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Cumulative Cultural Evolution Dynamics and Their Role in the Emergence of Complex Human Behavior

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ديناميكيات التطور الثقافي التراكمي ودورها في نشأة السلوك المعقّد لدى الإنسان الحديث

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Abstract:
This study discusses the emergence of complex behavior in modern humans, which is considered one of the major and important topics that still suffers from significant knowledge gaps. The study is based on a central hypothesis that finely crafted sharp stone tools and shell ornaments were the main driving force behind the emergence of this behavior. The primary objective of the study is to reconstruct, analyze, and interpret chronological sequences while linking them to material and cultural evidence, in addition to examining the assemblage of artifacts associated with modern human behavior and the changes that resulted from them. In this context, the study adopts a multidisciplinary research methodology based on the integration and interaction of various scientific fields. Modern behavior is viewed as a natural outcome of cumulative cultural evolution processes, which played a crucial role in the transmission of knowledge, its preservation, accumulation, and the introduction of improvements over time and across different generations. The results and manifestations of this behavioral transformation can be observed through changes in adaptation and survival strategies imposed by shifts in the natural environment, the development of stone tools, hunting methods and food-gathering practices, as well as the expansion of the geographical range of human populations. Moreover, this transformation is linked to symbolism and complex cognition, which represent the core of modern human behavior. Overall, by integrating historical and archaeological evidence with theoretical interpretations, this research may contribute to the ongoing discussions surrounding complex behavior and its development.

Keywords: Cultural Evolution Dynamics, Complex Behavior, Symbolism, Blombos Cave, Complex Cognition, Modern Human.

الملخص:
تناقش هذه الدراسة موضوع نشأة السلوك المعقد عند الإنسان الحديث – والذي يعتبر واحداً من المواضيع الرئيسة والمهمة التي لا تزال تعاني من وجود ثغرات معرفية- انطلاقا من فرضية أساسية وهي أن الأدوات الحجرية الدقيقة والقاطعة والحُلي الصدفية كانت هي المحرك الرئيس والقوة الدافعة التي أدت إلى نشأته. حيث يتمثل الهدف الرئيس في إعادة بناء وتحليل وتفسير التسلسلات الزمنية مع ربطها مع الأدلة المادية/الثقافية، فضلاً عن مجموعة الأدوات الصنعية المتصلة

بالسلوك الحديث، والمتغيرات التي نجمت عنها. في هذا السياق، تتبنى الدراسة منهجية بحثية متعددة التخصصات تقوم على تكامل وتداخل العلوم المختلفة، حيث ينظر إلى السلوك الحديث بكونه نتاج طبيعي لعمليات التطور الثقافي التراكمي، والتي كان لها دور كبير في نقل المعرفة، وحفظها وتراكمها وإدخال التحسينات عليها عبر الأزمنة وعبر الأجيال المختلفة. يمكن رؤية نتائج وتجليات هذا التحول في السلوك من خلال التغيرات في استراتيجيات التكيف والبقاء التي فرضتها التبدلات في البيئة الطبيعية، وتطوير الأدوات الحجرية وطرق الصيد وجمع الطعام، واتساع النطاق الجغرافي للسكان، فوق ذلك، فهو يرتبط بالرمزية والادراك المعقد واللذين يمثلان جوهر السلوك الحديث. علي كل، ومن خلال دمج الأدلة التاريخية والآثارية مع التفسيرات النظرية، قد يساهم هذا البحث في المساهمة في النقاشات الدائرة حول السلوك المعقد وتطوره.

الكلمات المفتاحية: التطور الثقافي التراكمي، السلوك المعقد، الرمزية، كهف بلومبوس، الادراك المعقد، الإنسان الحديث.

Introduction:

Since ancient times, the origin of complex behavior, often referred to as modern human behavior, has been a central focus of scholars across several disciplines, including philosophy, paleoanthropology, history, archaeology, biology, paleontology, and genetics, among others. In recent years, this field has gained considerable momentum due to new archaeological discoveries and the advancement and diversification of both theoretical frameworks and analytical techniques. As a result, a variety of interpretive models have emerged, including functional and structural approaches, as well as ethnographic and ethnoarchaeological analogies.

According to chronological, stratigraphic, and morphological evidence derived from stone tools, the emergence of complex behavior is believed to have occurred on the African continent, particularly in southern Africa. This development has been linked to absolute chronologies obtained through radiocarbon (14C) dating as well as highly precise luminescence dating techniques, placing it at approximately 200,000 years ago, during the Late Pleistocene. This complex behavior began to appear among hunter-gatherer groups and fishing communities of anatomically modern humans. Scholars have identified a range of manufactured artifacts that reflect the cultural horizon of complex behavior in Africa, including small stone blades, cutting tools, the use of hematite (red ochre) as a pigment, and the production of shell ornaments. The manufacture of these artifacts has been closely associated with symbolic behavior and complex cognition, both of which are considered key indicators of behavioral modernity or modern human thought (McBrearty, 2012, 531).

In this context, small stone blades, cutting tools, and shell ornaments may be viewed as **"**time capsules**"** that encapsulate hundreds of thousands of years of human cultural evolution. In addition to providing evidence of human presence at various archaeological sites, these artifacts allow researchers to trace patterns of ancient human migrations. They have also become valuable indicators of cognitive and behavioral changes in humans across time and space. Furthermore, they serve as important measures of technological and motor abilities in early human populations. Even processes related to brain evolution and the emergence of language are sometimes interpreted through the study of such manufactured materials. In other cases, artifacts can be linked to broader cultural processes; under these circumstances, they may be interpreted as representing distinct archaeological cultures and assigned specific cultural designations such as the Oldowan, Acheulean, Levallois-Microlithic, Mousterian, Aurignacian, Capsian, and Aterian, among others (Di Lernia, 1999, 3–4; Adaba, 2026, 656; Adaba, 2022).

Within this framework, the present study aims to test the following hypothesis: the production of stone blades, cutting tools, and shell ornaments constituted a major driving force in the development of modern human behavior. In this study, such behavior is understood as the natural outcome of complex cultural processes that accumulated across generations over extended periods of time, rather than the result of a sudden event. The concept of cumulative cultural evolution thus emerges as one of the most significant mechanisms underlying human change. It refers to the ability of human societies to transmit knowledge, experiences, and skills from one generation to the next while gradually modifying and improving them over time. This cultural accumulation contributed to the emergence of complex behavioral patterns among modern humans, including the development of cutting tools, symbolic thinking, and increasing cultural complexity. Therefore, understanding the dynamics of this cultural evolution is essential for tracing how complex behavior, and the associated technologies and cultural expressions, emerged and developed.

Nevertheless, several key questions remain unresolved. For instance, did the emergence of behavioral modernity occur early or late in the course of human history on Earth? Moreover, did it develop gradually over time, or did it appear relatively suddenly during the thousands of years that followed? These issues require further investigation, evaluation, and critical reassessment, an objective that the present study seeks to address in the following sections.

Methodology:

To test the proposed hypothesis and address the research questions, this study adopts an interdisciplinary research methodology grounded in the integration and interaction of multiple scientific fields. It draws on data and insights from several natural sciences, including history, archaeology, biology, paleoanthropology, paleontology, ecology, quantum mechanics, and brain and neuroscience. The primary objective is to reconstruct, analyze, and interpret chronological sequences, cultural evidence, and datasets related to manifestations of complex behavior, technological systems, symbolic practices, and the forms of complex cognition associated with them. Through this integrative approach, the study seeks to identify and clarify the relationships and potential connections among these elements.

The study also reviews topics related to variables that link environmental characteristics with adaptive behavior, as well as the dynamics of deposition and post-depositional processes that affect human habitation sites. In addition, it examines recent discoveries from several archaeological sites in southern Africa, which have contributed to shedding light on a number of issues that remain unresolved concerning the origins and developmental trajectories of complex human behavior.

More broadly, the biological and cultural evolution of humans is closely intertwined with technological innovation and creativity. Throughout history, technological developments have often coincided with population growth, the diversification of adaptation and survival strategies, the expansion of the geographical range of human populations, the emergence and increasing sophistication of symbolic behavior, and the broadening of the subsistence base, along with other related processes.

Undoubtedly, the biological and cultural evolution of humans is intrinsically linked to technological innovation and creative capacity. Throughout history, technological advancements have consistently coincided with demographic expansion, the diversification of adaptive and survival strategies, and the widening geographical distribution of human populations. These developments have further fostered the emergence of symbolic behavior and its increasing complexity, as well as the expansion of subsistence resources, in parallel with a range of interconnected socio-cultural and environmental processes. Furthermore, these phenomena are tightly interwoven with the dynamics of cumulative cultural evolution, a mechanism that has enabled the systematic transmission, preservation, and gradual accumulation of knowledge across human societies over successive generations.

Literature Review:

The concept of complex behavior, often referred to as behavioral modernity, encompasses a suite of cognitive and behavioral capacities that distinguish modern humans. These capacities include symbolic expression, strategic planning, the production of complex tools, social interaction, and the use of language, among others (Mellars, 2005). Archaeologists have frequently relied on material culture as a proxy for identifying the emergence of such behaviors. In this context, a range of manufactured artifacts has been interpreted as indicative of the cultural horizon of modern human behavior, including small stone blades, cutting implements, the use of hematite (ochre) as a pigment, and the production of shell ornaments. The creation and use of these artifacts are widely associated with symbolic practices and advanced cognitive abilities, both of which are considered key markers of behavioral modernity and modern human cognition (Mellars, 2005; Henshilwood & Dubreuil, 2011).

Scientific hypotheses and interpretations regarding the emergence of complex behavior vary considerably, reflecting differences in theoretical perspectives and analytical approaches. One influential hypothesis proposes a symbolic revolution that coincided with the arrival of anatomically modern humans in Europe approximately 40,000 years ago, which, to some extent, has been linked to neurological or linguistic mutations (d'Errico et al., 2003). In contrast, the gradual cultural evolution model (Henshilwood et al., 2002; McBrearty & Brooks, 2000) posits that complex behavior emerged progressively over hundreds of thousands of years across multiple regions of the African continent. Evidence supporting this view has been documented at several key archaeological sites. For example, Blombos Cave has yielded microlithic blades, engraved objects, and shell ornaments that indicate early symbolic behavior. Similarly**,** Pinnacle Point provides evidence of advanced strategies for exploiting marine resources, along with the controlled heat treatment of stone tools. Moreover, archaeological records from East Africa reveal that hunter-gatherer populations employed complex toolkits, participated in exchange networks, and developed increasingly sophisticated forms of social organization.

Another explanatory framework, commonly referred to as the cultural mosaic model, suggests that complex behavior did not emerge simultaneously in a single region but appeared at different times and in different locations. Within this framework, the development of behavioral complexity is understood as the result of multiple interacting factors, including population size, intergroup interaction, environmental variability, and cultural innovation (Tryon et al., 2019).

The Middle Stone Age (MSA) of Africa provides a particularly rich body of evidence for the emergence of complex behaviors. Archaeological discoveries,such as blades, cutting tools, pointed implements, bone tools, and the use of pigments, suggest a gradual accumulation of technological and symbolic innovations over time. This pattern of incremental development challenges models that posit a sudden behavioral transformation (Shixia et al, 2025).

At the same time, the archaeological record reveals significant regional variability in the expression of complex behavior. Evidence from West Eurasia, for example, indicates that Neanderthals developed behavioral patterns comparable in several respects to those of anatomically modern humans. Such findings suggest that complex behaviors may have emerged independently among multiple hominin populations, highlighting the polycentric and fragmented nature of behavioral evolution (Martín-Ramos, 2025; Scerri and Will, 2023).

Recent scholarship has therefore called for a critical reassessment of the concept of behavioral modernity as a rigid analytical framework. Increasing evidence demonstrates that Neanderthals engaged in symbolic and technological practices once considered exclusive to modern humans. As a result, many researchers now argue that the emergence of complex behavior should be understood as a continuous and dynamic evolutionary process that unfolded through interactions among different human populations rather than as a sudden or uniquely modern human phenomenon (Killin, 2026; Tryon et al, 2019).

Methodologically, contemporary research has increasingly challenged the traditional Eurocentric paradigm that long dominated interpretations of behavioral evolution. Rather than relying primarily on European archaeological records, scholars now advocate for broader analytical frameworks that situate complex behavior within the context of collective learning and cumulative culture. From this perspective, behavioral complexity arises not merely from genetic changes or isolated cognitive innovations, but from long-term social and cultural dynamics.

In this regard, interdisciplinary approaches have become particularly influential. The integration of ancient genome sequencing with archaeological, environmental, historical, and anthropological data has significantly expanded our understanding of human behavioral evolution. These approaches provide more robust explanatory models by highlighting the roles of population interaction, migration, and shared cultural traditions in shaping human behavioral development.

Within this framework, Africa occupies a central position in discussions of the origins of modern human behavior. Numerous archaeological discoveries across the continent indicate the early emergence of traits associated with behavioral complexity, in many cases predating the dispersal of modern humans beyond Africa. As archaeological research and field surveys continue to expand, it is expected that new discoveries will further refine our understanding of the origins and development of complex behavior across different temporal and regional contexts.

Chrono-Cultural Framework:

Traditionally, paleoanthropological literature has portrayed Neanderthals as an ancient human species with limited behavioral and technological capacities, and a constrained ability to adapt to changing environments. However, recent research has fundamentally challenged this view, revealing a diverse spectrum of complex behaviors among Neanderthal populations across Europe and the Levant. Consequently, advanced subsistence strategies and sophisticated technological practices are no longer considered exclusive to anatomically modern humans, vered from deposits dating between 250,000 and 200,000 years ago, likely used for coloring drawings and shell ornaments (Wong, 2015, 40).

Neanderthals demonstrated intricate strategies in the procurement and processing of food resources. Stratigraphic analyses at Cueva del Ángel in southern Spain, dated to the Middle Pleistocene, indicate that hunter-gatherers implemented systematic and intensive exploitation of large mammals,including deer, red deer, and bovids, focusing on high-energy resources such as meat and bone marrow. Patterns of bone fragmentation point to selective hunting practices and intensive resource utilization, complemented by the exploitation of smaller prey, reflecting adaptive strategies for resource management and risk mitigation (Solano-Garcia and Moigne, 2025).

Zooarchaeological and taphonomic evidence from Abric Pizarro in Spain, occupied during Marine Isotope Stage 4 (MIS 4) , a period characterized by marked climatic instability, demonstrates a diverse prey spectrum, structured hunting strategies, advanced tool use, and controlled fire management. These findings indicate that Neanderthals possessed the capacities necessary to establish and maintain long-term residential systems in marginal and environmentally variable habitats (Westbury et al, 2025). Research at Gruta da Figueira Brava in Portugal further underscores the flexibility of Neanderthal subsistence strategies. Within a mosaic environment combining coastal and inland zones during the last interglacial period, faunal remains reveal adaptive exploitation of large mammals, while butchery and processing techniques reflect strategic responses to fluctuating local environments (Nabais and Zilhão, 2025).

Evidence also suggests the emergence of cognitive modernity and symbolic behavior among Neanderthals. Archaeological and historical records indicate that Neanderthals exhibited levels of skill and symbolic thought comparable to anatomically modern humans, particularly in craftsmanship, ritual practices, and ornamentation. Supporting evidence includes systematic production of iron oxide, burial of the dead, body and facial decoration, and the use of pigments for symbolic purposes (Zilhão, 2010, 72–73).

Additional insights into Neanderthal culture and complex behaviors are provided by deposits from numerous European sites. Between approximately 250,000 and 28,000 years ago, Neanderthals inhabited Eurasia, remaining there until the arrival of anatomically modern humans from Africa (Wong, 2009, 32–37). At the Maastricht-Belvédère site in the Netherlands, researchers recovered residues of red ochre (iron oxide) from deposits dating between 250,000 and 200,000 years ago, which were likely used for coloring drawings and shell ornaments (McGil, 2015, 63).

In France, substantial quantities of eagle talons, carefully collected by Neanderthals, were discovered at Combe Grenal and Les Fieux. Absolute chronologies for these sites were established using radiocarbon and radiometric dating techniques, indicating that Combe Grenal dates to approximately 90,000 years ago, while Les Fieux dates to around 60,000 years ago (Wong, 2015, 40). This evidence has led some researchers to suggest that Neanderthals may have incorporated these large, prominent talons into symbolic practices, possibly as body ornaments (Wong, 2015, 40).

Furthermore, at the Pech-de-l'Azé site in France, bone tools crafted from deer rib bones were recovered. These tools were likely employed for softening, conditioning, and polishing animal hides and have been dated to approximately 53,000 years ago (Wong, 2015, 43).

Some of the most remarkable artifacts also reveal artistic sensibilities and evidence of abstract thought within Neanderthal cultures during the period preceding the arrival of modern humans in Europe, particularly in the use of shells and feathers for crafting personal ornaments. At Grotta di Fumane in Italy, red-colored shells were discovered threaded on strings, suggesting their use as necklaces approximately 47,000 years ago (Wong, 2015, 41; McGil, 2015, 64-65). Moreover, some archaeological evidence indicates that these shells may have also functioned as containers for mixing and storing multi-colored pigments. A notable example comes from Cueva de los Aviones in Spain, where two sets of marine shells were recovered: the first stained with various pigments, and the second pierced shells bearing colored pigments, suggesting their use as personal ornaments. These shells have been dated to over 50,000 years ago (McGil, 2015, 64).

The comparison of complex behaviors between Neanderthals and modern humans raises important questions regarding the possibility of biological and cultural interactions between the two species during the Middle Paleolithic, and the nature of such interactions. Several research efforts have addressed this issue, primarily relying on traditional or historical approaches based on information preserved in archaeological and fossil records. However, most findings and interpretations have been limited, often circular, and influenced by biased perspectives, sometimes shaped by competing ideologies, personal beliefs, or, even regrettably, political and racial considerations (Gravina et al, 2005; Sümer, Arev et al, 2025).

As a matter of fact, reconstructing evidence related to human emergence and evolution on Earth, while simultaneously interpreting historical and archaeological records and addressing gaps in knowledge—resembles investigative work. In the absence of conclusive evidence, inferences must be drawn from diverse sources, including bones, artifacts, organic deposits, and linguistic data, all of which are inherently incomplete. Consequently, it is widely acknowledged that understanding the biological and cultural characteristics of past populations cannot rely solely on material remains but must also take into account demographic and environmental factors, as well as genetic and hereditary influences.

Today, a new generation of researchers is applying modern genetic techniques to address questions raised by historical studies, aiming to use ancient genomes to reconstruct events from the distant past. Sequencing ancient genomes enables dynamic and detailed analyses, yielding more precise and flexible results, including horizontal and vertical distributions, as well as variations within both the historical and genetic records. Together, these data provide a robust foundation upon which diverse interpretations can be constructed (Sanches-Mazas, 2001; Haber et al, 2016; Reich and Eugenie Reich, 2018; Sirak et al, 2020).

For instance, the involvement of the Reich team in the genetic analysis of archaic humans, known as Denisovans, led to the revision of earlier findings that had relied solely on mitochondrial DNA. Their research demonstrated that Denisovans and Neanderthals were more closely related to each other than either was to modern humans. The ancestral groups that ultimately gave rise to modern humans diverged from the populations leading to both Denisovans and Neanderthals between approximately 770,000 and 550,000 years ago, predating the split between Neanderthals and Denisovans by roughly 100,000 to 400,000 years. Additionally, it was revealed that ancient Denisovan populations experienced gene flow with the ancestors of present-day New Guineans between approximately 54,000 and 44,000 years ago (Reich and Eugenie Reich, 2018; Guimarães et al. 2020; Brown et al, 2022).

Genetic evidence indicates that the last common ancestor of modern humans, Neanderthals, and Denisovans lived approximately 765,000 to 550,000 years ago. However, the geographical distribution of the morphological and anatomical traits of these ancestors remains poorly understood. Newly discovered fossils at the Thomas Quarry I (ThI-GH**)** site in Casablanca, Morocco, dated to roughly 773,000 years ago, are approximately contemporaneous with Homo antecessor but differ in morphology, exhibiting a combination of primitive and derived traits reminiscent of characteristics later observed in modern humans, Neanderthals, and Denisovans (Guimarães et al. 2020; Vernot et al, 2021; Hublin et al, 2026, 902–908).

Sex-biased patterns in population admixture and demographic shifts between Neanderthals and modern humans are also apparent, as evidenced by the low proportion of Neanderthal ancestry on the X chromosome of modern humans (Platt et al, 2026). Interbreeding between the two groups is thought to have occurred predominantly between Neanderthal males and modern human females. Analytical and numerical models suggest that sexual partner preference provides a more parsimonious explanation for this sex bias than purely demographic processes involving differential patterns of male and female migration (Kreier, 2026).

In the same context, genomic data from the Zlatý kůň site in Czechia and Bacho Kiro in Bulgaria reveal the presence of two genetically distinct groups that once inhabited Europe (Sümer et al, 2025). Another comparative study, analyzing one high-quality genome and five low-coverage genomes from approximately 45,000-year-old remains at the Ilsenhöhl**e** site in Ranis, Germany, along with a low-coverage genome from Zlatý kůň, indicates distant kinship between the Ilsenhöhle and Zlatý kůň individuals. These populations belonged to small, isolated groups, representing the oldest known branch of the out-of-Africa lineage to date.

Notably, the Ilsenhöhle genomes contain Neanderthal-derived segments resulting from a single admixture event shared by all non-Africans, dated to between 45,000 and 49,000 years ago (Sümer, Arev et al., 2025). Taken together, the genomic evidence suggests that interactions between Neanderthals and modern humans were largely limited to occasional interbreeding, while archaeological and technological data point to the potential for cultural and technological exchange.

Tracing the Evolution of Stone Tools: From the Lomekwian Industry to Microliths and Cutting Implements:

In paleoanthropological literature, humans are frequently portrayed as **toolmakers**, crafting objects from raw materials in ways that differ from their natural occurrence in the environment, while assigning them specific functions and forms. Stone was the primary material used for most tools, and the moment early humans began deliberately shaping stone, sharpening edges and refining points to enhance their effectiveness, is regarded as the dawn of the first technological revolutions in human history.

Over time, tool-making techniques evolved, giving rise to diverse models and forms. Stone tool production was closely linked to humans' understanding of different types of rock and their properties, such as volcanic stone, quartz, quartzite, limestone, flint, and others. These materials were carefully collected, selected, and then shaped into specific forms, each designed for a particular function. By the Middle Paleolithic, stone tools were increasingly employed not only for practical purposes but also as a means of expressing symbolic meanings, reflecting ideas and concepts that extended beyond immediate experience.

The question that naturally arises is: where and when were the oldest stone tools made by humans discovered? For decades, there was a single, seemingly indisputable answer: the oldest human-made tools, dated to approximately 2.6 million years ago (Figure 1), were found within the deposits of Olduvai Gorge in Tanzania and Gon**a** in Ethiopia. This assemblage has been classified within the technical complex known as Oldowan (Semaw et al, 2003, 169–170; Potts et al, 2004, 75; Ambrose & Stanley, 2001, 1748; Brown et al, 2012, 590).

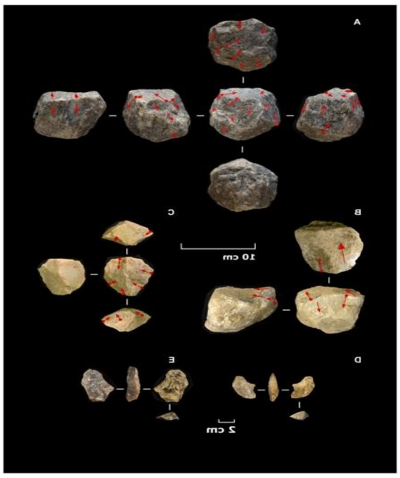

Figure (1): **Selection of Stone Tools from Phase I (2.015 ± 0.006 Ma)**. **(A)** Quartzite multipolar, multifacial core, illustrated with detailed technical schematics highlighting flake removal strategies. **(B)** Quartzite bifacial orthogonal core, depicted with schematic diagrams showing its reduction sequence. **(C)** Quartzite unifacial centripetal core, presented with technical schematics demonstrating centripetal flaking patterns. **(D, E)** Quartzite flakes, with red arrows indicating the directions of flake detachments. *(*After *Cueva*-Temprana et al., 2022, p. 7).

Field surveys uncovered discoidal cores, bifacial techniques, and cutting blades resembling knives, which were typically used for cutting animal meat and breaking bones to extract marrow. During this phase, the selection of flint as the primary material for tool production was closely linked to the techniques of stone flaking and shaping (Semaw, 2003, 171–172).

However, this understanding has shifted due to recent scientific discoveries, and the question of the oldest stone tools has once again become a topic of active debate (Shannon et al., 2010, 857–859). Between 2011 and 2014, tools were uncovered in the volcanic deposits of Lomekwi **3**, located on the western side of Lake Turkana in Kenya, dating to approximately 3.3 million years ago. These tools have been conventionally designated Lomekwian, making them roughly 700,000 years older than the previously documented oldest tools in the human archaeological and biological record (Harmand et al, 2015, 310; de la Torre, 2011). The Lomekwian assemblage comprises sharp stone flakes used for cutting, worked cobbles, as well as large hammers and anvils, some weighing up to 15 kg.

There appears to be a broad consensus among researchers that Lomekwi 3 served as a dedicated site repeatedly visited by groups of hunter-gatherers for the purpose of producing stone tools and transmitting these skills to subsequent generations (Callaway & Francisco, 2015, p. 421; Hovers, 2015, p. 294). This conclusion is supported by the high density of stone artifacts at the site, which were initially collected randomly and subsequently modified using a variety of techniques, including the Passive Hammer Technique**,** Bipolar Technique, and others (Figure 2). The emergence of these techniques also seems to be theoretically linked to environmental changes and human evolutionary patterns. This naturally leads to the question: how were these stone tools manufactured? Stratigraphic studies and typological analyses indicate several methods of tool production, such as striking with hard and soft hammers, which were strategically employed to produce sharp flakes with minimal effort (Callaway and Francisco, 2015, 421; Ambrose, 2001, 1749; Semaw et al, 2003, 171).

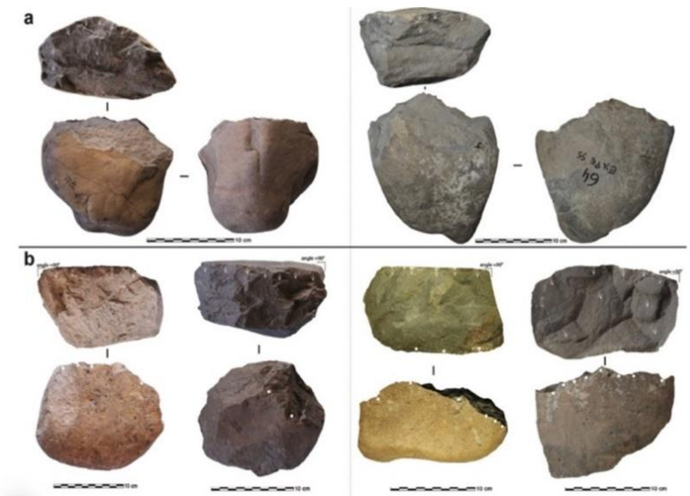

Figure (2): Replication experiments and technological analysis suggest LOM3 knappers used: (a) Passive hammer cores: Left: archaeological LOM3-2012 surf 106 (2.04 kg); Right: experimental Expe 55 (3.40 kg). Blocks are relatively flat with obtuse angles. Flake removals begin from slightly prominent areas (white arrows), tend to be invasive, and form semi-abrupt angles with the platform. Slight rotation enables semi-peripheral exploitation**.** (b) Bipolar cores: Left: archaeological LOM3-2012-H18-1 (3.45 kg) and LOM3-2012 surf 64 (2.58 kg); Right: experimental Expe 39 (4.20 kg) and Expe 24 (2.23 kg). Blocks are thicker, quadrangular, with angles < 90°. Flakes removed from a single secant platform (white arrows). Flaked surfaces form abrupt angles with other faces; contrecoup impacts (white dots) are visible opposite the platform. *(After Harmand, 2015, p. 320).*

For instance, studies suggest that approximately 76% of the modified tools at Lomekwi 3 were produced using hammer-and-anvil techniques rather than direct hand strikes for shaping and edge refinement (Harmand, 2015, pp. 311–314). By the end of the Middle Paleolithic, Acheulean tools disappeared, giving way to more advanced implements produced using Levallois technology. This Levallois technique involves pre-shaping the desired tool before detaching it from the original core (Figure 3). Flakes were removed unidirectionally, bidirectionally, or along the perimeter of the core's base (Adler et al, 2014, pp. 1609–1610). The reasons behind the disappearance of Acheulean techniques remain an unresolved mystery, largely due to gaps in the fossil and archaeological record. The evidence collected through excavations does not consistently appear within a verified evolutionary framework.

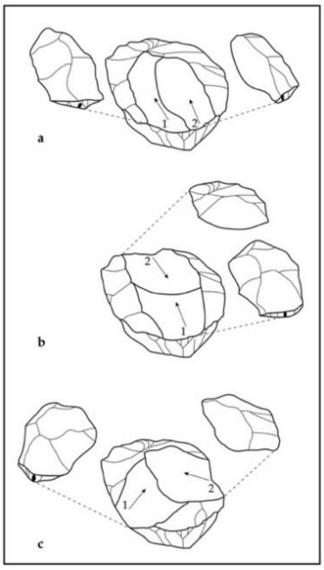

Figure (3): The Levallois 'méthodes': (a) Unipolar recurrent: The subsequent Levallois flake (no. 2) is removed along the same axis and in the same direction as the first flake (no. 1). (b) Bipolar recurrent: The subsequent Levallois flake (no. 2) is removed along the same axis as the first flake (no. 1), but in the opposite direction**.** (c) Centripetal recurrent: Levallois flakes (nos. 1 and 2) are removed in a variable sequence, directed toward the center of the core. *(After Schlanger, 1996, p. 240).*

The pressure-flaking technique marked a significant revolution in the production of stone tools. Through this method, the form of the intended tool became more precise and less dependent on chance. At Blombos Cave and Howieson's Poort, the use of pressure flaking coincided with the application of heat-treatment techniques for stone. Heat treatment enhanced the manufacturing process (Figure 4), allowing humans to achieve a high degree of control over the final shape of the tool, particularly the sharp microlithic stone blades used in the production of arrows (Brown et al., 2012, 591; Webb and Domanski, 2009, 820–821; Mourre and Villa, 2010, 659–660).

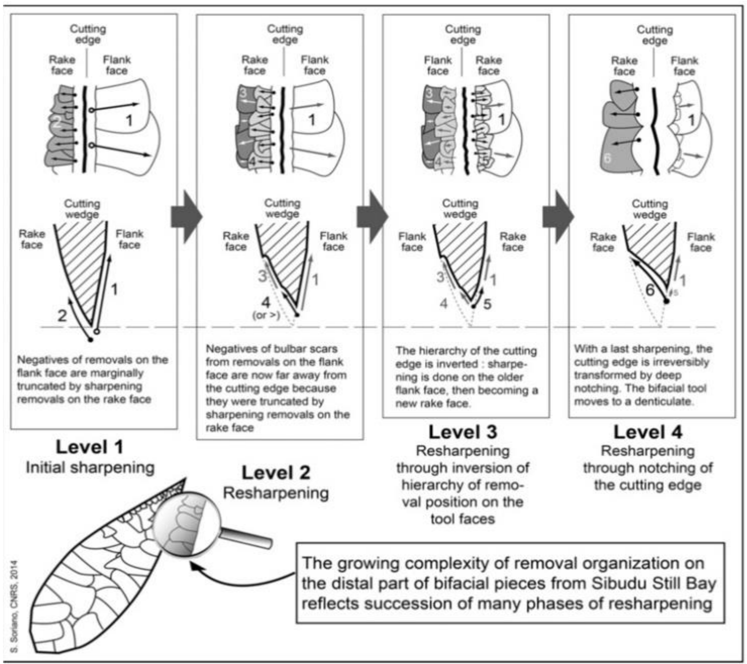

Figure (4): Phases of resharpening in the Sibudu Still Bay points .The figure illustrates the sequence or different stages that the bifacial points go through during resharpening, showing how flakes are gradually removed to maintain the sharpness and precision of the points. (After Soriano et al, 2015).

Here, we must acknowledge the existence of significant informational gaps in the African fossil record. Consequently, we lack a complete and continuous record documenting human activities across the chronological phases associated with the emergence and evolution of humans in this region. Several factors contribute to these gaps, the most important being the vast size of the African continent, which has been inhabited by humans and hominins for more than five million years (Savelkouls et al., 2026; Mongle et al., 2025). Since only a limited number of areas, amounting to a few hundred kilometers and relatively small portions of the continent, have been systematically explored by archaeologists and paleoanthropologists, it is unsurprising that the cultural record remains fragmented and incomplete.

For example, numerous artistic artifacts and decorated stone tools adorned with beads have been discovered at various sites across the African continent. These finds are often interpreted as evidence of modern ideas or behaviors and belong to different chronological periods. However, attempts to link them convincingly to the emergence of behavioral modernity remain inconclusive and largely unproductive, primarily because many of these materials have not been dated with sufficient precision. Consequently, they may represent only partial expressions of behavioral modernity, or perhaps may not represent it at all.

The gaps in the current record have been interpreted from multiple perspectives, the most prominent of which include the incomplete development of human cultural capacities, the isolation of small population groups during prehistoric times, and inherited variations in human adaptive patterns. Some researchers attribute this deficiency, and the associated chronological gaps, to biological factors. According to this view, the use of pigments, beads, and advanced stone and bone tools was already present and widespread in southern Africa around 75.000 years ago. However, many of these material manifestations had disappeared by approximately 60.000 years ago, suggesting that modern behavior initially emerged in a particular context but later declined before becoming firmly established (d'Errico et al., 2012, 13214–13219).

However, this situation may soon change, as researchers continue to probe the past in search of new evidence to address these gaps and mitigate existing knowledge deficits. Notably, between 2013 and 2015, Lee Berger and his team uncovered an extraordinary assemblage of bones and bone fragments, approximately 1,550 pieces, representing around fifteen individuals of varying ages. These remains were recovered from a confined chamber, designated the Dawn of Humanity Chamber, situated 30 meters below the surface and accessible only via narrow passages within the Rising Star Cave system, near Johannesburg, South Africa. This discovery provides unprecedented insight into early hominin diversity and behavior, underscoring the potential for future finds to reshape our understanding of human evolution.

This discovery, despite receiving considerable media attention, sparked extensive scientific debate, and the initial conclusions drawn from it were met with substantial criticism. Nevertheless, it opened new avenues in the search for the origins of humanity (Berger et al., 2015), as it brought to light a previously unknown extinct human species, named Homo naledi. The name "Naledi" means "star" in the Sotho language, one of the major indigenous languages of South Africa. Homo naledi inhabited the region approximately two million years ago and exhibited structural and anatomical features reminiscent of both Homo erectus and Homo habilis (Wong, 2016, 28–37).

Aurore Val posits that these bodies were deliberately placed in the burial chamber within the cave at different time intervals, suggesting that Homo naledi may have possessed a form of symbolic thought associated with burial practices (Aurore, 2016, 145–148). Currently, geologists and molecular biologists are conducting further analyses to reconstruct the cave's history (Martinón-Torres, María et al., 2024) and to extract DNA from the bones, aiming to obtain additional data, critically evaluate existing models, and document them comprehensively (Traynor et al., 2019, 84–91; Holloway et al., 2018, 5738–5743).

In a related context, Sally McBrearty adopts a different perspective in explaining the gaps in the African archaeological and fossil record. She proposes that a genetic mutation influenced cognitive capacity during the transitional period from the Middle Paleolithic to the Upper Paleolithic (McBrearty, 2012, 531) .As a result, there appears to be a disconnect between anatomical modernity and behavioral modernity, which is now believed to have emerged much earlier than the conventionally accepted date of 200,000 years ago (Wong, 2006, 80).

For instance, the findings from three sites in Kenya, Zambia, and Tanzania document a wide range of crafted tools and coloring materials considered indicative of behavioral modernity dating back to the Middle Pleistocene. At a site near Lake Baringo in Kenya, finely flaked stone blades approximately 51,000 years old were uncovered. At another nearby site, large quantities of hydrated iron oxide were recovered from sediment layers dating to around 285,000 years ago, suggesting that the inhabitants employed coloring materials for symbolic purposes. In Twin Rivers Cave in Zambia, similar crafted tools over 200,000 years old were found (d'Errico et al., 2003, 4). Furthermore, at the Mumba Rock Shelter in Tanzania, flakes made from black volcanic glass were discovered, notable for their high-quality flaking and polishing (Wong, 2006, 80).

In addition, Sally McBrearty and Alison Brooks published a comprehensive article in the *Journal of Human Evolution*entitled **"**The Revolution That Wasn't: A New Interpretation of the Emergence of Modern Human Behavior**"** (McBrearty and Brooks, 2000, 453–563), in which they argued that manifestations of behavioral modernity and symbolic thought have deep-rooted origins extending back prior to the Middle Pleistocene. Evidence of such behaviors can be observed tens of thousands of years before that period at certain Middle Pleistocene sites (McBrearty and Brooks, 2000, 456–458). They further contend that many components of this transitional process did not emerge suddenly or simultaneously; rather, they resulted from a gradual evolutionary trajectory occurring at dispersed sites over widely spaced time intervals (McBrearty and Brooks, 2000, 479–480).

On the other hand, the discovery of small stone blade technology has brought attention to an important bio-cultural process,one for which there is often no consensus among researchers due to the lack of definitive material evidence, namely, the use of language. In this context, Kyle Brown and his colleagues argue that the production of small blades, such as those found in Pinnacle Point 5-6 Cave in South Africa, provides evidence that the humans who inhabited the cave approximately 70,000 years ago possessed the advanced cognitive skills necessary to manufacture these tools, including the use of language (Brown, 2012, 592) .They further maintain that it is highly implausible, given the precision and skill with which these stone tools were crafted, for modern observers to accept that the ability to comprehend the complex concepts involved in their production, and to transmit them to others, could have occurred without the use of language (Brown, 2012, 594) .

The idea of linking stone tool production with the existence of language had been proposed in earlier studies. Anthropologist Ian Tattersall, expressing his views with notable enthusiasm and confidence, explored this topic in a paper entitled "How We Became Human?", published in a special issue of Scientific American in 2006. He argues that if there is one aspect of human cognitive function most closely associated with symbolic processes, it is undoubtedly the use of language. Language constitutes the ultimate symbolic mental capacity, and it is entirely impossible for thought, as we understand it today, to occur in the absence of language (Tattersall, 2006, 70–71).

Overall, the ideas proposed by Brown and Tattersall appear particularly logical and compelling when viewed from the perspective of our present era, in which language has become the primary medium through which we articulate our thoughts, convey knowledge, and communicate with others effortlessly. In my view, the most persuasive (and perhaps widely accepted) argument is that of Tattersall himself: ancient humans possessed a form of vocal communication, but it was neither as clear nor as structured as the speech we are familiar with today. This communication was limited to a form of primitive language, which later evolved through modifications in the structure of the vocal tract, eventually giving rise to the systematic construction of sentences (syntax). Words gradually became associated with the physical objects in the environment, most notably stone tools, ornaments, and other material items (Tattersall, 2006, 72–73) .

Based on the typological and well-documented morphological characteristics observed in Blombos and Howieson's Poort caves, I propose that the production of stone tools by humans during the Middle and Late Pleistocene was guided by the principles of permutations and combinations, two fundamental mathematical concepts. The first approach, permutations, involves selecting specific models or types of tools from a larger set of possibilities, while the second, combinations, entails choosing a single model within a predetermined and fixed arrangement of tools.

In most cases, humans required numerous attempts to produce a standardized form of the tool they intended. According to probability theory, the degree of correspondence between the predicted shape of a stone tool and the actual outcome depends on multiple trials; consequently, the more attempts made, the greater the alignment between expectation and result. Developing familiarity with crafted tools and the associated traditions was advantageous for humans in prehistoric times. However, attaining this level of proficiency necessitated extensive trial and error. If the expected outcome was not achieved on the first attempt, it prompted reflection on potential flaws in the process, leading the individual to reevaluate and adjust their strategies and expectations. It is evident that these experiments were accompanied by challenges that humans had to navigate, particularly the occurrence of mistakes—specifically practical errors. When a person chips and shapes a stone in an attempt to craft an Acheulean tool or employ the Levallois technique, mistakes are likely to happen. In truth, such errors are inevitable and cannot be entirely avoided, yet they can be anticipated and accounted for when creating a new tool. There is a natural link between making mistakes and the process of trying again.

The density of stone tool technologies in the African archaeological record raises numerous issues and additional questions that should be considered separately from the traditional question: How were the tools made? Among these are: Is it possible to modify the size and shape of manufactured tools? Can errors resulting from production defects be corrected? Can the fragments generated during the striking process be preserved for later use? And is there a system in place to maintain or repair tools that have been damaged?

From a technological perspective, Juan I. Morales and Josep Vergés sought to provide convincing answers to these questions by examining the typological data and characteristics from numerous European sites. They concluded that Paleolithic communities actively engaged in the maintenance of stone tools (Morales and Vergés, 2014, 302) and subsequently reused them. Evidence from the La Cativera site in Spain, uncovered within the Level B deposits dating to the Upper Paleolithic and comprising approximately 29 stone artifacts, indicates that roughly 63% of the tools had been reshaped (Morales and Vergés, 2014, 304). They further concluded that there is a correlation between the use of red ochre and the maintenance of stone tools, possibly applied to cover worn edges, especially on scrapers. Moreover, they suggested that scrapers were used and maintained repeatedly, and were only discarded once their edges had become completely worn down (Morales and Vergés, 2014, 305–307).

By examining all the available evidence, we can conclude that the emergence of these technologies was a phenomenon that significantly contributed to the advancement of human life and strengthened its economic foundation, equipping humans with the means to meet their various needs. The stone technologies employed by humans in Africa and other regions of the ancient world reflect the lifestyles of these communities, which evolved along distinct cultural trajectories. Nevertheless, there is a remarkable consistency in the improvements that spanned generations, suggesting some form of communication or knowledge exchange among these communities. The similarities observed in techniques across different parts of the ancient world can be interpreted as either the dissemination of knowledge or migrations that facilitated the transfer of these practices from one region to another. It also reflects a fundamental aspect of natural intelligence: imitation or copying. Applied archaeologist Dietrich Stout and his colleagues emphasize that imitation is essential for acquiring complex technical skills and, consequently, marked a turning point in the development of human knowledge (Stout et al., 2011, 1334–1335). Furthermore, we can interpret all innovations in tool types as evidence that transitioning from one state to another in tool production is impossible without a corresponding conceptual shift in technical understanding.

The knowledge of tool-making was transmitted across generations through learning, as humans needed to acquire appropriate behaviors at every stage of life. This process required the presence of guiding elders who taught their children the tool-making traditions they had themselves inherited from their parents. It seems that this cultural transmission also fostered the development of language and social communication, both within individual groups and between different groups (Straffon, 2019, 423–425). Language, as is widely recognized, opened new and expansive avenues for interaction, enabling ideas to be effectively passed from one generation to the next.

Consequently, it is important to emphasize that, over the course of their development, stone tools underwent numerous transformations, whether in terms of form, function, adaptation to environmental shifts, or interactions with social and cultural factors. These transformations followed a cumulative pattern, with each new tool evolving directly from its predecessor, reflecting evolutionary adaptations often fine-tuned in response to changes in the natural environment. The transition from Oldowan to Acheulean technologies offers compelling evidence in support of this interpretive model, as the expansion into the East African savanna played a pivotal role in driving the emergence of Acheulean techniques. It is worth noting that humans at that time perceived their natural world very differently from how we perceive ours. For them, the environment was experienced as a continuous, interconnected whole, rather than as a system fragmented into numerous discrete elements, which we now symbolize with distinct signs and names. Consequently, their mental framework was directly and automatically influenced by changes in their surrounding environment. It is also evident that, under the pressures of evolving environmental conditions, people adapted their lifestyles by developing new technologies tailored to these changes.

For instance, research employing an interdisciplinary approach provides extensive insights into the activities of southern African populations and their interactions with the environment during the Middle Paleolithic. Around 77,000 years ago, the inhabitants of the Gi ≠ site in Botswana (where ≠ denotes a click consonant) possessed hunting technologies, such as spear-throwers, which enabled them to pursue large game, including zebras, wild cattle, and African pigs. Similarly, the inhabitants of Klasies River Mouth Cave in South Africa, approximately 60,000 years ago, devised a variety of ingenious methods to extract food from their natural surroundings. Among these methods, they deliberately burned grasslands to promote the growth of certain edible root tubers, which are known to flourish following exposure to fire (Wong, 2006, 80). It can be concluded that the emergence of small, finely crafted (microlithic) tools, produced using the Levallois technique and tailored for specific functions, such as scraping hides, stone-tipped arrows for hunting large or small game, and tools for perforating shells and making ornaments, was closely connected to the use of earlier widely employed tools. Through continuous experimentation and the accumulation of practical experience, humans progressively developed tools that were more sophisticated, efficient, and functionally specialized. Although this process of innovation was gradual, requiring considerable time to fully crystallize and spread—whether through direct diffusion or cultural imitation, it proved to be both significant and transformative. The long-standing coexistence between humans and stone, "the primary material from which most of the most effective tools were made," was undoubtedly grounded in this evolutionary principle.

Based on the evidence presented, a coherent explanatory model can be proposed for the phenomenon of human coexistence within a quantum framework (Tegmark and Wheeler, 2001, 68–75). This model conceptualizes the phenomenon in terms of three quantum-like states: the observer/human, the object under investigation/technology, and the natural environment. Such a framework allows for the formation of quantum superpositions of mental and behavioral states. Humans, as observers, are inherently driven to elevate their behavior, often surrounding themselves with a constellation of objects that functions as an energetic field. This field is frequently measurable, particularly given the expansive nature of the aura relative to the human's complex organic structure. Furthermore, it appears evident that the mechanisms of natural selection in humans are intimately connected to the creation of cost-effective technologies capable of transforming materials from the biosphere into usable energy, thereby enhancing human adaptability and agency .

In numerous studies, researchers have applied emerging functional concepts, such as adaptations, to explain the dynamics of human-technology coexistence. A key focus is on the anatomical features of the human hand and the precise, firm grip necessary for using and producing stone tools,whether through striking or pressure techniques. From this perspective, once humans achieved fine control over wrist movements, they were able to manipulate stones in all directions with remarkable ease during the manufacturing process (Mary and Marzke, 2000, 121–140), ensuring that strikes were delivered accurately and uniformly across the stone surface. This advancement occurred alongside the development of sophisticated hand-eye coordination (Ambrose, 2001, 1750, as well as the critical moment of decision-making regarding the tool's intended form—a cognitive process governed by the brain. Together, these developments underscore the intricate integration of anatomy, motor control, and cognitive planning in the evolution of early human technology.

Grahame Clark observed that the way in which stone tools were selected to meet human needs held significant adaptive value, a fact that can be traced t G. Clark emphasized that the selection of stone tools to meet human needs carried significant adaptive value. This adaptive function is evident in the roles that hand axes, scrapers, and hunting arrows played in the daily lives of hunter-gatherer groups throughout the Pleistocene and Holocene (Clark, 1970, 78). The careful choice and use of these tools reflect not only technological skill but also a deep understanding of environmental demands and survival strategies, highlighting the intricate interplay between human behavior, cognition, and material culture. hrough the roles of hand axes, scrapers, and hunting arrows in the lives of hunter-gatherer groups during the Pleistocene and Holocene (Clark, 1970, 78). Based on the foregoing, it can be asserted that the production of manufactured tools revolved around stone as the primary material, with techniques varying to create diverse shapes and types, each serving a specific and distinct function. These industries, as previously mentioned, were in part influenced by environmental and climatic changes, and even more significantly by changes in human biological composition and cognitive capacities (Režek et al., 2018). Small stone blades and cutting tools emerged as clear indicators of behavioral modernity, as mastery of this complex technology undoubtedly reflects the capacity of late Pleistocene South African hunter-gatherers at Pinnacle Point 5–6 (5–6 Pinnacle Point) to comprehend intricate concepts and engage in symbolic behavior.

A final point to note in this section, which is dedicated to the study and analysis of stone tools and symbolic behavior, is that some scholars have attempted to explain the emergence of complex behavior through the framework proposed by the "Behavioral Big Bang" theories. This model emphasizes—drawing on various biological and evolutionary perspectives and employing precise terminology—that modern human behavior developed gradually over a long period within an evolutionary context, rather than as the outcome of a continuous linear progression in economic and social systems. In other words, it was not a sudden revolution akin to the Neolithic Revolution, which transformed human society from a subsistence economy based on hunting and gathering to a productive economy grounded in agriculture and animal husbandry, accompanied by the rise of cities and permanent settlements.

From both theoretical and practical perspectives, this model, at least in my view, has limited and narrow applicability and cannot be relied upon in isolation to study the evolution of symbolic behavior in Homo sapiens or even in their predecessors. This limitation arises from several factors; most importantly, changes in human behavior cannot be attributed solely to biological evolution, but rather emerge from a combination of diverse influences, including the environment, demography, economy, and other factors. Accordingly, the evolution of symbolic behavior in humans cannot, under any circumstances, be regarded merely as the development of an anatomical trait; rather, it represents the evolution of a complex historical and behavioral phenomenon.It is therefore clear that, based on the available evidence, the evolution of symbolically mediated behavior has been, and continues to be, closely intertwined, both temporally and geographically, with another critical factor: complex cognition.

Symbolism:

Paleoanthropological studies confirm that the origin of *Homo sapiens* lies in Africa. Archaeological excavations carried out in 2003 and 2005 uncovered human remains in the Herto region and at the Omo Kibish site in Ethiopia. These remains have been dated, using a variety of techniques, including luminescence dating, to approximately 195,000 years ago (Goebel, 2007, 194; Wong, 2001, 76). Modern humans had acquired the capacity for symbolic thought by this period. In its broadest sense, symbolic thinking involves extracting elements from accumulated experiences through interactions with natural, social, and metaphysical environments, and representing them as discrete mental symbols (Tattersall, 2006, 67–68). These symbols were, in various ways, linked to intuitive reasoning, a fundamental component of human cognition. Through this reasoning, tangible and measurable objects are connected with the ideas they evoke and subsequently transformed into distinct and specific symbols.

From a historical and geoarchaeological perspective, it can be stated that, between the Middle Paleolithic and the Neolithic across much of southern Africa, humans engaged in activities closely associated with symbolic behavior. They utilized advanced polished tools, including projectile weapons and related technologies, established alliances and social networks extending over thousands of miles across diverse geographic regions, and expressed themselves through art and its associated rituals (Brown, 2012, 591) .The discovery of stone tools at Pinnacle Point 5–6, Howiesons Poort, and Blombos Cave in South Africa (Jacobs and Roberts, 2009, 306), provides compelling evidence that their makers possessed the capacity for complex and sophisticated thought (Figure 5), which was transmitted across successive generations. These assemblages, as noted above, not only document the emergence of modern human cognition and behavior but also delineate the cultural horizon associated with anatomically modern humans, dating back approximately 200.000 years ago.

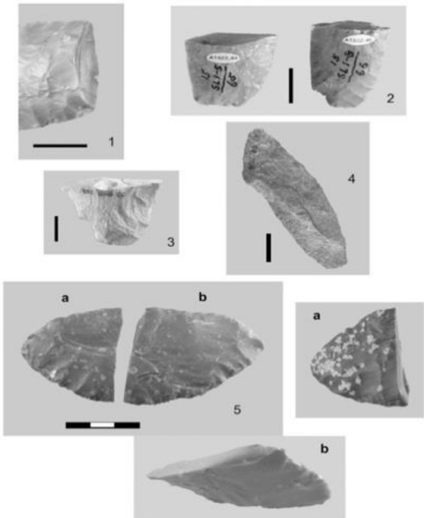

Figure (5): Examples of snap and perverse fractures. (1–2) Agate Basin projectile points from the Frazier site (Colorado). All three specimens have lateral snap fractures, due to impact on the distal end causing breakage in the haft. (1) Distal-middle portion; (2) two bases. All have grinding of the proximal edges, proof that they are finished and used points. (3) Lateral snap on P 53, a phase 2a Blombos point of fine silcrete; the hollow in the stone is an imperfection that may have been the cause of break during manufacture. (4) Perverse fracture on P 67, a phase 3 Blombos point of coarse-grained silcrete. (5a, b) Experimental, unfinished bifacial foliate point broken during manufacture by Jacques Pelegrin (direct percussion with a soft hammer); the twisting surface of the fracture is evident in Fig. 5b. Scale bars¼ 1 cm. (After Villa et al, 2009, 450).

One of the most intriguing aspects of symbolic behavior in Modern humans is the discovery of a piece of ochre within the stratigraphy of Blombos Cave, dated to approximately 75,000 years ago (Jacobs and Roberts, 2009, 304; Wong, 2006; 80; Mourre, 2010, 660; Straffon, 2019, 412). This piece is engraved with a fine-pointed stone tool, and its shape suggests it may have been used for record-keeping or possibly as a form of aesthetic design (Figure 6). The effort required to prepare this piece and engrave the marks, comprising "opposing groups of parallel straight lines", indicates that it was an activity involving deliberate thought, rather than a random or purposeless task (Figure 7).

Similar uses of ochre have been documented in other regions. In Mount Carmel, Palestine, Erella Hovers and her team discovered collections of red ochre pieces near the graves of *Homo sapiens* in the Qafzeh Cave deposits, dating to approximately 92,000 years ago. Hovers suggests that quantities of plant and animal pigments were likely heated in hearths to produce the crimson color, most likely for use in funerary rituals (Wong, 2006, 82-83).

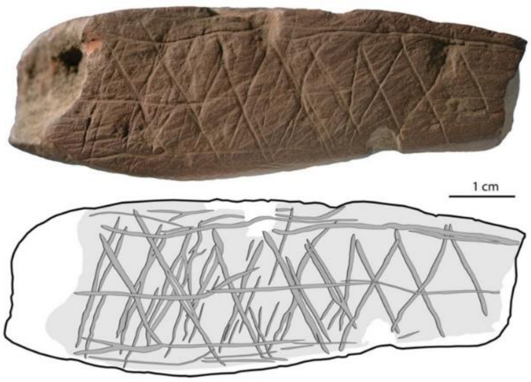

Figure (6): The engraved pattern consists of two sets of superimposed oblique lines, which are intersected and framed by three horizontal lines. Analysis of the lines suggests that the oblique lines were initially cut in sequence from the top right to the bottom left. (After Henshilwood et al., 2009, 35).

Figure (7): Nassarius kraussianus shells were experimentally perforated using different techniques: through the aperture with a lithic point (a–e), from the outside with a lithic point (f–h), from the outside with a bone point (i–k), through the aperture with a bone point (l–o), and using a crab claw (p). (h and k) Micro-chipping is observed on the internal shell wall in (h and k) and on the outer shell wall in (d–e, m–p). These results illustrate the varying effects of different perforation methods on shell integrity. (After d'Erric et al, 2005, 17).

The production of shell ornaments represents a key aspect through which behavioral modernity and the use of symbols can be understood. Marine mollusks were not only a rich source of nutrients but also served symbolic purposes. For instance, marine mollusks were the most frequently represented animal material in the records of Haua Fteah Cave and its stratigraphy, located in eastern Libya. These mollusks are associated with the Paleolithic cultural and industrial phase known as the Pre-Aurignacian, with optical dating placing their use between 101±6 and 67.7 thousand years ago. Mollusks were integrated into the diet of the cave's inhabitants during this period. Shells and beads became widely used during the Dabban industry phase, between 43.5 and 17.1 thousand years ago, serving similar roles to those found in Blombos Cave. These discoveries are considered key indicators of the emergence of Homo sapiens in North Africa around 73,000 to 65,000 years ago (Douka et al., 2014, 58-59; Adaba, 2020, 298).

Shells of marine mollusks became a means of artistic expression. In Blombos Cave (Fig. 7), the inhabitants collected a group of shells that were almost identical in size and perforated them near the aperture using stone tools, bones, or crab claws. They then strung them together into braided strands of shiny beads. These ornaments are considered the earliest known form of human-made jewelry and provide evidence that the inhabitants of Blombos used them as symbolic objects, possibly exchanged as gifts with other groups to strengthen social ties and ensure mutual support during times of hardship (d'Erric, 2005, 17).

The findings from the site of Enkapune Ya Muto (Shifting Cave) in central Kenya provide further support for this interpretation. Excavations of deposits dated to approximately 50,000 years ago revealed knives made of black volcanic glass (obsidian), microlithic stone scrapers, and a collection of disc-shaped beads fashioned from ostrich eggshells, which were likely exchanged as gifts with other human groups. Moreover, ethnoarchaeological studies of some contemporary societies that still maintain traditional lifeways suggest that modern hunter-gatherers, such as the Kung San people of Botswana,continue to exchange gifts in the form of beaded necklaces that closely resemble, in size and shape, those discovered at Enkapune Ya Muto (Wong, 2006, 79).

In this context, some researchers argue that humans evolved a genetic capacity for symbolic communication, closely linked to cognitive skills that facilitated the development of more effective hunting strategies and the efficient use of natural resources. This capacity served as a key driving force in the evolution of human symbolic behavior.

Practically, it is evident that the intricately crafted spears made of bone and ivory, equipped with barbs and designed for fishing, recovered from the stratigraphy of the Katanda site in the Democratic Republic of Congo—dated to approximately 80,000 years ago-carry clear symbolic significance. These spears are closely associated with the seasonal mobility system adopted by humans at the time as part of their subsistence strategy. Laboratory analyses also revealed traces of giant Nile catfish on the Katanda spears, providing researchers with strong evidence that people visited this site during the fish spawning season (Wong, 2006. 80). It is noteworthy that stone tools were not used solely for the practical exploitation of animal and plant resources; they also functioned as emblems and symbols in rituals and ceremonial practices of the time. For instance, the inhabitants of Tadrart Acacus, during the period spanning the Late Pleistocene to the Early Holocene, employed stone tools in a variety of ceremonial contexts-whether for slaughtering animals and burying their bones, or in activities tied to seasonal cycles, such as the summer dry season or the spring when plants grow and bloom (di Lernia et al, 2013, 25).

When discussing the natural environment, numerous questions naturally arise. For example, did hunter-gatherers perceive their surroundings as a single, interconnected entity, or as a fragmented system composed of numerous discrete elements? Examination of the material evidence suggests that hunter-gatherers viewed the environment as both connected and distinct, linking it to cognitive processes and expressing it through symbolic representation. Among the most notable artifacts reflecting this advanced cognitive behavior are the specialized bone tools crafted by the Aterian hunter-gatherers who inhabited Libya and North Africa approximately 90,000 years ago (Bouzouggar et al, 2018, 10). These tools, measuring roughly 122 mm in length, were primarily made from the rib of a large mammal, possibly from the bovine family, carefully cut, peeled, and polished. They were likely used as sharp knives for cutting and preparing fish for consumption.

The question that naturally arises is: how did modern humans manage to accomplish this feat? The answer can, in fact, be linked to concepts of adaptation and natural selection. Paleoanthropologists associate the material advances achieved by humans with the emergence of certain physiological changes, suggesting that selective pressures played a crucial role in driving these developments. In this context, Curtis Marean argues that the evolution and enlargement of brain size endowed Homo sapiens with the capacity to explore new territories, confront dangers, and exploit a diverse range of food resources (Marean, 2015, 34; Goebel, 2007, 194) .

In principle, groups using long-range projectile technologies, such as the bow and arrow, held significant advantages over those relying solely on short-range handheld weapons, both in hunting and in conflicts between individuals or groups (Brown, 2009, 591–592; Ambrose, 2001, 1753). Researchers suggest that Homo sapiens began migrating out of Africa around 80,000 years ago, spreading to various regions of the world, including Australia (Marean, 2015, 34). Archaeological evidence from several rock shelters in northern Australia, such as Malakunanja II and Nauwalabila I, indicates that modern humans reached the continent approximately 60,000 years ago. These migrants, traveling from Southeast Asia, were required to construct sturdy watercraft and navigate long distances across open ocean waters. Scholars agree that Homo sapiens at that time possessed both the cognitive capacities and technical skills necessary for boat construction, as well as extensive knowledge of navigation and seafaring (Wong, 2006, 82). They were equipped with advanced technologies and demonstrated a remarkable ability to adapt to new and diverse natural environments (Marean, 2015, 34–35).

A final point worth noting in the context of analyzing and interpreting stone tools and symbolic behavior is that some scholars have explained the emergence of modern human behavior through the “Behavioral Big Bang” model. This model emphasizes,using various biological and evolutionary perspectives and precise terminology, that modern human behavior developed gradually over an extended period as part of an evolutionary process, rather than as a direct result of continuous economic or social advancement. In other words, it was not a sudden revolution like the Neolithic Revolution, which transformed human societies from a subsistence economy based on hunting and gathering to a productive economy centered on agriculture and animal domestication, ultimately leading to the emergence of cities and permanent settlements.

From both theoretical and technical perspectives, I consider this model to be limited in scope and insufficient on its own for studying the evolution of symbolic behavior in Homo sapiens or even in earlier humans. This limitation arises from several factors, the most significant being that changes in human behavior cannot result solely from biological evolution; they are shaped by multiple factors, including the environment, demography, economy, and others. Therefore, the evolution of symbolic behavior in humans cannot be regarded merely as the development of an anatomical trait; rather, it is fundamentally the evolution of a historical and behavioral phenomenon. Based on the information currently available, I can assert that the development of symbolically mediated behavior has always been,and continues to be, closely intertwined, both temporally and geographically, with another essential element: complex cognition.

Complex Cognition:

Extensive research in neuroscience demonstrates that the acquisition of stone tool-making skills induces structural modifications in the brain, particularly within the neural pathways connecting the parietal and frontal lobes. These neuroanatomical changes are correlated with enhancements in executive functions, strategic planning, and memory capacity. Such findings underscore the pivotal role of specific brain systems in the production of stone tools, and suggest that the systematic practice of tool manufacture significantly contributed to the development and organization of the modern human brain (Putt, 2019, 308–309; Cataldo, 2018, 1–10; Stout et al, 2011, 1329–1338) .For a long time, it was widely assumed that Stone Age tools, including Acheulean hand axes, were simple implements that required minimal effort, little planning, or limited cognitive ability to produce. However, a recent study by experimental archaeologist Dietrich Stout (Fig. 8), published in Proceedings of the National Academy of Sciences in April 2016, shows that crafting a hand axe in the Lower Paleolithic involves complex cognitive control mediated by the brain's prefrontal cortex. This process engages a component of working memory known as the central executive function, highlighting the sophisticated mental capacities required for early stone tool production (Stout, 2016, 30–32).

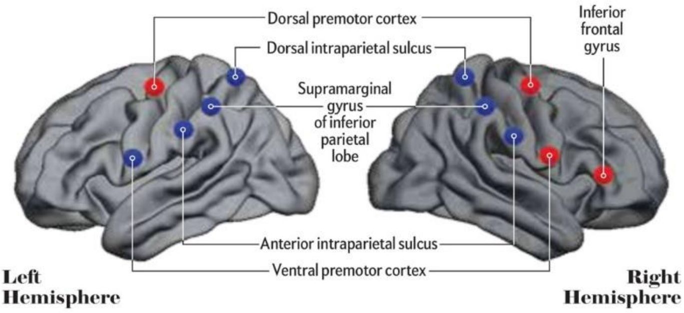

Figure (8): Expansion of Brainpower **:**Neuroimaging studies reveal that increasingly sophisticated toolmaking engages larger areas of the brain. The images highlight distinct regions activated when a modern toolmaker produced a tool resembling simple Oldowan implements (2.6 to 1.6 million years ago) compared with the regions involved in crafting Acheulean hand axes (1.6 million to 200,000 years ago). Blue dots indicate brain regions activated during the production of both Oldowan and Acheulean tools, while red dots show additional regions specifically engaged when shaping an Acheulean hand axe. (After Stout, 2016, 33).

This study involved subjecting a group of volunteers to multiple MRI scans to observe the neural regions activated while they were trained in stone knapping for two distinct lithic industries: Oldowan and Acheulean (Stout, 2016, 31). These industries were in use between 2.6 million and 200,000 years ago, a crucial evolutionary period marked by technological, anatomical, and behavioral changes among hunter-gatherers. The primary aim of the experiment was to examine the relative contributions of motor control versus strategic planning in the production of stone tools (Putt, 2019, 310–313).

This study further revealed that crafting an Acheulean hand axe is considerably more complex and detailed than previously thought (Fig. 9). The process goes beyond mere imitation and repetition; it demands specialized skills, careful preplanning, precise strike placement, and highly controlled hand movements. In addition, it requires a degree of complex cognitive processing (Stout, 2016, 31) .Even with extensive practice, mastering the production of a hand axe remains challenging due to its lens-shaped form, which tapers gradually toward its symmetrical edges.

Figure (9): Chips off the Block: A novice toolmaker produced a finished flint hand axe, with the surrounding flakes representing the material removed during the knapping process. Each flake was carefully labeled, weighed, and measured, enabling a detailed analysis of the learner's motor coordination, precision, and planning abilities throughout the tool-making sequence. (After Stout, 2016, 34).

For example, anticipating the outcome of striking a specific point on a stone involves reflexive actions, perceptual processing, and motor control, all of which are linked to the posterior regions of the brain. In contrast, determining whether striking the center of the stone at a particular spot is appropriate when making a hand axe relies on strategic thinking. This entails storing information and mental representations of the tool's shape and size, then retrieving them during decision-making to shape the final implement. Dietrich Stout highlighted a clear relationship between prefrontal cortex activity and the ability to execute precise motor actions while making informed technical decisions, ultimately resulting in the production of stone tools that are both more accurate and functionally effective (Stout, 2016, 34–35).

High-precision analyses using Optically Stimulated Luminescence (OSL) dating (see Roberts and Lian, 2015, 438–439), also referred to as luminescence dating, indicate that the bow and arrow were employed by humans in Africa as early as 71,000 years ago. The sophisticated production techniques of this weapon system provide compelling evidence that Homo sapiens had already mastered complex concepts and possessed the capacity for symbolic thought at that time.

Brown and colleagues detail the six-step process used by the inhabitants of Pinnacle Point 5–6 and Howiesons Poort for producing finely crafted small points that served as stone arrowheads. These steps include: collecting and transporting raw stone materials, gathering firewood, heat-treating the stones, selecting cores and removing small flakes, shaping and refining the points to their final form, and finally attaching these points to arrow shafts (McBrearty, 2012, 532).

The production of bows and arrows involved multiple sequential steps, reflecting a high level of planning and technological sophistication. These steps included collecting and transporting raw stone materials, gathering fuel wood, heat-treating the stones, selecting cores, and flaking them into small pieces to produce finely crafted microlithic points for arrowheads. The arrowheads were then shaped, polished, and attached to the shafts. Additional steps involved collecting and preparing other organic materials, such as wood, plant fibers, feathers, bones, and resins. Acacia gum, sometimes mixed with iron oxide, served as an adhesive to securely bind the different components of the arrow (Wadley et al, 2009, 9593–9594; McBrearty, 2012, 532).

From a technological perspective, crafting stone-tipped arrows and bows was a complex process that could take days, weeks, or even months. The ability to retain the forms, sizes, and production techniques of these tools in memory, and to reproduce them anywhere and at any time, demonstrates the operation of the executive function, a core component of the modern human mind. This highlights the advanced cognitive capacities of early Modern Human (McBrearty, 2012, 532; Stout, 2016, 35) .

Overall, the tools recovered from Blombos appear considerably more complex and technologically advanced than those typically found at Middle Paleolithic sites elsewhere in the Old World. Excavations have revealed sets of bone tools shaped into finely polished, pointed awls or borers, some treated with ochre to achieve a high degree of smoothness, as well as hundreds of bifacial silcrete points used as projectiles for hunting wildebeest and other large game. Additionally, the inhabitants of Blombos possessed the necessary equipment for hunting large aquatic animals in the ocean (Wong, *2006,* 82).

Conclusions:

This study demonstrates that the earliest stone tools crafted and used by humans for daily activities were discovered in Africa, within the volcanic deposits at the Lomekwi 3 site on the western shore of Lake Turkana, Kenya, dating back approximately 3.3 million years. Over time, the production of stone tools evolved to encompass a wide variety of forms and types, utilizing techniques such as the hammer-and-anvil method, pressure flaking, and heat treatment of stones. These tools played a central and transformative role in driving human development across successive cultural and civilizational stages.

Furthermore, the discovery of pointed stone tools, blades and arrows, scrapers, sharp flakes, as well as perforated spiral shells and pieces of ochre used for artistic purposes at multiple sites across southern Africa, demonstrates that Homo sapiens, by approximately 71,000 years ago, had developed the capacity to conceive complex and abstract ideas and to express them through symbolic forms.

The spiral shells recovered from Blombos Cave may have conveyed symbolic meanings analogous to those communicated today through diamond rings and bracelets. Although the physical forms of ornaments have evolved over time, the symbolic significance they embody has remained remarkably consistent and enduring. It has also been observed that a significant expansion of the brain accompanied the evolution of Homo sapiens, resulting in enhanced communication networks within the brain that enabled symbolic thought. This capacity for symbolic reasoning became a central element of human behavioral organization, allowing modern humans to expand in all directions and assume a dominant role in the living world. Crucially, the production of stone tools—particularly Acheulean hand axes and microlithic implements, including small sharp blades—depended on complex cognition. This complexity was grounded in the advanced capabilities of the central executive function, a key component of modern brain architecture.

The information and data gathered from multiple sites in southern Africa provide valuable insights into the evolution of modern human thought and behavior. At coastal sites such as Pinnacle Point**,** Howiesons Poort**,** Cabo**,** Klasies**,** Blombos**,** and Diepkloof, researchers have uncovered collections of small, pointed stone blades, ornaments, ochre-based pigments, and other materials indicative of symbolic and cognitive sophistication. This pattern is also observed at numerous other archaeological sites across Africa and the Near East, including Twin Rivers and Kalambo Falls in Zambia, Mumba in Tanzania, Enkapune Ya Muto and Kapthurin in Kenya, Taforalt in Morocco, and Es Skhul Cave**in** Mount Carmel, Palestine.

We also found that complex behavior, with its distinctive manifestations and diverse material expressions, emerged at approximately the same time as modern humans, around 200,000 years ago. However, it did not appear suddenly; rather, it developed gradually over the thousands of years that followed. The interdisciplinary approach adopted in this study has yielded significant results. On the one hand, it provides a solid foundation for historical research, equipping scholars not only with essential theoretical frameworks but also with the technical tools required for rigorous analysis. On the other hand, it enables the development of comprehensive explanatory models capable of interpreting a wide range of historical phenomena. Accordingly, I recommend adopting this approach as a foundational framework for a new research perspective in which different branches of knowledge are effectively integrated within departments of history, archaeology, and related disciplines.

Despite the gaps and limitations that characterize the African historical and archaeological record—issues discussed throughout this paper,it nevertheless preserves several cultural horizons and distinctive chronological, evolutionary, and technological sequences that are unparalleled in the Old World. In addition to the well-known sites associated with the earliest emergence of humans in Turkana, often described as the cradle of early humanity, and Olduvai Gorge, archaeological investigations at sites such as Blombos Cave, Pinnacle Point, and Howiesons Poort have yielded some of the earliest clear archaeological evidence of complex behavior among modern humans, including abstract symbolic engravings.

Several other sites also provide important cultural evidence of human adaptation to natural environments, together with the technological and social innovations associated with these processes. The stratigraphy of Haua Fteah represents a particularly significant case, as deep excavations have established a detailed cultural sequence extending from the Middle Paleolithic to the Neolithic period. Moreover, Haua Fteah has produced one of the most complete successions of Upper Pleistocene industries currently known in North Africa. Meanwhile, Uan Afuda Cave in the Acacus Mountains, with its distinctive and successive developmental sequence, offers an important model for examining the emergence and growth of cultural complexity among Acacus populations in the Libyan Sahara.

Stone tools, with their diverse morphologies, long perceived as simple and easily shaped implements, are increasingly recognized as repositories of critical evidence for human evolutionary history and the emergence of complex behaviors, potentially extending far earlier than previously assumed. The trajectory of tool development,from the Oldowan, through the Acheulean and Levallois Middle Paleolithic, to microlithic and Holocene technologies, cannot be understood as a single, linear narrative. Instead, it represents a complex, interwoven sequence of technological and behavioral innovations, reflecting patterns of adaptation and cognitive advancement that continue to challenge conventional interpretations. Furthermore, the historical and archaeological record remains inherently dynamic and open to reinterpretation. Just when a particular sequence appears fully resolved, new discoveries, ranging from minute stone tools to fragmentary faunal remains, can emerge, reshaping the narrative and opening entirely new perspectives on human prehistory.

References:

1. Adler D. S. et al (2014)." Early Levallois technology and the Lower to Middle Paleolithic transition in the Southern Caucasus ". In Science, vol. 345. Pp. 1609 – 1913. https://doi.org/10.1126/science.1256484
2. Adaba, Ahmed Salem (2026). "Phenological Factors and Subsistence Strategies in Changing Environments: A Case Study of Late Pre-Pastoral/Late Acacus Sites in the Libyan Sahara during the Early–Mid Holocene". African Journal of Advanced Studies in Humanities and Social Sciences. 5, (1). Pp. 648–666.
3. Adaba, Ahmed Salem (2020). A general look at the residential sites of the Upper Pleistocene in Libya and the cross cultural relations with its desert-coastal and Eastern Mediterranean. Journal of the Academic Forum, 4, (2). Pp. 283-334.
4. Adaba, Ahmed Salem (2022)."Structural Features of Early Acacus/Epipaleolithic Occupation Sites in Southwest Libya during the Early Holocene". Kan Journal. Vol. 15. Issue. 58. Pp. 14-31:
5. Ambrose, Stanley (2001). " Paleolithic Technology and Human Evolution ". In Science, Vol. 29. Pp. 1748 - 1753. https://doi.org/10.1126/science.1059487

6. Berger, Lee et al (2015). "Homo naledi, a New Species of the Genus Homo from the Dinaledi Chamber, South Africa". in eLife, Article No. 09560. Published online.
7. Bouzouggar, Abdeljalil et al (2018) . “90,000 year-old specialised bone technology in the Aterian Middle Stone Age of North Africa”. in. PLOS One. Vol. 13. No.10.
8. Brown, Kyle et al (2009). " Fire as an Engineering Tool of Early Modern Humans **".** In science, vol. 325.
9. Brown, Kyle et al (2012). " An early and enduring advanced technology originating 71,000 years ago in South Africa ". In Nature, vol. 491. Pp. 590 – 593: https://doi.org/10.1038/nature11660
10. Brown, Samantha et al (2022). " The earliest Denisovans and their cultural adaptation". Nature Ecology and Evolution. VOL. 6. Pp. 28–35.
11. Callaway, Ewen and San Francisco (2015). " Oldest stone tools raise questions about their creators ". In Nature, vol. 520.
12. Cataldo, Dana (2018). "Speech, stone tool-making and the evolution of language". In Plos On, Vol.13, No.1. Pp. 1-10.
13. Clark, G (1970). Aspects of Prehistory, University of California Press, London, 1970.
14. Cueva-Temprana, Arturo et al (2022). " Oldowan Technology Amid Shifting Environments∼2.03–1.83 Million Years Ago". Frontiers in Ecology and Evolution, Vol. 10. Pp. 1-14.
15. d’Errico, Francesco et al (2003). Archaeological Evidence for the Emergence of Language, Symbolism, and Music—An Alternative Multidisciplinary Perspective". Journal of World Prehistory, Vol. 17, No. 1.
16. d’Erric, Francesco et al (2005). "Nassarius kraussianus shell beads from Blombos Cave: evidence for symbolic behaviour in the Middle Stone Age". Journal of Human Evolution, Vol, 48. Issue. 1. Pp. 3-24.
17. d’Errico, Francesco et al (2012). "Early evidence of San material culture represented by organic artifacts from Border Cave, South Africa". PNAS, vol. 109, no. 33. Pp. 13214–13219.
18. de la Torre, Lgnacio (2011). " The origins of stone tool technology in Africa: a historical perspective ". In Philosophical Transactions of the Royal Society. Vol. 366. Pp. 1028–1037.
19. di Lernia , Savino et al (2013). “ Inside the ‘‘African Cattle Complex’’: Animal Burials inthe Holocene Central Sahara “. In PLOS ONE, vol. 8, issue 2.
20. di Lernia, Savino (1999). “ Why Uan Afuda? The “pre-pastoral” archaeology of the Acacus and surroundings “. In The Uan Afuda cave: hunter-gatherer Societies Central Sahara. Edizioni All’Insegna del Giglio, Firenze.
21. Douka, Katerina et al (2014)." The chronostratigraphy of the Haua Fteah cave (Cyrenaica, northeast Libya)". Journal of Human Evolution, vol. 66, 2014.
22. Goebel, Ted (2007). “The Missing Years for Modern Humans ". In science, vol. 315.
23. Gravina, Brad et al (2005). "Radiocarbon dating of interstratified Neanderthal and early modern human occupations at the Chatelperronian type-site". *Nature*, Vol. 438, pp. 51–56: https://doi.org/10.1038/nature04006
24. Guimarães, Santiago et al (2020). "What have the revelations about Neanderthal DNA revealed about Homo sapiens? ". In Anthropological Review, Vol. 83, No.1. pp. 93–107.
25. Haber, Marc et al (2016). " Ancient DNA and the rewriting of human history: be sparing with Occam’s razor". In Genome Biology, Vol. 17.
26. Harmand, Sonia et al (2015). " 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya ". In Nature, vol. 521, 2015.
27. Henshilwood, Christopher and Benoît Dubreuil (2011). "The Still Bay and Howiesons Poort: Symbolic material culture and the evolution of the mind in southern Africa". Current Anthropology, Vol. 52, No. 6. Pp. 693–727.
28. Henshilwood, Christopher et al (2002). "Emergence of modern human behavior: Middle Stone Age engravings from South Africa". *Science*, 295, (5558). Pp. 1278–1280.
29. Henshilwood, Christopher et al (2009). " Engraved ochres from the Middle Stone Age levels at Blombos Cave, South Africa". Journal of Human Evolution, 57. Pp. 27–47.
30. Holloway, Ralph et al (2018). " Endocast morphology of *Homo naledi* from the Dinaledi Chamber, South Africa". In PNAS. vol. 115, no. 22. PP. 5738-5743.
31. Hovers, Erella (2015). " Tools go back in time ". In Nature, vol 521.
32. Hublin, Jean-Jacques et al (2026). " Early hominins from Morocco basal to the *Homo sapiens* lineage". Nature, Vol. 649, 22. Pp. 902-908.
33. Jacobs, Zenobia and Richard Roberts (2009). " Human History Written in Stone and Blood ". In American Scientist, Vol. 97.
34. Killin, Anton (2026). "Behavioral Modernity, Neanderthals and Homo sapiens: a Case for Concept Retirement". Biol Theory .https://doi.org/10.1007/s13752-025-00527-2
35. Kreier F (2026). Neanderthal dad, human mum: study reveals ancient procreation pattern. Nature. doi: 10.1038/d41586-026-00583-z. Epub ahead of print. PMID: 41748888.
36. Marean, Curtis (2015). " The Most Invasive Species of All ". In Scientific American, vol. 313, no. 2. Pp. 32 – 39.

37. Martín-Ramos, Carmen (2025). "Evolutionary cognitive archaeology and Acheulean technology: A historiographic review". Cambridge Archaeological Journal. Vol. 35. Issue 4. Pp. 633-647.
38. Martinón-Torres, María et al (2024). "No scientific evidence that Homo naledi buried their dead and produced rock art". The Journal of Human Evolution, Vol. 195.
39. Mary, Marzke and Marzke. R (2000). " Evolution of the human hand: approaches to acquiring, analysing and interpreting the anatomical evidence ". In Journal of Anatom, vol. 197. Pp. 121 – 140.
40. McBrearty, Sally (2012). " Sharpening the mind ". In Nature, vol. 491.
41. McBrearty, Sally and Alison Brooks (2000). " The revolution that wasn't: a new interpretation of the origin of modern human behavior ". In Journal of Human Evolution, vol. 39, No. 5**.**
42. Mellars, P. (2005). The impossible coincidence: A single-species model for the origins of modern human behavior in Europe. *Evolutionary Anthropology*, 14(1), 12–27.
43. Mongle, Carrie et al (2025). " New fossils reveal the hand of Paranthropus boisei". Nature, Vol. 647 . pp. 944-951.
44. Morales, Juan and Josep Vergés (2014). " Technological behaviors in Paleolithic foragers. Testing the role of resharpening in the assemblage organization ". In Journal of Archaeological Science, no. 49. Pp. 302 – 316.
45. Mourre, Vincent et al (2010). " Early Use of Pressure Flaking on Lithic Artifacts at Blombos Cave, South Africa ". In science, Vol. 330.
46. Nabais, Mariana and Joao Zilhao (2025). "Ungulates and carnivores from the late MIS-5 Neanderthal occupation of Gruta da Figueira Brava (Portugal)". Frontiers in Environmental Archaeology, Vol. 4.
47. Platt, Alexander et al (2026). "Interbreeding between Neanderthals and modern humans was strongly sex biased". SCIENCE , Vol. 391, Issue. 6788. Pp. 922-925.
48. Potts, Richard et al (2004). " Small Mid-Pleistocene Hominin Associated with East African Acheulean Technology ". In Science, vol. 305.
49. Potts, Richard et al (2004). " Small Mid-Pleistocene Hominin Associated with East African Acheulean Technology ". In Science, vol. 305.
50. Putt, Shelby (2019). " The Stories Stones Tell of Language and Its Evolution". In Squeezing Minds From Stones: Cognitive Archaeology and the Evolution of the Human Mind. Oxford, Oxford University Press. Pp. 308-309.
51. Reich, David and Eugenie Reich (2018). Who we are and how we got here: Ancient DNA and the new science of the Human past. Oxford, Oxford University Press.
52. Režek**,** Željko_et al (2018). "Two million years of flaking stone and the evolutionary efficiency of stone tool technology". Nature Ecology and Evolution, Vol. 2. Pp. 628-633. doi: 10.1038/s41559-018-0488-4.
53. Roberts, Richard and Olav Lian (2015). " Dating techniques: Illuminating the past ". In Nature, vol, 520. 23 April 2015. Pp. 438 – 439.
54. Sanches-Mazas, Alicia (2001). "LES ORIGINES DE L' HOMME, AU COEUR DE SES GÉNES". Pour la science. No. 289, Novembre. p. 86.
55. Savelkouls, Ashley et al (2026) "High-resolution $^{40}Ar/^{39}Ar$ geochronology of the Koobi Fora Tuff Complex, Turkana Basin: Implications for the hominin bearing strata of the Early Pleistocene (1.6–1.4 Ma)". Quaternary Geochronology, Vol. 91.
56. Scerri, Eleanor and Manual Will (2023). "The revolution that still isn't**:** The origins of behavioral complexity in *Homo sapiens*". *Journal of Human Evolution, Vol. 179.*
57. Schlanger, Nathan (1996). " Understanding Levallois: Lithic Technology and Cognitive Archaeology ". Cambridge Archaeological Journal, Vol. 6, 2 . pp. 231–254.
58. Semaw, Sileshi (2000). " The World's Oldest Stone Artefacts from Gona, Ethiopia: Their Implications for Understanding Stone Technology and Patterns of Human Evolution Between 2·6–1·5 Million Years Ago ". In Journal of Archaeological Science, no. 27. Pp. 1197–1214.
59. Semaw, Sileshi et al (2003). " 2.6-Million -year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia ". In Journal of Human Evolution, no. 45 .
60. Shannon, McPherron et al (2010). " Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia ". In Nature, vol. 466.
61. Shixia, Yang et al (2025). Exploration of "behavioral modernity" in human evolution. *Acta* Anthropologica Sinica*.* https://www.anthropol.ac.cn/EN/10.16359/j.1000-3193/AAS.2025.0
62. Sirak, Kendra et al (2020). "Human auditory ossicles as an alternative optimal source of ancient DNA". In Genome Research. Vol. 30. No. 3. Pp. 427-436.
63. Solano-Garcia, Jose and Anne-Marie Moigne (2025). "Hunters of the "Mediterranean Triad": persistent and intensive exploitation of faunal resources during the Late Middle Pleistocene at Cueva del Ángel (Lucena, Spain)" .Frontiers in Environmental Archaeology, Vol. 4.

64. Soriano, Sylvain et al (2015). "The Still Bay and Howiesons Poort at Sibudu and Blombos: Understanding Middle StoneAge Technologies". PLoS ONE, Vol. 10,7.
65. Stout, Dietrich (2016). " Tales of a Stone Age Neuroscientist: By honing ax-making skills while scanning their own brains, researchers are studying how cognition evolved ". In Scientific American, vol. 314, no. 4.
66. Stout, Dietrich et al (2011). " Technology, expertise and social cognition in human evolution ". In European Journal of Neuroscience, vol. 33, 2011. pp. 1329–1338.
67. Straffon, Larissa (2019). "Evolution and the origins of visual art: An archaeological perspective". In Handbook of Evolutionary Research in Archaeology. Springer, Switzerland.
68. Sümer, Arev et al (2025). "Earliest modern human genomes constrain timing of Neanderthal admixture". Nature, vol. 638.
69. Tattersall, Ian (2006). " How We Came to Be Human ". In Scientific American, Special edition, vol. 16, no. 2. pp. 66 – 73.
70. Tegmark, Max and John Wheeler (2001). " 100 Years of Quantum Mysteries ". In Scientific American, Vol. 284. No. 2. Pp. 68 – 75.
71. Traynor, Sarah et al (2019). "Metatarsophalangeal proportions of Homo naledi ". In South African Journal of Science, Vol. 115, Issue. 5-6,. Pp. 84 – 91.
72. Tribolo, Chantal (2023). Luminescence Dating in Africa: Historical and Methodological Overview. In: Beyin, A., Wright, D.K., Wilkins, J., Olszewski, D.I. (eds) Handbook of Pleistocene Archaeology of Africa. Springer, Cham. Pp. 1917-1929.
73. Tryon, C. A et al (2019). African Middle Stone Age: Regional diversity and the emergence of behavioral modernity. Current Anthropology. Vol 60, (4), 401–432.
74. Val, Aurore (2016). " Deliberate body disposal by hominins in the Dinaledi Chamber, Cradle of Humankind, South Africa?". In Journal of Human Evolution, vol. 96.
75. Vernot, Benjamin et al (2021). "Unearthing Neanderthal population history using nuclear and mitochondrial DNA from cave sediments". In Science. Vol 372, Issue 6542.
76. Villa, Paola et al (2009). " The Still Bay points of Blombos Cave (South Africa). Journal of Archaeological Science, Vol. 36. Pp. 441–460
77. Wadley, Lyn et al (2009). " Implications for complex cognition from the hafting of tools with compound adhesives in the Middle Stone Age, South Africa ". In PNAS, vol. 106 , no. 24.
78. Webb, John and Marian Domanski (2009). " Fire and Stone ". In Science, vol. 325.
79. Westbury, Eboni et al (2025). "Neanderthal resilience and adaptability: insights from the Abric Pizarro faunal assemblage during the MIS 4". Frontiers in Environmental Archaeology, Vol. 4:
80. Wilkins, Jayne et al (2012). " Evidence for Early Hafted Hunting Technology ". In Science, vol. 338. Pp. 942 – 946.
81. Wong, Kate (2006). " The Morning of the Modern Mind ". In Scientific American, Special edition, vol. 16, no. 2.
82. Wong, Kate (2009). " Twilight of the Neandertals". In Scientific American, vol. 301, no. 2.
83. Wong, Kate (2015). " Neandertal Minds **".** In Scientific American, Vol. 312, no. 2.
84. Wong, Kate (2016). **"** Mystery Human". In Scientific American, vol. 314, no. 3. .
85. Zilhão, João (2010). " Did Neandertals Think Like Us? ". In Scientific American, vol, 302, no. 6.
86. McGil, Liam (2015). "Neanderthal Behavioral Modernity and Symbolic Capabilities". Journal of Collegiate Anthropology. Vol. 7. (1). Pp. 60–74