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COGS 184

Five Million Years Explained

In the open woodland of what is now Ethiopia, we see the first bones and stones of *Ardipithecus ramidus*—or 'Ardi' for short. Ardi retained abilities similar to its primate cousins in that they could still climb trees. We see evidence of this through its **opposable big toe** which would have been essential for grasping limbs as well as a straight **lower pelvis** that would have supported heavy thighs needed to scale trees.

However, Ardi had a number of traits that also supported walking upright. First, their leg bone was longer than the arm—the opposite of most non-human primates. Second, the **foramen magnum** had shifted forward which supports the mass of the head above a vertebrate—a posture that occurs when a figure stands vertically. Third, the **palm** was smaller and wrist weaker suggesting that Ardi was less likely to be a knuckle-walker and may have relied on its lower half to carry weight rather than arms. Fourth, the **upper pelvis** is more curved which supports pulling the body upright. Fifth, existence of the **os peroneum** would have made the foot more rigid which is necessary when converting a grasping foot into a lever for walking[1].

Finally, Ardi was a small creature, standing at the height of a bonobo. We also see evidence that males had reduced **canines** so we can predict that they had fewer displays than others with larger canines like gorillas.

We can assume that Ardi was primarily a vegetarian as he was small (couldn't take down large prey alone), did not have large canines, and lived around trees that would have provided nuts, bugs, and fruits. Most primates that subsist off of fruit need **high visuality acuity and color** to detect if a fruit is ripe (and therefore provides more calories). Similarly, some basic **extractive foraging** skills would be necessary to open nuts as well as **perishable tools**, like sticks, to trap bugs. Additionally, peeling or opening fruit, cracking nuts, or capturing bugs would have put pressure on **hand-eye-mouth coordination.**

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Not far from the homeland of Ardi, we see the signs of another famous fossil: Lucy. Lucy was a member of *Australopithecus afarensis* and lived in the exposed, hot savannah unlike the open woodland of the *Ardipithecenes*. It was likely that Lucy and her cohort were a

[1] https://cpb-us-e1.wpmucdn.com/sites.dartmouth.edu/dist/f/2053/files/2018/12/McNutt_et_al-2018-Evolutionary_Anthropology3A_Issues2C_News2C_and_Reviews-2gab32r.pdf

group of *Ardipithecus ramidus* that had enough bipedal abilities to move into the savannah. The tinkering of **knees**, **pelvis**, and **feet** may have enabled this species to be truly bipedal and form their own ecological niche away from other *Ardipithecus ramidus*.

First, Lucy had a flat tibia and femur which affords a vertical (walking) rather than bent (climbing) leg. Second, Lucy has a curved, forward **pelvis** which cannot bear as much of the weight of heavy thighs for climbing. While a narrow pelvis is ideal for walking, it reduces the size of the birth canal and can increase the chances of a mother dying in childbirth. If infant brains were expanding during this period and started to become problematic for mothers, then the infants who were more "half baked" or **motorically altricial** would have had a reduced head size and been less likely to die or kill their mothers. However, having motorically retarded infants creates a longer developmental period and dependence on a caretaker. A more **socially precocial** infant would have been more likely to maintain relationships with caretakers and reap the benefits.

Third, while the *Australopithecus afarensis* had a "true **foot**" in that its bones indicated a flexibility and stability for walking, it is still a mosaic of human-like and ape-like features[2]. While there is much debate, some claim that Lucy may have died from falling out of a tree by studying the fractures in her bones. This along with her long, curved hands suggests that she was still climbing. Although bipedalism may have compromised some of her ability to climb as well.

Given that Lucy was living on the savannah, she would have been more susceptible to larger prey and there would have been **predator pressure** (like sabertooth tigers). Foraging in groups would offer more protection than alone (not many trees or the ability to climb out of reach easily). The first **basecamps** may have emerged in this period. Similarly, the savannah would have been hot with all the sun exposure so having a more expansive network of blood vessels would cool the head (**Radiator Theory**). It would have also provided support for a growing brain in the future. We have evidence for this network thanks to **endocasts** of the inside of the skull.

Finally, to support walking and running, **breath control** would be essential. It is likely that the **thoracic spinal column** may have started to expand to account for the increasing number of nerves **innervating the lungs**. In addition to breath control and branching blood vessels, Lucy may not have had fur but, instead, sweat glands to cool off her body in the heat.

One final note is that we do not see great differences between males and females in size (compared to non-human primates). Therefore, it's likely that females would have competed over males as there was not just one dominant alpha that had dominion over all.

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[2] https://www.wired.com/2011/02/lucy-feet/

Because of this, we would see **social and sexual competition** among females which later may have been based on the best "helpers" or other factors that would be beneficial to have in a mate, in a social context. However, for Lucy, it's hard to know which factors would be more essential beyond **sexual dimorphism**.

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Spread across the Great Rift Valley, from Kenya to Ethiopia, we see the signs of yet another hominid and the first of the tool makers: *Homo habilis*. It is plausible that *habilis*—also called "handy man"—originated from *Australopithecus afarensis* but that the pressures of climate fluctuations and a variety of different ecosystems put different selective pressures that morphed *habilis* into a different species.

One reason for hypothesizing that handy man descended from *afarensis* is that it is truly bipedal with human-like **hands** and **feet**. It could have bootstrapped the initial adaptions to bipedalism—knee, pelvis, and foot—from *afarensis* but benefited from more of the arching seen in a human foot as well as a more ventral **foramen magnum** that bears the weight of a head when standing vertically. Handy man is also growing taller.

As mentioned previously, the world *habilis* inhabited was extremely unstable: there were **climate fluctuations** and **lake changes** that may have flooded the region. The only species that could have survived extensive change would have had to be extremely **adaptable**. We see *habilis* in a number of locations across East Africa which either enabled them to survive a fluctuating ecosystems if they could adapt to different locations or the changes forced them to seek more familiar habitats.

Because of flooding, handy man may have needed the ability to swim. If *habilis* descended from *afarensis* then it would have already had initial anatomy to support **breath control** like an expanding **thoracic spinal column** and nerves **innervating the lungs**. Swimming would put even more pressure on this system to regulate breathing and to hold a breath of air for an extended period. We often see that swimmers fall into a **rhythm** of alternating arms and which side of the face is exposed to air. If *habilis* was swimming long distances, it's likely **rhythm** would've played a role and even become intertwined with breath control.

Additionally, from *habilis* anatomy, we can posit that they spent much of their time walking (or at least had the support for this). Walking long distances would have exerted pressure on breath control and individuals with a larger **thoracic spinal column**—and therefore more control over their lungs—would have been more successful in foraging, outrunning predators, and migrating to different ecosystems. We also believe that *habilis* was on the move because of its teeth.

Handy man had smaller teeth that showed evidence of meat intake. If Ardi spent time in trees, it would have been easier to have access to fruits, nuts, or bugs, than handy man living in the expansive savannah. To obtain meat, *habilis* would have had to walk distances trying to find a carcass to scavenge off of or to run down smaller prey. This again suggests a bipedal nature.

We also see the first evidence of tools: the **Oldowan toolkit**. While some may look at these tools and think them just stones, some skill was involved in chipping away at the sides to shape them into stones for specific purposes. This toolkit consisted of about four variations and was **unchanged for a million years**. However, to strike a stone in the right way takes **hand-eye coordination**, **fine motor control** of the hands, and **high tactile acuity** of the hands. However, because these tools were relatively simple, it's unlikely they would have required teaching to speed up the learning process and I'd predict that members learned how to fashion these tools by watching another.

We also predict that handy man was a scavenger and would have used the stone tools to crack open the bones of a kill and access the bone marrow. We suggest this because we see a major increase in brain size: from 460cc to 660cc (and later to 950 in *erectus*). Foraging for fruits or bugs does not provide enough calories to support a much larger brain and it's unlikely that *habilis* would have been able to take down enough prey (given the rudimentary tools). Therefore, only bone marrow would have supplied a high caloric intake that would have allowed the brain's expansion to far surpass that of the gut.

If *habilis* was scavenging in groups and carrying Oldowan tools, this would have required a great amount of **self control** to inhibit the use of said tools. Non-human primates, given something in hand, will use that thing immediately; they can't resist not. But, carrying something for hours would require both the help of the **orbito-frontal cortex** (especially area 13 for inhibiting the amygdala)and **limbic/prefrontal cortex** to understand what the expected behavior is and top-down control over not doing something. The **ventral dentate nucleus of the cerebellum** may have also differentiated a result of initial self control and tool-making (though it was probably far more elaborated upon later with more attention, planning, and executive function required of complex tool making which the Oldowan is not).

Additionally, because hunting is often not successful, groups need to rely on foraging. Therefore, we may have seen an elaboration of basecamps and the first signs of **fission-fusion** in that some needed to stay with the camp, others out foraging, and few scavenging. Additionally, to scavenge, individuals would have to work in sync and potentially fall into **roles** (like chimps do) such as a lookout, bone-cracker, carrier, etc. I'd believe that there was a **division of labor** to undertake the operation of obtaining bone marrow, bringing it back to camp, and preparing food. While non-human primates can

form these roles without much communication, I'd posit that these hominids may have required **referential gestures** to indicate who does what and utilized specific **alarm calls** in case the predator was returning to its kill.

Because of the threat of predators with large teeth, being together was already adaptive. Scavenging only encouraged this. However, given changing temperatures, a fluctuating climate, and flooding, I'd predict that an interdependent group would be far more likely to survive than lone individuals or small kinship groups. This environment may have put the social nature of *afarensis* to the test and caused its decline. If *habilis* survived because they were able to form cultural groups, then this would add pressure to their infants to be even more **socially precocial**.

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Homo erectus was the first hominid to leave Africa and conquer Europe and Asia from the icy regions of the north to the islands in Southeast Asia. *Homo erectus* was one of the most adaptable, flexible, idiosyncratic hominids for its ability to survive in so many regions and migrate vast distances. *Erectus* likely descended from *habilis* as it would have needed the ability to walk, live in fission-fusion societies, and using tools to make tools. However, if we find fossils that predate *afarensis*, it's viable that *erectus* was an offshoot of *Ardipithecus ramidus*.

For *Homo erectus* to migrate, this would require long-distance walking and running and, generally, endurance. Therefore, this would have added more pressure to **breath control** and the expansion of the **thoracic spinal column**. More importantly, to migrate, *erectus* would have needed to carry supplies, water, food, tools, and weapons. As we mentioned earlier, carrying items requires suppression and executive control. But, to carry food and water, would require planning and keeping track of reserves. The importance of planning may have enabled the differentiation of **cerebellum** and the **orbito-frontal cortex**.

Additionally, during this span of a million years, there were repeated **glaciations**. If *erectus* had no fur (lost earlier), then they would have needed **clothes** to stay warm and, therefore, some ability to hunt large prey to skin them for their coat. It's likely they would have used some coverings to account for the variation in temperatures and fluctuations. Again, this would have involved planning.

We also the emergence of a new set of tools: the **Acheulian** toolkit. We see about 10 varieties of tools, the most famous of which included the bifacial hand axe and discoid. Now, these tools might seem crude like the Oldowan but they require a vast amount of work. In modern experiments[3], they have attempted to see how long it takes novices to

[3] https://carta.anthropogeny.org/mediaplayer/play/314365/303009

become experts in making hand axes. After 100 hours of training—teaching, they were proficient but not experts. To make a hand axe requires an understanding of geometry of the stone and where exactly to hit it to break off a specific pieces. This involves both spatial relationships and skilled manual movements. All of this requires an evolved visuospatial dorsal stream.

Specifically, the **basal ganglia** would be useful in **skill learning**, accessing tasks, and automating a subroutine (like hitting rock), the **cerebellum** on which muscle to move, **Broca's or F5** to determine the order of motor actions, and the **anterior principal nuclei** for sustained action (as this takes hours). This also relates to Donald's (DATE) first transition that gave rise to **mimesis** and voluntary retrievability. He claims that humans are unique in their ability to produce an infinite set of gestures which is only possible through rehearsal, refinement, and auto-cueing—all of which play a role in tool making.

One of the peer commentaries, "An Archeological Evidence of Mimetic Mind and Culture" by Wynn, suggests that the biface would have taken repetition and rehearsal to slowly chip away. Language would not have been necessary but **mimesis** would have to share the idea of the imposed shape. Because this hand axe takes so many hours of rehearsal and refinement, it may have led to the rise of **mimesis**.

The experiment we mentioned earlier also included teaching. This means that it would have likely taken more than 100 hours for an individual to figure out tool making from scratch. Even if individuals in a society were devoted to just producing a hand axe and did not need to be concerned over time to forage or hunt, this is still a huge demand of time (and one reason why apes do not spend much time on tools). Therefore, I posit that **teaching** emerged in this time.

In Lecture 4/28, we learned that there is evidence of *erectus* being **right-handed** because the tool was clearly held in the left and struck with the right. This suggests that the brain was becoming more **lateralized** so **Wernicke's** and the **arcuate fasiculus** may have become increasingly allometrically scaled to the left hemisphere though that's unclear. Broca's/F5 is important for the order of actions the hand takes so the **basal forebrain** may have differentiated a sub-area committed to arousing Broca's to sustain the action of hitting the stone into a discoid or hand axe.

We also see a huge spike in brain volume—to 950cc. I believe that this is a result of both diet (we'll get to diet soon) and teaching. With slightly more advanced tools, hominids can harness their environment and, for the first time, create a **food** surplus. This surplus would have been essential for migrating long distances. Now, this may not seem huge but it is. Chimps have equal rates of production and consumption. This means that most of their day is spent foraging and that chimps cannot afford to lose out on food by giving it away

(to anyone but children or maybe a mate). However, because hominids created a surplus, we could finally **creating an environment niche**, and, more importantly, **share food**.

With a surplus, there is less of a cost to share a resource and the **"hand-out" gesture** may have emerged to offer some of the surplus. With sharing food comes the trust and care of most kinship relationships. This may have set up the social conditions for **allo-parenting**, **empathy**, and **helping**. With this, we can now support a more expensive and lengthly development period. This period likely also included time spent teaching which, in turn, allows for more advanced technologic innovations. This likely created a **ratchet** between tech and cognition. I believe this accounted for part of the brain explosion.

From the tools, we can predict that *erectus* hunted small game. The discoid is a tool that has to be thrown to take down an animal in a pack. **Aimed throwing** would require great **hand-eye coordination**, the **STS** to detect biological motion, and **gaze detection** as gaze usually indicates the intention of the animal (like if it's going to head towards you).

Homo erectus was also the first to harness **fire**. Fire is key in social groups: you need to collaborate to produce a fire and a hearth is often a place to come together. As with tool-making and the repetition of hitting the edge of a stone with another, **rhythm** likely played a key role in not just repeating an action but **coordinating** behaviors together. Fire is also a hugely important contributor to diet. While meat may have provided more calories needed to support a growing brain, nothing beats cooked meat. Cooked meat makes it easier to extract the nutrients and cut down on the energy to digest. This may have also helped the brain expansion.

Because *erectus* hunted, they were the first **hunter-gatherer** society and were fission-fusion. It's plausible that individuals had **different roles**: some staying in the camp taking care of children or crafting tools, other foraging for fruits and nuts, and some hunting small prey. More interestingly, because individuals were not always together and present in the same context, there would be **differential access** to information.

If something occurred on the hunt, hunters may return to the camp and want to regale the community with a story of what occurred—a **narrative** through mimesis. This requires an understanding of what people do or don't know—**allo-epistemics**—as well as identifying the point at which you now have similar access—running the **epistemic engine**, and who gets to tell the story—determined by the **epistemic status**. Similar to informing the group, individuals may decide not to share if others do not deserve to be informed—**epistemic territory**—of if the deception would be self-serving.

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Homo neanderthalensis was the first hominid that did not originate in Africa. It likely descended from a group of *Homo erectus* in Eurasia. *Homo neanderthalensis*—also called neanderthal—was well adapted to the cold climate of Europe. They were shorter, stocky, with denser fat, and **thicker bones**. To survive the cold, they would have had to have **clothing** or thick furs to keep warm.

Neanderthals also had the largest brain of any hominid: 1400cc. The major visible difference in skull was the emergence of the occipital bun which might've afforded more advanced vision or it could have resulted from the growth of another area pushing into the back of the skull. The growth of this brain may have been due to similar reasons as *erectus*: diet and tool-making.

Neanderthals were superior hunters: they could take down large mammals. To do this would have required great coordination and gestures may not have been sufficient to plan the takedown of such a great beast. To foster cohesion, Jan Wind in "Did Primates Need More Than Social Grooming and Increased Group Size for Acquiring Language" suggests that social grooming is needed to maintain trust and perform cooperative actions (like hunting) and that language may have been the best form of social grooming (as other forms would be too lime consuming). But, we'll get to language later. Similarly, in "Clarifying the Time Frame and Units of Selection in the Cultural Group Selection Hypothesis," Whiten and Erdal emphasize that hunter-gatherer (or generally fission-fusion) societies see an interdependence among individuals which means that the actions and contributions of each individual play a huge role in the overall fitness of the group.

Homo neanderthalensis also had an impressive set of tools at their disposal: the **Mousterian** toolkit. Tools were crafted through the **Levallois method** which was a multi-step, hierarchically organized set of techniques. This would have been one of the most important examples of **combinatorics** that could have been exapted by—or co-evolved with—language (as grammar is combinatorial).

Their tools were also of mixed materials: wood, flint, sinew, etc. They are also the first evidence of hafted tools; for example, a piece of flint was attacked to a stick by sinew. These tools would have been far more cognitively demanding and only possible with teaching to cut down on the time to experiment and practice without demonstration. To learn these tools, these hominids may have utilized both the **mirror neuron system** and **entrainment** to match the actions and timing of the teacher. Because of the complexity of these tools, teacher may have had to use jargon to name specific pieces or the actions involved. **Jargon** allows individuals to have **"professional vision"** which may have speed up the time to craft tools.

If **jargon** did exist, this would have been pivotal in the development of language. In organizing hunts, hunters may have been able to rely on **iconic references** (like the movement or sound of an animal to represent it) but jargon is far more arbitrary and requires agreement or acceptance by others about what it represents. A larger set of words to describe parts of the tool-making process would have put pressure on memory as you need to remember the representations (as they're arbitrary).

In regard to language, we see that neanderthals had a more arched **basicranial flexure** which means they have more space in their vocal cavity. To have this adaption would indicate that it either didn't impede on its fitness or was likely a helpful feature. If it was helpful, this would mean that the ability to produce a wider range of sounds was important to a fission-fusion society. **Speech** likely was a key element of this society even if they didn't have full-blown language.

If they had speech, then it's likely their infants **babbled** to "tool up" their vocal abilities. It's likely that mothers also spoke to their babies in "baby talk"—or **motherese**—to practice turn-taking or for their child to know they were still there and paying attention. David Spurrett and Andrew Dellis in "Putting Infants in Their Place" suggest that mothers who were good at vocal comforting may have been freed to forage more effectively which would result in greater fitness (and therefore be selected for). And, on the other end, infants who were good at vocalizing their needs and elicited maternal care would have been fed more or had more success. Both parties had much to gain from compelling **vocalizations**.

Finally, we see unique characteristics in this hominid like burial, jewelry, and the use of red ocre. Burials indicate that they mourned the loss of their own or respected some transition beyond death. While I believe that empathy emerged earlier on, this is a clear sign that it existed. In "Multi-Level Selection, Social Signaling, and the Evolution of Human Suffering Gestures: The Example of Pain Behaviors," Vigil and Kruger note that our ability to detect when someone is in pain (and their ability to display it) could serve as a warning system to help the fitness of other individuals. When an individual suffers, others will (or are expected to) care for the. Caring for others, or feeling empathy, may have enabled group cohesion to grow stronger. Therefore, those who exhibited empathy whether by helping or performing burials might have been more sought-after partners.

Finally, the use of jewelry might indicate the emergence of a need for status in a society. This would put pressure on the **anterior thalamic nuclei** and **anterior cingulate cortex** to remember a history of interactions, the status of that person, and whether to interact.

Homo sapiens, unlike neanderthals, originated in Africa and were likely a different group that branched from the *erectus* in Africa. They did not face the same cold conditions and this may be why they have less thick bones, a receding **chin**, and greater height. Compared to neanderthals, *sapiens* have a far more arched **basicranial flexure**. We also have a, potentially, more titled and higher up **hyoid bone**. Both of these may have enabled *sapiens* to produce a wider array of sounds and made us the language-obsessed creatures we are today.

Humans are unique in their infinite array of tools. The upper paleo toolkit shows that we have the most varied and refined set of tools. Many of these tools are very specialized such as ones to catch large vs small fish. This would have put increasing pressure on numerous areas of the brain that support hand-eye coordination, fine-motor hand control, detail-discrimination, etc.

We are also the only to have **cave paintings**. These paintings show evidence of **iconic references** (e.g. outline of a cow represents a cow). However, we also see markings on the walls which may be evidence for **symbolic references**. To represent something like days of drought with lines would require a larger memory, incredibly arbitrary signs, and **conventionalization** (agreement about a sign and its value). Additionally, **religious icons** also are examples of symbolic references but may also indicate a desire to **police and access why** (as we often use religion to explain phenomena).

We also have music instruments that suggests we may have been keyed into **music** and rhythm and it may have been beneficial in bringing cohesion or **joint attention** to a society.

(I'm sorry I ran out of time to cite but thank you for a great quarter).

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