

Biological and evolutionary origins of humans: African context, climate variability, and planetary boundary conditions

Abstract

Homo sapiens is an African species. The hominin clade diverged from the lineage leading to living chimpanzees and bonobos in the late Miocene, and every major morphological and behavioral transition that produced our genus and species is first documented on the African continent. This review assembles a conservative timeline of that history, explains why Africa was the setting in which those transitions occurred, and places African climate change in its planetary context. Early hominins appear by approximately 7–6 million years ago (Ma). By about 4.2 Ma, *Australopithecus* combined habitual terrestrial bipedalism with a still-small brain. The genus *Homo* is first recognizable near 2.8 Ma. Stone-tool manufacture, however, is now known from 3.3 Ma and therefore cannot be treated as a unique hallmark of *Homo*. *Homo erectus* (including closely related early African forms) evolved near 1.9 Ma, dispersed into Eurasia by about 1.85–1.78 Ma, and is associated with later, still-debated evidence for the use of fire. Anatomically early members of *H. sapiens* are documented in Morocco at approximately 315 thousand years ago (ka), and comparable fossils and Middle Stone Age technologies are distributed across Africa. Present-day African populations retain the greatest autosomal genetic diversity of any continental group, a pattern expected if our species spent most of its history inside Africa before a subset of populations dispersed. African hydroclimate over the past several million years has been paced in large part by Milankovitch orbital cycles. Those cycles are themselves possible only because Earth's axial tilt remains within a narrow range. Numerical experiments show that the Moon supplies the gravitational torque that keeps Earth's obliquity out of a large chaotic zone. The giant-impact origin of the Moon therefore belongs among the deep boundary conditions of later climate history. It does not, by itself, explain the origin of *H. sapiens*. The scientifically defensible claim is narrower: a Moon-stabilized Earth produces relatively regular orbital climate oscillations, those oscillations repeatedly reorganized African habitats, and selection in that variable setting is one leading hypothesis for the evolution of ecological flexibility in the hominin lineage.

Homo-sapiens evolving from *Apes* because of the obvious too hot the summer of the 4 new seasons, due to the planet that collided with early Earth from the Moon is *Theia*. The collision with Earth tilted its spinning axis relative to the *Sun*'s rotation after the impact. Our ancestors climbed down the trees to migrate away from *Africa*, to avoid the hot weather. Consequently, their heads developed larger brains, resulting in bigger heads with increased intelligence. Moreover, they invented fire to cook meals with cutting knives so that their *jaws* became smaller.

Keywords: human evolution, *homo sapiens*, Africa, *Australopithecus*, climate variability, Milankovitch cycles, obliquity, moon, giant impact

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Introduction

The question of human origins is both a biological problem and a historical one. Biology supplies the mechanisms, such as mutation, natural selection, genetic drift, gene flow, and developmental constraints. History supplies the setting: a particular continent, a particular interval of the Earth's history, and a particular configuration of the local climate. The fossil, archaeological, and genomic records converge on a single first-order conclusion. The last common ancestor of humans and the African apes lived in Africa. Every subsequent hominin genus until the late Early Pleistocene is known only from Africa. *Homo sapiens* itself is first documented there, and the deepest branches of living human genetic variation remain African.¹⁻⁴

That conclusion does not require a single cradle the size of a valley, nor a single linear parade of prior ancestral species. The African record is geographically broad, taxonomically diverse, and incomplete. Early *H. sapiens* almost certainly evolved within a

structured metapopulation whose connections waxed and waned with climate.⁵ The purpose of this paper is to expand a short outline of that history into a coherent narrative, to correct several widely circulated simplifications, and to treat one additional claim with care: the idea that the massive collision which formed the Moon ultimately drove human evolution. The Moon's role is real, but it is several causal steps removed from hominin anatomy. Framing it as a direct forge of *Homo sapiens* overstates what planetary science and paleoanthropology can jointly support.

African origin: The last common ancestor of humans and African apes lived in Africa, and *Homo sapiens* first evolved on the continent. **Bipedalism and brain size:** Early hominins developed bipedal walking and upright posture in Africa amid changing environments. However, committed bipedalism and tool-making emerged millions of years before the significant acceleration in brain size (encephalization) seen in the genus *Homo*. **Cooking, fire, and jaw structure:** The later

adoption of fire and cooking softened diets, which reduced the need for heavy chewing apparatus and contributed to smaller teeth and jaws over evolutionary time.

A conservative evolutionary timeline

The dates below are approximate consensus values from radiometric, paleomagnetic, and stratigraphic work. They will continue to shift as new fossils are found and new technologies are developed.

Late Miocene divergence and the first hominins (approximately 8–6 Ma)

Molecular-clock estimates place the split between the human lineage and the lineage of chimpanzees and bonobos in the late Miocene, commonly in the range of about 8–6 Ma, with some genomic analyses allowing a broader window.⁶ Relevant fossils from this era are relatively scarce. *Sahelanthropus tchadensis* from Chad, dated to roughly 7 Ma, combines a reduced canine with an anteriorly placed foramen magnum. Associated limb bones have been interpreted by some research groups as showing early land-based bipedalism and by others as essentially ape-like.^{7,8} *Orrorin tugenensis* from Kenya (approximately 6 Ma) preserves a femur whose neck morphology is widely read as compatible with bipedal loading. *Ardipithecus* from Ethiopia, especially *Ar. ramidus* at 4.4 Ma, documents a woodland hominin with a grasping first toe and a pelvis that suggests upright walking.⁹ The cautious statement is that skeletal hints of upright posture appear early in the hominin record, habitual, committed terrestrial bipedalism is well-documented only later.

Australopithecus and committed bipedalism (approximately 4.2–2.0 Ma)

Australopithecus anamensis appears near 4.2 Ma in eastern Africa. *Au. afarensis*, best known from the 3.2 Ma Hadar skeleton “Lucy” and from the Laetoli footprint trackways of about 3.7 Ma, was a habitual biped with a relatively small brain (typically 400–550 cm³), long arms, and shoulders well-suited to climbing.^{1,10} Southern African *Au. africanus* and later species such as *Au. sediba* show that australopiths were a diverse group, and not a single stepping-stone. Robust forms placed in *Paranthropus* (from about 2.7 Ma) evolved massive chewing apparatus and represent a successful side branch rather than a proper step on the path to *Homo*.¹

A necessary correction to older textbook language concerns stone tools. The Lomekwi 3 assemblage from West Turkana, Kenya, dates to 3.3 Ma, and therefore precedes the first fossils currently assigned to *Homo* by several hundred thousand years.¹¹ The makers are not identified to a specific species, but the date places this percussion technology among late Pliocene hominins, most plausibly australopith-grade taxa. The more standardized Oldowan industry appears around 2.6 Ma. Extensive, repeated flaking of stone tools is thus older than the genus *Homo* as currently diagnosed, even though later *Homo* greatly expanded on the technology.

The genus homo (from approximately 2.8 Ma)

A partial mandible from Ledi-Geraru, Ethiopia (specimen LD 350-1), dated to 2.80–2.75 Ma, combines primitive australopith features with derived dental and mandibular traits used to recognize early *Homo*.¹² Slightly later fossils from the same general region and from Koobi Fora document a morphologically variable early *Homo* group often discussed under the names *H. habilis* and *H. rudolfensis*. Brain size begins a long-term increase after about 2 Ma, but the increase is neither sudden nor monotonic.¹

Homo erectus, fire, and the first extra-African dispersal (from approximately 1.9 Ma)

By about 1.9–1.8 Ma, African fossils commonly assigned to *Homo erectus* or *H. ergaster* show larger bodies, relatively longer hind limbs, and larger brains than early *Homo*. The Dmanisi locality in Georgia documents hominins outside Africa by 1.85–1.78 Ma.¹³ Those fossils are small-brained relative to later *H. erectus* and demonstrate that the first Eurasian colonists need not have been the large-bodied, large-brained form imagined in mid-twentieth-century narratives. Subsequent *H. erectus* populations are recorded in East Asia and Island Southeast Asia and persist for well over a million years.

Control of fire is often listed as a defining *H. erectus* trait at 1.8 Ma. However, that dating is not a consensus fact. The most widely accepted early archaeological fire record is from Wonderwerk Cave, South Africa, near 1.0 Ma, where micromorphology and infrared spectroscopy identify burned bone and plant ashes deep inside the cave structure.¹⁴ More recent analyses of older Wonderwerk strata have been argued to push repeated introduction of fire as far back as the 1.79–1.07 Ma interval.¹⁵ Even if that interpretation holds, the evidence speaks to transport and maintenance of fire, not necessarily to routine ignition on demand. Gesher Benot Ya’aqov in the Levant, near 0.8 Ma, remains an important later benchmark. Fire should therefore be described as an emerging *Homo* capacity during the Early and Middle Pleistocene, not as a securely dated 1.8 Ma invention.

Homo sapiens (from approximately 300 ka)

Fossils from Jebel Irhoud, Morocco, dated by thermoluminescence on heated flint to 315 ± 34 ka, combine a modern-looking face with a still-elongated braincase.^{2,16} They are the oldest well-dated remains assigned to *H. sapiens*. Other African fossils of comparable or somewhat younger age, including Florisbad in South Africa and later Omo Kibish and Herto in Ethiopia, show that early members of our species were geographically widespread. The accompanying Middle Stone Age record is likewise pan-African rather than confined to a single rift-valley corridor.^{2,5} Subsequent history includes limited earlier excursions into the Levant, a major lasting dispersal of non-African ancestors after roughly 70–50 ka, and limited interbreeding with Neanderthals and Denisovans outside Africa. Those later events are outside the scope of the origin question itself (Table 1).

Table 1 Summary timeline used in this review

Approximate date	Taxon or event	Notes
8–6 Ma	Human–chimpanzee split	Molecular-clock range, fossils rare
~7–6 Ma	<i>Sahelanthropus</i> , <i>Orrorin</i>	Possible early bipedal traits, interpretation debated
4.4 Ma	<i>Ardipithecus ramidus</i>	Woodland hominin, facultative upright walking
~4.2–2.0 Ma	<i>Australopithecus</i>	Habitual bipedalism, small brain
3.3 Ma	Lomekwi 3 stone tools	Predates first fossils of <i>Homo</i>
2.80–2.75 Ma	Earliest <i>Homo</i> (Ledi-Geraru)	Mandible LD 350-1, Ethiopia
~2.6 Ma	Oldowan industry	Repeated, systematic flaking
~1.9–1.8 Ma	<i>Homo erectus</i> / <i>ergaster</i>	Larger body and brain, Acheulean later follows

Table 1 Continued...

1.85–1.78 Ma	Dmanisi, Georgia	Earliest well-dated extra-African occupation
~1.0 Ma (possibly older)	Wonderwerk Cave fire	Strongest early archaeological fire evidence
~315 ka	Jebel Irhoud <i>H. sapiens</i>	Oldest well-dated fossils of our species
~70–50 ka	Major non-African dispersal	Source of most living extra-African ancestry

Why homo sapiens evolved in Africa

An African last common ancestor, not an African “first primate”

A common popular formulation says that humans evolved in Africa because “our earliest primate ancestors were already geographically isolated there.” That wording is too broad. Primates as an order have a deep and geographically complex history. What the hominin record actually shows is narrower and stronger. After the African ape clade was established, the entire stem of the human lineage lived in Africa. No convincing hominin is known from Eurasia before the Early Pleistocene dispersal of early *Homo*. Africa was therefore not merely a convenient stage, it was the only documented range of the lineage for more than five million years.^{1,10}

Africa also supplied a distinctive physical environment. Neogene uplift, rifting, and volcanism in eastern Africa created a landscape of basins, escarpments, lakes, and rain shadows. That tectonic template fragmented habitats at the same time that global climate was cooling and drying from the late Miocene into the Pleistocene.^{17,18} The combination of topographic complexity and climate oscillation is difficult to match on any other continent over the same interval.

Climate variability as a selective regime

African environments did not simply become “drier savanna” and stay that way. Proxy records from lakes, soils, dust, and marine cores show repeated swings between wetter, more wooded conditions and drier, more open conditions, paced in large part by orbital insolation.^{18–21} Two families of hypothesis connect that history to hominin evolution. Habitat-specific models emphasize adaptation to a particular setting, classically grassland or mixed woodland–grassland. Variability-selection models, developed most fully by Potts, emphasize adaptation to change itself: traits that maintain function when resources, vegetation, and water shift on timescales of thousands to hundreds of thousands of years.^{22,23}

Neither model is completely conclusive. Correlation between climate transitions and first-appearance dates is limited by the incompleteness of the fossil record, and orbital wet–dry cycles last far longer than an individual lifetime.²⁴ The value of the variability framework is that it explains a cluster of *Homo* traits that are not specialized for one habitat: a versatile diet, externalized technology, long-distance walking, and, later, an enlarged brain capable of storing and transmitting learned solutions. Those traits read more naturally as adaptations for unpredictable landscapes than as equipment for consuming a single vegetation type.

Recent Earth-system and habitat-suitability modeling finds that astronomically forced changes in temperature, rainfall, and net primary production structured the ranges of archaic humans, and that multiple antiphased climate disruptions in different regions after about 400–300 ka are temporally associated with the differentiation of African *H. sapiens* and Eurasian Neanderthals from shared ancestral

populations.²¹ It is consistent with climate as a recurring filter rather than a one-time trigger.

Structured populations across the continent

The older “single East African cradle” story is no longer the best reading of the evidence. Jebel Irhoud lies in North Africa. Florisbad lies in South Africa. Middle Stone Age technologies have regional flavors. Genetic structure within Africa is deep. Scerri and colleagues argued that *H. sapiens* coalesced from subdivided, intermittently connected populations distributed across the continent.⁵ Climate is again relevant: deserts, forests, and lakes expanded and contracted on different schedules in northern, eastern, tropical, and southern Africa, so isolation and contact were themselves orbitally modulated.²⁵

Genetic diversity as a record of time, not a racial ranking

Living African populations, taken as a whole, harbor more autosomal genetic diversity than populations outside Africa. Comprehensive surveys, including the continental-scale microsatellite study of Tishkoff and colleagues, document many ancestral clusters within Africa and a nested relationship in which non-African diversity is largely a subset of African diversity.^{3,4} Serial founder events during dispersal out of Africa reduced variation in descendant populations. High African diversity is therefore the expected signature of a longer effective history inside the continent, plus a structured ancestral population. It is not evidence that any living African group is “more evolved,” nor is it by itself a complete proof of every detail of the fossil chronology. Genetics and fossils answer related questions with different clocks, and both are required.

Planetary context: Theia, the moon, and a habitable climate oscillator

The giant-impact origin of the moon

The leading explanation for the Moon is a giant impact late in Earth’s accretion. A Mars-sized body, conventionally named Theia, struck the proto-Earth, debris from the collision re-accreted into the Moon.^{26,27} The model accounts for the Earth–Moon system’s angular momentum, the Moon’s depletion in iron, and the isotopic similarity of lunar and terrestrial rocks, although details of impactor size, angle, and mixing remain active research. The event belongs to the Hadean, more than four billion years before any hominin. It is relevant to human evolution only through the long-term physical consequences of having a large moon.

Stabilization of earth’s obliquity

Earth’s spin axis is tilted about 23.3° from the orbital normal. That tilt, or obliquity, varies by only about ±1.3° on a roughly 41,000-year cycle. Laskar, Joutel, and Robutel showed that this stability is not automatic. Without the Moon’s gravitational torque, Earth’s precession rate would slow, and obliquity would wander through a large chaotic zone extending from nearly 0° to about 85°. Mars, which lacks a large moon, still occupies a chaotic obliquity regime. Large, irregular swings in tilt would have produced extreme, poorly periodic climate states (long intervals of near-global glaciation or of ice-free poles) rather than the relatively well-behaved ice-age and monsoon rhythms of the late Cenozoic.

The scientifically supported claim is therefore this: the Moon is a climate regulator in the sense that it keeps Earth’s seasons within a bounded, quasi-periodic envelope. It is not a sculptor of hominin pelvises or brains. Removing the Moon would likely have made Earth a different kind of planet climatically. That counterfactual is the limit of the argument.

Milankovitch cycles and African hydroclimate

Within that bounded envelope, three orbital parameters modulate incoming sunlight: eccentricity (periodicity near 100 and 400 thousand years), obliquity (near 41 thousand years), and precession (near 19–23 thousand years). Together they constitute the Milankovitch forcing that paces Quaternary glacial cycles at high latitudes and monsoon intensity at low latitudes.³⁰ In Africa, eccentricity-modulated precession is often the dominant control on summer monsoon rainfall, producing a north–south antiphase in hydroclimate.^{19,31} Obliquity and high-latitude ice volume also leave a detectable imprint, especially after the mid-Pleistocene transition, when glacial cycles lengthened from roughly 41 thousand to 100 thousand years.^{18,21}

These oscillations repeatedly grew and contracted lakes, grasslands, and dispersal corridors. They are the proximate climatic mechanism through which a Moon-stabilized orbital architecture touches African landscapes. Linking them onward to particular speciation events remains a hypothesis only.^{22–24}

What the Theia–Moon argument does not say

Three overstatements should be declined. First, the Theia collision did not “aim” at humans, it is a contingent outcome of late-stage terrestrial accretion. Second, Milankovitch cycles would exist, in some form, on any spinning, orbiting Earth, the Moon changes their character by suppressing chaotic obliquity, not by inventing orbital mechanics. Third, climate variability is one candidate selective regime among several. Diet, social learning, predation, disease, and internal evolutionary dynamics also shaped the hominin lineage. A planetary boundary condition can make a climate regime possible without being the sufficient cause of a species.

Conclusion

Humans are African in origin by every independent line of evidence now available, e.g. fossils, artifacts, and genomes. The traits that distinguish *H. sapiens* accumulated over hundreds of thousands of years in populations that were already adapted to a changeable continent. African climate change, paced by Milankovitch cycles, is a serious and productive hypothesis for why flexibility itself was favored. The Moon, by stabilizing Earth’s obliquity after the Theia impact, is part of the reason those cycles remained relatively regular rather than chaotic.

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Conflicts of interest

The author declares no competing interests.

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