticipated in Figure 4. The points indicate some evolutionary instability. The (perhaps sudden) occurrence of an erect posture would be, as Zeuner points out, an "aromorph"; that is, an evolutionary change not merely adapting a species to a given fixed environment, but one leading to subsequent advances in the animals' development or to an increase in "life-energy" (Sewertzoff).[1]

[1] *Morphologische Gesetzmässigkeiten der Evolution*, Jena, 1931.

As was pointed out above, an erect posture can lead to an increased cranial capacity. So it may be that the gradual rise in the I_3 graph may have been initiated by the erect posture of the *Australopithecinae*. This could only be so if the other ape-men concerned could claim descent from these men-apes. But this is now considered improbable. Furthermore the rise in the I_3 graph is accompanied by an almost parallel rise in the I_1 and I_2 graphs. Therefore it seems to be a more rational explanation to link these graphs together and not to link them with the abnormally erect posture associated with the *Australopithecinae*. The fact that this erect posture was not continued (as judged by the later values of I_1 and I_2) seems to suggest that the erectness of posture in this case was almost a transitory phenomenon arising from the evolutionary instability which these abnormal indices seem to suggest. G. G. Simpson points out that a rapid rate of evolution is often accompanied by a period of instability.

ii. The indices for the Australian aborigine and for the chimpanzee are plotted against the zero abscissa of the present day. They are indicated respectively by the letters A and C. If the Australian aborigine came to Australia from Java and the mainland then there is no reason to assume that he was not descended from the earlier Javanese Solo River men. Affinities with the Choukoutien men have also been pointed out by Hooton. We are not here concerned with tracing the link between the Australian aborigine and his Asiatic forbears, but it seems reasonably certain that such a link existed before Australia became isolated or before there was the present large expanse of water separating that country from New Guinea. (But see paragraph on Wadjak men below.)

It is therefore most instructive to extend the curves of the gerontomorphic Neanderthalers up to the ordinate axis. If this be done then it is easily seen that the extended graphs would go almost directly to the points A.

The I_2 curve is an exception which, considering the I_1 and I_2 curves should be approximately the same, may possibly be entirely due to difficulties and consequent inaccuracies of measurement. Either the very low values of I_2 for the classical Neanderthal skulls or the rather high value of I_2 for the Australian aborigine may be the source of error. If both were in error as may be the case when judged by comparison with the I_1 data, then the errors are such as to accentuate the divergence between the extrapolated graph and the point A for the indices I_2. That the other three graphs all point towards A may reasonably be interpreted as indicating a possible link between the Australian aborigine and the Solo River men or with some descendants of Neanderthal man not yet discovered. Although Neanderthal man seems to have become extinct in Europe, he may well have persisted in some form in these more remote and isolated parts of the earth. From a study of the teeth of present day Mongolian peoples Professor E. K. Tratman[1] has noted similarities between them and Neanderthal men. It is therefore not improbable that the classical Neanderthaloids, including the Solo River men, hybridized with other eastern peoples and did not become extinct in Asia as they appear to have done in Europe. That these graphs tend to support such fascinating possibilities seems to

[1] "A Comparison of the Teeth of People: Indo-European racial stock with the Mongoloid racial stock," *Dental Record* 70, pp. 31–53 and 63–88, 1950.

justify the effort of producing them, for no such conclusions can be reached by any study of tabulated measurements.

Since these conclusions were reached and, in fact, after the above paragraph had been written, the author, through the kindness of Dr. L. D. Brongersma in Leiden, had the opportunity of seeing and measuring the Wadjak skulls and jaw and the values of the I_4 index have been included in Tables II and IX and on the graphs of Figure 53. It does now appear that Wadjak man fully justifies the foregoing conclusions deduced by extending the lower branch of the graphs to the ordinate axis, and Dr. Dubois' statement that Wadjak man was a proto-Australian having close affinities with the Melanesian stock seems to be confirmed. The Wadjak jaw and maxillae do, in fact, provide just the link between Solo man (and Neanderthal man) and the Australian native that was predicted in the preceding paragraph by extrapolating the I_4 graphs. But his skull capacity, on the other hand, places him on the upper (*Homo sapiens*) branch of the I_3 graph. Wadjak man seems to have a curious mixture of specialized and generalized characters which link him partly with modern peoples and partly with primitive Australian natives.

iii. Finally, the points C for the chimpanzee have been added for comparison. By far the most interesting conclusion arising from them is the fact that they are all less than the corresponding indices for *Proconsul africanus*. This at once gives support to the modern view that the apes have developed and became specialized along their particular lines whilst man has developed (and incidentally become less specialized) along his particular lines. The whole process seems to suggest another case of divergent evolution that took place many millions of years ago. This has already been anticipated in Figure 4 on page 19.

We can now summarize the conclusions and deductions which have been made from the four anatomical index graphs of Figure 53.

Major Deductions:

(1) From them it may be concluded that man's erectness of posture, size of brain and ability to speak probably developed in this order although more or less concurrently and with certain differences in the rates of evolution particularly during recent times.

(2) The graphs when extrapolated to several millions of years B.C. tend to pass close to the index values for *Proconsul africanus*.

(3) From the slopes of the graphs and from measurements by Weidenreich and Haldane it is concluded that man's rate of evolution is about 1 darwin and that for periods not exceeding 500,000 years the approximate equation $H = (100 - \alpha t)$ expresses a relationship between "percentage humanity" and time which is sufficiently accurate for all practical purposes.

Minor Deductions:

(1) The classical specialized Neanderthal men diverged from the more generalized type about 200,000 B.C.; the characteristics of the latter were continued to the present

day, whilst the former became extinct in Europe after the Würm Ice Age, but seem to have persisted in Asia and Australia.

(2) Skull capacities reached a maximum value about 50,000 B.C. and then decreased; a variation possibly arising from release of skull compression with erectness of posture and increased complexity of brain combined with a constant limited supply of cerebro-spinal fluid.

(3) An increase of speech potentiality occurred concurrently with the decrease of cranial capacity. The two variations may be associated.

(4) Concerning certain specific index values: (i) The indices of the *Australopithecinae* (except the cranial capacity I_3) are abnormal and may be due to evolutionary instability in the early stages of man's evolution, or may be due to a complete dissociation from the Hominid branch.

(ii) The divergent graphs of the classical Neanderthal men, when extrapolated to the present day pass close to the index values of the Australian aborigine. The one exception (I_2) is probably due to errors of measurement. The I_4 index for Wadjak man constitutes an interesting link between the Solo men of Java and the aborigines of Australia.

(iii) The low index values of the chimpanzee compared with those of *Proconsul* suggest that the apes became highly specialized as they diverged from the human stock and developed independently—a possible early example of divergent evolution.

4. Man's cultural development

4.1 *Limitations of the Graphs*

To "read" the graphs of Figure 54 is extremely difficult. They will indicate far more to a social anthropologist and to a sociologist than to an ordinary student of prehistory. It has been assumed that the chosen criteria (in particular C_1, C_2 and C_3) are some measure of man's culture and that when plotted against time will lead to graphs that will disclose how man's culture has developed with time. If "Culture" is to include man's ethical ideals and artistic appreciation, then it follows that the graphs of Figure 54 will yield no information concerning the development of these particular aspects. This follows because the relation of man's ethical and artistic senses to his control over his material environment and the forces of nature is not at all evident and in fact may not exist. In other words, the physical[1] data plotted may have little or no relation to the ethical or artistic aspects of culture. On the other hand most American authorities limit the term "Culture" to indicate man's control over his physical environment. For example, L. A. White in *The Science of Culture* says: "Culture is a means of carrying on the life processes of man. . . . The functioning of culture as a whole therefore rests upon and is determined by the amount of energy harnessed and by the way in which it is put to work". If we accept this rather limited view, then the "C" criteria plotted in Figure 54 can be accepted as quantitative measurements of culture. Alternatively, if the wider definition is accepted then the graphs only measure the physical or material aspect of culture.

[1] "Physical" used as in "Physics" and referring to the inert material universe as distinct from "physical" used in connection with the "Physical" or human body—an unfortunate shortcoming of accepted nomenclature.

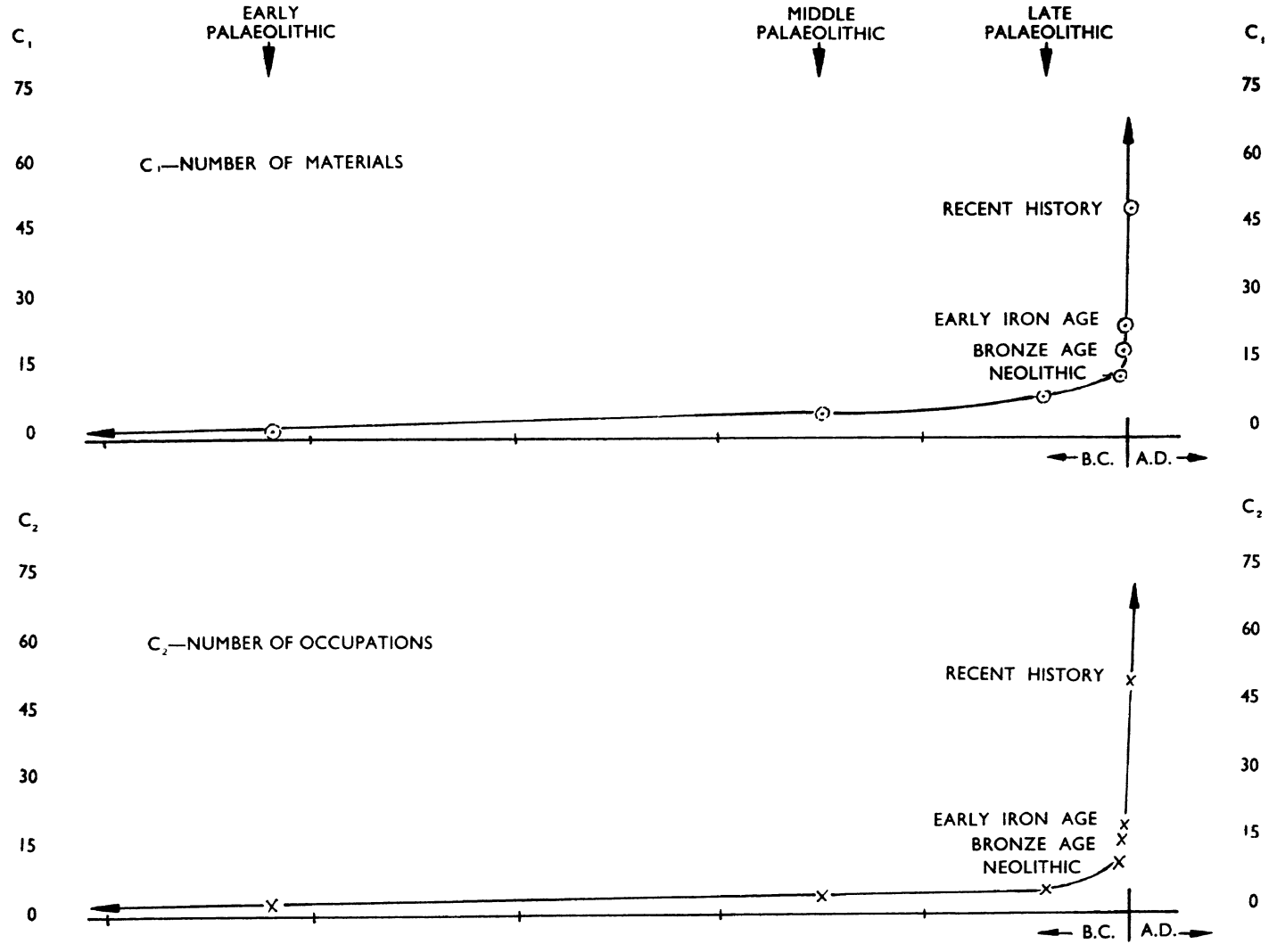
4.2 *Major Deductions—rate of cultural development*

From the cultural development/time graphs of Figure 54 two major deductions arise: one from the similarity of the graphs and the other from their general shape.

(1) The similarity of the graphs is striking. It means that the factors plotted as ordinates are all criteria of one and the same human characteristic which is measured by man's control of his material surroundings and (especially in the C_3 graph) of the energetic forces operating in the material world. To quote again from White he states on page 367, "It becomes the primary function of culture, therefore, to harness and control energy so that it may be put to work in man's service." The similarity of the graphs therefore indicates that the common characteristic which they are all measuring is in fact this particular aspect of culture. To quote from Gordon Childe, "The bronze axe which replaces . . . (the stone axe), is not only a superior implement, it also presupposes a more complex economic and social structure."

It is this point of view which underlies the present attempt to measure culture quantitatively. That the four chosen criteria do measure the same cultural factor seems to follow from the close similarity if the graphs and the factor measured is the "complex economic and social structure" which man has created around him. This is symbolized by the number of different materials brought into use, by the number and diversity of man's occupations, by the speed of his mechanized transport and by the complexity of design and extent of knowledge required to produce his "machines". Whether or not this last criterion has been measured correctly is discussed below, but the resulting graph when compared with the other three, does seem to justify the method adopted.

(2) The second major deduction follows from the general shape of the graphs. That cultural development has been and is an accelerating process is widely appreciated and can almost be taken for granted, but that it takes the startling form shown in Figure 54 is of profound importance. The development is not designed by man any more than is his physical or anatomical development. The tremendous acceleration is just happening and man must adapt himself to this new environmental factor now before he succumbs to it. This cultural environment and its rate of development are not controlled by man (as many people believe) but man can adapt himself to them and survive if he appreciates their significance in time. Man has understood and adapted himself to his material environment and, although he cannot change the forces of nature, he can control them and harness them to his service. So, too, he must learn to adapt himself to his cultural environment and use the cultural "forces" for his own benefit. Such cultural forces are forms of government, marriage laws, fashions, man-made laws and conventions, war, etiquette, religious prejudices (as distinct from conscientious appreciations of absolute right and wrong), customs (arising from what is considered good or bad for an individual or a community), accepted spelling, taxation, patriotism, and so on. This is a topic well beyond the scope of this book, but the urgent necessity of considering these matters follows from the shape of the graphs in Figure 54. The fact that the rapid increase of gradient starts round about 50,000 to 25,000 B.C. just when distinct changes were occurring in man's physical development may or may not be a coincidence. This question is discussed in the following Section where the two sets of graphs are compared.


EARLY PALAEOLITHIC
MIDDLE PALAEOLITHIC
LATE PALAEOLITHIC
C1
75
60
45
30
15
0
C1—NUMBER OF MATERIALS
RECENT HISTORY
EARLY IRON AGE
BRONZE AGE
NEOLITHIC
B.C.
A.D.
C2
75
60
45
30
15
0
C2—NUMBER OF OCCUPATIONS
RECENT HISTORY
EARLY IRON AGE
BRONZE AGE
NEOLITHIC
B.C.
A.D.

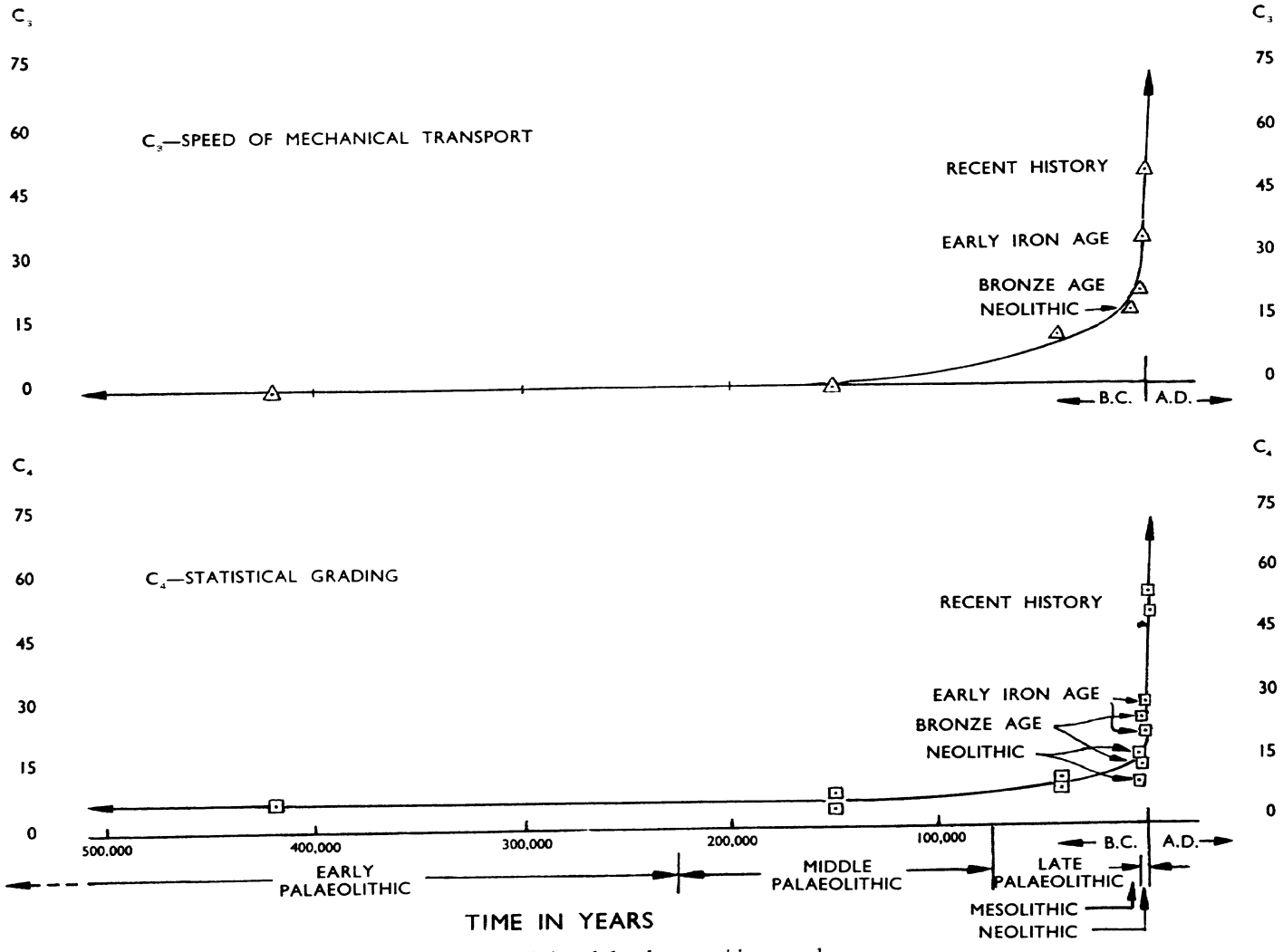


Fig. 54. Cultural development/time graphs.

That cultural development and therefore the shape of these graphs is not decided by man has been emphasized by many social-anthropologists. But many of them go too far—the "fatalists"—and forget that, although man cannot alter or design the laws associated with natural forces, yet he can adapt himself to their dictates and thereby control and utilize them for his own good. Similarly he must learn all about the "forces of culture" and so adapt himself to them that they become his servants and not his master. When he controlled fire at least 200,000 years ago he gained mastery over that powerful source of natural energy which has worked for him ever since and led to the comforts and advantages of the civilization which we now enjoy. He has certainly misused this source of energy when he burnt his fellow-men at the stake and used incendiary bombs. But in spite of these relapses he has, on the whole, benefited enormously from his ability to control fire.

Now in the twentieth century he has obtained control of atomic energy—a force which weight for weight is some nine million times more powerful than anything he has burnt or ever will burn. This is but another point on the upward branch of the cultural development/time graphs. This new source of enormous power can, if used properly, lead to greater benefits for all mankind than have ever been possible before.

The rate of acceleration is such that man must appreciate the need for immediate action and control. The mammoth could not by any physical effort accelerate his bodily adaptation to an oncoming warm climate following the Würm glacial epoch and so he became extinct. Man can, however, by his mental effort accelerate his cultural adaptation to cultural forces if he appreciates the necessity for doing so. In *Physical Anthropology* Ashley Montague points out that "Man possesses much more efficient means of achieving immediate . . . adaptation than any other biological species" and "has achieved a mastery of the world's varying environments quite unprecedented in the history of organic evolution". Thus it is within man's power to adapt himself to the new cultural environment which he is now beginning to experience. He has not got to learn how to control atomic energy. He has already done it, but he has yet to learn in what way to use it. If used as a weapon of war man can exterminate himself; but if used as an implement of peace, then the cultural development graphs will go on upward at an ever increasing rate to man's enormous advantage. This is by far the most important deduction to be made from these surprising graphs.

4.3 *Minor Deductions*

The harnessing of energy upon which man's culture has depended has been brought about by tools and machines and in particular by their efficiency. These in turn are dependent on the availability of suitable materials. The number of materials is thus a factor upon which the harnessing of energy is indirectly dependent. It would have been better to have measured the amount of natural energy utilized per head per annum but it is obviously impossible to do this. However, because an increase in the consumption of energy is dependent on an increase in the number of materials available, the C_1 criterion was felt to be a suitable measure of this aspect of culture. Similarly the energy

consumed increases with the number and diversity of occupations each of which absorbs its quota of energy. So, like the C_1 criterion, the C_2 values are directly related to energy harnessed and thence indirectly to the degree of culture achieved. It is not surprising therefore that the two curves are similar and so lead to the same conclusions. These conclusions are that man's culture was almost negligible during the greater part of his existence on the earth, and although it developed very slightly there was no appreciable change until between 50,000 and 20,000 B.C. From then and onwards man's culture in Europe and America has developed so rapidly that, today, appreciable changes may be experienced within the span of one generation. That such changes have been experienced is obvious to everyone over thirty years of age.

No simple law of cultural development can be given to represent these graphs. They do not increase exponentially nor do they follow a simple power law. It is, of course, possible to give an algebraic equation of the curves using arbitary coefficients, but nothing is to be gained thereby. Unless the law has some rational basis, it is useless as a means of understanding the mechanism of cultural development. A simple algebraic formula is only another and less satisfactory method of recording the results in Tables IV and VIII and is of less value than the graphs themselves. The form of the curves is such that there is nothing equivalent to Haldane's evolutionary constant that was deduced from the physical development graphs of Figure 53.

The same story of cultural development can be deduced from the C_3 criterion. The graph coincides with the axis of abscissae for over 500,000 years until someone used a sledge. When this was first done is unknown but the earliest evidence probably comes from the Late Palaeolithic cave painting depicted in Figure 40. Similarly it is not known exactly when a gear-wheel was introduced but this device must obviously have led directly to a greater consumption of energy in order to take advantage of the consequent possibility of increased speed.

In spite of this lack of precise data, there is little doubt that the few points plotted do give a correct picture of the changes in speed which have occurred. It is, of course, not surprising that they show the same rapid increase as do the previous culture graphs, because increase in the speed of mechanical transport is indirectly dependent on the development of the C_1 and C_2 criteria. One cannot, for example, have a motor car without a multiplicity of materials and a great array of machine tools, accompanied by all the specialized occupations of the motor industry.

The experiment upon which the last graph depends was undertaken more out of curiosity than with any hope of getting useful results. But the analysis of the figures presented seems to have fully justified the experiment. Originally it was hoped that by some specific measurements the complexity of a tool or machine might be assessed and its place on the cultural graph thereby determined. Because this did not seem practicable and because every educated person has some idea, however vague, concerning the cultural value of different implements, it was thought to be of interest to get a statistical survey of educated opinion on the subject. It could then be decided whether or not any consistent and reliable communal opinion existed. Not only does such an opinion exist but, from a comparison of the C_4 graphs with the others, the average opinion can be

judged to be reliable in spite of quite wide differences of opinion between individuals. The graph amounts to a self-assessment of man's cultural attainments.

4.4 *Effects of Location*

The physical development graphs dealt with man as a whole, the available data being insufficient to enable a graph to be plotted for each sub-species or for the development of man in a given locality. Had this been possible physical development/time graphs for the Chinese, Mongolians, Indians, Negroes, Europeans, Australian natives and so on could have been plotted and their different rates of development compared. Similarly with the cultural development graphs, the effects of geographical environment would lead to different graphs for different localities and peoples. When this becomes possible much new information will be obtained. The kind of variations that will arise can be anticipated by considering Figure 55 which is the bend or recent part of Figure 54 on an enlarged scale together with approximate cultural graphs for Egyptians and for the Australian aborigines.

Recent excavations into the foundations of Jericho have revealed a Neolithic civilization which flourished about 7,000 B.C. This was followed in 3,100 B.C. by the Early Bronze Age. In 1,560 B.C. the city was re-conquered by the Egyptians and it ceased to exist soon after the Israelites finally sacked the town at the beginning of the second millenium B.C. During this period Egypt rose from the Neolithic stage of civilization and was making bronze weapons by 4,000 B.C. The country then developed rapidly until it became a Roman province on the death of Cleopatra in 30 B.C. Similar graphs for Crete and Greece lie about mid-way between those for Egypt and for England.

Finally the graph for the Australian aborigine is added. It calls for little comment until the reasons for these differences of development in different localities are discussed. The problem is a fascinating one whether considered from the point of view of England's rapid and continued development or from the standpoint of the Australian aborigines' remarkably small development during the same period of time. These questions are dealt with in the next section.

5. Comparisons and causes

5.1 *Comparison between physical and cultural development*

The one outstanding comparison between the physical and cultural development graphs is their entirely different shape. Apart from certain minor fluctuations, the physical development graphs show a steady upward trend indicative of man's steady (but rapid) physical or anatomical evolution. The cultural development graphs on the other hand, show practically no change for hundreds of thousands of years and then suddenly shoot up from values of cultural criteria less than ten to values of many hundreds within the relatively short space of five or six thousand years. These effects are so completely outside the range of the relatively small though real errors of measurement, that our original inability to make more exact measurements now appears as a defect of negligible magnitude. Whatever more exact measurements may ultimately be available, they cannot

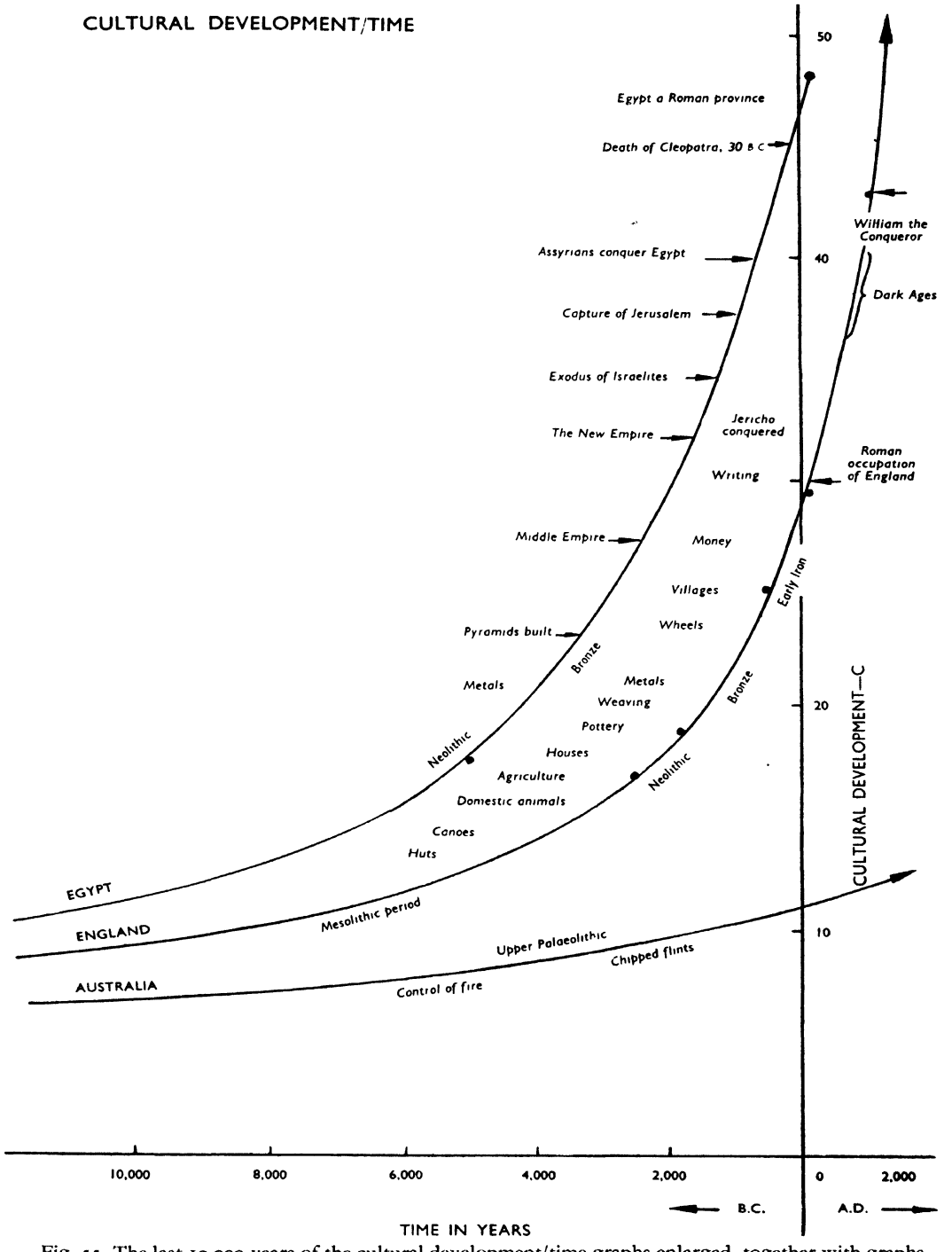


Fig. 55. The last 10,000 years of the cultural development/time graphs enlarged, together with graphs for Egyptian culture and for that of the Australian aborigine.

affect the general conclusions arising from the comparison of these two sets of graphs. They are an interesting example of allometry.[1] The reality of the two types of development is evident but the underlying causes are not so easy to elucidate. Before discussing possible causes certain other more detailed differences and similarities, which follow from a comparison of the graphs, will be considered.

Apart from the small and fairly constant upward gradients nothing of particular note occurs in the physical or cultural development graphs until about 200,000 B.C. Then, during the Riss Ice Age, one type of Neanderthal man adapted himself to the prevailing environment by an upward trend in his anatomical indices—whilst at the same time the other type developed the specialized characteristics usually associated with the classical Neanderthal men. During this time there is no corresponding change in the cultural development graphs. About the same time that the classical Neanderthal men disappear, the Late Palaeolithic men appear with the accompanying changes in the physical development graphs which have already been discussed. These changes occurred gradually somewhere between 75,000 and 25,000 B.C. About this period or a little later the cultural development graphs all commence to rise, culminating in an almost vertical gradient (with the graphical scales used in Figure 54). This extremely rapid development commenced in England towards the end of Maglemosian and beginning of Neolithic times when food producing began to supersede food gathering. The significance of this change can be appreciated when it is realized that a lone hunter requires about 8 square miles of game-land in order to feed himself; whilst the same area when ploughed and planted can provide sufficient food to support 5,000 people.

The magnitude of this cultural advance is best seen in Figure 55 which is an enlargement of the last few thousand years of Figure 54. Figure 55 also shows that a similarly rapid development had occurred in Egypt about 3,000 years earlier. It seems unlikely that these changes in the physical and cultural graphs are unrelated and that these accelerated developments occurred quite independently.

The fact that the Egyptian culture suddenly ceased to develop at this tremendous rate whilst the culture of the Australian aborigine never accelerated abnormally at all may help to suggest a cause or causes for the extraordinarily rapid development which we are still experiencing in Europe. There will certainly be causes both for the minor changes and for the major ones. These will now be considered.

5.2 *Causes for Development*

The ambitious title of this sub-section seems to suggest that the problems underlying the mechanism of evolution have been solved, but this is not so. When physicists and chemists discovered the atom some people thought that the ultimate particles had been found and the problems concerning the structure of inert matter were solved. We now know how far from the truth this optimistic opinion was. In the study of biology it would seem that the "biological atom"—the gene—has been discovered. It is an ultra-microscopic entity associated with the chromosomes. These, in turn, are constituent bodies in the germ cells of live matter. The term "chromosome" was given because of the possibility

[1] K. A. Kermack and J. B. S. Haldane: *Organic correlation and allometry*, Biometrika xxxvii, p. 30.

of seeing these thread-like structures when suitably stained. Their number and shapes are very constant in a given sex of a given species. The genes according to the work of Morgan in America are located in strings along the chromosomes. These genes determine all the characteristics of the organism with which they became associated in the process of fertilization. The normal transference of parental genes to the offspring determines the characteristics of the latter according to certain laws of inheritance discovered by Mendel. Slight variations in the number and kind of genes transmitted account for the variations (such as sex, colour, height, etc.) of the adult offspring. The word "variations" in this statement needs some amplification. J. B. S. Haldane in *The Causes of Evolution* points out that variations arise from the sudden appearance of new genes—a process known as "mutation". This is an important and essential part of the present theory of evolution. The time rate of mutation may be a controlling factor in the rate of evolution, but G. G. Simpson in *The Major Features of Evolution* states that "it seems probable that it (the mutation rate) is generally well above any really limiting factor" and so does not generally control the rate or direction of evolution. On the other hand, S. Wright (*The statistical consequences of Mendelian heredity in relation to speciation*) makes the very important statement that with very small populations the mutation rate could determine evolution and might lead to degenerative types or even to progressive types but this is less probable. That mutation leads to degeneration and ultimate extinction of a species rather than to its continuity and development has also been stressed by Haldane. In this connection he states, "Most mutations lead to loss of complexity. . . . This is probably the reason for the at first sight paradoxical fact that . . . most evolutionary change has been degenerate." In other words, the mutation of a gene might produce a genius, but it is more likely to lead to mediocrity. But as the mutated gene may determine the characteristics of an individual man, so the genius may affect the development of a community of men. The rare genius in a community is perhaps analogous to the mutated gene in an individual. The modern tendency of so-called democratic education to produce a mediocre uniformity by inhibiting and not encouraging the growth of a potential genius is a very serious indictment against such a misguided policy.

The reasons why genes mutate are not fully known but heat and exposure to high frequency electromagnetic radiations (γ rays and X-rays) do affect the rate of mutation. It therefore seems probable—if not certain—that changes in the solar radiation (with all the consequent climatic changes) are responsible for the survival and extinction of species which become exposed to them.

Another and second cause in variation in mutation rate is hybridization between species or sub-species. New types of genes can arise under these conditions and new variations will therefore appear in the hybrids.

A third factor affecting mutation rate is the spasmodic and random occurrence of new genes in the organisms themselves, leading to what is generally termed inheritable random variations. At the present time it is known that such random mutations occur but their cause is unknown. The probability is that some external or environmental cause is operative but if so it has not yet been recognized.

These mutations, from whatever cause, are sudden occurrences and not gradual changes. To use the language of the physicist they are "quantum jumps".

It must now be stressed that mutations resulting in new genes do not *necessarily* lead to variations in individuals or species. The potentiality or possibility for such variations is present but will only become effective if the environmental circumstances are suitable; in other words, if natural selection leading to adaptation to environment becomes operative. Thus, as Haldane points out, "It would seem that natural selection is the main cause of evolutionary changes in species as a whole." Hence Darwin's original ideas are still tenable but need to be supplemented with the discovery of genes and their mutability.

Let us now apply this knowledge of evolutionary processes to the curves in Figure 53 in order to determine, if possible, causes for the changes in human development which they depict.

There is not enough evidence to discuss the very earliest phases, but the steady development which occurred between 400,000 B.C. and 250,000 B.C. is worthy of consideration. Presumably there was, during this period, no abnormal environmental condition to disturb the normal rate of mutation and the steady development is the consequence of this state of affairs. Now it so happens that this interval of time coincides with the long Mindel-Riss interglacial period. That the period of steady human development was contemporary with a period of fairly constant solar radiation does not appear to be a mere chance coincidence. It resulted in a constant genetic controlling factor.[1]

The onset of the Riss glaciation means that the men of this time were exposed to an environment which was conducive to a change in mutation rate. As Wright has pointed out, this could affect the rate of evolution *if* the population was small. This would certainly apply to man at this time particularly in any given locality. It is therefore not surprising to see the divergent evolution at 200,000 B.C. which is so noticeable on all four of the physical development/time graphs. In this connexion Ashley Montagu states, "It is altogether possible that some proto-Neanderthaloid stock or stocks received infusions of Neanthropic genes which then participated in the process of that stock's differentiation into the various Neanderthaloid phases which we know." That the degenerate form of Neanderthal man *might* become extinct is also to be expected according to the statement by Haldane and others quoted above (page 163) which shows that extinction is the usual consequence of degeneracy.

The human remains at Mount Carmel and at Krapina have led many authorities—in particular Hooton—to suggest that hybridization occurred in these cases. If this is so, it may well have determined at least in part the subsequent direction of evolution of Neanthropic man. For instance, the increase in the skull capacity and the subsequent increase in the complexity of the brain convolutions presumably arose from the particular form of mutation that occurred. One of the deciding factors must have been the environmental one of erect posture which enabled the particular mutation to become operative. The consequent effects from a physiological point of view were discussed above on page 150.

[1] G. L. Jepsen, G. G. Simpson and E. Mayr, *Genetics, Palaeontology and Evolution*, p. 213.

Further abnormal mutations might be expected as a result of the Würm Ice Age of 100,000 B.C. when the curves again show changes in gradient. These changes become most noticeable about 50,000 B.C. and their possible inter-relations have already been discussed above. Of course it is by no means certain that climatic changes were directly responsible for abnormal rates in gene mutations. The climatic changes may have been operative only as the environmental factor which was conducive to, or suitable for, the natural selection and consequent functioning of genes already present. Be that as it may, it does seem that directly or indirectly the variations in solar radiations acting through gene mutations were responsible for, and therefore the cause of, changes in man's evolution which occurred more or less at these particular times.

Turning to the cultural development/time graphs the main feature to be explained is the tremendous acceleration which begins as early as 50,000 B.C. in Europe and the complete absence of such an acceleration in Australia. According to L. A. White (*The Science of Culture*) "Natural processes of biological evolution brought into existence man and in man alone a new and distinctive ability; the ability to use symbols" and again "Articulate speech is the most important form of symbolic expression". He then goes on to conclude that man's culture is largely consequent upon and determined by his ability to speak. He says in this connexion. "Culture is as old as man himself. It had its beginnings a million odd years ago when man first started to use articulate speech and he has continued and developed to the present day." Apart from the "million odd years"—a time which it is not supported by the present day evidence—it is acceptable that the development of culture was at least partly dependent on the ability to speak. But it is felt that there is at least one other factor perhaps equally important, and that is the physical environment to which man was subjected.

Men of the highest culture and greatest energy seem to be associated with temperate but vigorous climates. The post-glacial Mediterranean climate must have been of this type and may have been very largely responsible for the high degree of civilization and culture associated with the Egyptians. As the ice retreated this favourable climatic belt moved northward. So did the belt of civilization. The upward trend of the culture graph for Greece and Italy falls between that for Egypt and that for north-western Europe. Today the highest culture is to be found in the more northern latitudes of England (Scotland), Canada, Norway, and central Russia. No such climatic stimulation occurred to the Australian aborigine and hence his stagnation in spite of some form of articulate speech. It would therefore appear that at least two factors—articulate speech and an appropriate climatic environment—are necessary for cultural progress.

If the "I_4" graph in Figure 53 is compared with the "C" graphs of Figure 54 it will be noticed that a particularly marked gradient at 50,000 B.C. in the former is contemporary with the beginnings of the upward trend in the cultural development graphs. Is this but a chance coincidence? It certainly supports White's contention (but not his date for the occurrence) and would seem to accord with the fact that any marked cultural development could not possibly occur without speech as a means for the inter-communication of ideas. A further marked advance is to be anticipated when man has an international language. The "storage" of ideas from generation to generation in the form of writing

must have been the next cause or stimulus for cultural advancement and it is significant that the most rapid and steepest part of the cultural development/time graphs occurs somewhere about the time when writing was first introduced into north-western Europe and into England in particular.

The chain of causes leading to the cultural acceleration indicated in Figure 54 would thus seem to be:

A rigorous ameliorating climate→appropriate gene mutation→expansion of skull→development of brain→increased mental ability→development of articulate speech and the introduction of written records.

It is thought that the commencement of these circumstances about 50,000 years ago and their continuation to the present day constitutes the main causes for the marked cultural acceleration which has led to our present civilization.

6. The trends of evolution

6.1 *Extrapolations of Graphs*

One of the most important points connected with the graphical presentation of a sequence of changing events is the possibility of a forward extrapolation leading to a prediction of the probable trend of events in the future. This is of particular interest in the present work because the extrapolations lead to conclusions concerning the future of man's physical and cultural development which are as distinct and different from each other as are the graphs from which the predictions are made. Physically there is no reason to expect any marked changes for the next few thousands of years, except possibly in the speech faculty. This graph (the I_4 curve in Figure 53) has a steeper gradient at the present time than any of the others, and consequently it may be anticipated that man's ability to speak may be appreciably increased in the near future. This may arise due to his desire to be poly-lingual leading to the cultural environment that would encourage greater flexibility of the tongue and an enlarged mouth cavity in which to manipulate it. There are however hardly enough points on the graph to be able to make this prediction with any reasonable probability, although the general tendency of the graph seems to be in that direction.

The extrapolation of the cultural development graphs is a very different matter. That they could continue their rapid increase in the next few hundred years appears at first sight to be a reasonable conclusion. But, as was indicated in the introductory chapter, it is only possible to predict such a rapid increase in cultural development if no new or unconsidered circumstances exist that could modify the law depicted in Figure 54. As a matter of fact this ever-increasing rate can only continue if the human animal is capable of meeting the ever-increasing technical demands made upon him. In order to do this Dr. Derek Price,[1] judging from past conditions, has estimated that by the end of the next 50 to 70 years it will be necessary for every person in this country to become a scientist or a technician. After that time the rate of supply of manpower will be insufficient to meet the increased demands. But it is not reliable to judge from

[1] *The Exponential Curve of Science.* Discovery, Vol. 17, p. 240, June 1956.

past conditions when these are known to be changing with time. For example, the introduction of automatic electronic equipment to control and operate machinery will tend to release manpower from routine tasks and thereby counteract the ever-increasing demand for trained technicians. Furthermore the present necessity for increased specialization will certainly lead to further cultural advances, but they will only be of benefit to the whole community when each member realizes his dependence on his fellows. Individual men are no longer self-sufficient in a modern civilized society.

It is not yet possible to determine what influence these new factors will have on the slope of the cultural development graphs. But it seems probable that in the near future the present very rapid rate of cultural development will tend to be slowed down. Our standard of living should still go on improving but there may be a tendency towards "saturation" if the rate of future cultural development is dependent on the limited capacity of individual men. A slowing-down in the rate of cultural development is, in fact, just becoming apparent if judged by the present shortage of science teachers, the lack of technicians in industry and the tremendous output of scientific publications—now quite beyond the capacity of any one man to assimilate.

We certainly live in exciting times with definite indications of an even more exciting future.

6.2 *Progression and Retrogression*

On page 8 when the word "Development" was being defined, some care was taken to indicate that the word was to be used in a limited sense. It was applied to a series of related or connected values (of indices or criteria) which differed from each other from time to time. The relative magnitudes of both physical or cultural values were measured by arbitrarily assigning a particular number to represent the value of an index or criterion at a given time. Other values were then recorded as percentages of this particular value. In this way, the fact that a given value in the past might be greater or less than one hundred is no indication that the index or criterion is "better" or "worse" then than it is now. In other words, the slope of the graphs between any two points does not mean a "progression" or a "retrogression" of man's physique or culture. The time has now come when this aspect of our development may well be considered.

Concerning physical development Hooton states in *Up from the Ape*, "If there are any evidences of positive or progressive evolution of the physical man since Neolithic times, say 10,000 years ago, I am ignorant of them." He then goes on to point out certain retrogressive features of modern man such as the reduction and suppression of the wisdom teeth and the shrinking and mal-formation of the little toes. Haldane thinks along similar lines when he says that a monkey is a more satisfactory animal than a man, whose upright posture has led to many physical weaknesses.

Both these judgments are based entirely on physical comparisons and the standard of judgment seems to be completeness of bodily adaptation to present environment.

It seems reasonable to suppose that more generalized and therefore more realistic conclusions would follow if man's physical, cultural and moral aspects were treated together and man was studied as a whole. His physical defects have led to an enhanced

cultural environment and considerable intellectual development which have undoubtedly raised his standard of living. This has meant a gradual "advance to a better and better condition"—a dictionary definition of progress. His paedomorphic plasticity, compared with the gerontomorphic stability of the apes, is a sound insurance against early extinction in an ever-changing environment. This seems to outweigh the minor physical defects of erect posture without which his brain could not have developed as it has. If some physical retrogression has led to considerable cultural and mental progression, then this can be good. But, as has already been emphasized, no consideration has been given here to moral progress without which cultural progress may be an ultimate evil. Man will have retrogressed if his intellectual ability and his consequent command over the material world and its forces is not directed to his future betterment. However, there is potential progress in the fact that the course of human evolution has led to the inheritance of unique genes that have made the human animal so different from all others. These genes when nurtured in the right cultural environment and controlled by high moral principles can lead to a Utopia for all mankind.

Thus, whether the gradients of the graphs of physical and cultural development indicate a progressive or a retrogressive state of human evolution depends entirely on man's present and future behaviour. It is for the present and the next generations to ensure that the gradients do mean Progress. This is only possible if the spiritual part of the human being is allowed to control and direct the future course of his cultural development. Man will then survive and to quote Bertrand Russell's broadcast appeal, "There is every reason to expect the triumphs of the future to exceed immeasurably the triumphs of the past."

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