Background for understanding Human Evolution

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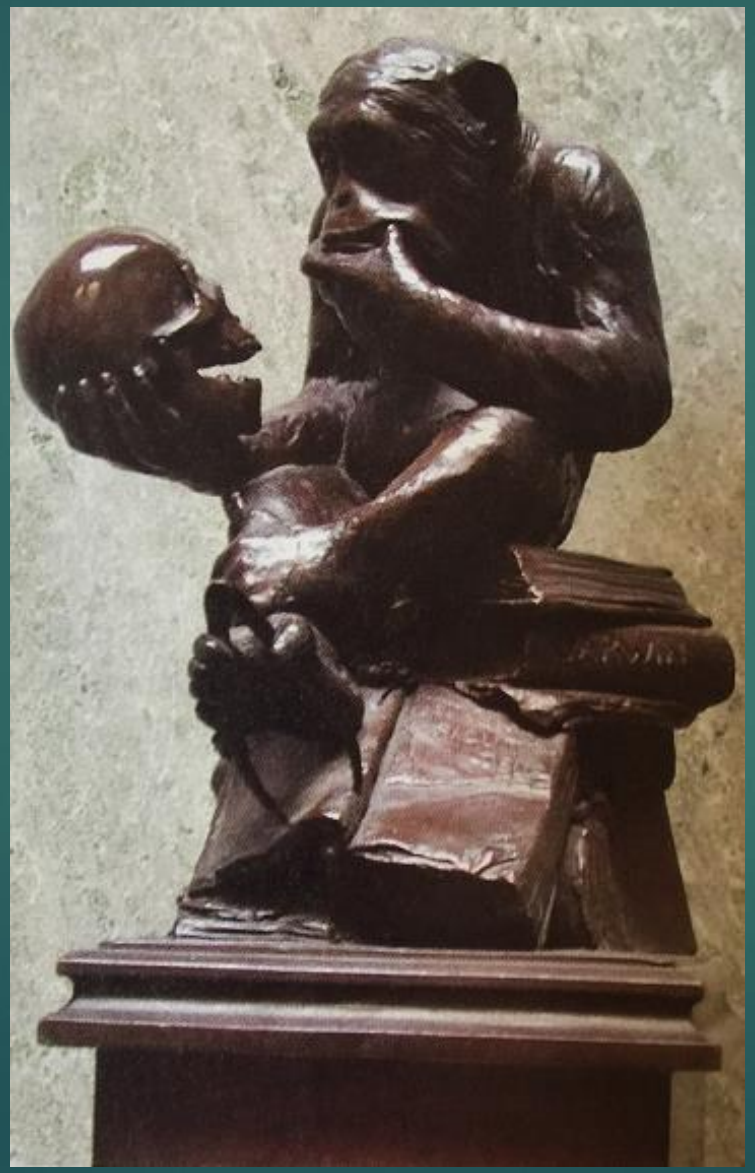
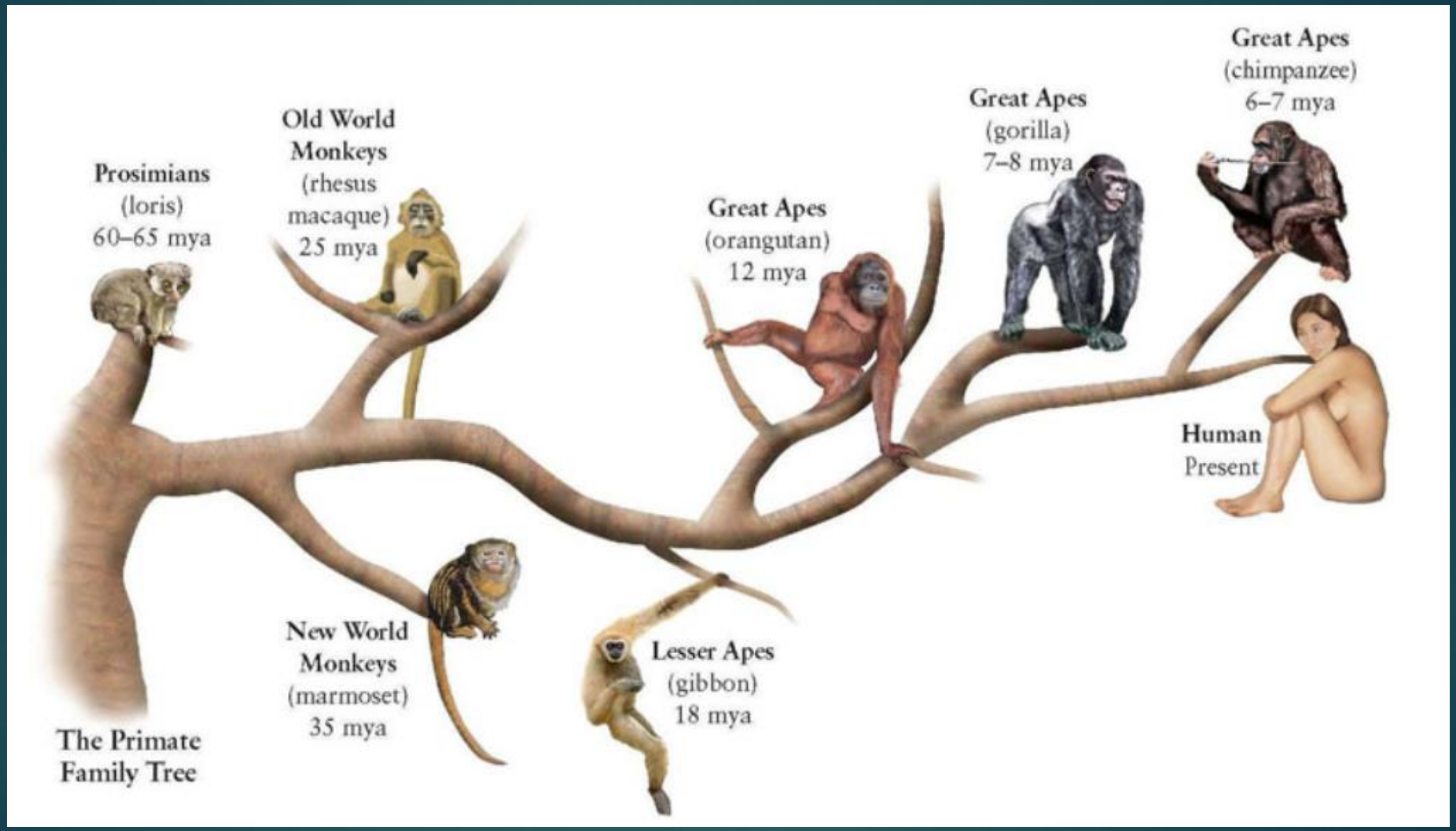
JULY 18, 2018

What do we need to know to understand human evolution?

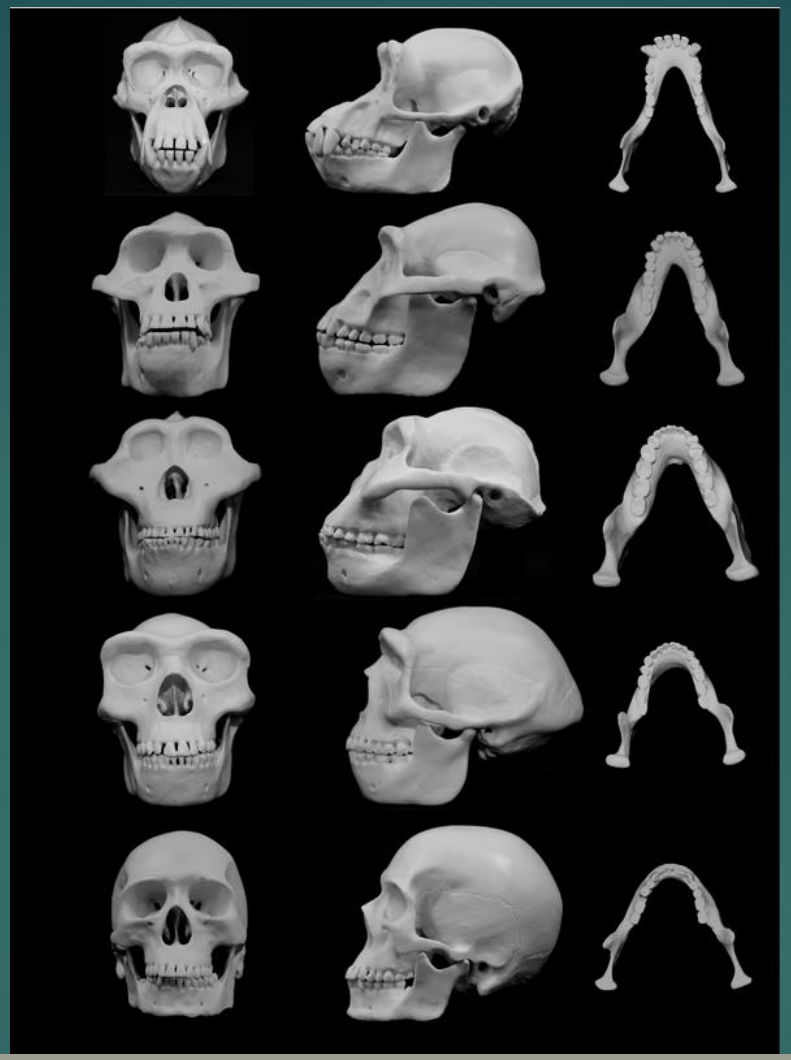


Primate Family Tree



Correct genetic relationships and times of divergence

Phylogeny of human evolution



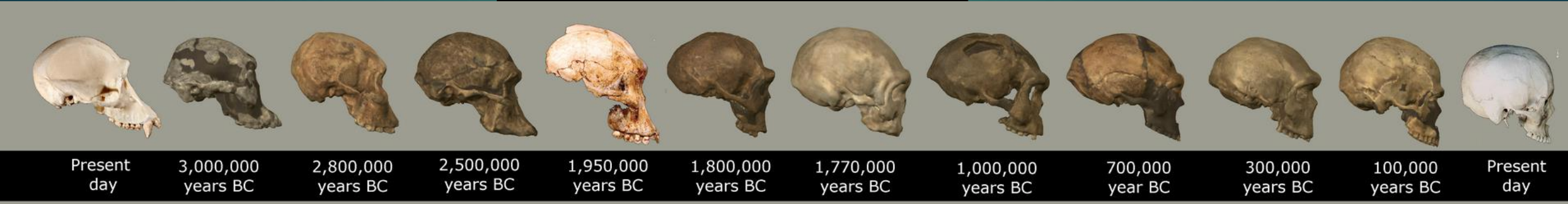
Pan

A. afarensis

P. boisei

H. neanderthalensis

H. sapiens



New paradigm

The new Human Evolution story: a review of what's coming

- Once upon a time, the story of our species' evolution was simple.
- It was the tale of a short, hairy, chimp-like creature living in Africa that gradually, over millions of years, transformed to become human. Now we know it's more interesting than that.

- Our ancestors were just one of many pre-human species living across a wide swath of the globe from South Africa to the Far East. They intermingling and sometimes interbreeding. Today we alone remain.

- Over the past 20 years, almost every part of our story, every assumption about who our ancestors were and where we came from, has been called into question.

Who are you? How the story of human origins is being rewritten
by Colin Barras, New Scientist, Aug 2017

The New picture

- A succession of spectacular fossil finds in recent years is starting to reveal our true family tree. Some of the new species have upending what we thought we knew about the evolution of key traits such as bipedalism and brain expansion.

- Studies of ancient DNA allow us to see how different species are related and to track their migration across continents.

- We have even uncovered some pre-human genes in our own genome, revealing that many of us are related to Neanderthals and the mysterious Eurasian pre-humans called Denisovans.

- Once upon a time, the human story seemed relatively straightforward. It began roughly 7 million years ago, somewhere in an east African forest, with an ape who was our LCA. Some of its descendants would change into modern chimps and bonobos. Others left the forest for the savannah. They learned to walk on two legs and, in doing so, launched our own hominin lineage.

New data

- By 4 Ma, the bipedal apes had given rise to a successful but still primitive group called the australopithecines, thought to be our direct ancestors.
  - The most famous of them, dubbed Lucy, was discovered in 1974 and given arch-grandmother status.
- By 2 million years ago, some of her descendants had grown larger brains and longer legs to become the earliest “true” human species.
  - *Homo erectus* used its long legs to march out of Africa.
- Other humans continued to evolve larger brains, with new waves of bigger-brained species migrating out of Africa over the next million years or so, eventually giving rise to the Neanderthals of Eurasia.

New look

- Those early migrant lines were all dead ends. The biggest brains of all evolved in those hominins who stayed in Africa, and they were the ones who gave rise to *Homo sapiens*.
- Until recently, the consensus was that our great march out of Africa began 60,000 years ago and that by 30,000 years ago, for whatever reason, every other contender was extinguished.
- Only *H. sapiens* remained – a species with a linear history stretching some 6 million years back into the African jungle.
- Or so we thought.

Revolution in human evolution research: line to bush

- When I first started learning about human fossils in East Africa nearly 50 years ago, the conventional wisdom was that almost all of our extinct close relatives were considered direct ancestors.

- But the discovery of multiple evolutionary branches who lived at the same time makes it much more difficult to identify our direct ancestors.

- In 1964, the path lead from *Australopithecus* to *Homo erectus* to *Homo Neanderthalensis* to *Homo sapiens*; all were assumed to be ancestral to modern humans.

Revolution in human evolution research 2

- This thinking changed when Louis and Mary Leakey's discoveries of hominins at Olduvai Gorge in Tanzania shifted the focus of research on early hominins that lived more than one million years ago from southern Africa to East Africa.

- The focus changed not only because the trickle of fossil discoveries in East Africa in the early 1960s turned into a torrent but also because the fossil evidence in East Africa was dateable, unlike those of S. Africa

- From 2.3 to 1.4 Ma, two very different kinds of hominins— *Paranthropus boisei* and *Homo habilis*— lived in the same region of East Africa. Either 1 or both was not ancestral to modern humans.

Revolution in human evolution research 3

- Image of a single, simple branch no longer seems apt for representing humans a couple of million years ago. Our early ancestry looks more like a bundle of twigs—or a tangled bush.

- Yet we still have much to learn. Some chapters of the human story are completely unknown from the fossil record; others have been drafted on the basis of evidence so scanty that they are little more than speculation.

- 55 years ago, human fossils could fit in a box

- Today: From skeletons to teeth, early human fossils have been found of more than 6,000 individuals.

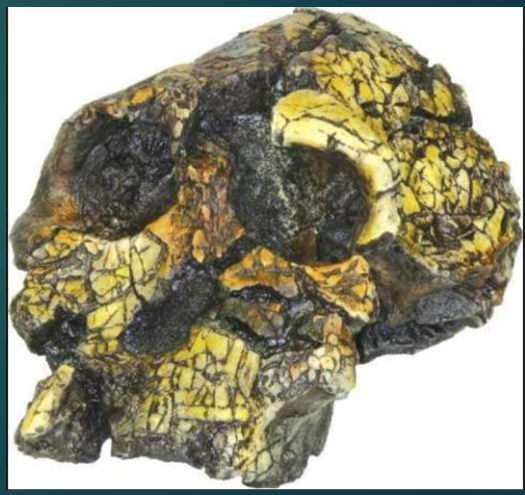
Revolution in human evolution research 4

- Whether before or after standing on two legs, at some stage our ancestors must have come down from the trees.
- Lucy shows up in 1974, dated at 3.2 Ma.
- By 2000, we knew of just one group that fitted the transition stage to humans: the australopithecines
- They lived in the right place at the right time to have evolved into humans just before 2 million years ago.

Australopithecus afarensis & Kenyanthropus platyops

- Since Lucy's discovery, she has served as a reassuring foundation stone on which to build the rest of our hominin family tree, a direct ancestor who lived in east Africa's Rift Valley.

- Then, in 2001, researchers unveiled a 3.5-million-year-old skull discovered in Kenya. The skull should have belonged to Lucy's species, *A. afarensis*, the only hominin species thought to be living in east Africa at the time.



- But its face didn't fit. It was so flat that it could barely be considered an australopith. Fred Spoor & Meave Leakey at Stony Brook University in New York, gave it a new name: *Kenyanthropus platyops*.

Who was ancestral to us

- The suggestion that Lucy's species shared east Africa with a completely different type of hominin seemed only of marginal interest. But within a few years, the potential significance of *Kenyanthropus* was beginning to grow.

- After comparing the skull's features with those of other hominin species, some researchers dared suggest that *K. platyops* was more closely related to us than any australopithecus species.

- The conclusion pushed Lucy on to a completely different branch of the family tree, robbing her of her arch-grandmother position.

Who was ancestral to us

- Other researchers were making a similar attack from a different direction. The discoverers of *Orrorin tugenensis*, the 6-million-year-old hominin found in 2001, also concluded that its anatomy was more human-like than that of the australopiths.

- Most of the research community remains unconvinced by these ideas, and a recent announcement that a human-like jawbone 2.8 million years old had been discovered at Ledi-Geraru, Ethiopia once more disputed Lucy's position.

- Intriguingly, in 2015, a team announced the discovery of the oldest known stone tools.

Who was Ancestral to us

- The 3.3-million-year-old artefacts were found in essentially the same deposits as *Kenyanthropus*. By all reasonable logic *Kenyanthropus* would be the tool-maker

- Perhaps that hints at a tool-making connection between *Kenyanthropus* and early humans – although there is circumstantial evidence that some australopiths used stone tools too.

- In any event, determining which hominins evolved into humans is no longer as clear-cut as it once was.

Dmanisi

- Shaking up the "Out of Africa" story: This idea assumes that the only hominins to leave Africa were big-brained humans with long legs ideally suited for long-distance travel, likely *H. erectus*

- In 2002, a 1.75-million-year-old human skull, with small cranial capacity of 600 cc, was discovered. Such a fossil wouldn't be an unusual find in east Africa, but this one turned up at Dmanisi in Georgia, in the Caucasus region. Clearly, small-brained hominins had left Africa.

- The Dmanisi hominins are now considered small-brained early versions of *H. erectus*.

Flores

- A discovery in 2003 would ultimately prove far more problematic. That year, researchers working on the Indonesian island of Flores found two bizarre skeletons. Had small body (3 feet tall) & brain. It was named *Homo floresiensis*, better known by its nickname: the hobbit. Originated dated to 16 Ka, now 60-100 Ka.

- One hypothesis about the hobbit: possibility that a very early migration out of Africa involving prehuman australopith-like hominins.

- In fact, the entire out-of-Africa narrative is in flux, with genetic and fossil evidence suggesting that even the once widely held opinion that our species left Africa 60,000 years ago may be wrong.

Humankind’s Journey out of Africa: MHs

- Now the story is changing in light of new research
- Recent findings suggest that the 'Out of Africa' theory does not tell the full story of our ancestors.
- Instead, multiple, smaller movements of *H. sapiens* out of Africa beginning 270,000 years ago were then followed by a major migration 60,000 years ago.
- Most of our DNA is made up of this latest group, but the earlier migrations, also known as 'dispersals', are still evident.
- *H. sapiens* remains have been found at sites in Germany at 270 Ka, India at 170 Ka, and China circa 120 Ka

Out of Africa & 2 misfits

- Other recent finds show that modern humans reached Southeast Asia and Australia prior to 65,000 years ago.

- Then two more weird misfits had come to light, both in South Africa.

- *Australopithecus sediba* and *Homo naledi* are quite unlike any hominin discovered before, says Lee Berger at the University of Witwatersrand in South Africa, who led the analysis of both.

Out of Africa: Sediba & Naledi

- Their mosaic skeletons seem almost cobbled together from different parts of unrelated hominins. Has led to lesson that you can no longer predict the whole from one of its parts.

- Significantly, the mishmash of features in the *A. sediba* skeleton, unveiled in 2010, is very different from those in the *H. naledi* skeleton, unveiled in 2015.

- We have historically tend to assume that ape-like species gradually morphed into human-like ones over millions of years

Complexity of human evolution: *Homo naledi*

- In reality, Berger thinks, there may have been a variety of evolutionary branches, each developing unique suites of advanced human-like features and retaining a distinct array of primitive ape-like ones. We were trying to tell the story too early, on too little evidence. It made great sense right up until the moment it didn't.

- In 2017, the age of the *H. naledi* was dated to 236,000 to 335,000 years old.

- Weeks later, news broke that 300,000-year-old fossils from Morocco might belong to early members of *H. sapiens*, extending our lineage by 100K.

- Was multiregionalism happening in Africa? Almost certainly.

Small and Large brains together: *Homo naledi*

- Human brains didn't grow and grow for millennia, with smaller-brained species falling to the wayside of the gradual evolutionary road.
- Instead, *H. sapiens* occupied an African landscape that was also home to humans with brains half the size of theirs.
- We can only speculate on how (or whether) the small-brained *H. naledi* interacted with the earliest *H. sapiens*.
- Controversial theory from Berger's team suggests that *H. naledi* intentionally disposed of its dead – perhaps a sign that even "primitive" hominins could behave in an apparently sophisticated way of dealing with their dead

Not as special after all

- Our species, *Homo sapiens*, is special. We have achieved things beyond the capacities of all others in our family tree. But the distinction between our species and those that went before may not be quite as stark as we once thought.

- In 2014, for instance, researchers found a zigzag that had been etched in a shell from 540 Ka at Trinil, Java. We had thought we were the only species to produce abstract symbols, yet here was *H. erectus* doing so more than 200,000 years before *H. sapiens* even evolved.

Not so special…Neandertals

- Researchers are also becoming increasingly convinced that Neanderthals had advanced behavior, like using watercraft to reach islands or exploiting simple chemistry to start fires.

- Evidence of symbolic ability now include a carved a hashtag sign on a rock in Gibraltar, mysterious stone circles out of stalagmites in French cave, and an abstract painting in Spain, dated to 65 Ka. The latter makes Ns the first artists in Europe.

Not so special…*Homo naledi* & Neandertals

- And then there's *H. naledi*, with a brain size of 465–560 cc, half the size of our own.
- According to the team that excavated its remains, *H. naledi* might have deliberately disposed of its dead in deep, inaccessible cave chambers.
- In the late 1990s, geneticists began to show an interest in archaeological remains. Advances in technology allowed them to sequence a small chunk of mitochondrial DNA (mtDNA) from an ancient Neanderthal bone.
- The mtDNA sequence was genetically distinct from *H. sapiens*, suggesting that Neanderthals had gone extinct without interbreeding with our species.

Not so special…Ns & Ds

- But mtDNA is unusual. Unlike the nuclear DNA responsible for the bulk of human genetics, it passes intact from a mother to her children and doesn't mix with the father's genes.
- In 2010, Nuclear DNA showed subtle but distinct evidence that Neanderthals had interbred with our species after all.
- Then came the Denisovans.
- To this day, the Denisovans remain enigmatic. All that we have of them are one finger bone and three teeth from a single cave. We don't know what they looked like, although *H. sapiens* considered them human enough to interbreed with them: a Denisovan nuclear genome sequence published in 2010 showed clear evidence of sex with our species. The DNA work also shows that they once lived all across East Asia. So where are their remains?

Not so special… Ns

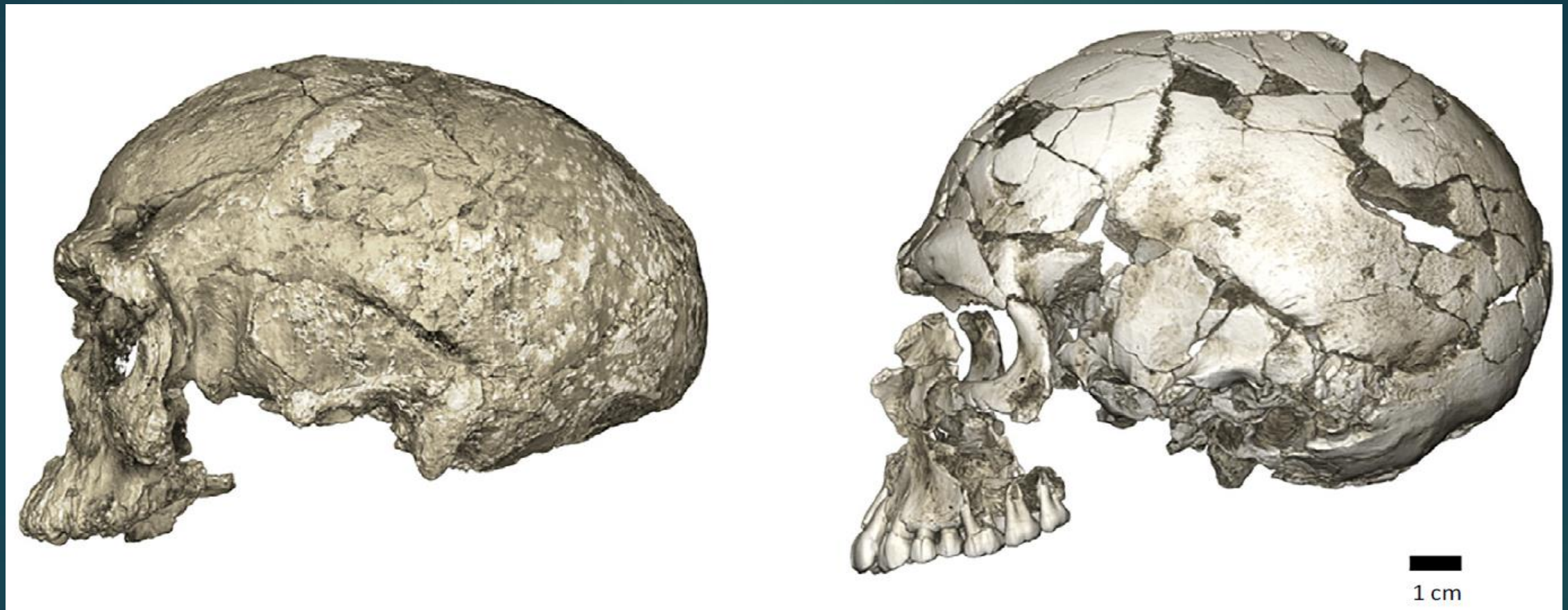
- Fast-forward to 2017, and the interbreeding story has become more complex than anyone could have imagined in 2000.
- Johannes Krause of U. of Tübingen reels off the list:
  - Neanderthals interbred with *H. sapiens*.
  - Neanderthals interbred with Denisovans.
  - Denisovans interbred with *H. sapiens*.
  - Something else that we don't even have a name for interbred with Denisovans – that could be some sort of *H. erectus*-like group…
  - And we do not know what *H. sapiens* was up to in Africa
- We all carry different bits – to the extent that if you could add them all up, Krause says you could reconstitute something like 30 % of the Neanderthal genome and 90 % of the Denisovan genome. With this knowledge, can we even say that these species are truly extinct?
- Pushing the idea one step further, if most living humans are a mishmash of *H. sapiens* DNA with a smattering from other species, is there such a thing as a "true" *H. sapiens*?

And just this month, July 2018

- July 2018: *Did Our Species Evolve in Subdivided Populations across Africa, and Why Does It Matter?* Review article related to multiregionalism in Africa – the interbreeding of multiple early *H. sapiens* groups across Africa.

- July 2018: Oldest stone tools outside Africa at 2.1 Ma at Shangchen China, claimed to be made by pre *H. erectus* hominin

Braincase changes from 300 Ka to 95 Ka



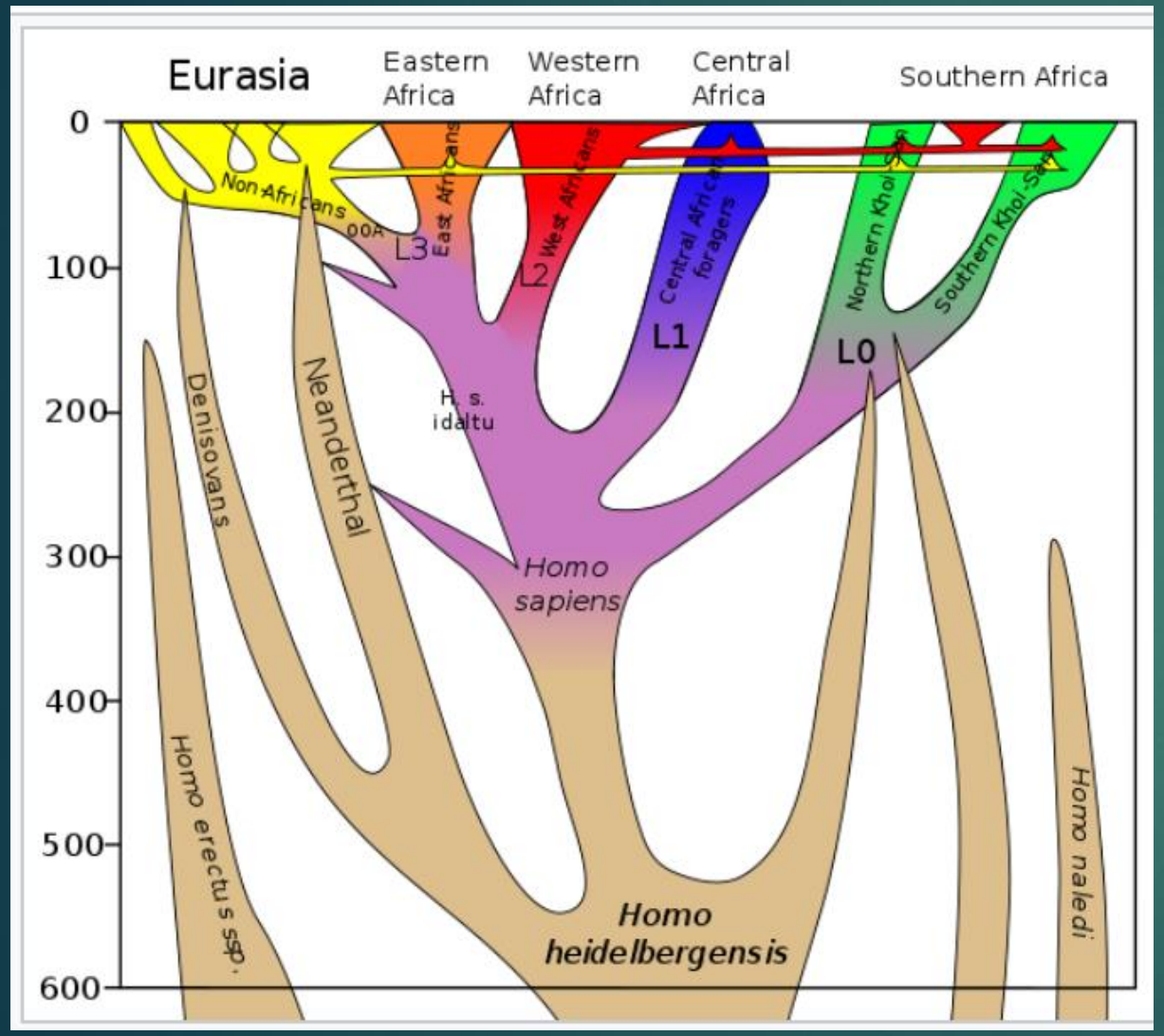
Trends in Ecology & Evolution

Figure 1. Evolutionary Changes of Braincase Shape from an Elongated to a Globular Shape. The latter evolves within the *H. sapiens* lineage via an expansion of the cerebellum and bulging of the parietal. (Left) Micro-computerized tomography scan of Jebel Irhoud 1 (~300 ka, North Africa). (Right) Qafzeh 9 (~95 ka, the Levant).

Not so special…

- Having dug ourselves into this philosophically troubling hole, there's probably only one way to find our way out again: keep digging for fossils and probe them for more DNA.

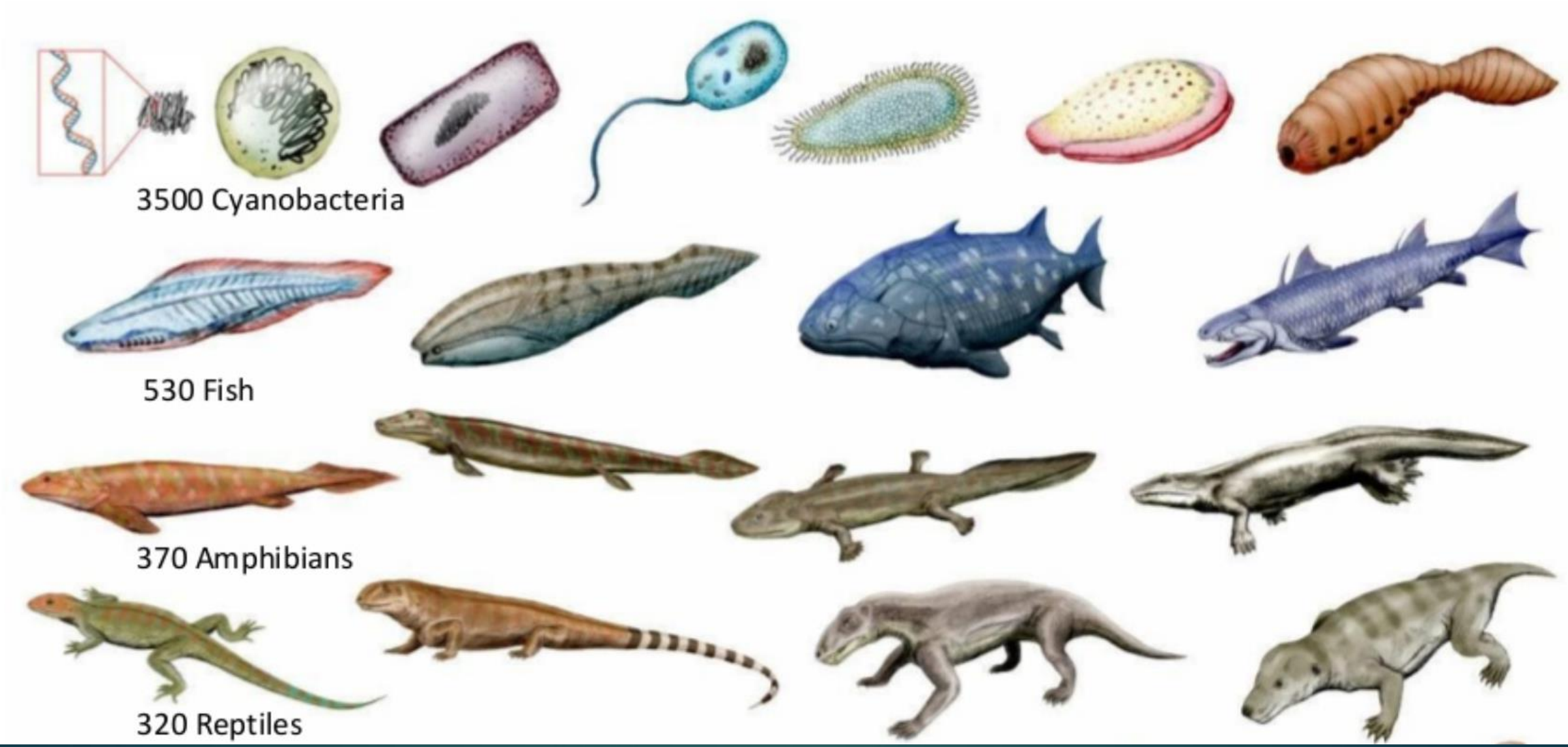
Model of the phylogeny of *H. sapiens*



- A model of the phylogeny of *H. sapiens* over the last 600,000 years (vertical axis).
- The horizontal axis represents geographic location; the vertical axis represents time in thousands of years ago.
- *Homo heidelbergensis* is shown as diverging into Neanderthals, Denisovans and *H. sapiens*.
- With the expansion of *H. sapiens* after 200 kya, Neanderthals, Denisovans and unspecified archaic African hominins are displayed as again subsumed into the *H. sapiens* lineage.
- Possible admixture events involving certain modern populations in Africa are also shown.

Currently postulated Hominin species (~23)

Ancestors



Oldest ancestor, Saccorhytus, 540 M: an early deuterostome

A tiny sea creature identified from fossils found in China may be the earliest known step on an evolutionary path that eventually led to the emergence of humans

Microscopic, bag-like sea creature, which lived about 540 million years ago.

Named Saccorhytus, after the sack-like features created by its elliptical body and large mouth; no anus

Jian Han, et al., Nature, 2017

Mother or uncle of us all?…*Megaconus mammaliaformis*

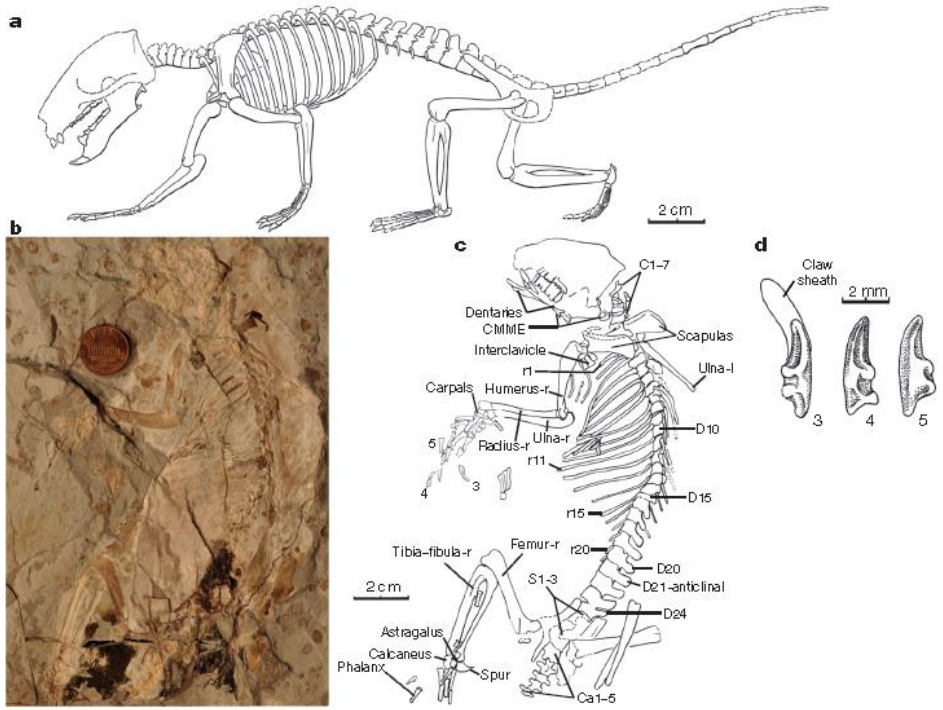


Figure 1 | New Jurassic mammaliaform *Megaconus mammaliaformis*. **a**, Skeletal reconstruction. **b**, Holotype counterpart (Paleontological Museum of Liaoning (PMOL)-AM00007B). **c**, Skeletal feature identification; the left (-l) versus right (-r) sides are designated according to the main-part PMOL-AM00007A (Supplementary Fig. 1). **d**, Manual terminal phalanges. Details on dental and skeletal structures can be found in Supplementary Figures. C, cervicals; Ca, caudal vertebrae; CMME, preserved elements of cynodont mandibular middle ear[24]; D, dorsal vertebrae (D1–15 designated as 'thoracic'; D16–24 as 'lumbar'); r, ribs; S, sacral vertebrae; 3–5, the preserved manual terminal phalanges 3–5.

- A Jurassic mammaliaform
- dated to be 165–164 Myr
- hair and fur residue; poisonous spur;
- middle ear still attached to the jaw is more reminiscent of reptile,
- but derived molars
- herbivory evolved among mammaliaforms, before the rise of crown mammals

Chang-Fu Zhou, et al., 2013

Agilodocodon scansorius: Chinese Mother of us all?

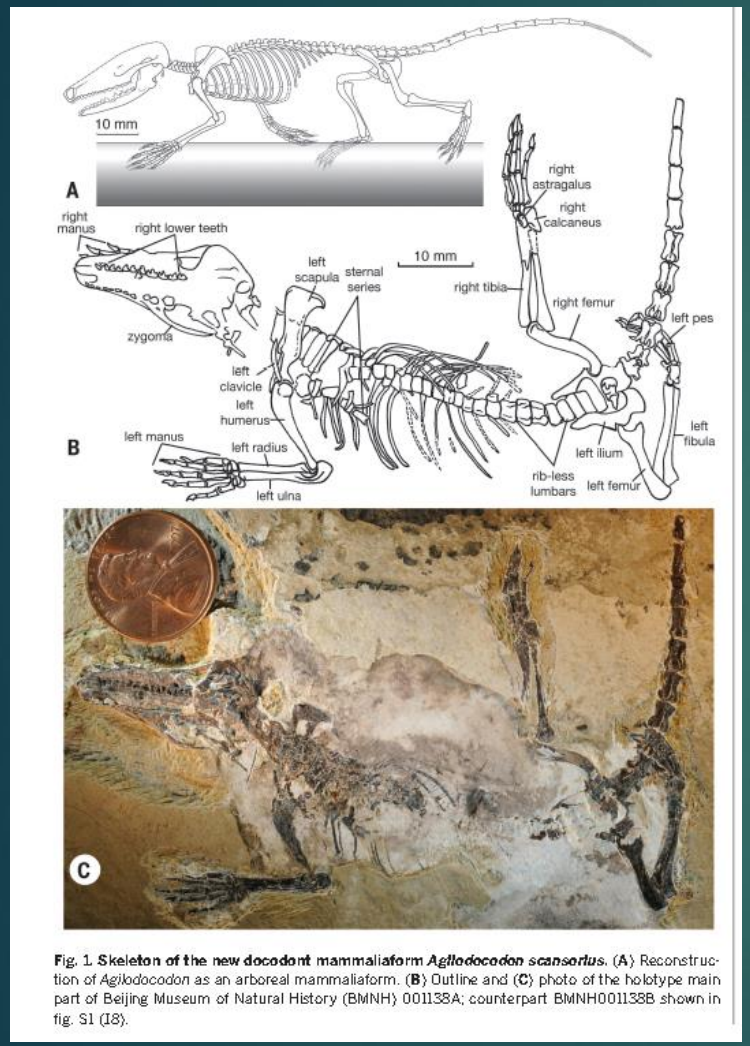
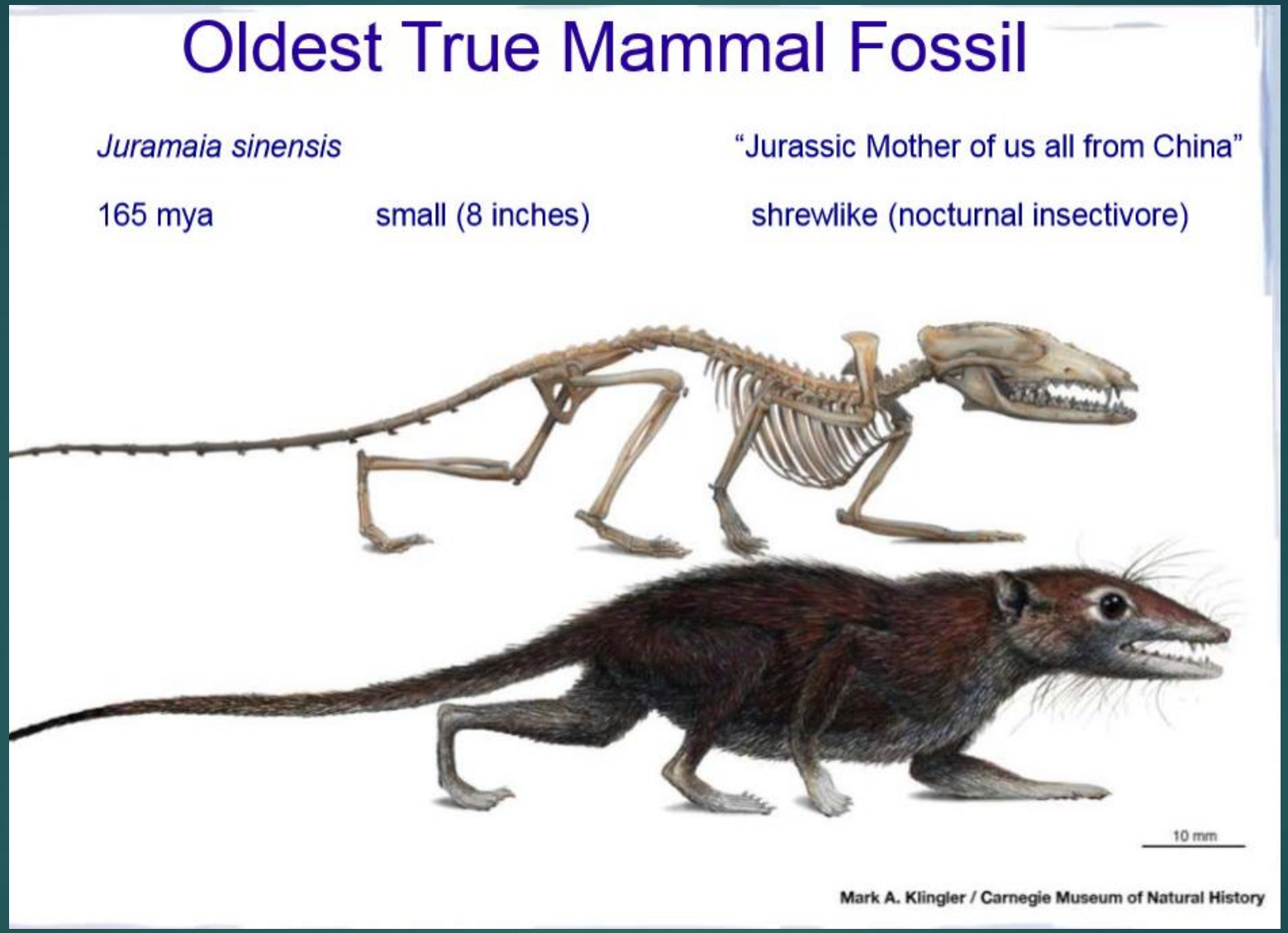


Fig. 1. Skeleton of the new docodont mammaliaform *Agilodocodon scansorius*. (**A**) Reconstruction of *Agilodocodon* as an arboreal mammaliaform. (**B**) Outline and (**C**) photo of the holotype main part of Beijing Museum of Natural History (BMNH) 001138A; counterpart BMNH001138B shown in fig. S1 (*18*).

Qing-Jin Meng, et al., 2015

OMNIVORE LIVED 165M YEARS AGO: SCIENTISTS EXPOSE TINY JURASSIC MAMMAL SPECIES IN CHINA

Docodontan mammaliaform from the Middle Jurassic of China: an omnivorous diet that included plant sap; 174-163 Ma



Liaoning, China: Juramaia sinensis - basal eutherian mammal from the Late Jurassic, 160 Ma; arboreal

Zhe-Xi Luo, et al., 2011

Our Ancestry

- From Eucynodontia (cynodonts) came the first mammals (small shrew-like animals that fed on insects; first neocortex; Triassic, 220 M>
- Eutherian mammal fossil, 160 M>Juramaia, Euarchontoglires (Last common ancestor of mice and humans, 100 M)
- Euarchonta (small, nocturnal and arboreal, insect-eating mammals), Plesiadapiformes, 85-65 M>
- Primates diverge into suborders Strepsirrhini (wet-nosed primates) and Haplorrhini (dry-nosed primates; lost the ability to make its own Vitamin C; require fruit). 63 M>
- Haplorrhini splits into infraorders Platyrrhini and Catarrhini. *Aegyptopithecus* or *Saadanius,* 30 M>
- Catarrhini (downward nosed primates) splits into 2 superfamilies, Old World monkeys (Cercopithecoidea) and apes (Hominoidea). Proconsul africanus, 25 M>

Our ancestry 2

- Hominidae (great apes) split from gibbon (lesser apes), 15M>
- Split from ancestor of orangutan, 13M>
- Split from ancestor of gorilla, 10M>
- Hominina, split from ancestor of chimpanzees, 7M>
- *Ardipithecus,* 4.4M>
- *A. afarensis*, 3.3M>
- ?? – 2 to 3 Ma is sparse
- *Homo erectus*, 2M> 75,000 generations ago
- *Homo antecessor*, 900 K
- *Homo heidelbergensis*, 600K>
- *Homo sapiens*, 500K>

We are primates

- Generalized body plan: quadrupeds who also walk
- Most tend to be arboreal, preferring tropical forest habitats
- Grasping hands with opposable thumbs or big toes
- Flattened nails, not claws
- Forward-facing eyes with stereoscopic vision
- Petrosal Bulla (tiny bit of skeleton that covers parts of inner ear)
- Enclosed bony eye orbits in skull: visually prioritized
- Single Offspring
- Larger brains relative to body size
- Extended ontogeny
- Diurnal
- Sociality: live in groups

Current paradigm in study of human evolution

- Apes were widespread across Africa, Europe and Asia about 20 million years ago – at this time the world really was the Planet of the Apes
- Modern humans originated in Africa
- Molecular clock (mutation rate in species) indicates separation of both hominins and chimpanzees from LCA around 7 million years ago

Apes

- There are only four genera of living apes outside of humans.
  - Pan, the chimpanzees and bonobos
  - Gorilla.
  - Pongo, the orangutans from Southeast Asia,
  - Hylobatidaes, gibbons and siamangs living in Southeast Asia.

- More than 20 million years ago, when apes first began to appear in the fossil record, the world had much larger tropical forest, extending across large parts of Eurasia in addition to Africa.

- Apes, relative to other primates, tend to be larger in body size (& larger brain for body size). Corresponding with that larger body size is they tend to lack a tail.

- They are knuckle walkers, they're quadrupedal, utilizing both their forelimbs and their hind limbs. But apes are also very good suspensory movers, using their arms to climb and swing through trees.

Apes 2

• The gibbons and siamangs are true suspensory primates. We refer to this as brachiation, where their primary locomotor behavior is actually using their forelimbs to swing from branch to branch within the high canopy of Southeast Asia.

• They engage in a different kind of social behaviors:

  • gorillas are single-male, multi-female groups that involve high degrees of sexual dimorphism,

  • gibbons, which tend to exist as monogamous pairs with essentially no sexual dimorphism or no characteristic differences between males and females.

  • orangutans are most socially isolate (smallest orbital frontal cortex)

  • chimpanzees have extended family groups of as many as 20-120 individuals; a fission-fusion social organization in that they break off into smaller interchangeable groups and periodically come together; females migrate to neighboring communities while males stay in their natal group; linear hierarchical structure where each member has a rank. An alpha male leads the community; have wars; 3% meat in diet
  •In bonobo society, females often take the lead; they are more sexual and peaceful

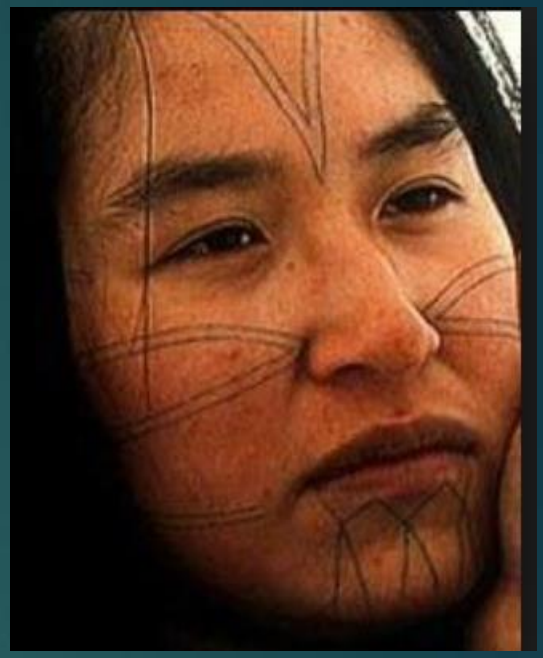
Simultaneous hominins

- During the last 300Ka, a bush of *Homo* species coexisted:
  - *Homo erectus,*
  - *Homo sapiens,*
  - *Homo neanderthalensis,*
  - *Denisovans,*
  - *Homo floresiensis,*
  - *Homo naledi.*
  - Thus six hominin species roamed the planet simultaneously.

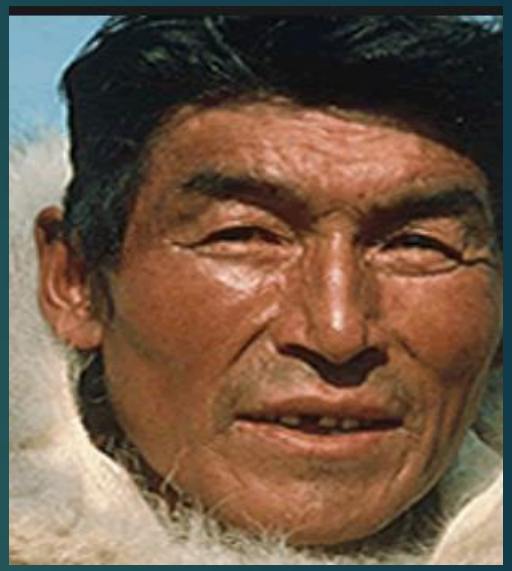
- Given that the fossil record always underestimates the number of species, we should expect that our current count is an underestimate

Inuits: diet for Vitamin D; lots of sunshine ½ year

- Northern latitude Europeans developed light skin via gene mutations to decrease melanin and to increase Vitamin D production.
- Remember that evolution has no goal & simply because one group evolved a means of dealing with a situation doesn't mean other groups will evolve the same method of dealing with the situation.
- Skin pigmentation can darken due to prolonged sun exposure, which increases in a landscape that is snow and ice covered, reflecting the sun, for 24 hours a day for 6 months during summer.
- Inuits vitamin D intake is not dependent upon sun exposure; they get it from diet loaded with fish
- They have more melanin than lighter skinned people.

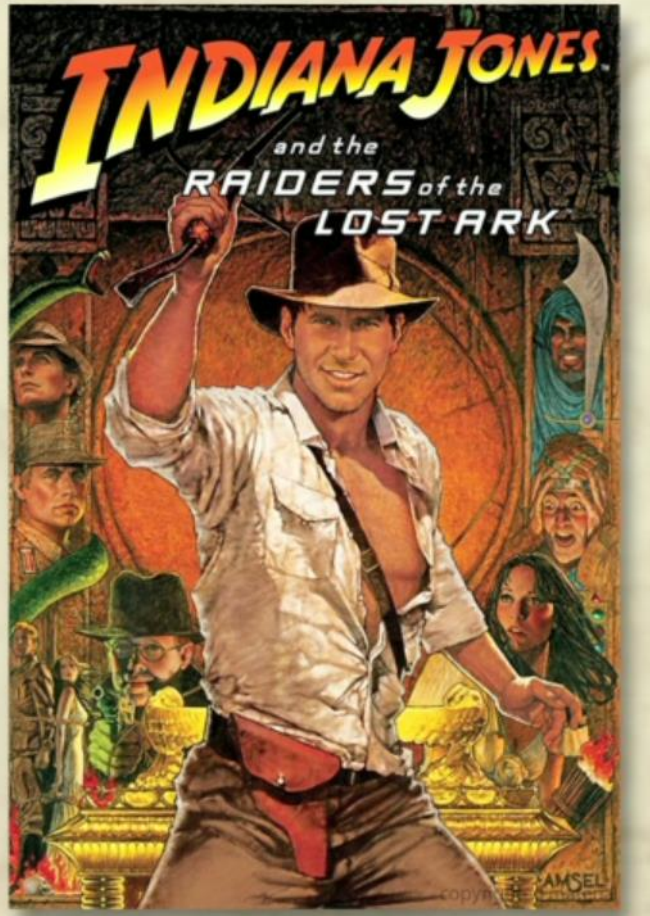


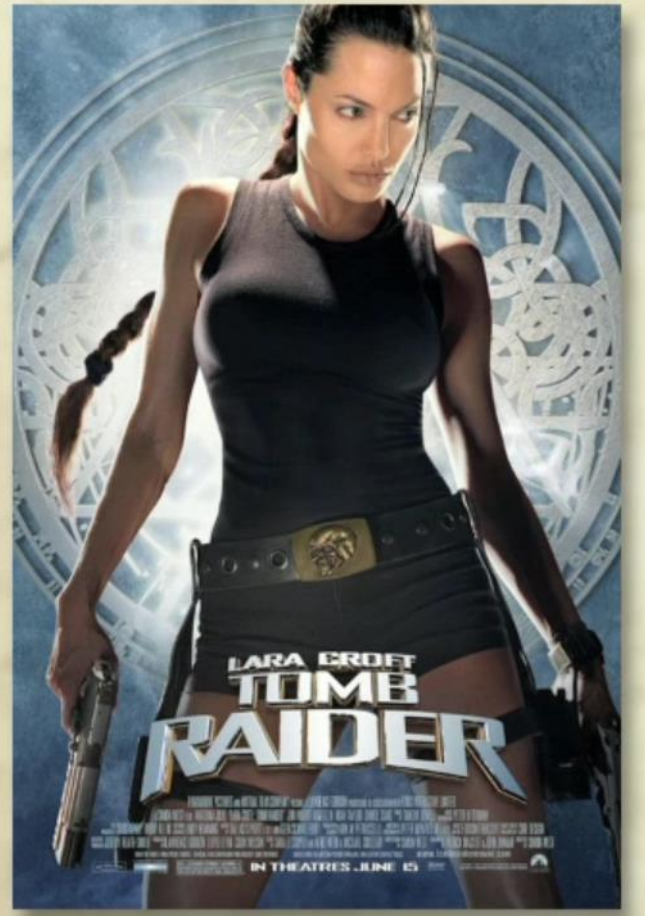
Inuits: diet for Vitamin D



- The plentiful amounts of the vitamin kept them from developing less melanin.
- In addition, the Inuit have been in the far north for only about 5,000 years. This may not have been enough time for significantly lower melanin production to have been selected for by nature.
- In fact, before milk was fortified with D, people living outside of Northern Canada and Alaska loaded their diets with fishy products, such as cod liver oil, to get their daily supplement
- Note that African Americans have only 3% of adequate Vitamin D; 15% African American women have pelvis deformities.

Archaeology Is In the Popular Media





Human Evolution Research

- The history of human paleontological research has been marked by misfortunes, false hopes, fraud, extraordinary bravery, and good luck.
- Until recently, it has been dominated by a handful of ambitious individuals, obsessed with their work and driven by hopes of fame and glory.
- The goal has been to find the oldest human ancestor. Each discovery was acclaimed as having iconic significance. Each wanted to name new species.
- This history has been marked by intense rivalries, personal feuds, and fierce controversies.

Human Evolution Research 2

- Ian Tattersall, a paleoanthropologist emeritus at the American Museum of Natural History, has said that the field often resembles “a swamp of ego, paranoia, possessiveness, and intellectual mercantilism.”
- Lee Berger: “It’s a competitive sport.” he said of paleontology.
- One scientist stated that his profession was marked by “treachery, cutthroat competition and backstabbing.”
- But also by increasing scientific professionalism.

Real Archeology/Paleontology

- It’s about facts; the discovery of evidence
- Need real fossil findings, need preservation, need detailed observations and notes, need measurements
- Share information in order to be assessed for it’s validity
- Needs quantification of objects and scientific communication and peer review
- Archeology = study of residues of human behavior
- Study of variability = why hominins do different things in different situations

Difficulties of interpreting fossils:

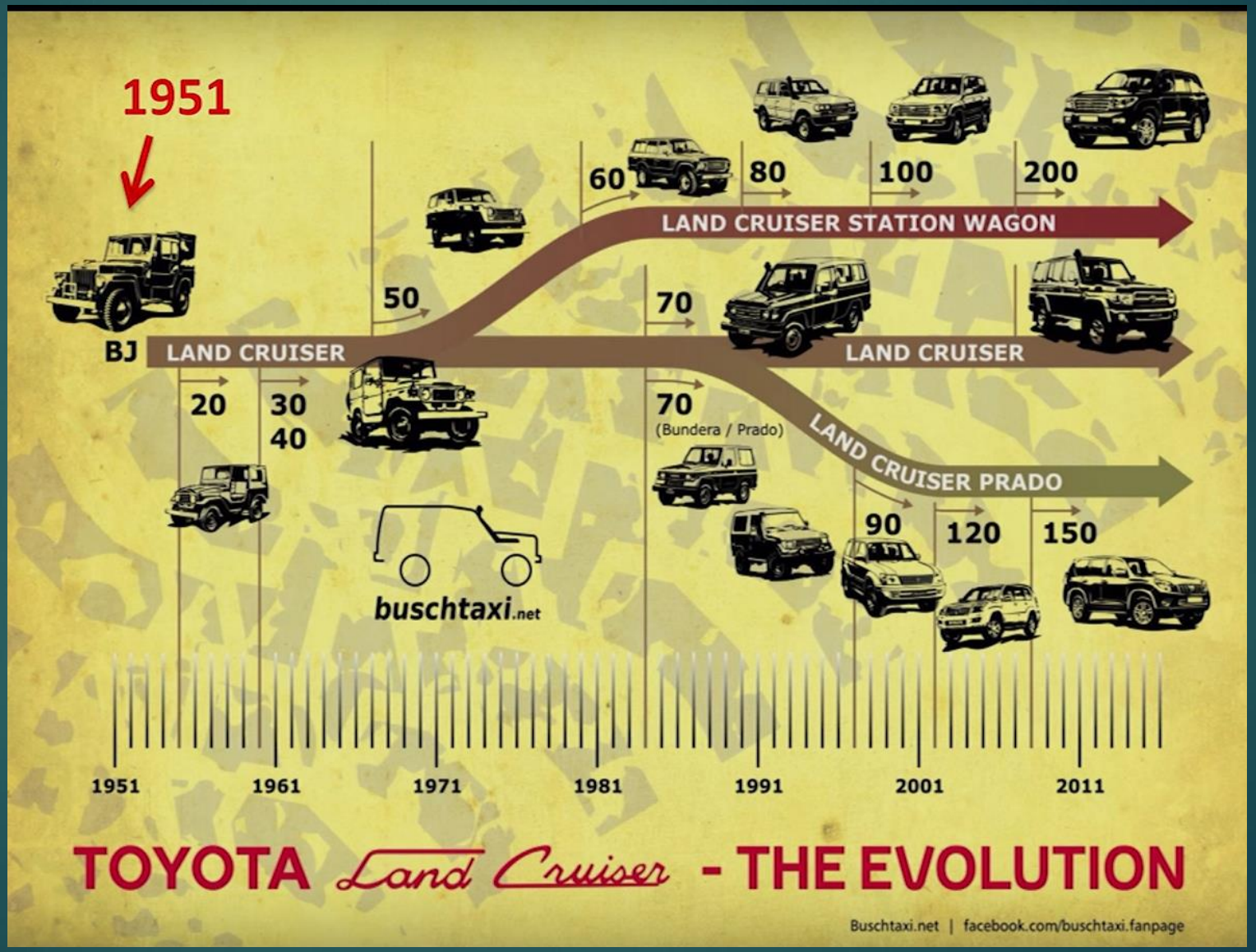
1935 – Toyoda (Toyota) *A1* passenger vehicle – first prototype

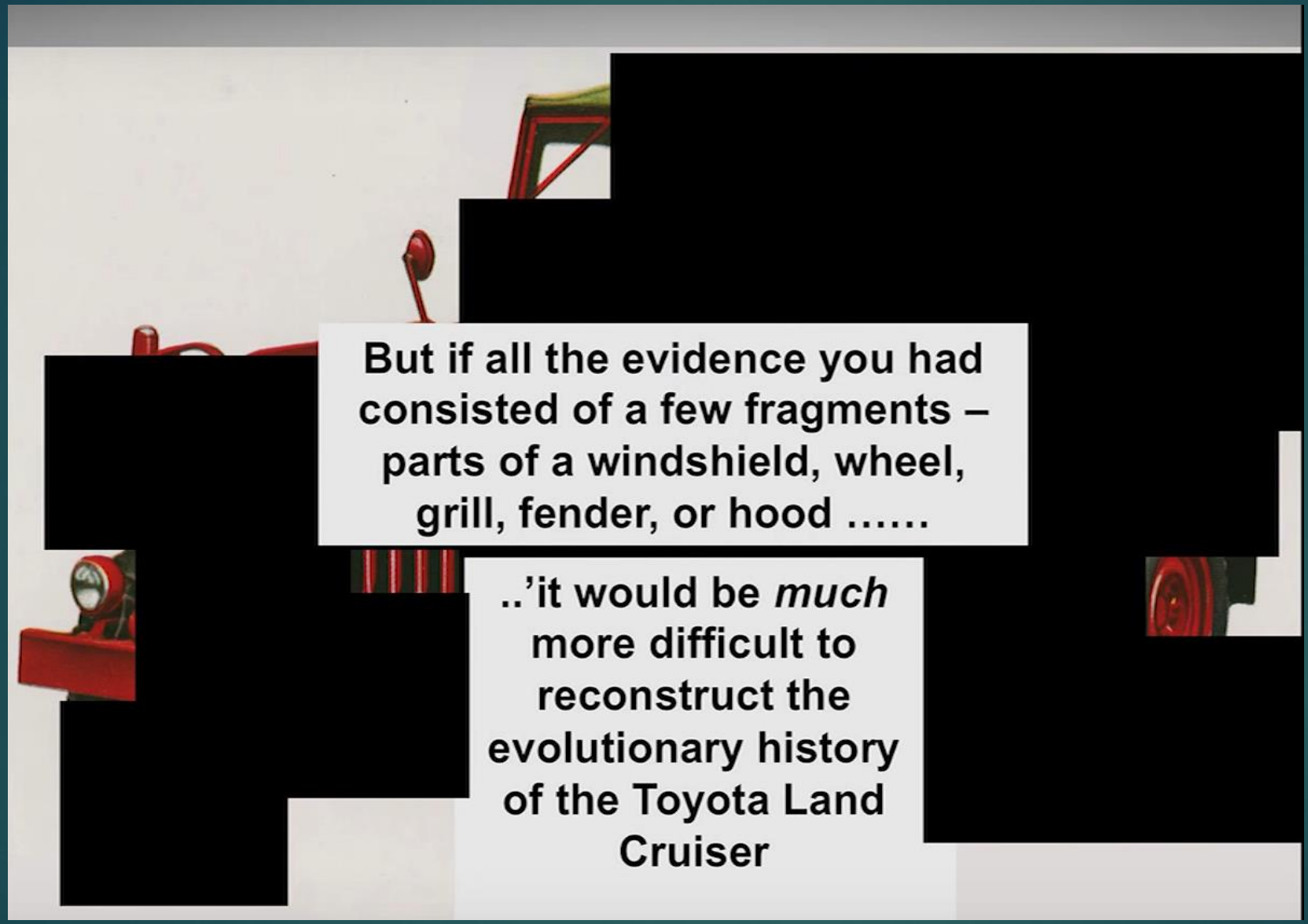
TOYODA

TOYOTA

If the common ancestor was a 1935 Toyota car

Similarity of evolution: Toyota Land Cruiser




But if all the evidence you had consisted of a few fragments – parts of a windshield, wheel, grill, fender, or hood ……
..'it would be *much* more difficult to reconstruct the evolutionary history of the Toyota Land Cruiser

Human Evolution

- Hominin fossils represent only 1% of fossil finds. Tracing a direct line of ancestry back along this branch is difficult because the fossil record is a patchy mosaic of incomplete skeletons.

- Entire species have probably become extinct without leaving a single toe bone for us to dig up in the smattering of places we are looking.

- And species that have been discovered are just as likely ancient "cousins" – offshoots of the branch leading to us – rather than our ancestral gggg…grandparents.

Human Evolution

- Most hominin fossils have been found in East & South Africa, thanks to leopards and Rift Valley. Incredibly few from West and North Africa.

- The fossil record between two and three million years ago – when our oldest *Homo* ancestors emerged – is particularly sparse, making it one of the least understood parts of human evolution.

- Some of the best evidence for evolution itself comes from fossils of pigs, elephants, and antelopes, were there is massive fossil evidence; pig molars have been used to date human fossils

Hominid vs. Hominin

- Older term: Hominid
- Newer term: Hominin

- **Hominoid** - all Great Apes (incl. gibbons, orangutans, gorillas, chimps, bonobos, humans)

- **Hominid** – the group consisting of all modern and extinct Great Apes (that is, modern humans, chimpanzees, gorillas and orangutans plus all their immediate ancestors).

- **Hominin** – the group consisting of modern humans, extinct human species and all our immediate ancestors (including members of the genera *Homo*, *Australopithecus*, *Paranthropus* and *Ardipithecus*).

- The subtribe Hominina is the "human" branch; that is, it contains the genus *Homo* exclusively.

Rarity of human fossils

- Human fossils are exceptionally rare.
- Most have been fragments and isolated finds.
- Donald Johanson has said that before he found Lucy in 1974 all of the hominid fossils older than three million years could “fit in the palm of your hand.”
- The fossil remains of only about 6000 individuals have been found.

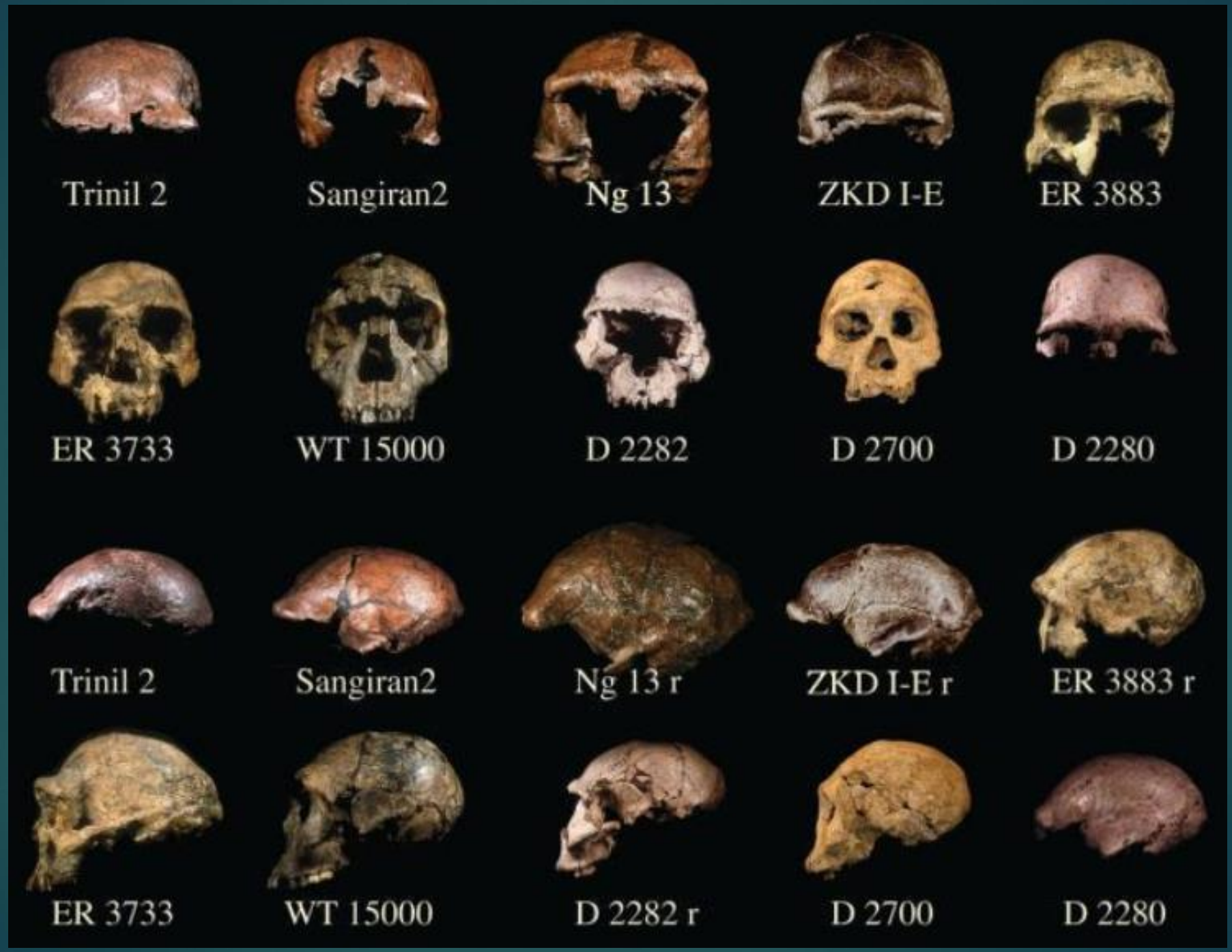
Number of Hominin fossils

- Total of hominin fossils in world:
  - Sima de los Huesos, Spain, 6500 from 28 individuals;
  - Rising Star, South Africa, 2000 from 18 individuals;
  - Krapina, Croatia, 30 individuals;
  - Sterkfontein caves, South Africa, 800;
  - Lake Turkana, Kenya, 100s
  - NMNH: hominin fossil record includes the remains of more than 6000 individuals, from pre-10 Ka.
  - Olduvai is up to Hominid #82 (teeth to partial skeleton).
- Vast majority are isolated bone fragments; a science of fragments
- 90% are isolated teeth
- Natural History Museums: 100s of 1000s of modern human skulls

Number of Fossil Hominins 2

- Before *A. sediba*, only 10 skeletons with craniums associated with post-cranial bones; *sediba* adds 2 more
- Fossil sites with skeletons are exceptional: Malapa, Nariokotome, Aramis, Dmanisi, Sterkfontein, Hadar, Woranso-Mille, Olduvai Gorge, and Koobi Fora.
- More than 200 relatively complete skulls from hominins other than modern humans:
  - Sangiran and Ngandong in Indonesia, and Zhoukoudian, China, are mainly known for their series of *H. erectus* skulls, numbering close to a dozen for each of these areas
  - Skulls from sites like Jebel Irhoud, Morocco, Laetoli, Tanzania, and Herto, Ethiopia,
- Last index of fossils, 10 years ago: 1800 pages.

- Among the least fossils are from 2.5 to 1.8 Ma: rise of *Homo* period


Trinil 2
Sangiran2
Ng 13
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ER 3883
ER 3733
WT 15000
D 2282
D 2700
D 2280
Trinil 2
Sangiran2
Ng 13 r
ZKD I-E r
ER 3883 r
ER 3733
WT 15000
D 2282 r
D 2700
D 2280

Skulls

1 Chimp *2 A. africanus 3 H. habilis 4 H. rudolfensis 5-8 H. erectus 9 H. heidelbegensis 10-11 Neanderthal 12 MH*

Sima de los Huesos

- ~6500 fossils; 28 individuals –
- First identified as *H. heidelbergensis*
- Now Early Neandertals ~430 Ka

Krapina

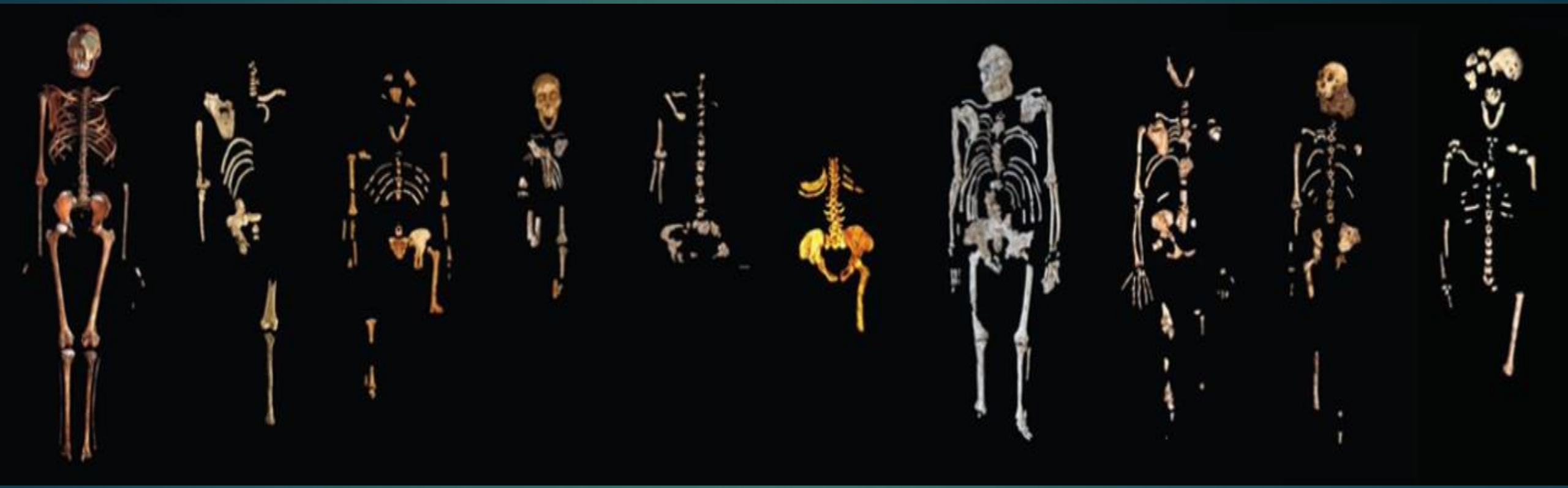
30 individuals
Neandertals

Homo naledi bones from the Dinaledi Chamber, South Africa.

18 individuals

Photo credit: John Hawks.

The major fuller skeletons



KNM-WT 15000 “Turkana Boy”
KSD-VP-1/1 “Kadanuumuu”
A.L. 288-1 “Lucy”
DIK-1-1 “Selam”
StW 431 *Au. africanus*
Sts 14 *Au. africanus*
StW 573 “Little Foot”
MH2 *Au. sediba*
MH1 *Au. Sediba*
LES1 “Nero” *H. naledi*

KNM-WT 15000
“Turkana Boy”

KSD-VP-1/1
“Kadanuumuu”

A.L. 288-1
“Lucy”

DIK-1-1
“Selam”

StW 431
Au. africanus

Sts 14
Au. africanus

StW 573
“Little Foot”

MH2
Au. sediba

MH1
Au. Sediba

LES1 “Nero”
H. naledi

2014, Matthias Meyer: Denisovan DNA: whole genome sequenced some 60 times over.

Denisova 3 finger bone (cast). Photo credit: Thilo Parg.

Counting such evidence is like counting the leaves of a million trees.

Homo

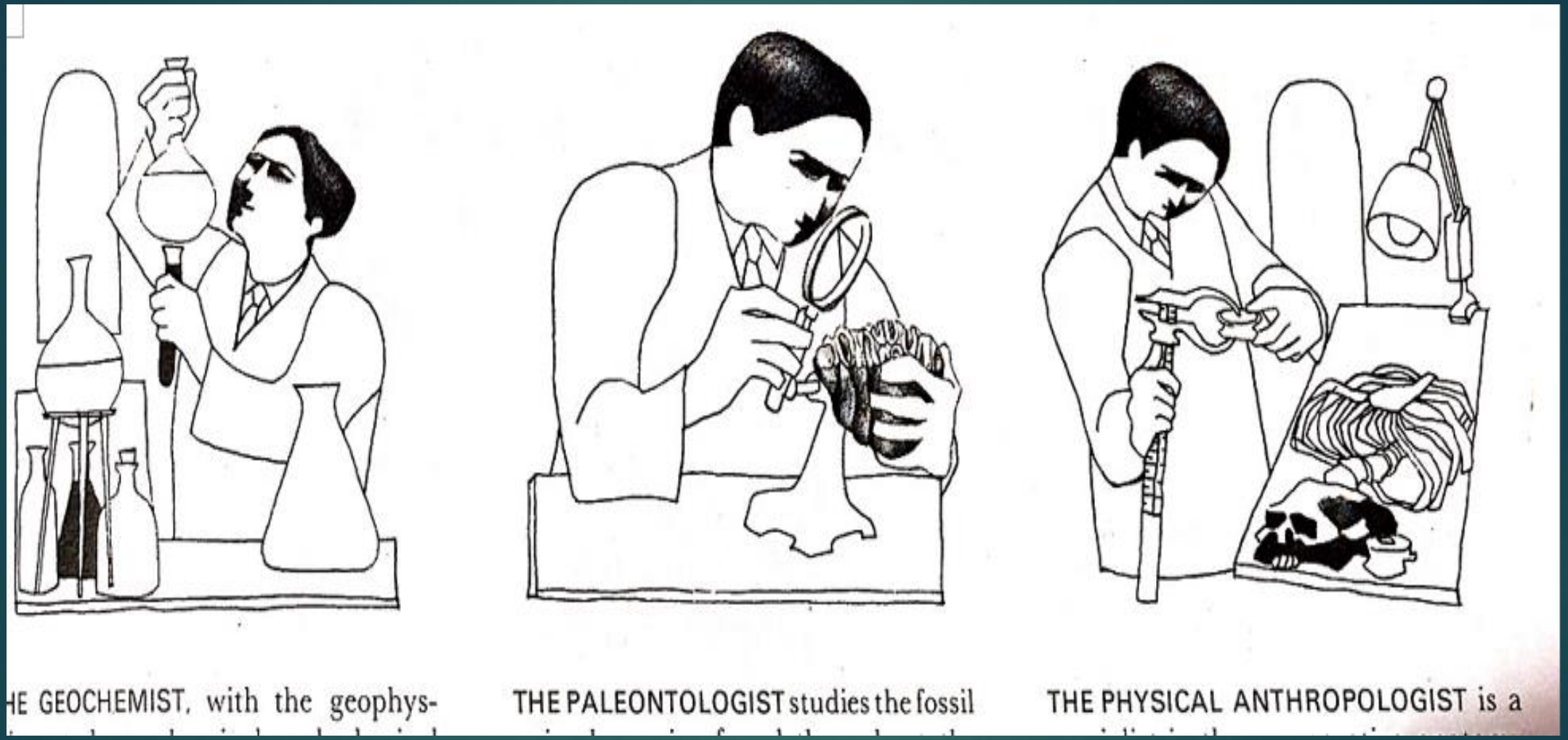
- Until lately, evolutionary biologists believed that the genus *Homo* was distinguished from its apelike forebears by an "adaptive package" that included:
  - bigger brains and bodies,
  - smaller teeth,
  - bipedalism,
  - tool use.

- Recent findings such as *H. naledi* suggest that these features may have arisen independently, in different combinations, in different species, at different times, in different places.

Current Research: multiple scientists

- Recent professionalization of paleontology
- What was once the field of fossil hunters, now includes:
  - molecular biologists,
  - biochemists,
  - geologists,
  - geneticists,
  - paleoclimatologists,
  - geochronologists

In the field - specialties



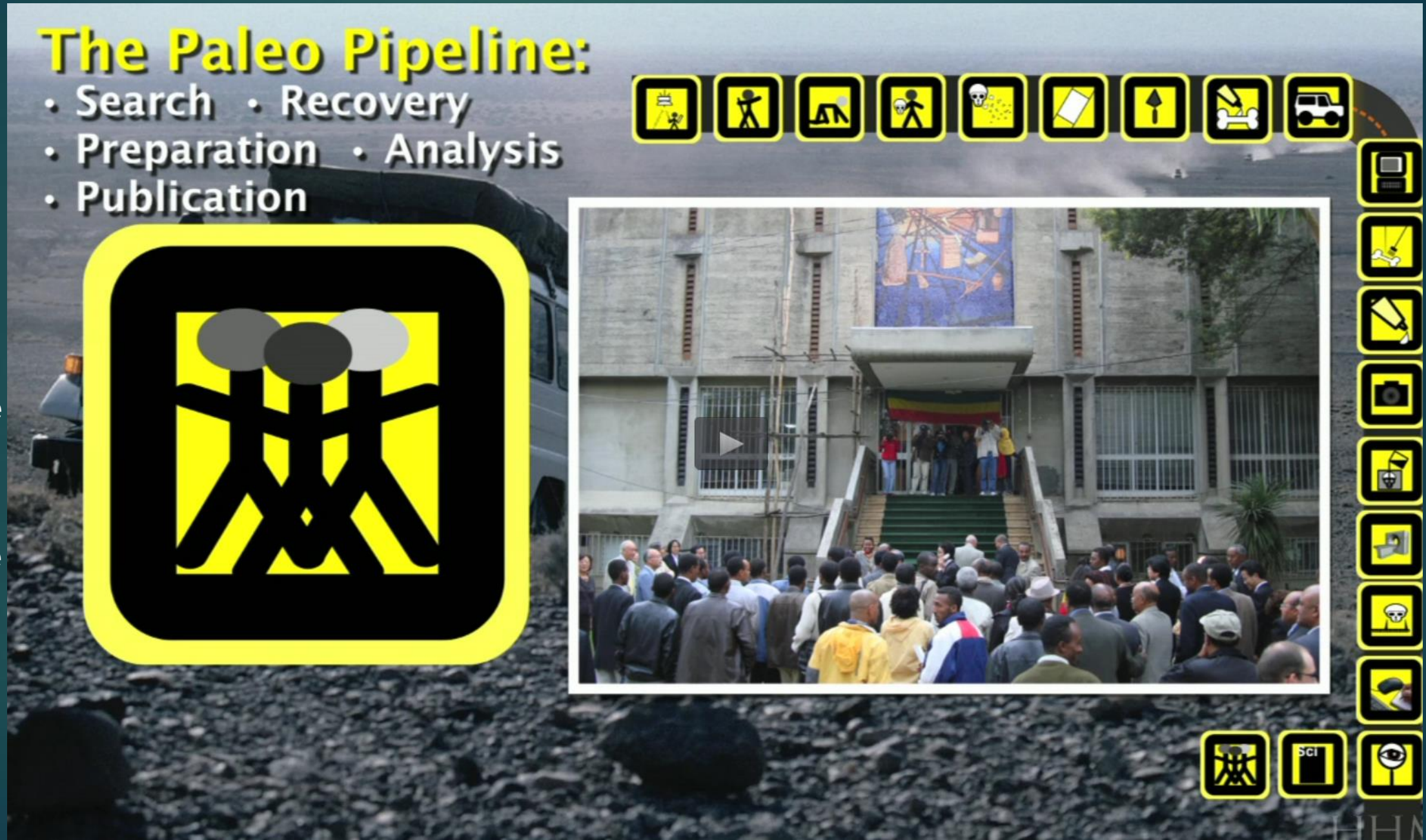
HE GEOCHEMIST, with the geophys-

THE PALEONTOLOGIST studies the fossil

THE PHYSICAL ANTHROPOLOGIST is a

Paleo Pipeline (Finding fossil to Publish)- Thanks to Tim White

Erosion
Pipeline
GPS
Search
Crawl
Find
Scattered
Find
Sieve
In Situ
Preservative
Transport
Catalog
Curate
Reassemble
Photo
Mold
MRI
Measure
Peer review
Publish
Media



Bernard Wood on Evolutionary Success

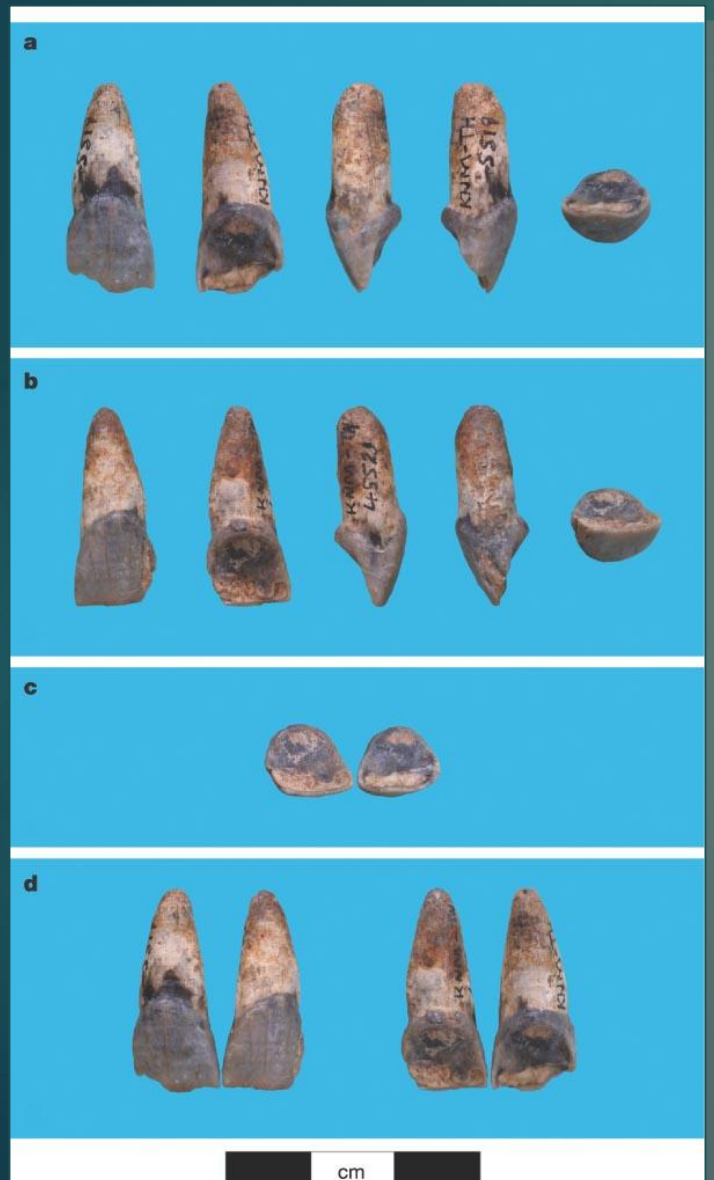
- Someone asked Wood that because we survived and they did not, we hu volved" than Neandertals.
- "What do you mean by ed, and pointed toward a skull of a hominid calle *isei,* a hominid that looks more like an ape than a
- "These guys lasted a million years." he said of the *Paranthropus.* When Neandertals went extinct around 40 Ka, he said, they likely had been on Earth longer than we have been now. We can start feeling truly superior in about 750,000 years", he said.

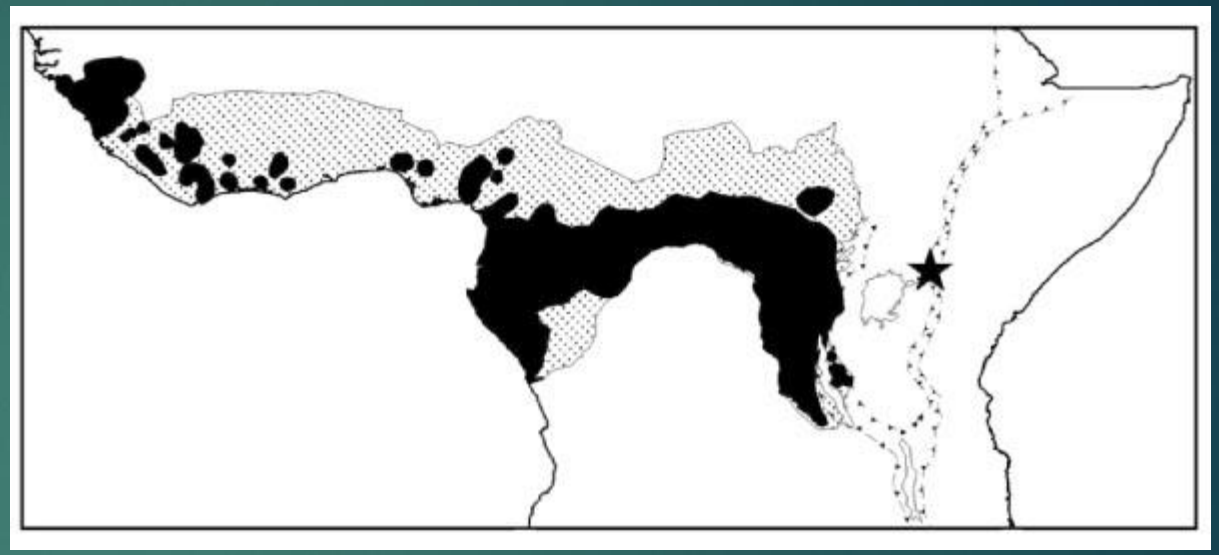
Fossil Preservation: hominin vs chimp

- Hominids may have lived all over Africa, but their remains are found only at sites where conditions allowed for the formation and preservation of fossils.
- Not all environments are conducive to fossil perseveration; some so acidic (forests), fossils rarely survive
- Fossil record for the chimp/bonobo clade is virtually nonexistent.
- The only panin fossil evidence in the last 8 myr consisted of a few 545 Ka-old isolated teeth from a site called Baringo, in Kenya.
  - A. Little chance of erosion in forests and therefore no exposures, and thus no places where fossils could be uncovered by erosion.
  - High levels of humic acid in soils of forests dissolve bones before they fossilize.
- B. Wood is unconvinced by above arguments. Thinks fossils are out there but undiscovered.

First and only chimpanzee fossils, 545 Ka

Sally McBrearty and Nina G. Jablonski, 2005





- First unequivocal chimp fossils dated to ~ 545 Ka. Contemporary with *Homo erectus* from the same site.

Nature **437**, 105-108 (1 September 2005)

Historical views of human evolution: science has changed

- Historical Views:
  - Large brain and complex language are unique to modern humans
    - No. Check out *H. heidelbergensis* and Neandertals
  - Human features (brain size, bipedalism, etc.) emerged together
    - Bipedalism emerged 7 Ma, large brain size c. 700 Ka

- Newer ideas:
  - Major differential for being hominin (closer to us than to chimp): bipedality & small canines & no tooth gap; not large brain
  - No linear progression of human evolution: now bush, tree model
  - Multiple hominin species existed at same time (*P. boisei, H. habilis, H erectus* at 2 Ma; also *H. erectus*, Neandertal, Denisovans, *H. naledi, H. floresiensis, H. sapiens* at 300 Ka)
  - Out of Africa: MHs originally evolved in Africa

Milestones in Human Evolution

- **Five key traits** make us who we are today. These traits are listed in the order that they developed—in other words, walking upright developed first, etc.
- **Bipedalism -** We get around by walking upright on two legs.
- **Tool Making -** We make and use tools ranging from stone hammers to smart phones.
- **Modern Body Plan -** We have longer legs and shorter arms than other primates.
- **Big Brain-** We have the largest and most complex brain of any primate
- **Symbolic Thinking -** We communicate using symbols such as images, numbers and letters

Hominin Evolution: Hominins & The 5 Major Steps

- Bipedalism: *Australopithecus afarensis,* & possibly in *Sahelanthropus tugensis. Orrorin*

- Tool Use:
  - *Homo habilis* (2 Ma)
  - *A. afarensis* (3.3 Ma) *(*Lomekwi 3 site, cut marks at Dikika site) ; *A. garhi*
  - Difference between tool use (chimps do) vs tool making (modifying stones) vs making tools to make tools (MHs)

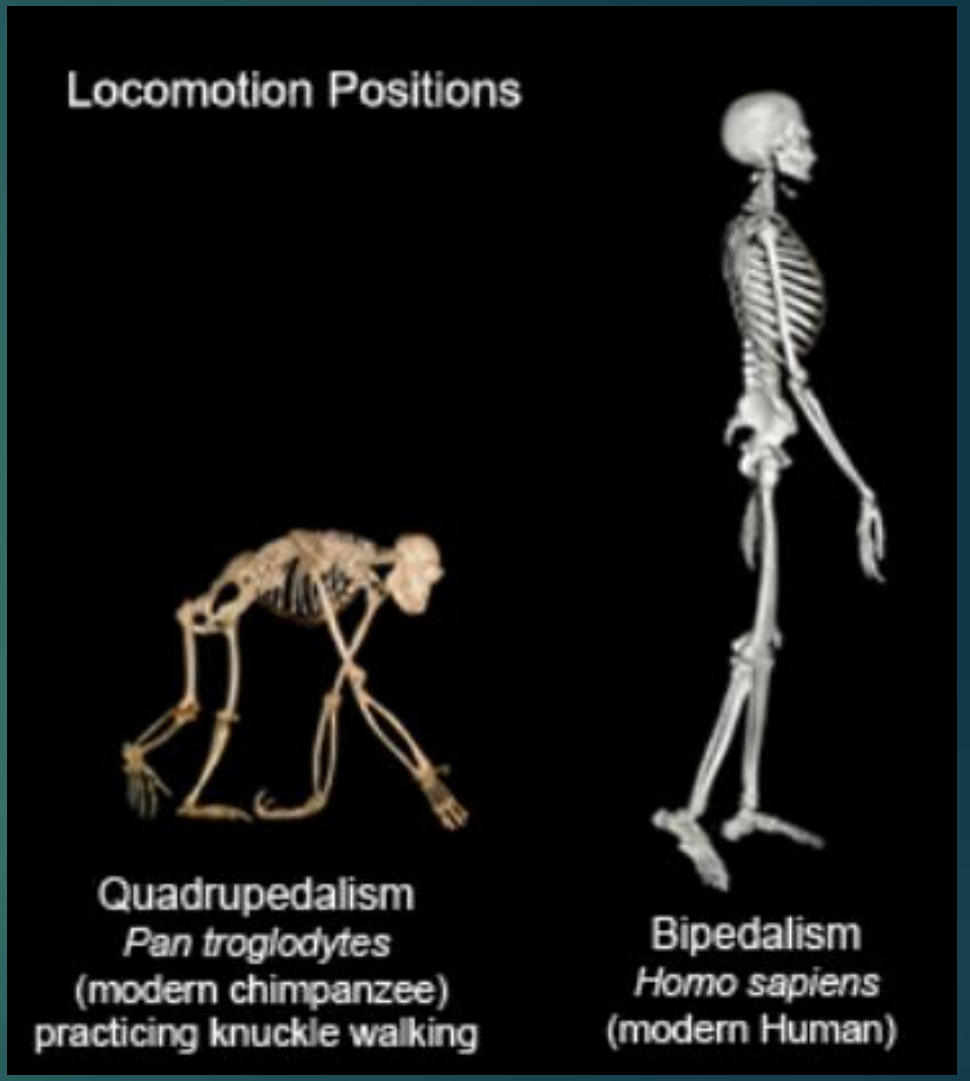
- Body Plan: *Homo erectus* (long legs, long distances)

- Bigger Brain: *Homo heidelbergensis & neanderthalensis & sapiens*

- Symbolic thinking: *Homo neanderthalensis & sapiens* (c 100K, art, pigments)

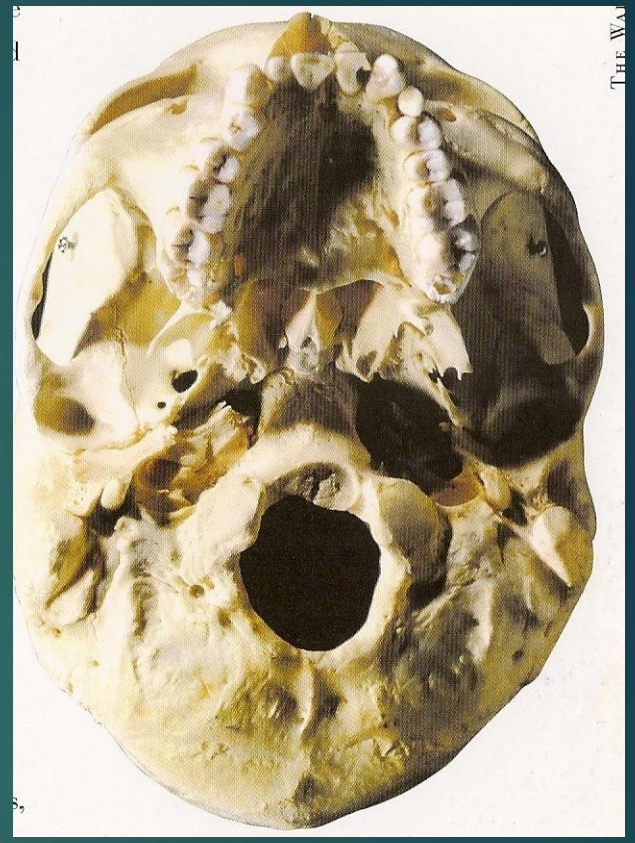
Evidence of Bipedalism

- Forward placement of foramen magnum
- Shape of spine
- Shape of pelvic girdle
- Bicondylar angle of femur (knock-kneed)
- Parallel toes (no divergent big toe)
- Two fixed arches in foot
  - Side to side / front to back



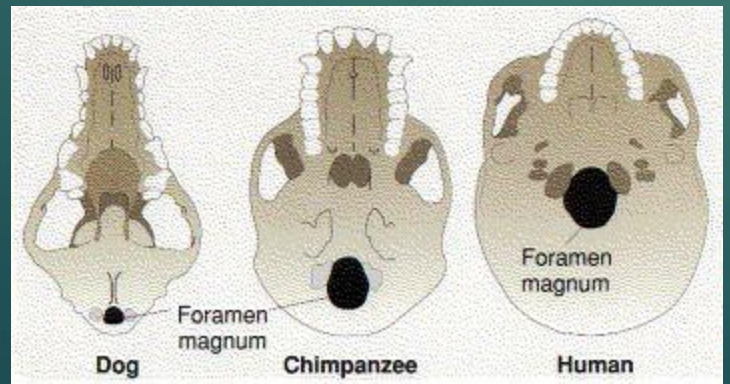
Foramen magnum: Ape vs. Hominid

1 Chimp *2 A. africanus 3 H. erectus 4 H. sapiens*



Modern human

In knucklewalkers,
In the back



More forward

Bipedalism: Six Major Hypotheses

Hauling Food

A New World

Attracting Mates

Grabbing A Bite

Keeping Cool

Weapons and Tools

ALL these models may have played a role in the emergence of habitual upright bipedalism

Splitters and Lumpers

- Number of current hominin species is controversial; not all researchers recognize the same number of species
- Splitters: those who think there are many species; new name for new find
- Lumpers: those who recognize fewer species
- Both are looking at same evidence; just interpret it differently – primarily difference is in interpretation of variation
  - Those who stress importance of continuities within fossil record, opt for fewer species
  - Those who stress discontinuities within fossil record, opt for more species
- Remember that all taxonomies are hypotheses

H. rudolfensis & H. habilis? Or just *H. habilis?*

Splitters separate *H. rudolfensis* (fossil reconstruction at left) and *H. habilis* (fossil reconstruction at right) into two species, whereas lumpers consider both to be *H. habilis*.

Splitters: 22 species

Informal Group	Splitting Taxonomy	Age (myr)	Type Specimen	Main Fossil Sites
	P. robustus	2.0–1.5	TM 1517	Cooper's, Drimolen, Gondolin, Kromdraai [Mb 3], and Swartkrans [Mbs 1, 2, and 3], South Africa
Premodern *Homo*	*H. habilis*	2.4–1.6	OH 7	Omo Shungura Formation, Ethiopia; Koobi Fora, Kenya; ?Sterkfontein and ?Swartkrans, South Africa; Olduvai, Tanzania
	H. rudolfensis	2.4–1.6	KNM-ER 1470	Koobi Fora, Kenya; Uraha, Malawi
	H. ergaster	1.9–1.5	KNM-ER 992	?Dmanisi, Georgia; Koobi Fora and West Turkana, Kenya
	H. erectus	1.8–0.2	Trinil 2	Many sites in the Old World e.g., Melka Kunturé, Ethiopia; Zhoukoudian, China; Sambungmacan, Sangiran, and Trinil, Indonesia; Olduvai, Tanzania
	H. floresiensis	0.095–0.018	LB1	Liang Bua, Flores, Indonesia
	H. antecessor	0.7–0.5	ATD6–5	Gran Dolina, Atapuerca
	H. heidelbergensis	0.6–0.1	Mauer 1	Many sites in Africa and Europe, e.g., Mauer, Germany; Boxgrove, England; Kabwe, Zambia
	H. neanderthalensis	0.2–0.03	Neanderthal 1	Many sites in Europe, the Near East, and Asia
Modern *Homo*	*H. sapiens*	0.2–pres	None designated	Many sites in the Old World and some in the New World

Splitters

Informal Group	Splitting Taxonomy	Age (myr)	Type Specimen	Main Fossil Sites
Possible hominins	*S. tchadensis*	7.0–6.0	TM 266-01-060-1	Toros-Menalla, Chad
	O. tugenensis	6.0	BAR 1000'00	Lukeino, Kenya
	Ar. ramidus	5.7–4.3	ARA-VP-6/1	Gona and Middle Awash, Ethiopia
	Ar. kadabba	5.8–5.2	ALA-VP-2/10	Middle Awash, Ethiopia
Archaic hominins	*Au. anamensis*	4.2–3.9	KNM-KP 29281	Allia Bay and Kanapoi, Kenya
	Au. afarensis	4.0–3.0	LH 4	Belohdelie, Dikika, Fejej, Hadar, Maka, and White Sands, Ethiopia; Allia Bay, Tabarin, and West Turkana, Kenya
	K. platyops	3.5–3.3	KNM-WT 40000	West Turkana, Kenya
	Au. bahrelghazali	3.5–3.0	KT 12/H1	Bahr el ghazal, Chad
	Au. africanus	3.0–2.4	Taung 1	Gladysvale, Makapansgat [Mb 3 and 4], Sterkfontein [Mb 4], and Taung, South Africa
	Au. garhi	2.5	BOU-VP-12/130	Bouri, Ethiopia
	P. aethiopicus	2.5–2.3	Omo 18.18	Omo Shungura Formation, Ethiopia; West Turkana, Kenya; Laetoli, Tanzania
	P. boisei	2.3–1.3	OH 5	Konso and Omo Shungura Formation, Ethiopia; Chesowanja, Koobi Fora, and West Turkana, Kenya; Melema, Malawi; Olduvai and Peninj (Natron), Tanzania

Lumpers: 8 species

Informal Group	Lumping Taxonomy	Age (myr)	Taxa Included from the Splitting Taxonomy
Possible hominins	*Ar. ramidus*	7.0–4.5	*Ar. ramidus, Ar. kadabba, S. tchadensis, O. tugenensis*
Archaic hominins	*Au. afarensis*	4.2–3.0	*Au. afarensis, Au. anamensis, Au. bahrelghazali, K. platyops*
	Au. africanus	3.0–2.4	*Au. africanus*
	P. boisei	2.5–1.3	*P. boisei, P. aethiopicus, Au. garhi*
	P. robustus	2.0–1.5	*P. robustus*
Premodern *Homo*	*H. habilis*	2.4–1.6	*H. habilis, H. rudolfensis*
	H. erectus	1.9–0.018	*H. erectus, H. ergaster, H. floresiensis*
Modern *Homo*	*H. sapiens*	0.7–pres	*H. sapiens, H. antecessor, H. heidelbergensis, H. neanderthalensis*

Fossil DNA

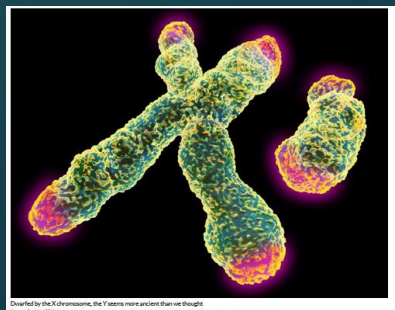
- Newest form of analysis for working out how hominin taxa are related depends on extraction and analysis of DNA
- Individuals within a taxon should share more DNA than 2 individuals from different taxa.
- DNA degrades into shorter fragments with time
- Svante Pääbo was first to recover DNA from fossil hominin (Neandertal)
- Contamination is major issue (a cave bear fossil had 20+ different modern human DNA; some are 98% bacterial DNA)

Functional/Behavioral Morphology

- Use of fossil record to work out adaptations of hominin species: how they lived their lives, habitat; how they adapted to environment
- Functional morphology: what function a fossil bone or tooth performed best and most frequently
  - i.e. curved finger bones for holding onto branches, climbing
  - Power grip for holding shaft of hammer vs precision grip for holding & using small stone tools
  - Reconstruction of diet from shape of teeth (teeth with large crowns with low, rounded cusps for diet of abrasive foods or hard shells; tubers have grit which leave microscopic scratches (microwear))
  - Use of stable isotope analysis: grass grazers vs carnivore, leaf browsers vs grass eaters

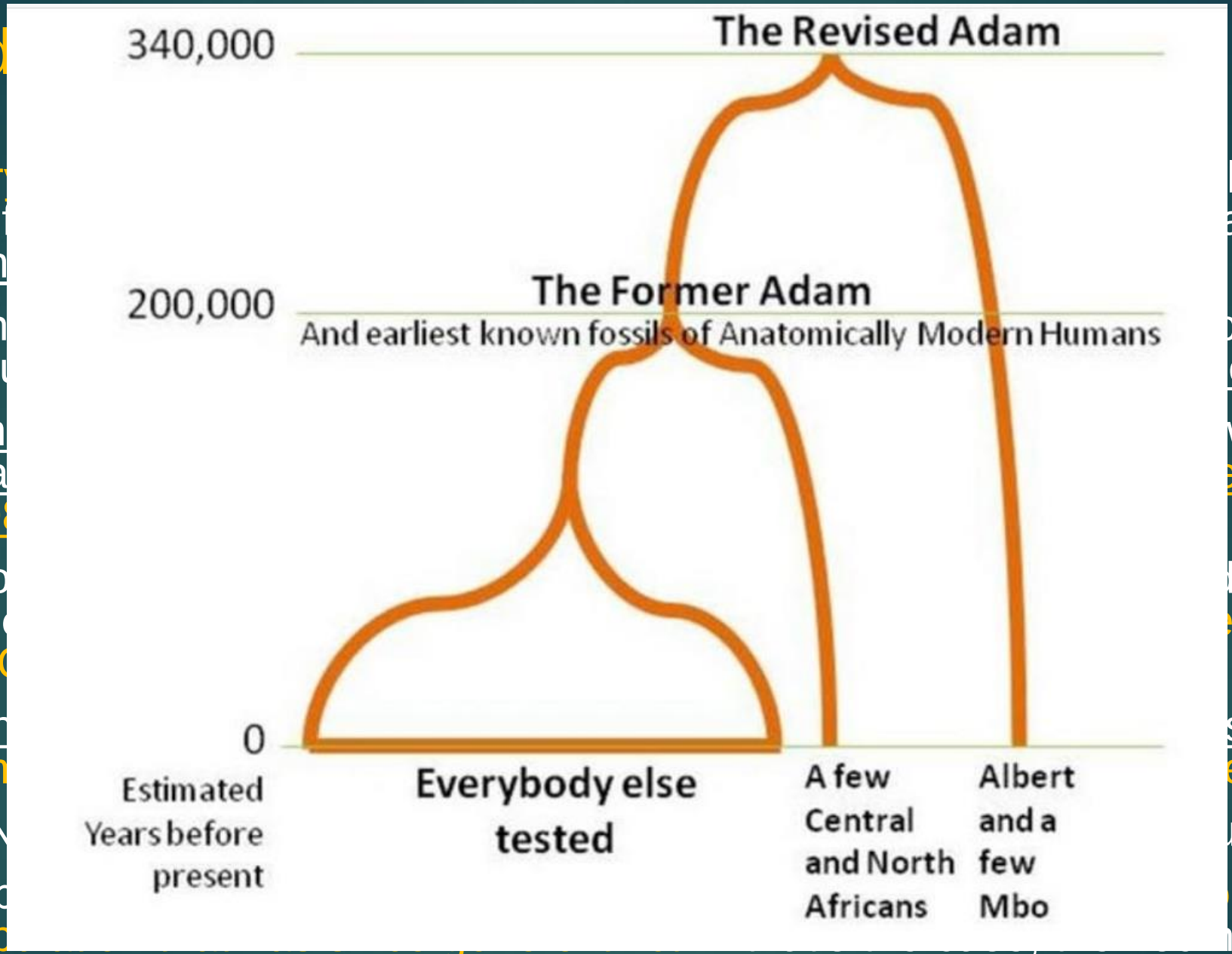
Mitochondrial Eve and Y-chromosomal Adam

- Because mitochondrial DNA are transferred from the mother to her offspring unchanged, scientists can use the variation in mitochondrial DNA across modern humans to estimate a rate of mutations (one every 3,500 years) and estimate a time back to a common ancestor who lived around 200,000 years ago. Mitochondrial Eve (Haplogroup L) in Africa
- Because Y-chromosomes are transferred from father to son unchanged, we can trace our ancestry using this DNA sequence. Using a survey of Y-chromosomes from all over the world and a reconstruction of ancestral Y-chromosome DNA from reversing mutated DNA segments, we can estimate that all men had a common ancestor: Y-DNA Haplogroup A, also known as Y-chromosome Adam, is the father of all human males, and is estimated to be 254,000 ybp
- All men except Albert Perry



Value of d

- Albert Perr lina. A few years ago, one o a sample of his descendan analysis.
- When Fam osome family tree, they ju ed.
- Perry did n was so distinct that his ma ears ago. (Some debate: 20
- Examinatio l similarities between P e village of Mbo people in C hailed from.
- The first an s, so Perry's Y chromoson es appeared.
- His is Y-DN up.
- One possib m an archaic human pop e time within the last 195,000 years, anatomically modern humans interbred with an ancient African human.

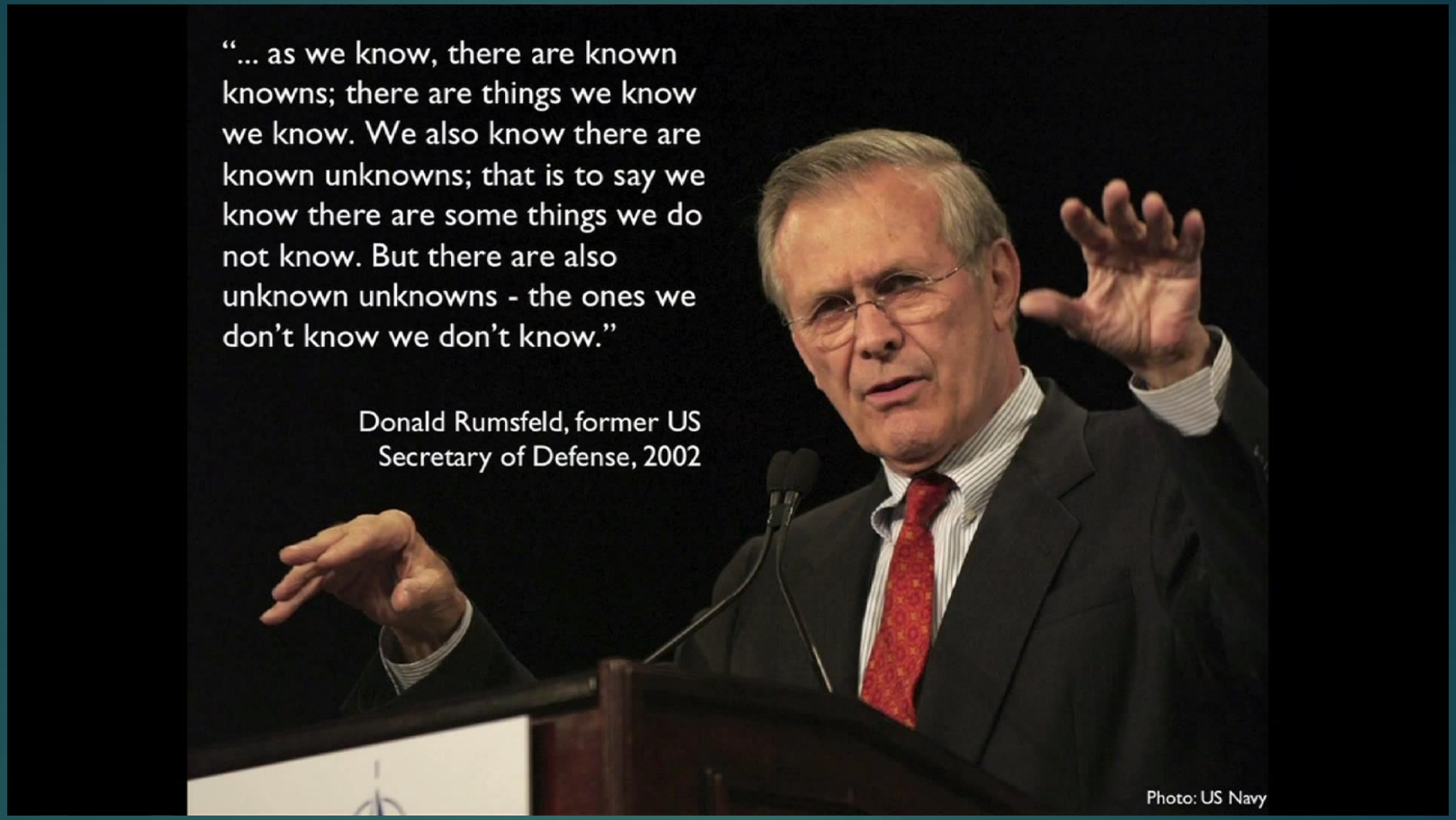


CJV's DNA = 23andme

- Born on island of Malta. Ancestry back to 1500s – all Maltese.

European	91.5%
Italian	80.9%
Malta	
Balkan	1.9%
Ashkenazi Jewish	0.2%
Broadly Southern European	5.7%
Broadly Northwestern European	0.3%
Broadly European	2.4%

Western Asian & North African	6.6%
Western Asian	3.7%
North African & Arabian	2.3%
Broadly Western Asian & North African	0.6%
Sub-Saharan African	**1.1%**
West African	0.6%
East African	0.2%
Broadly Sub-Saharan African	0.3%



Also true for fossilization

Taphonomy

• Taphonomy is the study of the process from how an individual goes from being a living, breathing organism to something that we might recover in the fossil record.

•This includes decomposition, post-mortem transport, burial, compaction, and other chemical, biologic, or physical activity which affects the remains of the organism.

• Taphonomy: study of processes of fossilization (literally, "laws of burial"; study of diagenetic processes acting on a dead animal's remains); process of death, eventually decay, or perhaps fossilization, that individuals may go through.

• Diagenesis: sum of the physical, chemical, and biological changes affecting a fossil-bearing sediment; conversion of sediment to sedimentary rock: chemicals from surrounding sediments replace organic material in hard tissue; later chemicals replace inorganic material; so a bone turns into a fossil; most common replacement minerals are calcite, silica, pyrite and hematite

Gaps and biases in hominin record

- Temporal bias in interpretation of lineages: Fossil record back to 6-7 Ma, with majority of fossils in later part of record; temporal gaps in the record

- Differential preservation:
  - Predators have preferences for which parts of carcass are eaten the most, i.e. leopards chew hands & feet of monkeys
  - Hands & feet are the parts mostly missing in human fossil record
  - Know more about fossil teeth than about hands & feet

- Body size: larger more likely to fossilize; will find larger individuals in a taxon more than smaller members

Gaps and biases in hominin record

- Differential body part preservation:
  - Teeth and mandible are the most well preserved,
  - Post cranial skeleton (vertebrae, hands, feet) tend to be poorly preserved
  - Lighter vertebra swept along in floods into lakes, mixed in with animal fossil bones
  - Heaver skull and jaws fall to bottom of floodwaters, trapped in stones on bed of streams, preserved in sediments

- Postdepositional mixing: intermixed bones can be deposited at different times, i.e. bear & N bones found together, but 1 was laid down long after N bones were buried

- What are associated with the fossils. Are there signs of butchery/cutmarks? Is there evidence for cutmark vs toothmark vs grinding.

Some principles in fossilization

- Effect of environment: cannot assume that there were more fossils from the time or place of current find; 1 place or time may have been more favorable for fossilization

- Absence of fossils at particular time or place does not have same implication as its presence (“absence of evidence is not evidence of absence”) (organism may have existed but not there or then)

- Taxa arise before they first appear in fossil record; and survive beyond last appearance in fossil record; first appearance and last appearance of fossil is conservative statement about origin & extinction

Some principles in fossilization 2

- Same reservations apply to geographical distribution of fossil sites. Hominins almost certainly lived in more locations than there are fossil sites.
- Environments in past often very different than current site, i.e. Sahara desert was forested area several times
- Not all environments conducive to fossil perseveration; some so acidic (forests), fossils rarely survive (i.e. almost no chimp fossils)

Fossilization

- Fossil = relic or trace of former living organism. Preserved skeletal material from creature that was once alive.
- Only a miniscule fraction of living organisms survive as fossils
- Fossils that survive are a biased sample of the original population
- Usually preserved in rocks
- Two types:
  - trace fossils (footprints and coprolites (fossilized feces);
  - true fossils (actual remains of animals or plants); true outnumber trace
- Animal fossils usually consist of hard tissues (bones & teeth); soft tissues only in recent fossil record (Bog People, Ice Man); rarely in rock

Fossil Types

https://www.sciencefriday.com/educational-resources/how-do-fossils-form-fossilize-me-card-game/

Fossilization: How to fossilize yourself

- Mechanisms required:
- Protection from elements: sun, water, wind, rain will erode bone; better to be fossilized in a cave or in the ground (burial)
- Area with high rate of sedimentation or movement of dirt (river banks, lake edges)
- Need rapid sedimentation for burial
- Fossilization: the biological component of the bone gets leached away into the environment and replaced with mineral components within the soil itself. This diagenesis is essentially turning a bone into a rock. So the process of fossilization is the mineralizing of a bone. What the minerals are determines what fossil looks like.
- Tropical forests have lots of decay processes and are mostly antithetical to fossilization
- Erosion for discovery: need fossil to erode from ground (often by movement of earth via tectonic action); i.e. Rift Valley

Fossils

- Teeth and jaws represent the majority of the fossil record. These are the densest bones in body. Teeth are highly mineralized (partially fossilized already)

- Some fossils preserve better than others. Some are not completely intact and are missing portions.

- If skull not completely intact, reconstruction requires hypotheses.

- Most specimens are small; often on surface; often difficult to identify what part of the skeleton it is or what species.

Where is the fossil?

Where is the fossil? Tugen Hills of Kenya, in the central Rift Valley

Color (bluish), shape, anatomy

Fossilization 2

- Chance of survival of a skeleton is very small.
  - Carnivores get first pick of dead body.
  - Then scavengers (hyenas, cats, vultures).
  - Then insects and finally bacteria.
  - Normally all of an organism's body is gone within 2-3 years

- For a skeleton to survive as a fossil, need to have been covered quickly by silt from stream, sand on beach, soil washed into a cave.

- Permineralization takes place when ground water carrying dissolved minerals infiltrates the microscopic pores and cavities in bone, wood or shell. The minerals being deposited produce stony fossils that still contain a good deal of their original solid material

- A fossil is essentially a bone or tooth-shaped rock

Fossilization 3

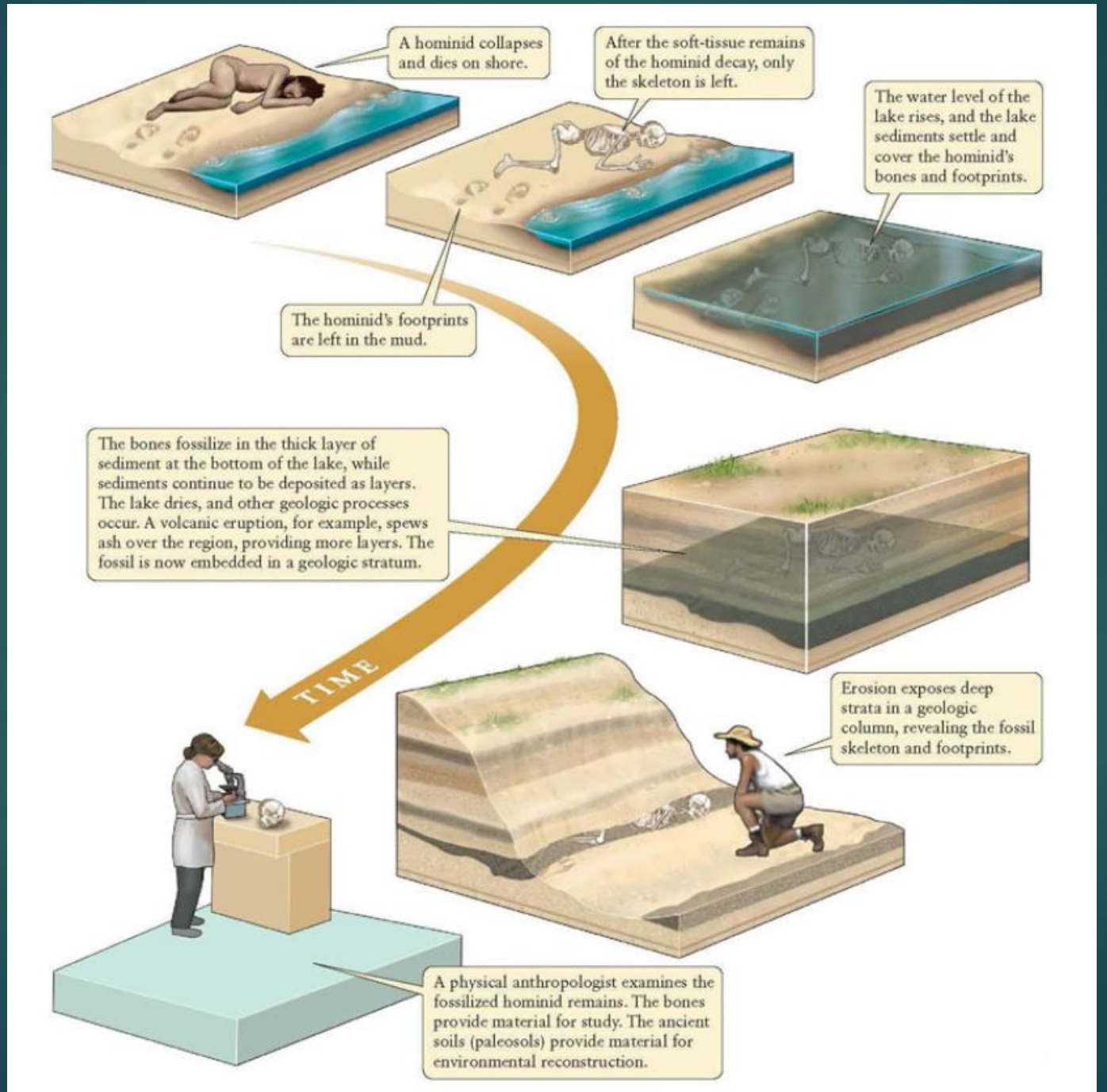
- Fossils that are freshly exposed are relatively durable.
- If a fossil is exposed to wind and rain for a longer period, or softened from plant acid, the fossil bone can become as fragile as wet tissue paper; it will decalcify and fracture (needs liquid plastic stabilizer).
- Deliberate burial increases preservation; fossil record gets better about 60-70 Ka.
- Most hominin fossils are found in rocks formed from sediments laid down by rivers or lakeshores or in cave floors.
- Law of superposition: Older rocks are in lower layers, younger ones nearer the surface; earth movement or shearing can mix these up, as do cave sediment dissolution or collapse

Fossilization 4

- Layer of rock a fossil was buried in = “parent horizon”
- Most fossils have been displaced through erosion from parent horizon. These are called “surface finds”
- Fossils found within a particular rock layer are considered to be same age as layer.
- Fossil found embedded in a rock is described as being found “in situ”.
- It helps if fossil still has some of parent rock or matrix attached to or embedded in it; can later be matched to original site. This is why scientist never completely cleans matrix from fossil

Fossil preservation tools

Air Scribe: miniature to large pneumatic jack hammer


A hominid collapses and dies on shore.
After the soft-tissue remains of the hominid decay, only the skeleton is left.
The water level of the lake rises, and the lake sediments settle and cover the hominid's bones and footprints.
The hominid's footprints are left in the mud.
The bones fossilize in the thick layer of sediment at the bottom of the lake, while sediments continue to be deposited as layers. The lake dries, and other geologic processes occur. A volcanic eruption, for example, spews ash over the region, providing more layers. The fossil is now embedded in a geologic stratum.
TIME
Erosion exposes deep strata in a geologic column, revealing the fossil skeleton and footprints.
A physical anthropologist examines the fossilized hominid remains. The bones provide material for study. The ancient soils (paleosols) provide material for environmental reconstruction.

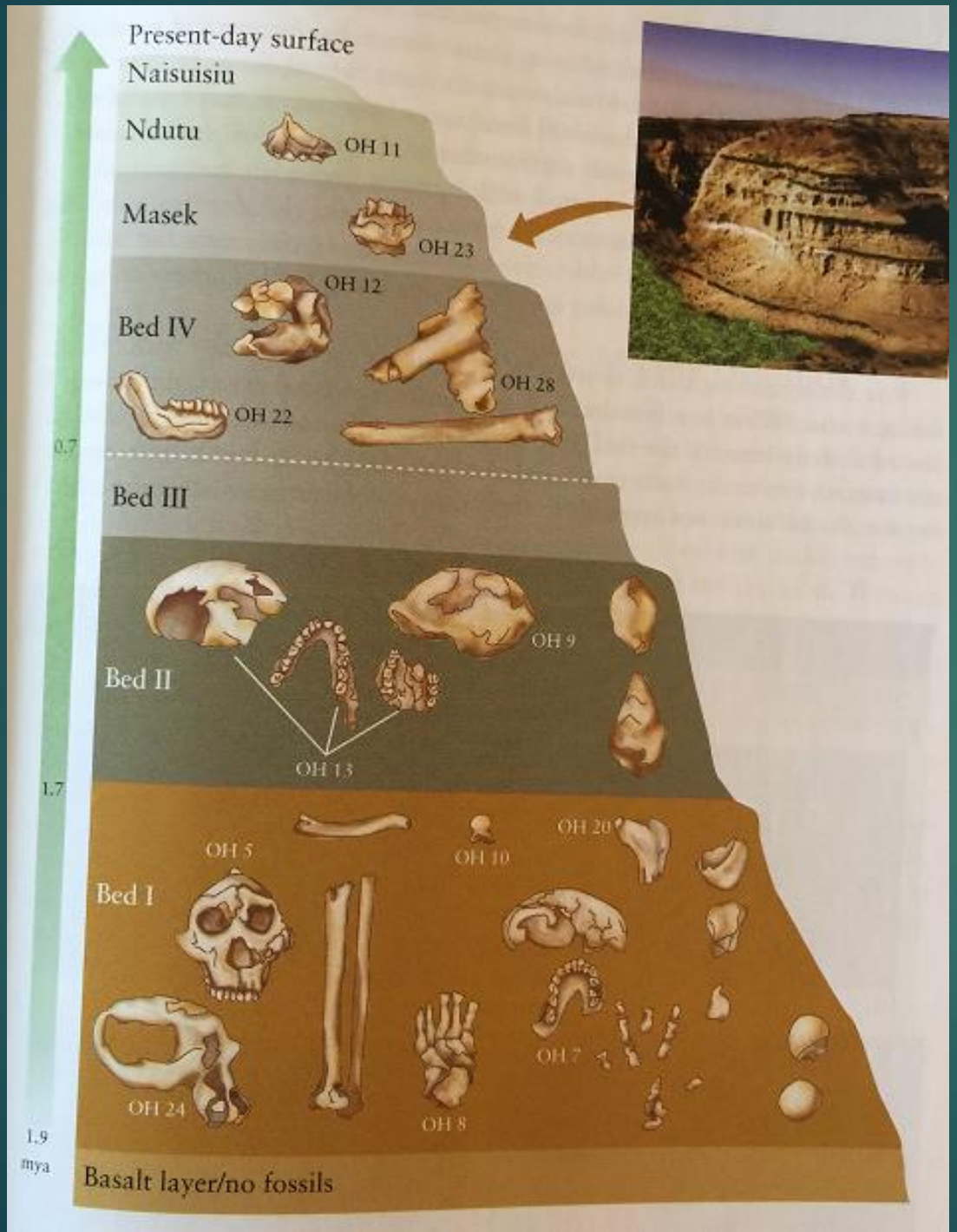
Olduvai Gorge

OH 9 – H. erectus

OH 13 - *H. habilis*

OH 7 - *H. habilis* jaw

OH 5 - *P. boisei*

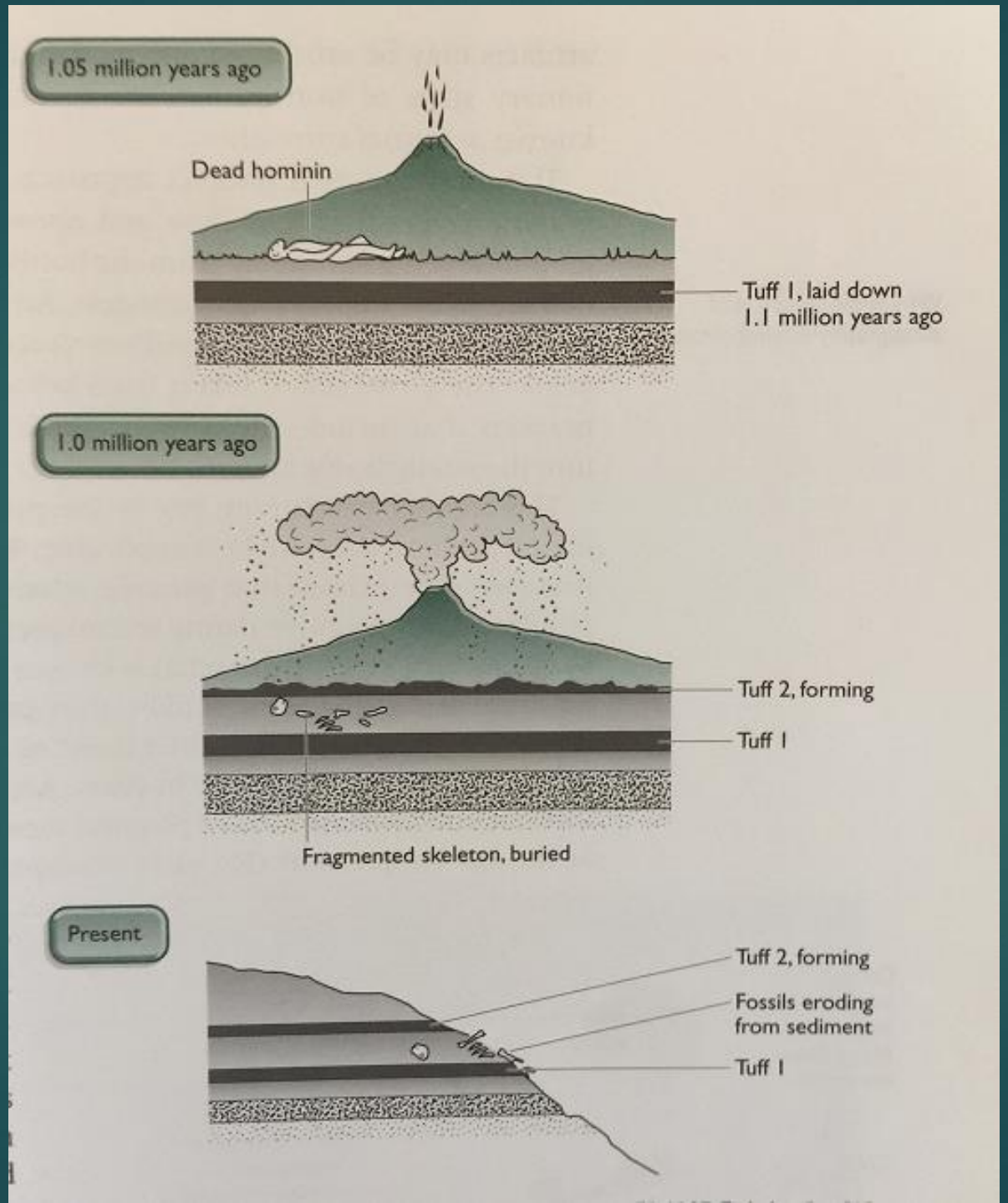


- Geologic Strata at Olduvai

- Key aspect of excavations at Olduvai is the exposed strata, dating back millions of years.
- The strata include volcanic rock, which can be radiometrically dated to provide accurate ages for each layer.
- Any fossils found in these layers can then be dated according to the stratum in which they were found.

Fossil hunting

- Paleoanthropologists look where rocks of the right age have been exposed by natural erosion, i.e. 2.0-3.0 Ma for origin of Homo species
- Walls and floor of rift valleys are formed by tectonic plates (area between faults are forced downward & crust on outside of fault is thrust upward); Rift volcanoes form when magma rises into the gap between diverging plates
- Olduvai Gorge in Tanzania is best-known example of rift valley site
- Tuffs are rocks formed from volcanic ash layers; tuffs are way many E. African hominin fossil sites are dated. Tuffs have unique chemical signatures; so they can be traced for 100s of miles.



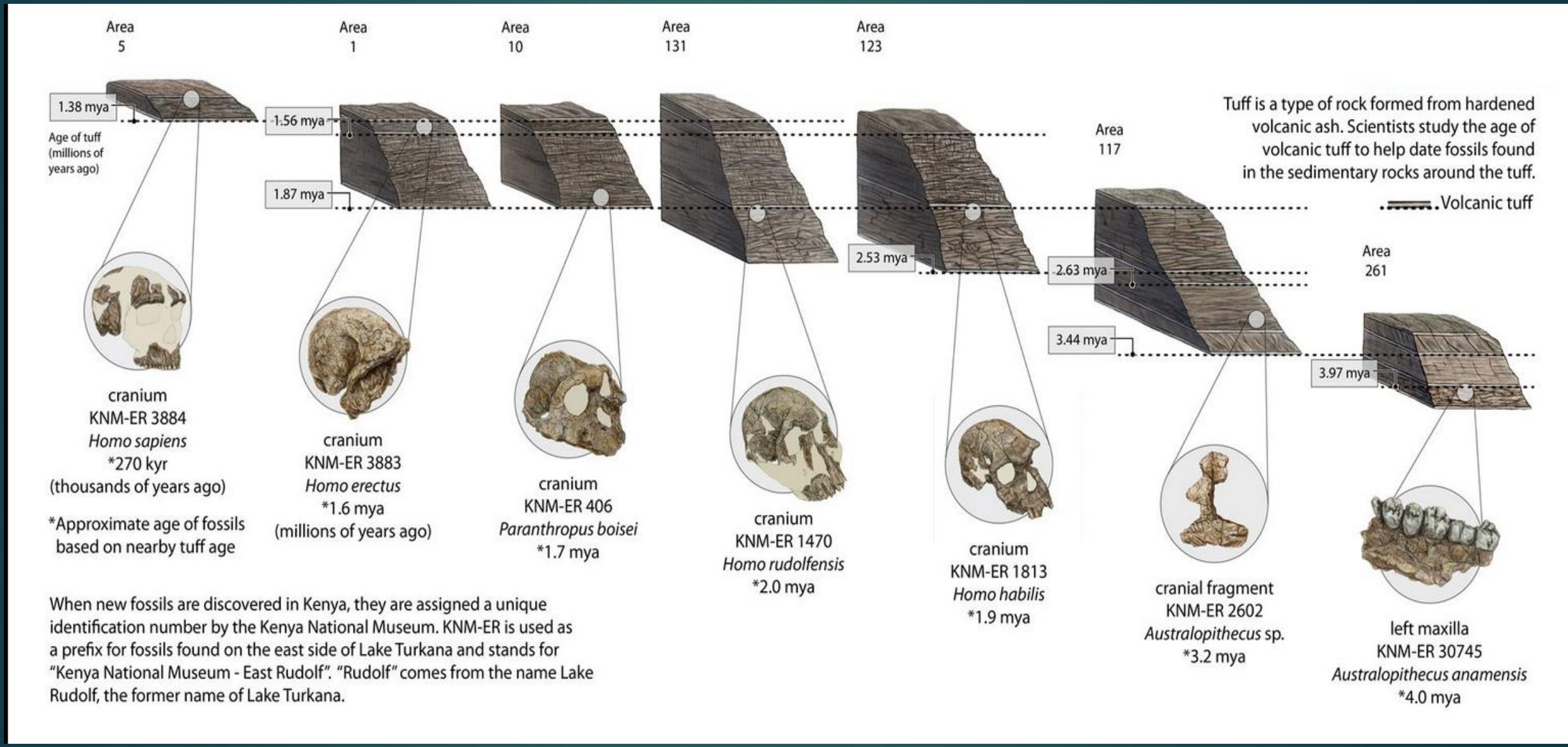
An eruption produces
Volcanic Tuff 1 = 1.1 Ma

Hominin dies at 1.05 Ma

Volcanic eruption lays
down Tuff 2 at 1.0 Ma

Tuff 2 = 1.0 Ma
Hominin date = 1.1 to 1.0 Ma
Tuff 1 = 1.1 Ma

Fossilization at Lake Turkana dating by volcanic tuff



When new fossils are discovered in Kenya, they are assigned a unique identification number by the Kenya National Museum. KNM-ER is used as a prefix for fossils found on the east side of Lake Turkana and stands for "Kenya National Museum - East Rudolf". "Rudolf" comes from the name Lake Rudolf, the former name of Lake Turkana.

Reconstructing whole fossils from fragments

- Hominin fossils that are millions of years old are seldom found in good condition

- Brain case and face are particularly fragile; easily trampled by hoofed animals or crushed by falling rocks; acacia tree seed grew from Turkana boy's skull (which fractured it into 70 pieces)

- Now use of virtual 3D anthropology: alternative to reassembly of fossils by hand; fossil is scanned by laser or CT; a virtual version is created; can do mirror imaging

How old is it?: Relative vs Absolute Dating

- Two kinds of dating techniques—
- Relative dating techniques, which attempt to place fossils into a relative sequence order, identifying those that are older and those that are younger
- Absolute dating techniques, which attempt to assign a specific date to a specific fossil, or at least a specific fossil locality. Obviously, ideally, we want absolute dating techniques, as they might provide more information.

Deep Time: How we know the Earth is old

- Rocks are clocks in disguise: relative dates through stratigraphy
- Radiometric methods: rely on half-life decay of radioactive elements to allow dating rocks and materials directly; gives absolute ages of rocks: measure ratio of a radioactive version of an element (uranium) to one of its breakdown products (lead) via mass spectroscopy and half life analysis
- Geomagnetic Reversals: Magnetic reversal of earth (N pole becomes S pole & reverse): see in sea floor spreading back to 250 Ma;
  - minerals record direction of magnetic field at time of their formation;
  - last occurred 41 Ka;
  - 184 polarity intervals in the last 83 million years.
- Volcanic hotspots: spawn new islands as crust moves over them, i.e. Hawaiian chain – perfect correlation between distance of island from active hotspot and age of its volcanic rock for last 64 M years

Incremental dating

- Incremental dating:
  - dendrochronology (tree rings);
  - varves (lake sediment layers; ice layers) back hundreds of thousands of years

- **Tephrochronology** is a geochronological technique that uses discrete layers of tephra—(from *tephra*, Gk ‘ashes’) - volcanic ash from a single eruption—to create a chronological framework in which paleoenvironmental or archaeological records can be placed.

1341 year-old Redwood

- Many trees grow a new ring in their trunk every year
- Dendrochronology – use of tree rings for relative dating of trees, and objects made from wood,
- very important for calibrating radiocarbon dates; tree rings are so reliable that they can correct carbon dates impacted by human-induced changes in atmosphere

Annual counting (including varves)

- Counting of layers to determine age in rocks, ice, etc.
- A **varve** is an annual layer of sediment or sedimentary rock.

Pleistocene age varves at Scarborough Bluffs, Toronto, Ontario, Canada. The thickest varves are

Problems with dating

- Absolute dating: date rock above (younger) and below (older) fossil; fossil's date is between those dates
- Potential problems:
  - Specter of Displaced bones: if bone is in water course, may have washed down from younger layer to current older layer
  - Strata have folded

- Potential solutions:
  - Use of other fossil faunal remains (elephants, pigs, etc.); can compare their evolutionary dating from other sites with the new find, i.e. Orrorin & faunal which were late Miocene in age (circa 6 Ma)
  - Encrustations of fresh water algae will indicate that mix of fossils are from same site

Dating S. African caves vs E. African volcanics

- East African volcanics: use Potassium-Argon (40K-40Ar); Argon-Argon (40Ar-39Ar); date layer above and below fossil

- South African caves: use of biostratigraphy – spatial and temporal use of well dated faunal fossils to date rock layers; pigs, carnivores, antelopes, rats, voles; but not always exactly same species

Relative dating methods: use of animal fossils

- **Biochronology**. Since animal species change over time, the fauna can be arranged from younger to older. At some sites, animal fossils can be dated precisely by one of these other methods. For sites that cannot be readily dated, the animal species found there can be compared to well-dated species from other sites. In this way, sites that do not have radioactive or other materials for dating can be given a reliable age estimate.

- Use of animal remains for dating (biochronology) has been important at S. African cave sites which have antelope and monkey fossils, which have been absolutely dated at key E. African sites. Has also been used in Chad and Dmanisi, Georgia.

Relative dating methods: use of animal fossils

- Paleohabitat: dating from types of animal fossils found along with human fossils; esp. micromammals (mice, gerbels) who have restricted ranges; can provide precise habitat reconstruction (i.e. parrots with Ardi means woodland)
- Rely on matching nonhominin fossils found at a site with equivalent evidence from another site that has been reliably dating using absolute methods.

- Example: Animal fossils at Site A (i.e. E. Africa) are similar to those at Site B (S. Africa). Site A can be assumed to be approximately same age as Site B. Only approximate ages for fossils.

Using pigs and elephants to date

- Evolution of pigs has been so well dated, via stratigraphy, that pig molars have been used to date human fossils

- Fossil suid (pig) data have been employed in a refinement of stratigraphic correlations at Omo Shungura, Olduvai, and east of Lake Turkana and in a correlation of East African and South African sites

- Famous fight:
  - R. Leakey found a fossil (1470), *H. rudolfensis*, that was dated as 2.9 Ma by Pot/Arg method of KBS tuff;
  - brought in faunal specialist who looked at associated pig molars and he said it could not be older than 2 Ma;
  - turned out there had been an error in original radiometric dating of tuff;
  - turned out to be 1.8 Ma *H. rudolfensis* fossil

Fossil hunting: S. African caves & Museum drawers

- South African sites are found in caves that form when rain runs through cracks in limestone. These caves fill with soils from rain runoffs.
- Leopards use trees at entrances of these caves to hide carcasses & hyenas use caves as dens.
- Current theory is that most of S. African hominin fossils were taken there by leopards or hyenas or by bone-collecting animals such as porcupines.

- Museum samples: Some dramatic hominin fossil discoveries are made in old museum collections: i.e. Spy N child; complete Neandertal skeleton of baby recovered from site of Le Moustier was sent to Marcellin Boule for age determination. It vanished until new researcher found the bones of a neonate among stone tools from site of Les Eyzies! Luckily bones had original matrix which matched original site.

How geologists date a rock

- Radioactive elements were incorporated into the Earth when the Solar System formed. All rocks and minerals contain tiny amounts of these radioactive elements. Radioactive elements are unstable; they breakdown spontaneously into more stable atoms over time, a process known as radioactive decay.
- Radioactive decay occurs at a constant rate, specific to each radioactive isotope. Since the 1950s, geologists have used radioactive elements as natural "clocks" for determining numerical ages of certain types of rocks.
- Radiometric clocks are "set" when each rock forms. "Forms" means the moment an igneous rock solidifies from magma, a sedimentary rock layer is deposited, or a rock heated by metamorphism cools off. It's this resetting process that gives us the ability to date rocks that formed at different times in earth history.

How geologists date rocks 2

- “Clock" is set the moment the rock first crystallizes from magma. Precise measurements of the amount of ^{40}K relative to ^{40}Ar in an igneous rock can tell us the amount of time that has passed since the rock crystallized.
- Any dead material incorporated with sedimentary deposits is a possible candidate for carbon-14 dating.
- Radiometric dating has been used to determine the ages of: the Earth, Moon, meteorites, ages of fossils, including early man, timing of glaciations, ages of mineral deposits, recurrence rates of earthquakes and volcanic eruptions, the history of reversals of Earth's magnetic field, and many of other geological events and processes.

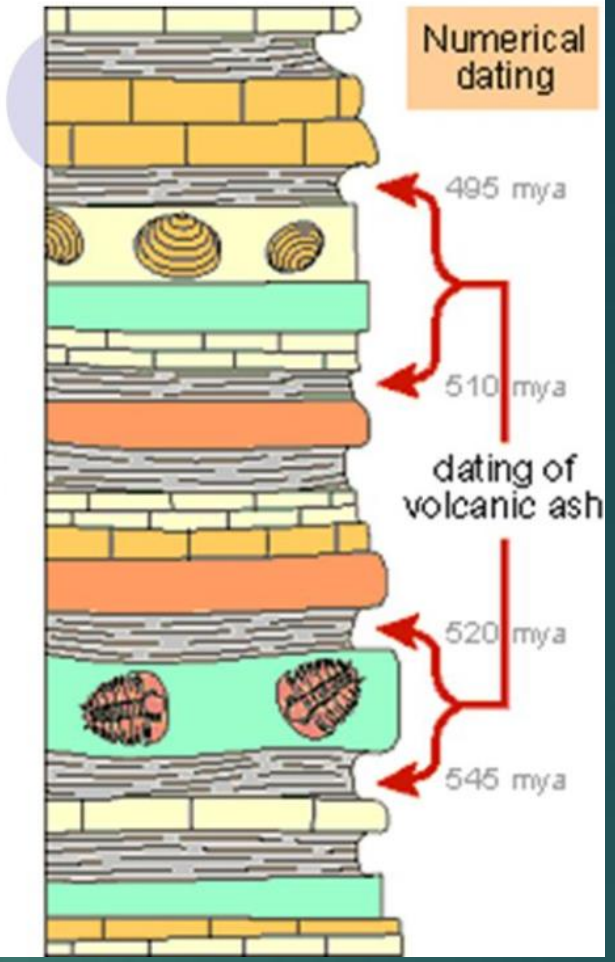
Radiometric timescale

- **Radiometric dating** or **radioactive dating** is a technique used to date materials such as rocks or carbon, in which trace radioactive impurities were selectively incorporated when they were formed.
- The method compares the abundance of a naturally occurring radioactive isotope within the material to the abundance of its decay products, which form at a known constant rate of decay.
- Decay from one kind of isotope to another: The different kinds of radiometric dating techniques have different windows of time periods for which they work effectively.
- Among the best-known techniques are radiocarbon dating, potassium–argon dating and uranium–lead dating.
- The precision of a dating method depends in part on the unique half-life of the radioactive isotope involved
- Dating can now be performed on samples as small as a nanogram using a mass spectrometer.

Dating

Absolute Dating

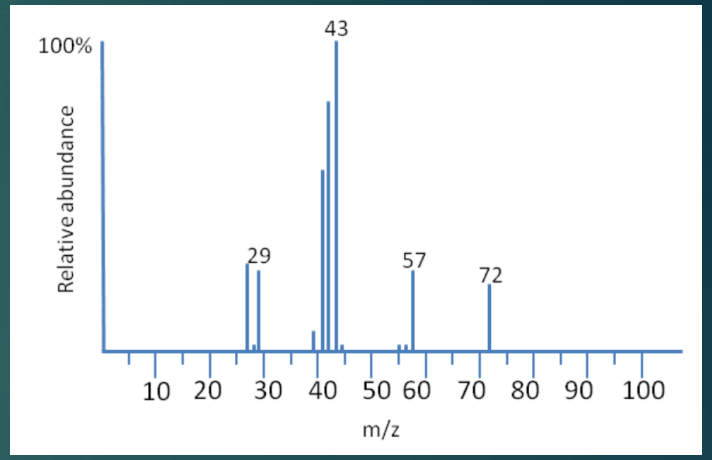
- Determining how old something is
- Use numbers (in millions of years, mya)



- **Sedimentary rocks** **can** be **dated** using radioactive carbon, but because carbon decays relatively quickly, this only works for **rocks** younger than about 50 thousand years.
- So in order to date most older fossils, scientists look for layers of igneous **rock** or volcanic ash above and below the fossil.

Absolute dating methods

- Applied to rocks in which fossils are found; need evidence that links fossil to particular rock layer
- Rely on knowing time it takes for natural processes, i.e. atomic delay, reversals in direction of earth's magnetic field; this is why absolute dates can be given precisely in calendar years.
- Best known is radiocarbon dating: after 5,730 years (+/- 40 yr) half of carbon 14 at death converts to nitrogen 14 (half life) - for dating organic materials (Maximum 50,000 to 70,000 years old), i.e. hominins in Australia and Europe;
- Amount analyzed with an accelerator mass spectrometer (measures "mass to charge" ratio of ions to identify and quantify the molecule)

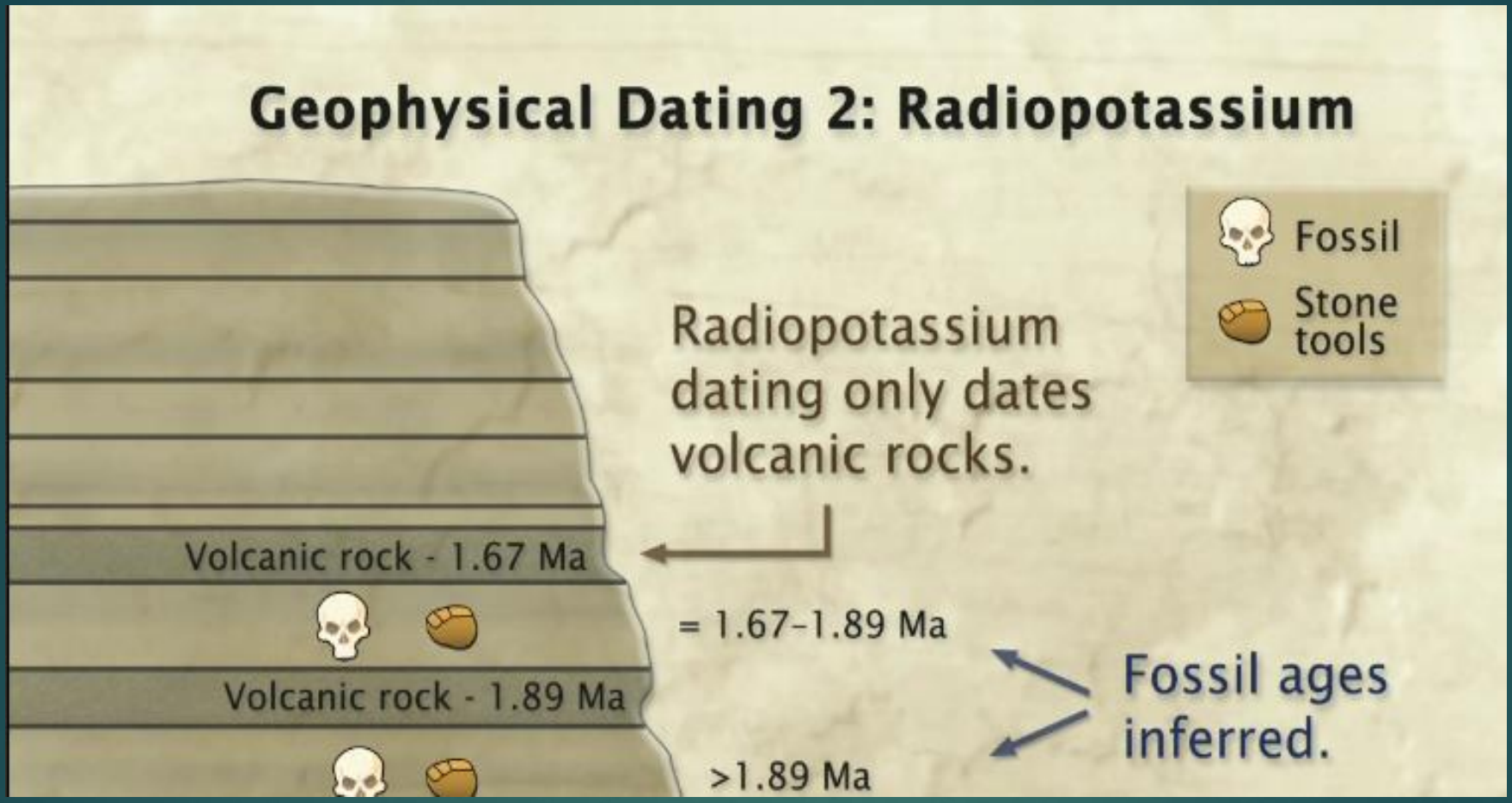


1948: Potassium-Argon Dating: Decay of radioactive potassium-40 to radioactive argon-40 in minerals and rocks

All of these methods measure the amount of radioactive decay of chemical elements; the decay occurs in a consistent manner, like a clock, over long periods of time.

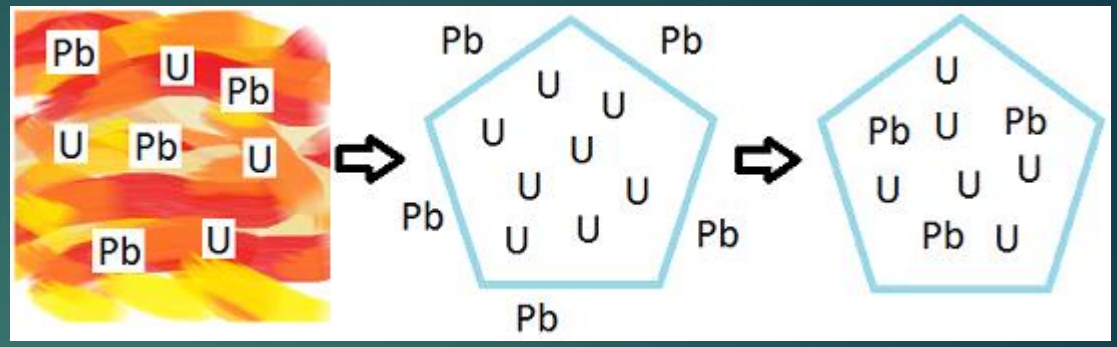
- Feldspar crystals found in the tuff layers contain an unstable isotope of potassium that can be used for this dating method. Over time, the unstable potassium isotope (^{40}K) from the rocks decay into a stable isotope of argon (^{40}Ar). The ratio of the stable argon isotope formed from decay to the unstable potassium isotopes tells scientists when the tuff layer cooled and solidified into rock.

- Range: 20 K to 4.5 billion years



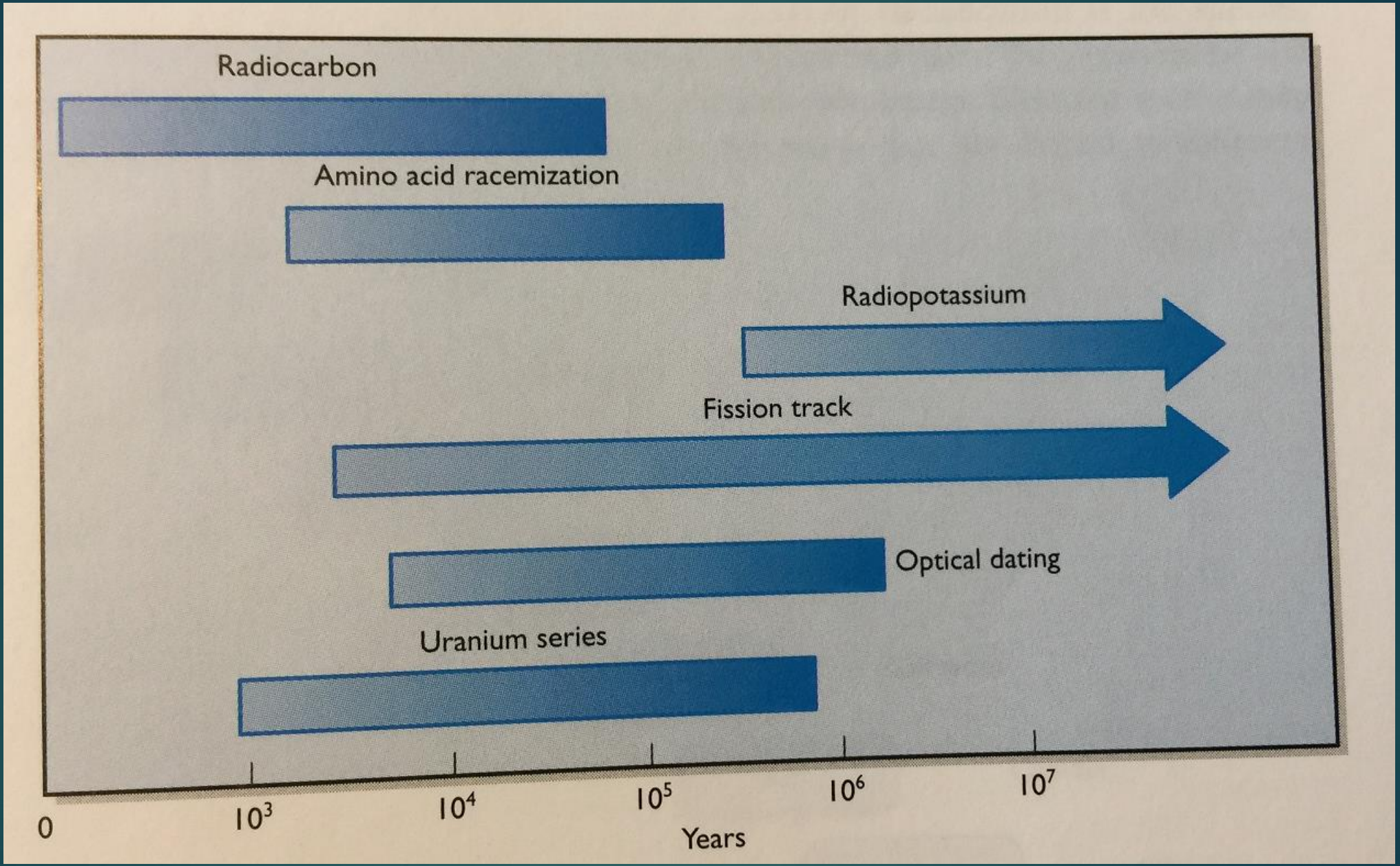
In volcanic rock, half life of 40 AR is 1.23 Billion years

Radiometric Dating:
Uranium-238 to Lead-206



Uranium Decays to Lead Inside Zircon

- Uranium–lead radiometric dating: often performed on the mineral zircon; dates a substance's absolute age. Uranium-238's decay to lead-206 has a half-life of about 4.5 billion years
- Take a quantity of uranium-238 and in 4.5 billion years half of it will have turned into lead-206.
- When molten rock hardens into a solid, the uranium-238 within it begins to decay. By comparing the ratio of uranium-238 to lead-206, we can estimate how old the rock is.
- The same thing can be done with Samarium-neodymium, Potassium-argon, Rubidium-strontium, and Uranium-thorium transitions.

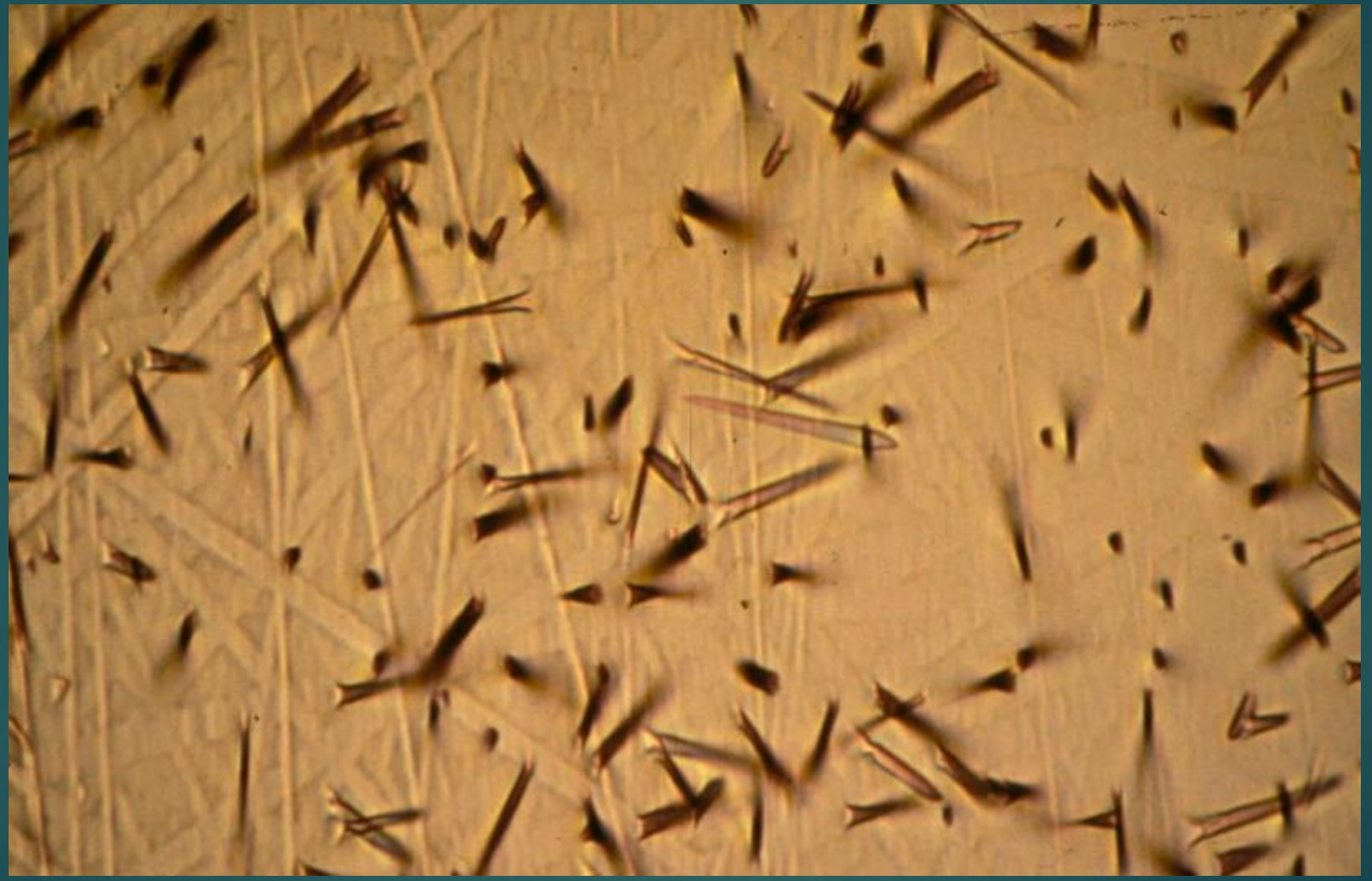


1000 10,000 100,000 1,000,000 10,000,000 years

ISOTOPES		HALF-LI FE OF PARENT (YEARS)	EFFECTIVE DATING RANGE (YEARS)	MINERALS AND OTHER MATERIALS THAT CAN BE DATED
PARENT	DAUGHTER			
Uranium-238	Lead-206	4.5 billion	10 million- 4.6 billion	Zircon Uraninite
Potassium-40	Argon-40	1.3 billion	50,000 - 4.6 billion	Muscovite Biotite Hornblende Whole volcanic rock
Rubidium-87	Strontium-87	47 billion	10 million - 4.6 billion	Muscovite Biotite Potassium feldspar Whole metamorphic or igneous rock
Carbon-14	Nitrogen-14	5730	100 -70,000	Wood, charcoal, peat Bone and tissue Shell and other calcium carbonate Groundwater, ocean water, and glacier ice containing dissolved carbon dioxide

Method	Basis	Material	Date Range
Relative Age			
Law of Superposition	Older is lower	Just about anything	Just about any time
Stratigraphic Correlation	Like strata in different regions are related to same event	Rocks and fossils	Just about any time
Biostratigraphic (Faunal) Dating	Evolution of animals	Bones and teeth	Just about any time
Chemical Dating	Fossils absorb chemicals, i.e. fluorine in soil	Bones	Less tan 100 Ka
Cultural Dating	Artifacts are time specific	Technology generally	Up to about 2.5 Ma
Numerical Age			
Dendrochronology	Tree growth	Specific tree types	12,000-8,000 yBP
Radiocarbon Dating	Carbon-14	Anything organic	75,000-50,000 yBP
Radiopotassium Dating	Potassium-40	Volcanic rocks	More than 200 Ka
Amino Acid Dating	Racemization	Bones, shells	1 Ma-40 Ka
Fission Track Dating	Fission tracks on rock crystal	Volcanic rock	Up to 3 Ma
Paleomagnetic Dating	Shifts in Earth's magnetic field	Sedimentary rocks	Up to 5 Ma
Electron Spin Resonance Dating	Concentration of radioisotopes	Bone, teeth	Several thousand to more than 1 Ma
Luminescence Dating	Trapped energy	Sediment, stone, ceramics	Up to 800 Ka

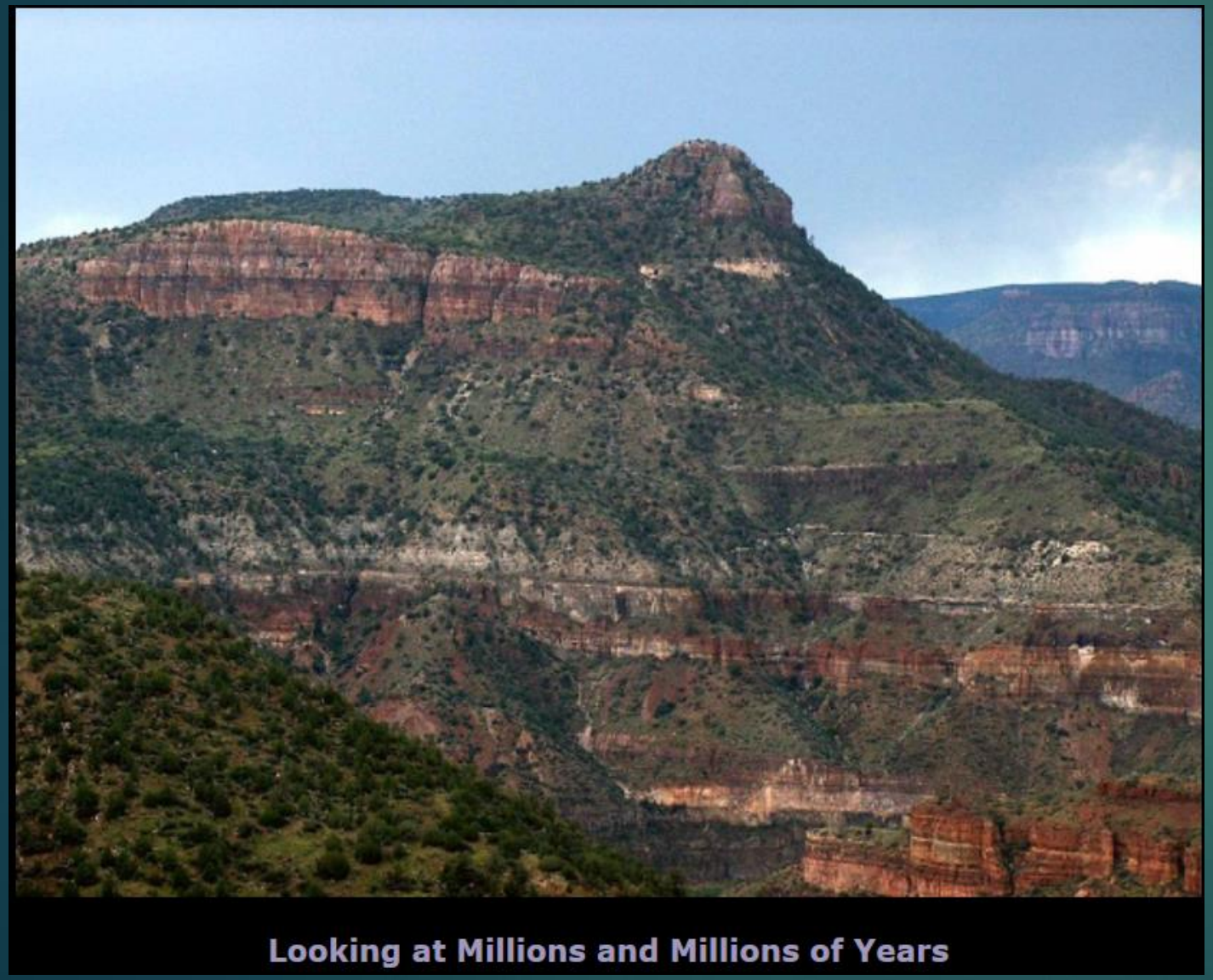
Fission tracks in apatite crystal: dates up to 3 Ma



Dating methods: heating & cooling of rocks preserve electronic properties

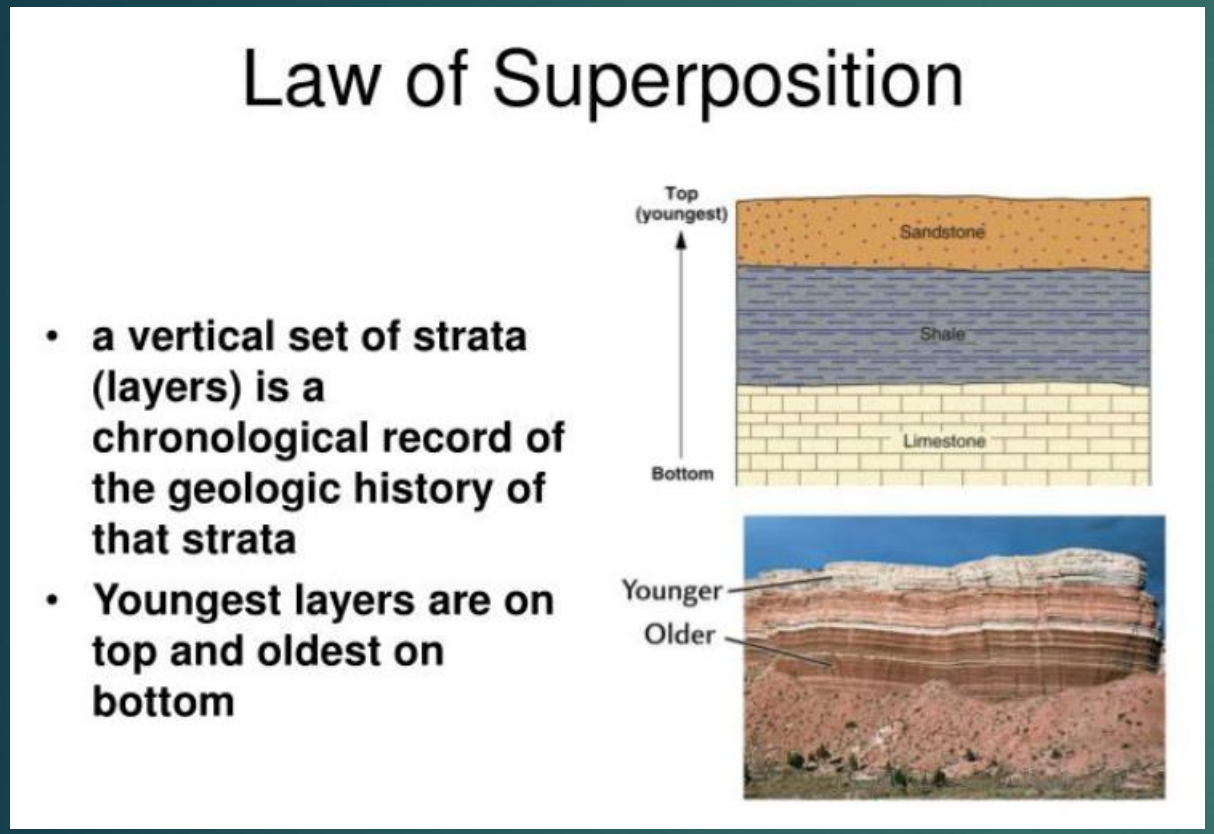
- Measurement of the amount of electrons that get absorbed and trapped inside a rock or tooth over time.
- Thermoluminescence dating - for dating inorganic material including ceramics
  - Certain materials within rocks had actually been buried and not exposed to the sunlight for a long period of time. By chemically treating those rocks, able to determine how long it was that they were last exposed to light, and measuring the light energy released when heating it.
- OSL or Optically stimulated luminescence: method for measuring doses from ionizing radiation
  - Luminescence dating of ancient materials: mainly geological sediments and sometimes fired pottery, bricks etc., although in the latter case thermoluminescence dating is used more often; applied to mineral grains such as quartz. OSL can establish age of sediments by determining when light last irradiated a mineral grain
- ESR, or electron spin resonance.
  - When something has been superheated and then cools very quickly, the electrons within the minerals within that rock actually preserve certain kinds of properties. By examining those properties, we're able to determine how old all these rocks are.

Lithographic Stratigraphy



- decomposition of sediment,
- chemical precipitation,
- decaying organic matter,
- volcanic lava.

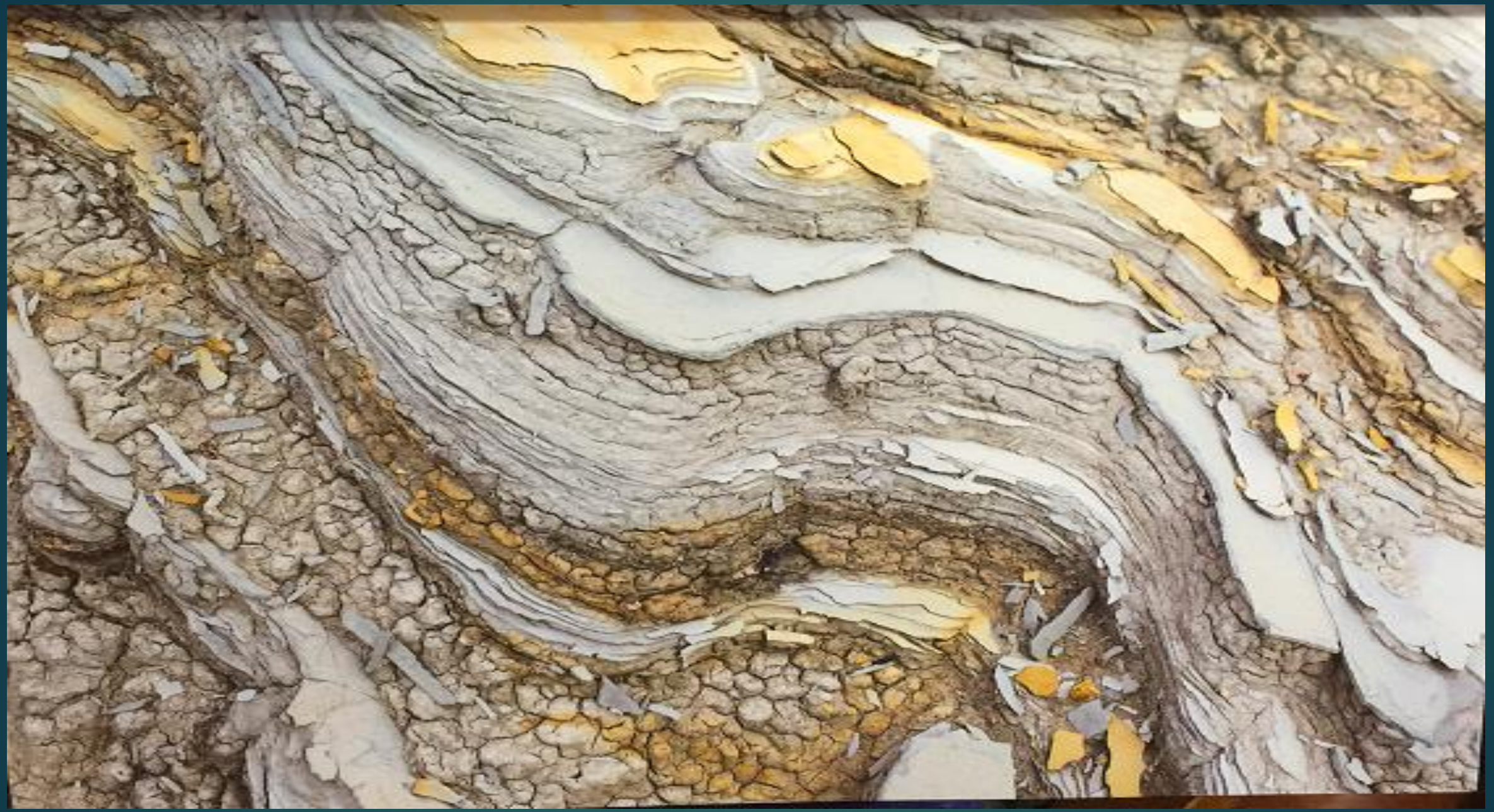
Law of superposition

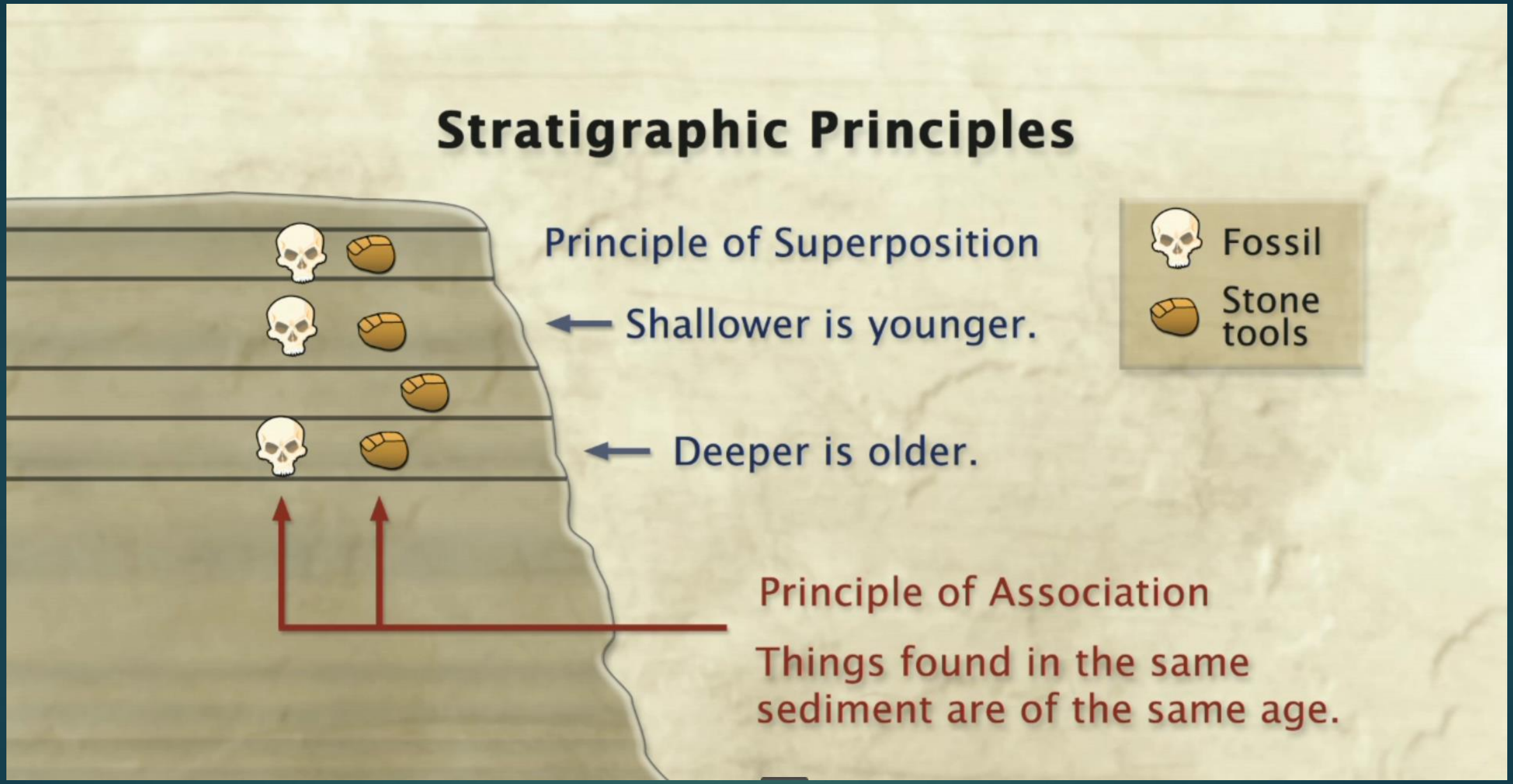


- Layers are laid down on top of each other,
- with the bottom layers laid down first (older)
- and the top layers laid down last (younger);
- So the general rule of thumb: the deeper you go into a sedimentary context, the further back in time you go.
- From younger to older.

Stratigraphy: Geology keeps time - Deeper/lower is older

- Provides a sequence of events from which relative dates can be extrapolated. How change occurs across time.
- Sediments and volcanic ash: sediments form layers, oldest at bottom, youngest on top
- Can correlate to other locales; This process known as geo-chronology allows us to correlate the age of different sedimentary layers across locations
- We can use this same basic process then to identify relative chronological sequences of specific categories of fossils. This is what we refer to as bio-chronology.

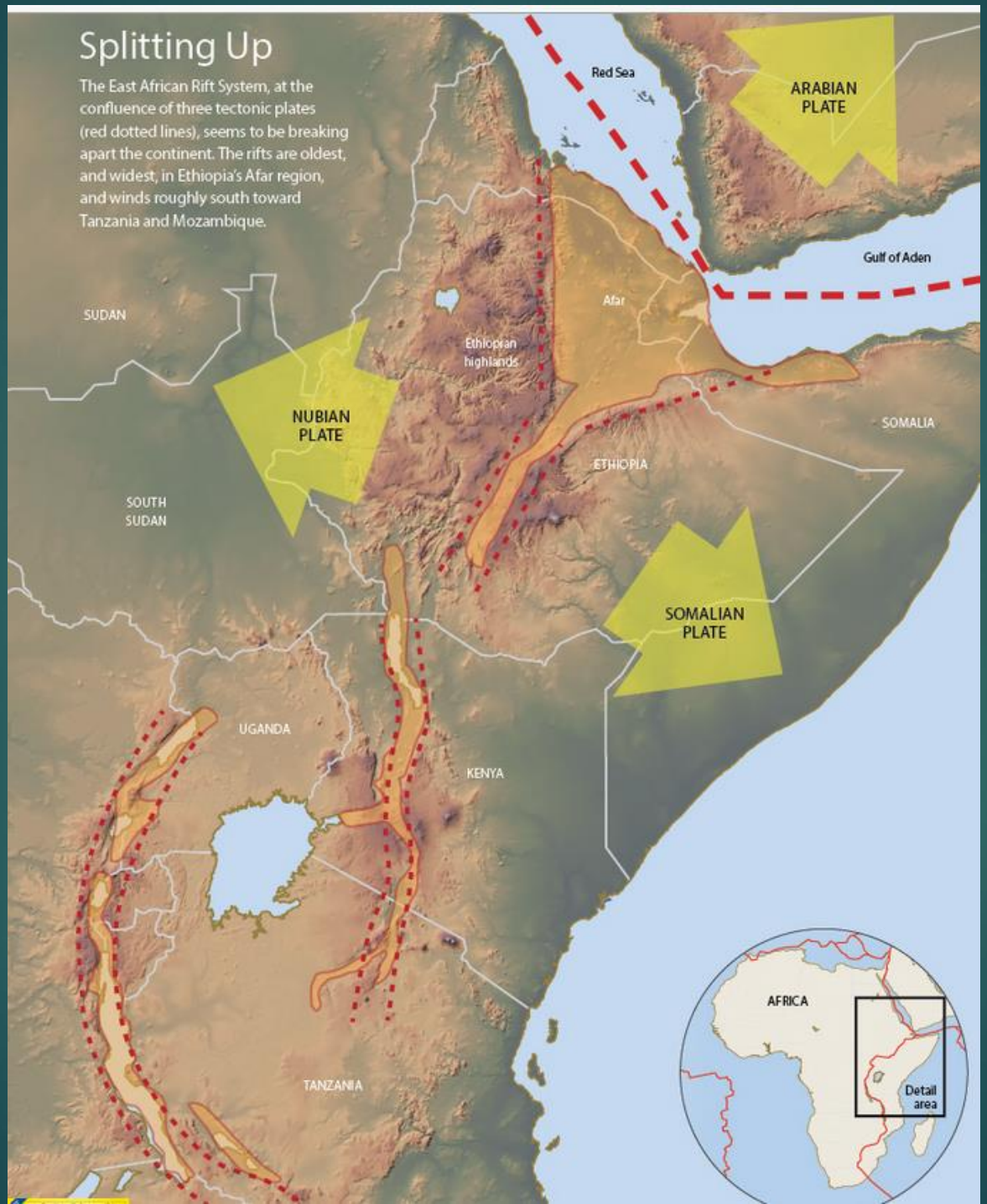




Deposited “at the same time” is sliding rule: days, weeks, years, etc.

East Africa and Rift Valley

- East Africa sits on top of 3 tectonic plates that are separating.
- Volcanos always sit on top of tectonic rift areas.
- Repeated volcanic eruptions have repeatedly spewed volcanic ash onto this landscape.
- So pattern of formation of layers of sedimentary rock (with fossils in them), blanketed repeatedly by layers of volcanic tuffs (igneous rock produced by volcanic eruption)
- Volcanic tuffs are radioactively dateable (all crystals solidify at same age). Grains of sediment can be dated, but have radically different ages.
- Layers of volcanic rocks, above and below the layers containing fossils, can be dated to provide a date range for the fossil containing sedimentary rocks.


Splitting Up
The East African Rift System, at the confluence of three tectonic plates (red dotted lines), seems to be breaking apart the continent. The rifts are oldest, and widest, in Ethiopia's Afar region, and winds roughly south toward Tanzania and Mozambique.
Red Sea
ARABIAN PLATE
Gulf of Aden
Afar
SUDAN
Ethiopian highlands
NUBIAN PLATE
SOMALIA
ETHIOPIA
SOUTH SUDAN
SOMALIAN PLATE
UGANDA
KENYA
TANZANIA
AFRICA
Detail area

Stratigraphy: 2 volcanic ash falls at Aramis, Ethiopia;1000 years apart

Therefore: Ardi, ~ 4.4 Ma

Fossils are very, very rare

Middle Awash:
1 km of sediment

Age (Ma)	Localities	Fossils	Archaeology	Hominids	Publications
0.08	Aduma	21	MSA	4	*AJPA 03*
0.10	Halibee	2,646	MSA	16	
0.16	Herto	104	MSA/L.Acheulean	12	*Nature 03*
0.2	Talalak	575	MSA/L.Acheulean	2	
0.5	Bodo	25	Typ. Acheulean	3	*Nature 84*
1.0	Bouri Daka	753	Early Acheulean	11	*Science 04* *Nature 02*
2.0	Guneta	753	Oldowan +	2	
2.5	Bouri Hata	576	Oldowan	11	*Science 99*
3.5	Maka	171		12	*Nature 84, 93*
3.9	Belohdelie	54		1	*Nature 84*
4.1	Asa Issie	605		37	*Nature 06*
4.4	Aramis	6,432		114	*Nature 94* *Science 09*
5.3	Amba	550		1	*Nature 01*
5.8	W. Margin	2,230		19	*Nature 01* *Science 04*

Law of Faunal Succession

- Sedimentary rock strata contain fossilized flora and fauna, and that these fossils succeed each other vertically in a specific, reliable order that can be identified over wide horizontal distances.

- Paluxy Texas Dinosaur/"Man Track" Controversy: Despite Creationist claims, you will never find a modern human bone in the same stratum as a *Tyrannosaurus rex* bone, or their tracks in same layer

- *Tyrannosaurus rex* and humans weren't alive at the same time; 60 million year separation; therefore, their stratum didn't get laid down at the same time.

Relationship of Metatarsal Dinosaur tracks to "man tracks"

Breakup of Pangaea

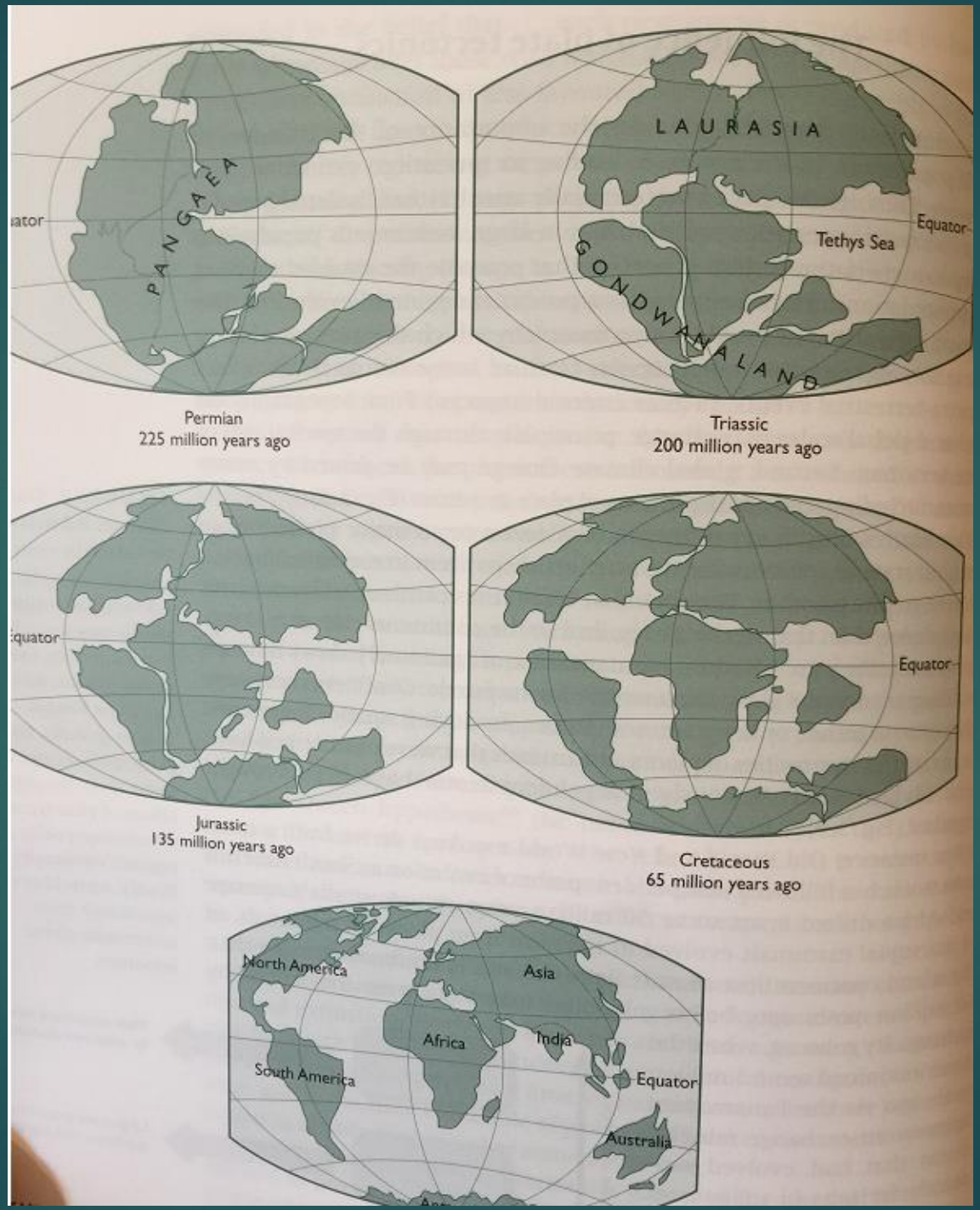
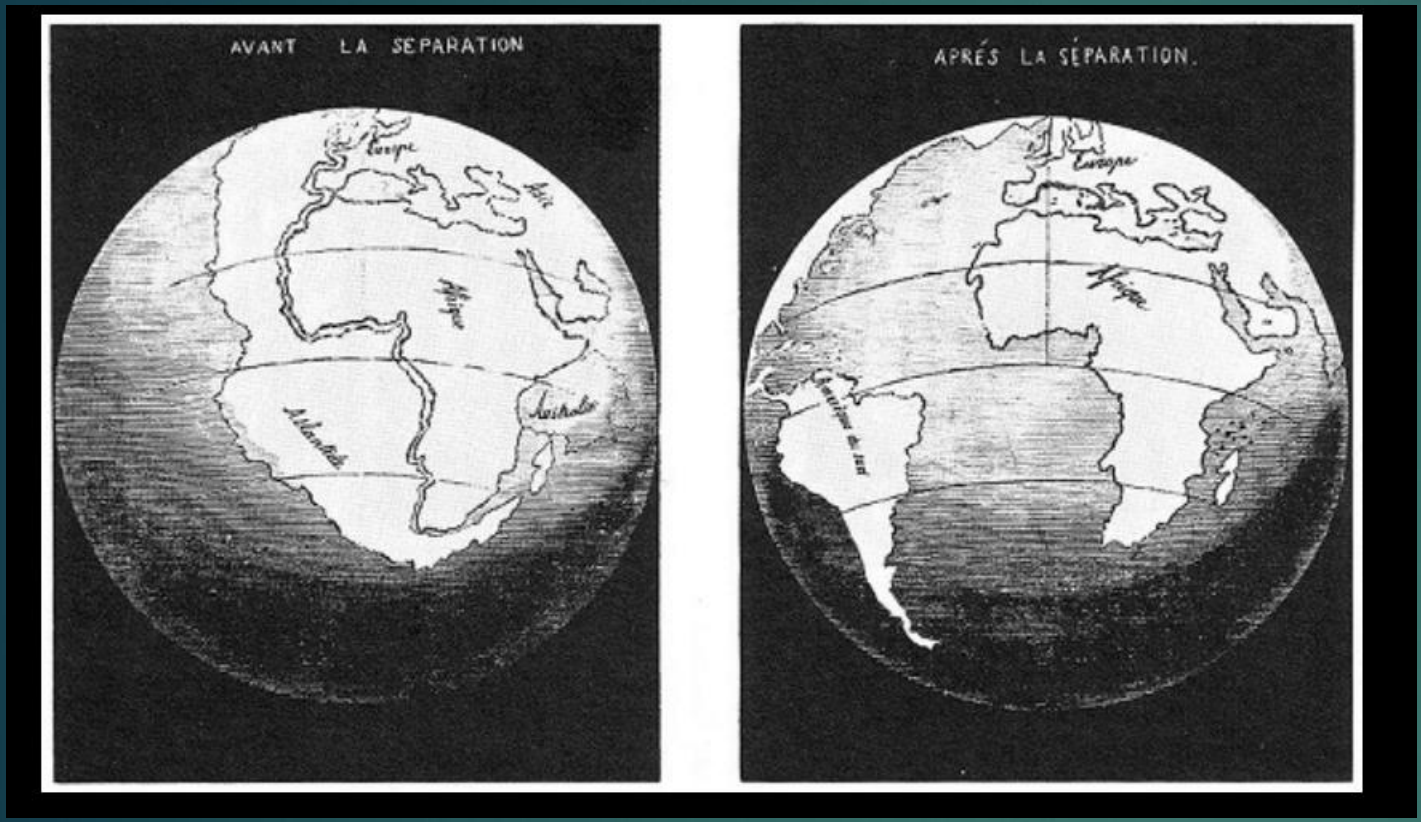


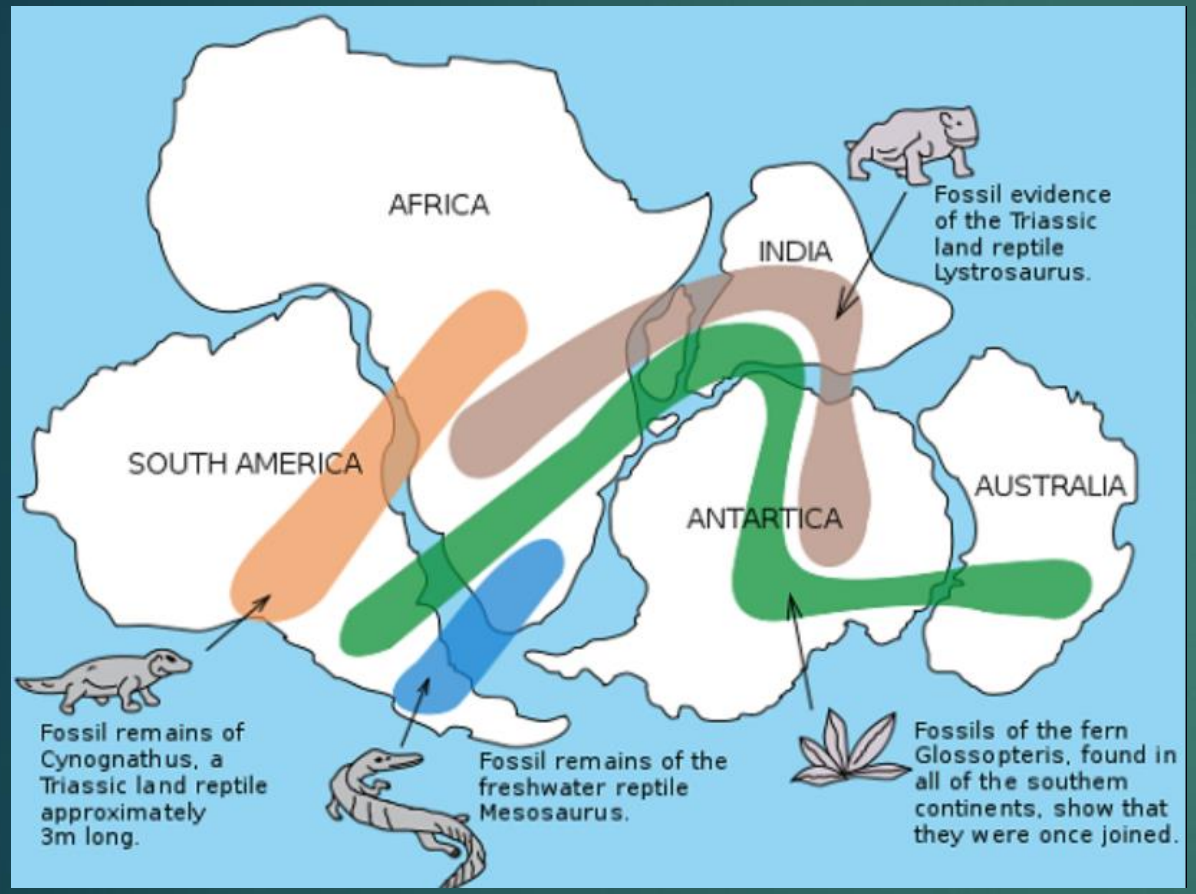
Plate tectonics & continental drift



First known illustration of the Opening of the Atlantic Ocean, by Antonio Snider-Pellegrini, 1858

- South America fits into Africa
- rocks get younger the closer you get to where the crust is spreading under the ocean
- Satellites have observed the drift
- The continents drift at a rate of a few centimeters a year and the distance between the Americas and Africa is now 455 M centimeters (2827 miles).

Biogeography: Same Fossils on Both Sides of the Atlantic



- There are matching fossils on both sides of where the continents appear to have split apart 200 Ma
- Cynognathus, a Triassic land reptile, fossils are found in South America and Africa.
- The Triassic era was between 250 & 200 Ma

Ostrich Eggshells: Amino acid racemization

- Uses biochemical reactions as a clock
- Eggshells contain amino acid Leucine. When eggshell formed, Leucine is in L form. Over time L form converts (racemizes) at steady rate to D form. Ratio of these two forms, plus rate of conversion, provides date for original formation of shell.
- OES (ostrich eggshell dating): Many late African hominin fossil sites contain ostrich eggshell fragments;
- Dating between 300 and 40 Ka: OES, electron spin resonance, ESR, uranium series dating (USD)

Dating methods

- Obsidian hydration dating - a geochemical method of determining age in either absolute or relative terms of an artifact (stone tool) made of obsidian; property of mineral hydration, and absorbs water, when exposed to air, at well defined rate.

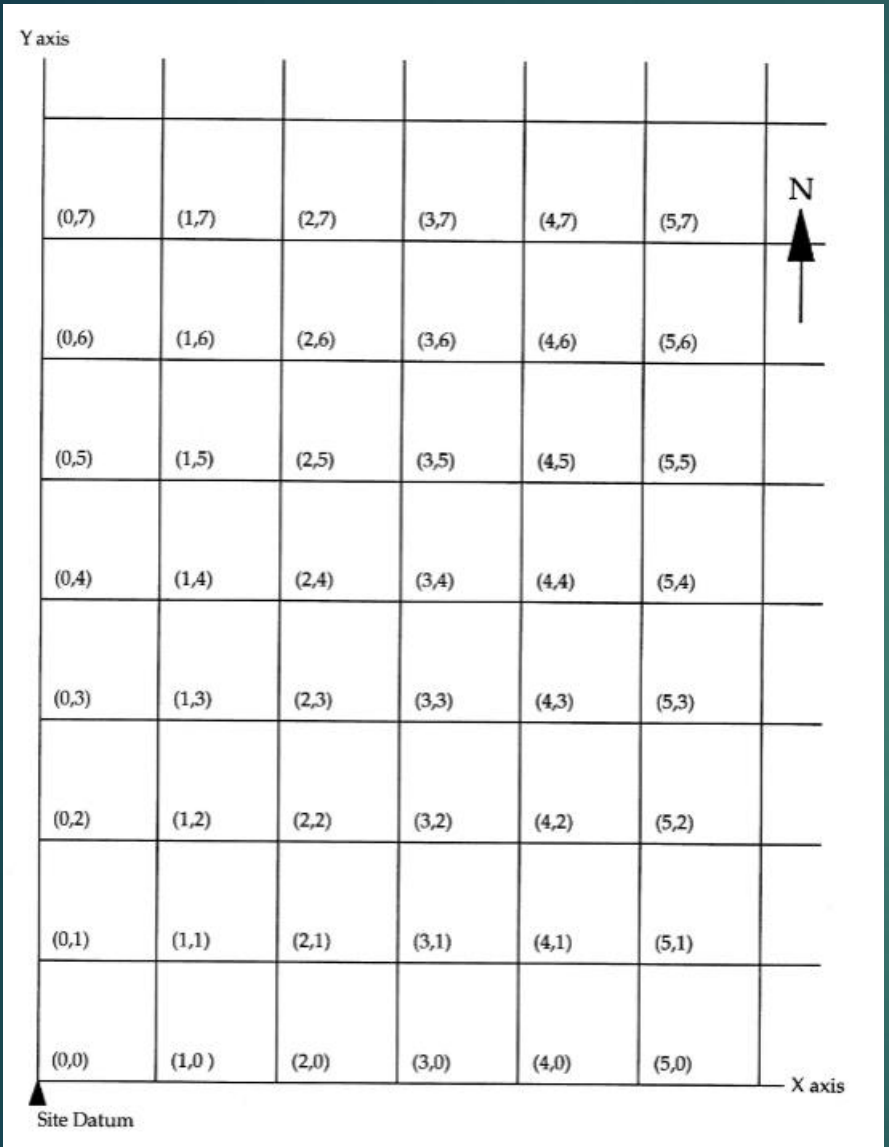
- Rehydroxylation dating - for dating ceramic materials; after a ceramic specimen is removed from the kiln at the time of production, it immediately begins to recombine chemically with moisture from the environment. This reaction reincorporates hydroxyl (OH) groups into the ceramic material

Cartesian coordinate system at excavation sites

- Way archaeologists preserve context on paper is through the use of the rectangular grid, or Cartesian coordinate system.

- The first step in the excavation process is to establish a grid. A site datum is set at an arbitrarily chosen location and is designated as (0,0). Two perpendicular axes or lines intersecting at the site datum are then established and a rectangular grid is superimposed over the entire site. Each square on the ground is marked with numbered stakes in the corners, so that each square or grid unit has a unique “name” referred to by its coordinates. The coordinates indicate the distance of a given point north, south, east, or west from the site datum.

- Once the grid is established, all artifacts and structures are measured and recorded using the system. Before excavation actually begins, all artifacts visible on the surface are collected and their locations on the grid are recorded. As the excavation proceeds, materials found under the surface are similarly recorded and collected.


Y axis
(0,7)
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(3,7)
(4,7)
(5,7)
(0,6)
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(1,0)
(2,0)
(3,0)
(4,0)
(5,0)
N
X axis
Site Datum


Y axis line
N
Flake
Sherd
Projectile point
(x,y)
(0,0)
Site Datum
X axis line

3D recordings of sites: Total Stations

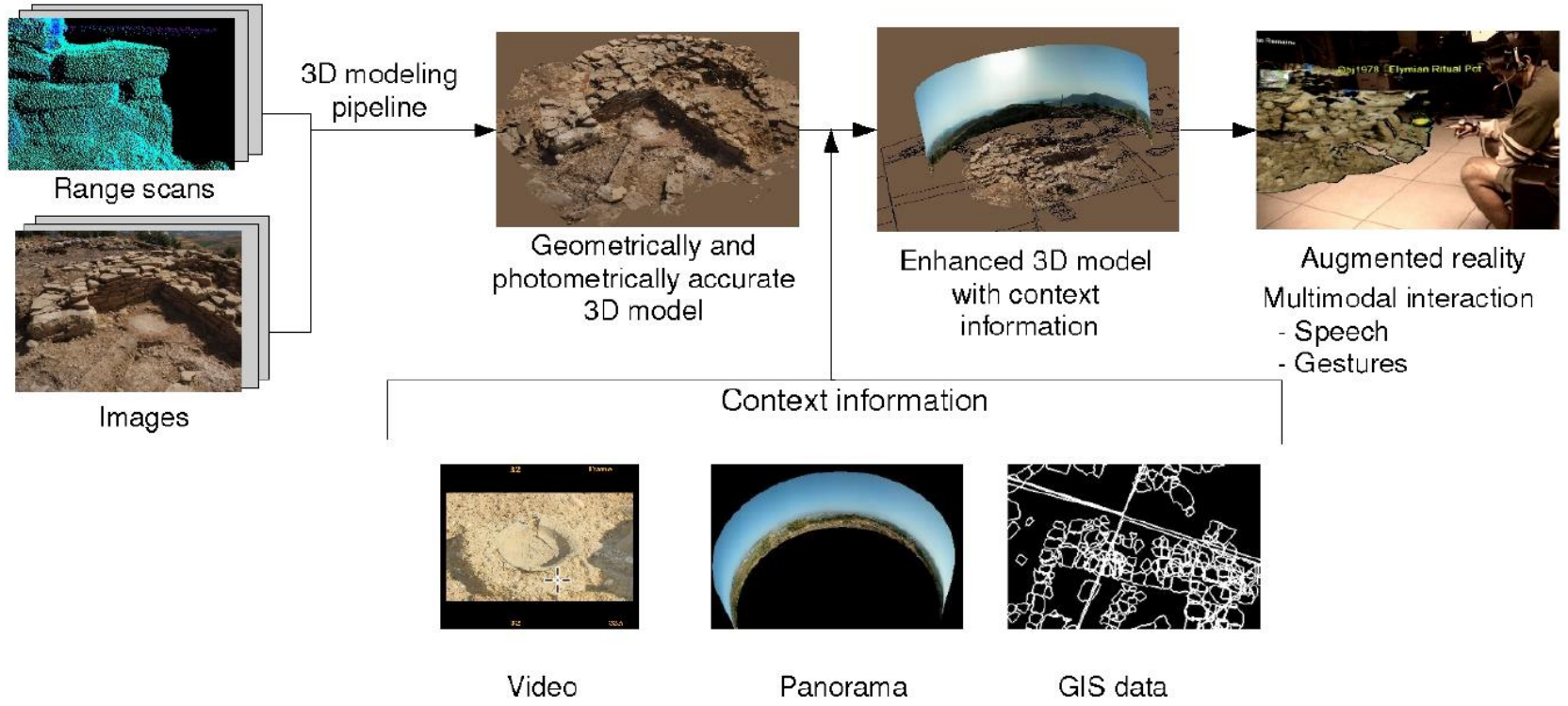
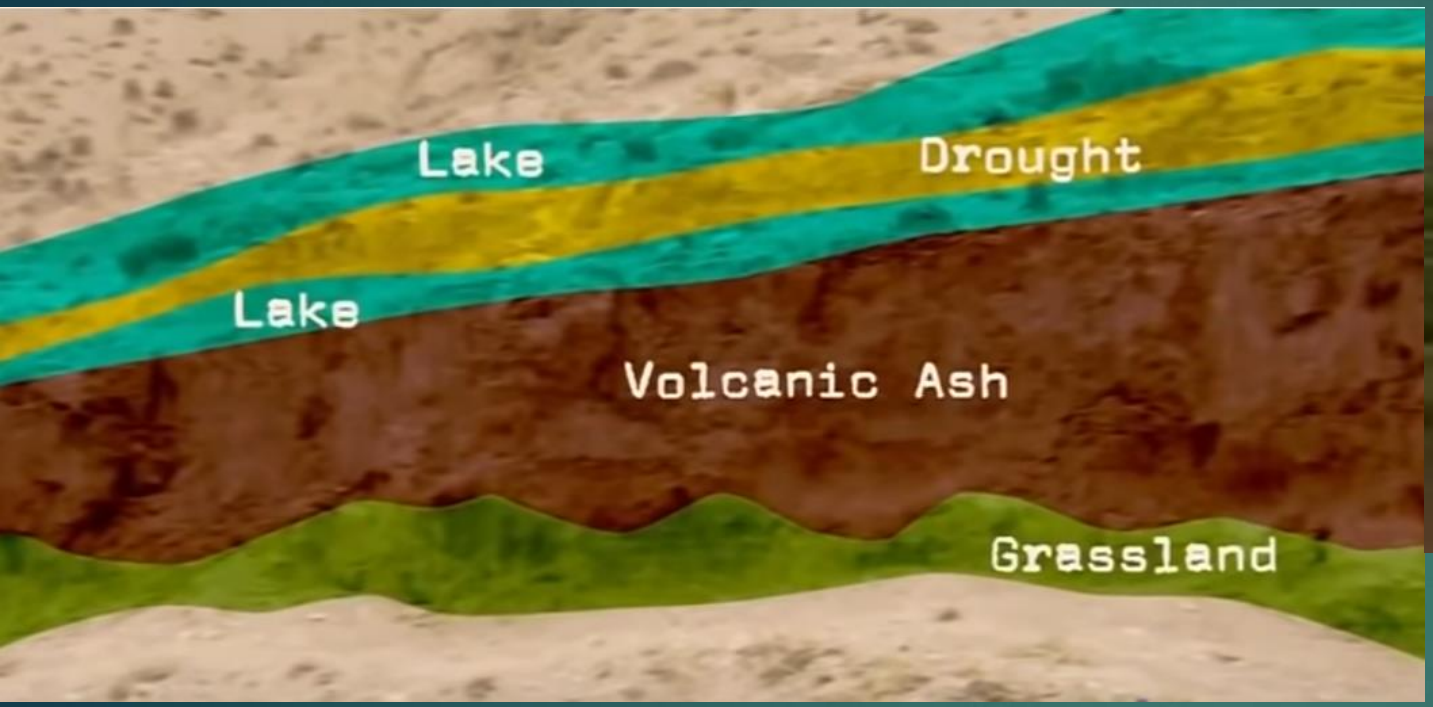


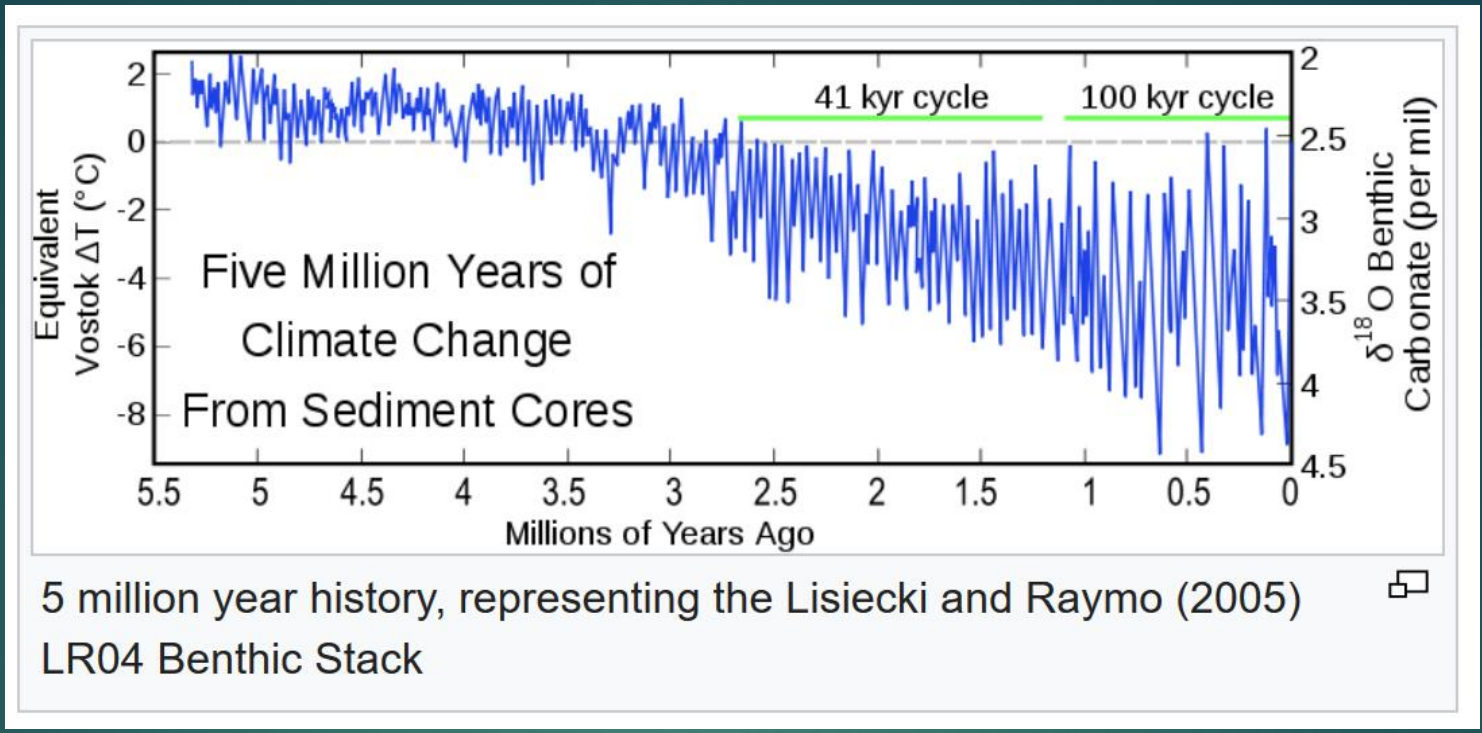
Figure 2. *Our 3D modeling and visualization pipeline. We start by building a textured 3D model using range scans and images, which we enhance with contextual information in the form of panoramic images, video, and GIS data. This context-rich model is then used as input to our multimodal augmented reality application.*

High-resolution field techniques and survey instruments called total stations that allow direct, accurate measurement of the 3D locations of found artefacts; allows exceptional precision of measurements & reconstruction

Climate instability: stratigraphic layering in Kenya, southern end of rift valley, is evidence of climatic change

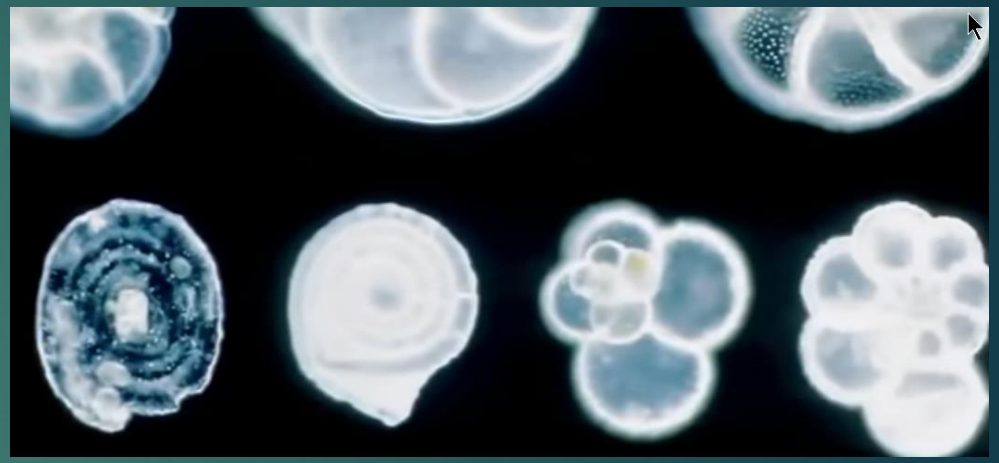


Rick Potts: Did the need to adapt to sudden climatic changes lead to evolution of bigger brains? Lakes appeared and disappeared many times; evidence from diatoms who specialize in deep and shallow water; Lakes the size of Lake Victoria repeatedly appeared and disappeared; landscape that changed from dry, desert to wet forest and back; all within 1000 years



- Marine isotope stages (MIS) are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples.
- Working backwards from the present, which is MIS 1 in the scale, stages with even numbers have high levels of oxygen-18 and represent cold glacial periods, while the odd-numbered stages are low levels in the oxygen-18 figures, representing warm interglacial intervals.
- The data are derived from pollen and foraminifera (plankton) remains in drilled marine sediment cores and other data that reflect historic climate; back to MIS 100 (2.6 Ma)

Ocean sediments: record of millions of years of climatic change



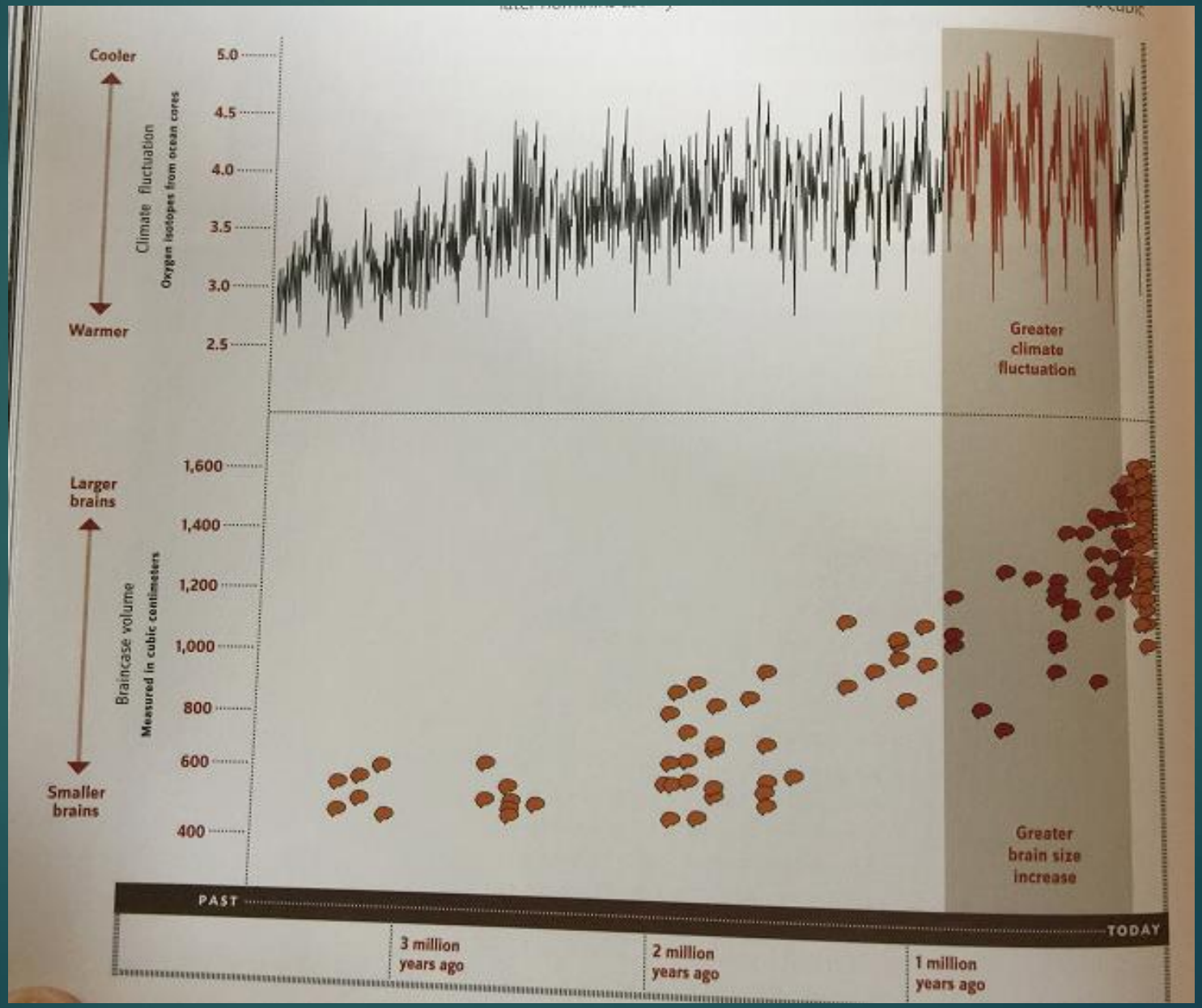
Deep sea sediment cores: history book of African climate change

- Can date foraminifera; the shells contain more heavy oxygen when ocean waters are cold and ice covers the Earth
- Since 8-5 Ma, general global drying and cooling trend; prior to 3 Ma global climate subject to 23 kyr hotter/drier and cooler/wetter cycles;
- Around 3 Ma, became every 41 kyr; around 800 Ka, 100 kyr cycle; latter are responsible for ice ages; lot of water in ice caps, sea level fall; access to Australia & New World

Climate changes & adaptability

- During 2 million period of hominin brain flatlining between *Sahelanthropus* (Toumai, at 7 Ma) and *A. afarensis* (Salem, at 3.3 Ma), African weather was mostly stable and dry
- Then 200 Ky of wildly fluctuating climate: stone tools appear at Olduvai
- Rick Potts: Discounts traditional theory of appearance of savannah as driving force for human evolution;
- He thinks variability of weather itself was driving force; adaptation to change was driving force
- Human evolution is nature's experiment with versatility; ability to adapt to any environment is core of humanness

Brain size and climactic instability

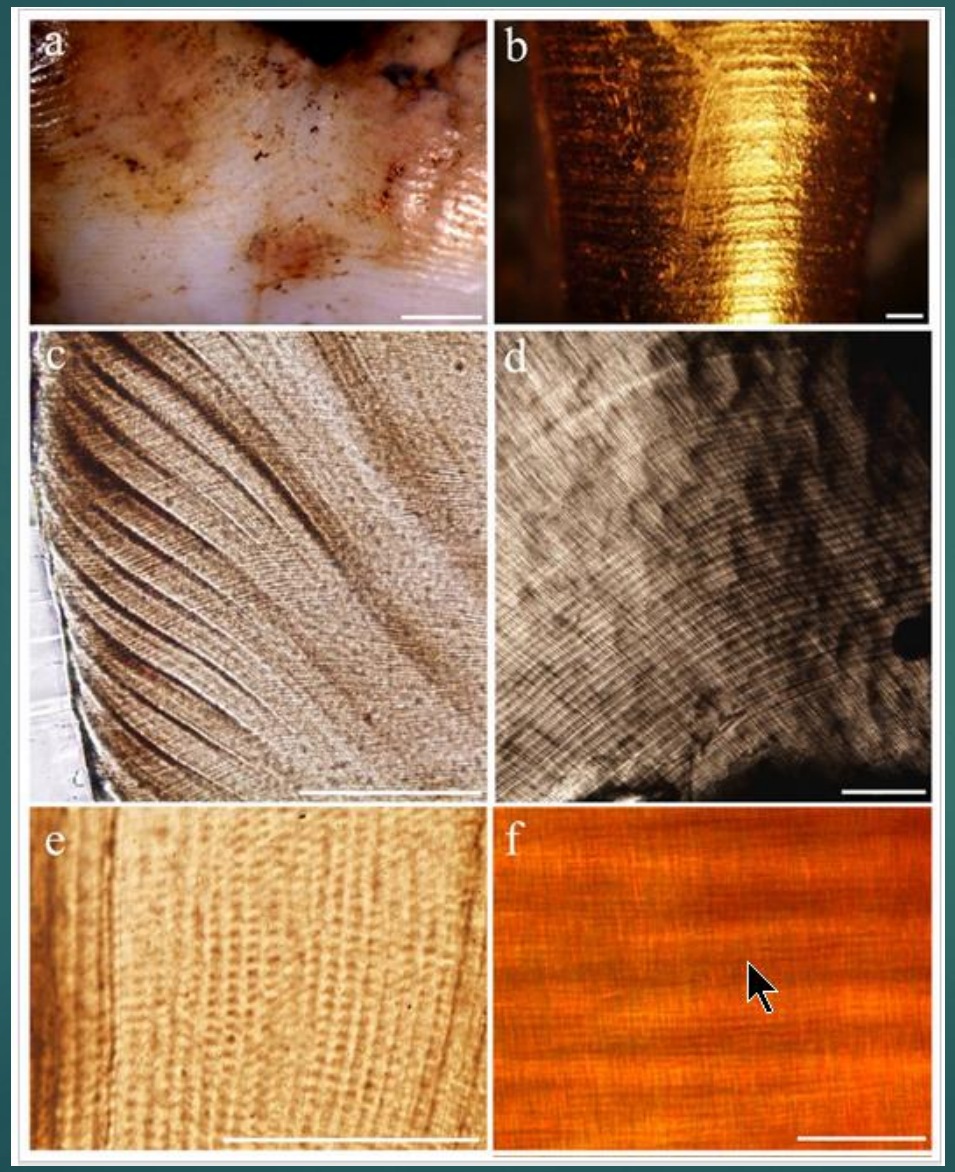


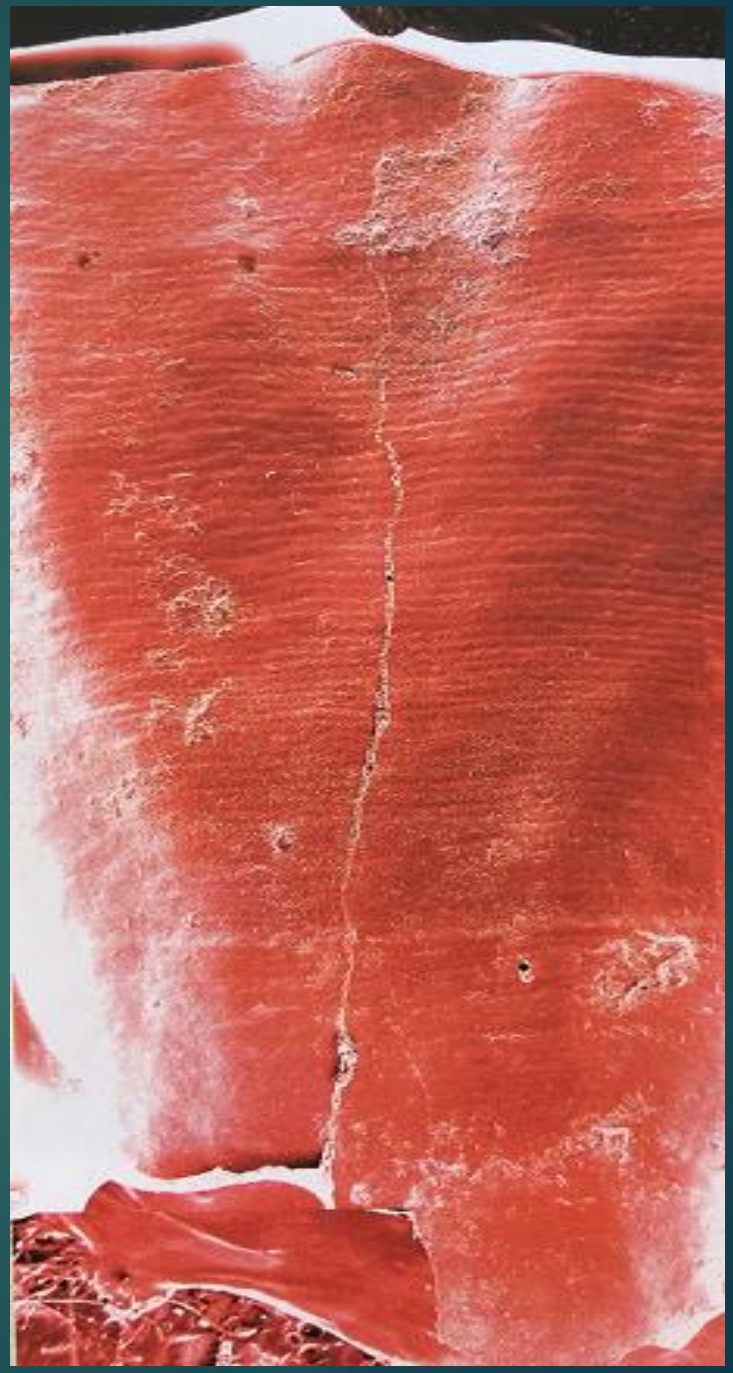
Determining age

- Age at death of fossil individual that has finished growing is difficult to determine
- Age can be confirmed by microscopic examination of tooth enamel. When tooth enamel grows, it produces tiny growth lines in the enamel. These lines can be counted to give the tooth's age.
- Dental development can help with age of immature individual; once all teeth erupted and roots of teeth formed, dental evidence is less useful.
- Skeleton's teeth or lack of teeth:
  - If the skeleton has wisdom teeth/3rd molars, the person was past the age of 17.
  - If there is significant bone loss, it indicates a more advanced age.
  - Permanent teeth in a child's skull indicate that the person reached late childhood.
- Fusion of long bones indicate adulthood. Clavicle is last at 25. Tibia at 18.

Determining age from Teeth

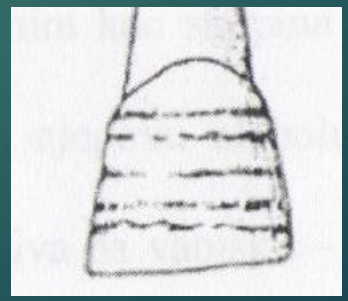
- Tiny lines are laid down during **enamel** and **dentine** secretion, which faithfully record the speed of growth every day as these hard tissues take shape
- Histological age determination





Information from teeth

- The outer layer of a tooth, called enamel, stays virtually unchanged during life.
- If an individual is ill or malnourished during the first few years of life, the formation of enamel will be disrupted and therefore be permanently etched (hypoplasia) on any tooth forming at the time.
- Extremely high levels suggest extensive periods of starvation or disease.



Teeth: Clue to age

- Permanent ‘adult’ teeth
  - central incisor (6-8 years)
  - lateral incisor (7-9 years)
  - canine (9-12 years)
  - first premolar (10-12 years)
  - second premolar (11-13 years)
  - first molar (6-7 years)
  - second molar (11-13 years)
  - third molar (17-25 years)

Determination of sex

- Male or female?:
  - While overall size is not always a reliable guide to sex:
  - Sex can be determined from size and shape of bones & teeth,
  - extent of muscle markings,
  - size and shape of pelvis (which rarely fossilized)

- Expectation of sexual dimorphism (males larger than females)

Humans and apes

Apes: generalized locomotor, quadrupeds, flat elongated pelvis

- Chimps have large testes, gorillas small, humans in between
- 2:1:2:3 dentition in both
- Apes generally have long fingers and short thumbs. In contrast, humans have somewhat shortened fingers (compared to apes), but long thumbs.

Human: specialized bipeds, but generalized arms and hands

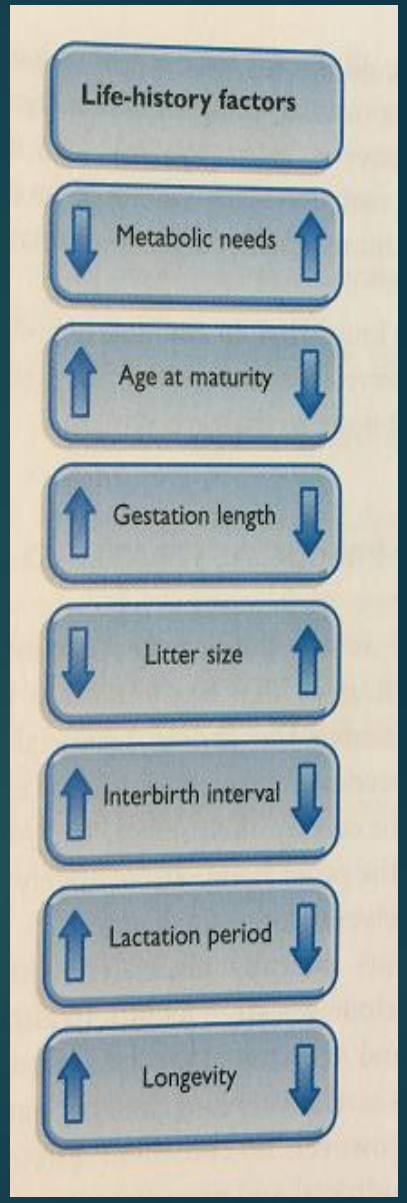
- Broad round pelvis and curved spine; backward lower, forward upper spinal bent
- Humans: hairless, fat babies; no enlarged genitalia at estrus

Rates of Development

- Modern humans have slow development to adulthood; twice as long as chimps; human adolescence begins at about 12 years of age but in chimps it occurs at about 6.5 years of age.
- Extended childhood allows more time for learning and socializing. Human brains are relatively small at birth but grow quickly, achieving 95% of adult size by five years of life
- Australopithecines developed quite quickly. Microscopic growth lines in their tooth enamel show that they developed at a rate similar to that of modern chimpanzees.
- Early *Homo* species appeared to have developed at rates that were intermediate between those of modern apes and modern humans.

Life history: *Homo sapiens*

- Typically single births
- Long, dependent childhood: growth spurts in early childhood, then adolescence
- More energy expenditure in weaning than in pregnancy
- More paternal investment than in other apes
- Reproduction: Gorilla = single male, multiple female; Chimps = multiple males and females; Marmosets = multiple males, single female; humans = all the above, but typically monogamous
- Females live long after menopause
- Morality: U shaped – early and late higher death rates
- Body size affects life-history factors: large primate = long lifespan, mature late, long gestation & lactation, long period between litters, which are small (usually 1), & low basal metabolic needs.



Locomotion - Limbs

- Limb proportions: the relative length of the forelimb and the hind limb are a very good reflection in primates of the kind of different locomotor behaviors they engage in:
  - Upper limb: used for brachiation (hanging on to tree limb)
  - Hind limb: humans are obligate bipeds; large toe in line with other toes; fairly immobile foot; double arch
  - Quadrupedal: knucklewalking - long forelimbs vs short hindlimbs; opposable toes and thumbs for climbing

Predator avoidance

Ways to avoid predation:

- Hominin fossils have been prey: eagles, crocodiles, leopards
- Larger size
- Arboreality & nighttime nests
- Diurnal: Being awake during day, sleep at night (predators at night)
- Sociality: vervet monkeys calls for hawks or snakes; gestures in chimps
- Larger group size

Caves and Fire

- In certain caves in southern Africa.
- The earliest, oldest strata of the caves contain whole skeletons of carnivores and many chewed-up bone fragments of the things they were eating, including us.
- Then comes the layer from when we discovered fire, and ownership of the caves switches: the human skeletons are whole, and the carnivores are bone fragments.
- Fire is the difference between eating lunch and being lunch.
- Best evidence for fire: charred bones; repeatedly heated stones exhibit microscopic fracture pattern; earliest evidence: 780 Ka, Israel

Form often reveals Function

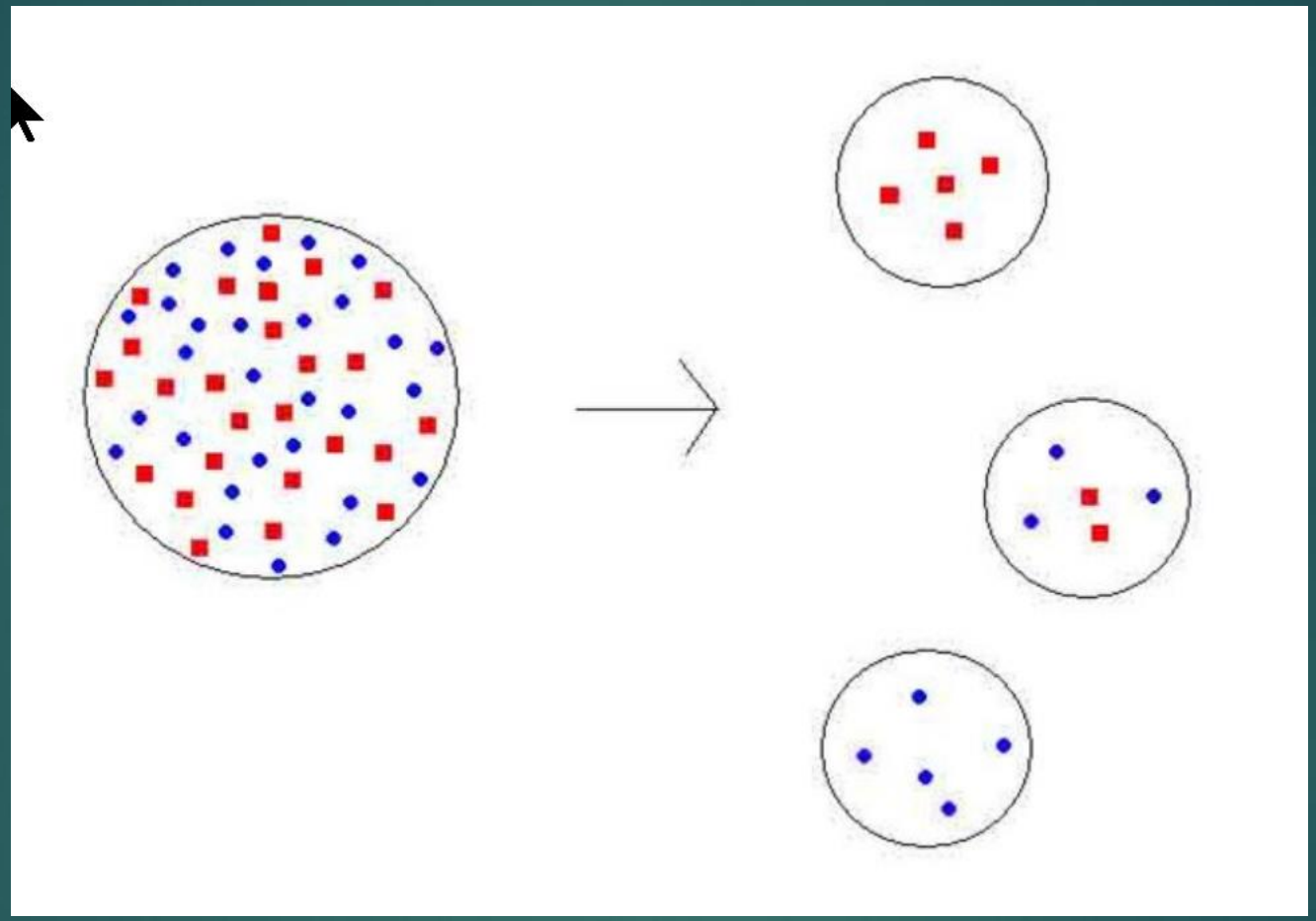
- To some degree morphology dictates function. See the differences in human and ape anatomy. The large canines in the gorilla, the huge area for the temporalis muscle in the sagittal bone, and occipital crest all indicate what kind of behaviors we see from gorillas

- The discovery of a fossil with a large sagittal crest like this is indicative of the fact that we can then reconstruct that fossil to have a large temporalis muscle associated with that crest, and thereby large chewing muscles, and in general, a large masticatory apparatus, or a chewing apparatus.

- The form, structure, and chemical makeup of skeletal materials can all give us information about behavior.

Founder effect

Most genetically diverse populations are in Africa



Genetic variability is reduced In each new group produced by founder effect: each new group has only the founder’s genetic mix

Founder effect via migrations

- A founder effect occurs when a new colony is started by a few members of the original population. This small population size means that the colony may have:
  - reduced genetic variation from the original population.
  - a non-random sample of the genes in the original population.
- For example, the Afrikaner population of Dutch settlers in South Africa is descended mainly from a few colonists.
  - Current Afrikaner population has an unusually high frequency of the gene that causes Huntington's disease

Human migrations

- Bottleneck origin/near extinction:
  - circa 70 Ka, 2000 -10,000? African MH pairs (not due to super volcano Mt. Toba explosion in Sumatra in 74K; massive climate change?)
  - full diversity of these African MHs, was diluted when small groups left Africa;
  - lead to low genetic diversity elsewhere

- Founder effect:
  - the further from Africa, less genetically diverse you are;
  - lose a portion of the original diversity with each move you make;
  - so Native Americans have lower diversity than Asians who have lower genetic diversity than Africans

African Migrations

- Migrations out of Africa:
  - 2.1 Ma, hominin to Shangchen, China
  - 1. 8 Ma, *H. erectus* to Dmanisi & China;
  - *H. heidelbergensis* develop into Neandertals & Denisovans in Europe & Asia
  - MHs in Germany, 270 K
  - MHs in India, 170 K
  - MHs, prior to 100K in South China (MH teeth, 80-120K)
  - MHs, 70 K to Levant; probably failed attempt
  - Australia, c 65 K
  - Then AMH migration out of Africa at 50-60K
  - MHs to Europe, c 40 K
  - MHs to Americas, c 20 K

Stone Tool Technology

What's a stone tool?

- Need to develop ability to identify what is a stone tool in a context.
- Is it man made?
- Or is it natural product of geological processes
- One way is to do experimental archeology: learn how to make an Oldowan or Acheulean tool; see process and products
- Need to know context: place where it was found; what was it associated with (cutmarks?, animal bones)

John Shay, PhD: experimental knapper

Lessons From Flintknapping Experiments

- Stone tools are easy to make
- Their edges are very sharp
- Children can make stone tools
- No differences in abilities of men versus women to make stone tools
- All ancient stone tools can be reproduced (no “lost technology”)

Stone Tools Origins

- Conventional wisdom in human evolutionary studies has assumed that the origins of hominin sharp-edged stone tool production were linked to the emergence of the genus *Homo* in response to climate change and the spread of savannah grasslands.
- In 1964, *Homo* fossils were discovered at Olduvai Gorge (Tanzania) in association with the earliest known stone tool culture, the Oldowan, and so were assigned to the new species: *Homo habilis* or 'handy man'.
- The premise was that our lineage alone took the cognitive leap of hitting stones together to strike off sharp flakes and that this was the foundation of our evolutionary success.

Early *Homo* Behavior

- Scientific Opinion from 2000: Stone tools 1st appear ca. 2.6 MA
  - Most often attributed to *H. habilis* (maybe *A. garhi*)
  - Earliest tools (Oldowan tradition)
    - Hammerstones
    - Flakes (cutting/scraping)
    - Chopper / chopping tools (“smashers / bashers”)
    - Some bone/horn w/scratches (digging?)
- Meat eating takes on increasing importance after 2.5 MA.

Stone Tools and Technological Modes

John J. Shay lecture

Stone tool modes

- Mode 1: pebble core – round rock, split off flacks
- Mode 2: large cutting tools (LCT) – scaled up versions of 1, Hummer
- Mode 3: prepared cores – split off from core, broad & thin, sharp
- Mode 4: prismatic blades – long, thin narrow – stretch of version 3
- Mode 5: geometric microliths – miniaturization, tiny versions of 4; glued to shafts to make complex tools; tips of arrow
- Mode 6: ground stone tools – edges ground by abrasion, sharp cut

- But complexity of stone tools is not perfect match for complexity of toolmaker; 5 year olds can do Mode 3

Termite lollypop & bushbaby spears

IGURE 6.39 Chimpanzee Spears

Chimps don’t teach; humans do; humans learn in groups, chimps as individuals

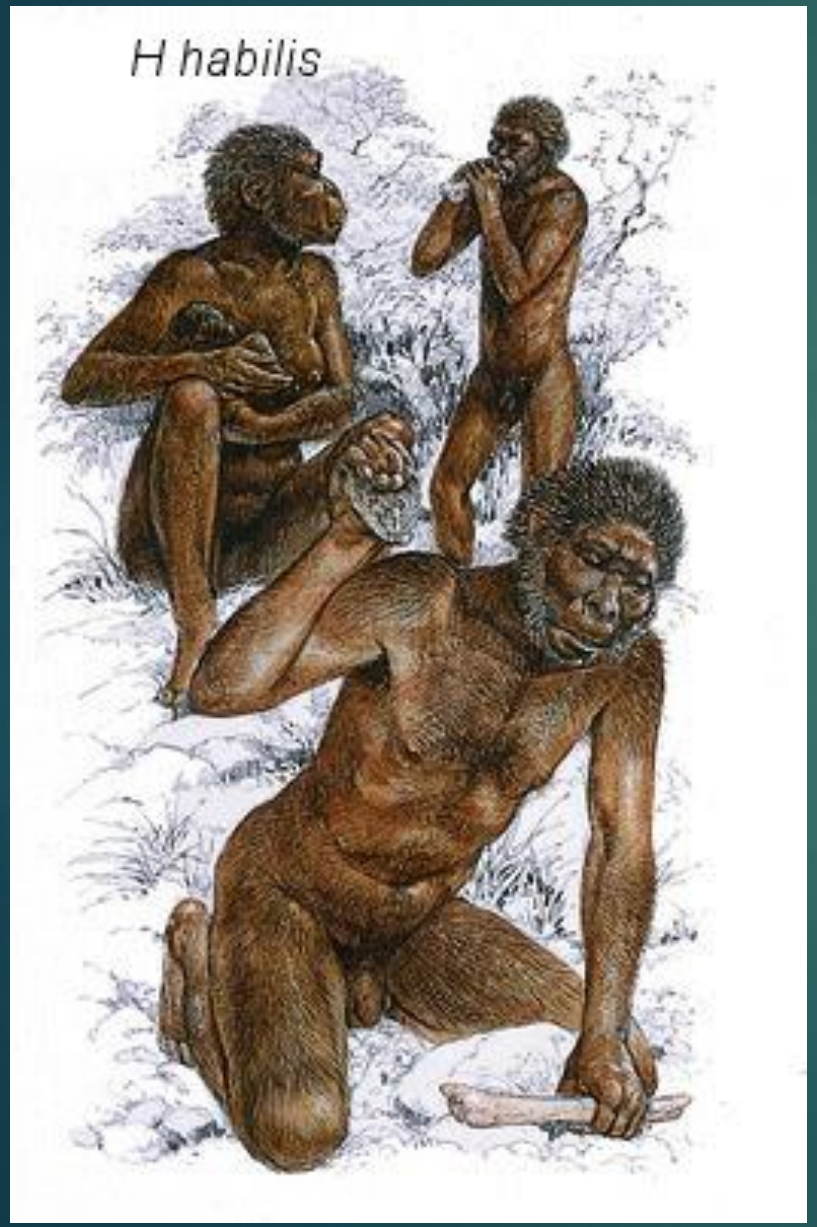
1 - Chimps use stone tools: heavier, transported short distances, used without modification to crack nuts; no fire
2 – Hominin stone tool use: knapped before use, transported greater distances (<10 miles), feature sharp edges; shape world to suit their needs

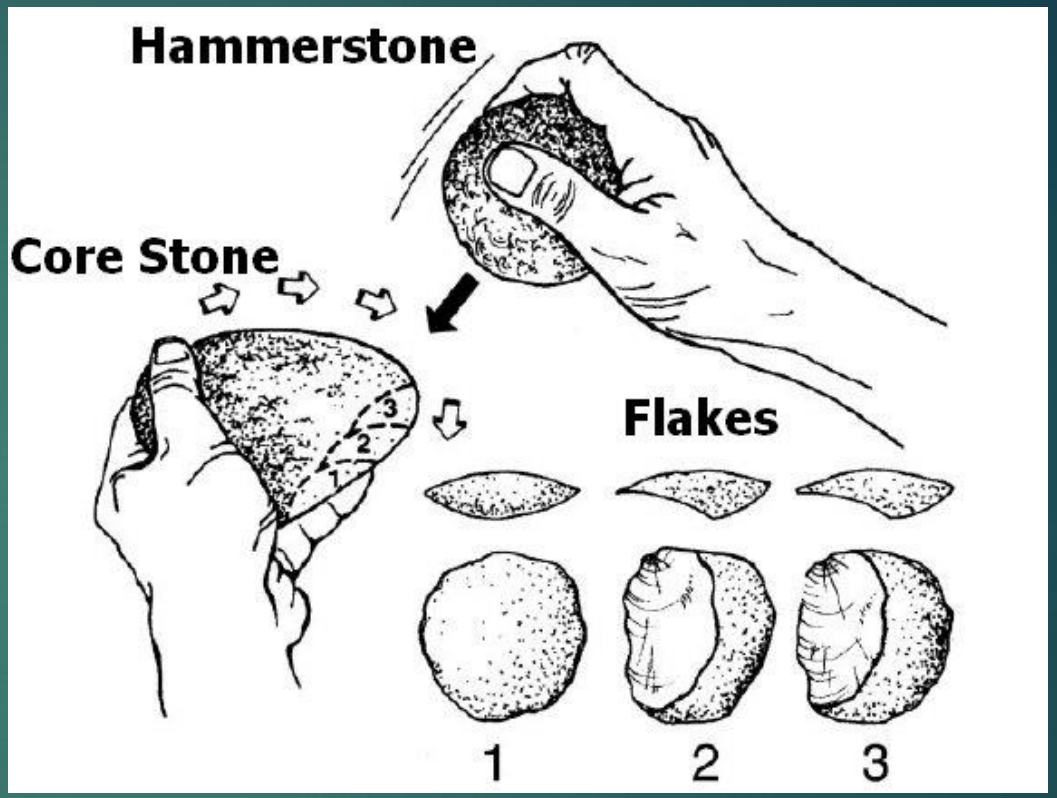
Table 1. List of types of tool use in Taï chimpanzees observed during a 9-year period

Tool-use activity	Tool-use aim	Number of observations	Tool material	Tool size in cm: length (range) thickness (range)	Number of tools used (number of tools made)
(1) Insert	ant dipping	20	twigs; (n = 28)	23.9 cm (58–11) 5.7 mm (3–10)	35 (34)
	wood-boring bee killing	6	twigs; (n = 3)	29.0 cm (29) 7.3 mm (7–8)	11 (11)
	honey fishing	15	twigs; (n = 42)	28.1 cm (60–14) 7.8 mm (3–18)	45 (45)
	bone marrow extraction	33	leaf stem, twigs; (n = 24)	14.4 cm (5–35) 4.0 mm (2–7)	51 (50)
	brain eating	1	twigs		1 (1)
	eye eating	1	twigs		3 (3)
	nut emptying	93	twigs; (n = 91)	15.4 cm (4–80) 4.1 mm (2–9)	196 (172)
(2) Probe	wood boring bee nests	6	leaf stem, twigs; (n = 7)	14.8 cm (10–22) 4.8 mm (4–6)	11 (10)
	corpses	4	twigs		4 (0)
	wounds	1	twigs		1 (1)
	bark interstice	1	twigs		2 (2)
	other objects	3	twigs		3 (1)
(3) Clean	sponging	12	leaves		12 (12)
(4) Display	aimed throwing	6	branches		16 (2)
	throwing	3	branches		13 (1)
	dragging	7	branches		12 (0)
	hitting	4	branches		4 (0)
(5) Pound	nuts	932	clubs, stones; (n = 719)	clubs = 81% stones = 19%	1,037 (85)[1]

Chimps make & use tools, esp. for pounding nuts

Making / Using Oldowan Tools





Hominins often traveled up to 10 km to acquire right kind of stone from which to make tools.

1960, Leakey: *Homo habilis* and stone tools at Olduvai Gorge

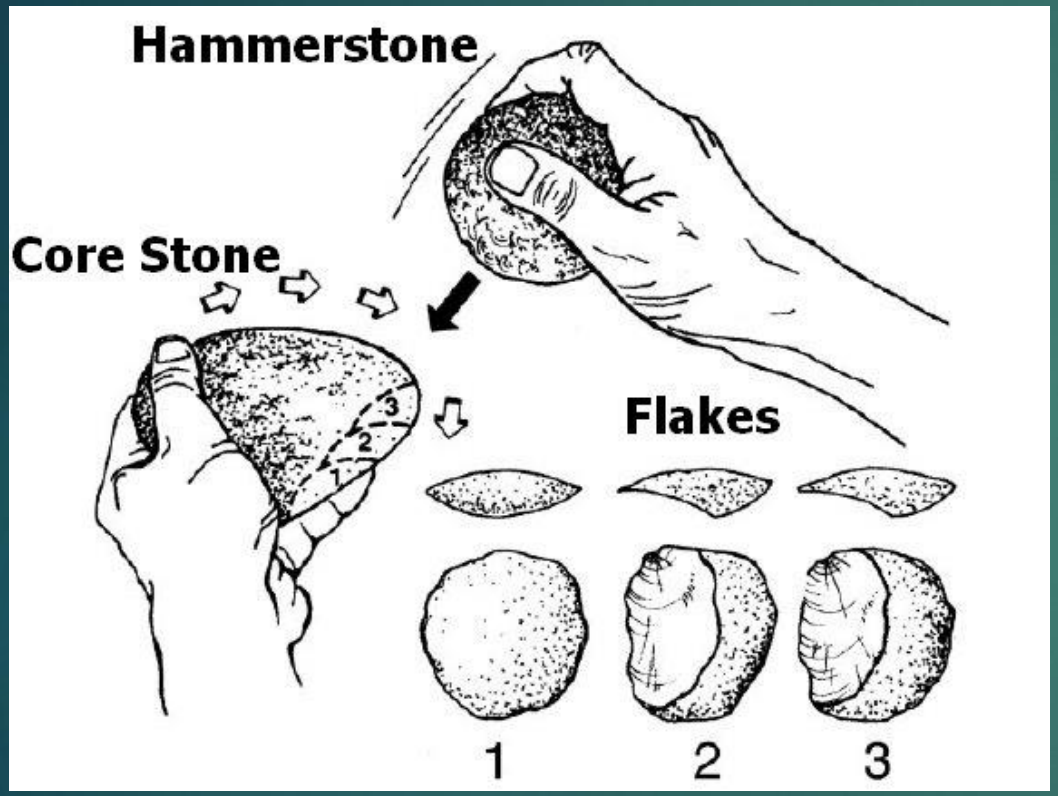
- Finds made by Louis and Mary Leakey at Olduvai Gorge, Tanzania, claimed they had discovered the first stone tools, chronologically dated to around 1.85 Ma
- The Oldowan, Mode 1 type
- Associated with H. habilis, early H. erectus in Dmanisi & Asia

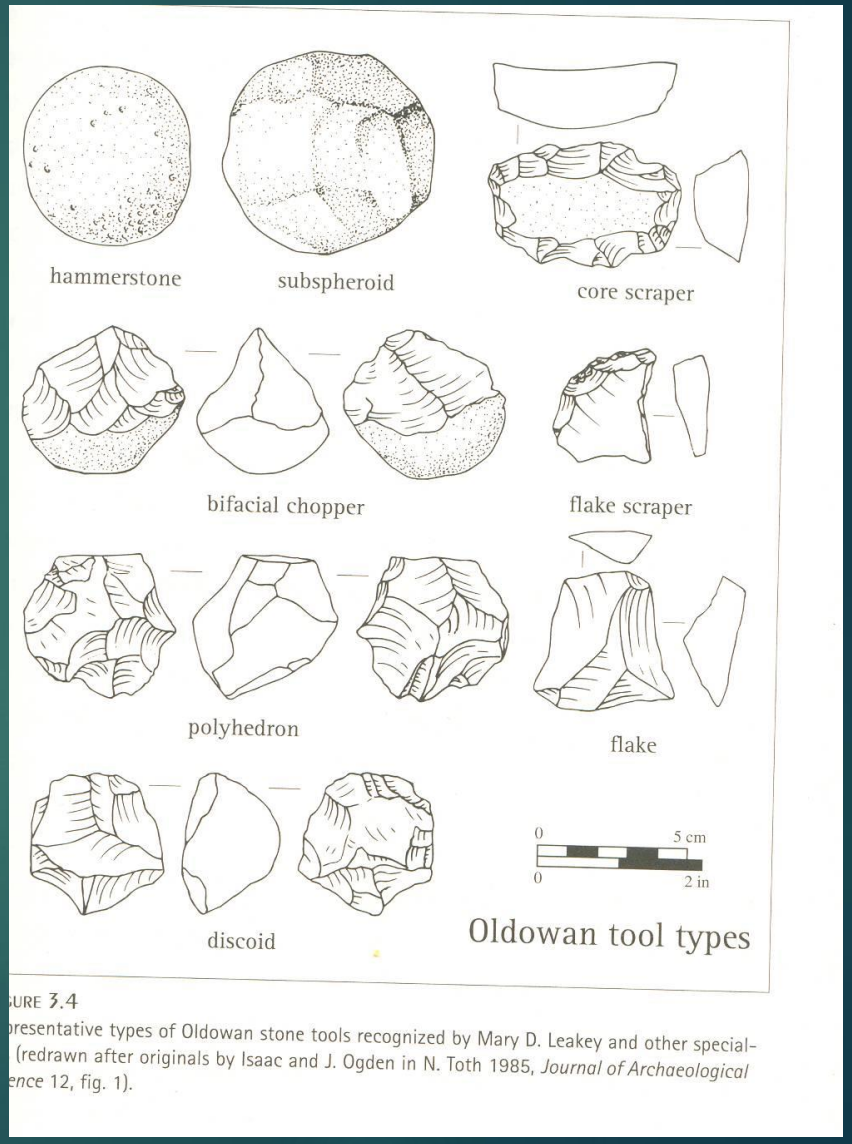
(Toth & Schick, 2013).

Oldowan Stone Tools

Associated with H. habilis, H. erectus in Dmanisi & Asia

Oldowan /Mode 1 Tools: 2.6-1.7 M





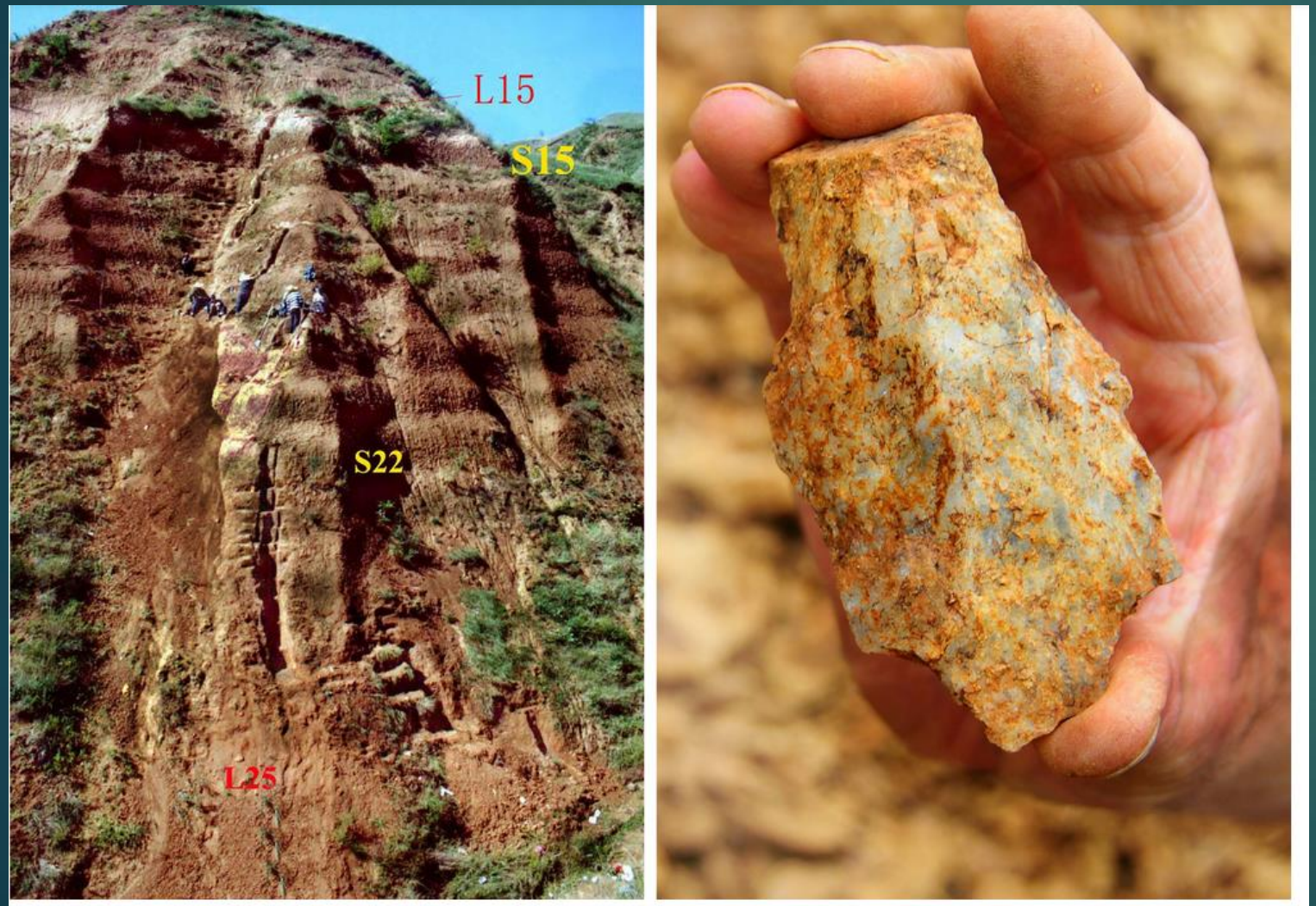
URE 3.4
presentative types of Oldowan stone tools recognized by Mary D. Leakey and other special-
(redrawn after originals by Isaac and J. Ogden in N. Toth 1985, *Journal of Archaeological*
ence 12, fig. 1).

Olduwan tools

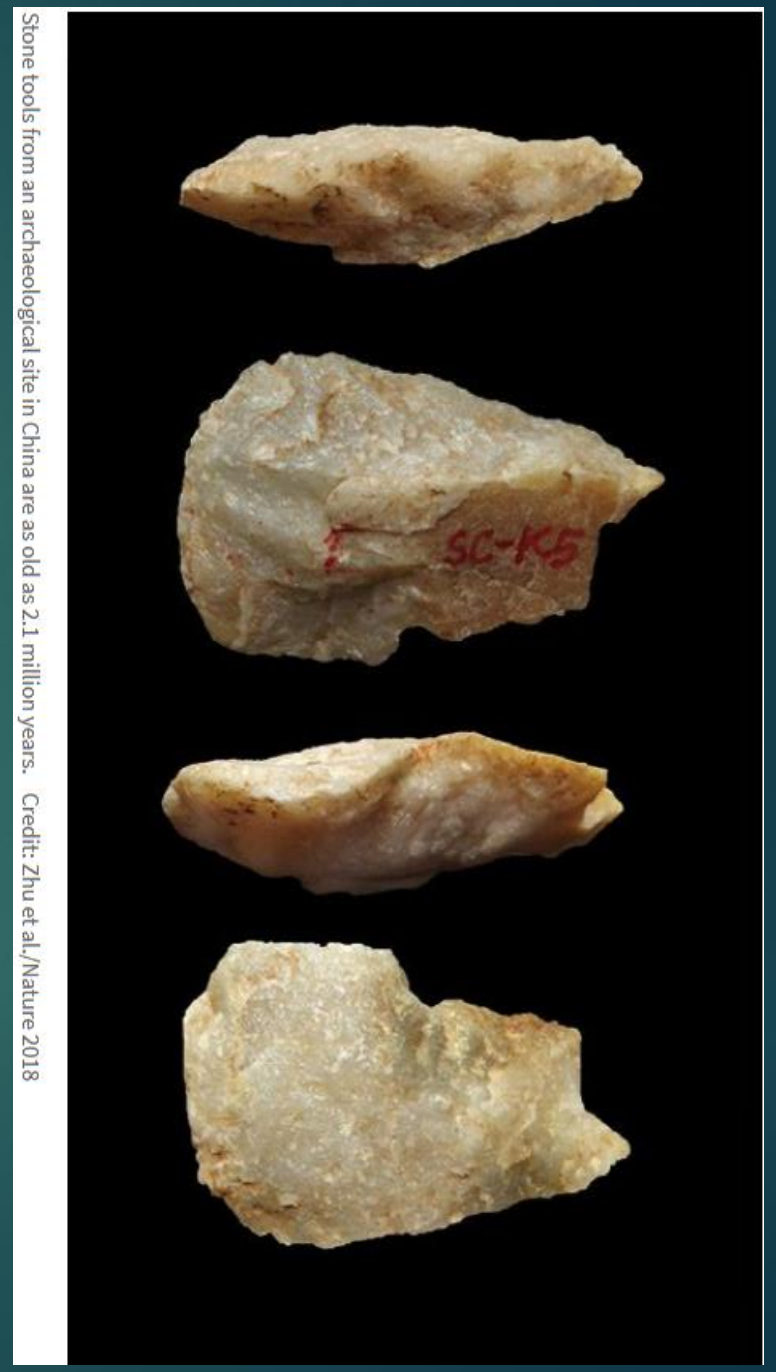
Dmanisi, Georgia

- Oldowan tools at 1.8 My found in 1984 at Dmanisi, Georgia associated with early *H. erectus*

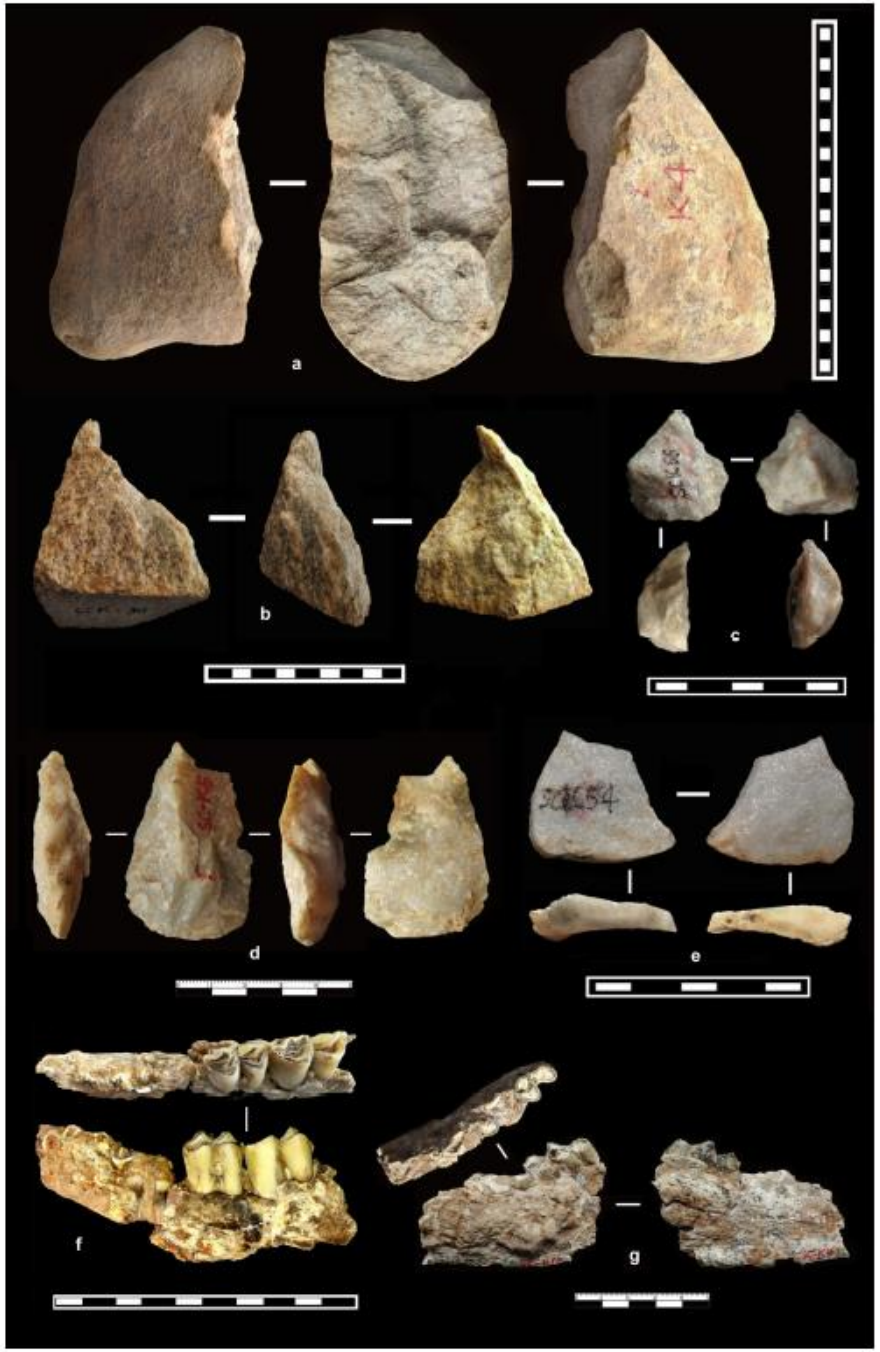
2018: Chinese stone tools dated to 2.1 Ma; Shangchen, Lantian region, China



One of the 2.1 million-year-old artifacts, right, recovered from a gully in western China, left, suggest that hominins may have left Africa far earlier than previously believed. Zhaoyu Zhu



Stone tools from an archaeological site in China are as old as 2.1 million years. Credit: Zhu et al./Nature 2018



Extended Data Fig. 10 | See next page for caption.

Early stone tools: 2.6 Ma and earlier

- Subsequent discoveries pushed back the date for the first Oldowan stone tools to 2.6 Ma
  - earliest fossils attributable to early *Homo* to only 2.4–2.3 Ma,
  - opening up the possibility of tool manufacture by hominins other than *Homo* before 2.6 Ma.
- The earliest known artefacts from the sites of Gona (~2.6 Ma), Hadar (2.36 Ma), and Omo (2.34 Ma) in Ethiopia, and especially Lokalalei 2C (2.34 Ma) in Kenya, demonstrate that these hominin knappers already had considerable abilities in terms of planning depth, manual dexterity and raw material selectivity.
- Cut-marked bones from Dikika, Ethiopia, dated at 3.39 Ma, has added to speculation on pre-2.6-Ma hominin stone tool use.
- It has been argued that percussive activities other than knapping, such as the pounding and/or battering of plant foods or bones, could have been critical components of an even earlier, as-yet-unrecognized, stage of hominin stone tool use

Stone Tools: Acheulean, Mode 2

- Core-and-flake technology:
  - Mode 1 stone tool technology: removal of flakes as desired products from a block of raw material, which is discarded as waste.
  - In contrast, core-and-flack technology involving the shaping of raw material into a product (e.g., a handaxe), where the shaping flakes are discarded as waste.

- Acheulean stone tools are named after the site of St. Acheul on the Somme River in France where artifacts from this tradition were first discovered in 1847.

- *Homo ergaster:* At first, like earlier *Homo*, made stone stools by taking a few flakes off a core, just enough to make a sharp edge on the core. They also used the flakes they removed as tools.

- But beginning at around 1.5 Ma, Homo erectus elaborated on this stone toolmaking technique by flaking the entire stone, controlling the shape of the whole core tool.
  - The core tool produced by this technique is called the hand axe.
  - It is a pear-shaped symmetrical and pointed tool, flaked on both sides (bifacial).
  - It was the all-purpose tool of its day, used for a multitude of tasks, from butchering to cutting wood.

Acheulean

Acheulean Tool Kit

Hand Axe

Acheulean Hand Axe

Cleaver

Acheulean: associated with *H. erectus & H. heidelbergensis*

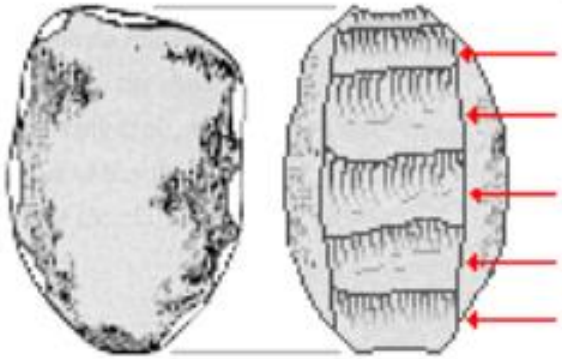
Middle Stone Age: Mode 3, prepared core

- The Mousterian is …of a method of stone-knapping or reduc…Technique, named after the type site in the…Paris, France
- **Levallois, or prep…** the suburb in Paris where it was first recogni…paration of a rough stone core so that a num…ape could be removed.
- One of the main ir…technique," was a core that was carefully …flake of predetermined size and shape co…blow. This technique probably raised th…d predictability in stone technology.
- Middle Stone Age … which could be hafted on to shafts to make spears.

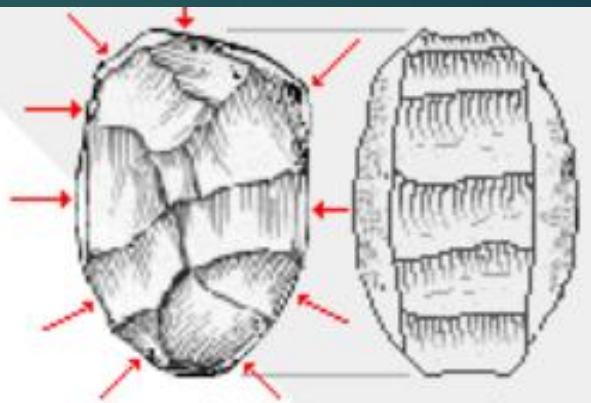
Mousterian

- The Mousterian technique (after the site of Le Moustier in France) is associated with the Neanderthals.
- This technique involved the careful retouching of flakes taken off cores. Neanderthals used tools for activities like hunting and sewing

A large cobble of brittle fracturing rock (e.g., flint) is selected.



The cobble is percussion flaked around its perimeter to prepare the core.



One side is percussion flaked to produce a tortoise shell shape.

A heavy percussion blow at one end of the cobble removes a large flake that is convex on one side and flat on the other.

This Levallois flake is now ready to be used immediately for scraping and cutting or to be shaped into a specialized tool.

Middle and Upper Paleolithic technology

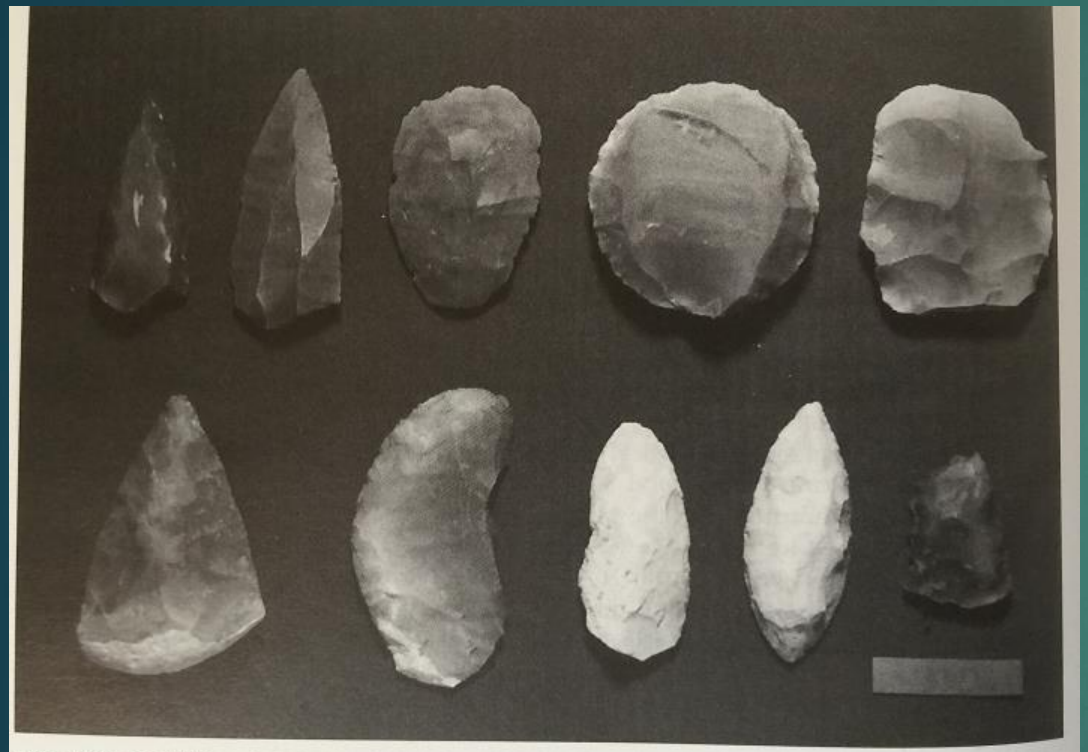


FIGURE 16.1 Middle Paleolithic artifacts: These typically retouched flakes of various types were made between 250,000 and 40,000 years ago. (top row, left to right) Mousterian point; Levallois point; Levallois flake (tortoise); Levallois core; disc core. (bottom row, left to right) Mousterian point; Mousterian scraper; Quina scraper; limace; denticulate. (Scale bar: 5 cm.) (Courtesy of Roger Lewin and Bruce Bradley.)

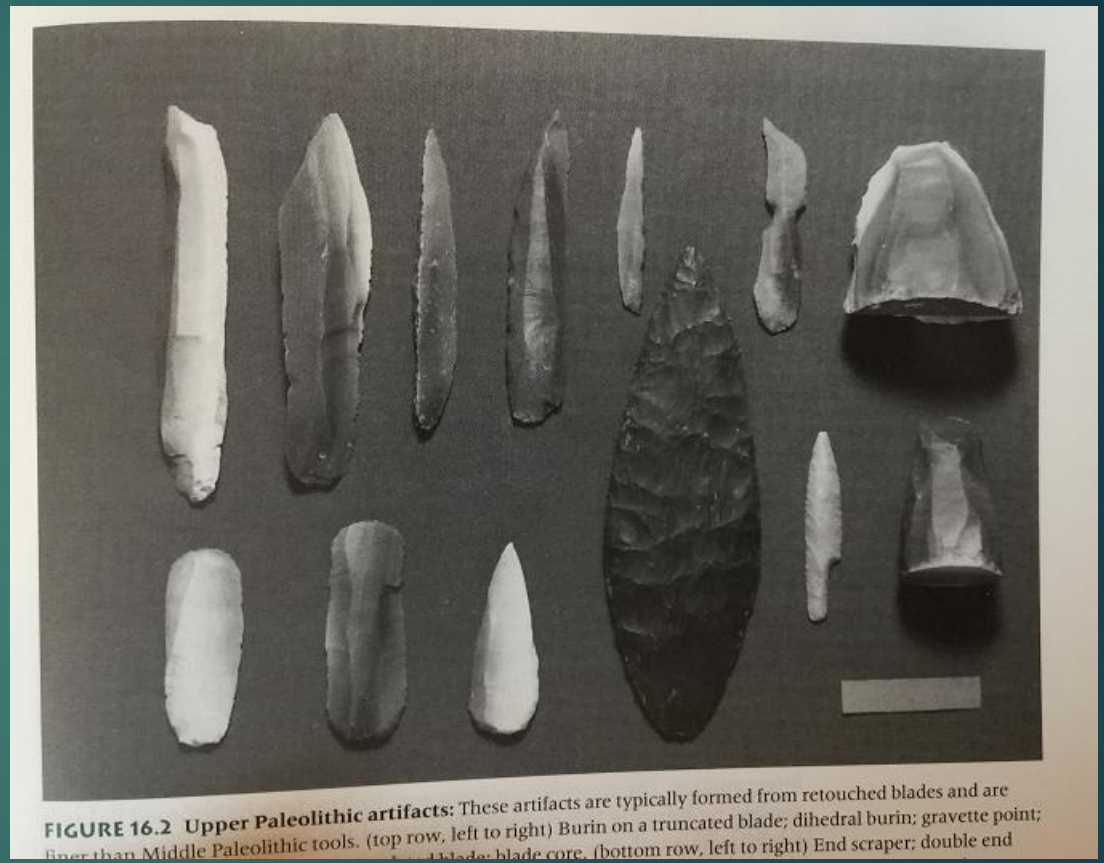


FIGURE 16.2 Upper Paleolithic artifacts: These artifacts are typically formed from retouched blades and are finer than Middle Paleolithic tools. (top row, left to right) Burin on a truncated blade; dihedral burin; gravette point; blade core. (bottom row, left to right) End scraper; double end

Upper Paleolithic

- About 40,000 years ago, there was a change in the dominant method of toolmaking in Africa and the Middle East. This change soon spread to other areas, such as Europe.
- Blades struck off cores became precisely and beautifully made. Whereas the usual procedure was to reduce a piece of rock down to only one or a few tools, the new method allowed many long, thin flakes (or blades) to be systematically produced from a single original block of stone.
- The blades were often knocked off by use of a pointed 'punch' made of bone or antler. They were then worked further to turn them into 'knives', 'scrapers', 'chisels', 'borers', etc.
- The industries concerned are called 'Upper Paleolithic' in Europe and western Asia, and 'Later Stone Age' in Africa.
- Associated with *H. sapiens*

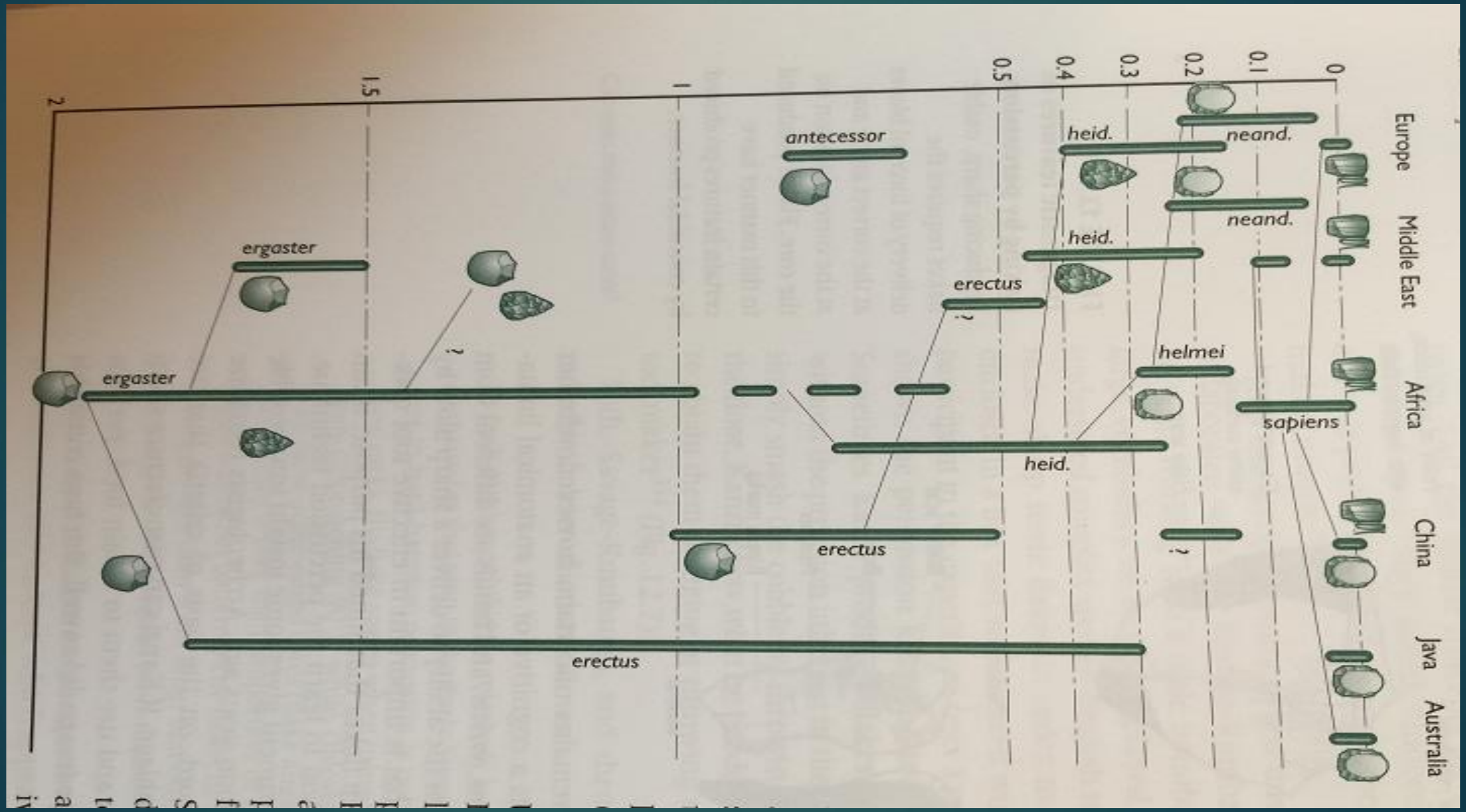
UP Tools

Associated with *H. sapiens*

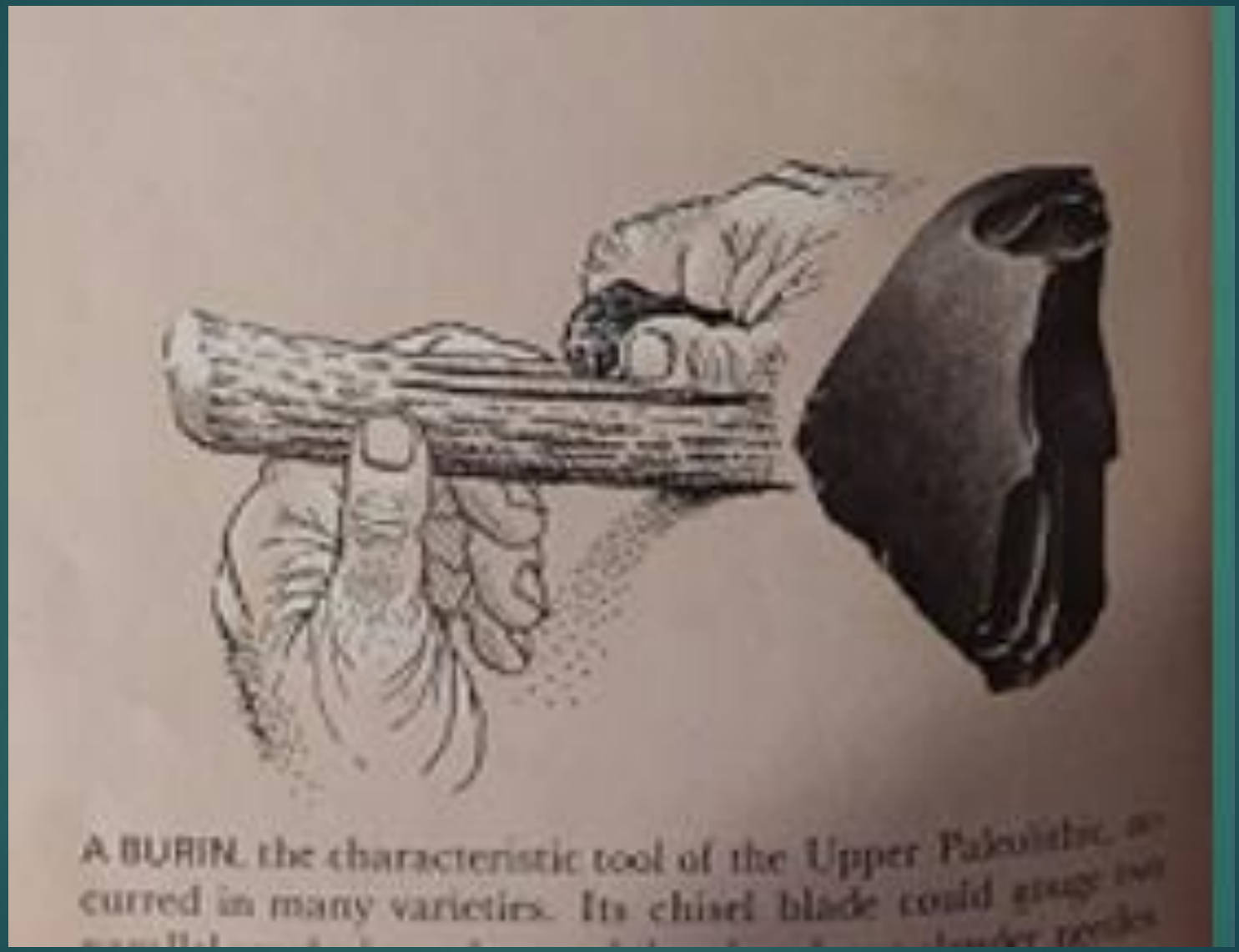
UP Tools

- Composite tools made of several parts become more common during this time
- An increase in the working of bone, antler, and ivory.
- The ax is no longer a hand ax, but an ax with a handle.
- Hafting (attaching point to spear) appears in the archaeological record.
- Spears were made with bone points hafted to a shaft.
- Spear throwers (atlatls) were used to increase the range of these projectiles as well as adding to the force of their penetration.
- Harpoons were made from barbed stone points that detached from the shaft after penetrating an animal.
- Fishing implements, such as barbed fish hooks and fish spears, are also known from this time.
- Some of these tools were practical, such as harpoons, spear points, and shaft straighteners. Some seem to have symbolic significance. Even some of the utilitarian objects were beautifully decorated.
- The Upper Paleolithic was a time of cultural innovation.

Relationships of hominins and tools

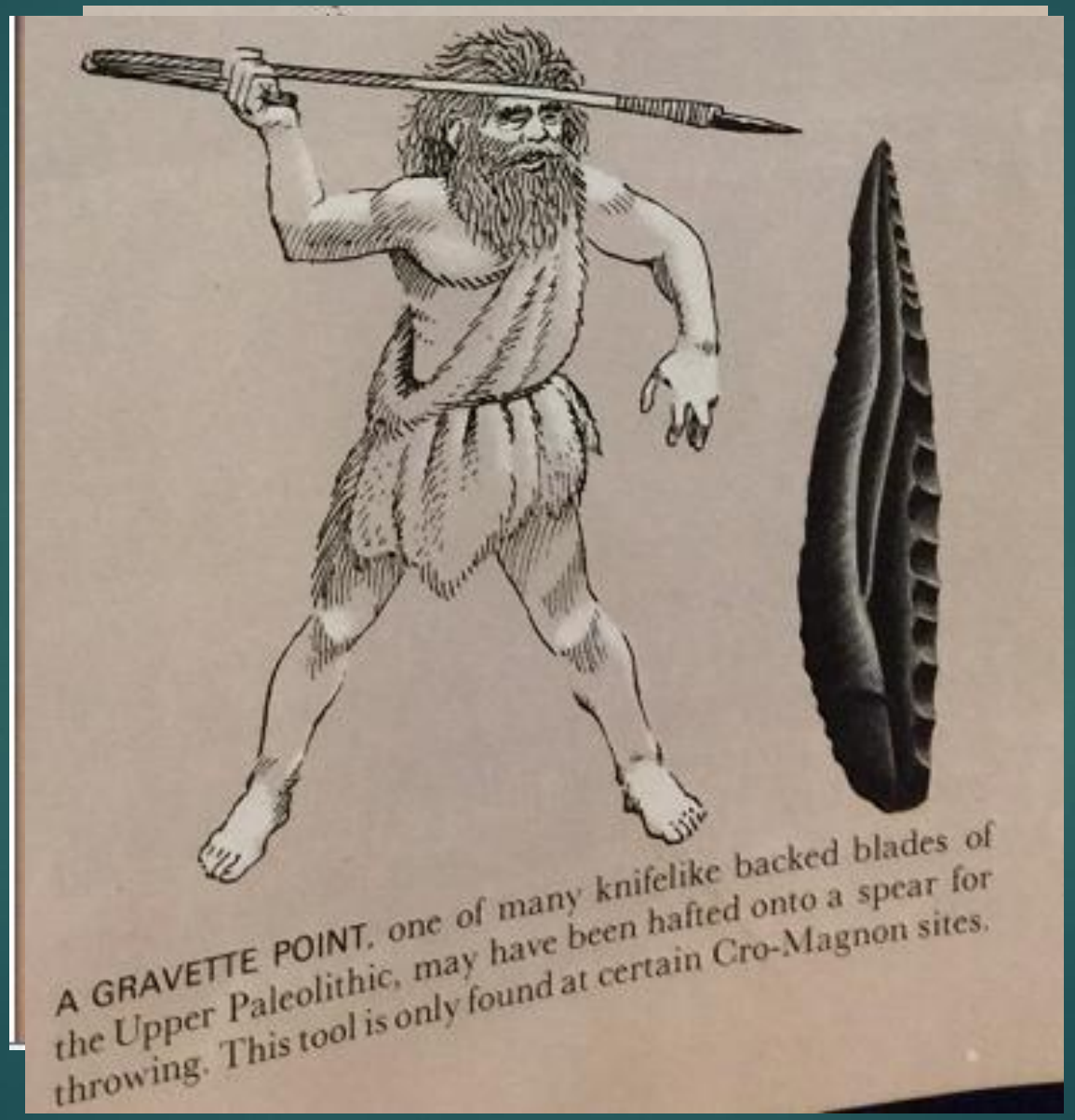


Tool Uses



A BURIN, the characteristic tool of the Upper Paleolithic, oc-
curred in many varieties. Its chisel blade could

Tool Uses 2



A GRAVETTE POINT, one of many knifelike backed blades of the Upper Paleolithic, may have been hafted onto a spear for throwing. This tool is only found at certain Cro-Magnon sites.

2.6-Million-year-old stone tools and associated bones from Gona, Afar, Ethiopia

No hominin remains were found in association with these Oldowan tools and they predate the oldest known remains of the genus *Homo.*

These tools are unlikely to be evidence of the very first use of tools.

The use of tools in apes and monkeys can be used to argue in favor of tool-use as an ancestral feature of the hominin family.

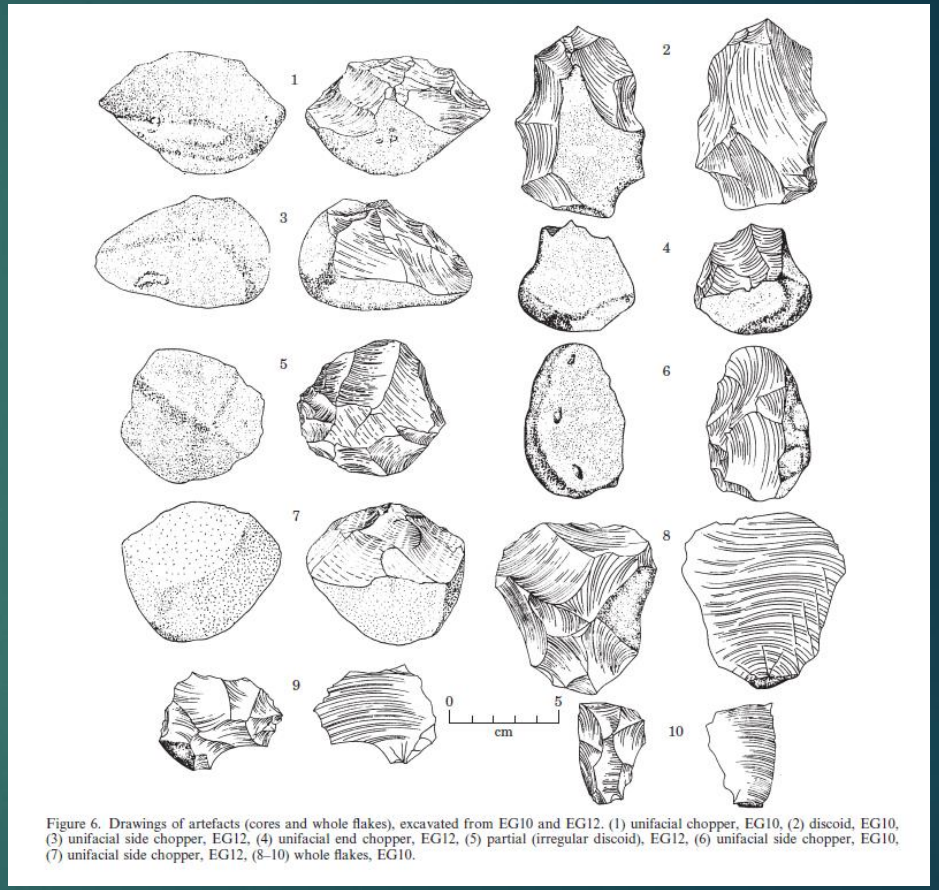


Figure 6. Drawings of artefacts (cores and whole flakes), excavated from EG10 and EG12. (1) unifacial chopper, EG10, (2) discoid, EG10, (3) unifacial side chopper, EG12, (4) unifacial end chopper, EG12, (5) partial (irregular discoid), EG12, (6) unifacial side chopper, EG10, (7) unifacial side chopper, EG12, (8–10) whole flakes, EG10.

Sileshi Semaw et al. 1997 & 2000

Sileshi Semaw, Gona stone tools, 2.6 Ma

- Archeologist
- Director of the Gona Paleoanthropological Research Project
- Sileshi Semaw is the Principal Investigator of the Gona Project,

- Consorcio CENIEH in Burgos, Spain; affiliation with the Stone Age Institute and CRAFT, Indiana University,

- The Gona study area is located in the Afar region of Ethiopia.
  - The site is primarily known for yielding the second oldest stone tools in the world dated to 2.6 million years ago.

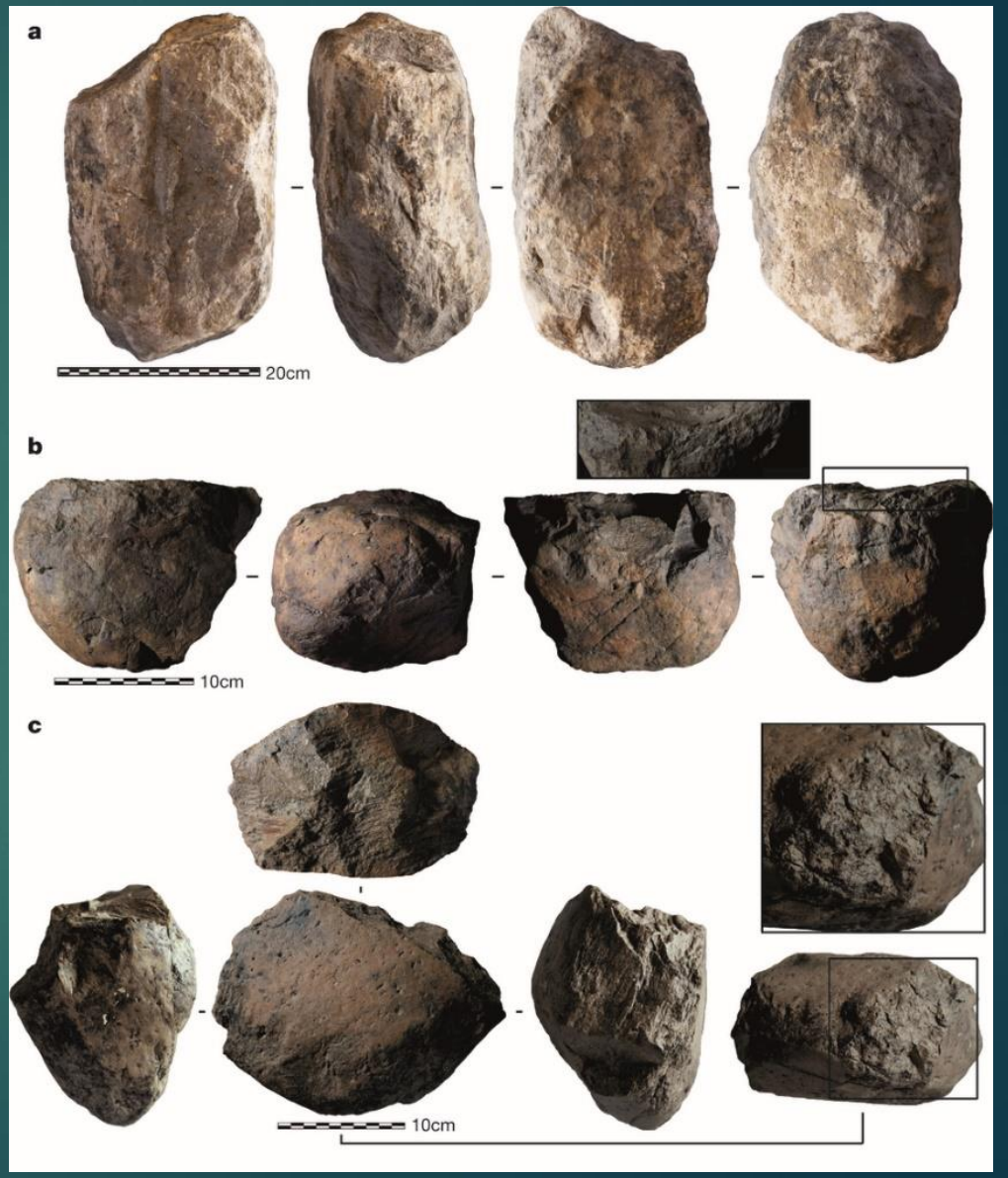
  - Ardipithecus Kadabba tooth


Hata, Gona
2.5–2.6 Myr
Cutmarked bone,
Oldowan tools

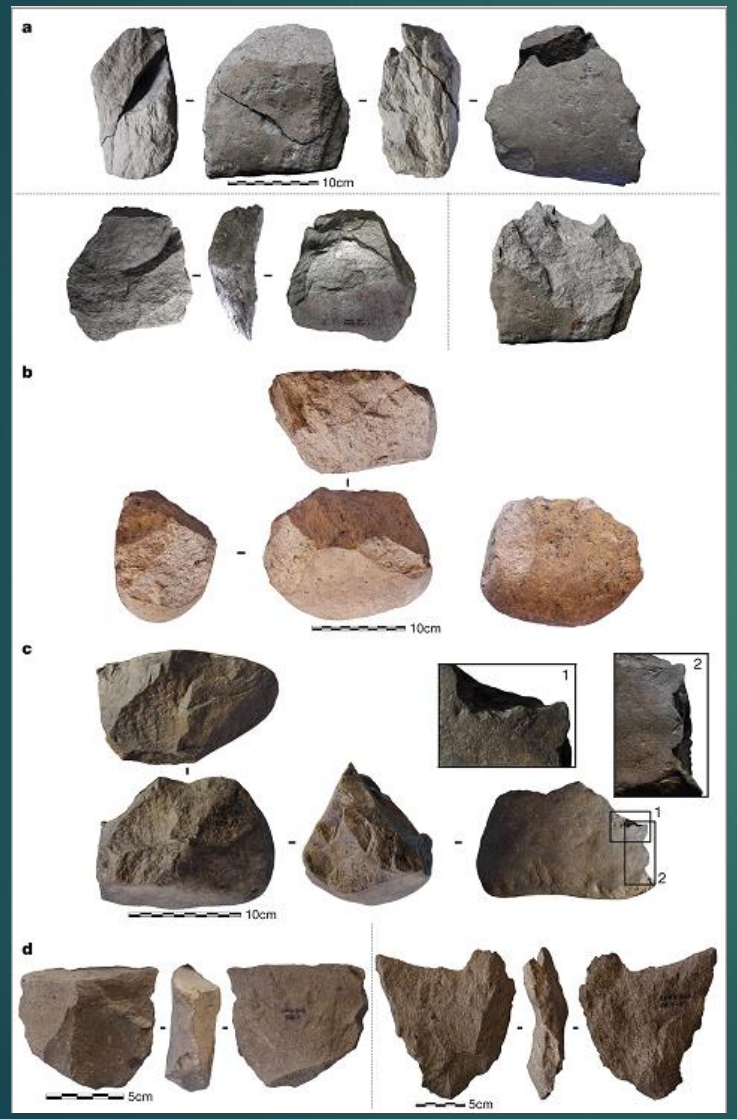
Pre-Oldowan Tools: Now 3.3 Ma old stone tools:

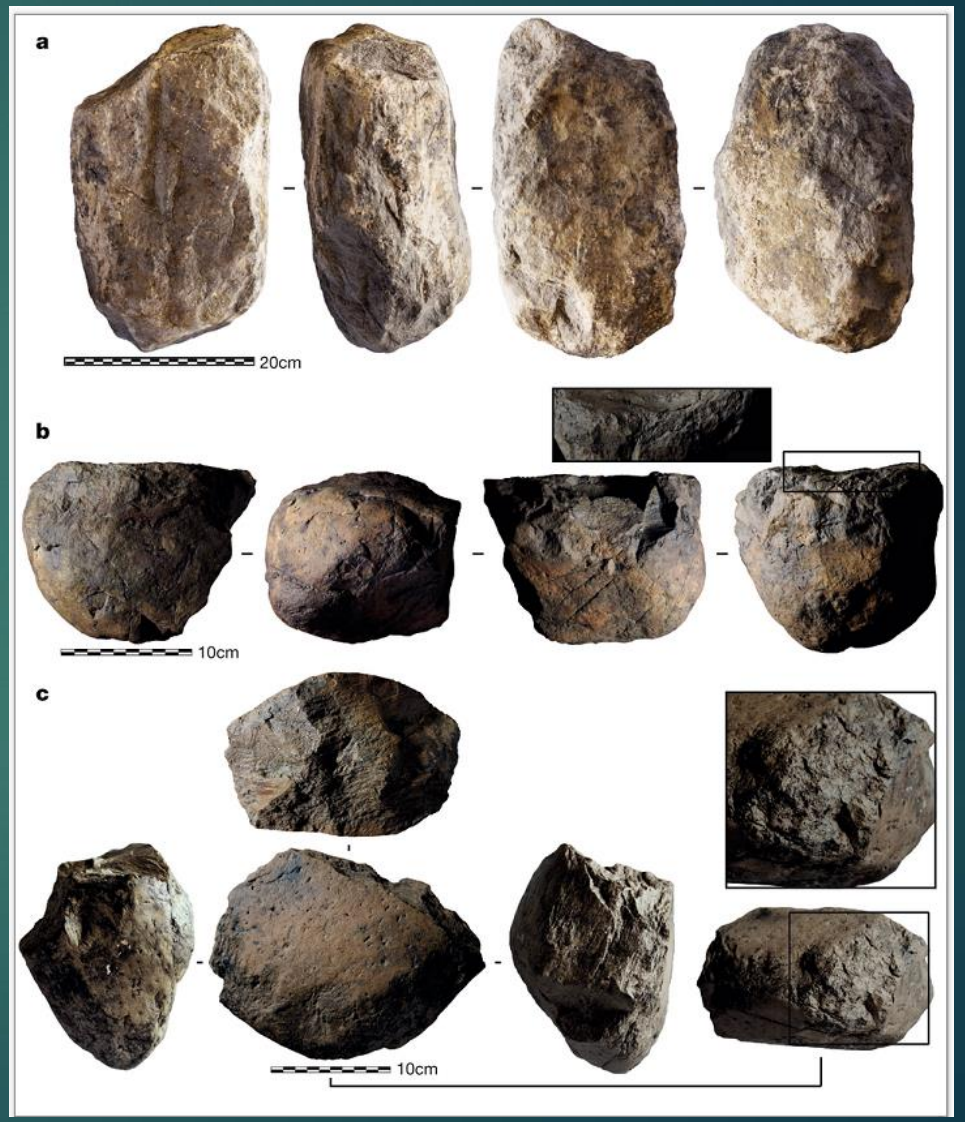
The recent discovery of stone tools, dated at 3.3 MA, was made near Olduvai Gorge at the site Lomekwi 3, situated to the west of Lake Turkana in Kenya.

The Lomekwian tools are larger; produced sharp flakes by pounding stones against a passive hammer or anvil, rather than through a freehand technique; similar to nut-cracking activities of chimpanzee stone tool-use behavior



3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya; predates the Oldowan by 700 K years





Sonia Harmand, et al., 2015

Lomekwian Stone Tools

- LOM3 predates the oldest fossil specimens attributed to *Homo* in West Turkana at 2.34 Ma by almost a million year
- The only hominin species known to have been living in the West Turkana region at 3.5 MA is *K. platyops*
- *Australopithecus afarensis* is found in the Lower Awash Valley at 3.39 Ma in association with cut-marked bones from Dikika

- The LOM3 artefacts indicate that their makers' hand motor control must have been substantial and implies reorganization and/or expansion of several regions of the cerebral cortex before 3.3 Ma

- 144 stones: 83 cores, 35 flakes, 7 passive elements or potential anvils, 7 percussors (whole, broken or potential), 3 worked cobbles, 2 split cobbles; made of volcanic rock

- Closer to less developed chimpanzee technique of hammer-on-anvil than to the direct freehand percussion evident in Oldowan assemblages.

- Could represent a technological stage between a hypothetical pounding-oriented stone tool use by an earlier hominin and the flaking-oriented knapping behavior of later, Oldowan toolmakers.

Who made the first stone tools?

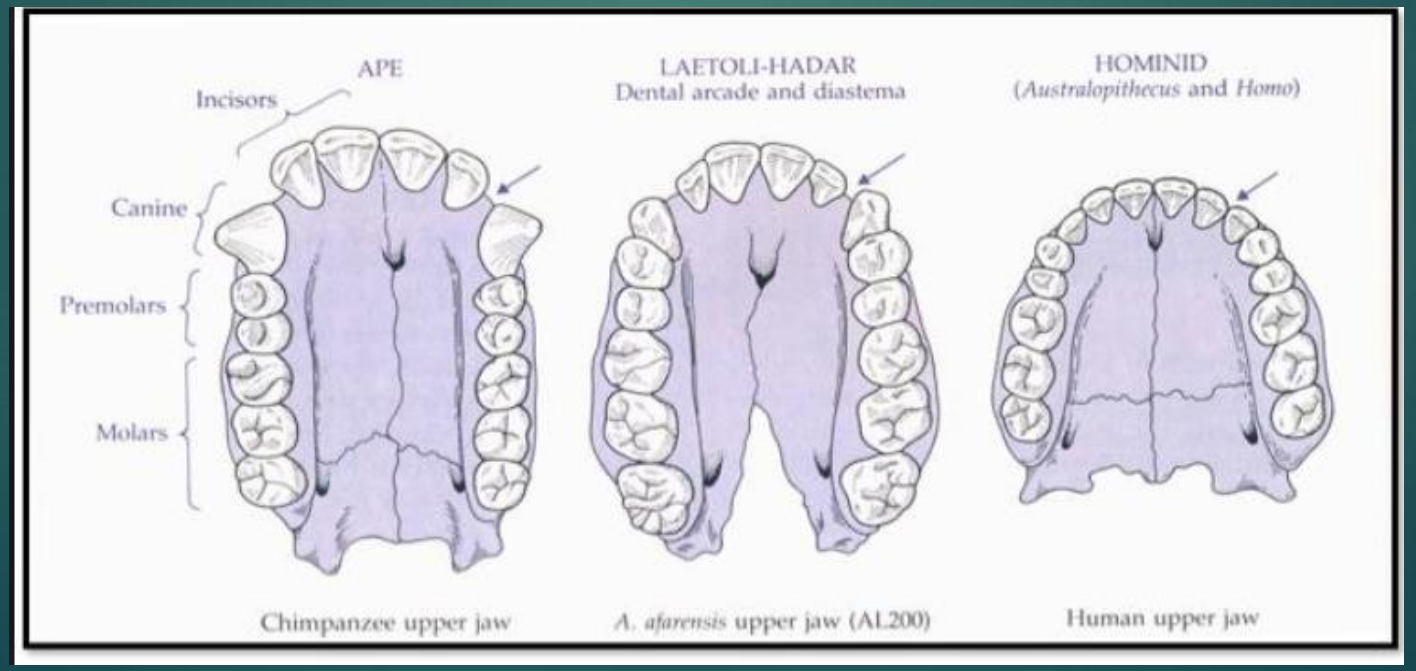
Was it *Homo habilis*? Or the Australopithecines?

- Now we have the Lomekwian stone tools at 3.3 Ma.
- There are also contested cut marks from stone tools on bones dated at 3.4 Ma at Dikika in Ethiopia (Zeray's discovery).
- Guess which species are around at that time in East Africa? The Australopithecines: *A. afarensis*, *K. platyops* and *A. deyiremeda*.
- Clearly Australopithecines used tools before *Homo.*

Teeth

Dentition: Ape vs Human

- Apes: U shaped; large canines
- Human: parabolic
- Human: thick enamel on molars; thin on apes
- Humans process food before eating it



Human and Orangutan

- Human = no evidence of projecting canines.
- No evidence of a honing complex.
- Humans have very reduced canines.

Human mandible (left) superimposed alongside a male orangutan (Pongo pygmaeus) mandible.
Each jaw shows a central (I1) and lateral incisor (I2), a canine (C), P3 (the first premolar), P4, M1, and M2.

Canines

- In both humans and primates, canine size is variable. This is normal variability.
- Canines are a feature that are oftentimes sexually dimorphic, meaning males have much larger canines than females.
- Gorillas & chimps, males have dramatically larger canines than female gorillas.
- Across the primates, canine dimorphism has been shown to be correlated with reproductive competition.
  - Species in which males are engaged in some kind of competition for a limited reproductive access tend to have more evidence of canine dimorphism.
  - Humans have reduced canines and not much sexual dimorphism in canines. The only other ape that has no canine dimorphism or insignificant canine dimorphism is the gibbon, who have large canniness in both sexes.

Canines: sexual competition

- In old world monkeys and the great apes, species that have very large canines, especially the males, oftentimes use them as weapons in male, male competition. Look at baboons.
- The notion that canine size is somehow connected to reproductive strategies is an argument that's been invoked to explain some of the fossil variation that we see in the earliest punitive hominins.

- One argument is that the origin of hominins is associated with a movement to more monogamous styles of reproductive behavior, particularly styles that involve less male, male competition for female mating partners and also more partnership between males and females.

- And by more partnership; males provisioning females with resources. By males providing females with more resources, it's possible that females are able to reproduce more frequently, creating more reproductive potential for hominins.

Downloads

- www.charlesjvellaphd.com
- Lecture Pdfs in:
  - 2018 OLLI: Human Evolution: The First 150 Years of Discovery