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Volume 3

Leon McDaniel

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Chapter 16

Three-age System

The three-age system is the periodization of human pre-history (with some overlap into the historical periods in a few regions) into three time-periods: the Stone Age, the Bronze Age, and the Iron Age; although the concept may also refer to other tripartite divisions of historic time-periods. In history, archaeology and physical anthropology, the three-age system is a methodological concept adopted during the 19th century according to which artefacts and events of late prehistory and early history could be broadly ordered into a recognizable chronology. C. J. Thomsen (1788-1865), director of the Royal Museum of Nordic Antiquities in Copenhagen (in office: 1825-1865), initially developed this categorization in the period 1816 to 1825 as a result of classifying the museum's collections chronologically - there resulted broad sequences with artefacts made successively of stone, bronze, and iron.

The system appealed to British researchers working in the science of ethnology – they adopted it to establish race sequences for Britain's past based on cranial types. Although the craniological ethnology that formed its first scholarly context holds no modern scientific value, the *relative chronology* of the Stone Age, the Bronze Age and the Iron Age remains in use in a general public context, and the three-ages concept underpins prehistoric chronology for Europe, the Mediterranean world and the Near East. The structure reflects the cultural and historical background of Mediterranean Europe and the Middle East. It soon underwent further subdivisions, including the 1865 partitioning of the Stone Age into Palaeolithic, Mesolithic and Neolithic periods by John Lubbock. The schema, however, has little or no utility for establishing chronological frameworks in sub-Saharan Africa, much of Asia, the Americas and some other areas; and has little importance in contemporary archaeological or anthropological discussion for these regions.

Origin

The concept of dividing pre-historical ages into systems based on metals extends far back in European history, probably originated by Lucretius in the first century BC. But the present archaeological system of the three main ages—stone, bronze and iron—originates with the Danish archaeologist Christian Jürgensen Thomsen (1788–1865), who placed the system on a more scientific basis by typological and chronological studies, at first, of tools and other artefacts present in the Museum of Northern Antiquities in Copenhagen (later the National Museum of Denmark). He later used artefacts and the excavation reports published or sent to him by Danish archaeologists who were doing controlled excavations. His position as curator of the museum gave him enough visibility to become highly influential on Danish archaeology. A well-known and well-liked figure, he explained his system in person to visitors at the museum, many of them professional archaeologists.

The Metallic Ages of Hesiod

In his poem, *Works and Days*, the ancient Greek poet Hesiod possibly between 750 and 650 BC, defined five successive Ages of Man: 1. Golden, 2. Silver, 3. Bronze, 4. Heroic and 5. Iron. Only the Bronze Age and the Iron Age are based on the use of metal:

> ... then Zeus the father created the third generation of mortals, the age of bronze ... They were terrible and strong, and the ghastly action of Ares was theirs, and violence. ... The weapons of these men were bronze, of bronze their houses, and they worked as bronzesmiths. There was not yet any black iron.

Hesiod knew from the traditional poetry, such as the *Iliad*, and the heirloom bronze artifacts that abounded in Greek society, that before the use of iron to make tools and weapons, bronze had been the preferred material and iron was not smelted at all. He did not continue the manufacturing metaphor, but mixed his metaphors, switching over to the market value of each metal. Iron was cheaper than bronze, so there must have been a golden and a silver age. He portrays a sequence of metallic ages, but it is a degradation rather than a progression. Each age has less of a moral value than the preceding. Of his own age he says: "And I wish that I were not any part of the fifth generation of men, but had died before it came, or had been born afterward."

The Progress of Lucretius

The moral metaphor of the ages of metals continued. Lucretius, however, replaced moral degradation with the concept of progress, which he conceived to be like the growth of an individual human being. The concept is evolutionary:

For the nature of the world as a whole is altered by age. Everything must pass through successive phases. Nothing remains forever what it was. Everything is on the move. Everything is transformed by nature and forced into new paths ... The Earth passes through successive phases, so that it can no longer bear what it could, and it can now what it could not before.

The Romans believed that the species of animals, including humans, were spontaneously generated from the materials of the Earth, because of which the Latin word *mater*, "mother", descends to English-speakers as matter and material. In Lucretius the Earth is a mother, Venus, to whom the poem is dedicated in the first few lines. She brought forth humankind by spontaneous generation. Having been given birth as a species, humans must grow to maturity by analogy with the individual. The different phases of their collective life are marked by the accumulation of customs to form material civilization:

The earliest weapons were hands, nails and teeth. Next came stones and branches wrenched from trees, and fire and flame as soon as these were discovered. Then men learnt to use tough iron and copper. With copper they tilled the soil. With copper they whipped up the clashing waves of war, ... Then by slow degrees the iron sword came to the fore; the bronze sickle fell into disrepute; the ploughman began to cleave the earth with iron, ...

Lucretius envisioned a pre-technological human that was "far tougher than the men of today ... They lived out their lives in the fashion of wild beasts roaming at large." The next stage was the use of huts, fire, clothing, language and the family. City-states, kings and citadels followed them. Lucretius supposes that the initial smelting of metal occurred accidentally in forest fires. The use of copper followed the use of stones and branches and preceded the use of iron.

Early lithic analysis by Michele Mercati

By the 16th century, a tradition had developed based on observational incidents, true or false, that the black objects found widely scattered in large quantities over Europe had fallen from the sky during thunderstorms and were therefore to be considered generated by lightning. They were so published by Konrad Gessner in *De rerum fossilium, lapidum et gemmarum maxime figuris & similitudinibus* at Zurich in 1565 and by many others less famous. The name ceraunia, "thunderstones," had been assigned.

Ceraunia were collected by many persons over the centuries including Michele Mercati, Superintendent of the Vatican Botanical Garden in the late 16th century. He brought his collection of fossils and stones to the Vatican, where he studied them at leisure, compiling the results in a manuscript, which was published posthumously by the Vatican at Rome in 1717 as *Metallotheca*. Mercati was interested in Ceraunia cuneata, "wedge-shaped thunderstones," which seemed to him to be most like axes and arrowheads, which he now called ceraunia vulgaris, "folk thunderstones," distinguishing his view from the popular one. His view was based on what may be the first in-depth lithic analysis of the objects in his collection, which led him to believe that they are artifacts and to suggest that the historical evolution of these artefacts followed a scheme. Mercati examining the surfaces of the ceraunia noted that the stones were of flint and that they had been chipped all over by another stone to achieve by percussion their current forms. The protrusion at the bottom he identified as the attachment point of a haft. Concluding that these objects were not ceraunia he compared collections to determine exactly what they were. Vatican collections included artifacts from the New World of exactly the shapes of the supposed ceraunia. The reports of the explorers had identified them to be implements and weapons or parts of them.

Mercati posed the question to himself, why would anyone prefer to manufacture artefacts of stone rather than of metal, a superior material? His answer was that metallurgy was unknown at that time.

He cited Biblical passages to prove that in Biblical times stone was the first material used. He also revived the 3-age system of Lucretius, which described a succession of periods based on the use of stone (and wood), bronze and iron respectively. Due to lateness of publication, Mercati's ideas were already being developed independently; however, his writing served as a further stimulus.

The usages of Mahudel and de Jussieu

On 12 November 1734, Nicholas Mahudel, physician, antiquarian and numismatist, read a paper at a public sitting of the Académie Royale des Inscriptions et Belles-Lettres in which he defined three "usages" of stone, bronze and iron in a chronological sequence. He had presented the paper several times that year but it was rejected until the November revision was finally accepted and published by the Academy in 1740. It was entitled *Les Monumens les plus anciens de l'industrie des hommes, et des Arts reconnus dans les Pierres de Foudres.* It expanded the concepts of Antoine de Jussieu, who had gotten a paper accepted in 1723 entitled *De l'Origine et des usages de la Pierre de Foudre*. In Mahudel, there is not just one usage for stone, but two more, one each for bronze and iron.

He begins his treatise with descriptions and classifications of the *Pierres de Tonnerre et de Foudre*, the ceraunia of contemporaneous European interest.

After cautioning the audience that natural and man-made objects are often easily confused, he asserts that the specific "*figures*" or "formes that can be distinguished (*formes qui les font distingues*)" of the stones were man-made, not natural:

- It was Man's hand that made them serve as instruments (C'est la main des hommes qui les leur a données pour servir d'instrumens...)

Their cause, he asserts, is "the industry of our forefathers (*l'industrie de nos premiers pères*)." He adds later that bronze and iron implements imitate the uses of the stone ones, suggesting a replacement of stone with metals. Mahudel is careful not to take credit for the idea of a succession of usages in time but states: "it is Michel Mercatus, physician of Clement VIII who first had this idea". He does not coin a term for ages, but speaks only of the times of usages. His use of *l'industrie* foreshadows the 20th century "industries," but where the moderns mean specific tool traditions, Mahudel meant only the art of working stone and metal in general.

The three-age system of C. J. Thomsen

An important step in the development of the Three-age System came when the Danish antiquarian Christian Jürgensen Thomsen was able to use the Danish national collection of antiquities and the records of their finds as well as reports from contemporaneous excavations to provide a solid empirical basis for the system. He showed that artefacts could be classified into types and that these types varied over time in ways that correlated with the predominance of stone, bronze or iron implements and weapons. In this way he turned the Three-age System from being an evolutionary scheme based on intuition and general knowledge into a system of relative chronology supported by archaeological evidence. Initially, the three-age system as it was developed by Thomsen and his contemporaries in Scandinavia, such as Sven Nilsson and J.J.A. Worsaae, was grafted onto the traditional biblical chronology. But, during the 1830s they achieved independence from textual chronologies and relied mainly on typology and stratigraphy.

In 1816 Thomsen at age 27 was appointed to succeed the retiring Rasmus Nyerup as Secretary of the *Kongelige Commission for Oldsagers Opbevaring* ("Royal Commission for the Preservation of Antiquities"), which had been founded in 1807. The post was unsalaried; Thomsen had independent means. At his appointment Bishop Münter said that he was an "amateur with a great range of accomplishments." Between 1816 and 1819 he reorganized the commission's collection of antiquities. In 1819 he opened the first Museum of Northern Antiquities, in Copenhagen, in a former monastery, to house the collections. It later became the National Museum.

Like the other antiquarians Thomsen undoubtedly knew of the three-age model of prehistory through the works of Lucretius, the Dane Vedel Simonsen, Montfaucon and Mahudel. Sorting the material in the collection chronologically he mapped out which kinds of artefacts co-occurred in deposits and which did not, as this arrangement would allow him to discern any trends that were exclusive to certain periods. In this way he discovered that stone tools did not co-occur with bronze or iron in the earliest deposits while subsequently bronze did not co-occur with iron – so that three periods could be defined by their available materials, stone, bronze and iron.

To Thomsen the find circumstances were the key to dating. In 1821 he wrote in a letter to fellow prehistorian Schröder:

- nothing is more important than to point out that hitherto we have not paid enough attention to what was found together.
- and in 1822:
- we still do not know enough about most of the antiquities either; ... only future archaeologists may be able to decide, but they will never be able to do so if they do not observe what things are found together and our collections are not brought to a greater degree of perfection.

This analysis emphasizing co-occurrence and systematic attention to archaeological context allowed Thomsen to build a chronological framework of the materials in the collection and to classify new finds in relation to the established chronology, even without much knowledge of their provenience. In this way, Thomsen's system was a true chronological system rather than an evolutionary or technological system. Exactly when his chronology was reasonably well established is not clear, but by 1825 visitors to the museum were being instructed in his methods. In that year also he wrote to J.G.G. Büsching:

To put artifacts in their proper context I consider it most important to pay attention to the chronological sequence, and I believe that the old idea of first stone, then copper, and finally iron, appears to be ever more firmly established as far as Scandinavia is concerned.

By 1831 Thomsen was so certain of the utility of his methods that he circulated a pamphlet, "*Scandinavian Artefacts and Their Preservation*, advising archaeologists to "observe the greatest care" to note the context of each artifact. The pamphlet had an immediate effect. Results reported to him confirmed the universality of the Three-age System. Thomsen also published in 1832 and 1833 articles in the *Nordisk Tidsskrift for Oldkyndighed*, "Scandinavian Journal of Archaeology." He already had an international reputation when in 1836 the Royal Society of Northern Antiquaries published his illustrated contribution to "Guide to Scandinavian Archaeology" in which he put forth his chronology together with comments about typology and stratigraphy.

Thomsen was the first to perceive typologies of grave goods, grave types, methods of burial, pottery and decorative motifs, and to assign these types to layers found in excavation. His published and personal advice to Danish archaeologists concerning the best methods of excavation produced immediate results that not only verified his system empirically but placed Denmark in the forefront of European archaeology for at least a generation. He became a national authority when C.C Rafn, secretary of the *Kongelige Nordiske Oldskriftselskab* ("Royal Society of Northern Antiquaries"), published his principal manuscript in *Ledetraad til Nordisk Oldkyndighed* ("Guide to Scandinavian Archaeology") in 1836. The system has since been expanded by further subdivision of each era, and refined through further archaeological and anthropological finds.

Stone Age subdivisions

The savagery and civilization of Sir John Lubbock

It was to be a full generation before British archaeology caught up with the Danish. When it did, the leading figure was another multi-talented man of independent means: John Lubbock, 1st Baron Avebury. After reviewing the Three-age System from Lucretius to Thomsen, Lubbock improved it and took it to another level, that of cultural anthropology. Thomsen had been concerned with techniques of archaeological classification. Lubbock found correlations with the customs of savages and civilization.

In his 1865 book, *Prehistoric Times*, Lubbock divided the Stone Age in Europe, and possibly nearer Asia and Africa, into the Palaeolithic and the Neolithic:

- "That of the Drift... This we may call the 'Palaeolithic' Period."
- "The later, or polished Stone Age ... in which, however, we find no trace ... of any metal, excepting gold, ... This we may call the 'Neolithic' Period."

- "The Bronze Age, in which bronze was used for arms and cutting instruments of all kinds."
- "The Iron Age, in which that metal had superseded bronze."

By "drift" Lubbock meant river-drift, the alluvium deposited by a river. For the interpretation of Palaeolithic artifacts, Lubbock, pointing out that the times are beyond the reach of history and tradition, suggests an analogy, which was adopted by the anthropologists. Just as the paleontologist uses modern elephants to help reconstruct fossil pachyderms, so the archaeologist is justified in using the customs of the "non-metallic savages" of today to understand "the early races which inhabited our continent." He devotes three chapters to this approach, covering the "modern savages" of the Indian and Pacific Oceans and the Western Hemisphere, but something of a deficit in what would be called today his correct professionalism reveals a field yet in its infancy:

Perhaps it will be thought ... I have selected ... the passages most unfavorable to savages. ... In reality the very reverse in the case. ... Their real condition is even worse and more abject than that which I have endeavoured to depict.

The elusive Mesolithic of Hodder Westropp

Sir John Lubbock's use of the terms Palaeolithic ("Old Stone Age") and Neolithic ("New Stone Age") were immediately popular. They were applied, however, in two different senses: geologic and anthropologic. In 1867–68 Ernst Haeckel in 20 public lectures in Jena, entitled *General Morphology*, to be published in 1870, referred to the Archaeolithic, the

Palaeolithic, the Mesolithic and the Caenolithic as periods in geologic history. He could only have got these terms from Hodder Westropp, who took Palaeolithic from Lubbock, invented Mesolithic ("Middle Stone Age") and Caenolithic instead of Lubbock's Neolithic. None of these terms appear anywhere, including the writings of Haeckel, before 1865. Haeckel's use was innovative.

Westropp first used Mesolithic and Caenolithic in 1865, almost immediately after the publication of Lubbock's first edition. He read a paper on the topic before the Anthropological Society of London in 1865, published in 1866 in the *Memoirs*. After asserting:

Man, in all ages and in all stages of his development, is a tool-making animal.

Westropp goes on to define "different epochs of flint, stone, bronze or iron; ..." He never did distinguish the flint from the Stone Age (having realized they were one and the same), but he divided the Stone Age as follows:

- "The flint implements of the gravel-drift"
- "The flint implements found in Ireland and Denmark"
- "Polished stone implements"

These three ages were named respectively the Palaeolithic, the Mesolithic and the Kainolithic. He was careful to qualify these by stating:

Their presence is thus not always an evidence of a high antiquity, but of an early and barbarous state; ...

Lubbock's savagery was now Westropp's barbarism. A fuller exposition of the Mesolithic waited for his book, *Pre-Historic Phases*, dedicated to Sir John Lubbock, published in 1872. At that time he restored Lubbock's Neolithic and defined a Stone Age divided into three phases and five stages.

The First Stage, "Implements of the Gravel Drift," contains implements that were "roughly knocked into shape." His illustrations show Mode 1 and Mode 2 stone tools, basically Acheulean handaxes. Today they are in the Lower Palaeolithic.

The Second Stage, "Flint Flakes" are of the "simplest form" and were struck off cores. Westropp differs in this definition from the modern, as Mode 2 contains flakes for scrapers and similar tools. His illustrations, however, show Modes 3 and 4, of the Middle and Upper Palaeolithic. His extensive lithic analysis leaves no doubt. They are, however, part of Westropp's Mesolithic.

The Third Stage, "a more advanced stage" in which "flint flakes were carefully chipped into shape," produced small arrowheads from shattering a piece of flint into "a hundred pieces", selecting the most suitable and working it with a punch. The illustrations show that he had microliths, or Mode 5 tools in mind. His Mesolithic is therefore partly the same as the modern.

The Fourth Stage is a part of the Neolithic that is transitional to the Fifth Stage: axes with ground edges leading to implements totally ground and polished. Westropp's agriculture is removed to the Bronze Age, while his Neolithic is pastoral. The Mesolithic is reserved to hunters.

Piette finds the Mesolithic

In that same year, 1872, Sir John Evans produced a massive work, *The Ancient Stone Implements*, in which he in effect repudiated the Mesolithic, making a point to ignore it, denying it by name in later editions. He wrote:

Sir John Lubbock has proposed to call them the Archaeolithic, or Palaeolithic, and the Neolithic Periods respectively, terms which have met with almost general acceptance, and of which I shall avail myself in the course of this work.

Evans did not, however, follow Lubbock's general trend, which was typological classification. He chose instead to use type of find site as the main criterion, following Lubbock's descriptive terms, such as tools of the drift. Lubbock had identified drift sites as containing Palaeolithic material. Evans added to them the cave sites. Opposed to drift and cave were the surface sites, where chipped and ground tools often occurred in unlayered contexts. Evans decided he had no choice but to assign them all to the most recent. He therefore consigned them to the Neolithic and used the term "Surface Period" for it.

Having read Westropp, Sir John knew perfectly well that all the former's Mesolithic implements were surface finds. He used his prestige to quell the concept of Mesolithic as best he could, but the public could see that his methods were not typological. The less prestigious scientists publishing in the smaller journals continued to look for a Mesolithic. For example, Isaac Taylor in *The Origin of the Aryans*, 1889, mentions the Mesolithic but briefly, asserting, however, that it formed "a transition between the Palaeolithic and Neolithic Periods." Nevertheless, Sir John fought on, opposing the Mesolithic by name as late as the 1897 edition of his work.

Meanwhile, Haeckel had totally abandoned the geologic uses of the -lithic terms. The concepts of Palaeozoic, Mesozoic and Cenozoic had originated in the early 19th century and were gradually becoming coin of the geologic realm. Realizing he was out of step, Haeckel started to transition to the -zoic system as early as 1876 in *The History of Creation*, placing the -zoic form in parentheses next to the -lithic form.

The gauntlet was officially thrown down before Sir John by J. Allen Brown, speaking for the opposition before the Anthropological Institute on 8 March 1892. In the journal he opens the attack by striking at a "hiatus" in the record:

It has been generally assumed that a break occurred between the period during which ... the continent of Europe was inhabited by Palaeolithic Man and his Neolithic successor ... No physical cause, no adequate reasons have ever been assigned for such a hiatus in human existence ...

The main hiatus at that time was between British and French archaeology, as the latter had already discovered the gap 20 years earlier and had already considered three answers and arrived at one solution, the modern. Whether Brown did not know or was pretending not to know is unclear. In 1872, the very year of Evans' publication, Mortillet had presented the gap to the Congrès international d'Anthropologie at Brussels:

Between the Palaeolithic and Neolithic, there is a wide and deep gap, a large hiatus.

Apparently prehistoric man was hunting big game with stone tools one year and farming with domestic animals and ground stone tools the next. Mortillet postulated a "time then unknown (*époque alors inconnue*)" to fill the gap. The hunt for the "unknown" was on. On 16 April 1874, Mortillet retracted. "That hiatus is not real (*Cet hiatus n'est pas réel*)," he said before the *Société d'Anthropologie*, asserting that it was an informational gap only. The other theory had been a gap in nature, that, because of the ice age, man had retreated from Europe. The information must now be found. In 1895 Édouard Piette stated that he had heard Édouard Lartet speak of "the remains from the intermediate period (*les vestiges de l'époque intermédiaire*)", which were yet to be discovered, but Lartet had not published this view. The gap had become a transition. However, asserted Piette:

I was fortunate to discover the remains of that unknown time which separated the Magdalenian age from that of polished stone axes ... it was, at Mas-d'Azil in 1887 and 1888 when I made this discovery.

He had excavated the type site of the Azilian Culture, the basis of today's Mesolithic. He found it sandwiched between the Magdalenian and the Neolithic. The tools were like those of the Danish kitchen-middens, termed the Surface Period by Evans, which were the basis of Westropp's Mesolithic. They were Mode 5 stone tools, or microliths. He mentions neither Westropp nor the Mesolithic, however. For him this was a "solution of continuity (*solution de continuité*)" To it he assigns the semi-domestication of dog, horse, cow, etc., which "greatly facilitated the work of Neolithic man (*a beaucoup facilité la tàche de l'homme néolithique*)." Brown in 1892 does not mention Mas-d'Azil. He refers to the "transition or 'Mesolithic' forms" but to him these are "rough hewn axes chipped over the entire surface" mentioned by Evans as the earliest of the Neolithic. Where Piette believed he had discovered something new, Brown wanted to break out known tools considered Neolithic.

The Epipaleolithic and Protoneolithic of Stjerna and Obermaier

Sir John Evans never changed his mind, giving rise to a dichotomous view of the Mesolithic and a multiplication of confusing terms. On the continent, all seemed settled: there was a distinct Mesolithic with its own tools and both tools and customs were transitional to the Neolithic. Then in 1910, the Swedish archaeologist, Knut Stjerna, addressed another problem of the Three-Age System: although a culture was predominantly classified as one period, it might contain material that was the same as or like that of another. His example was the Gallery grave Period of Scandinavia. It was not uniformly Neolithic, but contained some objects of bronze and more importantly to him three different subcultures.

One of these "civilisations" (sub-cultures) located in the north and east of Scandinavia was rather different, featuring but few gallery graves, using instead stone-lined pit graves containing implements of bone, such as harpoon and javelin heads. He observed that they "persisted during the recent Paleolithic period and also during the Protoneolithic." Here he had used a new term, "Protoneolithic", which was according to him to be applied to the Danish kitchen-middens.

Stjerna also said that the eastern culture "is attached to the Paleolithic civilization (*se trouve rattachée à la civilisation paléolithique*)." However, it was not intermediary and of its intermediates he said "we cannot discuss them here (*nous ne pouvons pas examiner ici*)." This "attached" and non-transitional culture he chose to call the Epipaleolithic, defining it as follows:

With Epipaleolithic I mean the period during the early days that followed the age of the reindeer, the one that retained Paleolithic customs. This period has two stages in Scandinavia, that of Maglemose and that of Kunda. (*Par époque épipaléolithique j'entends la période qui, pendant les premiers temps qui ont suivi l'âge du Renne, conserve les coutumes paléolithiques. Cette période présente deux étapes en Scandinavie, celle de Maglemose et de Kunda.*)

There is no mention of any Mesolithic, but the material he described had been previously connected with the Mesolithic. Whether or not Stjerna intended his Protoneolithic and Epipaleolithic as a replacement for the Mesolithic is not clear, but Hugo Obermaier, a German archaeologist who taught and worked for many years in Spain, to whom the concepts are often erroneously attributed, used them to mount an attack on the entire concept of Mesolithic. He presented his views in *El Hombre fósil*, 1916, which was translated into English in 1924. Viewing the Epipaleolithic and the Protoneolithic as a "transition" and an "interim" he affirmed that they were not any sort of "transformation:"

But in my opinion this term is not justified, as it would be if these phases presented a natural evolutionary development – a progressive transformation from Paleolithic to Neolithic. In reality, the final phase of the Capsian, the Tardenoisian, the Azilian and the northern Maglemose industries are the posthumous descendants of the Palaeolithic ...

The ideas of Stjerna and Obermaier introduced a certain ambiguity into the terminology, which subsequent archaeologists found and find confusing. Epipaleolithic and Protoneolithic cover the same cultures, more or less, as does the Mesolithic. Publications on the Stone Age after 1916 include some sort of explanation of this ambiguity, leaving room for different views. Strictly speaking the Epipaleolithic is the earlier part of the Mesolithic. Some identify it with the Mesolithic. To others it is an Upper Paleolithic transition to the Mesolithic. The exact use in any context depends on the archaeological tradition or the judgement of individual archaeologists. The issue continues.

Lower, middle and upper from Haeckel to Sollas

The post-Darwinian approach to the naming of periods in earth history focused at first on the lapse of time: early (Palaeo-), middle (Meso-) and late (Ceno-). This conceptualization automatically imposes a three-age subdivision to any period, which is predominant in modern archaeology: Early, Middle and Late Bronze Age; Early, Middle and Late Minoan, etc. The criterion is whether the objects in question look simple or are elaborative. If a horizon contains objects that are post-late and simpler-than-late they are sub-, as in Submycenaean.

Haeckel's presentations are from a different point of view. His *History of Creation* of 1870 presents the ages as "Strata of the Earth's Crust," in which he prefers "upper", "mid-" and "lower" based on the order in which one encounters the layers. His analysis features an Upper and Lower Pliocene as well as an Upper and Lower Diluvial (his term for the Pleistocene). Haeckel, however, was relying heavily on Lyell. In the 1833 edition of *Principles of Geology* (the first) Lyell devised the terms Eocene, Miocene and Pliocene to mean periods of which the "strata" contained some (Eo-, "early"), lesser (Mio-) and greater (Plio-) numbers of "living Mollusca represented among fossil assemblages of western Europe." The Eocene was given Lower, Middle, Upper; the Miocene a Lower and Upper; and the Pliocene an Older and Newer, which scheme would indicate an equivalence between Lower and Older, and Upper and Newer.

In a French version, *Nouveaux Éléments de Géologie*, in 1839 Lyell called the Older Pliocene the Pliocene and the Newer Pliocene the Pleistocene (Pleist-, "most"). Then in *Antiquity of Man* in 1863 he reverted to his previous scheme, adding "Post-Tertiary" and "Post-Pliocene."

In 1873 the Fourth Edition of *Antiquity of Man* restores Pleistocene and identifies it with Post-Pliocene. As this work was posthumous, no more was heard from Lyell. Living or deceased, his work was immensely popular among scientists and laymen alike. "Pleistocene" caught on immediately; it is entirely possible that he restored it by popular demand. In 1880 Dawkins published *The Three Pleistocene Strata* containing a new manifesto for British archaeology:

The continuity between geology, prehistoric archaeology and history is so direct that it is impossible to picture early man in this country without using the results of all these three sciences.

He intends to use archaeology and geology to "draw aside the veil" covering the situations of the peoples mentioned in proto-historic documents, such as Caesar's *Commentaries* and the *Agricola* of Tacitus. Adopting Lyell's scheme of the Tertiary, he divides Pleistocene into Early, Mid- and Late. Only the Palaeolithic falls into the Pleistocene; the Neolithic is in the "Prehistoric Period" subsequent. Dawkins defines what was to become the Upper, Middle and Lower Paleolithic, except that he calls them the "Upper Cave-Earth and Breccia," the "Middle Cave-Earth," and the "Lower Red Sand," with reference to the names of the layers. The next year, 1881, Geikie solidified the terminology into Upper and Lower Palaeolithic:

In Kent's Cave the implements obtained from the lower stages were of a much ruder description than the various objects detected in the upper cave-earth ... And a very long time must have elapsed between the formation of the lower and upper Palaeolithic beds in that cave.

The Middle Paleolithic in the modern sense made its appearance in 1911 in the 1st edition of William Johnson Sollas' *Ancient Hunters*. It had been used in varying senses before then. Sollas associates the period with the Mousterian technology and the relevant modern people with the Tasmanians. In the 2nd edition of 1915 he has changed his mind for reasons that are not clear. The Mousterian has been moved to the Lower Paleolithic and the people changed to the Australian aborigines; furthermore, the association has been made with Neanderthals and the Levalloisian added. Sollas says wistfully that they are in "the very middle of the Palaeolithic epoch." Whatever his reasons, the public would have none of it. From 1911 on, Mousterian was Middle

Paleolithic, except for holdouts. Alfred L. Kroeber in 1920, *Three essays on the antiquity and races of man,* reverting to Lower Paleolithic, explains that he is following Louis Laurent Gabriel de Mortillet. The English-speaking public remained with Middle Paleolithic.

Early and late from Worsaae through the three-stage African system

Thomsen had formalized the Three-age System by the time of its publication in 1836. The next step forward was the formalization of the Palaeolithic and Neolithic by Sir John Lubbock in 1865. Between these two times Denmark held the lead in archaeology, especially because of the work of Thomsen's at first junior associate and then successor, Jens Jacob Asmussen Worsaae, rising in the last year of his life to Kultus Minister of Denmark. Lubbock offers full tribute and credit to him in *Prehistoric Times*.

Worsaae in 1862 in *Om Tvedelingen af Steenalderen*, previewed in English even before its publication by *The Gentleman's Magazine*, concerned about changes in typology during each period, proposed a bipartite division of each age:

Both for Bronze and Stone it was now evident that a few hundred years would not suffice. In fact, good grounds existed for dividing each of these periods into two, if not more.

He called them earlier or later. The three ages became six periods. The British seized on the concept immediately. Worsaae's earlier and later became Lubbock's palaeo- and neo- in 1865, but alternatively English speakers used Earlier and

Later Stone Age, as did Lyell's 1883 edition of *Principles of Geology*, with older and younger as synonyms. As there is no room for a middle between the comparative adjectives, they were later modified to early and late. The scheme created a problem for further bipartite subdivisions, which would have resulted in such terms as early early Stone Age, but that terminology was avoided by adoption of Geikie's upper and lower Paleolithic.

Amongst African archaeologists, the terms Old Stone Age, Middle Stone Age and Late Stone Age are preferred.

Wallace's grand revolution recycled

When Sir John Lubbock was doing the preliminary work for his 1865 *magnum opus*, Charles Darwin and Alfred Russel Wallace were jointly publishing their first papers On the Tendency of Species to form Varieties; and on the Perpetuation of Varieties and Species by Natural Means of Selection. Darwins's On the Origin of Species came out in 1859, but he did not elucidate the theory of evolution as it applies to man until the Descent of Man in 1871. Meanwhile, Wallace read a paper in 1864 to the Anthropological Society of London that was a major influence on Sir John, publishing in the very next year. He quoted Wallace:

From the moment when the first skin was used as a covering, when the first rude spear was formed to assist in the chase, the first seed sown or shoot planted, a grand revolution was effected in nature, a revolution which in all the previous ages of the world's history had had no parallel, for a being had arisen who was no longer necessarily subject to change with the changing universe,—a being who was in some degree superior to nature, inasmuch as he knew how to control and regulate her action, and could keep himself in harmony with her, not by a change in body, but by an advance in mind.

Wallace distinguishing between mind and body was asserting that natural selection shaped the form of man only until the appearance of mind; after then, it played no part. Mind formed modern man, meaning that result of mind, culture. Its appearance overthrew the laws of nature. Wallace used the term "grand revolution." Although Lubbock believed that Wallace had gone too far in that direction he did adopt a theory of evolution combined with the revolution of culture. Neither Wallace not Lubbock offered any explanation of how the revolution came about, or felt that they had to offer one. Revolution is an acceptance that in the continuous evolution of objects and events sharp and inexplicable disconformities do occur, as in geology. And so it is not surprising that in the 1874 Stockholm meeting of the International Congress of Anthropology and Prehistoric Archaeology, in response to Ernst Hamy's denial of any "break" between Paleolithic and Neolithic based on material from dolmens near Paris "showing a continuity between the paleolithic and neolithic folks," Edouard Desor, geologist and archaeologist, replied: "that the introduction of domesticated animals was a complete revolution and enables us to separate the two epochs completely."

A revolution as defined by Wallace and adopted by Lubbock is a change of regime, or rules. If man was the new rule-setter through culture then the initiation of each of Lubbock's four periods might be regarded as a change of rules and therefore as a distinct revolution, and so *Chambers's Journal*, a reference work, in 1879 portrayed each of them as:

> ...an advance in knowledge and civilization which amounted to a revolution in the then existing manners and customs of the world.

Because of the controversy over Westropp's Mesolithic and Mortillet's Gap beginning in 1872 archaeological attention focused mainly on the revolution at the Palaeolithic—Neolithic boundary as an explanation of the gap. For a few decades the Neolithic Period, as it was called, was described as a kind of revolution. In the 1890s, a standard term, the Neolithic Revolution, began to appear in encyclopedias such as Pears. In 1925 the Cambridge Ancient History reported:

- There are quite a large number of archaeologists who justifiably consider the period of the Late Stone Age to be a Neolithic revolution and an economic revolution at the same time. For that is the period when primitive agriculture developed and cattle breeding began.

Vere Gordon Childe's revolution for the masses

In 1936 a champion came forward who would advance the Neolithic Revolution into the mainstream view: Vere Gordon Childe. After giving the Neolithic Revolution scant mention in his first notable work, the 1928 edition of *New Light on the Most Ancient East*, Childe made a major presentation in the first edition of *Man Makes Himself* in 1936 developing Wallace's and Lubbock's theme of the human revolution against the supremacy of nature and supplying detail on two revolutions, the Paleolithic—Neolithic and the Neolithic-Bronze Age, which he called the Second or Urban revolution.

Lubbock had been as much of an ethnologist as an archaeologist. The founders of cultural anthropology, such as Tylor and Morgan, were to follow his lead on that. Lubbock created such concepts as savages and barbarians based on the customs of then modern tribesmen and made the presumption that the terms can be applied without serious inaccuracy to the men of the Paleolithic and the Neolithic. Childe broke with this view:

- The assumption that any savage tribe today is primitive, in the sense that its culture faithfully reflects that of much more ancient men is gratuitous.

Childe concentrated on the inferences to be made from the artifacts:

- But when the tools ... are considered ... in their totality, they may reveal much more. They disclose not only the level of technical skill ... but also their economy .... The archaeologists's ages correspond roughly to economic stages. Each new "age" is ushered in by an economic revolution ....

The archaeological periods were indications of economic ones:

- Archaeologists can define a period when it was apparently the sole economy, the sole organization of production ruling anywhere on the earth's surface.

These periods could be used to supplement historical ones where history was not available. He reaffirmed Lubbock's view that the Paleolithic was an age of food gathering and the Neolithic an age of food production. He took a stand on the question of the Mesolithic identifying it with the Epipaleolithic. The Mesolithic was to him "a mere continuance of the Old Stone Age mode of life" between the end of the Pleistocene and the start of the Neolithic. Lubbock's terms "savagery" and "barbarism" do not much appear in *Man Makes Himself* but the sequel, *What Happened in History* (1942), reuses them (attributing them to Morgan, who got them from Lubbock) with an economic significance: savagery for food-gathering and barbarism for Neolithic food production. Civilization begins with the urban revolution of the Bronze Age.

The Pre-pottery Neolithic of Garstang and Kenyon at Jericho

Even as Childe was developing this revolution theme the ground was sinking under him. Lubbock did not find any pottery associated with the Paleolithic, asserting of its to him last period, the Reindeer, "no fragments of metal or pottery have yet been found." He did not generalize but others did not hesitate to do so. The next year, 1866, Dawkins proclaimed of Neolithic people that "these invented the use of pottery...." From then until the 1930s pottery was considered a sine qua non of the Neolithic. The term Pre-Pottery Age came into use in the late 19th century but it meant Paleolithic.

Meanwhile, the Palestine Exploration Fund founded in 1865 completing its survey of excavatable sites in Palestine in 1880 began excavating in 1890 at the site of ancient Lachish near

Jerusalem, the first of a series planned under the licensing system of the Ottoman Empire. Under their auspices in 1908 Ernst Sellin and Carl Watzinger began excavation at Jericho (Tell es-Sultan) previously excavated for the first time by Sir Charles Warren in 1868. They discovered a Neolithic and Bronze Age city there. Subsequent excavations in the region by them and others turned up other walled cities that appear to have preceded the Bronze Age urbanization.

All excavation ceased for World War I. When it was over the Ottoman Empire was no longer a factor there. In 1919 the new British School of Archaeology in Jerusalem assumed archaeological operations in Palestine. John Garstang finally resumed excavation at Jericho 1930–1936. The renewed dig uncovered another 3000 years of prehistory that was in the Neolithic but did not make use of pottery. He called it the Pre-pottery Neolithic, as opposed to the Pottery Neolithic, subsequently often called the Aceramic or Pre-ceramic and Ceramic Neolithic.

Kathleen Kenyon was a young photographer then with a natural talent for archaeology. Solving a number of dating problems she soon advanced to the forefront of British archaeology through skill and judgement. In World War II she served as a commander in the Red Cross.

In 1952–58 she took over operations at Jericho as the Director of the British School, verifying and expanding Garstang's work and conclusions. There were two Pre-pottery Neolithic periods, she concluded, A and B. Moreover, the PPN had been discovered at most of the major Neolithic sites in the near East and Greece. By this time her personal stature in archaeology was at least equal to that of V. Gordon Childe. While the three-age system was being attributed to Childe in popular fame, Kenyon became gratuitously the discoverer of the PPN. More significantly the question of revolution or evolution of the Neolithic was increasingly being brought before the professional archaeologists.

Bronze Age subdivisions

Danish archaeology took the lead in defining the Bronze Age, with little of the controversy surrounding the Stone Age. British archaeologists patterned their own excavations after those of the Danish, which they followed avidly in the media. References to the Bronze Age in British excavation reports began in the 1820s contemporaneously with the new system being promulgated by C.J. Thomsen. Mention of the Early and Late Bronze Age began in the 1860s following the bipartite definitions of Worsaae.

The tripartite system of Sir John Evans

In 1874 at the Stockholm meeting of the International Congress of Anthropology and Prehistoric Archaeology, a suggestion was made by A. Bertrand that no distinct age of bronze had existed, that the bronze artifacts discovered were really part of the Iron Age.

Hans Hildebrand in refutation pointed to two Bronze Ages and a transitional period in Scandinavia. John Evans denied any defect of continuity between the two and asserted there were three Bronze Ages, "the early, middle and late Bronze Age."

His view for the Stone Age, following Lubbock, was quite different, denying, in *The Ancient Stone Implements*, any concept of a Middle Stone Age. In his 1881 parallel work, *The Ancient Bronze Implements*, he affirmed and further defined the three periods, strangely enough recusing himself from his previous terminology, Early, Middle and Late Bronze Age (the current forms) in favor of "an earlier and later stage" and "middle". He uses Bronze Age, Bronze Period, Bronze-using Period and Bronze Civilization interchangeably. Apparently Evans was sensitive of what had gone before, retaining the terminology of the bipartite system while proposing a tripartite one. After stating a catalogue of types of bronze implements he defines his system:

- The Bronze Age of Britain may, therefore, be regarded as an aggregate of three stages: the first, that characterized by the flat or slightly flanged celts, and the knife-daggers ... the second, that characterized by the more heavy dagger-blades and the flanged celts and tanged spear-heads or daggers, ... and the third, by palstaves and socketed celts and the many forms of tools and weapons, ... It is in this third stage that the bronze sword and the true socketed spear-head first make their advent.

From Evans' gratuitous Copper Age to the mythical chalcolithic

In chapter 1 of his work, Evans proposes for the first time a transitional Copper Age between the Neolithic and the Bronze Age. He adduces evidence from far-flung places such as China and the Americas to show that the smelting of copper universally preceded alloying with tin to make bronze. He does not know how to classify this fourth age. On the one hand he distinguishes it from the Bronze Age. On the other hand, he includes it:

In thus speaking of a bronze-using period I by no means wish to exclude the possible use of copper unalloyed with tin.

Evans goes into considerable detail tracing references to the metals in classical literature: Latin *aer, aeris* and Greek *chalkós* first for "copper" and then for "bronze." He does not mention the adjective of *aes*, which is *aēneus*, nor is he interested in formulating New Latin words for the Copper Age, which is good enough for him and many English authors from then on. He offers literary proof that bronze had been in use before iron and copper before bronze.

In 1884 the center of archaeological interest shifted to Italy with the excavation of Remedello and the discovery of the Remedello culture by Gaetano Chierici. According to his 1886 biographers, Luigi Pigorini and Pellegrino Strobel, Chierici devised the term Età Eneo-litica to describe the archaeological context of his findings, which he believed were the remains of Pelasgians, or people that preceded Greek and Latin speakers in the Mediterranean. The age (Età) was:

A period of transition from the age of stone to that of bronze (periodo di transizione dall'età della pietra a quella del bronzo)

Whether intentional or not, the definition was the same as Evans', except that Chierici was adding a term to New Latin. He describes the transition by stating the beginning (litica, or Stone Age) and the ending (eneo-, or Bronze Age); in English, "the stone-to-bronze period." Shortly after, "Eneolithic" or "Aeneolithic" began turning up in scholarly English as a synonym for "Copper Age." Sir John's own son, Arthur Evans, beginning to come into his own as an archaeologist and already studying Cretan civilization, refers in 1895 to some clay figures of "aeneolithic date" (quotes his).

End of the Iron Age

The three-age system is a way of dividing prehistory, and the Iron Age is therefore considered to end in a particular culture with either the start of its protohistory, when it begins to be written about by outsiders, or when its own historiography begins. Although iron is still the major hard material in use in modern civilization, and steel is a vital and indispensable modern industry, as far as archaeologists are concerned the Iron Age has therefore now ended for all cultures in the world.

The date when it is taken to end varies greatly between cultures, and in many parts of the world there was no Iron Age at all, for example in Pre-Columbian America and the prehistory of Australia. For these and other regions the three-age system is little used. By a convention among archaeologists, in the Ancient Near East the Iron Age is taken to end with the start of the Achaemenid Empire in the 6th century BC, as the history of that is told by the Greek historian Herodotus. This remains the case despite a good deal of earlier local written material having become known since the convention was established. In Western Europe the Iron Age is ended by Roman conquest. In South Asia the start of the Maurya Empire about 320 BC is usually taken as the end point; although we have a considerable quantity of earlier written texts from India, they give us relatively little in the way of a conventional record of political history. For Egypt, China and Greece "Iron Age" is not a very useful concept, and relatively little used as a period term. In the first two prehistory has ended, and periodization by historical ruling dynasties has already begun, in the Bronze Age, which these cultures do have. In Greece the Iron Age begins during the Greek Dark Ages, and coincides with the cessation of a historical record for some centuries. For Scandinavia and other parts of northern Europe that the Romans did not reach, the Iron Age continues until the start of the Viking Age in about 800 AD.

Dating

The question of the dates of the objects and events discovered through archaeology is the prime concern of any system of thought that seeks to summarize history through the formulation of ages or epochs. An age is defined through comparison of contemporaneous events. Increasingly, the terminology of archaeology is parallel to that of historical method. An event is "undocumented" until it turns up in the archaeological record. Fossils and artifacts are "documents" of the epochs hypothesized. The correction of dating errors is therefore a major concern.

In the case where parallel epochs defined in history were available, elaborate efforts were made to align European and Near Eastern sequences with the datable chronology of Ancient Egypt and other known civilizations. The resulting grand sequence was also spot checked by evidence of calculateable solar or other astronomical events. These methods are only available for the relatively short term of recorded history. Most prehistory does not fall into that category.

Physical science provides at least two general groups of dating methods, stated below. Data collected by these methods is intended to provide an absolute chronology to the framework of periods defined by relative chronology.

Grand systems of layering

The initial comparisons of artifacts defined periods that were local to a site, group of sites or region. Advances made in the fields of seriation, typology, stratification and the associative dating of artifacts and features permitted even greater refinement of the system. The ultimate development is the reconstruction of a global catalogue of layers (or as close to it as possible) with different sections attested in different regions. Ideally once the layer of the artifact or event is known a quick lookup of the layer in the grand system will provide a ready date. This is considered the most reliable method. It is used for calibration of the less reliable chemical methods.

Measurement of chemical change

Any material sample contains elements and compounds that are subject to decay into other elements and compounds. In cases where the rate of decay is predictable and the proportions of initial and end products can be known exactly, consistent dates of the artifact can be calculated. Due to the problem of sample contamination and variability of the natural proportions of the materials in the media, sample analysis in the case where verification can be checked by grand layering systems has often been found to be widely inaccurate. Chemical dates therefore are only considered reliable used in conjunction with other methods. They are collected in groups of data points that form a pattern when graphed. Isolated dates are not considered reliable.

Other -liths and -lithics

- The term Megalithic does not refer to a period of time, but merely describes the use of large stones by ancient peoples from any period. An eolith is a stone that might have been formed by natural process but occurs in contexts that suggest modification by early humans or other primates for percussion.

Criticism

The Three-age System has been criticized since at least the 19th century. Every phase of its development has been contested. Some of the arguments that have been presented against it follow.

Unsound epochalism

In some cases criticism resulted in other, parallel three-age systems, such as the concepts expressed by Lewis Henry Morgan in *Ancient Society*, based on ethnology. These disagreed with the metallic basis of epochization. The critic generally substituted his own definitions of epochs. Vere Gordon Childe said of the early cultural anthropologists:

- Last century Herbert Spencer, Lewis H. Morgan and Tylor propounded divergent schemes ... they arranged these in a logical order .... They assumed that the logical order was a temporal one.... The competing systems of Morgan and Tylor remained equally unverified—and incompatible—theories.

More recently, many archaeologists have questioned the validity of dividing time into epochs at all.

For example, one recent critic, Graham Connah, describes the three-age system as "epochalism" and asserts:

- So many archaeological writers have used this model for so long that for many readers it has taken on a reality of its own. In spite of the theoretical agonizing of the last half-century, epochalism is still alive and well ... Even in parts of the world where the model is still in common use, it needs to be accepted that, for example, there never was actually such a thing as 'the Bronze Age.'

Simplisticism

Some view the three-age system as over-simple; that is, it neglects vital detail and forces complex circumstances into a mold they do not fit. Rowlands argues that the division of human societies into epochs based on the presumption of a single set of related changes is not realistic:

- But as a more rigorous sociological approach has begun to show that changes at the economic, political and ideological levels are not 'all of apiece'

> we have come to realise that time may be segmented in as many ways as convenient to the researcher concerned.

The three-age system is a relative chronology. The explosion of archaeological data acquired in the 20th century was intended to elucidate the relative chronology in detail. One consequence was the collection of absolute dates. Connah argues:

- As radiocarbon and other forms of absolute dating contributed more detailed and more reliable chronologies, the epochal model ceased to be necessary.

Peter Bogucki of Princeton University summarizes the perspective taken by many modern archaeologists:

- Although modern archaeologists realize that this tripartite division of prehistoric society is far too simple to reflect the complexity of change and continuity, terms like 'Bronze Age' are still used as a very general way of focusing attention on particular times and places and thus facilitating archaeological discussion.

Eurocentrism

Another common criticism attacks the broader application of the three-age system as a cross-cultural model for social change. The model was originally designed to explain data from Europe and West Asia, but archaeologists have also attempted to use it to explain social and technological developments in other parts of the world such as the Americas, Australasia, and

Africa. Many archaeologists working in these regions have criticized this application as eurocentric. Graham Connah writes that:

- ... attempts by Eurocentric archaeologists to apply the model to African archaeology have produced little more than confusion, whereas in the Americas or Australasia it has been irrelevant, ...

Alice B. Kehoe further explains this position as it relates to American archaeology:

- ... Professor Wilson's presentation of prehistoric archaeology was a European product carried across the Atlantic to promote an American science compatible with its European model.

Kehoe goes on to complain of Wilson that "he accepted and reprised the idea that the European course of development was paradigmatic for humankind." This criticism argues that the different societies of the world underwent social and technological developments in different ways. A sequence of events that describes the developments of one civilization may not necessarily apply to another, in this view. Instead social and technological developments must be described within the context of the society being studied.

Chapter 17

Stone Age Technology in the Old World

The Stone Age was a broad prehistoric period during which stone was widely used to make tools with an edge, a point, or a percussion surface. The period lasted for roughly 3.4 million years, and ended between 4,000 BCE and 2,000 BCE, with the advent of metalworking.

Though some simple metalworking of malleable metals, particularly the use of gold and copper for purposes of ornamentation, was known in the Stone Age, it is the melting and smelting of copper that marks the end of the Stone Age. In western Asia this occurred by about 3,000 BCE, when bronze became widespread. The term Bronze Age is used to describe the period that followed the Stone Age, as well as to describe cultures that had developed techniques and technologies for working copper alloys (bronze: originally copper and arsenic, later copper and tin) into tools, supplanting stone in many uses.

Stone Age artifacts that have been discovered include tools used by modern humans, by their predecessor species in the genus *Homo*, and possibly by the earlier partly contemporaneous genera *Australopithecus* and *Paranthropus*. Bone tools have been discovered that were used during this period as well but these are rarely preserved in the archaeological record. The Stone Age is further subdivided by the types of stone tools in use.

The Stone Age is the first period in the three-age system frequently used in archaeology to divide the timeline of human technological prehistory into functional periods, with the next two being the Bronze Age and the Iron Age respectively.

Historical significance

The Stone Age is contemporaneous with the evolution of the genus *Homo*, with the possible exception of the early Stone Age, when species prior to *Homo* may have manufactured tools. According to the age and location of the current evidence, the cradle of the genus is the East African Rift System, especially toward the north in Ethiopia, where it is bordered by grasslands. The closest relative among the other living primates, the genus *Pan*, represents a branch that continued on in the deep forest, where the primates evolved.

The rift served as a conduit for movement into southern Africa and also north down the Nile into North Africa and through the continuation of the rift in the Levant to the vast grasslands of Asia.

Starting from about 4 million years ago (mya) a single biome established itself from South Africa through the rift, North Africa, and across Asia to modern China. This has been called "transcontinental 'savannahstan'" recently. Starting in the grasslands of the rift, *Homo erectus*, the predecessor of modern humans, found an ecological niche as a tool-maker and developed a dependence on it, becoming a "tool equipped savanna dweller".

Stone Age in archaeology

Beginning of the Stone Age

The oldest indirect evidence found of stone tool use is fossilised animal bones with tool marks; these are 3.4 million years old and were found in the Lower Awash Valley in Ethiopia. Archaeological discoveries in Kenya in 2015, identifying what may be the oldest evidence of hominin use of tools known to date, have indicated that *Kenyanthropus platyops* (a 3.2 to 3.5-million-year-old Pliocene hominin fossil discovered in Lake Turkana, Kenya in 1999) may have been the earliest tool-users known.

The oldest stone tools were excavated from the site of Lomekwi 3 in West Turkana, northwestern Kenya, and date to 3.3 million years old. Prior to the discovery of these "Lomekwian" tools, the oldest known stone tools had been found at several sites at Gona, Ethiopia, on sediments of the paleo-Awash River, which serve to date them. All the tools come from the Busidama Formation, which lies above a disconformity, or missing layer, which would have been from 2.9 to 2.7 mya. The oldest sites discovered to contain tools are dated to 2.6–2.55 mya. One of the most striking circumstances about these sites is that they are from the Late Pliocene, where prior to their discovery tools were thought to have evolved only in the Pleistocene. Excavators at the locality point out that:

> ... the earliest stone tool makers were skilled flintknappers .... The possible reasons behind this seeming abrupt transition from the absence of stone

> tools to the presence thereof include ... gaps in the geological record.

The species who made the Pliocene tools remains unknown. Fragments of *Australopithecus garhi*, *Australopithecus aethiopicus*, and *Homo*, possibly *Homo habilis*, have been found in sites near the age of the Gona tools.

In July 2018, scientists reported the discovery in China of the known oldest stone tools outside Africa, estimated at 2.12 million years old.

End of the Stone Age

Innovation of the technique of smelting ore is regarded as ending the Stone Age and beginning the Bronze Age. The first highly significant metal manufactured was bronze, an alloy of copper and tin or arsenic, each of which was smelted separately. The transition from the Stone Age to the Bronze Age was a period during which modern people could smelt copper, but did not yet manufacture bronze, a time known as the Copper Age (or more technically the Chalcolithic or Eneolithic, both meaning 'copper–stone'). The Chalcolithic by convention is the initial period of the Bronze Age. The Bronze Age was followed by the Iron Age.

The transition out of the Stone Age occurred between 6000 and 2500 BCE for much of humanity living in North Africa and Eurasia. The first evidence of human metallurgy dates to between the 6th and 5th millennia BCE in the archaeological sites of Majdanpek, Yarmovac, and Pločnik in modern-day Serbia (including a copper axe from 5500 BCE belonging to the Vinca culture); though not conventionally considered part of the Chalcolithic, this provides the earliest known example of copper metallurgy. Note the Rudna Glava mine in Serbia. Ötzi the Iceman, a mummy from about 3300 BCE, carried with him a copper axe and a flint knife.

In some regions, such as Sub-Saharan Africa, the Stone Age was followed directly by the Iron Age. The Middle East and Southeast Asian regions progressed past Stone Age technology around 6000 BCE. Europe, and the rest of Asia became post-Stone Age societies by about 4000 BCE.

The proto-Inca cultures of South America continued at a Stone Age level until around 2000 BCE, when gold, copper, and silver made their entrance. The peoples of the Americas notably did not develop a widespread behavior of smelting bronze or iron after the Stone Age period, although the technology existed. Stone-tool manufacture continued even after the Stone Age ended in a given area. In Europe and North America, millstones were in use until well into the 20th century, and still are in many parts of the world.

Concept of the Stone Age

The terms "Stone Age", "Bronze Age", and "Iron Age" are not intended to suggest that advancements and time periods in prehistory are only measured by the type of tool material, rather than, for example, social organization, food sources exploited, adaptation to climate, adoption of agriculture, cooking, settlement, and religion.

Like pottery, the typology of the stone tools combined with the relative sequence of the types in various regions provide a chronological framework for the evolution of humanity and society. They serve as diagnostics of date, rather than characterizing the people or the society.

Lithic analysis is a major and specialised form of archaeological investigation. It involves measurement of stone tools to determine their typology, function and technologies involved. It includes scientific study of the lithic reduction of the raw materials and methods used to make the prehistoric artifacts that are discovered.

Much of this study takes place in the laboratory in the presence of various specialists. In experimental archaeology, researchers attempt to create replica tools, to understand how they were made. Flintknappers are craftsmen who use sharp tools to reduce flintstone to flint tool.

In addition to lithic analysis, field prehistorians utilize a wide range of techniques derived from multiple fields. The work of archaeologists in determining the paleocontext and relative sequence of the layers is supplemented by the efforts of geologic specialists in identifying layers of rock developed or deposited over geologic time; of paleontological specialists in identifying bones and animals; of palynologists in discovering and identifying pollen, spores and plant species; of physicists and chemists in laboratories determining ages of materials by carbon-14, potassium-argon and other methods. Study of the Stone Age has never been limited to stone tools and archaeology, even though they are important forms of evidence. The chief focus of study has always been on the society and the living people who belonged to it.

Useful as it has been, the concept of the Stone Age has its limitations. The date range of this period is ambiguous, disputed, and variable, depending upon the region in question. While it is possible to speak of a general 'stone age' period for the whole of humanity, some groups never developed metal-smelting technology, and so remained in the so-called 'stone age' until they encountered technologically developed cultures. The term was innovated to describe the archaeological cultures of Europe. It may not always be the best in relation to regions such as some parts of the Indies and Oceania, where farmers or hunter-gatherers used stone for tools until European colonisation began.

Archaeologists of the late 19th and early 20th centuries CE, who adapted the three-age system to their ideas, hoped to combine cultural anthropology and archaeology in such a way that a specific contemporaneous tribe can be used to illustrate the way of life and beliefs of the people exercising a particular Stone-Age technology. As a description of people living today, the term *stone age* is controversial. The Association of Social Anthropologists discourages this use, asserting:

To describe any living group as 'primitive' or 'Stone Age' inevitably implies that they are living representatives of some earlier stage of human development that the majority of humankind has left behind.

Three-stage system

In the 1920s, South African archaeologists organizing the stone tool collections of that country observed that they did not fit the newly detailed Three-Age System. In the words of J. Desmond Clark, It was early realized that the threefold division of culture into Stone, Bronze and Iron Ages adopted in the nineteenth century for Europe had no validity in Africa outside the Nile valley.

Consequently, they proposed a new system for Africa, the Three-stage System. Clark regarded the Three-age System as valid for North Africa; in sub-Saharan Africa, the Three-stage System was best. In practice, the failure of African archaeologists either to keep this distinction in mind, or to explain which one they mean, contributes to the considerable equivocation already present in the literature. There are in effect two Stone Ages, one part of the Three-age and the other constituting the Three-stage. They refer to one and the same artifacts and the same technologies, but vary by locality and time.

The three-stage system was proposed in 1929 by Astley John Hilary Goodwin, a professional archaeologist, and Clarence van Riet Lowe, a civil engineer and amateur archaeologist, in an article titled "Stone Age Cultures of South Africa" in the journal *Annals of the South African Museum*. By then, the dates of the Early Stone Age, or Paleolithic, and Late Stone Age, or Neolithic (*neo* = new), were fairly solid and were regarded by Goodwin as absolute. He therefore proposed a relative chronology of periods with floating dates, to be called the Earlier and Later Stone Age. The Middle Stone Age would not change its name, but it would not mean Mesolithic.

The duo thus reinvented the Stone Age. In Sub-Saharan Africa, however, iron-working technologies were either invented independently or came across the Sahara from the north (see *iron metallurgy in Africa*). The Neolithic was characterized primarily by herding societies rather than large agricultural societies, and although there was copper metallurgy in Africa as well as bronze smelting, archaeologists do not currently recognize a separate Copper Age or Bronze Age. Moreover, the technologies included in those 'stages', as Goodwin called them, were not exactly the same. Since then, the original relative terms have become identified with the technologies of the Paleolithic and Mesolithic, so that they are no longer relative. Moreover, there has been a tendency to drop the comparative degree in favor of the positive: resulting in two sets of Early, Middle and Late Stone Ages of quite different content and chronologies.

By voluntary agreement, archaeologists respect the decisions of the Pan-African Congress on Prehistory, which meets every four years to resolve archaeological business brought before it. Delegates are actually international; the organization takes its name from the topic. Louis Leakey hosted the first one in Nairobi in 1947. It adopted Goodwin and Lowe's 3-stage system at that time, the stages to be called Early, Middle and Later.

Problem of the transitions

The problem of the transitions in archaeology is a branch of the general philosophic continuity problem, which examines how discrete objects of any sort that are contiguous in any way can be presumed to have a relationship of any sort. In archaeology, the relationship is one of causality. If Period B can be presumed to descend from Period A, there must be a boundary between A and B, the A–B boundary. The problem is in the nature of this boundary. If there is no distinct boundary, then the population of A suddenly stopped using the customs characteristic of A and suddenly started using those of B, an unlikely scenario in the process of evolution. More realistically, a distinct border period, the A/B transition, existed, in which the customs of A were gradually dropped and those of B acquired. If transitions do not exist, then there is no proof of any continuity between A and B.

The Stone Age of Europe is characteristically in deficit of known transitions. The 19th and early 20th-century innovators of the modern three-age system recognized the problem of the initial transition, the "gap" between the Paleolithic and the Neolithic. Louis Leakey provided something of an answer by proving that man evolved in Africa.

The Stone Age must have begun there to be carried repeatedly to Europe by migrant populations. The different phases of the Stone Age thus could appear there without transitions. The burden on African archaeologists became all the greater, because now they must find the missing transitions in Africa. The problem is difficult and ongoing.

After its adoption by the First Pan African Congress in 1947, the Three-Stage Chronology was amended by the Third Congress in 1955 to include a First Intermediate Period between Early and Middle, to encompass the Fauresmith and Sangoan technologies, and the Second Intermediate Period between Middle and Later, to encompass the Magosian technology and others. The chronologic basis for definition was entirely relative. With the arrival of scientific means of finding an absolute chronology, the two intermediates turned out to be will-of-the-wisps. They were in fact Middle and Lower Paleolithic. Fauresmith is now considered to be a facies of

Acheulean, while Sangoan is a facies of Lupemban. Magosian is "an artificial mix of two different periods".

Once seriously questioned, the intermediates did not wait for the next Pan African Congress two years hence, but were officially rejected in 1965 (again on an advisory basis) by Burg Wartenstein Conference #29, *Systematic Investigation of the African Later Tertiary and Quaternary*, a conference in anthropology held by the Wenner-Gren Foundation, at Burg Wartenstein Castle, which it then owned in Austria, attended by the same scholars that attended the Pan African Congress, including Louis Leakey and Mary Leakey, who was delivering a pilot presentation of her typological analysis of Early Stone Age tools, to be included in her 1971 contribution to *Olduvai Gorge*, "Excavations in Beds I and II, 1960–1963."

However, although the intermediate periods were gone, the search for the transitions continued.

Chronology

In 1859 Jens Jacob Worsaae first proposed a division of the Stone Age into older and younger parts based on his work with Danish kitchen middens that began in 1851. In the subsequent decades this simple distinction developed into the archaeological periods of today. The major subdivisions of the Three-age Stone Age cross two epoch boundaries on the geologic time scale:

- The geologic Pliocene–Pleistocene boundary (highly glaciated climate)
- The Paleolithic period of archaeology

- The geologic Pleistocene–Holocene boundary (modern climate)
- Mesolithic or Epipaleolithic period of archaeology
- Neolithic period of archaeology

The succession of these phases varies enormously from one region (and culture) to another.

Three-age chronology

The Paleolithic or Palaeolithic (from Greek: παλαιός, *palaios*, "old"; and λίθος, *lithos*, "stone" lit. "old stone", coined by archaeologist John Lubbock and published in 1865) is the earliest division of the Stone Age. It covers the greatest portion of humanity's time (roughly 99% of "human technological history", where "human" and "humanity" are interpreted to mean the genus *Homo*), extending from 2.5 or 2.6 million years ago, with the first documented use of stone tools by hominans such as *Homo habilis*, to the end of the Pleistocene around 10,000 BCE. The Paleolithic era ended with the Mesolithic, or in areas with an early neolithisation, the Epipaleolithic.

Lower Paleolithic

- At sites dating from the Lower Paleolithic Period (about 2,500,000 to 200,000 years ago), simple pebble tools have been found in association with the remains of what may have been the earliest human ancestors. A somewhat more sophisticated Lower Paleolithic tradition, known as the Chopper chopping-tool industry, is widely distributed in the Eastern Hemisphere. This tradition is thought to have been the work of the hominin species named Homo erectus. Although no such fossil tools have yet been found, it is believed that H. erectus probably made tools of wood and bone as well as stone. About 700,000 years ago, a new Lower Paleolithic tool, the hand ax, appeared. The earliest European hand axes are assigned to the Abbevillian industry, which developed in northern France in the valley of the Somme River; a later, more refined hand-axe tradition is seen in the Acheulian industry, evidence of which has been found in Europe, Africa, the Middle East, and Asia. Some of the earliest known hand axes were found at Olduvai Gorge (Tanzania) in association with remains of H. erectus. Alongside the hand-axe tradition there developed a distinct and very different stone-tool industry, based on flakes of stone: special tools were made from worked (carefully shaped) flakes of flint. In Europe, the Clactonian industry is one example of a flake tradition. The early flake industries probably contributed to the development of the Middle Paleolithic flake tools of the Mousterian industry, which is associated with the remains of Neanderthal man.

Oldowan in Africa

The earliest documented stone tools have been found in eastern Africa, manufacturers unknown, at the 3.3 million year old site of Lomekwi 3 in Kenya.

Better known are the later tools belonging to an industry known as Oldowan, after the type site of Olduvai Gorge in Tanzania.

The tools were formed by knocking pieces off a river pebble, or stones like it, with a hammerstone to obtain large and small pieces with one or more sharp edges.

The original stone is called a core; the resultant pieces, flakes. Typically, but not necessarily, small pieces are detached from a larger piece, in which case the larger piece may be called the core and the smaller pieces the flakes. The prevalent usage, however, is to call all the results flakes, which can be confusing. A split in half is called bipolar flaking.

Consequently, the method is often called "core-and-flake". More recently, the tradition has been called "small flake" since the flakes were small compared to subsequent Acheulean tools.

The essence of the Oldowan is the making and often immediate use of small flakes.

Another naming scheme is "Pebble Core Technology (PBC)":

Pebble cores are ... artifacts that have been shaped by varying amounts of hard-hammer percussion.

Various refinements in the shape have been called choppers, discoids, polyhedrons, subspheroid, etc. To date no reasons for the variants have been ascertained:

- From a functional standpoint, pebble cores seem designed for no specific purpose.

However, they would not have been manufactured for no purpose:

- Pebble cores can be useful in many cutting, scraping or chopping tasks, but ... they are not particularly more efficient in such tasks than a sharp-edged rock.

The whole point of their utility is that each is a "sharp-edged rock" in locations where nature has not provided any. There is additional evidence that Oldowan, or Mode 1, tools were utilized in "percussion technology"; that is, they were designed to be gripped at the blunt end and strike something with the edge, from which use they were given the name of choppers. Modern science has been able to detect mammalian blood cells on Mode 1 tools at Sterkfontein, Member 5 East, in South Africa. As the blood must have come from a fresh kill, the tool users are likely to have done the killing and used the tools for butchering. Plant residues bonded to the silicon of some tools confirm the use to chop plants.

Although the exact species authoring the tools remains unknown, Mode 1 tools in Africa were manufactured and used predominantly by *Homo habilis*. They cannot be said to have developed these tools or to have contributed the tradition to technology. They continued a tradition of yet unknown origin. As chimpanzees sometimes naturally use percussion to extract or prepare food in the wild, and may use either unmodified stones or stones that they have split, creating an Oldowan tool, the tradition may well be far older than its current record.

Towards the end of Oldowan in Africa a new species appeared over the range of *Homo habilis*: *Homo erectus*. The earliest "unambiguous" evidence is a whole cranium, KNM-ER 3733 (a find identifier) from Koobi Fora in Kenya, dated to 1.78 mya.

An early skull fragment, KNM-ER 2598, dated to 1.9 mya, is considered a good candidate also. Transitions in paleoanthropology are always hard to find, if not impossible, but based on the "long-legged" limb morphology shared by *H. habilis* and *H. rudolfensis* in East Africa, an evolution from one of those two has been suggested.

The most immediate cause of the new adjustments appears to have been an increasing aridity in the region and consequent contraction of parkland savanna, interspersed with trees and groves, in favor of open grassland, dated 1.8–1.7 mya. During that transitional period the percentage of grazers among the fossil species increased from 15–25% to 45%, dispersing the food supply and requiring a facility among the hunters to travel longer distances comfortably, which *H. erectus* obviously had. The ultimate proof is the "dispersal" of *H. erectus* "across much of Africa and Asia, substantially before the development of the Mode 2 technology and use of fire ...." *H. erectus* carried Mode 1 tools over Eurasia.

According to the current evidence (which may change at any time) Mode 1 tools are documented from about 2.6 mya to about 1.5 mya in Africa, and to 0.5 mya outside of it. The genus Homo is known from *H. habilis* and *H. rudolfensis* from 2.3 to 2.0 mya, with the latest habilis being an upper jaw from Koobi Fora, Kenya, from 1.4 mya. *H. erectus* is dated 1.8–0.6 mya.

According to this chronology Mode 1 was inherited by *Homo* from unknown Hominans, probably *Australopithecus* and *Paranthropus*, who must have continued on with Mode 1 and then with Mode 2 until their extinction no later than 1.1 mya.

Meanwhile, living contemporaneously in the same regions *H. habilis* inherited the tools around 2.3 mya. At about 1.9 mya *H. erectus* came on stage and lived contemporaneously with the others. Mode 1 was now being shared by a number of Hominans over the same ranges, presumably subsisting in different niches, but the archaeology is not precise enough to say which.

Oldowan out of Africa

Tools of the Oldowan tradition first came to archaeological attention in Europe, where, being intrusive and not well defined, compared to the Acheulean, they were puzzling to archaeologists. The mystery would be elucidated by African archaeology at Olduvai, but meanwhile, in the early 20th century, the term "Pre-Acheulean" came into use in climatology. C.E.P, Brooks, a British climatologist working in the United States, used the term to describe a "chalky boulder clay" underlying a layer of gravel at Hoxne, central England, where Acheulean tools had been found. Whether any tools would be found in it and what type was not known. Hugo Obermaier, a contemporary German archaeologist working in Spain, quipped:

Unfortunately, the stage of human industry which corresponds to these deposits cannot be positively identified. All we can say is that it is pre-Acheulean.

This uncertainty was clarified by the subsequent excavations at Olduvai; nevertheless, the term is still in use for pre-Acheulean contexts, mainly across Eurasia, that are yet unspecified or uncertain but with the understanding that they are or will turn out to be pebble-tool.

There are ample associations of Mode 2 with *H. erectus* in Eurasia. *H. erectus* – Mode 1 associations are scantier but they do exist, especially in the Far East. One strong piece of evidence prevents the conclusion that only *H. erectus* reached Eurasia: at Yiron, Israel, Mode 1 tools have been found dating to 2.4 mya, about 0.5 my earlier than the known *H. erectus* finds. If the date is correct, either another Hominan preceded *H. erectus* out of Africa or the earliest *H. erectus* has yet to be found.

After the initial appearance at Gona in Ethiopia at 2.7 mya, pebble tools date from 2.0 mya at Sterkfontein, Member 5, South Africa, and from 1.8 mya at El Kherba, Algeria, North Africa. The manufacturers had already left pebble tools at Yiron, Israel, at 2.4 mya, Riwat, Pakistan, at 2.0 mya, and Renzidong, South China, at over 2 mya. The identification of a fossil skull at Mojokerta, Pernung Peninsula on Java, dated to 1.8 mya, as *H. erectus*, suggests that the African finds are not the earliest to be found in Africa, or that, in fact, erectus did not originate in Africa after all but on the plains of Asia. The outcome of the issue waits for more substantial evidence. Erectus was found also at Dmanisi, Georgia, from 1.75 mya in association with pebble tools.

Pebble tools are found the latest first in southern Europe and then in northern. They begin in the open areas of Italy and Spain, the earliest dated to 1.6 mya at Pirro Nord, Italy. The mountains of Italy are rising at a rapid rate in the framework of geologic time; at 1.6 mya they were lower and covered with grassland (as much of the highlands still are). Europe was otherwise mountainous and covered over with dense forest, a formidable terrain for warm-weather savanna dwellers.

Similarly there is no evidence that the Mediterranean was passable at Gibraltar or anywhere else to *H. erectus* or earlier hominans. They might have reached Italy and Spain along the coasts.

In northern Europe pebble tools are found earliest at Happisburgh, United Kingdom, from 0.8 mya. The last traces are from Kent's Cavern, dated 0.5 mya. By that time *H. erectus* is regarded as having been extinct; however, a more modern version apparently had evolved, *Homo heidelbergensis*, who must have inherited the tools. He also explains the last of the Acheulean in Germany at 0.4 mya.

In the late 19th and early 20th centuries archaeologists worked on the assumptions that a succession of Hominans and cultures prevailed, that one replaced another. Today the presence of multiple hominans living contemporaneously near each other for long periods is accepted as proved true; moreover, by the time the previously assumed "earliest" culture arrived in northern Europe, the rest of Africa and Eurasia had progressed to the Middle and Upper Palaeolithic, so that across the earth all three were for a time contemporaneous. In any given region there was a progression from Oldowan to Acheulean, Lower to Upper, no doubt.

Acheulean in Africa

The end of Oldowan in Africa was brought on by the appearance of Acheulean, or Mode 2, stone tools. The earliest known instances are in the 1.7–1.6 mya layer at Kokiselei, West Turkana, Kenya. At Sterkfontein, South Africa, they are in Member 5 West, 1.7–1.4 mya. The 1.7 is a fairly certain, fairly standard date. Mode 2 is often found in association with

H. erectus. It makes sense that the most advanced tools should have been innovated by the most advanced Hominan; consequently, they are typically given credit for the innovation.

A Mode 2 tool is a biface consisting of two concave surfaces intersecting to form a cutting edge all the way around, except in the case of tools intended to feature a point. More work and planning go into the manufacture of a Mode 2 tool. The manufacturer hits a slab off a larger rock to use as a blank. Then large flakes are struck off the blank and worked into bifaces by hard-hammer percussion on an anvil stone. Finally the edge is retouched: small flakes are hit off with a bone or wood soft hammer to sharpen or resharpen it. The core can be either the blank or another flake. Blanks are ported for manufacturing supply in places where nature has provided no suitable stone.

Although most Mode 2 tools are easily distinguished from Mode 1, there is a close similarity of some Oldowan and some Acheulean, which can lead to confusion. Some Oldowan tools are more carefully prepared to form a more regular edge. One distinguishing criterion is the size of the flakes. In contrast to the Oldowan "small flake" tradition, Acheulean is "large flake:" "The primary technological distinction remaining between Oldowan and the Acheulean is the preference for large flakes (>10 cm) as blanks for making large cutting tools (handaxes and cleavers) in the Acheulean." "Large Cutting Tool (LCT)" has become part of the standard terminology as well.

In North Africa, the presence of Mode 2 remains a mystery, as the oldest finds are from Thomas Quarry in Morocco at 0.9 mya. Archaeological attention, however, shifts to the Jordan

Rift Valley, an extension of the East African Rift Valley (the east bank of the Jordan is slowly sliding northward as East Africa is thrust away from Africa).

Evidence of use of the Nile Valley is in deficit, but Hominans could easily have reached the palaeo-Jordan river from Ethiopia along the shores of the Red Sea, one side or the other. A crossing would not have been necessary, but it is more likely there than over a theoretical but unproven land bridge through either Gibraltar or Sicily.

Meanwhile, Acheulean went on in Africa past the 1.0 mya mark and also past the extinction of *H. erectus* there. The last Acheulean in East Africa is at Olorgesailie, Kenya, dated to about 0.9 mya. Its owner was still *H. erectus*, but in South Africa, Acheulean at Elandsfontein, 1.0–0.6 mya, is associated with Saldanha man, classified as *H. heidelbergensis*, a more advanced, but not yet modern, descendant most likely of *H. erectus*. The Thoman Quarry Hominans in Morocco similarly are most likely Homo rhodesiensis, in the same evolutionary status as *H. heidelbergensis*.

Acheulean out of Africa

Mode 2 is first known out of Africa at 'Ubeidiya, Israel, a site now on the Jordan River, then frequented over the long term (hundreds of thousands of years) by Homo on the shore of a variable-level palaeo-lake, long since vanished. The geology was created by successive "transgression and regression" of the lake resulting in four cycles of layers. The tools are located in the first two, Cycles Li (Limnic Inferior) and Fi (Fluviatile Inferior), but mostly in Fi. The cycles represent different ecologies and therefore different cross-sections of fauna, which makes it possible to date them. They appear to be the same faunal assemblages as the Ferenta Faunal Unit in Italy, known from excavations at Selvella and Pieterfitta, dated to 1.6–1.2 mya.

At 'Ubeidiya the marks on the bones of the animal species found there indicate that the manufacturers of the tools butchered the kills of large predators, an activity that has been termed "scavenging". There are no living floors, nor did they process bones to obtain the marrow. These activities cannot be understood therefore as the only or even the typical economic activity of Hominans. Their interests were selective: they were primarily harvesting the meat of Cervids, which is estimated to have been available without spoiling for up to four days after the kill.

The majority of the animals at the site were of "Palaearctic biogeographic origin". However, these overlapped in range on 30–60% of "African biogeographic origin". The biome was Mediterranean, not savanna.

The animals were not passing through; there was simply an overlap of normal ranges. Of the Hominans, *H. erectus* left several cranial fragments. Teeth of undetermined species may have been *H. ergaster*. The tools are classified as "Lower Acheulean" and "Developed Oldowan". The latter is a disputed classification created by Mary Leakey to describe an Acheulean-like tradition in Bed II at Olduvai. It is dated 1.53–1.27 mya. The date of the tools therefore probably does not exceed 1.5 mya; 1.4 is often given as a date. This chronology, which is definitely later than in Kenya, supports the "out of Africa" hypothesis for Acheulean, if not for the Hominans.

From Southwest Asia, as the Levant is now called, the Acheulean extended itself more slowly eastward, arriving at Isampur, India, about 1.2 mya. It does not appear in China and Korea until after 1mya and not at all in Indonesia. There is a discernible boundary marking the furthest extent of the Acheulean eastward before 1 mya, called the Movius Line, after its proposer, Hallam L. Movius. On the east side of the line the small flake tradition continues, but the tools are additionally worked Mode 1, with flaking down the sides. In Athirampakkam at Chennai in Tamil Nadu the Acheulean age started at 1.51 mya and it is also prior than North India and Europe.

The cause of the Movius Line remains speculative, whether it represents a real change in technology or a limitation of archeology, but after 1 mya evidence not available to Movius indicates the prevalence of Acheulean. For example, the Acheulean site at Bose, China, is dated 0.803±3K mya. The authors of this chronologically later East Asian Acheulean remain unknown, as does whether it evolved in the region or was brought in.

There is no named boundary line between Mode 1 and Mode 2 on the west; nevertheless, Mode 2 is equally late in Europe as it is in the Far East. The earliest comes from a rock shelter at Estrecho de Quípar in Spain, dated to greater than 0.9 mya. Teeth from an undetermined Hominan were found there also. The last Mode 2 in Southern Europe is from a deposit at Fontana Ranuccio near Anagni in Italy dated to 0.45 mya, which is generally linked to *Homo cepranensis*, a "late variant of *H. erectus*", a fragment of whose skull was found at Ceprano nearby, dated 0.46 mya.

Middle Paleolithic

This period is best known as the era during which the Neanderthals lived in Europe and the Near East (c. 300,000–28,000 years ago). Their technology is mainly the Mousterian, but Neanderthal physical characteristics have been found also in ambiguous association with the more recent Châtelperronian archeological culture in Western Europe and several local industries like the Szeletian in Eastern Europe/Eurasia. There is no evidence for Neanderthals in Africa, Australia or the Americas.

Neanderthals nursed their elderly and practised ritual burial indicating an organised society. The earliest evidence (Mungo Man) of settlement in Australia dates to around 40,000 years ago when modern humans likely crossed from Asia by island-hopping. Evidence for symbolic behavior such as body ornamentation and burial is ambiguous for the Middle Paleolithic and still subject to debate. The Bhimbetka rock shelters exhibit the earliest traces of human life in India, some of which are approximately 30,000 years old.

Upper Paleolithic

From 50,000 to 10,000 years ago in Europe, the Upper Paleolithic ends with the end of the Pleistocene and onset of the Holocene era (the end of the last ice age). Modern humans spread out further across the Earth during the period known as the Upper Paleolithic.

The Upper Paleolithic is marked by a relatively rapid succession of often complex stone artifact technologies and a large increase in the creation of art and personal ornaments. During period between 35 and 10 kya evolved: from 38 to 30 kya Châtelperronian, 40–28 Aurignacian, 28–22 Gravettian, 22–17 Solutrean, and 18–10 Magdalenian. All of these industries except the Châtelperronian are associated with anatomically modern humans. Authorship of the Châtelperronian is still the subject of much debate.

Most scholars date the arrival of humans in Australia at 40,000 to 50,000 years ago, with a possible range of up to 125,000 years ago. The earliest anatomically modern human remains found in Australia (and outside of Africa) are those of Mungo Man; they have been dated at 42,000 years old.

The Americas were colonised via the Bering land bridge which was exposed during this period by lower sea levels. These people are called the Paleo-Indians, and the earliest accepted dates are those of the Clovis culture sites, some 13,500 years ago. Globally, societies were hunter-gatherers but evidence of regional identities begins to appear in the wide variety of stone tool types being developed to suit very different environments.

Epipaleolithic/Mesolithic

The period starting from the end of the last ice age, 10,000 years ago, to around 6,000 years ago was characterized by rising sea levels and a need to adapt to a changing environment and find new food sources. The development of Mode 5 (microlith) tools began in response to these changes. They were derived from the previous Paleolithic tools, hence the term Epipaleolithic, or were intermediate between the Paleolithic and the Neolithic, hence the term Mesolithic (Middle

Stone Age), used for parts of Eurasia, but not outside it. The choice of a word depends on exact circumstances and the inclination of the archaeologists excavating the site. Microliths were used in the manufacture of more efficient composite tools, resulting in an intensification of hunting and fishing and with increasing social activity the development of more complex settlements, such as Lepenski Vir. Domestication of the dog as a hunting companion probably dates to this period.

The earliest known battle occurred during the Mesolithic period at a site in Egypt known as Cemetery 117.

Neolithic

The Neolithic, or New Stone Age, was approximately characterized by the adoption of agriculture. The shift from food gathering to food producing, in itself one of the most revolutionary changes in human history, was accompanied by the so-called Neolithic Revolution: the development of pottery, polished stone tools, and construction of more complex, larger settlements such as Göbekli Tepe and Çatal Hüyük. Some of these features began in certain localities even earlier, in the transitional Mesolithic. The first Neolithic cultures started around 7000 BCE in the fertile crescent and spread concentrically to other areas of the world; however, the Near East was probably not the only nucleus of agriculture, the cultivation of maize in Meso-America and of rice in the Far East being others.

Due to the increased need to harvest and process plants, ground stone and polished stone artifacts became much more widespread, including tools for grinding, cutting, and chopping. Skara Brae located in Orkney off Scotland is one of Europe's best examples of a Neolithic village. The community contains stone beds, shelves and even an indoor toilet linked to a stream. The first large-scale constructions were built, including settlement towers and walls, e.g., Jericho (Tell es-Sultan) and ceremonial sites, e.g.: Stonehenge. The Ġgantija temples of Gozo in the Maltese archipelago are the oldest surviving free standing structures in the world, erected c. 3600–2500 BCE. The earliest evidence for established trade exists in the Neolithic with newly settled people importing exotic goods over distances of many hundreds of miles.

These facts show that there were sufficient resources and co-operation to enable large groups to work on these projects. To what extent this was a basis for the development of elites and social hierarchies is a matter of ongoing debate. Although some late Neolithic societies formed complex stratified chiefdoms similar to Polynesian societies such as the Ancient Hawaiians, based on the societies of modern tribesmen at an equivalent technological level, most Neolithic societies were relatively simple and egalitarian. A comparison of art in the two ages leads some theorists to conclude that Neolithic cultures were noticeably more hierarchical than the Paleolithic cultures that preceded them.

Early Stone Age (ESA)

The Early Stone Age in Africa is not to be identified with "Old Stone Age", a translation of Paleolithic, or with Paleolithic, or with the "Earlier Stone Age" that originally meant what became the Paleolithic and Mesolithic. In the initial decades of its definition by the Pan-African Congress of Prehistory, it was parallel in Africa to the Upper and Middle Paleolithic. However, since then Radiocarbon dating has shown that the Middle Stone Age is in fact contemporaneous with the Middle Paleolithic. The Early Stone Age therefore is contemporaneous with the Lower Paleolithic and happens to include the same main technologies, Oldowan and Acheulean, which produced Mode 1 and Mode 2 stone tools respectively. A distinct regional term is warranted, however, by the location and chronology of the sites and the exact typology.

Middle Stone Age (MSA)

- The Middle Stone Age was a period of African prehistory between Early Stone Age and Late Stone Age. It began around 300,000 years ago and ended around 50,000 years

ago. It is considered as an equivalent of European Middle Paleolithic. It is associated with anatomically modern or almost modern *Homo sapiens*. Early physical evidence comes from Omo and Herto, both in Ethiopia and dated respectively at c. 195 ka and at c. 160 ka.

Later Stone Age (LSA)

The Later Stone Age (LSA, sometimes also called the **Late Stone Age**) refers to a period in African prehistory. Its beginnings are roughly contemporaneous with the European Upper Paleolithic. It lasts until historical times and this includes cultures corresponding to Mesolithic and Neolithic in other regions.

Material culture

Tools

Stone tools were made from a variety of stones. For example, flint and chert were shaped (or *chipped*) for use as cutting tools and weapons, while basalt and sandstone were used for ground stone tools, such as quern-stones. Wood, bone, shell, antler (deer) and other materials were widely used, as well. During the most recent part of the period, sediments (such as clay) were used to make pottery. Agriculture was developed and certain animals were domesticated as well.

Some species of non-primates are able to use stone tools, such as the sea otter, which breaks abalone shells with them. Primates can both use and manufacture stone tools. This combination of abilities is more marked in apes and men, but only men, or more generally Hominans, depend on tool use for survival. The key anatomical and behavioral features required for tool manufacture, which are possessed only by Hominans, are the larger thumb and the ability to hold by means of an assortment of grips.

Food and drink

Food sources of the Palaeolithic hunter-gatherers were wild plants and animals harvested from the environment. They liked animal organ meats, including the livers, kidneys and brains. Large seeded legumes were part of the human diet long before the agricultural revolution, as is evident from archaeobotanical finds from the Mousterian layers of Kebara Cave, in Israel.

Moreover, recent evidence indicates that humans processed and consumed wild cereal grains as far back as 23,000 years ago in the Upper Paleolithic.

Near the end of the Wisconsin glaciation, 15,000 to 9,000 years ago, mass extinction of Megafauna such as the woolly mammoth occurred in Asia, Europe, North America and Australia. This was the first Holocene extinction event. It possibly forced modification in the dietary habits of the humans of that age and with the emergence of agricultural practices, plant-based foods also became a regular part of the diet. A number of factors have been suggested for the extinction: certainly over-hunting, but also deforestation and climate change. The net effect was to fragment the vast ranges required by the large animals and extinguish them piecemeal in each fragment.

Shelter and habitat

Around 2 million years ago, *Homo habilis* is believed to have constructed the first man-made structure in East Africa, consisting of simple arrangements of stones to hold branches of trees in position. A similar stone circular arrangement believed to be around 380,000 years old was discovered at Terra Amata, near Nice, France. (Concerns about the dating have been raised, see Terra Amata). Several human habitats dating back to the Stone Age have been discovered around the globe, including:

- A tent-like structure inside a cave near the Grotte du Lazaret, Nice, France.

- A structure with a roof supported with timber, discovered in Dolni Vestonice, the Czech Republic, dates to around 23,000 BCE. The walls were made of packed clay blocks and stones.
- Many huts made of mammoth bones have been found in Eastern Europe and Siberia. The people who made these huts were expert mammoth hunters. Examples have been found along the Dniepr river valley of Ukraine, including near Chernihiv, in Moravia, Czech Republic and in southern Poland.
- An animal hide tent dated to around 15000 to 10000 BCE, in the Magdalenian, was discovered at Plateau Parain, France.

Art

Prehistoric art is visible in the artifacts. Prehistoric music is inferred from found instruments, while parietal art can be found on rocks of any kind. The latter are petroglyphs and rock paintings. The art may or may not have had a religious function.

Petroglyphs

Petroglyphs appeared in the Neolithic. A Petroglyph is an intaglio abstract or symbolic image engraved on natural stone by various methods, usually by prehistoric peoples. They were a dominant form of pre-writing symbols. Petroglyphs have been discovered in different parts of the world, including Australia (Sydney rock engravings), Asia (Bhimbetka, India), North America (Death Valley National Park), South America (Cumbe Mayo, Peru), and Europe (Finnmark, Norway).

Rock paintings

- In paleolithic times, mostly animals were painted, in theory ones that were used as food or represented strength, such as the rhinoceros or large cats (as in the Chauvet Cave). Signs such as dots were sometimes drawn. Rare human representations include handprints and half-human/half-animal figures. The Cave of Chauvet in the Ardèche *département*, France, contains the most important cave paintings of the paleolithic era, dating from about 36,000 BCE. The Altamira cave paintings in Spain were done 14,000 to 12,000 BCE and show, among others, bisons. The hall of bulls in Lascaux, Dordogne, France, dates from about 15,000 to 10,000 BCE.

The meaning of many of these paintings remains unknown. They may have been used for seasonal rituals. The animals are accompanied by signs that suggest a possible magic use. Arrow-like symbols in Lascaux are sometimes interpreted as calendar or almanac use, but the evidence remains interpretative.

Some scenes of the Mesolithic, however, can be typed and therefore, judging from their various modifications, are fairly clear. One of these is the battle scene between organized bands of archers. For example, "the marching Warriors", a rock painting at Cingle de la Mola, Castellón in Spain, dated to about 7,000–4,000 BCE, depicts about 50 bowmen in two groups marching or running in step toward each other, each man carrying a bow in one hand and a fistful of arrows in the other. A file of five men leads one band, one of whom is a figure with a "high crowned hat".

In other scenes elsewhere, the men wear head-dresses and knee ornaments but otherwise fight nude. Some scenes depict the dead and wounded, bristling with arrows. One is reminded of Ötzi the Iceman, a Copper Age mummy revealed by an Alpine melting glacier, who collapsed from loss of blood due to an arrow wound in the back.

Stone Age rituals and beliefs

Modern studies and the in-depth analysis of finds dating from the Stone Age indicate certain rituals and beliefs of the people in those prehistoric times. It is now believed that activities of the Stone Age humans went beyond the immediate requirements of procuring food, body coverings, and shelters. Specific rites relating to death and burial were practiced, though certainly differing in style and execution between cultures.

- Megalithic tombs, multichambered, and dolmens, single-chambered, were graves with a huge stone slab stacked over other similarly large stone slabs; they have been discovered all across Europe and Asia and were built in the Neolithic and the Bronze Age.

Modern popular culture

- The image of the caveman is commonly associated with the Stone Age. For example, a 2003

> documentary series showing the evolution of humans through the Stone Age was called *Walking with Cavemen*, but only the last programme showed humans living in caves. While the idea that human beings and dinosaurs coexisted is sometimes portrayed in popular culture in cartoons, films and computer games, such as *The Flintstones*, *One Million Years B.C.* and *Chuck Rock*, the notion of hominids and non-avian dinosaurs co-existing is not supported by any scientific evidence.

Other depictions of the Stone Age include the best-selling *Earth's Children* series of books by Jean M. Auel, which are set in the Paleolithic and are loosely based on archaeological and anthropological findings.

The 1981 film *Quest for Fire* by Jean-Jacques Annaud tells the story of a group of early homo sapiens searching for their lost fire. A 21st-century series, *Chronicles of Ancient Darkness* by Michelle Paver tells of two New Stone Age children fighting to fulfil a prophecy and save their clan.

Chapter 18

Paleolithic Technology

The Paleolithic or Palaeolithic or Palæolithic (/ˌpeɪl-ˌˌpælioʊˈlɪθɪk/), also called the Old Stone Age (from Greek palaios - old, lithos - stone), is a period in human prehistory distinguished by the original development of stone tools that covers c. 99% of the period of human technological prehistory. It extends from the earliest known use of stone tools by hominins c. 3.3 million years ago, to the end of the Pleistocene c. 11,650 calBP.

The Paleolithic Age in Europe preceded the Mesolithic Age, although the date of the transition varies geographically by several thousand years. During the Paleolithic Age, hominins grouped together in small societies such as bands and subsisted by gathering plants, fishing, and hunting or scavenging wild animals. The Paleolithic Age is characterized by the use of knappedstone tools, although at the time humans also used wood and bone tools. Other organic commodities were adapted for use as tools, including leather and vegetable fibers; however, due to rapid decomposition, these have not survived to any great degree.

About 50,000 years ago a marked increase in the diversity of artifacts occurred. In Africa, bone artifacts and the first art appear in the archaeological record. The first evidence of human fishing is also noted, from artifacts in places such as Blombos cave in South Africa. Archaeologists classify artifacts of the last 50,000 years into many different categories, such as projectile points, engraving tools, knife blades, and drilling and piercing tools. Humankind gradually evolved from early members of the genus *Homo*—such as *Homo habilis*, who used simple stone tools—into anatomically modern humans as well as behaviourally modern humans by the Upper Paleolithic. During the end of the Paleolithic Age, specifically the Middle or Upper Paleolithic Age, humans began to produce the earliest works of art and to engage in religious or spiritual behavior such as burial and ritual. Conditions during the Paleolithic Age went through a set of glacial and interglacial periods in which the climate periodically fluctuated between warm and cool temperatures. Archaeological and genetic data suggest that the source populations of Paleolithic humans survived in sparsely-wooded areas and dispersed through areas of high primary productivity while avoiding dense forest-cover.

By c. 50,000 – c. 40,000 BP, the first humans set foot in Australia. By c. 45,000 BP, humans lived at 61°N latitude in Europe. By c. 30,000 BP, Japan was reached, and by c. 27,000 BP humans were present in Siberia, above the Arctic Circle. At the end of the Upper Paleolithic Age a group of humans crossed Beringia and quickly expanded throughout the Americas.

Paleogeography and climate

The Paleolithic coincides almost exactly with the Pleistocene epoch of geologic time, which lasted from 2.6 million years ago to about 12,000 years ago. This epoch experienced important geographic and climatic changes that affected human societies.

During the preceding Pliocene, continents had continued to drift from possibly as far as 250 km (160 mi) from their present locations to positions only 70 km (43 mi) from their current location. South America became linked to North America through the Isthmus of Panama, bringing a nearly complete end to South America's distinctive marsupial fauna. The formation of the isthmus had major consequences on global temperatures, because warm equatorial ocean currents were cut off, and the cold Arctic and Antarctic waters lowered temperatures in the now-isolated Atlantic Ocean.

Most of Central America formed during the Pliocene to connect the continents of North and South America, allowing fauna from these continents to leave their native habitats and colonize new areas. Africa's collision with Asia created the Mediterranean, cutting off the remnants of the Tethys Ocean. During the Pleistocene, the modern continents were essentially at their present positions; the tectonic plates on which they sit have probably moved at most 100 km (62 mi) from each other since the beginning of the period.

Climates during the Pliocene became cooler and drier, and seasonal, similar to modern climates. Ice sheets grew on Antarctica. The formation of an Arctic ice cap around 3 million years ago is signaled by an abrupt shift in oxygenisotope ratios and ice-rafted cobbles in the North Atlantic and North Pacific Ocean beds. Mid-latitude glaciation probably began before the end of the epoch. The global cooling that occurred during the Pliocene may have spurred on the disappearance of forests and the spread of grasslands and savannas. The Pleistocene climate was characterized by repeated glacial cycles during which continental glaciers pushed to the 40th parallel in some places. Four major glacial events have been identified, as well as many minor intervening events. A major event is a general glacial excursion, termed a "glacial". Glacials are separated by "interglacials". During a glacial, the glacier experiences minor advances and retreats.

The minor excursion is a "stadial"; times between stadials are "interstadials". Each glacial advance tied up huge volumes of water in continental ice sheets 1,500–3,000 m (4,900–9,800 ft) deep, resulting in temporary sea level drops of 100 m (330 ft) or more over the entire surface of the Earth. During interglacial times, such as at present, drowned coastlines were common, mitigated by isostatic or other emergent motion of some regions.

The effects of glaciation were global. Antarctica was ice-bound throughout the Pleistocene and the preceding Pliocene. The Andes were covered in the south by the Patagonian ice cap. There were glaciers in New Zealand and Tasmania. The now decaying glaciers of Mount Kenya, Mount Kilimanjaro, and the Ruwenzori Range in east and central Africa were larger. Glaciers existed in the mountains of Ethiopia and to the west in the Atlas mountains.

In the northern hemisphere, many glaciers fused into one. The Cordilleran Ice Sheet covered the North American northwest; the Laurentide covered the east. The Fenno-Scandian ice sheet covered northern Europe, including Great Britain; the Alpine ice sheet covered the Alps. Scattered domes stretched across Siberia and the Arctic shelf. The northern seas were frozen. During the late Upper Paleolithic (Latest Pleistocene) c. 18,000 BP, the Beringia land bridge between Asia and North America was blocked by ice, which may have prevented early Paleo-Indians such as the Clovis culture from directly crossing

Beringia to reach the Americas. According to Mark Lynas (through collected data), the Pleistocene's overall climate could be characterized as a continuous El Niño with trade winds in the south Pacific weakening or heading east, warm air rising near Peru, warm water spreading from the west Pacific and the Indian Ocean to the east Pacific, and other El Niño markers.

The Paleolithic is often held to finish at the end of the ice age (the end of the Pleistocene epoch), and Earth's climate became warmer. This may have caused or contributed to the extinction of the Pleistocene megafauna, although it is also possible that the late Pleistocene extinctions were (at least in part) caused by other factors such as disease and overhunting by humans. New research suggests that the extinction of the woolly mammoth may have been caused by the combined effect of climatic change and human hunting. Scientists suggest that climate change during the end of the Pleistocene caused the mammoths' habitat to shrink in size, resulting in a drop in population. The small populations were then hunted out by Paleolithic humans. The global warming that occurred during the end of the Pleistocene and the beginning of the Holocene may have made it easier for humans to reach mammoth habitats that were previously frozen and inaccessible. Small populations of woolly mammoths survived on isolated Arctic islands, Saint Paul Island and Wrangel Island, until c. 3700 BP and c. 1700 BP respectively. The Wrangel Island population became extinct around the same time the island was settled by prehistoric humans. There is no evidence of prehistoric human presence on Saint Paul island (though early human settlements dating as far back as 6500 BP were found on the nearby Aleutian Islands).

Human way of life

Nearly all of our knowledge of Paleolithic human culture and way of life comes from archaeology and ethnographic comparisons to modern hunter-gatherer cultures such as the !Kung San who live similarly to their Paleolithic predecessors. The economy of a typical Paleolithic society was a hunter-gatherer economy. Humans hunted wild animals for meat and gathered food, firewood, and materials for their tools, clothes, or shelters.

Human population density was very low, around only one person per square mile. This was most likely due to low body fat, infanticide, women regularly engaging in intense endurance exercise, late weaning of infants, and a nomadic lifestyle. Like contemporary hunter-gatherers, Paleolithic humans enjoyed an abundance of leisure time unparalleled in both Neolithic farming societies and modern industrial societies. At the end of the Paleolithic, specifically the Middle or Upper Paleolithic, humans began to produce works of art such as cave paintings, rock art and jewellery and began to engage in religious behavior such as burials and rituals.

Distribution

At the beginning of the Paleolithic, hominins were found primarily in eastern Africa, east of the Great Rift Valley. Most known hominin fossils dating earlier than one million years before present are found in this area, particularly in Kenya, Tanzania, and Ethiopia.

By c. 2,000,000 – c. 1,500,000 BP, groups of hominins began leaving Africa and settling southern Europe and Asia. Southern Caucasus was occupied by c. 1,700,000 BP, and northern China was reached by c. 1,660,000 BP. By the end of the Lower Paleolithic, members of the hominin family were living in what is now China, western Indonesia, and, in Europe, around the Mediterranean and as far north as England, France, southern Germany, and Bulgaria. Their further northward expansion may have been limited by the lack of control of fire: studies of cave settlements in Europe indicate no regular use of fire prior to c. 400,000 – c. 300,000 BP.

East Asian fossils from this period are typically placed in the genus *Homo erectus*. Very little fossil evidence is available at known Lower Paleolithic sites in Europe, but it is believed that hominins who inhabited these sites were likewise *Homo erectus*. There is no evidence of hominins in America, Australia, or almost anywhere in Oceania during this time period. Fates of these early colonists, and their relationships to modern humans, are still subject to debate. According to current archaeological and genetic models, there were at least two notable expansion events subsequent to peopling of Eurasia c. 2,000,000 – c. 1,500,000 BP. Around 500,000 BP a group of early humans, frequently called *Homo heidelbergensis*, came to Europe from Africa and eventually evolved into *Homo neanderthalensis* (Neanderthals). In the Middle Paleolithic, Neanderthals were present in the region now occupied by Poland.

Both *Homo erectus* and *Homo neanderthalensis* became extinct by the end of the Paleolithic. Descended from *Homo sapiens*, the anatomically modern *Homo sapiens sapiens* emerged in eastern Africa c. 200,000 BP, left Africa around 50,000 BP, and expanded throughout the planet. Multiple hominid groups coexisted for some time in certain locations. *Homo neanderthalensis* were still found in parts of Eurasia c. 30,000 BP years, and engaged in an unknown degree of interbreeding with *Homo sapiens sapiens*. DNA studies also suggest an unknown degree of interbreeding between *Homo sapiens sapiens* and *Homo sapiens denisova*.

Hominin fossils not belonging either to *Homo neanderthalensis* or to *Homo sapiens* species, found in the Altai Mountains and Indonesia, were radiocarbon dated to c. 30,000 – c. 40,000 BP and c. 17,000 BP respectively.

For the duration of the Paleolithic, human populations remained low, especially outside the equatorial region. The entire population of Europe between 16,000 and 11,000 BP likely averaged some 30,000 individuals, and between 40,000 and 16,000 BP, it was even lower at 4,000–6,000 individuals. However, remains of thousands of butchered animals and tools made by Palaeolithic humans were found in Lapa do Picareiro (pt), a cave in Portugal, dating back between 41,000 and 38,000 years ago.

Technology

Tools

Paleolithic humans made tools of stone, bone (primarily deer), and wood. The early paleolithic hominins, *Australopithecus*, were the first users of stone tools. Excavations in Gona, Ethiopia have produced thousands of artifacts, and through radioisotopic dating and magnetostratigraphy, the sites can be firmly dated to 2.6 million years ago. Evidence shows these early hominins intentionally selected raw materials with good flaking qualities and chose appropriate sized stones for their needs to produce sharp-edged tools for cutting.

The earliest Paleolithic stone tool industry, the Oldowan, began around 2.6 million years ago. It contained tools such as choppers, burins, and stitching awls. It was completely replaced around 250,000 years ago by the more complex Acheulean industry, which was first conceived by *Homo ergaster* around 1.8–1.65 million years ago. The Acheulean implements completely vanish from the archaeological record around 100,000 years ago and were replaced by more complex Middle Paleolithic tool kits such as the Mousterian and the Aterian industries.

Lower Paleolithic humans used a variety of stone tools, including hand axes and choppers. Although they appear to have used hand axes often, there is disagreement about their use. Interpretations range from cutting and chopping tools, to digging implements, to flaking cores, to the use in traps, and as a purely ritual significance, perhaps in courting behavior. William H. Calvin has suggested that some hand axes could have served as "killer Frisbees" meant to be thrown at a herd of animals at a waterhole so as to stun one of them. There are no indications of hafting, and some artifacts are far too large for that. Thus, a thrown hand axe would not usually have penetrated deeply enough to cause very serious injuries. Nevertheless, it could have been an effective weapon for defense against predators. Choppers and scrapers were likely used for skinning and butchering scavenged animals and sharp-ended sticks were often obtained for digging up edible roots. Presumably, early humans used wooden spears as early as 5 million years ago to hunt small animals, much as their relatives, chimpanzees, have been observed to do in Senegal, Africa. Lower Paleolithic humans constructed shelters, such as the possible wood hut at Terra Amata.

Fire use

Fire was used by the Lower Paleolithic hominins *Homo erectus* and *Homo ergaster* as early as 300,000 to 1.5 million years ago and possibly even earlier by the early Lower Paleolithic (Oldowan) hominin *Homo habilis* or by robust *Australopithecines* such as *Paranthropus*. However, the use of fire only became common in the societies of the following Middle Stone Age and Middle Paleolithic. Use of fire reduced mortality rates and provided protection against predators. Early hominins may have begun to cook their food as early as the Lower Paleolithic (c. 1.9 million years ago) or at the latest in the early Middle Paleolithic (c. 250,000 years ago). Some scientists have hypothesized that hominins began cooking food to defrost frozen meat, which would help ensure their survival in cold regions.

Raft

The Lower Paleolithic *Homo erectus* possibly invented rafts (c. 840,000 – c. 800,000 BP) to travel over large bodies of water, which may have allowed a group of *Homo erectus* to reach the island of Flores and evolve into the small hominin *Homo floresiensis*. However, this hypothesis is disputed within the anthropological community. The possible use of rafts during the Lower Paleolithic may indicate that Lower Paleolithic hominins such as *Homo erectus* were more advanced than previously believed, and may have even spoken an early form of modern language. Supplementary evidence from Neanderthal and modern human sites located around the Mediterranean Sea, such as Coa de sa Multa (c. 300,000 BP), has also indicated that both Middle and Upper Paleolithic humans used rafts to travel over large bodies of water (i.e. the Mediterranean Sea) for the purpose of colonizing other bodies of land.

Advanced tools

By around 200,000 BP, Middle Paleolithicstone tool manufacturing spawned a tool making technique known as the prepared-core technique, that was more elaborate than previous Acheulean techniques. This technique increased efficiency by allowing the creation of more controlled and consistent flakes.

It allowed Middle Paleolithic humans to create stone tipped spears, which were the earliest composite tools, by hafting sharp, pointy stone flakes onto wooden shafts. In addition to improving tool making methods, the Middle Paleolithic also saw an improvement of the tools themselves that allowed access to a wider variety and amount of food sources. For example, microliths or small stone tools or points were invented around 70,000–65,000 BP and were essential to the invention of bows and spear throwers in the following Upper Paleolithic.

Harpoons were invented and used for the first time during the late Middle Paleolithic (c. 90,000 BP); the invention of these devices brought fish into the human diets, which provided a hedge against starvation and a more abundant food supply. Thanks to their technology and their advanced social structures, Paleolithic groups such as the Neanderthals—who had a Middle Paleolithic level of technology—appear to have hunted large game just as well as Upper Paleolithic modern humans. and the Neanderthals in particular may have likewise hunted with projectile weapons.

Nonetheless, Neanderthal use of projectile weapons in hunting occurred very rarely (or perhaps never) and the Neanderthals hunted large game animals mostly by ambushing them and attacking them with mêlée weapons such as thrusting spears rather than attacking them from a distance with projectile weapons.

Other inventions

During the Upper Paleolithic, further inventions were made, such as the net (c. 22,000 or c. 29,000 BP) bolas, the spear thrower (c. 30,000 BP), the bow and arrow (c. 25,000 or c. 30,000 BP) and the oldest example of ceramic art, the Venus of Dolní Věstonice (c. 29,000 – c. 25,000 BP). Kilu Cave at Buku island, Solomon islands, demonstrates navigation of some 60 km of open ocean at 30,000 BCcal.

Early dogs were domesticated, sometime between 30,000 and 14,000 BP, presumably to aid in hunting. However, the earliest instances of successful domestication of dogs may be much more ancient than this. Evidence from canineDNA collected by Robert K. Wayne suggests that dogs may have been first domesticated in the late Middle Paleolithic around 100,000 BP or perhaps even earlier. Archaeological evidence from the Dordogne region of France demonstrates that members of the European early Upper Paleolithic culture known as the Aurignacian used calendars (c. 30,000 BP). This was a lunar calendar that was used to document the phases of the moon. Genuine solar calendars did not appear until the Neolithic. Upper Paleolithic cultures were probably able to time the migration of game animals such as wild horses and deer. This ability allowed humans to become efficient hunters and to exploit a wide variety of game animals. Recent research indicates that the Neanderthals timed their hunts and the migrations of game animals long before the beginning of the Upper Paleolithic.

Social organization

The social organization of the earliest Paleolithic (Lower Paleolithic) societies remains largely unknown to scientists, though Lower Paleolithic hominins such as *Homo habilis* and *Homo erectus* are likely to have had more complex social structures than chimpanzee societies. Late Oldowan/Early Acheulean humans such as *Homo ergaster*/*Homo erectus* may have been the first people to invent central campsites or home bases and incorporate them into their foraging and hunting strategies like contemporary hunter-gatherers, possibly as early as 1.7 million years ago; however, the earliest solid evidence for the existence of home bases or central campsites (hearths and shelters) among humans only dates back to 500,000 years ago.

Similarly, scientists disagree whether Lower Paleolithic humans were largely monogamous or polygynous. In particular, the Provisional model suggests that bipedalism arose in pre-Paleolithic australopithecine societies as an adaptation to monogamous lifestyles; however, other researchers note that sexual dimorphism is more pronounced in Lower Paleolithic humans such as *Homo erectus* than in modern humans, who are less polygynous than other primates, which suggests that Lower Paleolithic humans had a largely polygynous lifestyle, because species that have the most pronounced sexual dimorphism tend more likely to be polygynous.

Human societies from the Paleolithic to the early Neolithic farming tribes lived without states and organized governments. For most of the Lower Paleolithic, human societies were possibly more hierarchical than their Middle and Upper Paleolithic descendants, and probably were not grouped into bands, though during the end of the Lower Paleolithic, the latest populations of the hominin *Homo erectus* may have begun living in small-scale (possibly egalitarian) bands similar to both Middle and Upper Paleolithic societies and modern hunter-gatherers.

Middle Paleolithic societies, unlike Lower Paleolithic and early Neolithic ones, consisted of bands that ranged from 20–30 or 25–100 members and were usually nomadic. These bands were formed by several families. Bands sometimes joined together into larger "macrobands" for activities such as acquiring mates and celebrations or where resources were abundant. By the end of the Paleolithic era (c. 10,000 BP), people began to settle down into permanent locations, and began to rely on agriculture for sustenance in many locations. Much evidence exists that humans took part in long-distance trade between bands for rare commodities (such as ochre, which was often used for religious purposes such as ritual) and raw materials, as early as 120,000 years ago in Middle Paleolithic. Inter-band trade may have appeared during the Middle Paleolithic because trade between bands would have helped ensure their survival by allowing them to exchange resources and commodities such as raw materials during times of relative scarcity (i.e. famine, drought). Like in modern hunter-gatherer societies, individuals in Paleolithic societies may have been subordinate to the band as a whole. Both Neanderthals and modern humans took care of the elderly members of their societies during the Middle and Upper Paleolithic.

Some sources claim that most Middle and Upper Paleolithic societies were possibly fundamentally egalitarian and may have rarely or never engaged in organized violence between groups (i.e. war). Some Upper Paleolithic societies in resource-rich environments (such as societies in Sungir, in what is now Russia) may have had more complex and hierarchical organization (such as tribes with a pronounced hierarchy and a somewhat formal division of labor) and may have engaged in endemic warfare. Some argue that there was no formal leadership during the Middle and Upper Paleolithic. Like contemporary egalitarian hunter-gatherers such as the Mbuti pygmies, societies may have made decisions by communal consensus decision making rather than by appointing permanent rulers such as chiefs and monarchs. Nor was there a formal division of labor during the Paleolithic. Each member of the group was skilled at all tasks essential to survival, regardless of individual abilities. Theories to explain the apparent egalitarianism have arisen, notably the Marxist concept of primitive communism. Christopher Boehm (1999) has hypothesized that egalitarianism may have evolved in

Paleolithic societies because of a need to distribute resources such as food and meat equally to avoid famine and ensure a stable food supply. Raymond C. Kelly speculates that the relative peacefulness of Middle and Upper Paleolithic societies resulted from a low population density, cooperative relationships between groups such as reciprocal exchange of commodities and collaboration on hunting expeditions, and because the invention of projectile weapons such as throwing spears provided less incentive for war, because they increased the damage done to the attacker and decreased the relative amount of territory attackers could gain. However, other sources claim that most Paleolithic groups may have been larger, more complex, sedentary and warlike than most contemporary hunter-gatherer societies, due to occupying more resource-abundant areas than most modern hunter-gatherers who have been pushed into more marginal habitats by agricultural societies.

Anthropologists have typically assumed that in Paleolithic societies, women were responsible for gathering wild plants and firewood, and men were responsible for hunting and scavenging dead animals. However, analogies to existent hunter-gatherer societies such as the Hadza people and the Aboriginal Australians suggest that the sexual division of labor in the Paleolithic was relatively flexible. Men may have participated in gathering plants, firewood and insects, and women may have procured small game animals for consumption and assisted men in driving herds of large game animals (such as woolly mammoths and deer) off cliffs. Additionally, recent research by anthropologist and archaeologist Steven Kuhn from the University of Arizona is argued to support that this division of labor did not exist prior to the Upper Paleolithic and was invented relatively recently in human pre-history. Sexual division of labor may have been developed to allow humans to acquire food and other resources more efficiently. Possibly there was approximate parity between men and women during the Middle and Upper Paleolithic, and that period may have been the most gender-equal time in human history. Archaeological evidence from art and funerary rituals indicates that a number of individual women enjoyed seemingly high status in their communities, and it is likely that both sexes participated in decision making. The earliest known Paleolithic shaman (c. 30,000 BP) was female. Jared Diamond suggests that the status of women declined with the adoption of agriculture because women in farming societies typically have more pregnancies and are expected to do more demanding work than women in hunter-gatherer societies. Like most contemporary hunter-gatherer societies, Paleolithic and the Mesolithic groups probably followed mostly matrilineal and ambilineal descent patterns; patrilineal descent patterns were probably rarer than in the Neolithic.

Sculpture and painting

Early examples of artistic expression, such as the Venus of Tan-Tan and the patterns found on elephant bones from Bilzingsleben in Thuringia, may have been produced by Acheulean tool users such as *Homo erectus* prior to the start of the Middle Paleolithic period. However, the earliest undisputed evidence of art during the Paleolithic comes from Middle Paleolithic/Middle Stone Age sites such as Blombos Cave–South Africa–in the form of bracelets, beads, rock art, and ochre used as body paint and perhaps in ritual. Undisputed evidence of art only becomes common in the Upper Paleolithic.

Lower Paleolithic Acheulean tool users, according to Robert G. Bednarik, began to engage in symbolic behavior such as art around 850,000 BP. They decorated themselves with beads and collected exotic stones for aesthetic, rather than utilitarian qualities. According to him, traces of the pigment ochre from late Lower Paleolithic Acheulean archaeological sites suggests that Acheulean societies, like later Upper Paleolithic societies, collected and used ochre to create rock art. Nevertheless, it is also possible that the ochre traces found at Lower Paleolithic sites is naturally occurring.

Upper Paleolithic humans produced works of art such as cave paintings, Venus figurines, animal carvings, and rock paintings. Upper Paleolithic art can be divided into two broad categories: figurative art such as cave paintings that clearly depicts animals (or more rarely humans); and nonfigurative, which consists of shapes and symbols. Cave paintings have been interpreted in a number of ways by modern archaeologists. The earliest explanation, by the prehistorian Abbe Breuil, interpreted the paintings as a form of magic designed to ensure a successful hunt. However, this hypothesis fails to explain the existence of animals such as saber-toothed cats and lions, which were not hunted for food, and the existence of half-human, half-animal beings in cave paintings. The anthropologist David Lewis-Williams has suggested that Paleolithic cave paintings were indications of shamanistic practices, because the paintings of half-human, half-animal figures and the remoteness of the caves are reminiscent of modern hunter-gatherer shamanistic practices. Symbol-like images are more common in Paleolithic cave paintings than are depictions of animals or humans, and unique symbolic patterns might have been trademarks that represent different

Upper Paleolithic ethnic groups. Venus figurines have evoked similar controversy. Archaeologists and anthropologists have described the figurines as representations of goddesses, pornographic imagery, apotropaic amulets used for sympathetic magic, and even as self-portraits of women themselves.

R. Dale Guthrie has studied not only the most artistic and publicized paintings, but also a variety of lower-quality art and figurines, and he identifies a wide range of skill and ages among the artists. He also points out that the main themes in the paintings and other artifacts (powerful beasts, risky hunting scenes and the over-sexual representation of women) are to be expected in the fantasies of adolescent males during the Upper Paleolithic. The "Venus" figurines have been theorized, not universally, as representing a mother goddess; the abundance of such female imagery has inspired the theory that religion and society in Paleolithic (and later Neolithic) cultures were primarily interested in, and may have been directed by, women. Adherents of the theory include archaeologist Marija Gimbutas and feminist scholar Merlin Stone, the author of the 1976 book *When God Was a Woman*. Other explanations for the purpose of the figurines have been proposed, such as Catherine McCoid and LeRoy McDermott's hypothesis that they were self-portraits of woman artists and R.Dale Gutrie's hypothesis that served as "stone age pornography".

Music

The origins of music during the Paleolithic are unknown. The earliest forms of music probably did not use musical instruments other than the human voice or natural objects such as rocks. This early music would not have left an archaeological footprint. Music may have developed from rhythmic sounds produced by daily chores, for example, cracking open nuts with stones. Maintaining a rhythm while working may have helped people to become more efficient at daily activities. An alternative theory originally proposed by Charles Darwin explains that music may have begun as a hominin mating strategy. Bird and other animal species produce music such as calls to attract mates. This hypothesis is generally less accepted than the previous hypothesis, but nonetheless provides a possible alternative.

Upper Paleolithic (and possibly Middle Paleolithic) humans used flute-like bone pipes as musical instruments, and music may have played a large role in the religious lives of Upper Paleolithic hunter-gatherers. As with modern hunter-gatherer societies, music may have been used in ritual or to help induce trances. In particular, it appears that animal skin drums may have been used in religious events by Upper Paleolithic shamans, as shown by the remains of drum-like instruments from some Upper Paleolithic graves of shamans and the ethnographic record of contemporary hunter-gatherer shamanic and ritual practices.

Religion and beliefs

According to James B. Harrod humankind first developed religious and spiritual beliefs during the Middle Paleolithic or Upper Paleolithic. Controversial scholars of prehistoric religion and anthropology, James Harrod and Vincent W. Fallio, have recently proposed that religion and spirituality (and art) may have first arisen in Pre-Paleolithic chimpanzees or Early Lower Paleolithic (Oldowan) societies. According to Fallio, the common ancestor of chimpanzees and humans experienced altered states of consciousness and partook in ritual, and ritual was used in their societies to strengthen social bonding and group cohesion.

Middle Paleolithic humans' use of burials at sites such as Krapina, Croatia (c. 130,000 BP) and Qafzeh, Israel (c. 100,000 BP) have led some anthropologists and archaeologists, such as Philip Lieberman, to believe that Middle Paleolithic humans may have possessed a belief in an afterlife and a "concern for the dead that transcends daily life". Cut marks on Neanderthal bones from various sites, such as Combe-Grenal and Abri Moula in France, suggest that the Neanderthals—like some contemporary human cultures—may have practiced ritual defleshing for (presumably) religious reasons. According to recent archaeological findings from *Homo heidelbergensis* sites in Atapuerca, humans may have begun burying their dead much earlier, during the late Lower Paleolithic; but this theory is widely questioned in the scientific community.

Likewise, some scientists have proposed that Middle Paleolithic societies such as Neanderthal societies may also have practiced the earliest form of totemism or animal worship, in addition to their (presumably religious) burial of the dead. In particular, Emil Bächler suggested (based on archaeological evidence from Middle Paleolithic caves) that a bearcult was widespread among Middle Paleolithic Neanderthals. A claim that evidence was found for Middle Paleolithic animal worship c. 70,000 BCE originates from the Tsodilo Hills in the African

Kalahari desert has been denied by the original investigators of the site. Animal cults in the Upper Paleolithic, such as the bear cult, may have had their origins in these hypothetical Middle Paleolithic animal cults. Animal worship during the Upper Paleolithic was intertwined with hunting rites. For instance, archaeological evidence from art and bear remains reveals that the bear cult apparently involved a type of sacrificial bear ceremonialism, in which a bear was shot with arrows, finished off by a shot or thrust in the lungs, and ritually worshipped near a clay bear statue covered by a bear fur with the skull and the body of the bear buried separately. Barbara Ehrenreich controversially theorizes that the sacrificial hunting rites of the Upper Paleolithic (and by extension Paleolithic cooperative big-game hunting) gave rise to war or warlike raiding during the following Epipaleolithic and Mesolithic or late Upper Paleolithic.

The existence of anthropomorphic images and half-human, half-animal images in the Upper Paleolithic may further indicate that Upper Paleolithic humans were the first people to believe in a pantheon of gods or supernatural beings, though such images may instead indicate shamanistic practices similar to those of contemporary tribal societies. The earliest known undisputed burial of a shaman (and by extension the earliest undisputed evidence of shamans and shamanic practices) dates back to the early Upper Paleolithic era (c. 30,000 BP) in what is now the Czech Republic. However, during the early Upper Paleolithic it was probably more common for all members of the band to participate equally and fully in religious ceremonies, in contrast to the religious traditions of later periods when religious authorities and part-time ritual specialists such as shamans, priests and medicine men were relatively common and integral to religious life. Additionally, it is also possible that Upper Paleolithic religions, like contemporary and historical animistic and polytheistic religions, believed in the existence of a single creator deity in addition to other supernatural beings such as animistic spirits.

Religion was possibly apotropaic; specifically, it may have involved sympathetic magic. The Venus figurines, which are abundant in the Upper Paleolithic archaeological record, provide an example of possible Paleolithic sympathetic magic, as they may have been used for ensuring success in hunting and to bring about fertility of the land and women. The Upper Paleolithic Venus figurines have sometimes been explained as depictions of an earth goddess similar to Gaia, or as representations of a goddess who is the ruler or mother of the animals. James Harrod has described them as representative of female (and male) shamanistic spiritual transformation processes.

Diet and nutrition

Paleolithic hunting and gathering people ate varying proportions of vegetables (including tubers and roots), fruit, seeds (including nuts and wild grass seeds) and insects, meat, fish, and shellfish. However, there is little direct evidence of the relative proportions of plant and animal foods. Although the term "paleolithic diet", without references to a specific timeframe or locale, is sometimes used with an implication that most humans shared a certain diet during the entire era, that is not entirely accurate. The Paleolithic was an extended period of time, during which multiple technological advances were made, many of which had impact on human dietary structure. For example, humans probably did not possess the control of fire until the Middle Paleolithic, or tools necessary to engage in extensive fishing. On the other hand, both these technologies are generally agreed to have been widely available to humans by the end of the Paleolithic (consequently, allowing humans in some regions of the planet to rely heavily on fishing and hunting). In addition, the Paleolithic involved a substantial geographical expansion of human populations. During the Lower Paleolithic, ancestors of modern humans are thought to have been constrained to Africa east of the Great Rift Valley. During the Middle and Upper Paleolithic, humans greatly expanded their area of settlement, reaching ecosystems as diverse as New Guinea and Alaska, and adapting their diets to whatever local resources were available.

Another view is that until the Upper Paleolithic, humans were frugivores (fruit eaters) who supplemented their meals with carrion, eggs, and small prey such as baby birds and mussels, and only on rare occasions managed to kill and consume big game such as antelopes. This view is supported by studies of higher apes, particularly chimpanzees. Chimpanzees are the closest to humans genetically, sharing more than 96% of their DNA code with humans, and their digestive tract is functionally very similar to that of humans. Chimpanzees are primarily frugivores, but they could and would consume and digest animal flesh, given the opportunity. In general, their actual diet in the wild is about 95% plant-based, with the remaining 5% filled with insects, eggs, and baby animals. In some ecosystems, however, chimpanzees are predatory, forming parties to hunt monkeys. Some comparative studies of human and higher primate digestive tracts do suggest that humans have evolved to obtain greater amounts of calories from sources such as animal foods, allowing them to shrink the size of the gastrointestinal tract relative to body mass and to increase the brain mass instead.

Anthropologists have diverse opinions about the proportions of plant and animal foods consumed. Just as with still existing hunters and gatherers, there were many varied "diets" in different groups, and also varying through this vast amount of time. Some paleolithic hunter-gatherers consumed a significant amount of meat and possibly obtained most of their food from hunting, while others were believed to have a primarily plant-based diet. Most, if not all, are believed to have been opportunistic omnivores. One hypothesis is that carbohydrate tubers (plant underground storage organs) may have been eaten in high amounts by pre-agricultural humans. It is thought that the Paleolithic diet included as much as 1.65–1.9 kg (3.6–4.2 lb) per day of fruit and vegetables. The relative proportions of plant and animal foods in the diets of Paleolithic people often varied between regions, with more meat being necessary in colder regions (which weren't populated by anatomically modern humans until c. 30,000 – c. 50,000 BP). It is generally agreed that many modern hunting and fishing tools, such as fish hooks, nets, bows, and poisons, weren't introduced until the Upper Paleolithic and possibly even Neolithic. The only hunting tools widely available to humans during any significant part of the Paleolithic were hand-held spears and harpoons. There's evidence of Paleolithic people killing and eating seals and elands as far as c. 100,000 BP. On the other hand, buffalo bones found in African caves from the same period are typically of very young or very old individuals, and there's no evidence that pigs, elephants, or rhinos were hunted by humans at the time.

Paleolithic peoples suffered less famine and malnutrition than the Neolithic farming tribes that followed them. This was partly because Paleolithic hunter-gatherers accessed a wider variety of natural foods, which allowed them a more nutritious diet and a decreased risk of famine. Many of the famines experienced by Neolithic (and some modern) farmers were caused or amplified by their dependence on a small number of crops. It is thought that wild foods can have a significantly different nutritional profile than cultivated foods. The greater amount of meat obtained by hunting big game animals in Paleolithic diets than Neolithic diets may have also allowed Paleolithic hunter-gatherers to enjoy a more nutritious diet than Neolithic agriculturalists. It has been argued that the shift from hunting and gathering to agriculture resulted in an increasing focus on a limited variety of foods, with meat likely taking a back seat to plants. It is also unlikely that Paleolithic hunter-gatherers were affected by modern diseases of affluence such as type 2 diabetes, coronary heart disease, and cerebrovascular disease, because they ate mostly lean meats and plants and frequently engaged in intense physical activity, and because the average lifespan was shorter than the age of common onset of these conditions.

Large-seeded legumes were part of the human diet long before the Neolithic Revolution, as evident from archaeobotanical finds from the Mousterian layers of Kebara Cave, in Israel. There is evidence suggesting that Paleolithic societies were gathering wild cereals for food use at least as early as 30,000 years ago. However, seeds—such as grains and beans—were rarely eaten and never in large quantities on a daily basis. Recent archaeological evidence also indicates that winemaking may have originated in the Paleolithic, when early humans drank the juice of naturally fermented wild grapes from animal-skin pouches. Paleolithic humans consumed animal organ meats, including the livers, kidneys, and brains. Upper Paleolithic cultures appear to have had significant knowledge about plants and herbs and may have, albeit very rarely, practiced rudimentary forms of horticulture. In particular, bananas and tubers may have been cultivated as early as 25,000 BP in southeast Asia. Late Upper Paleolithic societies also appear to have occasionally practiced pastoralism and animal husbandry, presumably for dietary reasons. For instance, some European late Upper Paleolithic cultures domesticated and raised reindeer, presumably for their meat or milk, as early as 14,000 BP. Humans also probably consumed hallucinogenic plants during the Paleolithic. The Aboriginal Australians have been consuming a variety of native animal and plant foods, called bushfood, for an estimated 60,000 years, since the Middle Paleolithic.

In February 2019, scientists reported evidence, based on isotope studies, that at least some Neanderthals may have eaten meat. People during the Middle Paleolithic, such as the Neanderthals and Middle Paleolithic Homo sapiens in Africa, began to catch shellfish for food as revealed by shellfish cooking in Neanderthal sites in Italy about 110,000 years ago and in Middle Paleolithic *Homo sapiens* sites at Pinnacle Point, South Africa around 164,000 BP. Although fishing only became common during the Upper Paleolithic, fish have been part of human diets long before the dawn of the Upper Paleolithic and have certainly been consumed by humans since at least the

Middle Paleolithic. For example, the Middle Paleolithic *Homo sapiens* in the region now occupied by the Democratic Republic of the Congo hunted large 6 ft (1.8 m)-long catfish with specialized barbed fishing points as early as 90,000 years ago. The invention of fishing allowed some Upper Paleolithic and later hunter-gatherer societies to become sedentary or semi-nomadic, which altered their social structures. Example societies are the Lepenski Vir as well as some contemporary hunter-gatherers, such as the Tlingit. In some instances (at least the Tlingit), they developed social stratification, slavery, and complex social structures such as chiefdoms.

Anthropologists such as Tim White suggest that cannibalism was common in human societies prior to the beginning of the Upper Paleolithic, based on the large amount of “butchered human" bones found in Neanderthal and other Lower/Middle Paleolithic sites. Cannibalism in the Lower and Middle Paleolithic may have occurred because of food shortages. However, it may have been for religious reasons, and would coincide with the development of religious practices thought to have occurred during the Upper Paleolithic. Nonetheless, it remains possible that Paleolithic societies never practiced cannibalism, and that the damage to recovered human bones was either the result of excarnation or predation by carnivores such as saber-toothed cats, lions, and hyenas.

A modern-day diet known as the Paleolithic diet exists, based on restricting consumption to the foods presumed to be available to anatomically modern humans prior to the advent of settled agriculture.

Chapter 19

Lower Paleolithic Technology

The Lower Paleolithic (or Lower Palaeolithic) is the earliest subdivision of the Paleolithic or Old Stone Age. It spans the time from around 3 million years ago when the first evidence for stone tool production and use by hominins appears in the current archaeological record, until around 300,000 years ago, spanning the Oldowan ("mode 1") and Acheulean ("mode 2") lithics industries.

In African archaeology, the time period roughly corresponds to the Early Stone Age, the earliest finds dating back to 3.3 million years ago, with Lomekwian stone tool technology, spanning Mode 1 stone tool technology, which begins roughly 2.6 million years ago and ends between 400,000 and 250,000 years ago, with Mode 2 technology.

The Middle Paleolithic followed the Lower Paleolithic and recorded the appearance of the more advanced prepared-core tool-making technologies such as the Mousterian. Whether the earliest control of fire by hominins dates to the Lower or to the Middle Paleolithic remains an open question.

Gelasian

The Lower Paleolithic began with the appearance of the first stone tools in the world. Formerly associated with the emergence of *Homo habilis*, some 2.8 million years ago, this date has been pushed back significantly by finds of the early 2000s, the Oldowan or Mode 1 horizon, long considered the oldest type of lithic industry, is now considered to have developed from about 2.6 million years ago, with the beginning Gelasian (Lower Pleistocene), possibly first used by australopithecine forbears of the genus *Homo* (such as *Australopithecus garhi*).

Still older tools discovered at the single site of Lomekwi 3 in Kenya, announced in 2015, dated to as early as 3.3 million years ago. As such, they would predate the Pleistocene (the Gelasian), and fall into the late Pliocene (the Piacenzian).

The early members of the genus *Homo* produced primitive tools, summarized under the Oldowan industry, which remained dominant for nearly a million years, from about 2.5 to 1.7 million years ago. *Homo habilis* is assumed to have lived primarily on scavenging, using tools to cleave meat off carrion or to break bones to extract the marrow.

The move from the mostly frugivorous or omnivorous diet of hominin *Australopithecus* to the carnivorous scavenging lifestyle of early *Homo* has been explained by the climate changes in East Africa associated with the Quaternary glaciation. Decreasing oceanic evaporation produced a drier climate and the expansion of the savannah at the expense of forests. Reduced availability of fruits stimulated some proto-australopithecines to search out new food sources found in the drier savannah ecology. Derek Bickerton (2009) has designated to this period the move from simple animal communication systems found in all great apes to the earliest form of symbolic communication systems capable of displacement (referring to items not currently within sensory perception) and motivated by the need to "recruit" group members for scavenging large carcasses. *Homo erectus* appeared by about 1.8 million years ago, via the transitional variety *Homo ergaster*.

Calabrian

Homo erectus moved from scavenging to hunting, developing the hunting-gathering lifestyle that would remain dominant throughout the Paleolithic into the Mesolithic. The unlocking of the new niche of hunting-gathering subsistence drove a number of further behavioral and physiological changes leading to the appearance of *Homo heidelbergensis* by some 600,000 years ago.

Homo erectus migrated out of Africa and dispersed throughout Eurasia. Stone tools in Malaysia have been dated to be 1.83 million years old. The Peking Man fossil, discovered in 1929, is roughly 700,000 years old.

In Europe, the Olduwan tradition (known in Europe as Abbevillian) split into two parallel traditions, the Clactonian, a flake tradition, and the Acheulean, a hand-axe tradition. The Levallois technique for knapping flint developed during this time.

The carrier species from Africa to Europe was undoubtedly *Homo erectus*. This type of human is more clearly linked to the flake tradition, which spread across southern Europe through the Balkans to appear relatively densely in southeast Asia. Many Mousterian finds in the Middle Paleolithic have been knapped using a Levallois technique, suggesting that Neanderthals evolved from *Homo erectus* (or, perhaps, *Homo heidelbergensis*; see below).

Monte Poggiolo, near Forlì, Italy, is the location of an Acheulian littoral handaxe industry dating from 1.8 to 1.1 million years ago.

Middle Pleistocene

The appearance of *Homo heidelbergensis* about 600,000 years ago heralds a number of other new varieties, such as *Homo rhodesiensis* and *Homo cepranensis* about 400,000 years ago. *Homo heidelbergensis* is a candidate for first developing an early form of symbolic language. Whether control of fire and earliest burials date to this period or only appear during the Middle Paleolithic is an open question. Also, in Europe, a type of human appeared that was intermediate between *Homo erectus* and *Homo sapiens*, sometimes summarized under archaic *Homo sapiens*, typified by such fossils as those found at Swanscombe, Steinheim, Tautavel, and Vertesszollos (*Homo palaeohungaricus*). The hand-axe tradition originates in the same period. The intermediate may have been *Homo heidelbergensis*, held responsible for the manufacture of improved *Mode 2* Acheulean tool types, in Africa, after 600,000 years ago. Flakes and axes coexisted in Europe, sometimes at the same site. The axe tradition, however, spread to a different range in the east. It appears in Arabia and India, but more importantly, it does not appear in southeast Asia.

Transition to the Middle Paleolithic

- From about 300,000 years ago, technology, social structures and behaviour appear to grow more complex, with prepared-core technique lithics, earliest instances of burial and changes to hunting-gathering patterns of subsistence. *Homo sapiens*first appear about 300,000 years ago, as evidenced by fossils found at Jebel Irhoud in Morocco.

Lower Paleolithic era by region

- India

Guy Ellcock Pilgrim, a British geologist and palaeontologist, who discovered 1.5 million-year-old prehistoric human teeth and part of a jaw denoting that the ancient people, intelligent hominins dating as far back as 1,500,000 ybp Acheulean period, lived in the Pinjore region near Chandigarh. Quartzite tools of the lower Paleolithic period were excavated in this region extending from Pinjore in Haryana to Nalagarh (Solan district in Himachal Pradesh).

Chapter 20

Stone Tool

A stone tool is, in the most general sense, any tool made either partially or entirely out of stone. Although stone tool-dependent societies and cultures still exist today, most stone tools are associated with prehistoric (particularly Stone Age) cultures that have become extinct. Archaeologists often study such prehistoric societies, and refer to the study of stone tools as lithic analysis. Ethnoarchaeology has been a valuable research field in order to further the understanding and cultural implications of stone tool use and manufacture.

Stone has been used to make a wide variety of different tools throughout history, including arrowheads, spearheads, and querns. Stone tools may be made of either ground stone or chipped stone, and a person who creates tools out of the latter is known as a flintknapper.

Chipped stone tools are made from cryptocrystalline materials such as chert or flint, radiolarite, chalcedony, obsidian, basalt, and quartzite via a process known as lithic reduction. One simple form of reduction is to strike stone flakes from a nucleus (core) of material using a hammerstone or similar hard hammer fabricator. If the goal of the reduction strategy is to produce flakes, the remnant lithic core may be discarded once it has become too small to use. In some strategies, however, a flintknapper reduces the core to a rough unifacial, or bifacial preform, which is further reduced using soft hammer flaking techniques or by pressure flaking the edges.

More complex forms of reduction include the production of highly standardized blades, which can then be fashioned into a variety of tools such as scrapers, knives, sickles, and microliths. In general terms, chipped stone tools are nearly ubiquitous in all pre-metal-using societies because they are easily manufactured, the tool stone is usually plentiful, and they are easy to transport and sharpen.

Evolution

Archaeologists classify stone tools into industries (also known as complexes or technocomplexes) that share distinctive technological or morphological characteristics.

In 1969 in the 2nd edition of *World Prehistory*, Grahame Clark proposed an evolutionary progression of flint-knapping in which the "dominant lithic technologies" occurred in a fixed sequence from Mode 1 through Mode 5. He assigned to them relative dates: Modes 1 and 2 to the Lower Palaeolithic, 3 to the Middle Palaeolithic, 4 to the Advanced and 5 to the Mesolithic. They were not to be conceived, however, as either universal—that is, they did not account for all lithic technology; or as synchronous—they were not in effect in different regions simultaneously. Mode 1, for example, was in use in Europe long after it had been replaced by Mode 2 in Africa.

Clark's scheme was adopted enthusiastically by the archaeological community. One of its advantages was the simplicity of terminology; for example, the Mode 1 / Mode 2 Transition. The transitions are currently of greatest interest. Consequently, in the literature the stone tools used in the period of the Palaeolithic are divided into four "modes", each of which designate a different form of complexity, and which in most cases followed a rough chronological order.

Pre-Mode I

- Kenya

Stone tools found from 2011 to 2014 at Lake Turkana in Kenya, are dated to be 3.3 million years old, and predate the genus *Homo* by about one million years. The oldest known *Homo* fossil is about 2.4-2.3 million years old compared to the 3.3 million year old stone tools. The stone tools may have been made by *Australopithecus afarensis*, the species whose best fossil example is Lucy, which inhabited East Africa at the same time as the date of the oldest stone tools, or by *Kenyanthropus platyops* (a 3.2 to 3.5-million-year-old Pliocene hominin fossil discovered in 1999). Dating of the tools was by dating volcanic ash layers in which the tools were found and dating the magnetic signature (pointing north or south due to reversal of the magnetic poles) of the rock at the site.

- Ethiopia

Grooved, cut and fractured animal bone fossils, made by using stone tools, were found in Dikika, Ethiopia near (200 yards) the remains of Selam, a young *Australopithecus afarensis* girl who lived about 3.3 million years ago.

Mode I: The Oldowan Industry

The earliest stone tools in the life span of the genus *Homo* are Mode 1 tools, and come from what has been termed the

Oldowan Industry, named after the type of site (many sites, actually) found in Olduvai Gorge, Tanzania, where they were discovered in large quantities. Oldowan tools were characterised by their simple construction, predominantly using core forms.

These cores were river pebbles, or rocks similar to them, that had been struck by a spherical hammerstone to cause conchoidal fractures removing flakes from one surface, creating an edge and often a sharp tip. The blunt end is the proximal surface; the sharp, the distal. Oldowan is a percussion technology. Grasping the proximal surface, the hominid brought the distal surface down hard on an object he wished to detach or shatter, such as a bone or tuber.

The earliest known Oldowan tools yet found date from 2.6 million years ago, during the Lower Palaeolithic period, and have been uncovered at Gona in Ethiopia.

After this date, the Oldowan Industry subsequently spread throughout much of Africa, although archaeologists are currently unsure which Hominan species first developed them, with some speculating that it was *Australopithecus garhi*, and others believing that it was in fact *Homo habilis*. *Homo habilis* was the hominin who used the tools for most of the Oldowan in Africa, but at about 1.9-1.8 million years ago Homo erectus inherited them.

The Industry flourished in southern and eastern Africa between 2.6 and 1.7 million years ago, but was also spread out of Africa and into Eurasia by travelling bands of *H. erectus*, who took it as far east as Java by 1.8 million years ago and Northern China by 1.6 million years ago.

Mode II: The Acheulean Industry

Eventually, more complex Mode 2 tools began to be developed through the Acheulean Industry, named after the site of Saint-Acheul in France. The Acheulean was characterised not by the core, but by the biface, the most notable form of which was the hand axe. The Acheulean first appears in the archaeological record as early as 1.7 million years ago in the West Turkana area of Kenya and contemporaneously in southern Africa.

The Leakeys, excavators at Olduvai, defined a "Developed Oldowan" Period in which they believed they saw evidence of an overlap in Oldowan and Acheulean. In their species-specific view of the two industries, Oldowan equated to *H. habilis* and Acheulean to *H. erectus*. Developed Oldowan was assigned to *habilis* and Acheulean to *erectus*. Subsequent dates on *H. erectus* pushed the fossils back to well before Acheulean tools; that is, *H. erectus* must have initially used Mode 1. There was no reason to think, therefore, that Developed Oldowan had to be *habilis*; it could have been *erectus*. Opponents of the view divide Developed Oldowan between Oldowan and Acheulean. There is no question, however, that *habilis* and *erectus* coexisted, as *habilis* fossils are found as late as 1.4 million years ago. Meanwhile, African *H. erectus* developed Mode 2. In any case a wave of Mode 2 then spread across Eurasia, resulting in use of both there. *H. erectus* may not have been the only hominin to leave Africa; European fossils are sometimes associated with *Homo ergaster*, a contemporary of *H. erectus* in Africa.

In contrast to an Oldowan tool, which is the result of a fortuitous and probably ex tempore operation to obtain one sharp edge on a stone, an Acheulean tool is a planned result of a manufacturing process. The manufacturer begins with a blank, either a larger stone or a slab knocked off a larger rock. From this blank he or she removes large flakes, to be used as cores. Standing a core on edge on an anvil stone, he or she hits the exposed edge with centripetal blows of a hard hammer to roughly shape the implement. Then the piece must be worked over again, or retouched, with a soft hammer of wood or bone to produce a tool finely chipped all over consisting of two convex surfaces intersecting in a sharp edge. Such a tool is used for slicing; concussion would destroy the edge and cut the hand.

Some Mode 2 tools are disk-shaped, others ovoid, others leaf-shaped and pointed, and others elongated and pointed at the distal end, with a blunt surface at the proximal end, obviously used for drilling. Mode 2 tools are used for butchering; not being composite (having no haft) they are not very appropriate killing instruments. The killing must have been done some other way. Mode 2 tools are larger than Oldowan. The blank was ported to serve as an ongoing source of flakes until it was finally retouched as a finished tool itself. Edges were often sharpened by further retouching.

Mode III: The Mousterian Industry

- Eventually, the Acheulean in Europe was replaced by a lithic technology known as the Mousterian Industry, which was named after the site of Le Moustier in France, where examples were first uncovered in the 1860s. Evolving from the Acheulean, it adopted the Levallois technique to produce smaller and sharper knife-like tools as well as scrapers. Also known as the "prepared core technique," flakes are struck from worked cores and then subsequently retouched. The Mousterian Industry was developed and used primarily by the Neanderthals, a native European and Middle Eastern hominin species, but a broadly similar industry is contemporaneously widespread in Africa.

Mode IV: The Aurignacian Industry

The widespread use of long blades (rather than flakes) of the Upper Palaeolithic Mode 4 industries appeared during the Upper Palaeolithic between 50,000 and 10,000 years ago, although blades were produced in small quantities much earlier by Neanderthals. The Aurignacian culture seems to have been the first to rely largely on blades. The use of blades exponentially increases the efficiency of core usage compared to the Levallois flake technique, which had a similar advantage over Acheulean technology which was worked from cores.

Mode V: The Microlithic Industries

Mode 5 stone tools involve the production of microliths, which were used in composite tools, mainly fastened to a shaft. Examples include the Magdalenian culture. Such a technology makes much more efficient use of available materials like flint, although required greater skill in manufacturing the small flakes. Mounting sharp flint edges in a wood or bone handle is the key innovation in microliths, essentially because the handle gives the user protection against the flint and also improves leverage of the device.

Neolithic industries

In prehistoric Japan, ground stone tools appear during the Japanese Paleolithic period, that lasted from around 40,000 BC to 14,000 BC. Elsewhere, ground stone tools became important during the Neolithic period beginning about 10,000 BC. These ground or polished implements are manufactured from larger-grained materials such as basalt, jade and jadeite, greenstone and some forms of rhyolite which are not suitable for flaking. The greenstone industry was important in the English Lake District, and is known as the Langdale axe industry. Ground stone implements included adzes, celts, and axes, which were manufactured using a labour-intensive, time-consuming method of repeated grinding against an abrasive stone, often using water as a lubricant. Because of their coarse surfaces, some ground stone tools were used for grinding plant foods and were polished not just by intentional shaping, but also by use. Manos are hand stones used in conjunction with metates for grinding corn or grain. Polishing increased the intrinsic mechanical strength of the axe. Polished stone axes were important for the widespread clearance of woods and forest during the Neolithic period, when crop and livestock farming developed on a large scale. They are distributed very widely and were traded over great distances since the best rock types were often very local. They also became venerated objects, and were frequently buried in long barrows or round barrows with their former owners.

During the Neolithic period, large axes were made from flint nodules by chipping a rough shape, a so-called "rough-out". Such products were traded across a wide area. The rough-outs were then polished to give the surface a fine finish to create the axe head. Polishing not only increased the final strength of the product but also meant that the head could penetrate wood more easily.

There were many sources of supply, including Grimes Graves in Suffolk, Cissbury in Sussex and Spiennes near Mons in Belgium to mention but a few. In Britain, there were numerous small quarries in downland areas where flint was removed for local use, for example.

Many other rocks were used to make axes from stones, including the Langdale axe industry as well as numerous other sites such as Penmaenmawr and Tievebulliagh in Co Antrim, Ulster. In Langdale, there many outcrops of the greenstone were exploited, and knapped where the stone was extracted. The sites exhibit piles of waste flakes, as well as rejected rough-outs. Polishing improved the mechanical strength of the tools, so increasing their life and effectiveness. Many other tools were developed using the same techniques. Such products were traded across the country and abroad.

Modern uses

- The invention of the flintlock gun mechanism in the sixteenth century produced a demand for specially shaped gunflints. The gunflint industry survived until the middle of the twentieth century in some places, including in the English town of Brandon.

Threshing boards with lithic flakes are used in agriculture from Neolithic, and are still used today in the regions where agriculture has not been mechanized and industrialized.

Glassy stones (flint, quartz, jasper, agate) were used with a variety of iron pyrite or marcasite stones as percussion fire starter tools. That was the most common method of producing fire in pre-industrial societies. Stones were later superseeded by use of steel, ferrocerium and matches.

For specialist purposes glass knives are still made and used today, particularly for cutting thin sections for electron microscopy in a technique known as microtomy. Freshly cut blades are always used since the sharpness of the edge is very great. These knives are made from high-quality manufactured glass, however, not from natural raw materials such as chert or obsidian. Surgical knives made from obsidian are still used in some delicate surgeries.

Tool stone

In archaeology, a tool stone is a type of stone that is used to manufacture stone tools.

Chapter 21

Homo Habilis

Homo habilis ("handy man") is a species of archaic human from the Early Pleistocene of East and South Africa about 2.3–1.65 million years ago (mya). Upon species description in 1964, *H. habilis* was highly contested, with many researchers recommending it be synonymised with *Australopithecus africanus*, the only other early hominin known at the time, but *H. habilis* received more recognition as time went on and more relevant discoveries were made. By the 1980s, *H. habilis* was proposed to have been a human ancestor, directly evolving into *Homo erectus* which directly led to modern humans. This viewpoint is now debated. Several specimens with insecure species identification were assigned to *H. habilis*, leading to arguments for splitting, namely into "*H. rudolfensis*" and "*H. gautengensis*" of which only the former has received wide support.

Like contemporary *Homo*, *H. habilis* brain size generally varied from 500–900 cm (31–55 cu in). The body proportions of *H. habilis* are only known from two highly fragmentary skeletons, and is based largely on assuming a similar anatomy to the earlier australopithecines. Because of this, it has also been proposed *H. habilis* be moved to the genus *Australopithecus* as *Australopithecus habilis*. However, the interpretation of *H. habilis* as a small-statured human with inefficient long distance travel capabilities has been challenged. The presumed female specimen OH 62 is traditionally interpreted as having been 100–120 cm (3 ft 3 in–3 ft 11 in) in height and 20–37 kg (44–82 lb) in weight assuming australopithecine-like proportions, but assuming humanlike proportions she would have been about 148 cm (4 ft 10 in) and 35 kg (77 lb). Nonetheless, *H. habilis* may have been at least partially arboreal like what is postulated for australopithecines. Early hominins are typically reconstructed as having thick hair and marked sexual dimorphism with males much larger than females, though relative male and female size is not definitively known.

H. habilis manufactured the Oldowan stone tool industry and mainly used tools in butchering. Early *Homo*, compared to australopithecines, are generally thought to have consumed high quantities of meat and, in the case of *H. habilis*, scavenged meat.

Typically, early hominins are interpreted as having lived in polygynous societies, though this is highly speculative. Assuming *H. habilis* society was similar to that of modern savanna chimps and baboons, groups may have numbered 70–85 members, with multiple males to defend against open savanna predators, such as big cats, hyenas and crocodiles. *H. habilis* coexisted with *H. rudolfensis*, *H. ergaster* / *H. erectus* and *Paranthropus boisei*.

Taxonomy

Research history

The first recognised remains—OH 7, partial juvenile skull, hand, and foot bones dating to 1.75 million years ago (mya)—were discovered in Olduvai Gorge, Tanzania, in 1960 by Jonathan Leakey. However, the actual first remains—OH 4, a molar—were discovered by the senior assistant of Louis and Mary Leakey (Jonathan's parents), Heselon Mukiri, in 1959, but this was not realised at the time. By this time, Louis and Mary had spent 29 years excavating in Olduvai Gorge for early hominin remains, but had instead recovered mainly other animal remains as well as the Oldowan stone tool industry. The industry had been ascribed to *Paranthropus boisei* (at the time "*Zinjanthropus*") in 1959 as it was the first and only hominin recovered in the area, but this was revised upon OH 7's discovery.

In 1964, Louis, South African palaeoanthropologist Phillip V. Tobias, and British primatologist John R. Napier officially assigned the remains into the genus *Homo* as, on recommendation by Australian anthropologist Raymond Dart, *H. habilis*, the specific name meaning "able, handy, mentally skillful, vigorous" in Latin. The specimen's association with the Oldowan (then considered evidence of advanced cognitive ability) was also used as justification for classifying it into *Homo*. OH 7 was designated the holotype specimen.

After description, it was hotly debated if *H. habilis* should be reclassified into *Australopithecus africanus* (the only other early hominin known at the time), in part because the remains were so old and at the time *Homo* was presumed to have evolved in Asia (with the australopithecines having no living descendants). Also, the brain size was smaller than what Wilfrid Le Gros Clark proposed in 1955 when considering *Homo*. The classification *H. habilis* began to receive wider acceptance as more fossil elements and species were unearthed. In 1983, Tobias proposed that *A. africanus* was a direct ancestor of *Paranthropus* and *Homo* (the two were sister taxa), and that *A. africanus* evolved into *H. habilis* which evolved into *H. erectus* which evolved into modern humans (by a process of cladogenesis). He further said that there was a major evolutionary leap between *A. africanus* and *H. habilis*, and thereupon human evolution progressed gradually because *H. habilis* brain size had nearly doubled compared to australopithecine predecessors. However, OH 24, at the time the oldest *H. habilis* specimen, was similar to the younger OH 13, which showed there was no evolutionary progression through the lineage.

Many had accepted Tobias' model and assigned Late Pliocene to Early Pleistocene hominin remains outside the range of *Paranthropus* and *H. erectus* into *H. habilis*. For non-skull elements, this was done on the basis of size as there was a lack of clear diagnostic characteristics. Because of these practices, the range of variation for the species became quite wide, and the terms *H. habilis* sensu stricto ("in the strict sense") and *H. habilis* sensu lato ("in the broad sense") were in use to include and exclude, respectively, more discrepant morphs.

To address this, in 1985, English palaeoanthropologist Bernard Wood proposed that the comparatively massive skull KNM-ER 1470 from Lake Turkana, Kenya, discovered in 1972 and assigned to *H. habilis*, actually represented a different species, now referred to as *Homo rudolfensis*. It is also argued that instead it represents a male specimen whereas other *H. habilis* specimens are female. It has been suggested that early *Homo* from South Africa can be variously assigned to *H. habilis* or *H. ergaster* / *H. erectus*, but in 2010, Australian archaeologist Darren Curoe proposed splitting off South African early *Homo* into a new species, *Homo gautengensis*. In 1986, OH 62, a fragmentary skeleton, was discovered by American anthropologist Tim D. White in association with *H. habilis* skull fragments, definitively establishing aspects of *H. habilis* skeletal anatomy for the first time, and revealing more *Australopithecus*-like than *Homo*-like features. Because of this, as well as similarities in dental adaptations, Wood and biological anthropologist Mark Collard suggested moving the species to *Australopithecus* in 1999. However, reevaluation of OH 62 to a more humanlike physiology, if correct, would cast doubt on this. The discovery of the 1.8 Ma Georgian Dmanisi skulls in the early 2000s, which exhibit several similarities with early *Homo*, has led to suggestions that all contemporary groups of early *Homo* in Africa, including *H. habilis* and *H. rudolfensis*, are the same species and should be assigned to *H. erectus*.

Classification

There is still no wide consensus as to whether or not *H. habilis* is ancestral to *H. ergaster* / *H. erectus* or is an offshoot of the human line, and whether or not all specimens assigned to *H. habilis* are correctly assigned or the species is an assemblage of different *Australopithecus* and *Homo* species. Nonetheless, *H. habilis* and *H. rudolfensis* generally are recognised members of the genus at the base of the family tree, with arguments for synonymisation or removal from the genus not widely adopted.

Though it is now largely agreed upon that *Homo* evolved from *Australopithecus*, the timing and placement of this split has been much debated, with many *Australopithecus* species having been proposed as the ancestor. The discovery of LD 350-1, the oldest *Homo* specimen, dating to 2.8 mya, in the Afar Region of Ethiopia may indicate that the genus evolved from *A. afarensis* around this time.

The species LD 350-1 belongs to could be the ancestor of *H. habilis*, but this is unclear. The oldest *H. habilis* specimen, A.L. 666-1, dates to 2.3 mya, but is anatomically more derived (has less ancestral, or basal, traits) than the younger OH 7, suggesting derived and basal morphs lived concurrently, and that the *H. habilis* lineage began before 2.3 mya. Based on 2.1 million year old stone tools from Shangchen, China, *H. habilis* or an ancestral species may have dispersed across Asia. The youngest *H. habilis* specimen, OH 13, dates to about 1.65 mya.

Anatomy

Skull

It has generally been thought that brain size increased along the human line especially rapidly at the transition between species, with *H. habilis* brain size smaller than that of *H. ergaster* / *H. erectus*, jumping from about 600–650 cc (37–40 cu in) in *H. habilis* to about 900–1,000 cc (55–61 cu in) in *H. ergaster* and *H. erectus*.

However, a 2015 study showed that the brain sizes of *H. habilis*, *H. rudolfensis*, and *H. ergaster* generally ranged between 500–900 cc (31–55 cu in) after reappraising the brain volume of OH 7 from 647–687 cc (39.5–41.9 cu in) to 729–824 cc (44.5–50.3 cu in). This does, nonetheless, indicate a jump from australopithecine brain size which generally ranged from 400–500 cc (24–31 cu in).

The brain anatomy of all *Homo* features an expanded cerebrum in comparison to australopithecines. The pattern of striations on the teeth of OH 65 slanting right, which may have been accidentally self-inflicted when the individual was pulling a piece of meat with its teeth and the left hand while trying to cut it with a stone tool using the right hand. If correct, this could indicate right handedness, and handedness is associated with major reorganisation of the brain and the lateralisation of brain function between the left and right hemispheres. This scenario has also been hypothesised for some Neanderthal specimens. Lateralisation could be implicated in tool use. In modern humans, lateralisation is weakly associated with language.

The tooth rows of *H. habilis* were V-shaped as opposed to U-shaped in later *Homo*, and the mouth jutted outwards (was prognathic), though the face was flat from the nose up.

Build

Based on the fragmentary skeletons OH 62 (presumed female) and KNM-ER 3735 (presumed male), *H. habilis* body anatomy has generally been considered to have been more apelike than even that of the earlier *A. afarensis* and consistent with an at least partially arboreal lifestyle in the trees as is assumed in australopithecines. Based on OH 62 and assuming comparable body dimensions to australopithecines, *H. habilis* has generally been interpreted as having been small-bodied like australopithecines, with OH 62 generally estimated at about 100–120 cm (3 ft 3 in–3 ft 11 in) in height and 20–37 kg (44–82 lb) in weight. However, assuming longer, modern humanlike legs, OH 62 would have been about 148 cm (4 ft 10 in) and

35 kg (77 lb), and KNM-ER 3735 about the same size. For comparison, modern human men and women in the year 1900 averaged 163 cm (5 ft 4 in) and 152.7 cm (5 ft) respectively. It is generally assumed that pre-*H. ergaster* hominins, including *H. habilis*, exhibited notable sexual dimorphism with males markedly bigger than females. However, relative female body mass is unknown in this species.

Early hominins, including *H. habilis*, are thought to have had thick body hair coverage like modern non-human apes because they appear to have inhabited cooler regions and are thought to have had a less active lifestyle than (presumed hairless) post-*ergaster* species. Consequently, they probably required thick body hair to stay warm. Based on dental development rates, *H. habilis* is assumed to have had an accelerated growth rate compared to modern humans, more like that of modern non-human apes.

Limbs

The arms of *H. habilis* and australopithecines have generally been considered to have been proportionally long and so adapted for climbing and swinging. In 2004, anthropologists Martin Haeusler and Henry McHenry argued that, because the humerus to femur ratio of OH 62 is within the range of variation for modern humans, and KNM-ER 3735 is close to the modern human average, it is unsafe to assume apelike proportions. Nonetheless, the humerus of OH 62 measured 258–270 mm (10.2–10.6 in) long and the ulna (forearm) 245–255 mm (9.6–10.0 in), which is closer to the proportion seen in chimps. The hand bones of OH 7 suggest precision gripping, important in dexterity, as well as adaptations for climbing. In regard to the femur, traditionally comparisons with the *A. afarensis* specimen AL 288-1 have been used to reconstruct stout legs for *H. habilis*, but Haeusler and McHenry suggested the more gracile OH 24 femur (either belonging to *H. ergaster* / *H. erectus* or *P. boisei*) may be a more apt comparison. In this instance, *H. habilis* would have had longer, humanlike legs and have been effective long-distance travellers as is assumed to have been the case in *H. ergaster*. However, estimating the unpreserved length of a fossil is highly problematic.

The thickness of the limb bones in OH 62 is more similar to chimps than *H. ergaster* / *H. erectus* and modern humans, which may indicate different load bearing capabilities more suitable for arboreality in *H. habilis*. The strong fibula of OH 35 (though this may belong to *P. boisei*) is more like that of non-human apes, and consistent with arboreality and vertical climbing.

OH 8, a foot, is better suited for terrestrial movement than the foot of *A. afarensis*, though still retains many apelike features consistent with climbing. However, the foot has projected toe bone and compacted mid-foot joint structures, which restrict rotation between the foot and ankle as well as at the front foot.

Foot stability enhances the efficiency of force transfer between the leg and the foot and vice versa, and is implicated in the plantar arch elastic spring mechanism which generates energy while running (but not walking). This could possibly indicate *H. habilis* was capable of some degree of endurance running, which is typically thought to have evolved later in *H. ergaster* / *H. erectus*.

Culture

Society

Typically, *H. ergaster / H. erectus* is considered to have been the first human to have lived in a monogamous society, and all preceding hominins were polygynous. However, it is highly difficult to speculate with any confidence the group dynamics of early hominins. The degree of sexual dimorphism and the size disparity between males and females is often used to correlate between polygyny with high disparity and monogamy with low disparity based on general trends (though not without exceptions) seen in modern primates. Rates of sexual dimorphism are difficult to determine as early hominin anatomy is poorly known, and are largely based on few specimens.

In some cases, sex is arbitrarily determined in large part based on perceived size and apparent robustness in the absence of more reliable elements in sex identification (namely the pelvis). Mating systems are also based on dental anatomy, but early hominins possess a mosaic anatomy of different traits not seen together in modern primates; the enlarged cheek teeth would suggest marked size-related dimorphism and thus intense male–male conflict over mates and a polygynous society, but the small canines should indicate the opposite. Other selective pressures, including diet, can also dramatically impact dental anatomy. The spatial distribution of tools and processed animal bones at the FLK Zinj and PTK sites in Olduvai Gorge indicate the inhabitants used this area as a communal butchering and eating grounds, as opposed to the nuclear family system of modern hunter gatherers where the group is subdivided into smaller units each with their own butchering and eating grounds.

The behaviour of early *Homo*, including *H. habilis*, is sometimes modelled on that of savanna chimps and baboons. These communities consist of several males (as opposed to a harem society) in order to defend the group on the dangerous and exposed habitat, sometimes engaging in a group display of throwing sticks and stones against enemies and predators. The left foot OH 8 seems to have been bitten off by a crocodile, possibly *Crocodylus anthropophagus*, and the leg OH 35, which either belongs to *P. boisei* or *H. habilis*, shows evidence of leopard predation. *H. habilis* and contemporary hominins were likely predated upon by other large carnivores of the time, such as (in Olduvai Gorge) the hunting hyena *Chasmaporthetes nitidula*, and the saber-toothed cats *Dinofelis* and *Megantereon*. In 1993, American palaeoanthropologist Leslie C. Aiello and British evolutionary psychologist Robin Dunbar estimated that *H. habilis* group size ranged from 70–85 members—on the upper end of chimp and baboon group size—based on trends seen in neocortex size and group size in modern non-human primates.

H. habilis coexisted with *H. rudolfensis*, *H. ergaster* / *H. erectus*, and *P. boisei*. It is unclear how all of these species interacted. To explain why *P. boisei* was associated with Olduwan tools despite not being the knapper (the one who made the tools), Leakey and colleagues, when describing *H. habilis*, suggested that one possibility was *P. boisei* was killed by *H. habilis*, perhaps as food. However, when describing *P. boisei* five years earlier, Louis Leakey said, "There is no reason whatever, in this case, to believe that the skull represents the victim of a cannibalistic feast by some hypothetical more advanced type of man."

Diet

It is thought *H. habilis* derived meat from scavenging rather than hunting (scavenger hypothesis), acting as a confrontational scavenger and stealing kills from smaller predators such as jackals or cheetahs. Fruit was likely also an important dietary component, indicated by dental erosion consistent with repetitive exposure to acidity. Based on dental microwear-texture analysis, *H. habilis* (like other early *Homo*) likely did not regularly consume tough foods. Microwear-texture complexity is, on average, somewhere between that of tough-food eaters and leaf eaters (folivores), and points to an increasingly generalised and omnivorous diet.

It is typically thought that the diets of *H. habilis* and other early *Homo* had a greater proportion of meat than *Australopithecus*, and that this led to brain growth. The main hypotheses regarding this are: meat is energy- and nutrient-rich and put evolutionary pressure on developing enhanced cognitive skills to facilitate strategic scavenging and monopolise fresh carcasses, or meat allowed the large and calorie-expensive ape gut to decrease in size allowing this energy to be diverted to brain growth. Alternatively, it is also suggested that early *Homo*, in a drying climate with scarcer food options, relied primarily on underground storage organs (such as tubers) and food sharing, which facilitated social bonding among both male and female group members. However, unlike what is presumed for *H. ergaster* and later

Homo, short-statured early *Homo* are generally considered to have been incapable of endurance running and hunting, and the long and *Australopithecus*-like forearm of *H. habilis* could indicate early *Homo* were still arboreal to a degree. Also, organised hunting and gathering is thought to have emerged in *H. ergaster*. Nonetheless, the proposed food-gathering models to explain large brain growth necessitate increased daily travel distance. It has also been argued that *H. habilis* instead had long, modern humanlike legs and was fully capable of effective long distance travel, while still remaining at least partially arboreal.

Large incisor size in *H. habilis* compared to *Australopithecus* predecessors implies this species relied on incisors more. The bodies of the mandibles of *H. habilis* and other early *Homo* are thicker than those of modern humans and all living apes, more comparable to *Australopithecus*. The mandibular body resists torsion from the bite force or chewing, meaning their jaws could produce unusually powerful stresses while eating. The greater molar cusp relief in *H. habilis* compared to *Australopithecus* suggests the former used tools to fracture tough foods (such as pliable plant parts or meat), otherwise the cusps would have been more worn down. Nonetheless, the jaw adaptations for processing mechanically challenging food indicates technological advancement did not greatly affect diet.

Technology

H. habilis is associated with the Early Stone Age Oldowan stone tool industry. Individuals likely used these tools primarily to butcher and skin animals and crush bones, but also sometimes to saw and scrape wood and cut soft plants.

Knappers appear to have carefully selected lithic cores and knew that certain rocks would break in a specific way when struck hard enough and on the right spot, and they produced several different types, including choppers, polyhedrons, and discoids. Nonetheless, specific shapes were likely not thought of in advance, and probably stem from a lack of standardisation in producing such tools as well as the types of raw materials at the knappers' disposal. For example, spheroids are common at Olduvai which features an abundance of large and soft quartz and quartzite pieces, whereas Koobi Fora lacks spheroids and provides predominantly hard basalt lava rocks. Unlike the later Acheulean culture invented by *H. ergaster / H. erectus*, Oldowan technology does not require planning and foresight to manufacture, and thus does not indicate high cognition in Oldowan knappers, though it does require a degree of coordination and some knowledge of mechanics. Oldowan tools infrequently exhibit retouching and were probably discarded immediately after use most of the time.

The Olduwan was first reported in 1934, but it was not until the 1960s that it become widely accepted as the earliest culture, dating to 1.8 mya, and as having been manufactured by *H. habilis*. Since then, more discoveries have placed the origins of material culture substantially backwards in time, with the Oldowan being discovered in Ledi-Geraru and Gona in Ethiopia dating to 2.6 mya, perhaps associated with the evolution of the genus. Australopithecines are also known to have manufactured tools, such as the 3.3 Ma Lomekwi stone tool industry, and some evidence of butchering from about 3.4 mya. Nonetheless, the comparatively sharp-edged Oldowan culture was a major innovation from australopithecine technology, and it would have allowed different feeding strategies and the ability to process a wider range of foods, which would have been advantageous in the changing climate of the time. It is unclear if the Oldowan was independently invented or if it was the result of hominin experimentation with rocks over hundreds of thousands of years across multiple species.

In 1962, a 366 cm × 427 cm × 30 cm (12 ft × 14 ft × 1 ft) circle made with volcanic rocks was discovered in Olduvai Gorge. At 61–76 cm (2–2.5 ft) intervals, rocks were piled up to 15–23 cm (6–9 in) high. Mary Leakey suggested the rock piles were used to support poles stuck into the ground, possibly to support a windbreak or a rough hut. Some modern day nomadic tribes build similar low-lying rock walls to build temporary shelters upon, bending upright branches as poles and using grasses or animal hide as a screen. Dating to 1.75 mya, it is attributed to some early *Homo*, and is the oldest claimed evidence of architecture.

Chapter 22

Homo Ergaster

Homo ergaster is an extinct species or subspecies of archaic humans who lived in Africa in the Early Pleistocene. Whether *H. ergaster* constitutes a species of its own or should be subsumed into *H. erectus* is an ongoing and unresolved dispute within palaeoanthropology. Proponents of synonymisation typically designate *H. ergaster* as "African *Homo erectus*" or "*Homo erectus ergaster*". The name *Homo ergaster* roughly translates to "working man", a reference to the more advanced tools used by the species in comparison to those of their ancestors. The fossil range of *H. ergaster* mainly covers the period of 1.7 to 1.4 million years ago, though a broader time range is possible. Though fossils are known from across East and Southern Africa, most *H. ergaster* fossils have been found along the shores of Lake Turkana in Kenya. There are later African fossils, some younger than 1 million years ago, that indicate long-term anatomical continuity, though it is unclear if they can be formally regarded as *H. ergaster* specimens. As a chronospecies, *H. ergaster* may have persisted to as late as 600,000 years ago, when new lineages of *Homo* arose in Africa.

Those who believe *H. ergaster* should be subsumed into *H. erectus* consider there to be too little difference between the two to separate them into distinct species. Proponents of keeping the two species as distinct cite morphological differences between the African fossils and *H. erectus* fossils from Asia, as well as early *Homo* evolution being more complex than what is implied by subsuming species such as *H. ergaster* into *H. erectus*. Additionally, morphological differences between the specimens commonly seen as constituting *H. ergaster* might suggest that *H. ergaster* itself does not represent a cohesive species. Regardless of their most correct classification, *H. ergaster* exhibit primitive versions of traits later expressed in *H. erectus* and are thus likely the direct ancestors of later *H. erectus* populations in Asia. Additionally, *H. ergaster* is likely ancestral to later hominins in Europe and Africa, such as modern humans and Neanderthals.

Several features distinguish *H. ergaster* from australopi thecines as well as earlier and more basal species of *Homo*, such as *H. habilis*. Among these features are their larger body mass, relatively long legs, obligate bipedalism, relatively small jaws and teeth (indicating a major change in diet) as well as body proportions and inferred lifestyles more similar to modern humans than to earlier and contemporary hominins. With these features in mind, some researchers view *H. ergaster* as being the earliest true representative of the genus *Homo*.

H. ergaster lived on the savannah in Africa, a unique environment with challenges that would have resulted in the need for many new and distinct behaviours. Earlier *Homo* probably used counter-attack tactics, like modern primates, to keep predators away. By the time of *H. ergaster*, this behaviour had probably resulted in the development of true hunter-gatherer behaviour, a first among primates.

Further behaviours that might first have arisen in *H. ergaster* include male-female divisions of foraging and true monogamous pair bonds. *H. ergaster* also marks the appearance of more advanced tools of the Acheulean industry, including the earliest known hand axes. Though undisputed evidence is missing, *H. ergaster* might also have been the earliest hominin to master control of fire.

Taxonomy

Research history

The systematics and taxonomy of *Homo* in the Early to Middle Pleistocene is one of the most disputed areas of palaeoanthropology. In early palaeoanthropology and well into the twentieth century, it was generally assumed that *H. sapiens* was the end result of gradual modifications within a single lineage of hominin evolution. As the perceived transitional form between early hominins and modern humans, *H. erectus*, originally assigned to contain archaic human fossils in Asia, came to encompass a wide range of fossils covering a large span of time (almost the entire temporal range of *Homo*). Since the late twentieth century, the diversity within *H. erectus* has led some to question what exactly defines the species and what it should encompass. Some researchers, such as palaeoanthropologist Ian Tattersall in 2013, have questioned *H. erectus* since it contains an "unwieldly" number of fossils with "substantially differing morphologies".

In the 1970s, palaeoanthropologists Richard Leakey and Alan Walker described a series of hominin fossils from Kenyan fossil localities on the eastern shore of Lake Turkana. The most notable finds were two partial skulls; KNM ER 3733 and KNM ER 3883, found at Koobi Fora. Leakey and Walker assigned these skulls to *H. erectus*, noting that their brain volumes (848 and 803 cc respectively) compared well to the far younger type specimen of *H. erectus* (950 cc). Another significant fossil was a fossil mandible recovered at Ileret and described by Leakey with the designation KNM ER 992 in 1972 as "*Homo* of indeterminate species".

In 1975, palaeoanthropologists Colin Groves and Vratislav Mazák designated KNM ER 992 as the holotype specimen of a distinct species, which they dubbed *Homo ergaster*. The name (*ergaster* being derived from the Ancient Greek ἐργαστήρ, *ergast□r*, 'workman') roughly translates to "working man" or "workman".

Groves and Mazák also included many of the Koobi Fora fossils, such as KNM ER 803 (a partial skeleton and some isolated teeth) in their designation of the species, but did not provide any comparison with the Asian fossil record of *H. erectus* in their diagnosis, inadvertently causing some of the later taxonomic confusion in regards to the species.

A nearly complete fossil, interpreted as a young male (though the sex is actually undetermined), was discovered at the western shore of Lake Turkana in 1984 by Kenyan archaeologist Kamoya Kimeu. The fossils were described by Leakey and Walker, alongside paleanthropologists Frank Brown and John Harris, in 1985 as KNM-WT 15000 (nicknamed "Turkana Boy"). They interpreted the fossil, consisting of a nearly complete skeleton, as representing *H. erectus*. Turkana Boy was the first discovered comprehensively preserved specimen of *H. ergaster*/*erectus* found and constitutes an important fossil in establishing the differences and similarities between early *Homo* and modern humans. Turkana Boy was placed in *H. ergaster* by paleanthropologist Bernard Wood in

1992, and is today, alongside other fossils in Africa previously designated as *H. erectus*, commonly seen as a representative of *H. ergaster* by those who support *H. ergaster* as a distinct species.

Classification

H. ergaster is easily distinguished from earlier and more basal species of *Homo*, notably *H. habilis* and *H. rudolfensis*, by a number of features that align them, and their inferred lifestyle, more closely to modern humans than to earlier and contemporary hominins. As compared to their relatives, *H. ergaster* had body proportions more similar to later members of the genus *Homo*, notably relatively long legs which would have made them obligately bipedal. The teeth and jaws of *H. ergaster* are also relatively smaller than those of *H. habilis* and *H. rudolfensis*, indicating a major change in diet. In 1999, palaeoanthropologists Bernard Wood and Mark Collard argued that the conventional criteria for assigning species to the genus *Homo* were flawed and that early and basal species, such as *H. habilis* and *H. rudolfensis*, might appropriately be reclassified as ancestral australopithecines. In their view, the true earliest representative of *Homo* was *H. ergaster*.

Since its description as a separate species in 1975, the classification of the fossils referred to *H. ergaster* has been in dispute. *H. ergaster* was immediately dismissed by Leakey and Walker and many influential researchers, such as palaeoanthropologist G. Philip Rightmire, who wrote an extensive treatise on *H. erectus* in 1990, continued to prefer a more inclusive and comprehensive *H. erectus*. Overall, there is no doubt that the group of fossils composing *H. erectus* and *H.*

ergaster represent the fossils of a more or less cohesive subset of closely related archaic humans. The question is instead whether these fossils represent a radiation of different species or the radiation of a single, highly variable and diverse, species over the course of almost two million years. This long-running debate remains unresolved, with researchers typically using the terms *H. erectus* s.s. (*sensu stricto*) to refer to *H. erectus* fossils in Asia and the term *H. erectus* s.l. (*sensu lato*) to refer to fossils of other species that may or may not be included in *H. erectus*, such as *H. ergaster*, *H. antecessor* and *H. heidelbergensis*.

For obvious reasons, *H. ergaster* shares many features with *H. erectus*, such as large forward-projecting jaws, large brow ridges and a receding forehead. Many of the features of *H. ergaster* are clearly more primitive versions of features later expressed in *H. erectus*, which somewhat obscures the differences between the two. There are subtle, potentially significant, differences between the East African and East Asian fossils. Among these are the somewhat higher-domed and thinner-walled skulls of *H. ergaster*, and the even more massive brow ridges and faces of Asian *H. erectus*.

The question is made more difficult since it regards how much intraspecific variation can be exhibited in a single species before it needs to be split into more, a question that in and of itself does not have a clear-cut answer. A 2008 analysis by anthropologist Karen L. Baab, examining fossils of various *H. erectus* subspecies, and including fossils attributed to *H. ergaster*, found that the intraspecific variation within *H. erectus* was greater than expected for a single species when compared to modern humans and chimpanzees, but fell well within the variation expected for a species when compared to gorillas, and even well within the range expected for a single subspecies when compared to orangutans (though this is partly due to the great sexual dimorphism exhibited in gorillas and orangutans). Baab concluded that *H. erectus* s.l. was either a single but variable species, several subspecies divided by time and geography or several geographically dispersed but closely related species. In 2015, paleanthropologists David Strait, Frederick Grine and John Fleagle listed *H. ergaster* as one of the seven "widely recognized" species of *Homo*, alongside *H. habilis*, *H. rudolfensis*, *H. erectus*, *H. heidelbergensis*, *H. neanderthalensis* and *H. sapiens*, noting that other species, such as *H. floresiensis* and *H. antecessor*, were less widely recognised or more poorly known.

Variation in the fossil material

Comparing various African fossils attributed to *H. erectus* or *H. ergaster* to Asian fossils, notably the type specimen of *H. erectus*, in 2013, Ian Tattersall concluded that referring to the African material as *H. ergaster* rather than "African *H. erectus*" was a "considerable improvement" as there were many autapomorphies distinguishing the material of the two continents from one another. Tattersall believes it to be appropriate to use the designation *H. erectus* only for eastern Asian fossils, disregarding its previous use as the name for an adaptive grade of human fossils from throughout Africa and Eurasia. Though Tattersall concluded that the *H. ergaster* material represents the fossils of a single clade of *Homo*, he also found there to be considerable diversity within this clade; the KNM ER 992 mandible accorded well with other fossil mandibles from the region, such as OH 22 from Olduvai and

KNM ER 3724 from Koobi Fora, but did not necessarily match with cranial material, such as KNM ER 3733 and KNM ER 3883 (since neither preserves the jaw), nor with the mandible preserved in Turkana Boy, which has markedly different dentition.

The most "iconic" fossil of *H. ergaster* is the KNM ER 3733 skull, which is sharply distinguished from Asian *H. erectus* by a number of characteristics, including that the brow ridges project forward as well as upward and arc separately over each orbit and the braincase being quite tall compared to its width, with its side walls curving. KNM ER 3733 can be distinguished from KNM ER 3883 by a number of features as well, notably in that the margins of KNM ER 3883's brow ridges are very thickened and portrude outwards but slightly downwards rather than upwards. Both skulls can be distinguished from the skull of Turkana Boy, which possesses only slightly substantial thickenings of the superior orbital margins, lacking the more vertical thickening of KNM ER 3883 and the aggressive protrusion of KNM ER 3733. In addition to this, the facial structure of Turkana Boy is narrower and longer than that of the other skulls, with a higher nasal aperture and likely a flatter profile of the upper face. It is possible that these differences can be accounted for through Turkana Boy being a subadult, 7 to 12 years old. Furthermore, KNM ER 3733 is presumed to have been the skull of a female (whereas Turkana Boy is traditionally interpreted as male), which means that sexual dimorphism may account for some of the differences.

The differences between Turkana Boy's skull and KNM ER 3733 and KNM ER 3883, as well as the differences in dentition between Turkana Boy and KNM ER 992 have been interpreted by some, such as paleanthropologist Jeffrey H. Schwartz, as suggesting that Turkana Boy and the rest of the *H. ergaster* material does not represent the same taxon. Schwartz also noted none of the fossils seemed to represent *H. erectus* either, which he believed was in need of significant revision. In 2000, French palaeoanthropologist Valéry Zeitoun suggested that KNM ER 3733 and KNM ER 3883 should be referred to two separate species, which she dubbed *H. kenyaensis* (type specimen KNM ER 3733) and *H. okotensis* (type specimen KNM ER 3883), but these designations have found little acceptance.

Evolutionary history

Evolution and temporal range

Although frequently assumed to have originated in East Africa, the origins of *H. ergaster* are obscured by the fact that the species marks a radical departure from earlier species of *Homo* and *Australopithecus* in its long limbs, height and modern body proportions. Though a large number of Pleistocene tools have been found in East Africa, it can not be fully ascertained that *H. ergaster* originated there without further fossil discoveries. It is assumed that *H. ergaster* evolved from earlier species of *Homo*, probably *H. habilis*.

Though populations of *H. ergaster* outside of Africa have been inferred based on the geographical distribution of their descendants and tools matching those in East Africa, fossils of the species are mainly from East Africa in the time range of 1.8 to 1.7 million years ago. Most fossils have been recovered from around the shores of Lake Turkana in Kenya.

The oldest known specimen of *H. erectus* s.l. in Africa (i.e. *H. ergaster*) is DNH 134, a skull recovered in the Drimolen Palaeocave System in South Africa, dated to 2.04 to 1.95 million years ago. The skull is also the oldest known *H. erectus* s.l. specimen overall, showing clear similarities to KNM ER 3733, and demonstrates that early *H. ergaster* coexisted with other hominins such as *Paranthropus robustus* and *Australopithecus sediba.*

There are also younger specimens of *H. ergaster*; notably, Turkana Boy is dated to about 1.56 million years ago.

A handful of even younger African skulls make the case for long-term anatomical continuity, though it is unclear if they can appropriately be formally regarded as *H. ergaster* specimens; the "Olduvai Hominid 9" skull from Olduvai Gorge is dated to about 1.2 to 1.1 million years ago and there are also skulls from Buia (near the coast of Eritrea, dated to ~1 million years old), the Bouri Formation in Ethiopia (dated to between 1 million and 780,000 years old) and a fragmentary skull from Olorgesailie in Kenya (dated to between 970,000 and 900,000 years ago). The Olduvai skull is similar to Asian *H. erectus* in its massive brow ridge, but the others only show minor differences to earlier *H. ergaster* skulls.

The *H. erectus* in Asia, as well as later hominins in Europe (i. e. *H. heidelbergensis* and *H. neanderthalensis*) and Africa (*H. sapiens*) are all probably lineages descended from *H. ergaster.* Because *H. ergaster* is thought to have been ancestral to these later *Homo*, it might have persisted in Africa until around 600,000 years ago, when brain size increased rapidly and *H. heidelbergensis* emerged.

Expansion out of Africa

Traditionally, *H. erectus* was seen as the hominin that first left Africa to colonise Europe and Asia. If *H. ergaster* is distinct from *H. erectus*, this role would apply to *H. ergaster* instead. Very little concrete information is known on when and which *Homo* first appeared in Europe and Asia, since Early Pleistocene fossil hominins are scarce on both continents, and that it would have been *H. ergaster* (or "early *H. erectus*") that expanded, as well as the particular manner in which they did, remains conjecture. The presence of *H. erectus* fossils in East Asia means that a human species, most likely *H.ergaster*, had left Africa before 1 million years ago, the assumption historically having been that they first migrated out of Africa around 1.9 to 1.7 million years ago. Discoveries in Georgia and China push the latest possible date further back, before 2 million years ago, also casting doubt on the idea that *H. ergaster* was the first hominin to leave Africa.

The main reason for leaving Africa is likely to have been an increasing population periodically outgrowing their resource base, with splintering groups moving to establishing themselves in neighboring, empty territories over time.

The physiology and improved technology of *H. ergaster* might have allowed them to travel to and colonise territories that no one had ever occupied before. It is unclear if *H. ergaster* was truly uniquely capable of expanding outside Africa; australopithecines had likely colonised savannah grasslands throughout Africa by 3 million years ago and there are no clear reasons as to why they would not have been able to expand into the grasslands of Asia before *H. ergaster*.

The general assumption is that hominins migrated out of the continent either across the southern end of the Red Sea or along the Nile Valley, but there are no fossil hominins known from either region in the Early Pleistocene. The earliest *Homo* fossils outside Africa are the Dmanisi skulls from Georgia (dated to 1.77–1.85 million years old, representing either early *H. ergaster* or a new taxon, *H. georgicus*), three incisors from Ubeidiya in Israel (about 1.4 to 1 million years old) and the fossils of Java Man (*H. erectus erectus*, more than five thousand miles away). The dating of key Asian *H. erectus* specimens (including Java Man) is not entirely certain, but they are all likely to be 1.5 million years old or younger. Ubeidiya is also the oldest firmly confirmed site of Acheulean tools (one of the tool industries associated with *H. ergaster*) outside Africa, the tools recovered there closely resembling older tools discovered in East Africa.

The earliest fossil evidence of *Homo* in Asia are the aforementioned Dmanisi skulls, which share many traits with *H. ergaster* in Africa, suggesting that *H. ergaster* might have expanded out of Africa as early as 1.7–1.9 million years ago. In addition to *H. ergaster*-like traits, the Dmanisi skulls possess a wide assortment of other traits, some of which are similar to traits in earlier hominins such as *H. habilis*, and the site notably lacks preserved hand axes (otherwise characteristic of *H. ergaster*), which means that hominins might have spread out of Africa even earlier than *H. ergaster*. The skull D2700 (Dmanisi skull 3) in particular resembles *H. habilis* in the small volume of its braincase (600 cc), the form of the middle and upper face and the lack of an external nose. The mixture of skulls at Dmanisi suggests that the definition of *H. ergaster* (or *H. erectus*) might most appropriately be expanded to contain fossils that would otherwise be assigned to *H. habilis* or that two separate species of archaic humans left Africa early on. In addition to the Dmanisi fossils, stone tools manufactured by hominins have been discovered on the Loess Plateau in China and dated to 2.12 million years old, meaning that hominins must have left Africa before that time.

An alternative hypothesis historically has been that *Homo* evolved in Asia from earlier ancestors that had migrated there from Africa, and then expanded back into Europe, where it gave rise to *H. sapiens*. This view was notably held by Eugène Dubois, who first described *H. erectus* fossils in the 19th century and considered the fossils of Java Man, at the time undeniably the earliest known hominin fossils, as proof of the hypothesis. Though the discovery of australopithecines and earlier *Homo* in Africa meant that *Homo* itself did not originate in Asia, the idea that *H. erectus*(or *H. ergaster*) in particular did, and then expanded back into Africa, has occasionally resurfaced. Various fossil discoveries have been used to support it through the years, perhaps most famously a massive set of jaws from Indonesia which were perceived to be similar to those of australopithecines and dubbed *Meganthropus* (now believed to be an unrelated hominid ape). The discovery of *H. floresiensis* in 2003, which preserved primitive foot and wrist anatomy reminiscent of that of *H. habilis* and *Australopithecus* again led to suggestions of pre-*erectus* hominins in Asia, though there are no known comparable foot or wrist bones from *H. erectus* which makes comparisons impossible. The idea that *H. ergaster*/*H. erectus* first evolved in Asia before expanding back into Africa was substantially weakened by the dating of the DNH 134 skull as approximately 2 million years old, predating all other known *H. ergaster*/*H. erectus* fossils.

Anatomy

Build and appearance

The only well-preserved post-cranial remains of *H. ergaster* come from the Turkana Boy fossil. Unlike the australopithecines, Turkana Boy's arms were not longer relative to his/her legs than the arms of living people and the cone-shaped torso of his/her ancestors had evolved into a more barrel-shaped chest over narrow hips, another similarity to modern humans. The tibia (shin bone) of Turkana Boy is relatively longer than the same bone in modern humans, potentially meaning that there was more bend in the knee when walking. The slim and long build of Turkana Boy may be explained by *H. ergaster* living in hot and arid, seasonal environments. Through thinning of the body, body volume decreases faster than skin area and greater skin area means more effective heat dissipation.

H. ergaster individuals were significantly taller than their ancestors. Whereas Lucy, a famous *Australopithecus* fossil, would only have been about 1 m (3 ft 3 in) tall at her death, Turkana Boy was about 1.62 m (5 ft 4 in) tall and would probably have reached 1.82 m (6 ft) or more if he/she had survived to adulthood. Adult *H. ergaster* are believed to have ranged in size from about 1.45 to 1.85 m (4 ft 9 in to 6 ft 1 in) tall.

Because of being adapted to a hot and arid climate, *H. ergaster* might also have been the earliest human species to have nearly hairless and naked skin. If instead *H. ergaster* had an ape-like covering of body hair, sweating (the primary means through which modern humans prevent their brains and bodies from overheating) would not have been as efficient. Though sweating is the generally accepted explanation for hairlessness, other proposed explanations include a reduction of parasite load and sexual selection.

It is doubtful if australopithecines and earlier *Homo* were sufficiently mobile to make hair loss an advantageous trait, whereas *H. ergaster* was clearly adapted for long-distance travel and noted for inhabiting lower altitudes (and open, hot savannah environments) than their ancestors. Australopithecines typically inhabited colder and higher altitudes 1,000–1,600 m (3,300–5,200 ft), where nighttime temperatures would have gotten significantly colder and insulating body hair may have been required.

Alternatively and despite this, the loss of body hair could have occurred significantly earlier than *H. ergaster*. Though skin impressions are unknown in any extinct hominin, it is possible that human ancestors were already losing their body hair around 3 million years ago. Human ancestors acquired pubic lice from gorillas about 3 million years ago, and speciation of human from gorilla pubic lice was potentially only possible because human ancestors had lost most of their body hair by this early date. It is also possible that the loss of body hair occurred at a significantly later date. Genetic analysis suggests that high activity in the melanocortin 1 receptor, which produces dark skin, dates back to about 1.2 million years ago. This could indicate the evolution of hairlessness around this time, as a lack of body hair would have left the skin exposed to harmful UV radiation.

Skull and face

Differences to modern humans would have been readily apparent in the face and skull of *H. ergaster*. Turkana Boy's brain was almost fully grown at the time of his/her death, but its volume (at 880 cc) was only about 130 cc greater than the maximum found in *H. habilis*, about 500 cc below the average of modern humans. The 130 cc increase from *H. habilis* becomes much less significant than what could be presumed when the larger body size of Turkana Boy and *H. ergaster* is considered. With all *H. ergaster* skulls considered, the brain volume of the species mostly varied between 600 and 910 cc, with some small examples only having a volume of 508–580 cc. Since their brain was smaller than that of modern humans, the skull of *H. ergaster* immediately narrowed behind the eye sockets (post-orbital constriction).

The brain case was long and low, and Turkana Boy's forehead was flat and receding, merging at an angle with the brow ridge above his/her eyes. A noticeable difference between Turkana Boy and the australopithecines and *H. habilis* would have been his/her nose, which would have been similar to that of modern humans in projecting forwards and having nostrils oriented downwards. This external nose may have also been an adaptation towards a warmer climate, since the noses of modern humans are usually cooler than their central bodies, condensing moisture that would otherwise have been exhaled and lost during periods of increased activity.The face of Turkana Boy would have been longer from top to bottom than that of modern humans, with the jaws projecting farther outwards (prognathism). Though the jaws and teeth were smaller than those of the average australopithecine and *H.*

habilis, they were still significantly larger than those of modern humans. Since the jaw slanted sharply backwards, it is probable that he/she was chinless.

The overall structure of Turkana Boy's skull and face is also reflected in other *H. ergaster* skulls, which combine large and outwardly projecting faces with brow ridges, receding foreheads, large teeth and projecting nasal bones.

Though Turkana Boy would have been no more than 12 years old when he/she died, his/her stature is more similar to that of a modern 15-year-old and the brain is comparable to that of a modern 1-year-old. By modern standards, *H. ergaster* would thus have been cognitively limited, though the invention of new tools prove that they were more intelligent than their predecessors.

Body mass and sexual dimorphism

H. ergaster possessed a significantly larger body mass in comparison to earlier hominins such as early *Homo*, *Australopithecus* and *Paranthropus*.

Whereas australopithecines typically ranged in weight from 29–48 kg (64–106 lbs), *H. ergaster* typically ranged in weight from 52–63 kg (115–139 lbs).

It is possible that the increased body size was the result of life in an open savannah environment, where increased size gives the ability to exploit broader diets in larger foraging areas, increases mobility and also gives the ability to hunt larger prey. The increased body mass also means that parents would have been able to carry their children to an older age and larger mass. Though reduced sexual dimorphism has often been cited historically as one of the radical differences between *H. ergaster* and earlier *Homo* and australopithecines, it is unclear whether australopithecines were significantly more sexually diamorphic than *H. ergaster* or modern humans. Skeletal evidence suggests that sexes in *H. ergaster* differed no more in size than sexes in modern humans do, but a 2003 study by palaeoanthropologists Philip L. Reno, Richard S. Meindl, Melanie A. McCollum and C. Owen Lovejoy suggested that the same was also true for the significantly earlier *Australopithecus afarensis*. Sexual dimorphism is difficult to measure in extinct species since the sex of fossils is usually not determinable. Historically, scientists have typically measured differences between the extreme ends (in terms of size and morphology) of the fossil material attributed to a species and assumed that the resulting ratio applies to the mean difference between male and female individuals.

Growth and development

The dimensions of a 1.8 million years old adult female *H. ergaster* pelvis from Gona, Ethiopia suggests that *H. ergaster* would have been capable of birthing children with a maximum prenatal (pre-birth) brain size of 315 cc, about 30–50 % of adult brain size. This value falls intermediately between that of chimpanzees (~40 %) and modern humans (28%). Further conclusions about the growth and development in early *Homo* can be drawn from the Mojokerto child, a ~1.4–1.5 million year old ~1-year old Asian *H. erectus*, which had a brain at about 72–84% the size of an adult *H. erectus* brain, which suggests a brain growth trajectory more similar to that of other great apes than of modern humans. Both the Gona pelvis and the

Mojokerto child suggest that the prenatal growth of *H. ergaster* was similar to that of modern humans but that the postnatal (post-birth) growth and development was intermediate between that of chimpanzees and modern humans. The faster development rate suggests that altriciality (an extended childhood and a long period of dependency on your parents) evolved at a later stage in human evolution, possibly in the last common ancestor of Neanderthals and modern humans. The faster development rate might also indicate that the expected lifespan of *H. ergaster* and *H. erectus* was lower than that of later and modern humans.

Culture

Diet and energetics

It is frequently assumed that the larger body and brain size of *H. ergaster*, compared to its ancestors, would have brought with it increased dietary and energy needs. In 2002, palaeoanthropologists Leslie C. Aiello and Jonathan C. K. Wells stated that the average resting metabolic requirements of *H. ergaster* would have been 39% higher than those of *Australopithecus afarensis*, 30% higher in males and 54% higher in females. However, the torso proportions of *H. ergaster* implies a relatively small gut, which means that energy needs might not necessarily have been higher in *H. ergaster* than in earlier hominins. This is because the earlier ape (and australopithecine) gut was large and energy-expensive since it needed to synthesise fat through fermenting plant matter, whereas *H. ergaster* likely ate significantly more animal fat than their predecessors. This would have allowed more energy to be diverted to brain growth, increasing brain size while maintaining the energy requirements of earlier species.

If they had increased energy requirements, *H. ergaster* would have needed to eat either vastly more food than australopithecines, or would have needed to eat food of superior quality. If they ate the same type of foods as the australopithecines, feeding time would then have had to be dramatically increased in proportion to the extra calories required, reducing the time *H. ergaster* could use for resting, socialising and travelling. Though this would have been possible, it is considered unlikely, especially since the jaws and teeth of *H. ergaster* are reduced in size compared to those of the australopithecines, suggesting a shift in diet away from fibrous and difficult-to-chew foods. Regardless of energy needs, the small gut of *H. ergaster* also suggests a more easily digested diet composed of food of higher quality.

It is likely that *H. ergaster* consumed meat in higher proportions than the earlier australopithecines. Meat was probably acquired through a combination of ambushes, active hunting and confrontational scavenging. *H. ergaster* must not only have possessed the ability of endurance running, but must also have been able to defend themselves and the carcasses of their prey from the variety of contemporary African predators. It is possible that a drop in African carnivoran species variety around 1.5 million years ago can be ascribed to competition with opportunistic and carnivorous hominins.

On its own, meat might not have been able to fully sustain *H. ergaster*. Modern humans can not sufficiently metabolise protein to meet more than 50% of their energy needs and modern humans who heavily rely on animal-based products in their diet mostly rely on fat to sustain the rest of their energy requirements. Multiple reasons make a fully meat-based diet in *H. ergaster* unlikely, the most prominent being that African ungulates (the primary prey available) are relatively low in fat and that high meat diets demand increased intake of water, which would have been difficult in an open and hot environment. Modern African hunter-gatherers who rely heavily on meat, such as the Hadza and San peoples, also use cultural means to recover the maximum amount of fat from the carcasses of their prey, a method that would not have been available to *H. ergaster*.

H. ergaster would thus likely have consumed large quantities of meat, vastly more than their ancestors, but would also have had to make use of a variety of other food sources, such as seeds, honey, nuts, invertebrates, nutritious tubers, bulbs and other underground plant storage organs. The relatively small chewing capacity of *H. ergaster*, in comparison to its larger-jawed ancestors, means that the meat and high quality plant food consumed would likely have required the use of tools to process before eating.

Social structure and dynamics

H. ergaster lived on the African savannah, which during the Pleistocene was home to a considerably more formidable community of carnivorans than the present savannah. Hominins could probably only have adapted to life on the savannah if effective anti-predator defense behaviours had already evolved. Defense against predators would likely have come through *H. ergaster* living in large groups, possessing stone (and presumably wooden) tools and effective counter-attack behaviour having been established. In modern primates that spend significant amounts of time on the savannah, such as chimpanzees and savannah baboons, individuals form large, multi-male, groups wherein multiple males can effectively work together to fend off and counter-attack predators, occasionally with the use of stones or sticks, and protect the rest of the group. It is possible that similar behaviour was exhibited in early *Homo*. Based on the male-bonded systems within bonobos and chimpanzees, and the tendency towards male bonding in modern foragers, groups of early *Homo* might have been male-bonded as well. Because of the scarcity of fossil material, group size in early *Homo* cannot be determined with any certainty. Groups were probably large, it is possible groups were above the upper range of known group sizes among chimpanzees and baboons (c. 100 individuals or more). In 1993, palaeoanthropologists Leslie C. Aiello and R. I. M. Dunbar estimated that the group size of *H. habilis* and *H. rudolfensis*, based on neocortex size (as there is a known relationship between neocortex size and group size in modern non-human primates), would have ranged from about 70–85 individuals. With the additional factor of bipedalism, which is energetically cheaper than quadrupedalism, the maximum ecologically tolerable group size may have been even larger. Aiello's and Dunbar's group size estimate in regards to *H. ergaster* was 91–116 individuals.

Social and counter-attack behaviour of earlier *Homo* probably carried over into *H. ergaster*, where they are likely to have developed even further. *H. ergaster* was probably the first primate to move into the niche of social carnivore (i. e. hunter-gatherer). Such behaviour would probably have been the result of counter-attacks in the context of competition over nutritious food with other carnivores and would probably have evolved from something akin to the opportunistic hunting sometimes exhibited by chimpanzees. The switch to predation in groups might have triggered a cascade of evolutionary changes which changed the course of human evolution. Cooperative behaviours such as opportunistic hunting in groups, predator defense and confrontational scavenging would have been critical for survival which means that a fundamental transition in psychology gradually transpired. With the typical "competitive cooperation" behaviour exhibited by most primates no longer being favored through natural selection and social tendencies taking its place, hunting, and other activities, would have become true collaborative efforts. Because counter-attack behaviour is typically exhibited in males of modern primates, social hunting in archaic humans is believed to have been a primarily male activity. Females likely conducted other types of foraging, gathering food which did not require hunting (i.e. fruits, nuts, eggs etc.).

With hunting being a social activity, individuals probably shared the meat with one another, which would have strengthened the bonds both between the hunters themselves and between the hunters and the rest of the *H. ergaster* group. Females likely shared what they had foraged with the rest of the group as well. This development could have led to the development of male-female friendships into opportunistic monogamous pair bonds. Since sexual selection from females probably favored males that could hunt, the emerging social behaviour resulting from these new behaviours would have been carried over and amplified through the generations.

The only direct evidence of *H. ergaster* group composition comes from a series of sites outside of Ileret in Kenya, where 97 footprints made around 1.5 million years ago by a group of at least 20 individuals have been preserved. Based on the size of the footprints, one of the trackways appears to have been a group entirely composed of males, possibly a specialised task group, such as a border patrol or a hunting or foraging party. If this assessment is correct, this would further suggest a male-female division of responsibilities. In modern hunter-gatherer societies who target large prey items, male parties are typically dispatched to bring down these high-risk animals, and, due to the low success rate, female parties tend to focus on more predictable foods.

Technology

Tool production

- Early *H. ergaster* inherited the Oldowan culture of tools from australopithecines and earlier *Homo*, though quickly learnt to strike much larger stone flakes than their predecessors and contemporaries. By 1.65 million years ago, *H. ergaster* had created the extensively flaked artefacts and early hand axes that mark the Acheulean culture, and by 1.6–1.4 million years ago, the new tool industry was widely established in East Africa. Acheulean tools differ from Oldowan tools in that the core forms of the tools were clearly deliberate. Whereas the shape of the core forms in Oldowan tools, which were probably used mostly as hammers to crack bones for marrow, appears to not have mattered much, the

> hand axes of the Acheulean culture demonstrate an intent to produce narrow and sharp objects, typically in teardrop, oval or triangular shapes. Once in place, the Acheulean industry remained unchanged throughout *H. ergaster*'s existence and later times, with tools produced near its end about 250,000 years ago not being significantly different from tools produced 1.65 million years ago.

The oldest Acheulean assemblages also preserve core forms similar to those in Oldowan tools, but there are no known true intermediate forms between the two, suggesting that the appearance of Acheulean tools was an abrupt and sudden development. The most significant development that led to the Acheulean tools was likely early hominins learning the ability to strike large flakes, up to 30 cm (1 ft) or more in length, from larger boulders, from which they could manufacture new tools such as hand axes. Though "hand axe" implies that all hand axes were used for chopping and were hand-held, they came in a variety of different shapes and size and probably served several different functions. Carefully shaped and symmetric examples may have been hurled at prey akin to modern discuses, more casually made examples may simply have served as portable sources for sharp flakes and some could have been used for scraping or chopping wood. Additionally, hand axes are effective butchering tools and were possibly also used for dismembering carcasses of large animals.

There are preserved hand axes that are too unwieldy and large to be used for any apparent practical purpose. The use of these larger hand axes, and for some discovered collections of hundreds of hand axes without obvious signs of use, is speculative and conjectural. An idea that has been popular in the popular press, and frequently cited in academia, is that large and impressive hand axes might have been emblems used for attracting mates, with makers of large axes showing strength, coordination and determination, qualities that may have been regarded as attractive. Palaeoanthropologists April Nowell and Melanie Lee Chang noted in 2009 that though this theory is "both intriguing and emotionally appealing", there is little evidence for it and it is untestable. They considered it more probable that variations in hand axe morphology over the course of hundreds of thousands of years was the result of various different factors rather than a single, overarching factor in sexual selection.

Fire

As *Homo* migrated into open savannah environments, encounters with natural fires must have become more frequent and significant. It is possible that *H. ergaster* was the earliest humans to master the control of fire, which they may have used for cooking purposes. Cooking renders both meat and plant foods more digestible, which might have been important since the guts of *H. ergaster* were reduced in size compared to those of their ancestors. Though *H. ergaster*/*H. erectus* is frequently assumed to have been the earliest *Homo* to control fire, concrete evidence is somewhat lacking in the fossil record, perhaps partly due to the difficulty for actual evidence of fire usage to be preserved. Two of the earliest sites commonly claimed to preserve evidence of fire usage are FxJj20 at Koobi Fora and GnJi 1/6E near Lake Baringo, both in Kenya and both dated as up to 1.5 million years old. The evidence at FxJj20 consists of burned sediments and heat-altered stone tools, whereas GnJi 1/6E preserves large clasts of baked clay, associated with stone tools and faunal remains. Though it is difficult to exclude a natural origin for the fire residue evidenced, the sites remain strong candidates for early fire use.

Several sites, preserving more widely accepted evidence of fire usage, have been dated to 1 million years ago or younger, postdating the emergence and last generally accepted record of *H. ergaster*. These sites include cave sites, such as Wonderwerk and Swartkrans in South Africa, and open sites, such as Kalambo Falls in Zambia. The site Gesher Benot Ya'aqov in Israel, dated to about 700,000 years ago, preserves widely accepted evidence of fire usage through burnt materials and burnt flint microartefacts being preserved at numerous levels. From around 400,000 years ago and onwards, traces of fire become even more numerous in sites across Africa, Europe and Asia.

Language

The spinal cord of Turkana Boy would have been narrower than that of modern humans, which means that the nervous system of *H. ergaster*, and their respiratory muscles, may not have been developed enough to produce or control speech. In 2001, anthropologists Bruce Latimer and James Ohman concluded that Turkana Boy was afflicted by skeletal dysplasia and scoliosis, and thus would not have been representative of the rest of his species in this respect. In 2006, when anthropologist Marc Meyer and colleagues described a *H. erectus* s.l. specimen from Dmanisi, Georgia, dated to 1.78 million years old. The fossil preserves the oldest known

Homo vertebrae and the spine found falls within the range of modern human spines, suggesting that the individual would have been capable of speech. Meyer and colleagues concluded that speech was probably possible within *Homo* very early on and that Turkana Boy probably suffered from some congenital defect, possibly spinal stenosis.

In 2013 and 2014, anthropologist Regula Schiess and colleagues concluded that there was no evidence of any congenital defects in Turkana Boy, and, in contrast to the 2001 and 2006 studies, considered the specimen to be representative of the species.

Chapter 23

Homo Erectus

Homo erectus (meaning "upright man") is an extinct species of archaic human from the Pleistocene, with its earliest occurrence about 2 million years ago, and its specimens are among the first recognisable members of the genus *Homo*. *H. erectus* was the first human ancestor to spread throughout Eurasia, with a continental range extending from the Iberian Peninsula to Java. African populations of *H. erectus* are likely to be the ancestors to several human species, such as *H. heidelbergensis* and *H. antecessor*, with the former generally considered to have been the ancestor to Neanderthals and Denisovans, and sometimes also modern humans. Asian populations of *H. erectus* may be ancestral to *H. floresiensis* and possibly to *H. luzonensis*. As a chronospecies, the time of the disappearance of *H. erectus* is a matter of contention. There are also several proposed subspecies with varying levels of recognition. The last known population of *H. erectus* is *H. e. soloensis* from Java, around 117,000–108,000 years ago.

H. erectus had a humanlike gait and body proportions, and was the first human species to have exhibited a flat face, prominent nose, and possibly sparse body hair coverage. Though brain size certainly exceeds that of ancestor species, capacity varied widely depending on the population. In older populations, brain development seemed to cease early in childhood, suggesting that offspring were largely self-sufficient at birth, thus limiting cognitive development through life. Nonetheless, sites generally show consumption of medium to large animals, such as bovines or elephants, and suggest the development of predatory behaviour and coordinated hunting. *H. erectus* is associated with the Acheulean stone tool industry, and is postulated to have been the earliest human ancestor capable of using fire, hunting and gathering in coordinated groups, caring for injured or sick group members, and possibly seafaring and art (though examples of art are controversial, and are otherwise rudimentary and few and far between).

H. erectus men and women may have been roughly the same size as each other (i.e. exhibited reduced sexual dimorphism) like modern humans, which could indicate monogamy in line with general trends exhibited in primates. Size, nonetheless, ranged widely from 146–185 cm (4 ft 9 in–6 ft 1 in) in height and 40–68 kg (88–150 lb) in weight. It is unclear if *H. erectus* was anatomically capable of speech, though it is postulated they communicated using some proto-language.

Taxonomy

Naming

The first remains, Java Man, were described by Dutch anatomist Eugène Dubois in 1893, who set out to look for the "missing link" between apes and humans in Southeast Asia, because he believed gibbons to be the closest living relatives to humans in accordance with the "Out of Asia" hypothesis. *H. erectus* was the first fossil hominin found as a result of a directed expedition.

Excavated from the bank of the Solo River at Trinil, East Java, he first allocated the material to a genus of fossil chimpanzees as *Anthropopithecus erectus*, then the following year assigned it to a new genus as *Pithecanthropus erectus* (the genus name had been coined by Ernst Haeckel in 1868 for the hypothetical link between humans and fossil Apes). The species name *erectus* was given because the femur suggested that Java Man had been bipedal and walked upright. However, few scientists recognized it as a "missing link", and, consequently, Dubois' discovery had been largely disregarded.

In 1921, two teeth from Zhoukoudian, China discovered by Johan Gunnar Andersson had prompted widely publicized interest. When describing the teeth, Davidson Black named it a new species *Sinanthropus pekinensis* from Ancient Greek Σίνα*sino-* "China" and Latin *pekinensis* "of Peking". Subsequent excavations uncovered about 200 human fossils from more than 40 individuals including five nearly complete skullcaps. Franz Weidenreich provided much of the detailed description of this material in several monographs published in the journal *Palaeontologica Sinica* (Series D).

Nearly all of the original specimens were lost during World War II during an attempt to smuggle them out of China for safekeeping. However, casts were made by Weidenreich, which exist at the American Museum of Natural History in New York City and at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing.

Similarities between Java Man and Peking Man led Ernst Mayr to rename both as *Homo erectus* in 1950. Throughout much of the 20th century, anthropologists debated the role of *H. erectus* in human evolution. Early in the century, due in part to the discoveries at Java and Zhoukoudian, the belief that modern humans first evolved in Asia was widely accepted. A few naturalists—Charles Darwin the most prominent among them—theorized that humans' earliest ancestors were African. Darwin pointed out that chimpanzees and gorillas, humans' closest relatives, evolved and exist only in Africa.

Evolution

It has been proposed that *H. erectus* evolved from *H. habilis* about 2 Mya, though this has been called into question because they coexisted for at least a half a million years. Alternatively, a group of *H. habilis* may have been reproductively isolated, and only this group developed into *H. erectus* (cladogenesis).

Because the earliest remains of *H. erectus* are found in both Africa and East Asia (in China as early as 2.1 Mya, in South Africa 2.04 Mya), it is debated where *H. erectus* evolved. A 2011 study suggested that it was *H. habilis* who reached West Asia from Africa, that early *H. erectus* developed there, and that early *H. erectus* would then have dispersed from West Asia to East Asia (Peking Man), Southeast Asia (Java Man), back to Africa (*Homo ergaster*), and to Europe (Tautavel Man), eventually evolving into modern humans in Africa. Others have suggested that *H. erectus*/*H. ergaster* developed in Africa, where it eventually evolved into modern humans.

H. erectus had reached Sangiran, Java, by 1.6 Mya, and a second and distinct wave of *H. erectus* had colonized Zhoukoudian, China, about 780 kya. Early teeth from Sangiran are bigger and more similar to those of basal (ancestral) Western *H. erectus* and *H. habilis* than to those of the derived Zhoukoudian *H. erectus*. However, later Sangiran teeth seem to reduce in size, which could indicate a secondary colonization event of Java by the Zhoukoudian or some closely related population.

Subspecies

- *Homo erectus erectus* (Java Man, 1.6–0.5 Ma)
- *Homo erectus ergaster* (1.9–1.4 Ma)
- *Homo erectus georgicus* (1.8–1.6 Ma)
- *Homo erectus lantianensis* (Lantian Man, 1.6 Ma)
- *Homo erectus nankinensis* (Nanjing Man, 0.6 Ma)
- *Homo erectus pekinensis* (Peking Man, 0.7 Ma)
- *Homo erectus soloensis* (Solo Man, 0.546–0.143 Ma)
- *Homo erectus tautavelensis* (Tautavel Man, 0.45 Ma)
- *Homo erectus yuanmouensis* (Yuanmou Man)

"Wushan Man" was proposed as *Homo erectus wushanensis*, but is now thought to be based upon fossilized fragments of an extinct non-hominin ape.

Since its discovery in 1893 (Java man), there has been a trend in palaeoanthropology of reducing the number of proposed species of *Homo*, to the point where *H. erectus* includes all early (Lower Paleolithic) forms of *Homo* sufficiently derived from *H. habilis* and distinct from early *H. heidelbergensis* (in Africa also known as *H. rhodesiensis*). It is sometimes considered as a wide-ranging, polymorphous species.

Due to such a wide range of variation, it has been suggested that the ancient *H. rudolfensis* and *H. habilis* should be considered early varieties of *H. erectus*. The primitive *H. e. georgicus* from Dmanisi, Georgia has the smallest brain capacity of any known Pleistocene hominin (about 600 cc), and its inclusion in the species would greatly expand the range of variation of *H. erectus* to perhaps include species as *H. rudolfensis*, *H. gautengensis*, *H. ergaster*, and perhaps *H. habilis*. However, a 2015 study suggested that *H. georgicus* represents an earlier, more primitive species of *Homo* derived from an older dispersal of hominins from Africa, with *H. ergaster/erectus* possibly deriving from a later dispersal. *H. georgicus* is sometimes not even regarded as *H. erectus*.

It is debated whether the African *H. e. ergaster* is a separate species (and that *H. erectus* evolved in Asia, then migrated to Africa), or is the African form (*sensu lato*) of *H. erectus (sensu stricto)*. In the latter, *H. ergaster* has also been suggested to represent the immediate ancestor of *H. erectus*. It has also been suggested that *H. ergaster* instead of *H. erectus*, or some hybrid between the two, was the immediate ancestor of other archaic humans and modern humans. It has been proposed that Asian *H. erectus* have several unique characteristics from non-Asian populations (autapomorphies), but there is no clear consensus on what these characteristics are or if they are indeed limited to only Asia. Based on supposed derived characteristics, the 120 ka Javan *H. e. soloensis* has been proposed to have speciated from *H. erectus*, as *H. soloensis*, but this has been challenged because most of the basic cranial features are maintained.

In a wider sense, *H. erectus* had mostly been replaced by *H. heidelbergensis* by about 300 kya years ago, with possible late survival of *H. erectus soloensis* in Java an estimated 117-108kya.

Descendants and synonyms

Homo erectus is the most long-lived species of *Homo*, having survived for almost two million years. By contrast, *Homo sapiens* emerged about a third of a million years ago.

Regarding many archaic humans, there is no definite consensus as to whether they should be classified as subspecies of *H. erectus* or *H. sapiens* or as separate species.

- African *H. erectus* candidates
- *Homo ergaster* ("African *H. erectus*")
- *Homo naledi* (or *H. e. naledi*)
- Eurasian *H. erectus* candidates:
- *Homo antecessor* (or *H. e. antecessor*)
- *Homo heidelbergensis* (or *H. e. heidelbergensis*)
- *Homo cepranensis* (or *H. e. cepranensis*)
- *Homo floresiensis*
- *Homo sapiens* candidates
- *Homo neanderthalensis* (or *H. s. neanderthalensis*)
- *Homo denisova* (or *H. s. denisova* or *Homo* sp. *Altai*, and *Homo sapiens* subsp. *Denisova*)
- *Homo rhodesiensis* (or *H. s. rhodensis*)
- *Homo heidelbergensis* (or *H. s. heidelbergensis*)
- *Homo sapiens idaltu*
- the Narmada fossil, discovered in 1982 in Madhya Pradesh, India, was at first suggested as *H. erectus* (*Homo erectus narmadensis*) but later recognized as *H. sapiens*.

Meganthropus, based on fossils found in Java, dated to between 1.4 and 0.9 Mya, was tentatively grouped with *H.*

erectus in contrast to earlier interpretations of it as a giant species of early human although older literature has placed the fossils outside of *Homo* altogether. However, Zanolli et al. (2019) judged *Meganthropus* to be a distinct genus of extinct ape.

Anatomy

Head

Homo erectus featured a flat face compared to earlier hominins; pronounced brow ridge; and a low, flat skull. The presence of sagittal, frontal, and coronal keels, which are small crests that run along these suture lines, has been proposed to be evidence of significant thickening of the skull, specifically the cranial vault. CT scan analyses reveal this to not be the case. However, the squamous part of occipital bone, particularly the internal occipital crest, at the rear of the skull is notably thicker than that of modern humans, likely a basal (ancestral) trait. The fossil record indicates that *H. erectus* was the first human species to have featured a projecting nose, which is generally thought to have evolved in response to breathing dry air in order to retain moisture. American psychologist Lucia Jacobs hypothesized that the projecting nose instead allowed for distinguishing the direction different smells come from (stereo olfaction) to facilitate navigation and long-distance migration.

The average brain size of Asian *H. erectus* is about 1,000 cc (61 cu in). However, markedly smaller specimens have been found in Dmanisi, Georgia (*H. e. georgicus*); Koobi Fora and

Olorgesailie, Kenya; and possibly Gona, Ethiopia. Overall, *H. erectus* brain size varies from 546–1,251 cc (33.3–76.3 cu in), which is greater than the range of variation seen in modern humans and chimps, though less than that of gorillas.

Dentally, *H. erectus* have the thinnest enamel of any Plio–Pleistocene hominin. Enamel prevents the tooth from breaking from hard foods, but impedes shearing through tough foods. The bodies of the mandibles of *H. erectus*, and all early *Homo*, are thicker than those of modern humans and all living apes. The mandibular body resists torsion from the bite force or chewing, meaning their jaws could produce unusually powerful stresses while eating, but the practical application of this is unclear. Nonetheless, the mandibular bodies of *H. erectus* are somewhat thinner than those of early *Homo*. The premolars and molars also have a higher frequency of pits than *H. habilis*, suggesting *H. erectus* ate more brittle foods (which cause pitting). These all indicate that the *H. erectus* mouth was less capable of processing hard foods and more at shearing through tougher foods, thus reducing the variety of foods it could process, likely as a response to tool use.

Body

Like modern humans, *H. erectus* varied widely in size, ranging from 146–185 cm (4 ft 9 in–6 ft 1 in) in height and 40–68 kg (88–150 lb) in weight, thought to be due to regional differences in climate, mortality rates, and nutrition. Like modern humans and unlike other great apes, there does not seem to have been a great size disparity between *H. erectus* men and women (size-specific sexual dimorphism), though there is not much fossil data regarding this. Brain size in two adults from Koobi Fora measured 848 and 804 cc (51.7 and 49.1 cu in), and another significantly smaller adult measured 691 cc (42.2 cu in), which could possibly indicate sexual dimorphism, though sex was undetermined. If *H. erectus* did not exhibit sexual dimorphism, then it is possible that they were the first in the human line to do so, though the fragmentary fossil record for earlier species makes this unclear. If yes, then there was a substantial and sudden increase in female height.

H. erectus had about the same limb configurations and proportions as modern humans, implying humanlike locomotion. *H. erectus* tracks near Ileret, Kenya, also indicate a human gait. A humanlike shoulder suggests an ability for high speed throwing. It was once thought that Turkana boy had 6 lumbar vertebra instead of the 5 seen in modern humans and 11 instead of 12 thoracic vertebrae, but this has since been revised, and the specimen is now considered to have exhibited a humanlike curvature of the spine (lordosis) and the same number of respective vertebrae.

It is largely unclear when human ancestors lost most of their body hair. Genetic analysis suggests that high activity in the melanocortin 1 receptor, which would produce dark skin, dates back to 1.2 Mya. This could indicate the evolution of hairlessness around this time, as a lack of body hair would have left the skin exposed to harmful UV radiation. It is possible that exposed skin only became maladaptive in the Pleistocene, because the increasing tilt of the Earth (which also caused the ice ages) would have increased solar radiation bombardment- which would suggest that hairlessness first emerged in the australopithecines. However, australopithecines seem to have lived at much higher, much colder elevations—

typically 1,000–1,600 m (3,300–5,200 ft) where the nighttime temperature can drop to 10 or 5 °C (50 or 41 °F)—so they may have required hair to stay warm, unlike early *Homo* which inhabited lower, hotter elevations. Populations in higher latitudes potentially developed lighter skin to prevent vitamin D deficiency. A 500–300 ka *H. erectus* specimen from Turkey was diagnosed with the earliest known case of tuberculous meningitis, which is typically exacerbated in dark-skinned people living in higher latitudes due to vitamin D deficiency. Hairlessness is generally thought to have facilitated sweating, but reduction of parasite load and sexual selection have also been proposed.

Metabolism

The 1.8 Ma Mojokerto child specimen from Java, who died at about 1 year of age, presented 72–84% of the average adult brain size, which is more similar to the faster brain growth trajectory of great apes than modern humans. This indicates that *H. erectus* was probably not cognitively comparable to modern humans, and that secondary altriciality—an extended childhood and long period of dependency due to the great amount of time required for brain maturation—evolved much later in human evolution, perhaps in the modern human/Neanderthal last common ancestor. It was previously believed that, based on the narrow pelvis of Turkana boy, *H. erectus* could only safely deliver a baby with a brain volume of about 230 cc (14 cu in), equating to a similar brain growth rate as modern humans to achieve the average adult brain size of 600–1,067 cc (36.6–65.1 cu in). However, a 1.8 Ma female pelvis from Gona, Ethiopia, shows that *H. erectus* babies with a brain volume of 310 cc (19 cu in) could have been safely delivered, which is 34–36% the mean adult size, compared to 40% in chimps and 28% in modern humans. This more aligns with the conclusions drawn from the Mojokerto child. A faster development rate could indicate a lower expected lifespan.

Based on an average mass of 63 kg (139 lb) for males and 52.3 kg (115 lb) for females, the total energy expenditure (TEE)—the amount of calories consumed in one day—was estimated to be about 2271.8 and 1909.5 kcal, respectively. This is similar to that of earlier *Homo*, despite a marked increase in activity and migratory capacity, likely because the longer legs of *H. erectus* were more energy-efficient in long-distance movement. Nonetheless, the estimate for *H. erectus* females is 84% higher than that for *Australopithecus* females, possibly due to an increased body size and a decreased growth rate. A 2011 study, assuming high energy or dietary fat requirements based on the abundance of large game animals at *H. erectus* sites, calculated a TEE of 2,700–3,400 kcal of which 27–44% derived from fat, and 44–62% of the fat from animal sources. In comparison, modern humans with a similar activity level have a DEE of 2,450 calories, of which 33% derives from fat, and 49% of the fat from animals.

Bone thickness

The cortical bone (the outer layer of the bone) is extraordinarily thickened, particularly in East Asian populations. The skullcaps have oftentimes been confused with fossil turtle carapaces, and the medullary canal in the long bones (where the bone marrow is stored, in the limbs) is extremely narrowed (medullary stenosis). This degree of thickening is usually exhibited in semi-aquatic animals which used their heavy (pachyosteosclerotic) bones as ballasts to help them sink, induced by hypothyroidism. Male specimens have thicker cortical bone than females.

It is largely unclear what function this could have served. All pathological inducers would leave scarring or some other indicator not normally exhibited in *H. erectus*. Before more complete skeletons were discovered, Weidenreich suggested *H. erectus* was a gigantic species, thickened bone required to support the massive weight. It was hypothesised that intense physical activity could have induced bone thickening, but in 1970, human biologist Stanley Marion Garn demonstrated there is a low correlation between the two at least in modern humans.

Garn instead noted different races have different average cortical bone thicknesses, and concluded it is genetic rather than environmental. It is unclear if the condition is caused by increased bone apposition (bone formation) or decreased bone resorption, but Garn noted the stenosis is quite similar to the congenital condition in modern humans induced by hyper-apposition. In 1985, biological anthropologist Gail Kennedy argued for resorption as a result of hyperparathyroidism caused by hypocalcemia (calcium deficiency), a consequence of a dietary shift to low-calcium meat. Kennedy could not explain why the calcium metabolism of *H. erectus* never adjusted. In 1985, American palaeoanthropologist Mary Doria Russell and colleagues argued the supraorbital torus is a response to withstanding major bending stress which localises in that region when significant force is applied through the front teeth, such as while using the mouth as a third hand to carry objects.

In 2004, Noel Boaz and Russel Ciochon suggested it was a result of a cultural practice, wherein *H. erectus* would fight each other with fists, stones, or clubs to settle disputes or battle for mates, since the skull is reinforced in key areas. The mandible is quite robust, capable of absorbing heavy blows (no "glass jaw"); the heavy brow ridge protects the eyes, and transitions into a bar covering the ears, connecting all the way in the back of the skull, meaning blows to any of these regions can be effectively dissipated across the skull; and the sagittal keel protects the top of the braincase. Many skullcaps bear usually debilitating fractures, such as the Peking Man skull X, yet they can show signs of surviving and healing. Anthropologist Peter Brown suggested a similar reason for the unusual thickening of the modern Australian Aboriginal skull, a result of a ritual popular in central and southeast Australian tribes where adversaries would wack each other with waddies (sticks) until knockout.

Culture

Social structure

The only fossil evidence regarding *H. erectus* group composition comes from 4 sites outside of Ileret, Kenya, where 97 footprints made 1.5 Mya were likely left by a group of at least 20 individuals. One of these trackways, based on the size of the footprints, may have been an entirely male group, which could indicate they were some specialised task group, such as a hunting or foraging party, or a border patrol. If correct, this would also indicate sexual division of labour, which distinguishes human societies from those of other great apes and social mammalian carnivores. In modern hunter gatherer societies who target large prey items, typically male parties are dispatched to bring down these high-risk animals, and, due to the low success rate, female parties focus on more predictable foods.

Based on modern day savanna chimp and baboon group composition and behaviour, *H. erectus ergaster* may have lived in large, multi-male groups in order to defend against large savanna predators in the open and exposed environment. However, dispersal patterns indicate that *H. erectus* generally avoided areas with high carnivore density. It is possible that male–male bonding and male–female friendships were important societal aspects.

Because *H. erectus* children had faster brain growth rates, *H. erectus* likely did not exhibit the same degree of maternal investment or child-rearing behaviours as modern humans.

Because *H. erectus* men and women are thought to have been about the same size compared to other great apes (exhibit less size-specific sexual dimorphism), it is generally hypothesised that they lived in a monogamous society, as reduced sexual dimorphism in primates is typically correlated with this mating system.

However, it is unclear if *H. erectus* did in fact exhibit humanlike rates of sexual dimorphism. If they did, then it would mean only female height increased from the ancestor species, which could have been caused by a shift in female fertility or diet, and/or reduced pressure on males for large size. This in turn could imply a shift in female behaviour which made it difficult for males to maintain a harem.

Food

Increasing brain size is often directly associated with a meatier diet and resultant higher caloric intake. However, it is also possible that the energy-expensive guts decreased in size in *H. erectus*, because the large ape gut is used to synthesize fat by fermenting plant matter which was replaced by dietary animal fat, allowing more energy to be diverted to brain growth. This would have increased brain size indirectly while maintaining the same caloric requirements of ancestor species. *H. erectus* may have also been the first to use a hunting and gathering food collecting strategy as a response to the increasing dependence on meat. With an emphasis on teamwork, division of labor, and food sharing, hunting and gathering was a dramatically different subsistence strategy from previous modes.

H. erectus sites frequently are associated with assemblages of medium- to large-sized game, namely elephants, rhinos, hippos, bovine, and boar. *H. erectus* would have had considerable leftovers, potentially pointing to food sharing or long-term food preservation (such as by drying) if most of the kill was indeed utilized. It is possible that *H. erectus* grew to become quite dependent on large-animal meat, and the disappearance of *H. erectus* from the Levant is correlated with the local extinction of the straight-tusked elephant. Nonetheless, *H. erectus* diet likely varied widely depending upon location. For example, at the 780 ka Gesher Benot Ya'aqov site, Israel, the inhabitants gathered and ate 55 different types of fruits, vegetables, seeds, nuts, and tubers, and it appears that they used fire to roast certain plant materials that otherwise would have been inedible; they also consumed amphibians, reptiles, birds, aquatic and terrestrial invertebrates, in addition to the usual large creatures such as elephant and fallow deer. At the 1.95 Ma FwJJ20 lakeside site in the East Turkana Basin, Kenya, the inhabitants ate (alongside the usual bovids, hippos, and rhinos) aquatic creatures such as turtles, crocodiles, and catfish. The large animals were likely scavenged at this site, but the turtles and fish were possibly collected live. At the 1.5 Ma Trinil H. K. site, Java, *H. erectus* likely gathered fish and shellfish.

Dentally, *H. erectus* mouths were not as versatile as those of ancestor species, capable of processing a narrower range of foods. However, tools were likely used to process hard foods, thus affecting the chewing apparatus, and this combination may have instead increased dietary flexibility (though this does not equate to a highly varied diet). Such versatility may have permitted *H. erectus* to inhabit a range of different environments, and migrate beyond Africa.

In 1999, British anthropologist Richard Wrangham proposed the "cooking hypothesis" which states that *H. erectus* speciated from the ancestral *H. habilis* because of fire usage and cooking 2 Million years ago to explain the rapid doubling of brain size between these two species in only a 500,000 year timespan, and the sudden appearance of the typical human body plan. Cooking makes protein more easily digestible, speeds up nutrient absorption, and destroys food-borne pathogens, which would have increased the environment's natural carrying capacity, allowing group size to expand, causing selective pressure for sociality, requiring greater brain function. However, the fossil record does not associate the emergence of *H. erectus* with fire usage nor with any technological breakthrough for that matter, and cooking likely did not become a common practice until after 400 kya.

Java Man's dispersal through Southeast Asia coincides with the extirpation of the giant turtle *Megalochelys*, possibly due to overhunting as the turtle would have been an easy, slow-moving target which could have been stored for quite some time.

Technology

Tool production

H. erectus is credited with inventing the Acheulean stone tool industry, succeeding the Oldowan industry, and were the first to make lithic flakes bigger than 10 cm (3.9 in), and hand axes (which includes bifacial tools with only 2 sides, such as picks, knives, and cleavers). Though larger and heavier, these hand axes had sharper, chiseled edges. They were likely multi-purpose tools, used in variety of activities such as cutting meat, wood, or edible plants. In 1979, American paleontologist Thomas Wynn stated that Acheulean technology required operational intelligence (foresight and planning), being markedly more complex than Oldowan technology which included lithics of unstandardized shape, cross-sections, and symmetry. Based on this, he concluded that there is not a significant disparity in intelligence between *H. erectus* and modern humans and that, for the last 300,000 years, increasing intelligence has not been a major influencer of cultural evolution. However, a 1 year old *H. erectus* specimen shows that this species lacked an extended childhood required for greater brain development, indicating lower cognitive capabilities. A few sites, likely due to occupation over several generations, features hand axes en masse, such as at Melka Kunture, Ethiopia; Olorgesailie, Kenya; Isimila, Tanzania; and Kalambo Falls, Zambia.

The earliest record of Acheulean technology comes from West Turkana, Kenya 1.76 Mya. Oldowan lithics are also known from the site, and the two seemed to coexist for some time. The earliest records of Acheulean technology outside of Africa date to no older than 1 Mya, indicating it only became widespread after some secondary *H. erectus* dispersal from Africa.

On Java, *H. erectus* produced tools from shells at Sangiran and Trinil. Spherical stones, measuring 6–12 cm (2.4–4.7 in) in diameter, are frequently found in African and Chinese Lower Paleolithic sites, and were potentially used as bolas; if correct, this would indicate string and cordage technology.

Fire

H. erectus is credited as the first human ancestor to have used fire, though the timing of this invention is debated mainly because campfires very rarely and very poorly preserve over long periods of time, let alone thousands or millions of years. The earliest claimed fire sites are in Kenya, FxJj20 at Koobi Fora and GnJi 1/6E in the Chemoigut Formation, as far back as 1.5 Mya, and in South Africa, Wonderwerk Cave, 1.7 Mya. The first firekeepers are thought to have simply transported to caves and maintained naturally occurring fires for extended periods of time or only sporadically when the opportunity arose. Maintaining fires would require firekeepers to have knowledge on slow-burning materials such as dung. Fire becomes markedly more abundant in the wider archaeological record after 400,000–300,000 years ago, which can be explained as some advancement in fire management techniques took place at this time or human ancestors only opportunistically used fire until this time. It is possible that firestarting was invented and lost and reinvented multiple times and independently by different communities rather than being invented in one place and spreading throughout the world. The earliest evidence of hearths comes from Gesher Benot Ya'aqov, Israel, over 700,000 years ago, where fire is recorded in multiple layers in an area close to water, both uncharacteristic of natural fires.

Artificial lighting may have led to increased waking hours—modern humans have about a 16-hour waking period, whereas other apes are generally awake from only sunup to sundown—and these additional hours were probably used for socializing. Because of this, fire usage is probably also linked to the origin of language. Artificial lighting may have also made sleeping on the ground instead of the trees possible by keeping terrestrial predators at bay.

Migration into the frigid climate of Ice Age Europe may have only been possible because of fire, but evidence of fire usage in Europe until about 400–300,000 years ago is notably absent. If these early European *H. erectus* did not have fire, it is largely unclear how they stayed warm, avoided predators, and prepared animal fat and meat for consumption; and lightning is less common farther north equating to a reduced availability of naturally occurring fires. It is possible that they only knew how to maintain fires in certain settings in the landscapes and prepared food some distance away from home, meaning evidence of fire and evidence of hominin activity are spaced far apart. Alternatively, *H. erectus* may have only pushed farther north during warmer interglacial periods—thus not requiring fire, food storage, or clothing technology— and their dispersal patterns indicate they generally stayed in warmer lower-to-middle latitudes. It is debated if the *H. e. pekinensis* inhabitants of Zhoukoudian, Northern China, were capable of controlling fires as early as 770 kya to stay warm in what may have been a relatively cold climate.

Construction

In 1962, a 366 cm × 427 cm × 30 cm (12 ft × 14 ft × 1 ft) circle made with volcanic rocks was discovered in Olduvai Gorge. At 61–76 cm (2–2.5 ft) intervals, rocks were piled up to 15–23 cm (6–9 in) high. British palaeoanthropologist Mary Leakey suggested the rock piles were used to support poles stuck into the ground, possibly to support a windbreak or a rough hut. Some modern day nomadic tribes build similar low-lying rock walls to build temporary shelters upon, bending upright branches as poles and using grasses or animal hide as a screen. Dating to 1.75 Mya, it is the oldest claimed evidence of architecture.

In Europe, evidence of constructed dwelling structures dating to or following the Holstein Interglacial (which began 424 kya) has been claimed in Bilzingsleben, Germany; Terra Amata, France; and Fermanville and Saint-Germain-des-Vaux in Normandy. The oldest evidence of a dwelling (and a campfire) in Europe comes from Přezletice, Czech Republic, 700 kya during the Cromerian Interglacial. This dwelling's base measured about 3 m × 4 m (9.8 ft × 13.1 ft) on the exterior and

3 m × 2 m (9.8 ft × 6.6 ft) on the interior, and is considered to have been a firm surface hut, probably with a vaulted roof made of thick branches or thin poles, supported by a foundation of big rocks and earth, and likely functioned as a winter base camp.

The earliest evidence of cave habitation is Wonderwerk Cave, South Africa, about 1.6 Mya, but evidence of cave use globally is sporadic until about 600 kya.

Clothing

It is largely unclear when clothing was invented, with the earliest estimate stretching as far back as 3 Mya to compensate for a lack of insulating body hair. It is known that head lice and body lice (the latter can only inhabit clothed individuals) for modern humans diverged about 170 kya, well before modern humans left Africa, meaning clothes were already well in use before encountering cold climates. One of the first uses of animal hide is thought to have been for clothing, and the oldest hide scrapers date to about 780 kya, though this is not indicative of clothing.

Seafaring

Acheulean artifacts discovered on isolated islands that were never connected to land in the Pleistocene may show seafaring by *H. erectus* as early as 1 Mya in Indonesia. They had arrived on the islands of Flores, Timor, and Roti, which would have necessitated crossing the Lombok Strait (the Wallace Line), at least before 800 kya. It is also possible they were the first European mariners as well and crossed the Strait of Gibraltar between North Africa and Spain. A 2021 genetic analysis of these island populations of *H. erectus* found no evidence of interbreeding with modern humans. Seafaring capability would show *H. erectus* had a great capacity for planning, likely months in advance of the trip.

Similarly, *Homo luzonensis* is dated between 771,000 to 631,000 years ago. Because Luzon has always been an island in the Quaternary, the ancestors of *H. luzonensis* would have had to have made a substantial sea crossing and crossed the Huxley Line.

Healthcare

The earliest probable example of infirming sick group members is a 1.77 Ma *H. e. georgicus* specimen who had lost all but one tooth due to age or gum disease, the earliest example of severe chewing impairment, yet still survived for several years afterwards. However, it is possible australopithecines were capable of caring for debilitated group members. Unable to chew, this *H. e. georgicus* individual probably ate soft plant or animal foods possibly with assistance from other group members. High-latitude groups are thought to have been predominantly carnivorous, eating soft tissue such as bone marrow or brains, which may have increased survival rates for toothless individuals.

The 1.5 Ma Turkana boy was diagnosed with juvenile spinal disc herniation, and, because this specimen was still growing, this caused some scoliosis (abnormal curving of the spine). These usually cause recurrent lower back pain and sciatica (pain running down the leg), and likely restricted Turkana boy in walking, bending, and other daily activities. The specimen appears to have survived into adolescence, which evidences advanced group care.

The 1,000–700 ka Java man specimen presents a noticeable osteocyte on the femur, likely Paget's disease of bone, and osteopetrosis, thickening of the bone, likely resulting from skeletal fluorosis caused by ingestion of food contaminated by fluorine-filled volcanic ash (as the specimen was found in ash-filled strata). Livestock that grazes on volcanic ash ridden fields typically die of acute intoxication within a few days or weeks.

Art and rituals

An engraved Pseudodon shell DUB1006-fL with geometric markings could possibly be evidence of the earliest art-making, dating back to 546–436 kya. Art-making capabilities could be considered evidence of symbolic thinking, which is associated with modern cognition and behavior. In 1976, American archeologist Alexander Marshack asserted that engraved lines on an ox rib, associated with Acheulean lithics, from Pech de l'Azé, France, are similar to a meander design found in modern human Upper Paleolithic cave art. Three ostrich eggshell beads associated with Achuelian lithics were found in northwestern Africa, the earliest disc beads ever found, and Acheulian disc beads have also been found in France and Israel. The Middle Pleistocene "Venus of Tan-Tan" and "Venus of Berekhat Ram" are postulated to been crafted by *H. erectus* to resemble a human form. They were mostly formed by natural weathering, but slightly modified to emphasize certain grooves to suggest hairline, limbs, and eyes. The former has traces of pigments on the front side, possibly indicating it was colored.

H. erectus was also the earliest human to have intentionally collected red-colored pigments, namely ochre, recorded as early as the Middle Pleistocene. Ochre lumps at Olduvai Gorge, Tanzania—associated with the 1.4 Ma Olduvai Hominid 9—and Ambrona, Spain—which dates to 424–374 kya—were suggested to have been struck by a hammerstone and purposefully shaped and trimmed. At Terra Amata, France—which dates to 425–400 or 355–325 kya—red, yellow, and brown ochres were recovered in association with pole structures; ochre was probably heated to achieve such a wide color range. As it is unclear if *H. erectus* could have used ochre for any practical application, ochre collection might indicate that *H. erectus* was the earliest human to have exhibited a sense of aesthetics and to think beyond simply survival. Later human species are postulated to have used ochre as body paint, but in the case of *H. erectus*, it is contested if body paint was used so early in time. Further, it is unclear if these few examples are not simply isolated incidents of ochre use, as ochre is much more prevalent in Middle and Upper Paleolithic sites attributed to Neanderthals and *H. sapiens*.

In 1935, Jewish German anthropologist Franz Weidenreich speculated that the inhabitants of the Chinese Zhoukoudian Peking Man site were members of some Lower Paleolithic Skull Cult because the skulls all showed fatal blows to the head, breaking in of the foramen magnum at the base of the skull, by-and-large lack of preserved facial aspects, an apparently consistent pattern of breaking on the mandible, and a lack of post-cranial remains (elements that are not the skull). He believed that the inhabitants were headhunters, and smashed open the skulls and ate the brains of their victims. However, scavenging animals and natural forces such as flooding can also inflict the same kind of damage to skulls, and there is not enough evidence to suggest manhunting or cannibalism.

In 1999, British science writers Marek Kohn and Steven Mithen said that many hand axes exhibit no wear and were produced en masse, and concluded that these symmetrical, tear-drop shaped lithics functioned primarily as display tools so males could prove their fitness to females in some courting ritual, and were discarded afterwards. However, an apparent lack of reported wearing is likely due to a lack of use-wear studies, and only a few sites yield an exorbitant sum of hand axes likely due to gradual accumulation over generations instead of mass production.

Language

In 1984, the vertebral column of the 1.6 Ma adolescent Turkana boy indicated that this individual did not have properly developed respiratory muscles in order to produce speech. In 2001, American anthropologists Bruce Latimer and James Ohman concluded that Turkana boy was afflicted by skeletal dysplasia and scoliosis. In 2006, American anthropologist Marc Meyer and colleagues described a 1.8 Ma *H. e. georgicus* specimen as having a spine within the range of variation of modern human spines, contending that Turkana boy had spinal stenosis and was thus not representative of the species. Also, because he considered *H. e. georgicus* ancestral to all non-African *H. erectus*, Meyer concluded that the respiratory muscles of all *H. erectus* (at least non-*ergaster*) would not have impeded vocalisation or speech production. However, in 2013 and 2014, anthropologist Regula Schiess and colleagues concluded that there is no evidence of any congenital defects in Turkana boy, and considered the specimen representative of the species.

Neurologically, all *Homo* have similarly configured brains, and, likewise, the Broca's and Wernicke's areas (in charge of sentence formulation and speech production in modern humans) of *H. erectus* were comparable to those of modern humans.

However, this is not indicative of anything in terms of speech capability as even large chimpanzees can have similarly expanded Broca's area, and it is unclear if these areas served as language centers in archaic humans. A 1 year old *H. erectus* specimen shows that an extended childhood to allow for brain growth, which is a prerequisite in language acquisition, was not exhibited in this species.

The hyoid bone supports the tongue and makes possible modulation of the vocal tract to control pitch and volume. A 400 ka *H. erectus* hyoid bone from Castel di Guido, Italy, is bar-shaped—more similar to that of other *Homo* than to that of non-human apes and *Australopithecus*—but is devoid of muscle impressions, has a shield-shaped body, and is implied to have had reduced greater horns, meaning *H. erectus* lacked a humanlike vocal apparatus and thus anatomical prerequisites for a modern human level of speech. Increasing brain size and cultural complexity in tandem with technological refinement, and the hypothesis that articulate Neanderthals and modern humans may have inherited speech capabilities from the last common ancestor, could possibly indicate that *H. erectus* used some proto-language and built the basic framework which fully fledged languages would eventually be built around. However, this ancestor may have instead been *H. heidelbergensis*, as a hyoid bone of a 530 ka *H. heidelbergensis* specimen from the Spanish Sima de los Huesos Cave is like that of modern humans, and another specimen from the same area shows an auditory capacity sensitive enough to pick up human speech.

Extinction

The last known occurrence of *Homo erectus* is 117,000–108,000 years ago in Ngandong, Java according to a study published in 2019.

In 2020 researchers reported that *Homo erectus* and *Homo heidelbergensis* lost more than half of their climate niche – climate they were adapted to – space, with no corresponding reduction in physical range, just before extinction and that climate change played a substantial role in extinctions of past *Homo* species.

Fossils

The lower cave of the Zhoukoudian cave, China, is one of the most important archaeological sites worldwide. There have been remains of 45 homo erectus individuals found and thousands of tools recovered. Most of these remains were lost during World War 2, with the exception of two postcranial elements that were rediscovered in China in 1951 and four human teeth from 'Dragon Bone Hill'.

New evidence has shown that *Homo erectus* does not have uniquely thick vault bones, as was previously thought. Testing showed that neither Asian or African *Homo erectus* had uniquely large vault bones.

Individual fossils

Some of the major *Homo erectus* fossils:

- Indonesia (island of Java): Trinil 2 (holotype), Sangiran collection, Sambungmachan collection, Ngandong collection
- China ("Peking Man"): Lantian (Gongwangling and Chenjiawo), Yunxian, Zhoukoudian, Nanjing, Hexian
- Kenya: KNM ER 3883, KNM ER 3733
- Vietnam: Northern, Tham Khuyen, Hoa Binh
- Republic of Georgia: Dmanisi collection ("Homo erectus georgicus")
- Ethiopia: Daka calvaria
- Eritrea: Buia cranium (possibly H. ergaster)
- Denizli Province, Turkey: Kocabas fossil
- Drimolen, South Africa: DNH 134

Chapter 24

Homo Antecessor

Homo antecessor (Latin "pioneer") is an archaic human species recorded in the Spanish Sierra de Atapuerca from 1.2 to 0.8 million years ago during the Early Pleistocene. Populations may have been present elsewhere in Western Europe, and were among the first to colonise that region of the world (hence, the name). The first fossils were found in the Gran Dolina cave in 1994, and the species was formally described in 1997 as the last common ancestor of modern humans and Neanderthals, supplanting the popular *H. heidelbergensis* in this function. *H. antecessor* has since been reinterpreted as merely an offshoot, though probably one branching off just before the modern human/Neanderthal split.

Despite being so ancient, the face conspicuously parallels the morphology seen in modern humans rather than other archaic humans — namely in its overall flatness as well as the curving of the cheekbone as it merges into the upper jaw — though these elements are known only from a juvenile specimen. Various stature estimates range from 162.3–186.8 cm (5 ft 4 in–6 ft 2 in). *H. antecessor* may have been broad-chested and rather heavy, much like Neanderthals, though the limbs were proportionally long, a trait more frequent in tropical populations.

The kneecaps are thin and have poorly developed tendon attachments. The feet indicate *H. antecessor* was walking and transmitting body weight differently than modern humans do.

H. antecessor was predominantly manufacturing simple pebbles and flakes out of namely quartz and chert, though they used a variety of materials. This industry may represent a precursor to the Acheulean industry, which later becomes ubiquitous across Western Eurasia and Africa. Groups may have been dispatching hunting parties, which mainly targeted deer in their savanna and mixed-woodland environment. Many of the *H. antecessor*specimens were cannibalised, perhaps as a cultural practice or to survive severe famine. There is no evidence they were using fire, and they consequently only inhabited Iberia during warm periods.

Taxonomy

Research history

- The Sierra de Atapuerca had long been known to be abundant in fossil remains. The Gran Dolina ("great sinkhole") was first explored for fossils by archaeologist Francisco Jordá Cerdá [es] in a short field trip to the region in 1966, who recovered a few animal fossils and stone tools. He lacked the resources and manpower to continue any further. In 1976, Spanish palaeontologist Trinidad Torres investigated the Gran Dolina for bear fossils (he recovered *Ursus* remains), but was advised by the Edelweiss Speleological Team to continue at the nearby Sima de los Huesos ("bone pit"). In addition to a wealth of bear fossils, he also recovered archaic human fossils, which prompted a massive exploration of the Sierra de Atapuerca, at first

> headed by Spanish palaeontologist Emiliano Aguirre but quickly taken over by José María Bermúdez de Castro, Eudald Carbonell, and Juan Luis Arsuaga. They restarted excavation of the Gran Dolina in 1992, and found human remains 2 years later, which in 1997 they formally described as a new species, *Homo antecessor*.

The 25 m (82 ft) of Pleistocene sediments at the Gran Dolina are divided into 11 units, TD1 to TD11 ("trinchera dolina" or "sinkhole trench"). *H. antecessor* was recovered from TD6, which has consequently become the most well-researched layer of the site. The first field season 1994–1996 excavated a small test pit (to see if the unit warrants further investigation) measuring 6 m (65 sq ft). This recovered nearly 100 specimens, the best-preserved being ATD6-15 and ATD6-69 (possibly belonging to the same individual) which most clearly elucidate facial anatomy. In subsequent field seasons from 2003 to 2007, a 13 m (140 sq ft) triangular section was excavated, yielding about 70 more specimens. In 2007, a human molar was recovered from the nearby Sima del Elefante ("elephant pit") in layer TE9 ("trinchera elefante"), belonging to a 20–25 year old individual. This was also classified into *H. antecessor*. In 2008, the Sima del Elefante yielded an additional mandible fragment, stone flakes, and evidence of butchery.

Additionally, the stone tool assemblage at the Gran Dolina is broadly similar to several other contemporary ones across Western Europe, which may represent the work of the same species, though this is unconfirmable because many of these sites have not even produced human fossils at all. In 2014, 50 footprints dating to between 1.2 million and 800,000 years ago were discovered in Happisburgh, England, which could potentially be attributed to an *H. antecessor* group given it is the only species identified during that time in Western Europe.

Age and taphonomy

The 2003 to 2007 excavations revealed a much more intricate stratigraphy than previously thought, and TD6 was divided into 3 sub-units spanning 13 layers and 9 sedimentary facies. Human presence is recorded in sub-units 1 and 2 and in facies A, D1, and F. Randomly orientated scattered bones were deposited in Facies D1 of layer TD6.2.2 (TD6 sub-unit 2, layer 2) and Facies F of layers TD6.2.2 and TD6.2.3, but in Facies D they seem to have been conspicuously clumped into the northwest area. This might indicate they were dragged into the cave via a debris flow. As for Facies F, which contains the most human remains, may have been deposited by a floodplain-related geological process inflowing from the main entrance to the northwest, as well as a stronger debris flow from another entrance to the south. Fluvially deposited fossils (dragged in by water) were recovered from Facies A in layers TD6.2.2, TD6.2.1 and TD6.1.2, indicated by limestone gravel within the size range of the remains. Thus, *H. antecessor* may not have inhabited the cave, but was active nearby. Only 5.6% of the fossils bear any evidence of weathering from open air, roots, and soil, which could mean they were dragged into the cave relatively soon after death.

In 1999, two ungulate teeth from TD6 were dated using uranium–thorium dating to 794 to 668 thousand years ago, further constrained palaeomagnetically to before 780,000 years ago. In 2008, TE9 of the Sima del Elefante was constrained to

1.2–1.1 million years ago using palaeomagnetism and cosmogenic dating. In 2013, TD6 was dated to about 930 to 780 thousand years ago using palaeomagnetism, in addition to uranium–thorium and ESR dating on more teeth. In 2018, ESR dating of the *H. antecessor* specimen ATD6-92 resulted in an age of 949 to 624 thousand years ago, further constrained palaeomagnetically to before 772,000 years ago. Human occupation seems to have occurred in waves corresponding to timespans featuring a warm, humid savanna habitat (though riversides likely supported woodlands). These conditions were only present during transitions from cool glacial to warm interglacial periods, after the climate warmed and before the forests could expand to dominate the landscape.

Until 2013 with the discovery of the 1.4 million year old infant tooth from Barranco León, Orce, Spain, these were the oldest human fossils known from Europe, though human activity on the continent stretches back as early as 1.6 mya in Eastern Europe and Spain indicated by stone tools. The original describers believed the species was the first human to colonise Europe, hence the name *antecessor* (Latin for explorer, pioneer, early settler, etc.)

Classification

The face of *H. antecessor* is conspicuously quite similar to that of modern humans than other archaic groups, so the original describers (Castro and colleagues) classified it as the last common ancestor between modern humans and Neanderthals, supplanting *H. heielbergensis* in this capacity. The facial anatomy came under close scrutiny in subsequent years. In 2001, French palaeoanthropologist Jean-Jacques Hublin postulated (without a formal analysis) the Gran Dolina remains and the contemporaneous Tighennif remains from Algeria (originally "*Atlantanthropus mauritanicus*") represent the same population; this would mean *H. antecessor* is a junior synonym of "*Homo mauritanicus*", i. e., the Gran Dolina and Tighennif humans should be classified into the latter. In 2003, American palaeoanthropologist Chris Stringer echoed this concern. In 2007, Castro and colleagues formally investigated the matter, and found the Tighennif remains are much larger than *H. antecessor* and dentally similar to other African populations. Nonetheless, they still recommended reviving *mauritanicus* to house all Early Pleistocene North African specimens as "*H. ergaster mauritanicus*".

In 2009, American palaeoanthropologist Richard Klein stated he was skeptical that *H. antecessor* was ancestral to *H. heidelbergensis*, interpreting *H. antecessor* as "an offshoot of *H. ergaster* [from Africa] that disappeared after a failed attempt to colonize southern Europe". The legitimacy of *H. antecessor* as a separate species has also been questioned because the fossil record is fragmentary, especially because much of the skull is undefined as of yet. The species was only separated from *H. heidelbergensis* by 50,000 years, and because the type specimen was a child, it was debated whether or not the supposedly characteristic features would disappear with maturity. Such restructuring of the face can also be caused by regional climatic adaptation rather than speciation. In 2013, anthropologist Sarah Freidline and colleagues suggested the modern humanlike face evolved independently several times among *Homo*. In 2017, Castro and colleagues conceded that *H. antecessor* may not be a modern human ancestor, though probably split quite shortly before the modern human/Neanderthal split. In 2020, Danish geneticist Frido Welker and colleagues corroborated this hypothesis by analysing ancient proteins collected from the tooth ATD6-92.

Anatomy

Skull

The facial anatomy of the 10 to 11.5 year old specimen ATD6-69 is strikingly similar to modern humans (as well as East Asian Middle Pleistocene archaic humans) as opposed to West Eurasian or African Middle Pleistocene archaic humans or Neanderthals. Though, African Middle Pleistocene humans (the direct ancestors of modern humans) would later evolve this condition. The most notable traits are a completely flat face and a curved zygomaticoalveolar crest (the bar of bone connecting the cheek to the part of the maxilla which holds the teeth). Assuming these features would not disappear with maturity, *H. antecessor* suggests the modern human face evolved and disappeared multiple times in the past, which is not unlikely as facial anatomy is strongly influenced by diet and thus the environment.

The nasal bones are like that of modern humans. The mandible (lower jaw) is quite gracile unlike most other archaic humans. It exhibits several archaic features, but the shape of the mandibular notch is modern humanlike, and the alveolar part (adjacent to the teeth) is completely vertical. Like many Neanderthals, the medial pterygoid tubercle is large. Unlike most Neanderthals, there is no retromolar space (a large gap between the last molar and the end of the mandible).

The upper incisors are shovel-shaped (the tongue side is distinctly convex), characteristic of other Eurasian human populations. The canines bear the cingulum (towards the base) and the essential ridge (towards the midline) like derived species, but retain the cuspules (small bumps) near the tip and bordering incisor.

The upper premolar crowns are rather derived, being nearly symmetrical and bearing a lingual cusp (on the tongue side), and a cingulum and longitudinal grooves on the cheekward side. The upper molars feature several traits typically seen in Neanderthals.

The mandibular teeth, on the other hand, are quite archaic. The P_3 (the first lower premolar) crowns are strongly asymmetrical and have complex tooth root systems. P_3 is smaller than P_4 like more derived species, but like other early *Homo*, M_1 (the first lower molar) is smaller than M_2 and the cusps of the molar crowns make a Y shape. Like other archaic humans except Neanderthals, the enamel on the molars is thick by relative and absolute measure, but the distribution of enamel is Neanderthal-like, with thicker layers at the periphery than at the cusps.

The parietal bone (comprising the back of the top of the skull) is flattened, each exhibiting a "tent-like" posterior profile (when looking at the individual from the back), much like more archaic African *H. ergaster* and Asian *H. erectus*. Like *H. ergaster*, the temporal styloid process just below the ear is fused to the base of the skull. The brow ridge is prominent. The upper margin of the squamous part of temporal bone (on the side of the skull) is convex, like in more derived species.

Torso

The notably large adult clavicle specimen ATD6-50, assumed male based on absolute size, was estimated to have stood 162.3–186.8 cm (5 ft 4 in–6 ft 2 in), mean of 174.5 cm (5 ft 9 in), based on the correlation among modern Indian people between clavicle length and stature. An adult radius, ATD6-43, which could be male based on absolute size or female based on gracility, was estimated to have been 172.5 cm (5 ft 8 in) tall based on the average of equations among several modern populations relating radial length to stature. Based on metatarsal (toe bone) length, a male is estimated to have stood 173 cm (5 ft 8 in) and a female 168.9 cm (5 ft 6 in). These are all rather similar values. For comparison, Western European Neanderthal estimates average 165.3 cm (5 ft 5 in), and early European modern humans 178.4 cm (5 ft 10 in). The ankle joint is adapted for handling high stress, which may indicate a heavy, robust body plan, much like Neanderthals.

Two atlases (the first neck vertebra) are known, which is exceptional as this bone rarely ever fossilizes for archaic humans. They are indistinguishable from those of modern humans. For the axis (the second neck vertebra), the angle of the spinous process (jutting out from the vertebra) is about 19°, comparable with Neanderthals and modern humans, diverging from *H. ergaster* with a low angle of about 8°. The vertebral foramen (which houses the spinal cord) is on the narrow side compared to modern humans. The spine as a whole otherwise aligns with modern humans.

There is one known (and incomplete) clavicle, ATD6-50, which is thick compared to those of modern humans. This may indicate *H. antecessor* had long and flattish (platycleidic) clavicles like other archaic humans. This would point to a broad chest. The proximal curvature (twisting of the bone on the side nearest the neck) in front-view is on par with that of Neanderthals, but the distal curvature (on the shoulder side) is much more pronounced. The sternum is narrow. The acromion (which extends over the shoulder joint) is small. The shoulder blade is similar to all *Homo* with a general human body plan, indicating *H. antecessor* was not as skilled a climber as non-human apes or pre-*erectus* species, but was capable of efficiently launching projectiles such as stones or spears.

Limbs

The incomplete radius, ATD6-43, (a forearm bone) was estimated to have measured 257 mm (10.1 in). It is oddly long and straight for an archaic human, which could indicate a high brachial index (radial to humeral length ratio), reminiscent of the proportions seen in early modern humans and many people from tropical populations.

This could be explained as retention of the ancestral long-limbed tropical form, as opposed to Neanderthals which evolved shorter limbs. Compared to more recent human species, the cross-section of the radial shaft is rather round and gracile throughout its length. Like archaic humans, the radial neck (near the elbow) is long, giving more leverage to the biceps brachii. Like modern humans and *H. heidelbergensis*, but unlike Neanderthals and more archaic hominins, the radial tuberosities (a bony knob jutting out just below the radial neck) are anteriorly placed (towards the front side).

Like other archaic humans, the femur features a developed trochanteric fossa and posterior crest. These traits are highly variable among modern human populations. The two known kneecaps, ATD6-22 and ATD6-56, are subrectangular in shape as opposed to the more common subtriangular, though are rather narrow like those of modern humans. They are quite small and thin, falling at the lower end for modern human females.

The apex of the kneecap (the area which does not join to another bone) is not well developed, leaving little attachment for the patellar tendon. The medial (towards the midline) and lateral (towards the sides) facets for the knee joint are roughly the same size in ATD6-56 and the medial is larger in ATD6-22, whereas the lateral is commonly larger in modern humans. The lateral facet encroaches onto a straight flat area as opposed to being limited to a defined vastus notch, an infrequent condition among any human species.

The phalanges and metatarsals of the foot are comparable to those of later humans, but the big toe bone is rather robust, which could be related to how *H. antecessor* was pushing off the ground. The ankle bone is exceptionally long and high as well as the facet where it connects with the leg (the trochlea), which may be related to how *H. antecessor* transmitted body weight. The long trochlea caused a short neck of the talus. This somewhat converges with the condition exhibited in Neanderthals, which is generally explained as a response to a heavy and robust body, to alleviate the consequently higher stress to the articular cartilage in the ankle joint. This would also have permitted greater flexion.

Growth rate

In 2010, Castro and colleagues approximated ATD6-112, represented by a permanent upper and lower first molar, died between 5.3 and 6.6 years of age based on the tooth formation rates in chimps (lower estimate) and modern humans (upper). The molars are hardly worn at all, which means the individual died soon after the tooth erupted, and that the age of first molar eruption occurred at roughly this age. The age is within the range of variation of modern humans, and this developmental landmark can debatably be correlated with life history. If the relation is true, *H. antecessor* had a prolonged childhood, a characteristic of modern humans in which significant cognitive development takes place.

Behaviour

Technology

The Sierra de Atapuerca features an abundance and diversity of mineral outcroppings suitable for stone tool manufacturing, namely chert, quartzite, quartz, sandstone, and limestone, which could all be collected within only 3 km (1.9 mi) of the Gran Dolina. In the lower part of TD6.3 (TD6 subunit 3), 84 lithics were recovered, predominantly small quartz pebbles with percussive damage. This pattern suggests the inhabitants were normally using unmodified pebbles to crush or pound items, such as bones, as opposed to manufacturing more specialised implements. Nonetheless, 41% of the section's assemblage consists of flakes, which are rather crude and large — averaging 38 mm × 30 mm × 11 mm (1.50 in × 1.18 in

× 0.43 in) — either resulting from rudimentary knapping (stoneworking) skills or difficulty working such poor quality materials. They made use of the unipolar longitudinal method, flaking off only one side, probably to compensate for the lack of pre-planning, opting to knap irregularly shaped and thus poorer-quality pebbles.

Most of the stone tools resided in the lower (older) half of TD6.2, with 831 lithics. The knappers made use of a much more diverse array of materials, most commonly chert, which indicates they were moving farther out in search of better raw materials. They produced far fewer pebbles and spent more time knapping off flakes, but they were not particularly economic with their materials, and about half of the cores could have produced more flakes. They additionally modified irregularly shaped blanks before working them. Consequently, they were able to use other techniques, namely the centripetal method (flaking off only the edges of the core), and the bipolar method (laying the core on an anvil and slamming it with a hammerstone). There are 62 flakes measuring below 20 mm (0.79 in) in height, and 28 above 60 mm (2.4 in). There are 3 conspicuously higher quality flakes, thinner and longer than the others, which may have been produced by the same person. There are also retouched tools: notches, spines, denticulates, points, scrapers, and a single chopper. These small retouched tools are rare in the European Early Pleistocene.

TD6 yielded 124 lithics, but they are badly preserved as the area was also used by hyenas as a latrine. The layer lacks pebbles and cores, and 44 of the lithics are indeterminate. Flakes are much smaller with an average of 28 mm × 27 mm × 11 mm (1.10 in × 1.06 in × 0.43 in), with 10 measuring below

20 mm (0.79 in), and only 3 exceeding 60 mm (2.4 in). They seem to have been using the same methods as the people who manufactured the TD6.2 tools. They were only retouching larger flakes, the 14 such tools averaging 35 mm × 26 mm × 14 mm (1.38 in × 1.02 in × 0.55 in): 1 marginally retouched flake, 1 notch, 3 spines, 7 denticulate sidescrapers, and 1 denticulate point.

Similar lithic assemblages are found elsewhere in Early Pleistocene Spain — notably in Barranc de la Boella and the nearby Galería — distinguished by the preparation and sharpening of cores before flaking, the presence of (crude) bifaces, and some degree of standardisation of tool types. Consequently, they are postulated to represent the ancestor of the Acheulean industry, wherein these and several other techniques would evolve further predominantly in sites across Western Eurasia and Africa. Occupation of the Gran Dolina occurred over a rather short interval; resultantly, no sizable cultural evolution is visible in the archaeological record.

Food

A total of 16 species were recorded from the Gran Dolina, including the bush-antlered deer, an extinct species of fallow deer, an extinct red deer, an extinct bison, the rhino *Stephanorhinus etruscus*, the Stenon zebra, a monkey, the fox *Vulpes praeglacialis*, the Gran Dolina bear, a wild boar, a mammoth, the Mosbach wolf, the spotted hyena, and a lynx. Some specimens of the former 9 species exhibit cut marks consistent with butchery, with about 13% of all Gran Dolina remains bearing some evidence of human modification. Deer are the most commonly butchered animal, with 106 specimens.

They seem to have carried carcasses back whole when feasible, and only the limbs and skulls of larger quarries. This indicates the Gran Dolina *H. antecessor* were dispatching hunting parties who killed and hauled back prey to share with the entire group rather than eating their share beforehand, which evinces social cooperation and division of labour. Less than 5% of all the remains retain animal carnivore damage, in two instances toothmarks overlapping cutmarks, which could indicate animals were sometimes scavenging *H. antecessor* leftovers.

The Sima del Elefante site records: macaques, pigs, bison, fallow deer, the bush-antlered deer, rhinos, the Stenon zebra, the European jaguar, the Issoir lynx, the Mosbach wolf, the Gran Dolina bear, the fox *Vulpes alopecoides*, and a beaver (in addition to several rats, shrews, and rabbits). The large mammals are most commonly represented by long bones, a few of which are cracked open, presumably to access the bone marrow. Some others bear evidence of percussion and defleshing.

The cool and humid montane environment encouraged the growth of olive, mastic, beech, hazelnut, and chestnut trees, which *H. antecessor* may have used as food sources. Trees probably grew along rivers and streams, while the rest of the hills and ridges were dominated by grasses.

Fire

Only a few charcoal particles have been collected from TD6, which probably originated from a fire well outside the cave. There is no evidence of any fire use or burnt bones (cooking) in the long occupation sequences of the Gran Dolina. In other parts of the world, such evidence does not surface in the archaeological record until roughly 400,000 years ago.

These early Europeans probably physiologically withstood the cold, such as by eating a high-protein diet or supporting a heightened metabolism. Despite glacial cycles, the climate was probably similar to that of today's, with the coldest average temperature reaching 2 °C (36 °F) sometime in December and January, and the hottest in July and August 18 °C (64 °F). Freezing temperatures could have been hit from November to March, but the presence of olive and oak suggests subfreezing was an infrequent occurrence. Nonetheless, TD6 occupation sequences seem to have been a few degrees warmer than present-day, and *H. antecessor* probably migrated into Iberia when colder glacial periods were transitioning to warmer interglacials, vacating the region (probably via the Ebro river) at any other time. TE9 similarly indicates a generally warm climate, corresponding to the Waalian interglacial.

Cannibalism

Eighty adult and child *H. antecessor* specimens from the Gran Dolina exhibit cut marks, crushing, burning, and other trauma indicative of cannibalism, and are the second-most common remains bearing evidence of butchering. Human bodies were efficiently utilised, and may be the reason why most bones are smashed or otherwise badly damaged. There are no complete skulls; elements from the face and back of the skull are usually percussed, and the muscle attachments on the face and the base of the skull were cut off. The intense modification of the face was probably to access the brain. The crown of the head was probably struck, resulting in the impact scars on the teeth at the gum line. Several skull fragments exhibit peeling.

The ribs also bear cut marks along the muscle attachments consistent with defleshing, and ATD6-39 has cuts along the length of the rib, which may be related to disembowelment. The nape muscles were sliced off, and the head and neck were probably detached from the body. The vertebrae were often cut, peeled, and percussed. The muscles on all of the clavicles were sawed off to disconnect the shoulder. One radius, ATD6-43, was cut up and peeled. The femur was shattered, probably to extract the bone marrow. The hands and feet variably exhibit percussion, cutting, or peeling, likely a result of dismemberment.

In sum, mainly the meatier areas were prepared, and the rest discarded. This suggests they were butchering humans for nutritional purposes (presumably under dire circumstances), but the face generally exhibits significantly more cutmarks than the faces of animals. Because of this, in 1986, Italian archaeologist Paola Villa and colleagues hypothesised they were instead practising ritual cannibalism. Similarly, in 1992, American anthropologists Christy and Jacqueline Turner postulated the butcherers were mutilating their vanquished enemies from a neighbouring tribe. In 1999, Spanish palaeontologist Yolanda Fernandez-Jalvo and colleagues instead ascribed the relative abundance of facial cut marks to the strongly contrasting structure of the muscle attachments between humans and typical animal prey items.

Nonetheless, *H. antecessor* is conspicuously abundant among the butchered, and the assemblage only comprises young adults and juveniles. In 2010, Carbonell hypothesised that they were hunting down youths from neighboring tribes to reduce competition. In 2019, Spanish palaeoanthropologist Jesús Rodríguez and colleagues argued the demographics can more parsimoniously be explained as the consumption of fellow tribesmen which had already died from natural causes, simply as to not let valuable food go to waste, especially considering the high infant and youth mortality rates in modern hunter-gatherer groups.

Chapter 25

Homo Heidelbergensis

Homo heidelbergensis (also *H. sapiens heidelbergensis*) is an extinct species or subspecies of archaic human which existed during the Middle Pleistocene. It was subsumed as a subspecies of *H. erectus* in 1950 as *H. e. heidelbergensis*, but towards the end of the century, it was more widely classified as its own species. It is debated whether or not to constrain *H. heidelbergensis* to only Europe or to also include African and Asian specimens, and this is further confounded by the type specimen (Mauer 1) being a jawbone, because jawbones feature few diagnostic traits and are generally missing among Middle Pleistocene specimens. Thus, it is debated if some of these specimens could be split off into their own species or a subspecies of *H. erectus*. Because the classification is so disputed, the Middle Pleistocene is often called the "muddle in the middle".

H. heidelbergensis is regarded as a chronospecies, evolving from an African form of *H. erectus* (sometimes called *H. ergaster*). By convention, *H. heidelbergensis* is placed as the most recent common ancestor between modern humans (*H. sapiens* or *H. s. sapiens*) and Neanderthals (*H. neanderthalensis* or *H. s. neanderthalensis*). Many specimens assigned to *H. heidelbergensis* likely existed well after the modern human/Neanderthal split. In the Middle Pleistocene, brain size averaged about 1,200 cc, comparable to modern humans. Height in the Middle Pleistocene can only be estimated off remains from 3 localities: Sima de los Huesos, Spain, 169.5 cm (5 ft 7 in) for males and 157.7 cm (5 ft 2 in) for females; 165 cm (5 ft 5 in) for a female from Jinniushan, China; and 181.2 cm (5 ft 11 in) for a specimen from Kabwe, Zambia. Like Neanderthals, they had wide chests and were robust overall.

The Middle Pleistocene of Africa and Europe features the advent of Late Acheulian technology, diverging from earlier and contemporary *H. erectus*, and probably related to increasing intelligence. Fire likely became an integral part of daily life after 400,000 years ago, and this roughly coincides with more permanent and widespread occupation of Europe (above 45°N), and the appearance of hafting technology to create spears. *H. heidelbergensis* may have been able to carry out coordinated hunting strategies, and similarly they seem to have had a higher dependence on meat.

Taxonomy

Research history

- The first fossil, Mauer 1 (a jawbone), was discovered by a worker in Mauer, southeast of Heidelberg, Germany, in 1907. It was formally described the next year by German anthropologist Otto Schoetensack, who made it the type specimen of a new species, *Homo heidelbergensis*. He split this off as a new species primarily because of the mandible's archaicness—in particular its enormous size—and it was the then-oldest human jaw in the European fossil record at 640,000 years old. The mandible is well preserved, missing only the left premolars, part of the 1st left molar, the tip of the left coronoid process (at the jaw hinge), and fragments of the mid-section as the jaw was found in 2 pieces and had to be glued together. It may have belonged to a young adult based on slight wearing on the 3rd molar. In 1921, the skull Kabwe 1 was discovered by Swiss miner Tom Zwiglaar in Kabwe, Zambia (at the time Broken Hill, Northern Rhodesia), and was assigned to a new species, "*H. rhodesiensis*", by English palaeontologist Arthur Smith Woodward. These were two of the many putative species of Middle Pleistocene *Homo* which were described throughout the first half of the 20th century. In the 1950s, Ernst Mayr had entered the field of anthropology, and, surveying a "bewildering diversity of names," decided to define only 3 species of *Homo*: "*H. transvaalensis*" (the australopithecines), *H. erectus* (including the Mauer mandible, and various putative African and Asian taxa), and *Homo sapiens* (including anything younger than *H. erectus*, such as modern humans and Neanderthals). Mayr defined them as a sequential lineage, with each species evolving into the next (chronospecies). Though later Mayr changed his opinion on the australopithecines (recognising *Australopithecus*), his more conservative view of archaic human diversity became widely adopted in the subsequent decades.

Though *H. erectus* is still maintained as a highly variable, widespread, and long-lasting species, it is still much debated whether or not sinking all Middle Pleistocene remains into it is justifiable. Mayr's lumping of *H. heidelbergensis* was first opposed by American anthropologist Francis Clark Howell in 1960. In 1974, British physical anthropologist Chris Stringer pointed out similarities between the Kabwe 1 and the Greek Petralona skulls to the skulls of modern humans (*H. sapiens* or *H. s. sapiens*) and Neanderthals (*H. neanderthalensis* or *H. s. neanderthalensis*). So, Stringer assigned them to *Homo sapiens sensu lato* ("in the broad sense"), as ancestral to modern humans and Neanderthals. In 1979, Stringer and Finnish anthropologist Björn Kurtén found that the Kabwe and Petralona skulls are associated with the Cromerian industry like the Mauer mandible, and thus postulated these three populations might be allied with each other. Though these fossils are poorly preserved and do not provide many comparable possible diagnostic traits (and likewise it was difficult at the time to properly define a unique species), they argued that at least these Middle Pleistocene specimens should be allocated to *H. (s.?) heidelbergensis* or "*H. (s.?) rhodesiensis*" (depending on, respectively, the inclusion or exclusion of the Mauer mandible) to formally recognise their similarity.

Further work most influentially by Stringer, palaeoanthropologist Ian Tattersall, and human evolutionary biologist Phillip Rightmire reported further differences between Middle Pleistocene Afro-European specimens and *H. erectussensu stricto* ("in the strict sense", in this case specimens from East Asia). Consequently, Afro-European remains from 600 to 300 thousand years ago—most notably from Kabwe, Petralona, Bodo, and Arago—are often classified as *H. heidelbergensis*. In 2010, American physical anthropologist Jeffrey H. Schwartz and Tattersall suggested classifying all Middle Pleistocene European as well as Asian specimens—namely from Dali and Jinniushan in China—as *H.*

heidelbergensis. This model is not as universally accepted. After the 2010 identification of the genetic code of some unique archaic human species in Siberia, termed "Denisovans" pending diagnostic fossil finds, it is postulated that the Asian remains could represent that same species. Thus, Middle Pleistocene Asian specimens, such as Dali Man or the Indian Narmada Man, remain enigmatic. The palaeontology institute at Heidelberg University, where the Mauer mandible has been kept since 1908, changed the label from *H. e. heidelbergensis* to *H. heidelbergensis* in 2015. In 1976 at Sima de los Huesos (SH) in the Sierra de Atapuerca, Spain, Spanish palaeontologists Emiliano Aguirre, José María Basabe, and Trinidad Torres began to excavate archaic human remains. Their investigation of the site was prompted by the finding of several bear remains (*Ursus deningeri*) since the early 20th century by amateur cavers (which consequently destroyed some of the human remains in that section). By 1990, about 600 human remains were reported, and by 2004 the number had increased to roughly 4,000. These represent at least 28 individuals, of which possibly only 1 is a child, and the rest teenagers and young adults. The fossil assemblage is exceptionally complete, with whole corpses buried rapidly, with all bodily elements represented. In 1997, Spanish palaeoanthropologist Juan Luis Arsuaga assigned these to *H. heidelbergensis*, but in 2014, he retracted this, stating that Neanderthal-like features present in the Mauer mandible are missing in the SH humans.

Classification

In palaeoanthropology, the Middle Pleistocene is often termed the "muddle in the middle" because the species-level classification of archaic human remains from this time period has been heavily debated. The ancestors of modern humans (*Homo sapiens* or *H. s. sapiens*) and Neanderthals (*H. neanderthalensis* or *H. s. neanderthalensis*) diverged during this time period, and, by convention, *H. heidelbergensis* is typically considered the last common ancestor (LCA). This would make *H. heidelbergensis* a member of a chronospecies. It is much debated if the name *H. heidelbergensis* can be extended to Middle Pleistocene humans across the Old World, or if it is better to restrict it to just Europe. In the latter case, Middle Pleistocene African remains can be split off into "*H. rhodesiensis*". In the latter view, "*H. rhodesiensis*" can either be seen as the direct ancestor of modern humans, or of "*H. helmei*" which evolved into modern humans.

Regarding the Middle Pleistocene European remains, some are more firmly placed on the Neanderthal line (namely SH, Pontnewyyd, Steinheim, and Swanscombe), whereas others seem to have few uniquely Neanderthal features (Arago, Ceprano, Vértesszőlős, Bilzingsleben, Mala Balanica, and Aroeira). Because of this, it is suggested there were multiple lineages (or species) in this region and time period, but French palaeoanthropologist Jean-Jacques Hublin considers this an unjustified extrapolation as they may have simply been different but still interconnected populations of a single, highly variable species. In 2015, Marie Antoinette de Lumley suggested the less derived material can also be split off into their own species or a subspecies of *H. erectus s. l.* (for example, the Arago material as "*H. e. tautavelensis*"). In 2018, Mirjana Roksandic and colleagues revised the hypodigm of *H. heidelbergensis* to include only the specimens with no Neanderthal-derived traits (namely Mauer, Mala Balanica, Ceprano, HaZore'a, and Nadaouiyeh Aïn Askar). There is no defined distinction between latest potential *H. heidelbergensis* material—specifically Steinheim and SH—and the earliest Neanderthal specimens—Biache, France; Ehringsdorf, Germany; or Saccopastore, Italy.

The use of the Mauer mandible, an isolated jawbone, as the type specimen for the species has been problematic, since the mandible is missing for several Middle Pleistocene specimens, and it does not present many diagnostic features anyways. Anthropologist William Straus said on this topic that, "While the skull is the creation of God, the jaw is the work of the devil." If the Mauer mandible is actually a member of a different species than the Kabwe skull and most other Afro-European Middle Pleistocene archaic humans, then "*H. rhodesiensis*" would take priority as the name of the LCA.

Evolution

- As for its evolution, *H. heidelbergensis* is thought to have descended from African *H. erectus*—sometimes classified as *Homo ergaster*—during the first early expansions of hominins out of Africa beginning roughly 2 million years ago. Those that dispersed across Europe and stayed in Africa evolved into *H. heidelbergensis* or speciated into *H. heidelbergensis* in Europe and "*H. rhodesiensis*" in Africa, and those that dispersed across East Asia evolved into *H. erectus s. s.* The exact derivation from an ancestor species is obfuscated by a long gap in the human fossil record near the end of the Early Pleistocene. In 2016, Antonio Profico and colleagues suggested that

875,000 year old skull materials from the Gombore II site of the Melka Kunture Formation, Ethiopia, represent a transitional morph between *H. ergaster* and *H. heidelbergensis*, and thus postulated that *H. heidelbergensis* originated in Africa instead of Europe.

According to genetic analysis, the LCA of modern humans and Neanderthal split into a modern human line, and a Neanderthal/Denisovan line, and the latter later split into Neanderthal and Denisovans. According to nuclear DNA analysis, the 430,000 year old SH humans are more closely related to Neanderthals than Denisovans (and that the Neanderthal/Denisovan, and thus the modern human/Neanderthal split, had already occurred), suggesting the modern human/Neanderthal LCA had existed long before many European specimens typically assigned to *H. heidelbergensis* did, such as the Arago and Petralona materials.

In 1997, Spanish archaeologist José María Bermúdez de Castro [es], Arsuaga, and colleagues described the roughly million year old *H. antecessor* from Gran Dolina, Sierra de Atapuerca, and suggested supplanting this species in the place of *H. heidelbergensis* for the LCA between modern humans and Neanderthals, with *H. heidelbergensis* descending from it and being a strictly European species ancestral to only Neanderthals. This was refuted in 2020 by Frido Welker and colleagues who analysed ancient proteins collected from an *H. antecessor* tooth, and found that it was a member of a sister lineage to the LCA rather than being the LCA itself (that is, *H. heidelbergensis* did not derive from *H. antecessor*).

Human dispersal beyond 45°N seems to have been quite limited during the Lower Palaeolithic, with evidence of short-lived dispersals northward beginning after a million years ago. Beginning 700,000 years ago, more permanent populations seem to have persisted across the line coinciding with the spread of hand axe technology across Europe, possibly associated with the dispersal of *H. heidelbergensis* and behavioural shifts to cope with the cold climate. Such occupation becomes much more frequent after 500,000 years ago.

Anatomy

Skull

In comparison to Early Pleistocene *H. erectus/ergaster*, Middle Pleistocene humans have a much more humanlike face. The nasal opening is set completely vertically in the skull, and the anterior nasal sill can be crested or sometimes a prominent spine. The incisive canals (on the roof of the mouth) open near the teeth, and are orientated like those of more recent human species. The frontal bone is broad, the parietal bone can be expanded, and the squamous part of temporal bone is high and arched, which could all be related to increasing brain size. The sphenoid bone features a spine extending downwards, and the articular tubercle on the underside of the skull can jut out prominently as the surface behind the jaw hinge is otherwise quite flat. In 2004, Rightmire estimated the brain volumes of 10 Middle Pleistocene humans variously attributable to *H. heidelbergensis* — from Kabwe, Bodo, Ndutu, Dali, Jinniushan, Petralona, Steinheim, Arago, and 2 from SH. This set gives an average volume of about 1,206 cc, ranging from 1,100 to 1,390 cc. He also averaged the brain volumes of 30 *H. erectus/ergaster* specimens, spanning nearly 1.5 million years from across East Asia and Africa, as 973 cc, and thus concluded a significant jump in brain size, though conceded brain size was extremely variable ranging from 727 to 1,231 cc depending on the time period, geographic region, and even between individuals within the same population (the last one probably due to notable sexual dimorphism with males much bigger than females). In comparison, for modern humans, brain size averages 1,270 cc for males and 1,130 cc for females; and for Neanderthals 1,600 cc for males and 1,300 cc for females.

In 2009, palaeontologists Aurélien Mounier, François Marchal, and Silvana Condemi published the first differential diagnosis of *H. heidelbergensis* using the Mauer mandible, as well as material from Tighennif, Algeria; SH, Spain; Arago, France; and Montmaurin, France. They listed the diagnostic traits as: a reduced chin, a notch in the submental space (near the throat), parallel upper and lower boundaries of the mandible in side-view, several mental foramina (small holes for blood vessels) near the cheek teeth, a horizontal retromolar space (a gap behind the molars), a gutter between the molars and the ramus (which juts up to connect with the skull), an overall long jaw, a deep fossa (a depression) for the masseter muscle (which closes the jaw), a small gonial angle (the angle between the body of the mandible and the ramus), an extensive planum alveolare (the distance from the frontmost tooth socket to the back of the jaw), a developed planum triangulare (near the jaw hinge), and a mylohyoid line originating at the level of the 3rd molar.

Build

Trends in body size through the Middle Pleistocene are obscured due to a general lack of limb bones and non-skull (post-cranial) remains. Based on the lengths of various long bones, the SH humans averaged roughly 169.5 cm (5 ft 7 in) for males and 157.7 cm (5 ft 2 in) for females, with maximums of respectively 177 cm (5 ft 10 in) and 160 cm (5 ft 3 in). The height of a female partial skeleton from Jinniushan is estimated to have been quite tall at roughly 165 cm (5 ft 5 in) in life, much taller than the SH females. A tibia from Kabwe is typically estimated to have been 181.2 cm (5 ft 11 in), among the tallest Middle Pleistocene specimens, but it is possible this individual was either unusually large or had a much longer tibia to femur ratio than expected. If these specimens are representative of their respective continents, they would suggest that above-medium to tall people were prevalent throughout the Middle Pleistocene Old World.

If this is the case, then most all populations of any archaic human species would have generally averaged to 165–170 cm (5 ft 5 in–5 ft 7 in) in height. Early modern humans were notably taller, with the Skhul and Qafzeh remains averaging 185.1 cm (6 ft 1 in) for males and 169.8 cm (5 ft 7 in) for females, an average of 177.5 cm (5 ft 10 in), possibly to increase the energy-efficiency of long-distance travel with longer legs. A conspicuously massive proximal (upper half) femur recovered from Berg Aukas Mine, Namibia, about 20 km (12 mi) east of Grootfontein was originally estimated to have been as much as 93 kg (205 lb) in life, but the exorbitant size is now attributed to intense activity level while maturing; the Berg Aukas individual was probably proportionally similar to

Kabwe 1. The human bauplan (body plan) had evolved in *H. ergaster*, and characterises all later *Homo* species, but among the more derived members there are 2 distinct morphs: a narrow-chested and gracile build like modern humans, and a broader-chested and robust build like Neanderthals. It was once assumed that the Neanderthal build was unique to Neanderthals based on the gracile *H. ergaster* partial skeleton KNM WT-15000 ("Turkana Boy"), but the discovery of some Middle Pleistocene skeletal elements (though generally fragmentary and far and few between) seems to suggest Middle Pleistocene humans overall featured a more Neanderthal morph. Thus, the modern human morph may be unique to modern humans, evolving quite recently. This is most clearly demonstrated in the exceptionally well-preserved SH assemblage. Based on skull robustness, it was assumed Middle Pleistocene humans featured a high degree of sexual dimorphism, but the SH humans demonstrate a modern humanlike level.

The SH humans and other Middle Pleistocene *Homo* have a more basal pelvis and femur (more similar to earlier *Homo* than Neanderthals). The overall broad and elliptical pelvis is broader, taller, and thicker (expanded anteroposteriorly) than those of Neanderthals or modern humans, and retains an anteriorly located acetabulocristal buttress (which supports the iliac crests during hip abduction), a well defined supraacetabular groove (between the hip socket and the ilium), and a thin and rectangular superior pubic ramus (as opposed to the thick, stout one in modern humans). The foot of all archaic humans has a taller trochlea of the ankle bone, making the ankle more flexible (specifically dorsiflexion and plantarflexion).

Pathology

On the left side of its face, an SH skull (Skull 5) presents the oldest known case of orbital cellulitis (eye infection which developed from an abscess in the mouth). This probably caused sepsis, killing the individual.

A male SH pelvis (Pelvis 1), based on joint degeneration, may have lived for more than 45 years, making him one of the oldest examples of this demographic in the human fossil record. The frequency of 45+ individuals gradually increases with time, but has overall remained quite low throughout the Palaeolithic. He similarly had the age-related maladies lumbar kyphosis (excessive curving of the lumbar vertebrae of the lower back), L5–S1 spondylolisthesis (misalignment of the last lumbar vertebra with the first sacral vertebra), and Baastrup disease on L4 and 5 (enlargement of the spinous processes). These would have produced lower back pain, significantly limiting movement, and may be evidence of group care.

An adolescent SH skull (Cranium 14) was diagnosed with lambdoid single suture craniosynostosis (immature closing of the left lambdoid suture, leading to skull deformities as development continued). This is a rare condition, occurring in less than 6 out of every 200,000 individuals in modern humans. The individual died near the age of 5, suggesting it was not abandoned due its deformity as has been done in historical times, and received the same quality of care as any other child.

Enamel hypoplasia on the teeth is used to determine bouts of nutritional stress. At a rate of 40% for the SH humans, this is significantly higher than exhibited in the earlier South African hominin *Paranthropus robustus* at Swartkrans (30.6%) or Sterkfontein (12.1%). Nonetheless, Neanderthals suffered even higher rates and more intense bouts of hypoplasia, but it is unclear if this is because Neanderthals were less capable of exploiting natural resources, or because they lived in harsher environments. A peak at 3.5 years of age may be correlated with weaning age. In Neanderthals this peak was at 4 years, and many modern hunter gatherers also wean at about 4 years of age.

Culture

Food

Middle Pleistocene communities in general seem to have eaten big game at a higher frequency than predecessors, with meat becoming an essential dietary component. Diet could overall be varied—for example the inhabitants of Terra Amata seem to have been mainly eating deer, but also elephants, boar, ibex, rhino, and aurochs. African sites typically commonly yield bovine and horse bones. Though carcasses may have simply been scavenged, some Afro-European sites show specific targeting of a single species, which more likely indicates active hunting; for example: Olorgesailie, Kenya, which has yielded over 50 to 60 individual baboons (*Theropithecus oswaldi*); and Torralba and Ambrona in Spain which have an abundance of elephant bones (though also rhino and large hoofed mammals). The increase in meat subsistence could indicate the development of group hunting strategies in the Middle Pleistocene. For instance, at Torralba and Ambrona, the animals may have been run into swamplands before being killed, entailing encircling and driving by a large group of hunters in a coordinated and organised attack. Exploitation of aquatic environments is generally quite lacking, despite some sites being in close proximity to the ocean, lakes, or rivers.

Plants were probably also frequently consumed, including seasonally available ones, but the extent of their exploitation is unclear as they do not fossilise as well as animal bones. Assuming a diet heavy in lean meat, an individual would have needed a high carbohydrate intake to prevent protein poisoning, such as by eating typically abundant underground storage organs, tree bark, berries, or nuts. The Schöningen site, Germany, has over 200 plants in the vicinity which are either edible raw or when cooked.

Art

Upper Palaeolithic modern humans are well known for having etched engravings seemingly with symbolic value. As of 2018, only 27 Middle and Lower Palaeolithic objects have been postulated to have symbolic etching, out of which some have been refuted as having been caused by natural or otherwise non-symbolic phenomena (such as the fossilisation or excavation processes). The Lower Palaeolithic ones are: three 380,000 year old pebbles from Terra Amata; a 250,000 year old pebble from Markkleeberg, Germany; 18 roughly 200,000 year old pebbles from Lazaret (near Terra Amata); a roughly 200,000 year old lithic from Grotte de l'Observatoire, Monaco; a 370,000 year old bone from Bilzingsleben, Germany; and a 200 to 130 thousand year old pebble from Baume Bonne, France.

In the mid-19th century, French archaeologist Jacques Boucher de Crèvecœur de Perthes began excavation at St. Acheul, Amiens, France, (the area where the Acheulian was defined), and, in addition to hand axes, reported perforated sponge fossils (*Porosphaera globularis*) which he considered to have been decorative beads.

This claim was completely ignored. In 1894, English archaeologist Worthington George Smith discovered 200 similar perforated fossils in Bedfordshire, England, and also speculated that their function was beads, though he made no reference to Boucher de Perthes' find possibly because he was unaware of it. In 2005, Robert Bednarik reexamined the material, and concluded that—because all the Bedfordshire *P. globularis* fossils are sub-spherical and range 10–18 mm (0.39–0.71 in) in diameter, despite this species having a highly variable shape—they were deliberately chosen. They appear to have been bored through completely or almost completely by some parasitic creature (i. e., through natural processes), and were then percussed on what would have been the more closed-off end to fully open the hole. He also found wear facets which he speculated were begotten from clacking against other beads when they were strung together and worn as a necklace. In 2009, Solange Rigaud, Francisco d'Errico, and colleagues noticed that the modified areas are lighter in colour than the unmodifed, suggesting they were inflicted much more recently such as during excavation. They were also unconvinced that the fossils could be confidently associated with the Acheulian artefacts from the sites, and suggested that—as an alternative to archaic human activity—apparent size-selection could have been caused by either natural geological processes or 19th century collectors favouring this specific form.

Early modern humans and late Neanderthals (the latter especially after 60,000 years ago) made wide use of red ochre for presumably symbolic purposes as it produces a blood-like colour, though ochre can also have a functional medicinal application. Beyond these two species, ochre usage is recorded at Olduvai Gorge, Tanzania, where two red ochre lumps have been found; Ambrona where an ochre slab was trimmed down into a specific shape; and Terra Amata where 75 ochre pieces were heated to achieve a wide colour range from yellow to red-brown to red. These may exemplify early and isolated instances of colour preference and colour categorisation, and such practices may not have been normalised yet.

In 2006, Eudald Carbonell and Marina Mosquera suggested the SH hominins were buried by people rather than being the victims of some catastrophic event such as a cave-in, because young children and infants are absent which would be unexpected if this were a single and complete family unit. The SH humans are conspicuously associated with only a single stone tool, a carefully-crafted hand axe made of high-quality quartzite (rarely used in the region), and so Carbonell and Mosquera postulated this was purposefully and symbolically placed with the bodies as some kind of grave good. Supposed evidence of symbolic graves would not surface for another 300,000 years.

Technology

Stone tools

The Lower Palaeolithic (Early Stone Age) comprises the Oldowan which was replaced by the Acheulian characterised by the production of mostly symmetrical hand axes. The Acheulian has a timespan of about a million years, and such technological stagnation has typically been ascribed to comparatively limited cognitive abilities which significantly reduced innovative capacity, such as a deficit in cognitive fluidity, working memory, or a social system compatible with apprenticeship. Nonetheless, the Acheulian does seem to subtly change over time, and is typically split up into Early Acheulian and Late Acheulian, the latter becoming especially popular after 600 to 500 thousand years ago. Late Acheulian technology never crossed over east of the Movius Line into East Asia, which is generally believed to be due to either some major deficit in cultural transmission (namely smaller population size in the East) or simply preservation bias as far fewer stone tool assemblages are found east of the line.

The transition is indicated by the production of smaller, thinner, and more symmetrical hand axes (though thicker, less refined ones were still produced). At the 500,000 year old Boxgrove site in England—an exceptionally well-preserved site with abundance of tool remains—thinning may have been produced by striking the hand axe near-perpendicularly with a soft hammer, possible with the invention of prepared platforms for tool making. The Boxgrove knappers also left behind large lithic flakes leftover from making hand axes, possibly with the intention of recycling them into other tools later. Late Acheulian sites elsewhere pre-prepared lithic cores ("Large Flake Blanks," LFB) in a variety of ways before shaping them into tools, making prepared platforms unnecessary. LFB Acheulian spreads out of Africa into West and South Asia before a million years ago and is present in Southern Europe after 600,000 years ago, but northern Europe (and the Levant after 700,000 years ago) made use of soft hammers as they mainly made use of small, thick flint nodules. The first prepared platforms in Africa come from the 450,000 year old Fauresmith industry, transitional between the Early Stone Age (Acheulian) and the Middle Stone Age.

With either method, knappers (tool makers) would have had to have produced some item indirectly related to creating the desired product (hierarchical organisation), which could represent a major cognitive development. Experiments with modern humans have shown that platform preparation cannot be learned through purely observational learning, unlike earlier techniques, and could be indicative of well developed teaching methods as well as self-regulated learning. At Boxgrove, the knappers used not only stone but also bone and antler to make hammers, and the use of such a wide range of raw materials could speak to advanced planning capabilities as stoneworking requires a much different skillset to work and gather materials for than boneworking.

The Kapthurin Formation, Kenya, has yielded the oldest evidence of blade and bladelet technology, dating to 545 to 509 thousand years ago. This technology is rare even in the Middle Palaeolithic, and is typically associated with Upper Palaeolithic modern humans. It is unclear if this is part of a long blade-making tradition, or if blade technology was lost and reinvented several times by multiple different human species.

Fire and construction

Despite apparent pushes into colder climates, evidence of fire is scarce in the archaeological record until 400 to 300 thousand years ago. Though it is possible fire remnants simply degraded, long and overall undisturbed occupation sequences such as at Arago or Gran Dolina conspicuously lack convincing evidence of fire usage. This pattern could possibly indicate the invention of ignition technology or improved fire maintenance techniques at this time, and that fire was not an integral part of people's lives before then in Europe. In Africa, on the other hand, humans may have been able to frequently scavenge fire as early as 1.6 million years ago from natural wildfires, which occur much more often on Africa, thus possibly (more or less) regularly using fire. The oldest established continuous fire site beyond Africa is the 780,000 year old Gesher Benot Ya'aqov, Israel.

In Europe, evidence of constructed dwelling structures—classified as firm surface huts with solid foundations built in areas mostly sheltered from the weather—has been recorded since the Cromerian Interglacial, the earliest example a 700,000 year old stone foundation from Přezletice, Czech Republic. This dwelling probably featured a vaulted roof made of thick branches or thin poles, supported by a foundation of big rocks and earth. Other such dwellings have been postulated to have existed during or following the Holstein Interglacial (which began 424,000 years ago) in Bilzingsleben, Germany; Terra Amata, France; and Fermanville and Saint-Germain-des-Vaux in Normandy. These were probably occupied during the winter, and, averaging only 3.5 m × 3 m (11.5 ft × 9.8 ft) in area, they were probably only used for sleeping in, while other activities (including firekeeping) seem to have been done outside. Less-permanent tent technology may have been present in Europe in the Lower Paleolithic.

Spears

The appearance of repeated fire usage—earliest in Europe from Beeches Pit, England, and Schöningen, Germany—roughly coincides with hafting technology (attaching stone points to spears) best exemplified by the Schöningen spears. These 9 wooden spears and spear fragments—in addition to a lance, and a double-pointed stick—date to 300,000 years ago and were preserved along a lakeside. The spears vary from 2.9–4.7 cm (1.1–1.9 in) in diameter, and may have been 210–240 cm (7–8 ft) long, overall similar to present day competitive javelins. The spears were made of soft spruce wood, except for spear 4 which was (also soft) pine wood.

This contrasts with the Clacton spearhead from Clacton-on-Sea, England, perhaps roughly 100,000 years older, which was made of hard yew wood. The Schöningen spears may have had a range of up to 35 m (115 ft), though would have been more effective short range within about 5 m (16 ft), making them effective distance weapons either against prey or predators. Besides these two localities, the only other site which provides solid evidence of European spear technology is the 120,000 year old Lehringen site, Germany, where a 238 cm (8 ft) yew spear was apparently lodged in an elephant.

In Africa, 500,000 year old points from Kathu Pan 1, South Africa, may have been hafted onto spears. Judging by indirect evidence, a horse scapula from the 500,000 year old Boxgrove shows a puncture wound consistent with a spear wound. Evidence of hafting (in both Europe and Africa) becomes much more common after 300,000 years.

Language

The SH humans had a modern humanlike hyoid bone (which supports the tongue), and middle ear bones capable of finely distinguishing frequencies within the range of normal human speech. Judging by dental striations, they seem to have been predominantly right-handed, and handedness is related to the lateralisation of brain function, typically associated with language processing in modern humans. So, it is postulated that this population was speaking with some early form of language. Nonetheless, these traits do not absolutely prove the existence of language and humanlike speech, and its presence so early in time despite such anatomical arguments has been primarily opposed by cognitive scientist Philip Lieberman.