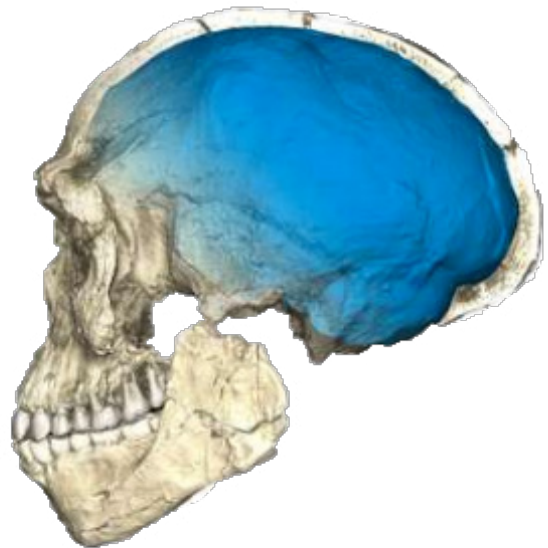


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SAPIENS: THE NEW BEGINNING

SCRIPT - JUNE 21st 2018

A TWO-PART DOCUMENTARY - 104 MINUTES
DIRECTED BY OLIVIER JULIEN - PRODUCED BY HIND SAIH

Homo Sapiens: A New Departure

a two-part documentary - 104 minutes

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**THE DISCOVERY OF THE JEBEL IRHOUD MAN:
THE WORLD'S OLDEST HOMO SAPIENS FOSSILS**

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HOMO SAPIENS, A NEW SCIENTIFIC MODEL

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Episode 1

The discovery of the Jebel Irhoud man: the world's oldest Homo sapiens fossils

Introduction

In June 2017, in the scientific journal *Nature*, an international team led by professors Jean-Jacques Hublin and Abdelouahed Ben-Ncer published an article about their archeological finds at Jebel Irhoud in Morocco.

The news swept across the world in the press: the team announced the discovery of *Homo sapiens* fossils that were 300,000-year-old, according to thermoluminescence dating.

Their results contradicted the generally accepted theory placing the dawn of our species in East Africa 200,000 years ago. These remains are 100,000 older, and they were found over 6,000 kilometers from the region considered to be “the cradle of humanity.”

A - Ben-Ncer: “It was a shock, even for us! We thought they were old, but we couldn’t have imagined they would date back so far... It’s quite extraordinary...”

And this discovery did not come out of the blue. The first hominin skull had been found at the Irhoud site over 50 years ago. But its dating and interpretation have varied significantly ever since, influenced by historical vicissitudes, advances in dating techniques and the progress made in our understanding of human evolution. Since its discovery, the site has been poorly preserved, left abandoned and damaged by erosion, looting and vandalism.

For 30 years, Jean-Jacques Hublin and Abdelouahed Ben-Ncer were fascinated by Jebel Irhoud and dreamed of excavating it again. In 2004, they persuaded two institutions, the Moroccan National Institute of Archeology and Heritage (known as the INSAP, Institut National des Sciences de l’Archéologie et du Patrimoine) in Rabat and the Max Planck Institute in Leipzig, to provide them with all of the technological resources of modern archeology.

The findings from this new excavation at Jebel Irhoud mark an undeniable turning point in the way we understand the origins of our species.



PART 1: JEBEL IRHOUD, A WIDELY-DEBATE AND FRAGILE ARCHEOLOGICAL SITE (1960 TO 2004)

A - Introduction

In May 2018, during a final excavation campaign prior to the definitive closure of the archaeological site, an unexpected discovery was made:

excavators came across yet another cavity with deposits that seemed to extend under the cliff face to the east. If these deposits contained other remains, they would be older than previous finds.

Over night, there was a massive landslide.

The mission was suspended to stabilize the site, but miraculously the freshly excavated area was spared.

J.J. Hublin, A. Ben-Ncer and S. McPherron arrived on site to appraise the situation and recounted the stories that drew them to this excavation.

B - Unearthing the Jebel Irhoud man (1960s to 1970s)

This sequence features shots of the researchers at work interwoven with interviews set on-site or in archeological laboratories, illustrated with archival footage, renderings and fossil and tool collections.

The scene opens with drone shots over the Jebel Irhoud site and archival photographs of Moroccan miners. A miner lifts a skull from the rubble created by a blast.

In the 1960s, during a mining operation in one of the many caves that dot Jebel Irhoud's hillside, miners unearthed an impressive fossilized skull.

Computer-generated imagery (CGI) of the 3D model of the site created at the Max Planck Institute & archival photographs from Ennouchi's collection.

Shannon McPherron provides analysis on site and in another untouched cave in Jebel Irhoud.

Emile Ennouchi, a professor at Morocco's University of Rabat, led a campaign to excavate the site. The cave's ceiling was blasted away to gain access, creating 2,000 metric tons of debris.

Collections at the Rabat Archeological Museum: skulls, tools and animal remains.

Over the course of 3 years, many artifacts and fossils were unearthed at the site: another adult skull, the lower mandible of a child, many animal remains and a collection of flint tools. But unfortunately, the exact location of many of the specimens was not recorded.

Drawing upon European understandings of stone tools, Ennouchi identified these skeletal remains as belonging to African Neanderthals. Carbon-14 dating estimated that they were 40,000 years old.

A. Ben-Ncer on location

"In 1961, the true identity of the Jebel Irhoud man was unthinkable: it didn't fit with the theories of that time and it was beyond the scope of available dating technologies ... It went against everything we thought we knew... and nevertheless..."

After a number of cursory excavations in the 1970s, the archeological site was left abandoned. And most of the skeletal remains were stored at institutions in France. However, a number of researchers had serious reservations about Ennouchi's conclusion that they belonged to Neanderthals. They were also puzzled by the carbon dating results.

C - New interpretations offered by other researchers (1980s to 1990s)

J.J. Hublin studies and measures the mandible fossil

Jean Jacques Hublin is one of the researchers to have taken an interest in these fossils, publishing his first article in 1981 based on an examination of the mandible fossil, designated as Irhoud 3.

"It was my first encounter with the material from Irhoud, but this jaw line could not have been that of a Neanderthal."

Rabat, Morocco: A comparative analysis of the skulls by Professor A. Ben-Ncer

For A. Ben-Ncer, it was his doctoral exam at the University of Bordeaux that led him to assess the differences between the skull found at Jebel Irhoud and that of a Neanderthal.

"Despite the elongated shape of the skull, the face is retracted and angular below the cheekbones, but without the prognathous jaw found in Neanderthals. Without a doubt, it's the face of a *Homo sapiens*. But the skull doesn't yet have all the traits found in the modern man. So it's indisputably a primitive *Homo sapiens*."

Carrying cases containing skulls, designated as Irhoud 1 and 2

In 1982, the 2 skulls unearthed at Jebel Irhoud were returned to Morocco: on the occasion of King Hassan II's birthday, Yves Coppens was sent as a French envoy to present the fossils to him. 20 years after its initial discovery, the Jebel Irhoud man had finally been confirmed to belong to the *Homo sapiens* species.

But the age of the remains, estimated to be 40,000 years old, remained problematic.

Professor Fethi Amani

"An analysis of the remains of small rodents, such as mice and gerbils, suggested the site was much older; some of the species found were known to have only lived in the region between 700,000 and 125,000 years ago."

Electro spin resonance (ESR) dating at the Max Planck Institute in Leipzig, Germany

In the 1990s, J.J. Hublin, a world-leading paleontologist, sought to recalculate the direct age of the Irhoud 3 mandible, using a technique called electro resonance spin spectroscopy (ESR), also known as electro paramagnetic resonance (EPR).

Daniel Richter, a geochronology expert at the Max Planck Institute (MPI)

"With carbon-14 dating, it is impossible to date materials further back than 50,000 years ago and so a result of 40,000 years actually indicates a range between 40,000 and infinity. ESR allows us to go back 1 one million years."

A visual demonstration of the ESR technique

This method takes advantage of a specific property in crystalline substances such as tooth enamel: over time electrons are trapped in the defects of the mineral's structure due to the natural background radioactivity emitted by the soils in which the specimens had been buried. The number of trapped electrons varies, depending on the annual intensity of the soils' radioactivity and the duration of the object's exposure. An analysis of these electrons can reveal the specimen's age. This time, the results indicated that the Irhoud 3 fossil is 160,000 years old.

An animated map of Africa, archival footage & skulls from Omo Kibish and Herto

In the early 2000s, all eyes were on Ethiopia in East Africa, where the oldest known *Homo sapiens* fossils had been discovered:

the 195,000-year-old Omo Kibish remains and the 160,000-year-old Herto fossils. These finds along with early genetic studies gave rise to the theory that our species had evolved from a "Garden of Eden" in East Africa

J.J. Hublin

"For me, the Omo Kibish and Herto skulls, which were believed to be the same age or older than those of Irhoud, seem in some ways less archaic... And the ESR dating had been done without an accurate calibration of the site's radioactivity because it was inaccessible at the time... I dreamed of settling this once and for all, but it took time to make it possible..."

PART 2: THE REDISCOVERY OF THE JEBEL IRHOUD MAN: A 21ST CENTURY ARCHEOLOGICAL DIG (2004 TO 2010)

A - A gamble made with state-of-the-art technology

The archeological site at Jebel Irhoud

In 2004, J.J. Hublin was appointed Director of the Department of Human Evolution at the Institute Max Plank in Leipzig. He immediately went to work to build a partnership with the Moroccan National Institute of Archeology and Heritage (INSAP, Rabat), where Professor A. Ben-Ncer was teaching, to launch a new joint excavation project. This new venture sought to collect new fossils that could be more accurately dated with modern-day methods.

J.J. Hublin

"It was a gamble to believe that, despite all the damage to the site, there were still elements on location that would allow us to finally establish a valid chronology."

A. Ben-Ncer

"The first stage consisted mostly of clearing the rocks that had fallen onto the site during the 20 years it had been left abandoned with bulldozers to uncover the area that had previously been excavated."

Scanning the site with a 'Total Station' laser: a digital model in the making

Knowing that this could very likely be their last opportunity to excavate the site, the researchers left nothing to chance: they adopted a multidisciplinary approach, using the most cutting-edge techniques.

Shannon McPherron

"Thanks to the digital measurements recorded for all of the finds along with the photographs taken at each step along the way, we will be able to build a digital replica of the entire dig site, pinpointing the location of each object unearthed from the sediment. It will be an archive that can be used by future generations to test other hypotheses."

B - New fossils

Filming the Jebel Irhoud excavation site

When the dig resumed in 2005, their excavation strategy proved worthwhile: within the first few years, the site had yielded an unimaginable amount of material. Soon after, Jebel Irhoud became one of the richest and well-documented archeological sites in all of Africa.

A. Ben-Ncer

"The site proved to be exceptionally generous. One of the most memorable moments was during a dig in 2007, when we discovered a skull. And then underneath this skull, we found a tibia, in the same place!!! These are once-in-a-lifetime moments for an archeologist!!"

J.J. Hublin

"I already had a long career behind me, but I found myself digging and not wanting to stop... discovering new fossils was the opportunity of a lifetime."

Skulls and other remains conserved at the INSAP and the Max Planck Institute (MPI)

The number of unearthed human fragments soars from 5 to 22.

A. Ben-Ncer

"In all, we have collected the remains of at least 5 individuals: three adults, a juvenile and a child between the ages of 6 and 8. We wonder if it might be a family."

C - Virtual analysis of archeological data

3D modeling of the fossils & a virtual reconstruction of the mandible at the MPI

Jean Jacques Hublin is a pioneer in the field of virtual paleoanthropology.

3D images were created from each fossil with computed tomographic (CT) scans. Using algorithms, virtual reconstructions were made, accounting for the missing or deformed parts of the fossils from this data.

Interview with J.J. Hublin and P. Gunz

"The process of reconstructing damaged fossils from hundreds of thousands of years ago has been completely revolutionized: we now have powerful computer technologies and all of most recent statistical tools at our disposal. And we can test and visualize all sorts of interpretations."

CGI of a skull reconstruction & 3D morphometric measurements

The most impressive work to date has been the composite reconstruction of a full skull of these early *Homo sapiens*, generated from CT scans of multiple original fossil fragments.

J.J. Hublin and his team then compared the shape of this virtual skull to those of modern humans through a statistical analysis of hundreds of 3D measurements.

Scatter plot graphic

The most stunning revelation: the face of the Jebel Irhoud man would not stand out in a crowd today. However, the skull shape and tooth size retain the characteristics of more archaic features.

D - The mystery of the Jebel Irhoud man is gradually revealed

Meanwhile, a picture of these primitive *H. sapiens* and the world they inhabited is pieced together little by little in the multidisciplinary study.

The following sequence interweaves film shot at the dig site and at the laboratories at MPI and beyond. The landscape footage will be overlaid with short graphic animations, gradually revealing the silhouettes of 5 Jebel Irhoud people in their cave, around a fire, making flint tools or looking out over the plains.

At the Max Planck Institute, with S. McPherron & a 3D model of the dig site

The majority of the fossils were extracted primarily from level 7 and some from level 6 of the excavation site, which is also where most of the animal remains, stone tools and vestiges of human dwellings were unearthed. These finds indicate that these archaic humans had inhabited the site on a permanent basis for a short time, and then later stayed on occasion before completely abandoning the area.

At the dig site, Professor F. Amani examines small bone fragments brought to him by excavators.

"We have found the remains of thirty-some mammal species, principally those of gazelles, which seem to be their food of choice.... But small game as well which was much rarer."

Professor Teresa Steele of the University of California, Davis examines specimens with an electron microscope

Once the animal remains had undergone traditional analyses, Professor Teresa Steele conducted a taphonomic study, an in-depth examination of the bones using an electron microscope to identify any significant markings. "Clearly, the animal remains are for the most part from game, which had been eaten here. Many of the bones have been burned or fractured..."

In Steele's analysis, she points to traces of cut marks in longer bones, an indication that they had been broken to extract the marrow.

A. Ben-Ncer at the excavation site

“What we are seeing are very selective tastes. The Jebel Irhoud man knew what he liked. The primitive humans who lived here preferred to hunt big game. Clearly, this location was advantageous for these hunters: perched up high and overlooking a vast plain, game can be spotted kilometers away in every direction from Jebel Irhoud.

S. McPherron at the archeological site and in the laboratory cataloguing flint tools.

The theory that this site was used as a hunting encampment was confirmed by an analysis of the stone tool assemblages.

These observations are as valuable as they are rare, for few early human fossils have been discovered alongside lithic technologies in Africa.

S. McPherron

“These tools have been fashioned from flint flakes rather than stone cores, which is a more sophisticated and advanced development in tool making. They are similar to those found at Neanderthal sites in Europe, but also to tools that are found throughout sub-Saharan Africa, which have been identified as “Middle Stone Age” technology. The emergence of this type of tool is considered an important step in the evolution of human behavior.”

The complete lithic collection from Jebel Irhoud at the INSAP

The remarkable discovery: the majority of these tools were made from high-grade flint, which is not present in the area surrounding the site. And very few flint cores or nuclei were found in the excavation. These observations suggest that the tools from Jebel Irhoud were made elsewhere.

A. Ben-Ncer with two colleagues in the flint artifact tent

Upon further investigation, similar types of flint were found at two local sites: 30 kilometers from Jebel Irhoud flint flakes are scattered across hundreds of meters.



PART 3: A GAME CHANGING DISCOVERY FOR OUR SPECIES

A - A new chronology

At the Jebel Irhoud site

While these new findings enriched our understanding of the primitive humans at Jebel Irhoud, the central issue driving this new excavation had yet to be resolved: establishing an accurate chronology for the site. And the unearthed hearths along with the many burned flint flakes would play a key role in revealing this mystery.

J.J. Hublin

"Well dated sites documenting the emergence and evolution of *H. sapiens* in Africa are incredibly rare. But we were extraordinarily lucky to find a large number of artifacts at Jebel Irhoud that had been heated in the past. This allowed us to apply thermoluminescence dating methods."

Graphic sequence illustrating the thermoluminescence dating (TL) technique
Based on the same principles of ESR (electron spin resonance), thermoluminescence dating is used to analyze different crystalline structures such as flint. In contrast to ESR, heat is applied to the sample, which emits a measurable light signal as trapped electrons are released.

Daniel Richter, a geochronology expert at the MPI

"The clock is 'reset to zero' when the crystals are heated to temperatures above 500° Celsius. In the period after the flint artifacts were initially exposed to high temperatures in the unearthed dwellings, they have absorbed additional electrons over time."

Archival footage of Richter installing detectors on the site / Filming at the MPI thermoluminescence laboratory

However, precise calibration is the key to thermoluminescence (TL) dating. Every year, Daniel Richter installed 47 detectors on the site to measure the levels of ambient radioactivity. Before proceeding with the excavation of each new layer of sediment, measurements were collected over the course of an entire year. In 2010, he got the first results of his TL dating. The findings were a bombshell: Level 7 and the fossils it contained dated back 315,000 years, give or take 34,000.

A. Ben-Ncer

"We simply couldn't believe it. The data was recalculated dozens of times. It means that every history book from the last 30 years has to be re-written!"

B - In the wake of the discovery

Archival footage and photographs

The findings made the front page of over 2,000 newspapers around the world.

In Morocco, it was a source of great national pride. The researchers received the nation's highest honors from the King of Morocco and a monumental project was undertaken to make the site more accessible to the public.

The discovery has also been lauded throughout the field of archeology.

Yves Coppens, Chris Stringer & Richard Klein

"With this remarkable work, Jebel Irhoud is now the only African site from this period to be so accurately dated and documented. It's a breakthrough in terms of chronology and geography. It's a game changer. It forces us to think beyond the generally accepted theory that our species emerged from a sub-Saharan 'Garden of Eden' and to conduct research throughout the African continent."

S. McPherron

"It's unprecedented to find MSA [Middle Stone Age] tools associated with 300,000-year-old *Homo sapiens* fossils. And it provides answers to a longstanding question."

J.J. Hublin

"From an evolutionary standpoint, it's highly significant. It suggests that face of modern humans had evolved much earlier than we had previously thought. Therefore, the primary factor in history of our species' evolution is the adaptation of the human brain. And this evolution spanned over 200,000 years."

Conclusion & a preview of Episode 2

The hypothesis of a 'cradle of humanity' in sub-Saharan Africa has been laid to rest, but this discovery has far wider reaching implications than simply pushing back the origins of *H. sapiens* by 100,000 years or crowning Jebel Irhoud as humanity's new "Garden of Eden".

The findings in the Nature publication suggest an entirely different origin story for our species. Drawing upon research carried out over the course of the last decade in various regions of Africa, the authors propose a new scientific model in which humans evolved more gradually across the whole of Africa, developing adaptations that would later allow humans to inhabit the entire planet.



Episode 2

Homo Sapiens, a new scientific model

All earlier scientific certainties about the origin of our species have recently been upended with the discovery of 300,000-year-old *Homo sapiens* fossils at Jebel Irhoud in Morocco. These finds notably call into question the theory that the first archaic humans emerged 200,000 years ago in an East African "Garden of Eden", quickly evolving and developing adaptations that would allow them to spread out across Africa before migrating around the world.

Moreover, the well-documented and accurately dated site at Jebel Irhoud provides a solid framework through which research conducted in Africa over the past 20 years can be reinterpreted. As our understanding of the Jebel Irhoud man grows, a new model is revealed: a much more complex, 200,000-year-long process of human evolution that took place across the continent of Africa, shaped by enormous fluctuations in climate and environmental shifts, regional species diversification, intermixing with other populations and adaptations.



PART 1: NORTH AFRICA REDISCOVERED

A - A historical blind spot

A map of Africa highlighting Ethiopia, Kenya, South Africa and then Jebel Irhoud and finally North Africa

The widely accepted geographic framework of human evolution was nullified with the discovery of *Homo sapiens* remains dating back 300,000 years in the northeast of Africa.

This breakthrough drew attention to a vast region that had previously been completely overlooked: North Africa. With the recent revelations at Jebel Irhoud, a key piece of the puzzle has been found.

J.J. Hublin

"Up until now, North Africa rarely came up in these debates for historical reasons: little research on these periods had been published in leading scientific journals and flawed dating made it difficult to interpret these fossils and compare them with those from other regions."

Archival photographs documenting archeological digs in Morocco & Algeria in the 1950s

Even so, North Africa contains a large number of Paleolithic sites. Yet, most were discovered and excavated during or just after the colonial period, using less exacting methods. They were primarily interpreted through the framework of chronologies developed in Europe and elsewhere, but not Africa. As a result, nearly all of these sites were plagued by the same problems that had long masked the reality of Jebel Irhoud.

B - The presence of very ancient populations

At contemporary excavation sites in Morocco

Since the late 1980s, a huge effort has been undertaken, especially in Morocco, to bring researchers to study these sites from across the world.

Like Jebel Irhoud, newly excavated artifacts and fossils are analyzed with more advanced methods to determine their chronological age.

As these sites are excavated, this region's part in human history is uncovered.

Maps and archives of archeological digs / Filming at the Thomas Quarry & at the INSAP collections

In Algeria, the remains of a *Homo erectus* were unearthed, the predecessor of *H. sapiens*, at the Tighennif site. In 1986, a team J.J. Hublins was working with dated these fossils back to 700,000 to 800,000 years ago.

In Morocco, near Casablanca, the Thomas Quarry yielded new fossils associated with the Acheulean stone tool industry.

Jean Paul Raynal of the French National Center for Scientific Research & the University of Bordeaux: "The hominids from Thomas Quarry 1 comprise the most abundant and oldest series to be excavated with modern methods from a site in Morocco. They indicate the presence of a large population of hominids in the area 500,000 years ago."

Animated maps

Several sites in North Africa have yielded undeniable traces (i.e. bones and tools) of the immediate predecessors of *H. sapiens* at different stages of evolution dating between 800,000 and 400,000 years ago.

C - A key piece of the puzzle

Animated maps of 'Aterian' archeological sites / Filming at INSAP's Aterian collection

The most significant revelation from these recent excavations comes from the new chronological information established for a large number of sites spread throughout the Sahara zone, a region larger than the United States.

They are characterized by stone tools classified as "Aterian", which are found only in North Africa.

S. McPherron

"To a large extent, these tools resemble a more evolved version of those found at Jebel Irhoud, featuring a defining characteristic of the Aterian style: a stem or tang that suggests they were once hafted."

Filming at the Ifri n'Amman site (or the sites of Taforalt or Rhafas) / collections of human remains

Due to the fact that these tools were excavated along with *Homo sapiens* fossils, these sites were originally dated between 40,000 and 20,000 years ago, the period in which modern humans replaced Neanderthals in Europe.

But the layers of sediment surrounding these fossils have been re-dated in these recent digs. And just as with Jebel Irhoud, the findings have significantly turned back the clocks.

Graphic sequence of maps and timelines

The Taforalt site, also known as the Grotte des pigeons, was dated to between 80 to 90,000 years old ; in northeast Morocco, the Rhafas site was dated to 135,000 years old through luminescence dating; and the Ifri n'Amman site was dated to 145,000 years old.

These sites are much older than originally thought and they provide evidence of significant human presence throughout the Saharan zone from 150,000 to 40,000 years ago.

J.J. Hublin

"North Africa has yielded an extremely rich fossil series, recognized today as documenting human evolution between 700,000 and 40,000 years ago. It is now obvious that this region has a primordial role to play in our understanding of the emergence and evolution of *H. sapiens*, certainly as important as that of sub-Saharan Africa."



PART 2: A TRANSCONTINENTAL “CRADLE OF HUMANITY”

Footage of the desert / animated maps

Today, North Africa is separated from the rest of the continent by the planet's largest desert, the Sahara. This zone constitutes a natural barrier that is nearly impossible to cross. But we are gradually coming to the realization that things have not always been this way:

A - A shared African fauna

Animal remains unearthed at North African sites set researchers on a track to explain the presence of early *Homo sapiens* on either side of the Sahara zone.

Professors T. Steele & F. Amani with the collection of animal remains from Jebel Irhoud

“The presence of a very rich fauna is suggested by the food refuse left behind by the inhabitants of Jebel Irhoud.

They seem to have had a distinct preference for gazelles, but also zebra, wildebeest, antelope-like hartebeest and buffalo. Carnivores were also found, primarily leopards, but also some lions and smaller felines. And then smaller animals such as hedgehogs, hares, turtles, snakes and even freshwater shellfish...”

At the excavation site near Casablanca J.P. Raynal

“At the Thomas Quarry, we've found a large amount of remains from animals hunted by its inhabitants, including white rhinoceros, hippopotamuses, felines and gazelles.”

Wildlife footage shot in the Serengeti savannah in Tanzania

Taken together, the presence of these animals suggests that area's climate was much more humid than it is today and featured wide-open spaces like that of a savannah grasslands.

T. Steele carried out a thorough analysis comparing the animal remains found in northwest Africa to those of South Africa:

“On the whole, the fauna is fairly similar to that of eastern and southern Africa. Many species are common to both regions, as are nearly all of the genera. As a result, it is clear that animals migrated freely from northwestern Africa to the rest of the continent, and vice-versa, implying the absence of a continuous Saharan barrier.”



B - The “Green Sahara” phenomena

On the site of a Max Planck Institute (MPI) project in the caves of northern Morocco

This new environmental frame is corroborated by findings about the Saharan paleoclimate from research carried out in recent decades. And it requires that the entire continent of Africa be taken into consideration in the study of human evolution.

Satellite images & maps of Professor Nick Drake’s Sahara Megalake model

In areas that are deserts today, irrefutable evidence of ancient lakes, rivers and inland deltas has been discovered. An analysis of the topographic traces they left behind along with satellite images has provided an astonishing vision of North Africa’s environment 70,000 years ago: vast swaths of the Saharan zone were once home to wide rivers and lakes the size of Germany and covered with trees.

On the site of MPI’s project: collecting speleothem samples

To build models of ancient climates in Africa, scientists have a number of sources at their disposal that have recorded paleoclimate conditions, the most precise being the marine sediment cores and speleothems (mineral cave formations) collected in North African caves.

Analyzing speleothems at Washington University’s Earth and Planetary Science laboratory - Jennifer Smith

“The ratio of carbon and oxygen isotopes contained in the stalagmites provides an indication of the climactic conditions and vegetation contemporaneous to their development. Some stalactites contain pollen, which provides clues about the types of vegetation that covered the continent at a given period of time as well as the climactic fluctuations that occurred over the course of their formation.”

Graphic animation of the climate model

The climate models developed from this data have revealed a startling phenomenon: the Sahara had only become a desert in relatively recent times, about 70,000 years ago. Before then, the region had experienced what scientists have coined “green Sahara” periods.

J. Smith

“The models pinpoint volatile, oscillating monsoon patterns, which provoked significant environmental shifts throughout the entire Sahara zone.”

Animated maps and graphic reconstructions of Saharan landscapes and fauna

Over the span of thousands of years, the region experienced many intermittent periods of heavy rainfall, extending much further north than usual. During these periods, the Sahara was largely composed of savannah grasslands, prairies and, in some places, hosted lush vegetation.

J. Smith

“About 330,000 years ago, the monsoon phenomenon was particularly intense. And without a doubt, these conditions created an ecological continuity between North and sub-Saharan Africa. We can confirm that during the period in which *Homo sapiens* emerged, the inhabitants of the North African region were in close contact with the rest of Africa.”

C - The mark of *H. sapiens* throughout Africa

Stone tools found at Jebel Irhoud & Middle Stone Age (MSA) collections

Comparative analysis of stone tools from across the continent corroborates these exchanges.

S. McPherron

"The stone tools of Jebel Irhoud closely resemble artifacts from what we call the 'Middle Stone Age' in eastern and southern Africa, distinguished by stone knapping using the Levallois technique."

Mapping the emergence of MSA tools

MSA tools appeared across sub-Saharan Africa about 300,000 years ago. However, human remains had never been unearthed at these excavation sites.

Skulls and tools from Jebel Irhoud

300,000 years ago at Jebel Irhoud, these tools were associated with early representatives of the *Homo sapiens* species for the first time.

Mapping the regional variation of MSA tools

Resembling tools developed by Neanderthals during the same period in Europe, but the shape of these MSA tools evolved over time in a manner that was unique to Africa.

S. McPherron with Acheulean and MSA tools:

"The emergence of the MSA marks a remarkable transition in behavioral evolution: for over a million years the predecessors of *H. sapiens* made rudimentary tools in the Acheulean tradition, with very little variation.

And suddenly, MSA appears and in the following 200,000 years we find many regional variations of this style across Africa: more advanced techniques, new tools developed for specific tasks and new shapes. This extensive variation can be considered a reflection of the toolmakers' unique ability to adapt to different regions.

J.J. Hublin

"The findings from Irhoud suggest this type of tool could be the distinctive marker of *Homo sapiens*, which means that a cradle of humanity, dating 100,000 years earlier, was not located in Irhoud nor North Africa. To the contrary, they suggest that 300,000 years ago the first representatives of our species were already spread across the entire African continent: in North Africa, in Ethiopia, in Kenya and in South Africa. If we were to retain the notion of a cradle of humanity, I think it would be the size of all of Africa."



PART 3: THE BIRTH OF MODERN MAN: A DIFFERENT MODEL

A - A more tangled family tree

A 3D reconstruction of the Irhoud 1 skull at the MPI laboratory

J.J. Hublin

"If we consider that the evolution of our species took place across the whole of the African continent, what is new is that with Irhoud we now have a well-archived and dated series of fossils that trace the emergence and evolution of *Homo sapiens*."

Sequence interweaving maps with a timeline & images of skulls

Salé in Morocco and Ndutu in Tanzania (400,000 years old); Kabwe in Zambia (between 300 and 400,000 years old); Jebel Irhoud in Morocco (300,000 years old); Florisbad in South Africa (260,000 years old); Omo Kibish (190,000 years old) and Herto (160 000 years old) in Ethiopia; and Qafzeh in Israel (115,000 years old).

3D renderings of skulls from each site

JJ Hublin

He carried out comparative 3D morphometric analyses of each of these first *H. sapiens* skulls to see whether they might correspond, and to find out if considering them together might indicate a path or trajectory of modern man's evolution.

Images of the comparative 3D morphometric analyses with visualizations of key points and distances & findings from the cloud data

The results indicate a considerable dispersal of cranium shapes within Africa.

Here and there, characteristics maintained in modern human anatomy are found ; other features are still archaic. But the combinations of these traits vary, which makes it quite challenging to establish a direct line of descent.

J.J. Hublin

"Overall, this dispersal tells a complex evolutionary story of our species. It occurred on the scale of the entire continent. Between northern and southern Africa, there were great movements underway during this 300,000-year period. Modern human morphology was developed very gradually and in a disparate fashion: a tangled evolutionary process with adaptations occurring in different locations and undoubtedly much intermixing with different branches making for an accretion evolutionary model in the form of a mosaic."

B - Transcontinental exchanges

Recent discoveries reinforce this gradual evolutionary model, fed by exchanges on the scale of the whole African landmass.

Animated maps / archives & collections from Blombos Cave in South Africa

Since the 1990s, South Africa has drawn much attention following the discovery of oldest-known evidence of modern human behavior. At Blombos Cave, in an excavation led by Chris Henshilwood, bone tools, engraved ochre blocks (one of the oldest-known forms of prehistoric art) and pierced sea-shell beads (one of the oldest pieces of jewelry) were unearthed from deposits dating back 73,000 years.

These artifacts, generally attributed to modern man, provide evidence of behavior.

Animated maps / archives and collections from El Mnasra / shell beads from Taforalt

However, excavations at El Mnasra (on the Moroccan Atlantic coast, near Dar es Soltane) have also yielded bone tools, hearth structures and proof of widespread use of ochre pigment. In the Aterian deposits at Taforalt, recently re-dated to 100,000 years ago, shell beads were also discovered. Like the ones from Blombos Cave, they are made from Nassarius whelks. And they are probably somewhat older than the artifacts found in South Africa.

J.J. Hublin

"It's rather extraordinary to think that humans living in Morocco and in South Africa used the same shells to make jewelry. During the period in which modern man emerged, material production and social behaviors grew more complex across Africa. Here too, a model of a continent marked by long-distance exchanges is taking shape: a vibrant continent on the move."

C - Climate fluctuations: a driving force of evolution

Once again, recent paleoclimate discoveries provide a plausible explanation for this phenomenon.

A concentration time curve of "green Sahara" periods

Paleoclimatologists' models suggest that there were key monsoon fluctuations between 350,000 and 50,000 years ago, creating the "green Sahara" phenomena. And they may have been a driving force of our species' evolution.

Juan Cruz Larrasoana (Geological and Mining Institute of Spain, Zaragoza)

"The climate and environment reconstitutions we were able to do for North Africa suggest that there was a cluster of green episodes occurring every 100,000 years or so.

The periods of highest rainfall can be observed about 315,000, 215,000, and 115,000 years ago. Within these clusters, green episodes lasting from 5,000 to 10,000 years alternate with arid times that lasted from 10,000 to 15,000 years. In contrast, around 275,000, 150,000 and 45,000 years ago arid periods lasted for over 40,000 years.

Images of the Serengeti's great migration integrated with animated human silhouettes

For thousands of years, grasslands covered North Africa, making it possible for humans and animals to settle there for hundreds of generations. During those times, migratory exchanges could take place with the rest of Africa. Then the land would gradually dry out, leading to the formation of a desert.

Animals would seek greener pastures, and the hunter-gatherers would follow them.

And a new climatic cycle would begin anew.

Animated maps

The Stone Age population of North Africa seems to have ebbed and flowed in relation to these climate changes. It developed over broad areas during green episodes. When rainfall became scarce for centuries, early humans gathered around oases, or migrated to coastal zones or south to sub-Saharan Africa.

J.C. Larrasoana

"Actually, the majority of the African hunter-gatherer populations probably migrated this way, following the game, seeking the grassland environment where life could flourish.

The central African forest belt was also subject to occasional drought. When monsoon rains did not fall, it contracted. The Kalahari Desert also seems to have varied as a consequence of these fluctuations."

J.J. Hublin

"By isolating populations for long periods of time and then bringing them into contact again, these environmental and climate events forced humans to adapt to different environments, leading to migrations and exchanges across the whole of Africa. Because of this, these events undoubtedly bolstered our species' evolution throughout the continent."

Animated maps

A new model of modern man's emergence is born: one spanning the African continent, sparked by climate and environmental changes over thousands of years, evolving from a massive "melting pot" of diverse groups of *Homo sapiens*.

D - The evolution of the human brain (optional)

But then, how might we pinpoint what makes us unique from this tangled family tree?

Which trait led modern *Homo sapiens* to be the only surviving representatives of our species and eventually inhabit the entire planet?

If this new model of a mosaic evolution across Africa renders the notion of a singular geographic origin rather preposterous, might it be possible to identify the timing of our species' emergence?

J.J. Hublin

"The Jebel Irhoud man teaches us that following his emergence, the evolution that takes place is primarily concerned with that of the human brain. And what distinguishes the modern human brain from that of other hominins is not its size - the brain cavity of the Neanderthal has the same volume, if not greater - but its globular shape, evidenced by the shape of the brain case, indicating a different brain organization."

The tools that are currently available to us can extract previously inaccessible information from fossil remains. 3D scans of skulls are the first step in producing extremely precise molds of the inside of the skull. This mold is called an "endocast." The inside of the skull yields a 3-dimensional model of the shape of the brain.

In Leipzig, **Simon Neubauer, Philippe Gunz, and J.J. Hublin** carried out extensive comparisons of the evolution of these endocasts in a variety of species, including *Homo sapiens*.

Simon Neubauer

"Irhoud provides us with a new, more complete and precisely dated starting point from which to compare other fossils. Now we can learn more about the evolutionary path of the human brain within the *H. sapiens* species. And compare it with the brains of extinct family members like the Neanderthals."

A comparative Procrustes analysis of the endocasts - J.J. Hublin

"We observe the same phenomenon with *Homo sapiens* and Neanderthals: a continuous evolutionary line from the oldest to the most recent representatives of our species. But this evolution abides by different mechanisms. And it's from this mechanism that our singularity arises."

Graphic animations of brain development: curve charts and scatterplot graphs

A comparison of the brain development in primates, Neanderthals (based on 3D reconstructions) and *Homo sapiens* reveals a postnatal growth pattern that is unique to humans: differences in brain growth rates and timing set our species apart.

A genetic chart

Today, we know that among the genetic differences between Neanderthals and modern humans, only a small number of genes relate to divergences in brain development. Could this difference be the key to our evolutionary "success"? It's quite possible.

When did this difference emerge? An analysis of endocasts suggests this "modern" variation may have occurred 100,000 years ago, a date that corresponds to the appearance of artifacts associated with modern human behavior.

Our species emerged at least 300,000 years ago. And over the course of 200,000 years, *Homo sapiens* evolved through a process of diversification and proliferation to the point of developing a brain organization similar to that of ours today.

CODA

The discovery of Jebel Irhoud overturned all earlier scientific certainties about the origin of our species. And it opened new horizons and upset the paradigms.

Paleontologists researching the dawn of humankind usually seek a single starting point: a sudden separation or emergence, a single evolutionary leap. Jebel Irhoud suggests a model of continuity, gradual mixing and shifting borders. It is a much more complex and gradual model in which climate and environment played a primordial role in accelerating evolution.

Yet at the same time, Jebel Irhoud gives today's scientists the oldest and most reliable landmark date in the history of our species, a point from which we can re-think our evolutionary path. The findings expand the horizons for investigation to the whole African continent. New visions of our ancestry are in store.



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