HUMAN EVOLUTION AND CUMULATIVE CULTURE

Origins and Evolution of Language
Week 4

TODAY

Wrap-up from week 3

Hominid evolution

Social learning and cultural evolution

LATENT CAPACITY FOR SYNTAX IN APES?

Savage-Rumbaugh, E. S., Murphy, J., Sevcik, R., Brakke, K., Williams, S., Rumbaugh, D., & Bates, E. (1993).
Language comprehension in ape and child. Monographs of the Society for Research in Child Development, 58, 1–252.

LATENT CAPACITY FOR SYNTAX IN APES?

Could just be 'semantic soup' plus smart interpretation?

- Cut the onions with your knife
- Put the pine needles in the refrigerator

But he can handle reversible events

- Put the tomato in the oil
- Put some oil in the tomato [Kanzi pours oil in a bowl with the tomato]

But no strong evidence for hierarchy

- Give the water and the doggie to Rose. [Gives dog only]
- Give the lighter and the shoe to Rose. [Gives lighter only]
- Give me the milk and the lighter [Responds correctly]

Truswell, R. (2017). Dendrophobia in bonobo comprehension of spoken English. Mind & Language, 32(4), 395-415.

STRUCTURE IN AVIAN COMMUNICATION

Songs consist of sequences of notes, including sub-parts

Constraints on the ordering of parts

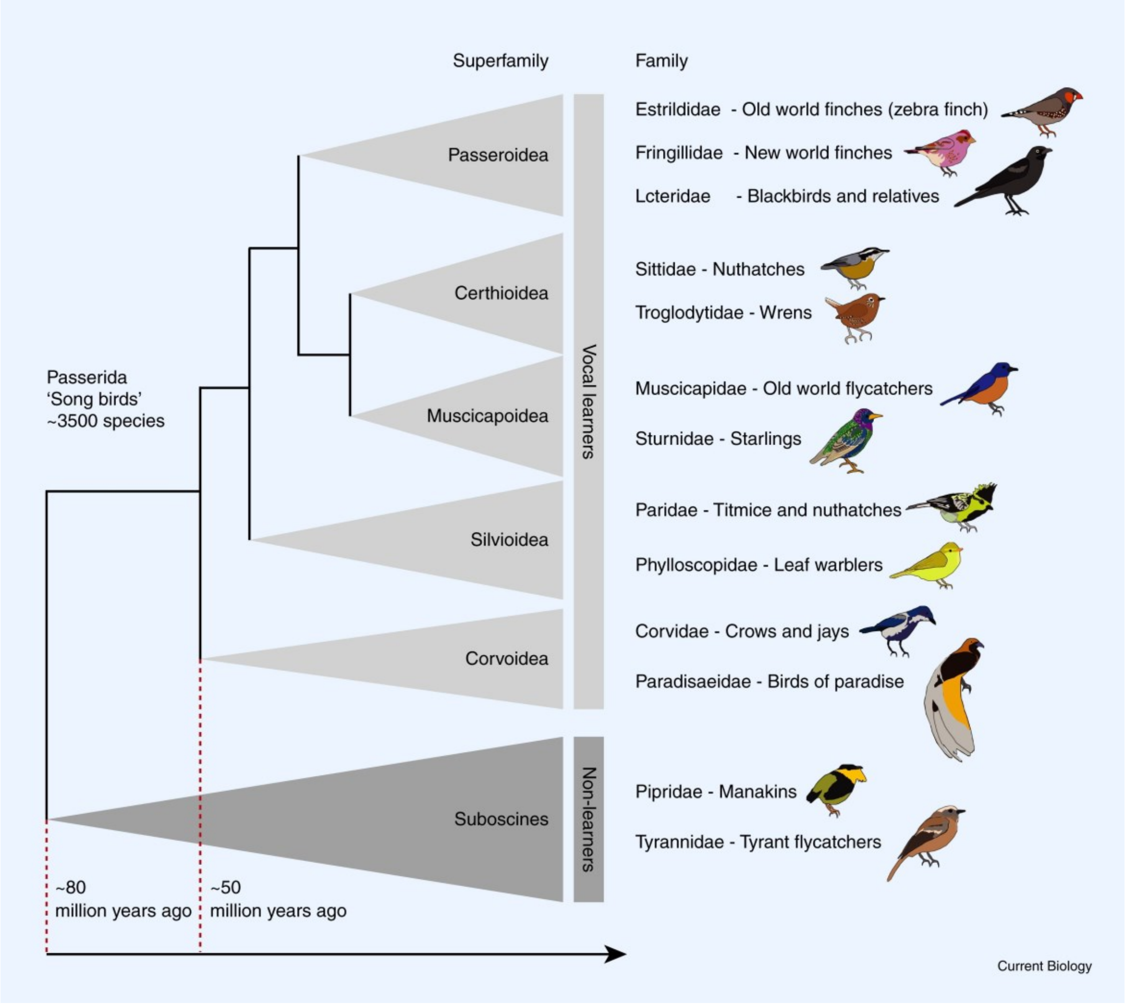
- but, structure in the signal does not convey structured (or any) meaning

Socially learned, rather than innate

- most primate vocal behaviour is innate

Ultimate functions

- Territorial defence
- Courtship
- Pair/group boding and duetting
- …just like gibbons



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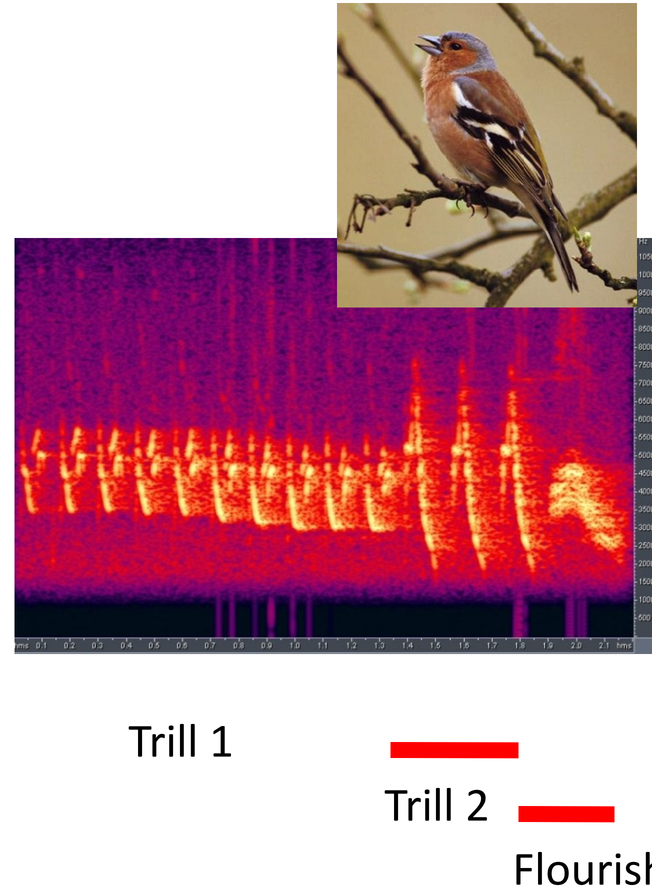
CHAFFINCH



Each bird has 1-6 song types

- Mean 2-3

Order of notes in each song fixed

2-5 trill phrases, followed by a flourish

- Trill: sequence of 2 or more near-identical units
  - Number of repetitions can vary
- Flourish: no repetition
- Transitional notes: single notes between trill phrases
- Re-use of notes
  - Different songs may share, e.g., a flourish

Slater, P. J. B., & Sellar, P. J. (1986). Contrasts in the Songs of Two Sympatric Chaffinch Species . *Behaviour, 99,* 46-64.

Slater, P. J. B., Clements, F. A., & Goodfellow, D. J. (1984). Local and regional variations in chaffinch song and the question of dialects. *Behaviour, 88,* 76-97.

SEDGE WARBLER

Large repertoire of syllables

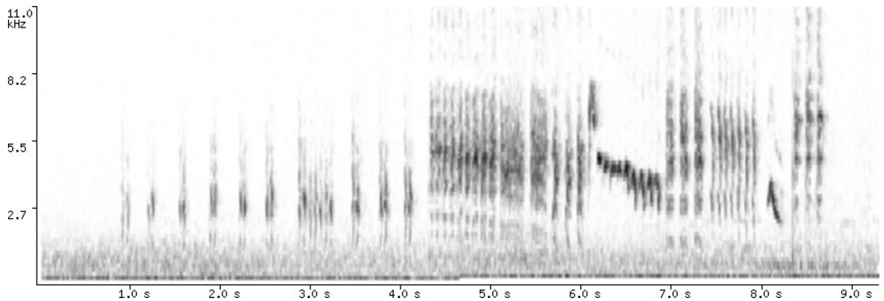
- 40-60 (?)

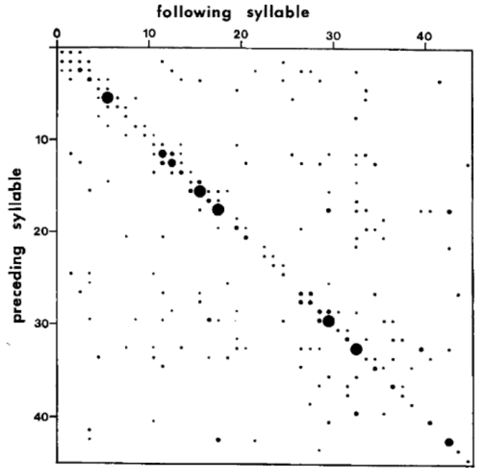
Highly variable

- No two songs are the same (probably)

General organising principles

- Song start: long complex sequence of repetitions of 2 syllable types
- Middle: Multiple new syllable types introduced in quick succession
- End: similar to start, but using 2 syllables selected from middle





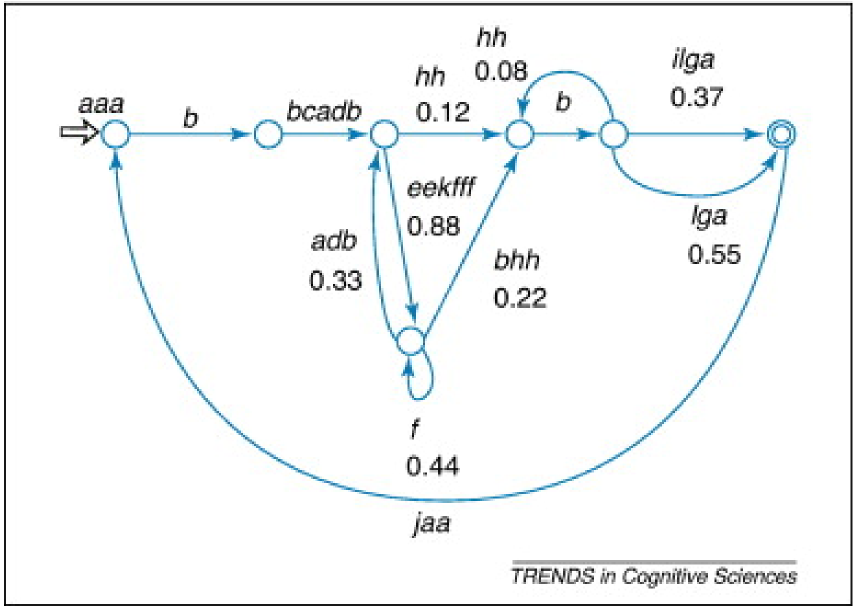
Catchpole, C. K. (1976). Temporal and sequential organisation of song in the sedge warbler (*Acrocephalus schoenbaenus*). *Behaviour, 59,* 226-245.

AVIAN SONG STRUCTURE: OVERVIEW

Beyond bigram dependencies

No nested dependencies

Crucially: no meaning



Berwick, R. C., Okanoya, K., Beckers, G. J., & Bolhuis, J. J. (2011).
Songs to syntax: the linguistics of birdsong. Trends in cognitive sciences, 15(3), 113-121.

VOCAL COMMUNICATION IN BATS

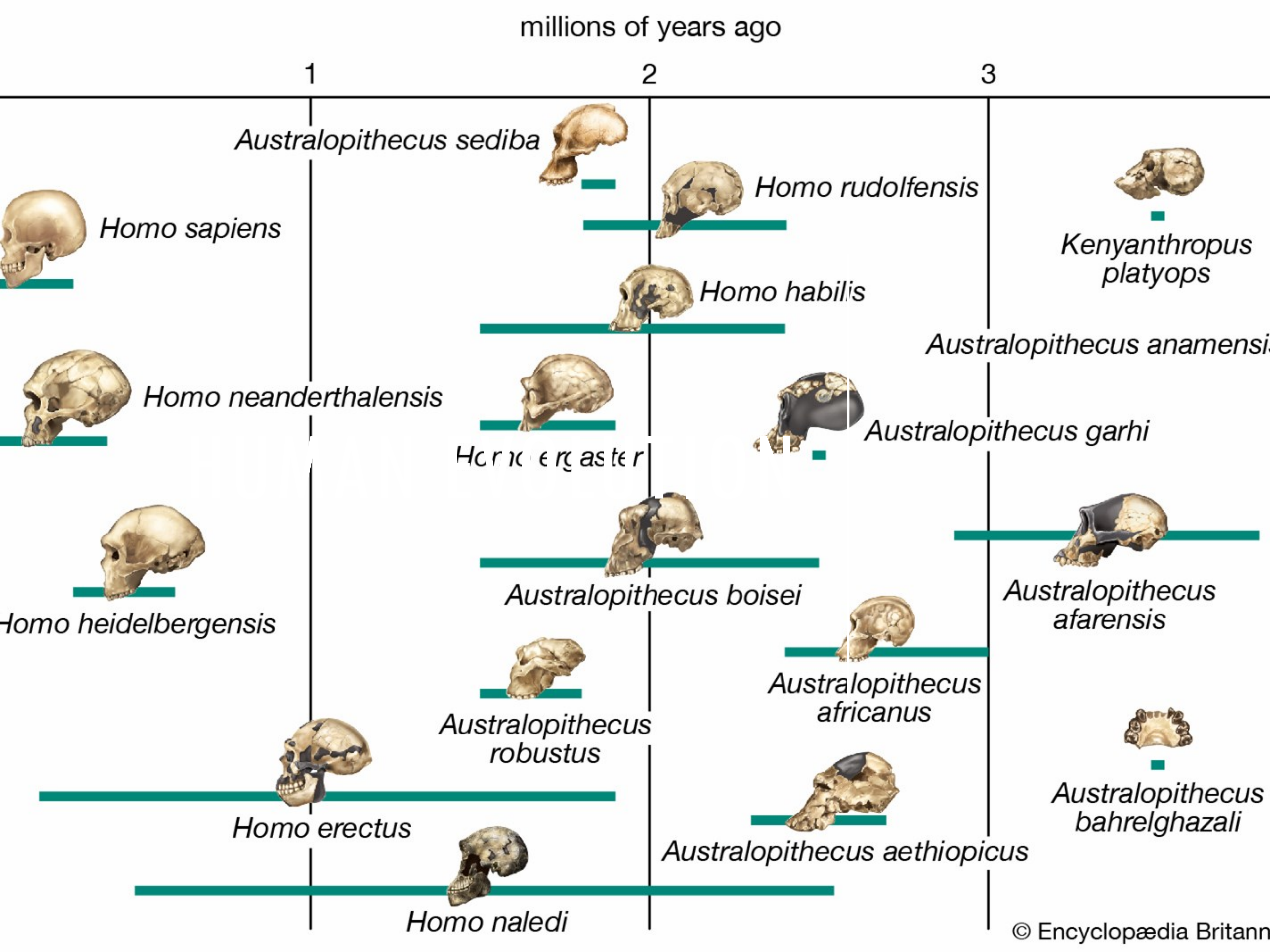
Complex vocalisations for navigation (e.g., echolocation)

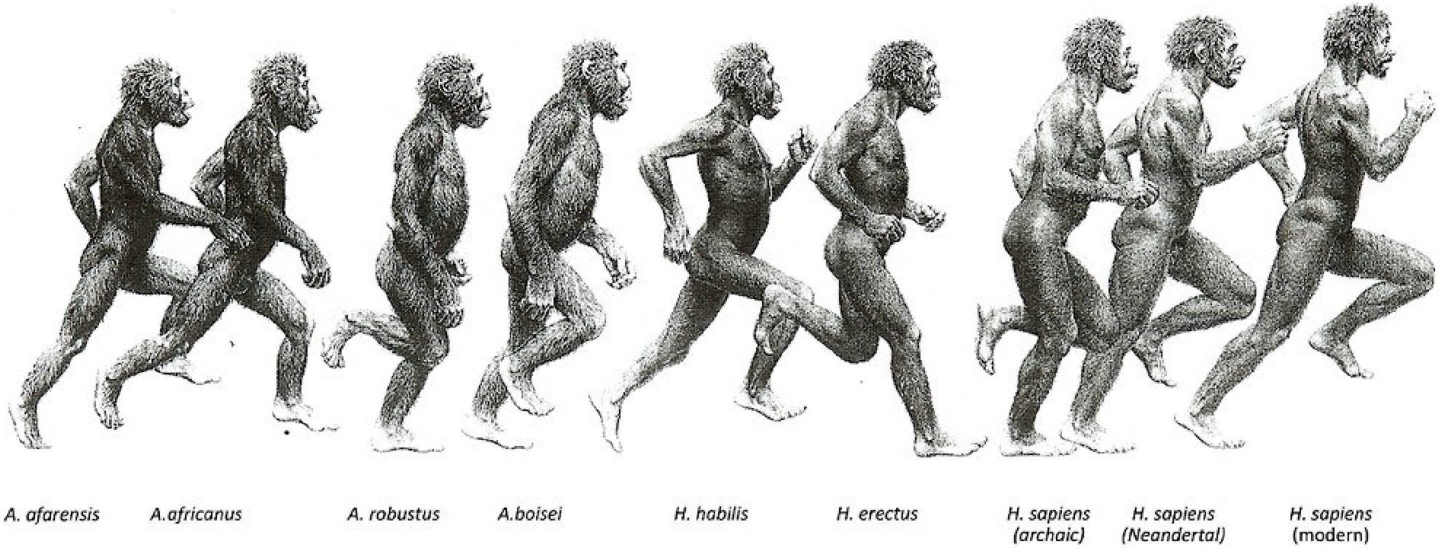
Also used for social bonding and interaction

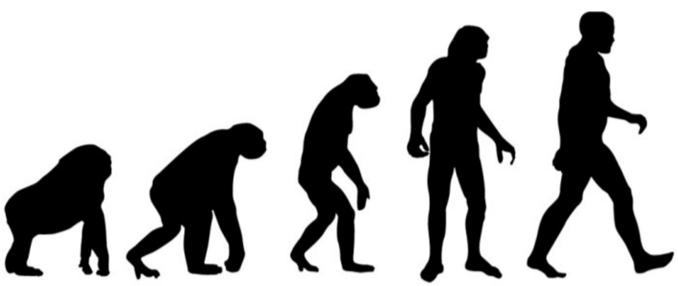
In some species , learned and open-ended

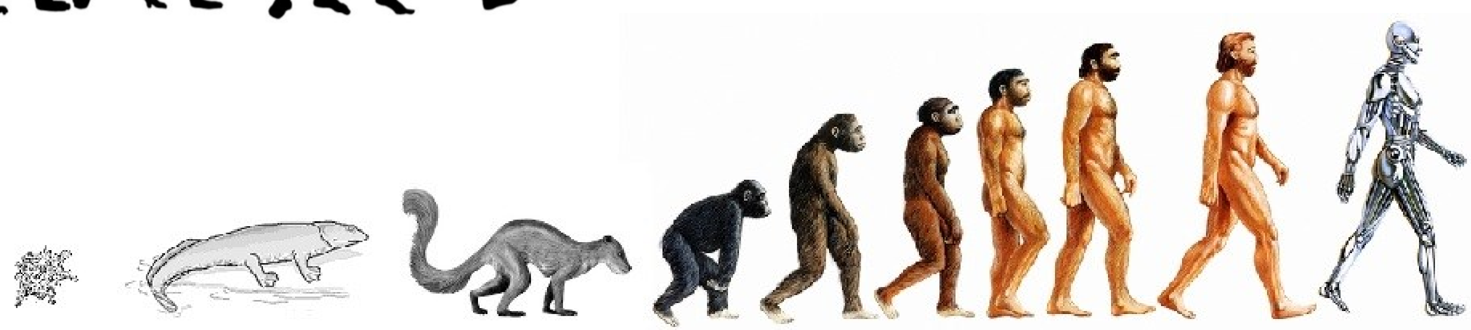
Exhibits turn-taking

Vernes, S. C. (2017). What bats have to say about speech and language. *Psychonomic bulletin & review*, *24*(1), 111-117.


millions of years ago
1
2
3
Australopithecus sediba
Homo rudolfensis
Homo sapiens
Kenyanthropus platyops
Homo habilis
Australopithecus anamensis
Homo neanderthalensis
Australopithecus garhi
Homo ergaster
Australopithecus boisei
Australopithecus afarensis
Homo heidelbergensis
Australopithecus africanus
Australopithecus robustus
Homo erectus
Australopithecus bahrelghazali
Australopithecus aethiopicus
Homo naledi
© Encyclopædia Britann

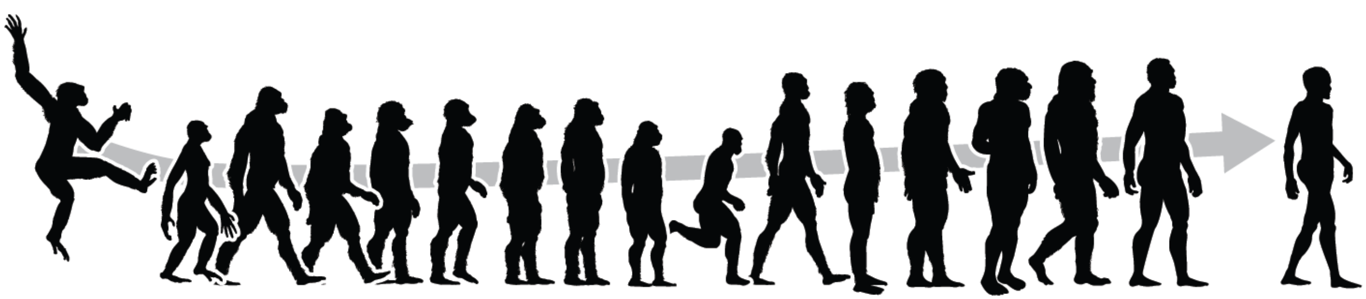

A. afarensis
A.africanus
A. robustus
A.boisei
H. habilis
H. erectus
H. sapiens
(archaic)
H. sapiens
(Neandertal)
H. sapiens
(modern)





This is what evolution looks like.

This is not what evolution looks like.



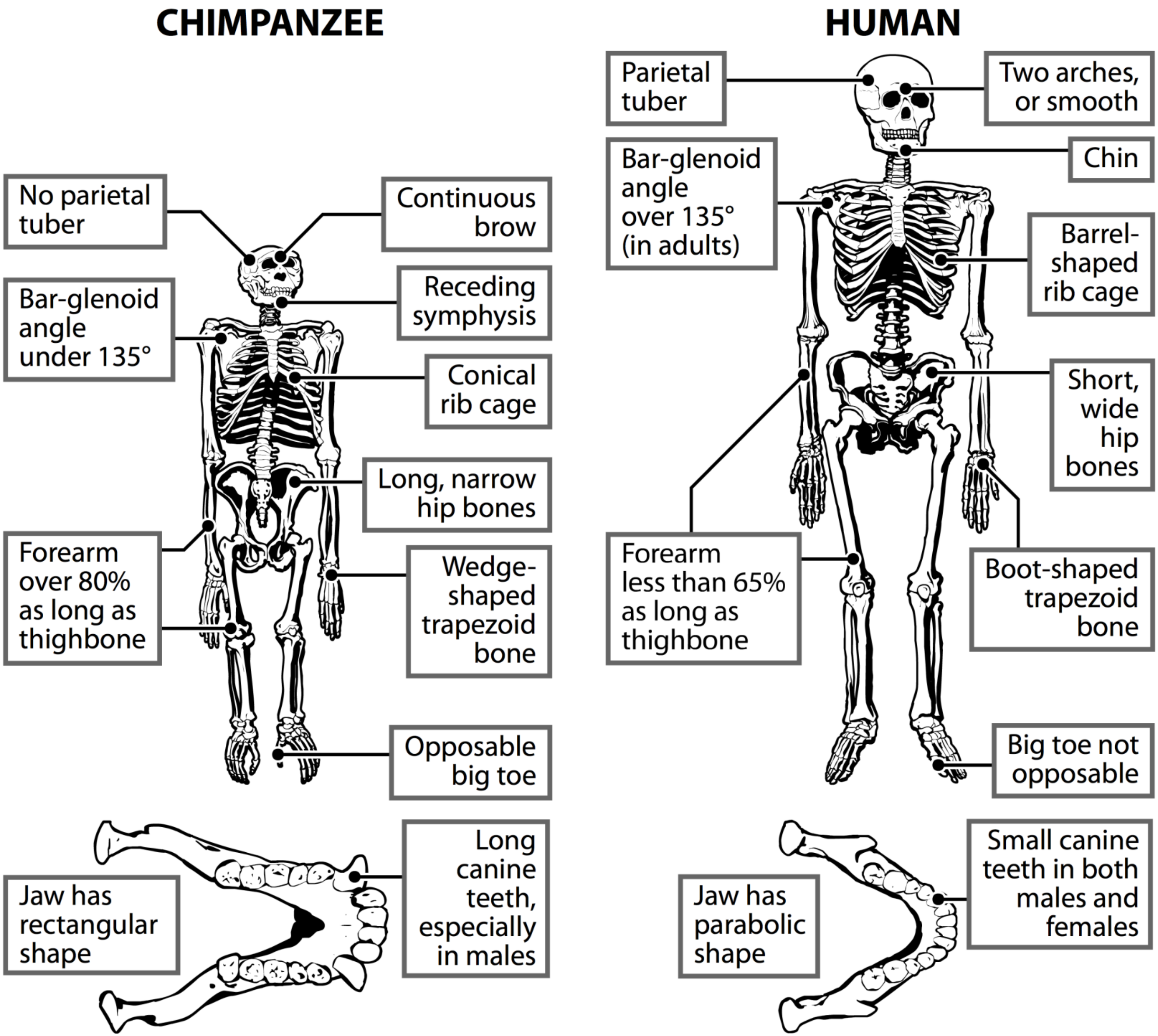
HOMINID PHENOTYPE

HOMINID PHENOTYPE

H. neanderthalensis

H. florensiensis

H. denisova



https://www.flickr.com/photos/keesey/sets/72157653196880464

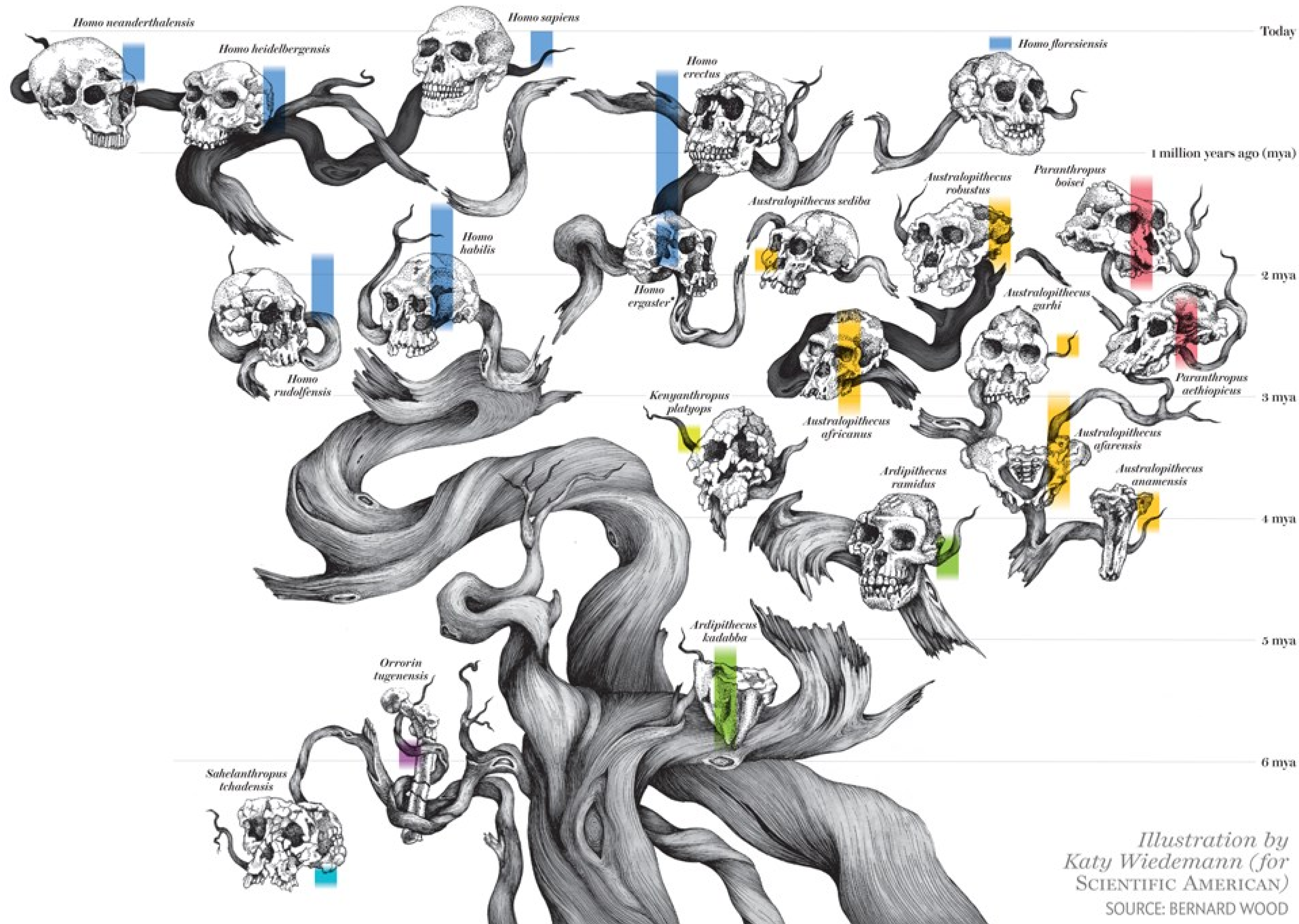
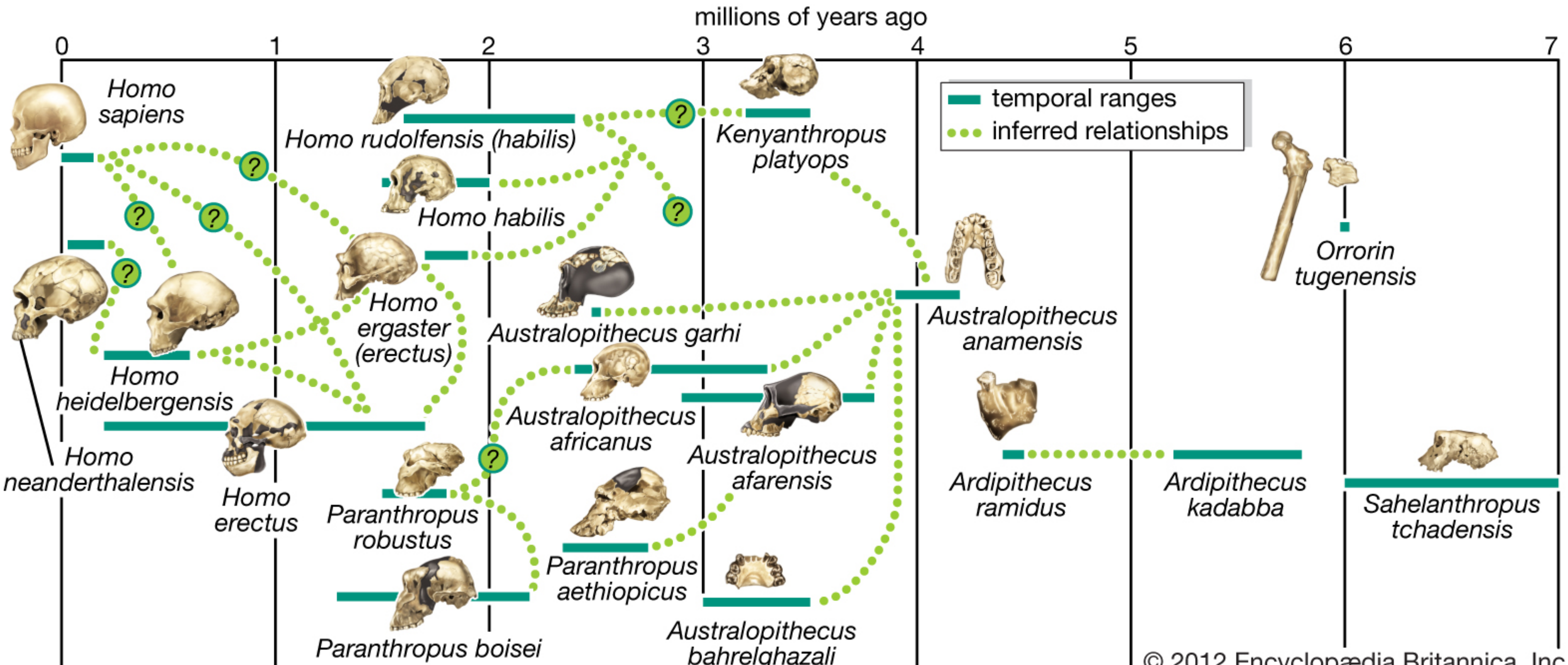


Illustration by Katy Wiedemann (for Scientific American)

SOURCE: BERNARD WOOD



millions of years ago
0
1
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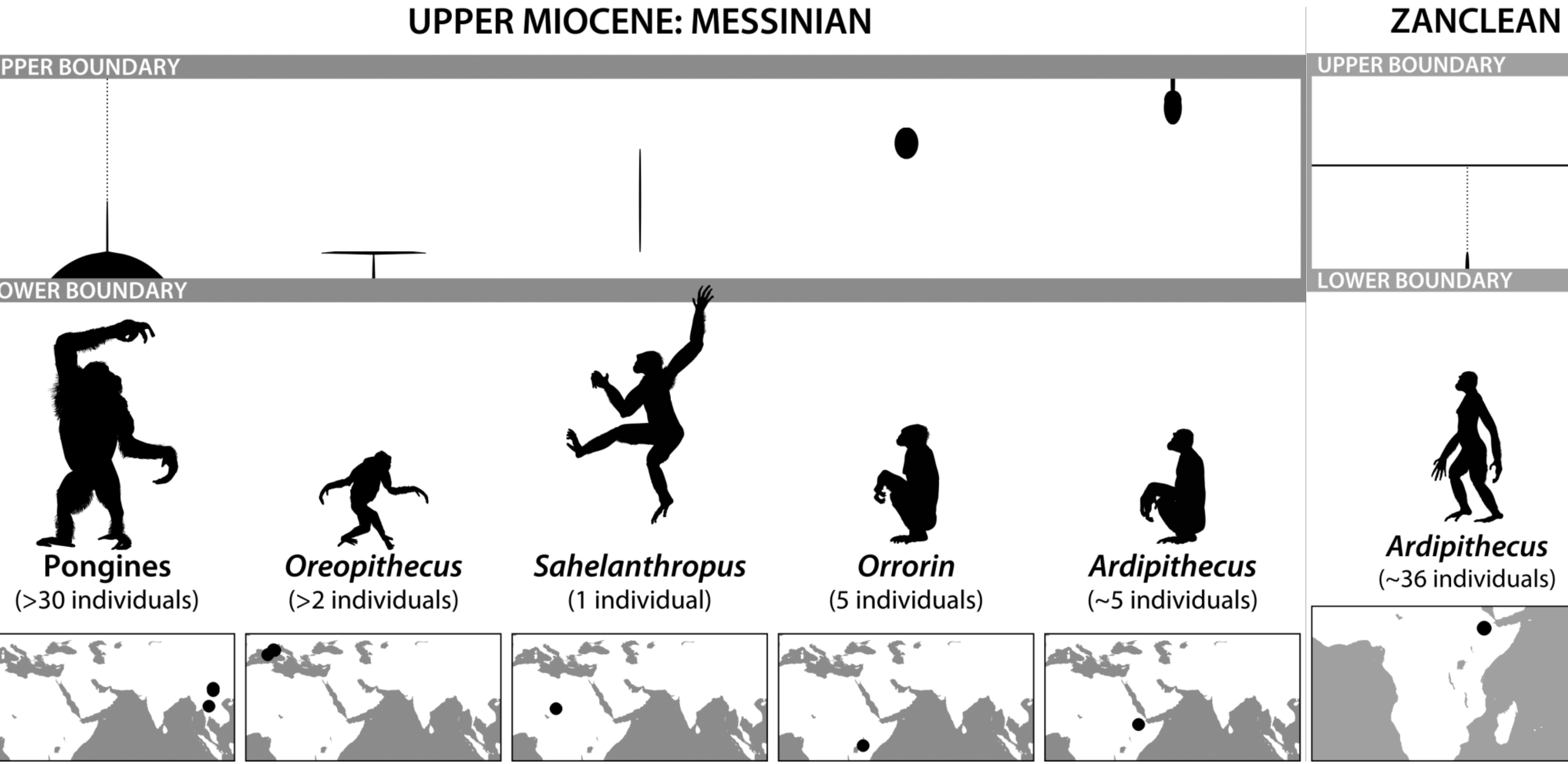
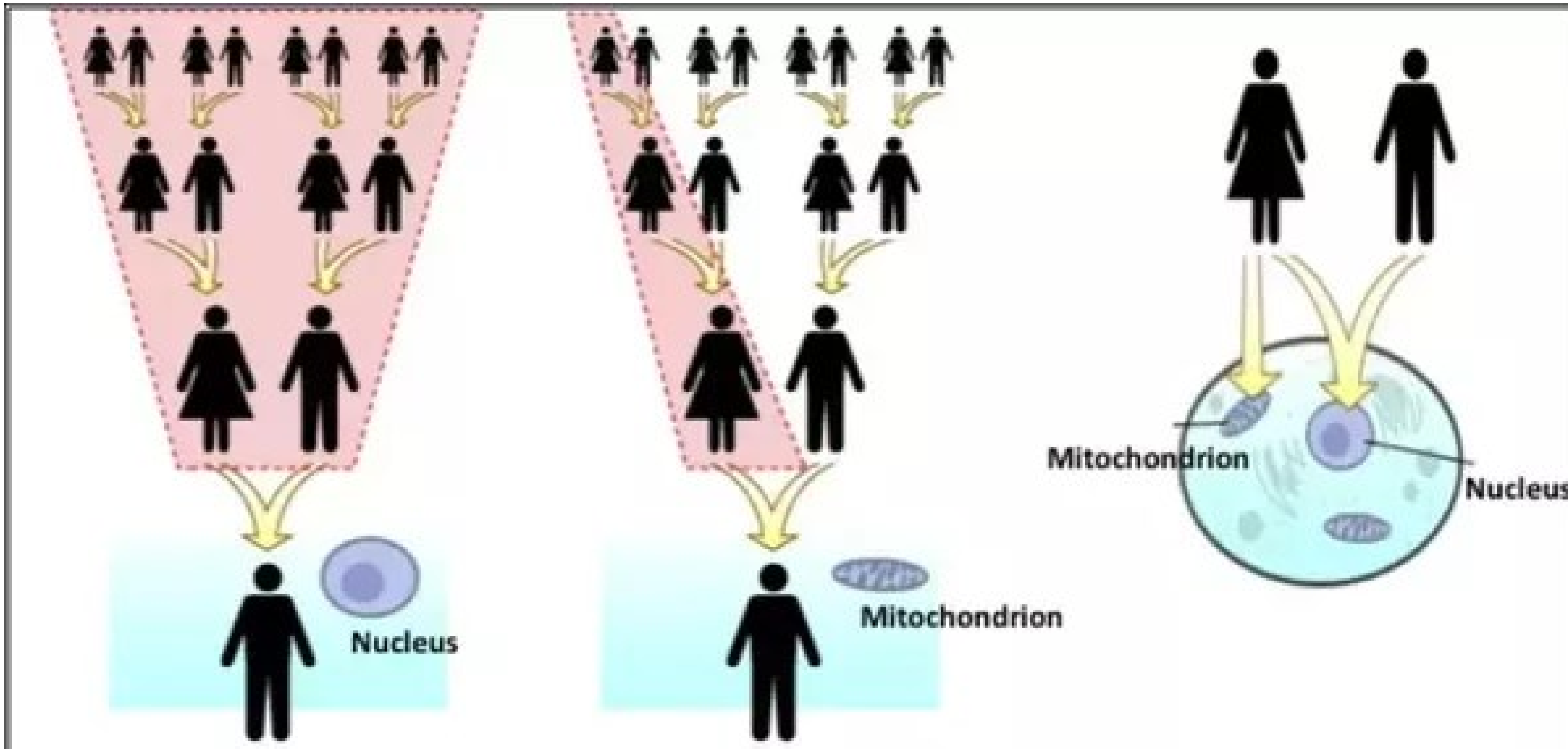
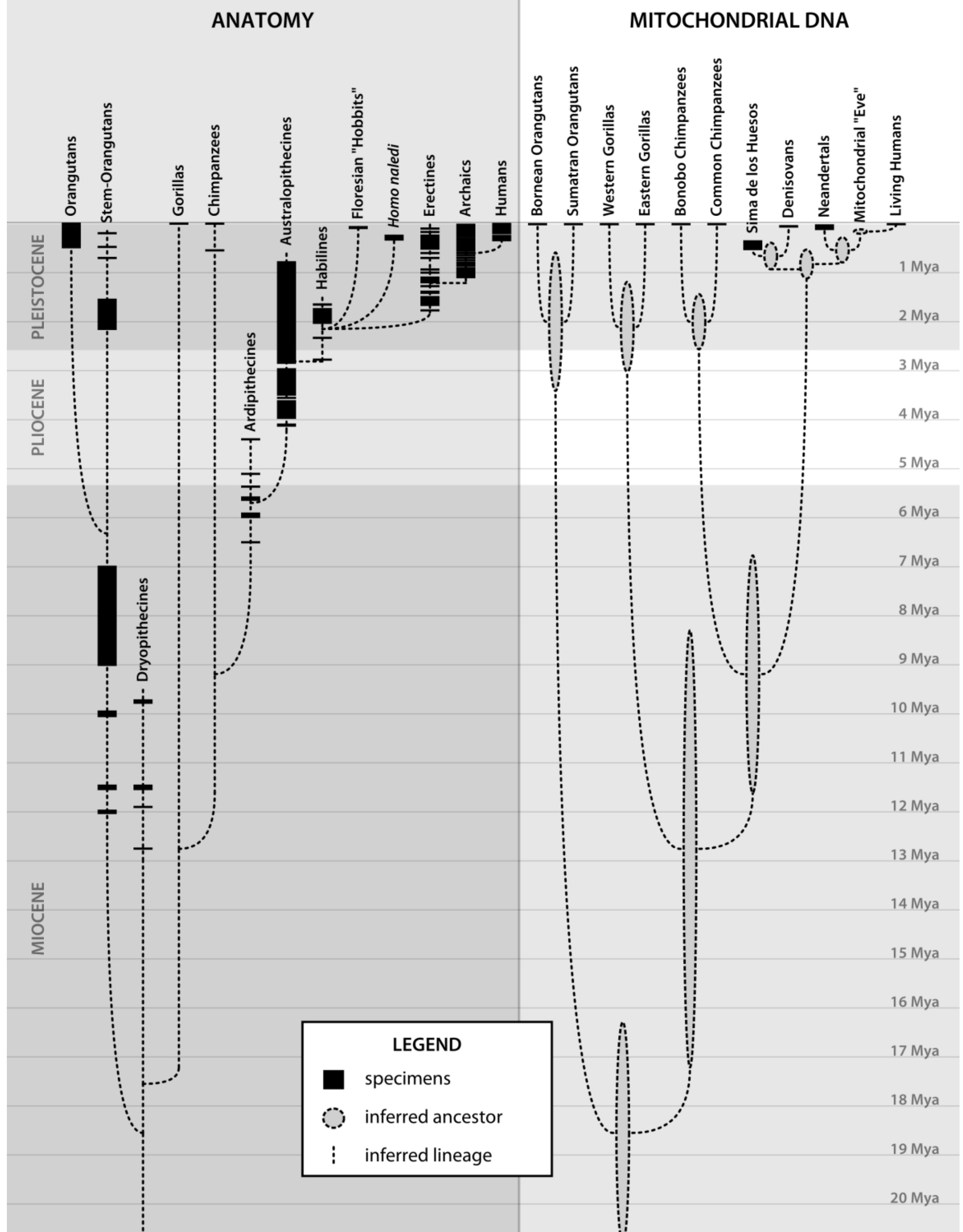
4
5
6
7
temporal ranges
inferred relationships
Homo sapiens
Homo rudolfensis (habilis)
Kenyanthropus platyops
Homo habilis
Orrorin tugenensis
Homo ergaster (erectus)
Australopithecus garhi
Australopithecus anamensis
Homo heidelbergensis
Australopithecus africanus
Homo neanderthalensis
Homo erectus
Paranthropus robustus
Australopithecus afarensis
Ardipithecus ramidus
Ardipithecus kadabba
Sahelanthropus tchadensis
Paranthropus aethiopicus
Paranthropus boisei
Australopithecus bahrelghazali
?


UPPER MIOCENE: MESSINIAN
ZANCLEAN
PPER BOUNDARY
OWER BOUNDARY
UPPER BOUNDARY
LOWER BOUNDARY
Pongines
(>30 individuals)
Oreopithecus
(>2 individuals)
Sahelanthropus
(1 individual)
Orrorin
(5 individuals)
Ardipithecus
(~5 individuals)
Ardipithecus
(~36 individuals)

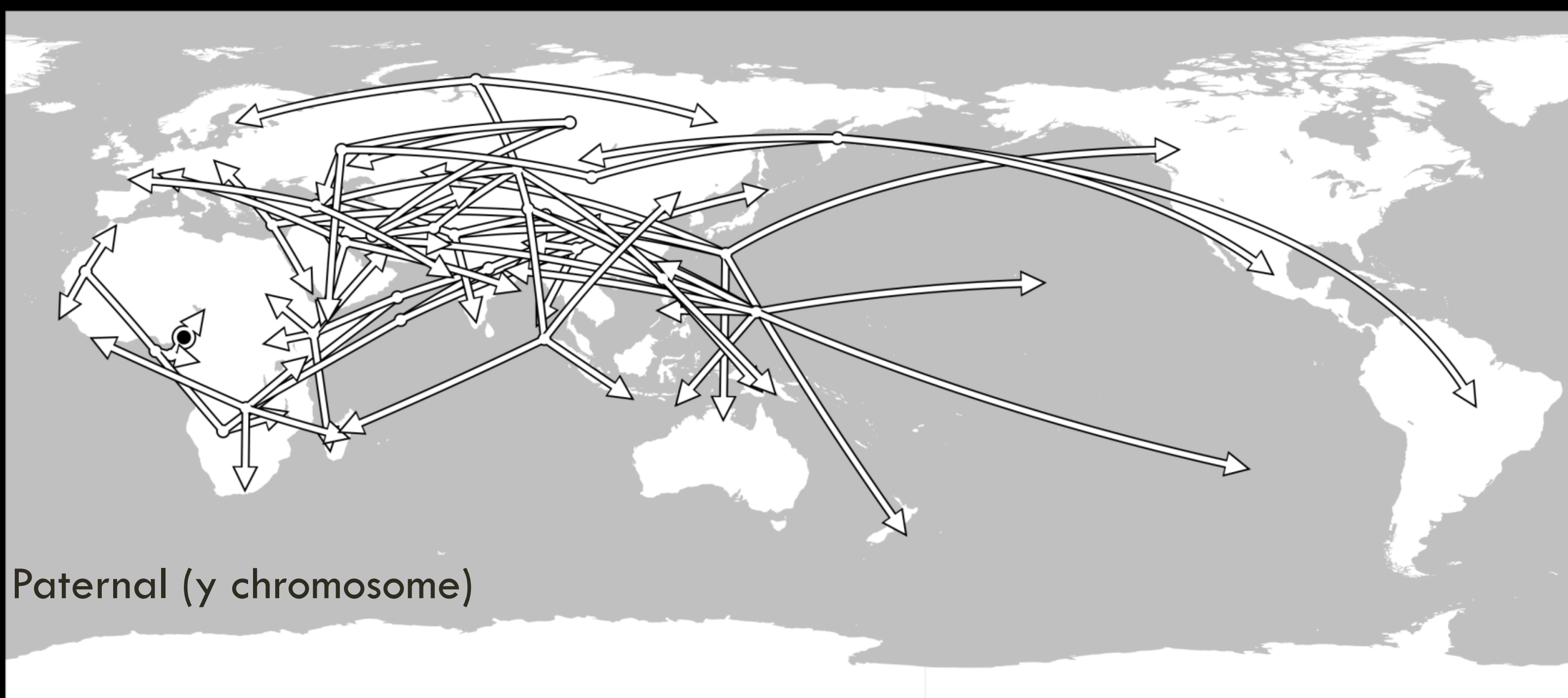


Nuclear DNA is inherited from all ancestors (left panel); Mitochondrial DNA is inherited from a single lineage, maternal (center panel); mitochondria are passed from mother to child only, whereas the genes in the nuclei of your cells come from both parents (right panel). From the University of California Museum of Paleontology's Understanding Evolution (http://evolution.berkeley.edu).

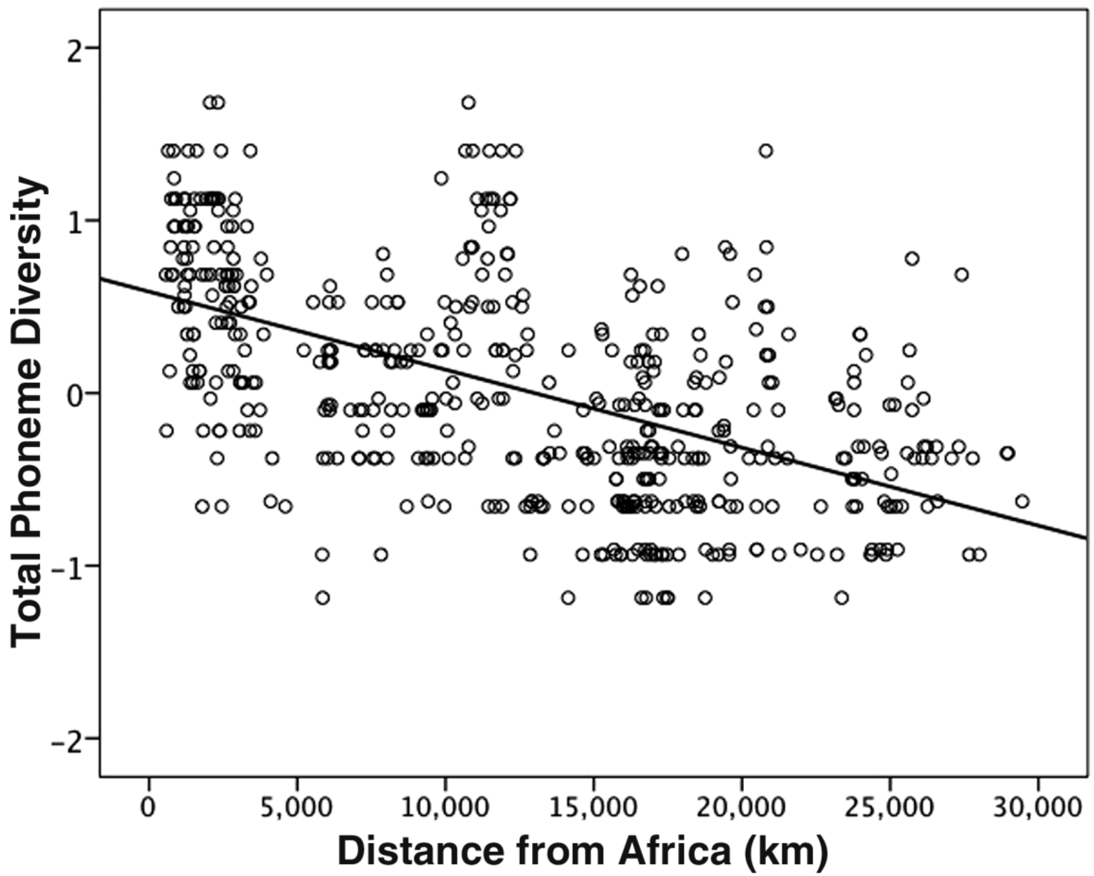
ANATOMY VS DNA




Maternal (mitochondrial DNA)

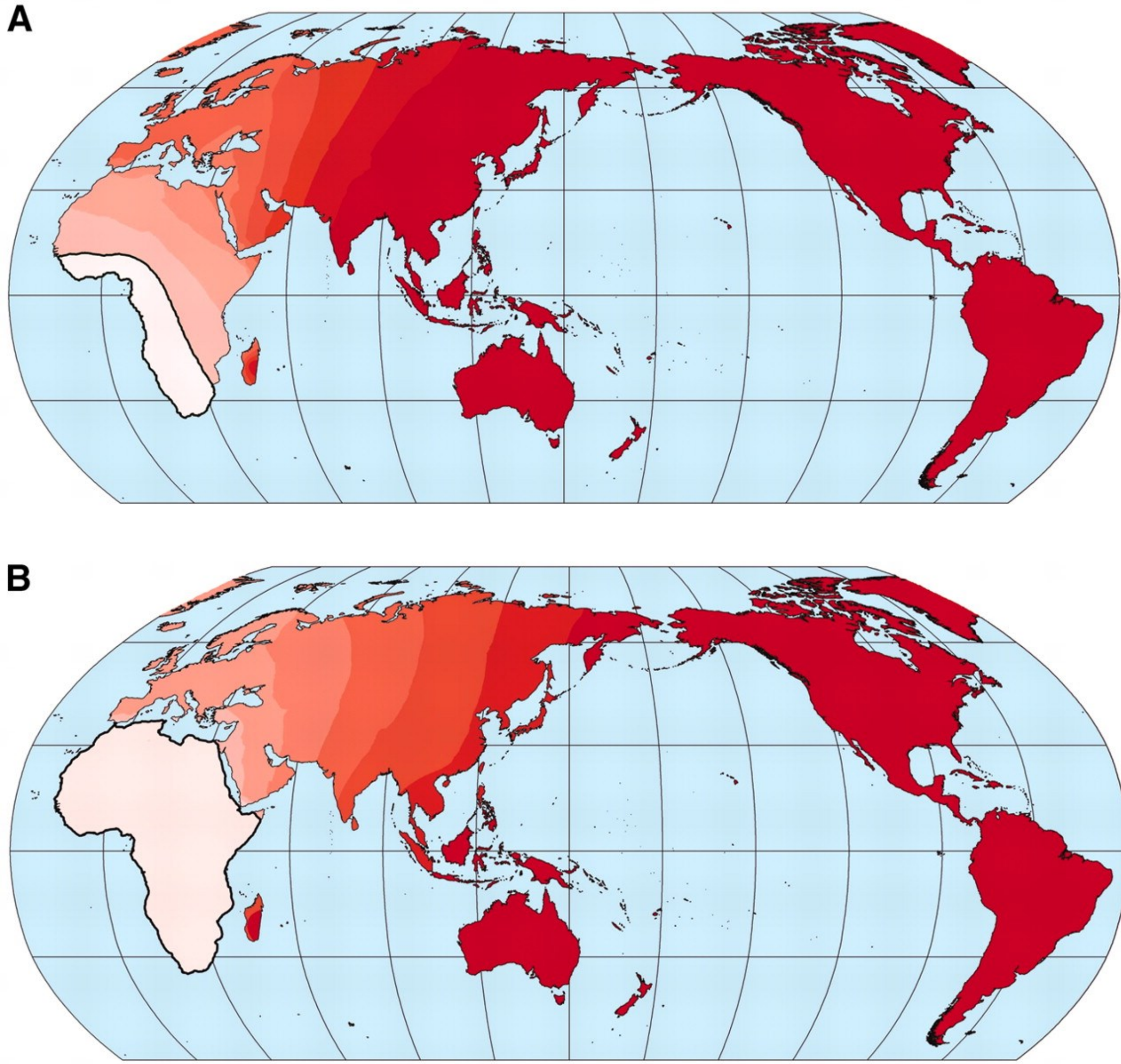

Paternal (y chromosome)

LANGUAGES OUT OF AFRICA?



Atkinson, Quentin D. "Phonemic diversity supports a serial founder effect model of language expansion from Africa." *Science* 332.6027 (2011): 346-349.

LANGUAGES OUT OF AFRICA?

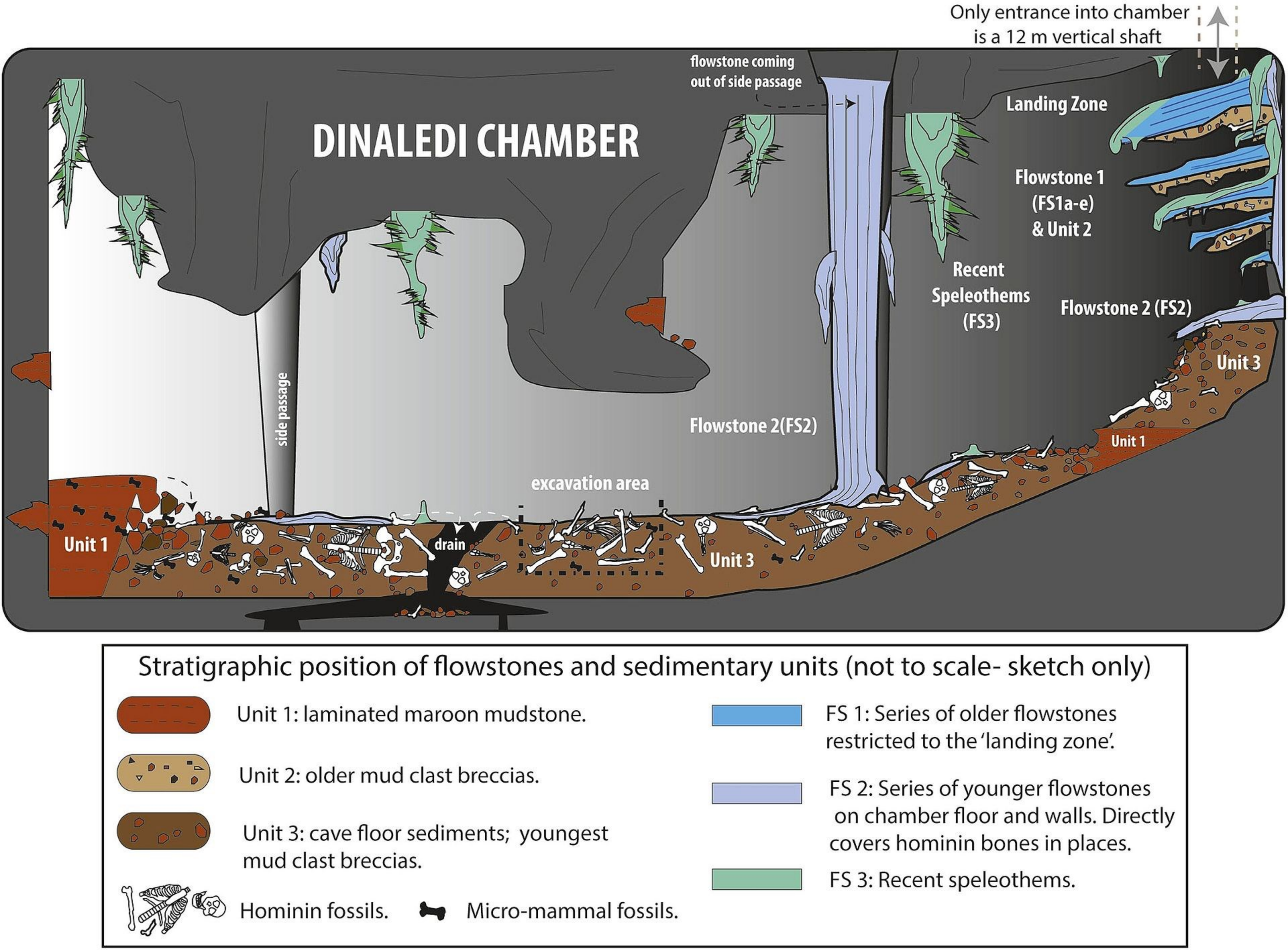


Likely area of language origin. Maps show the likely location of a single language origin under a founder effect model of phonemic diversity (controlling for population size) inferred from (**A**) individual languages and (**B**) mean diversity across language families. Lighter shading implies a stronger inverse relationship between phonemic diversity and distance from the origin and better fit of the model

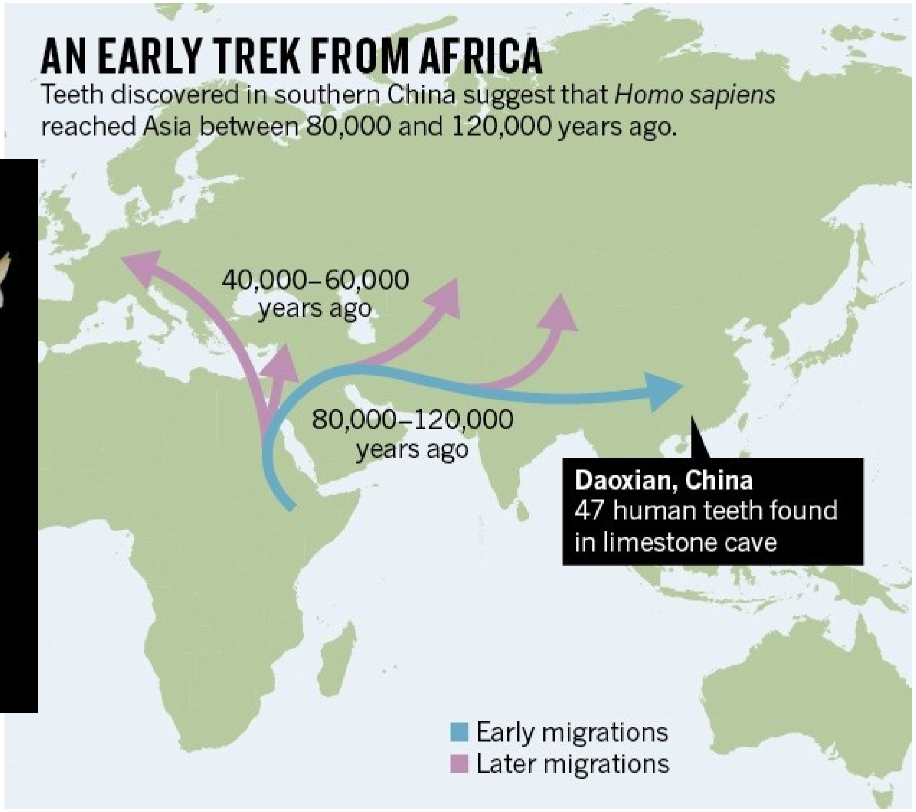
HOMO NALEDI

Berger, L. R. (2015). Homo naledi, a new species of the genus Homo from the Dinaledi Chamber, South Africa. *eLife, 4,* e09560

Dirks, P. H., Roberts, E. M., Hilbert-Wolf, H., Kramers, J. D., Hawks, J., Dosseto, A., ... & Hellstrom, J. (2017). The age of Homo naledi and associated sediments in the Rising Star Cave, South Africa. eLife, 6, e24231.

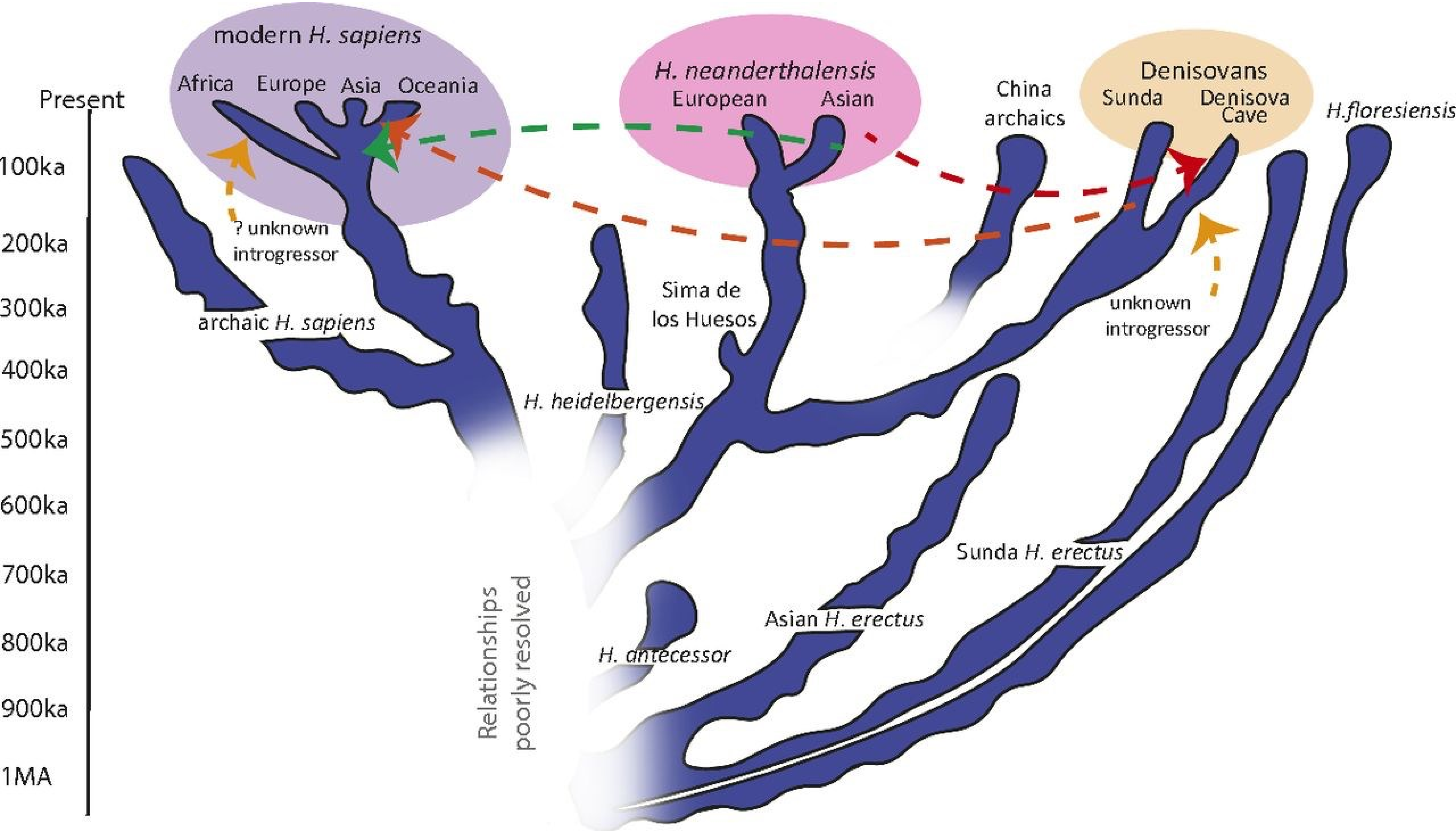

Only entrance into chamber
is a 12 m vertical shaft
flowstone coming
out of side passage
DINALEDI CHAMBER
Landing Zone
Flowstone 1
(FS1a-e)
& Unit 2
Recent
Speleothems
(FS3)
Flowstone 2 (FS2)
Unit 3
Unit 1
side passage
Flowstone 2(FS2)
excavation area
drain
Unit 1
Unit 3
Stratigraphic position of flowstones and sedimentary units (not to scale- sketch only)
Unit 1: laminated maroon mudstone.
Unit 2: older mud clast breccias.
Unit 3: cave floor sediments; youngest mud clast breccias.
Hominin fossils.
Micro-mammal fossils.
FS 1: Series of older flowstones restricted to the 'landing zone'.
FS 2: Series of younger flowstones on chamber floor and walls. Directly covers hominin bones in places.
FS 3: Recent speleothems.

SAPIENS VS NEANDERTHALS



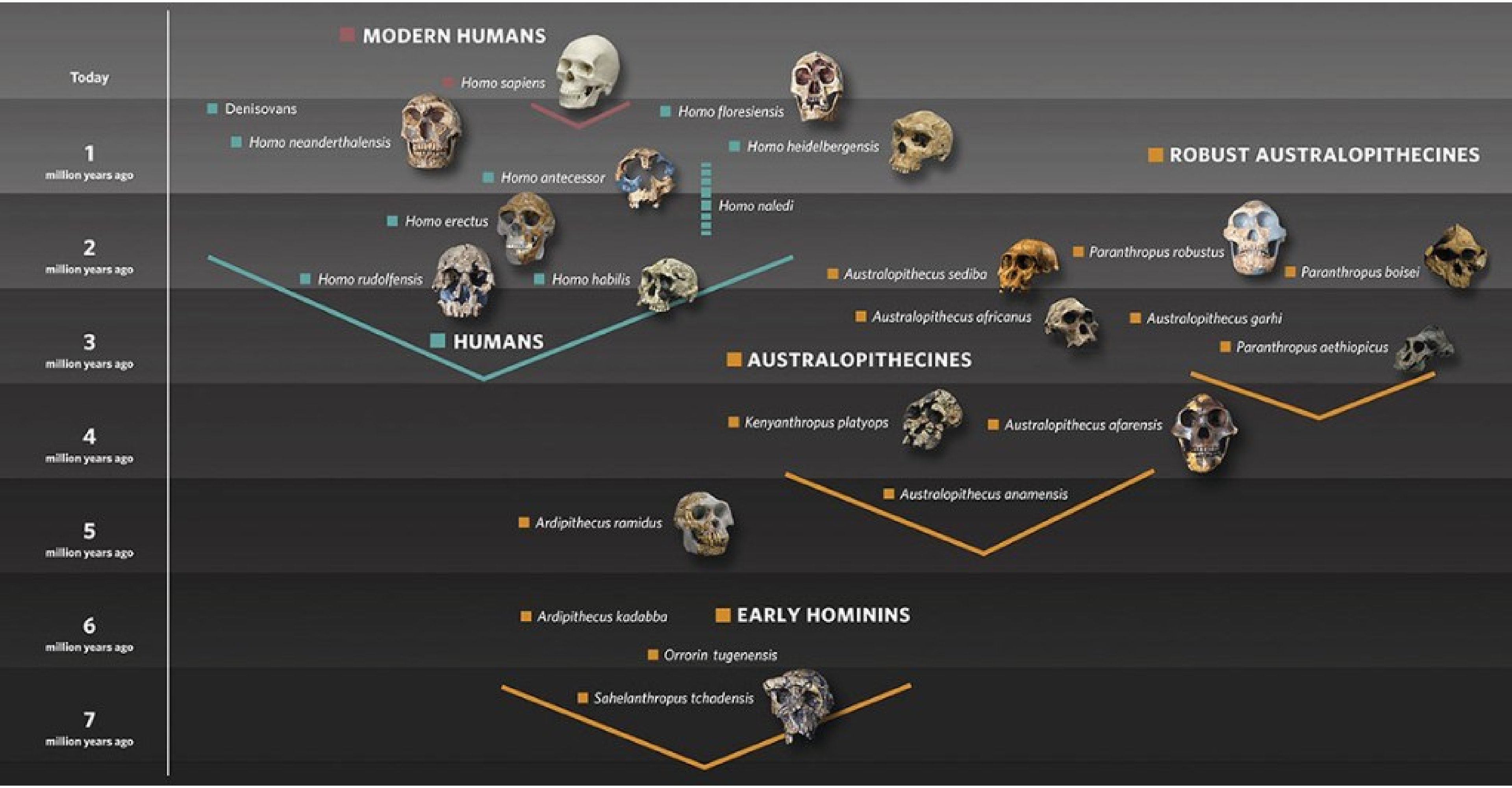
Liu, W. *et al. Nature* [http://dx.doi.org/10.1038/nature15696.](http://dx.doi.org/10.1038/nature15696)

DENISOVANS

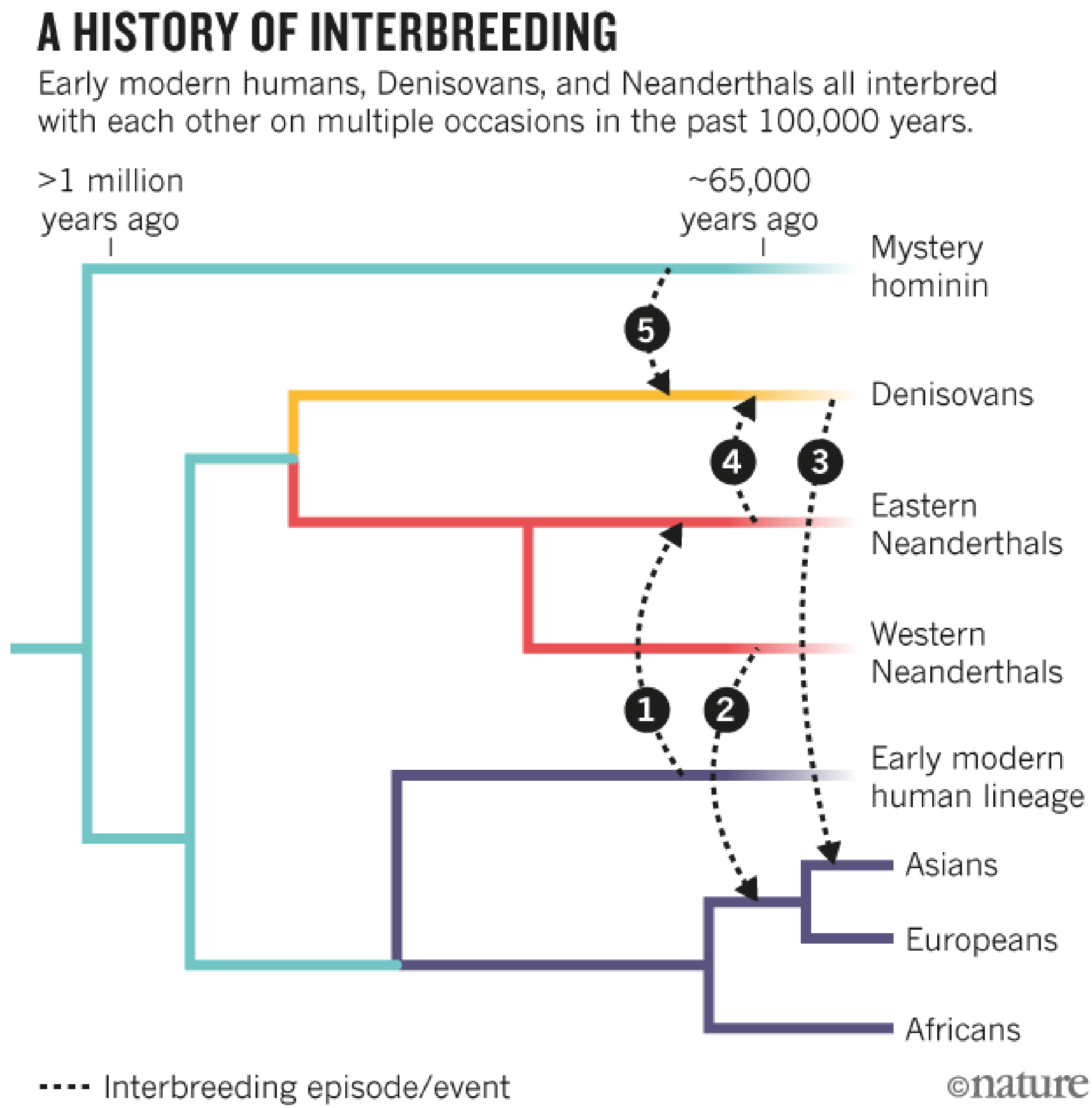


Stringer, C. & Barnes, I. (2015) Deciphering the Denisovans. PNAS, 112(51), 15542-15543, DOI: 10.1073/pnas.1522477112

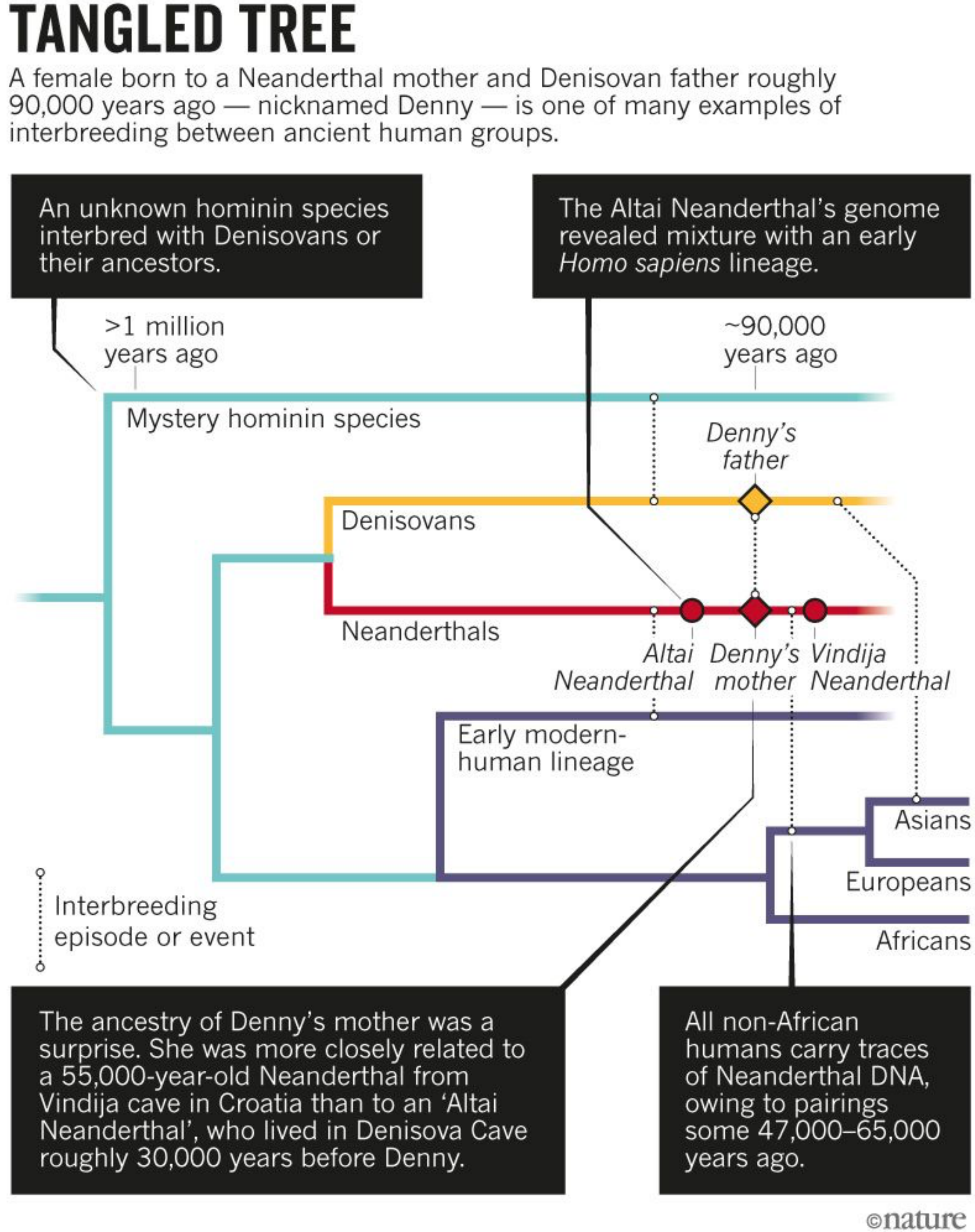
NEW DISCOVERIES



HOMINID INTERBREEDING

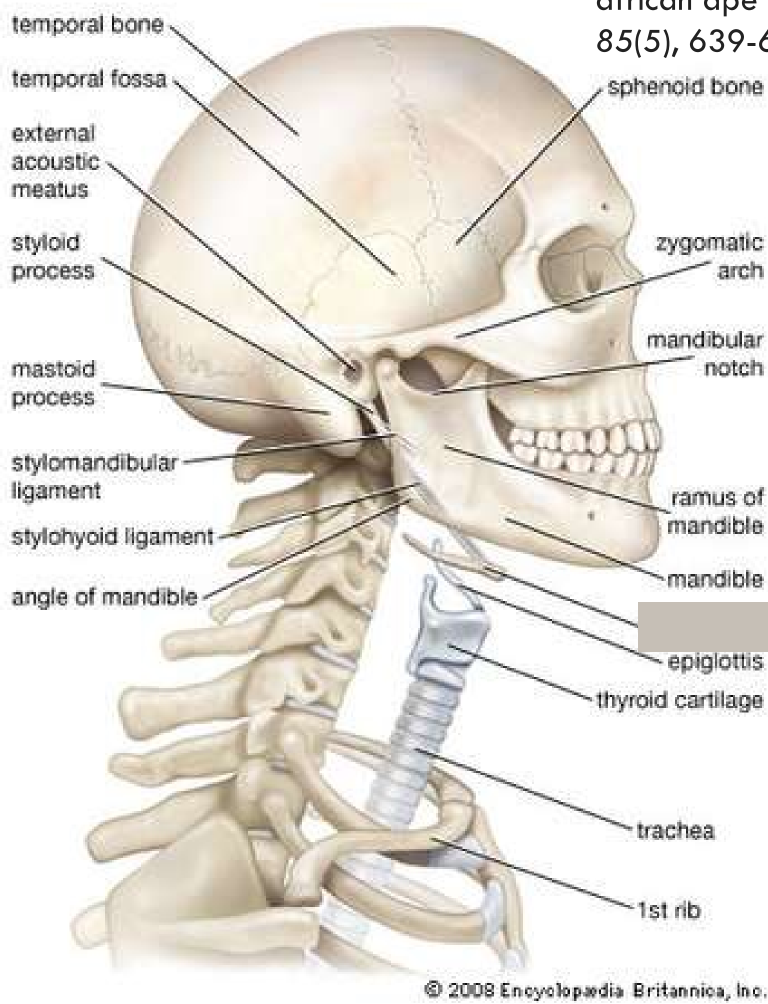


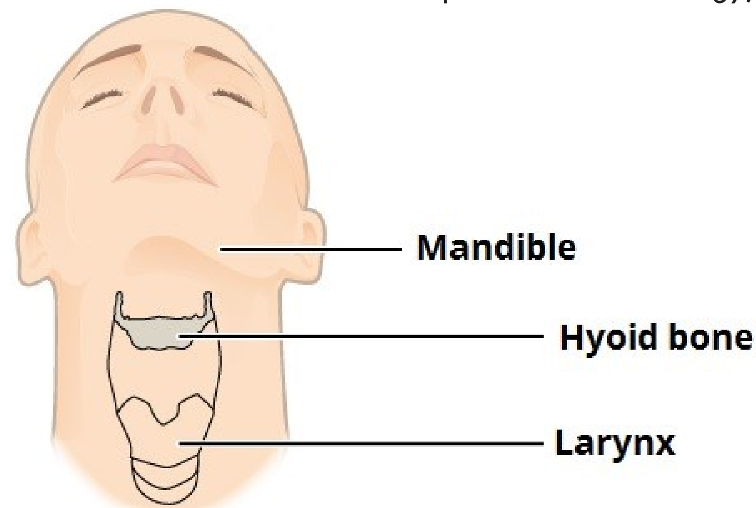
DENNY

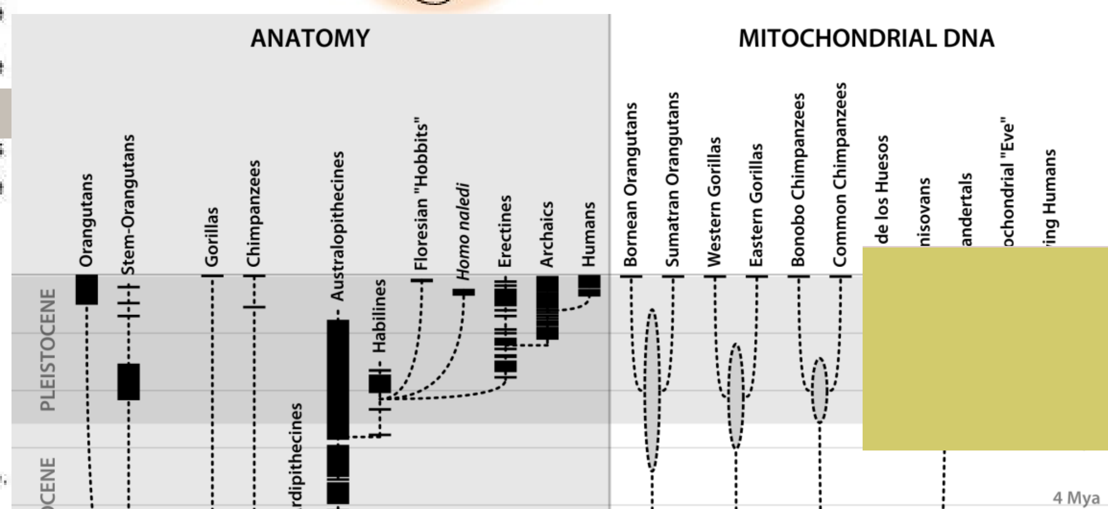

TANGLED TREE
A female born to a Neanderthal mother and Denisovan father roughly 90,000 years ago — nicknamed Denny — is one of many examples of interbreeding between ancient human groups.
An unknown hominin species interbred with Denisovans or their ancestors.
The Altai Neanderthal's genome revealed mixture with an early *Homo sapiens* lineage.
>1 million years ago
~90,000 years ago
Mystery hominin species
Denny's father
Denisovans
Neanderthals
Altai Neanderthal
Denny's mother
Vindija Neanderthal
Early modern-human lineage
Asians
Europeans
Africans
Interbreeding episode or event
The ancestry of Denny's mother was a surprise. She was more closely related to a 55,000-year-old Neanderthal from Vindija cave in Croatia than to an 'Altai Neanderthal', who lived in Denisova Cave roughly 30,000 years before Denny.
All non-African humans carry traces of Neanderthal DNA, owing to pairings some 47,000–65,000 years ago.
©nature

SKELETAL REMAINS AND LANGUAGE

Steele, J., Clegg, M., & Martelli, S. (2013). Comparative morphology of the hominin and african ape hyoid bone, a possible marker of the evolution of speech. *Human biology*, *85*(5), 639-672.







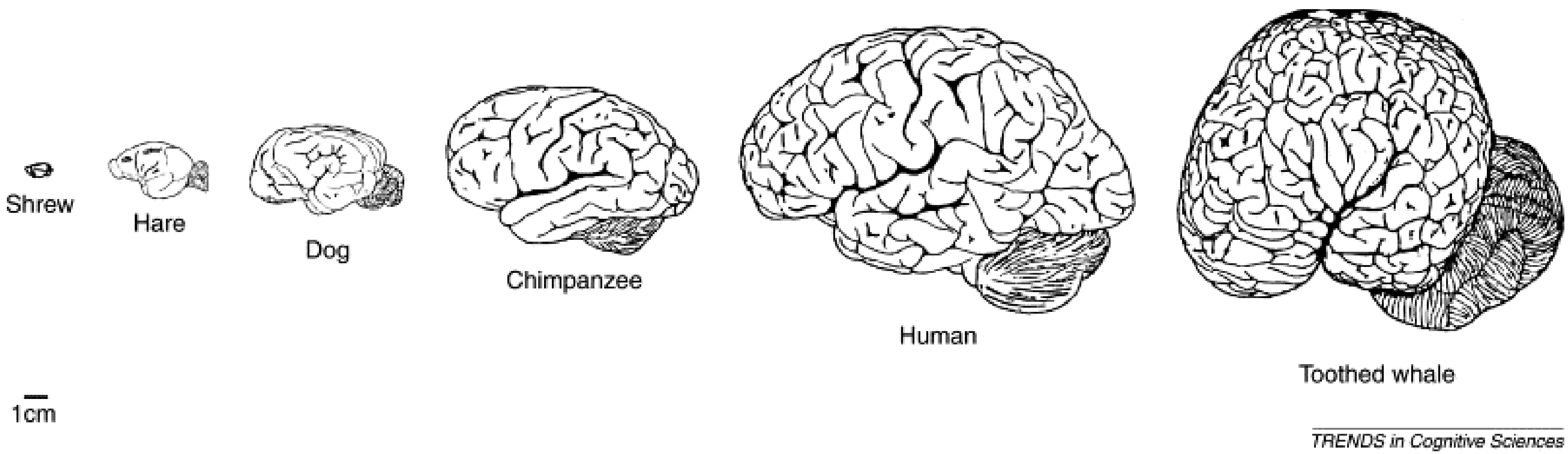
BREAK

When we return:

- Brain Size
- Tools and symbolic artefacts
- Cumulative cultural evolution

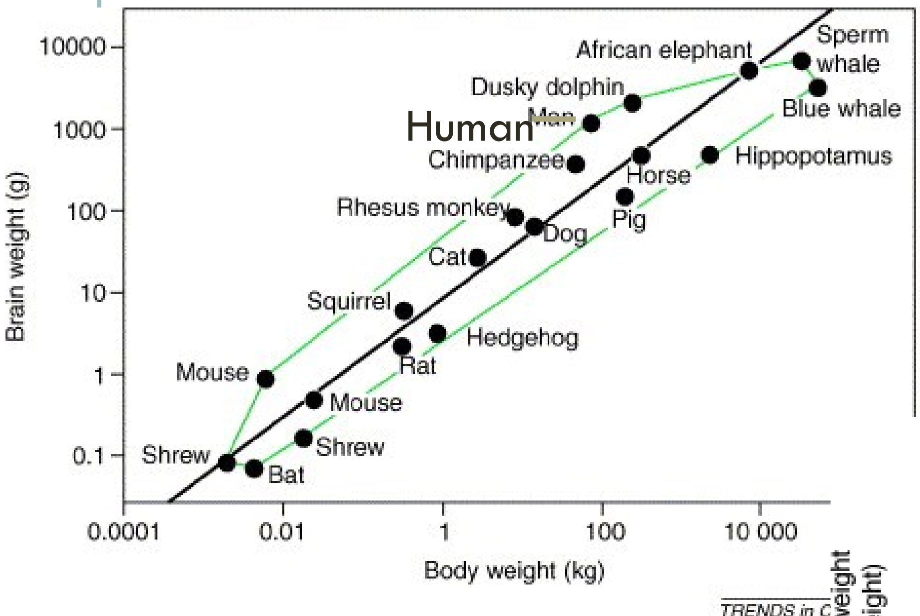
ABSOLUTE BRAIN SIZE

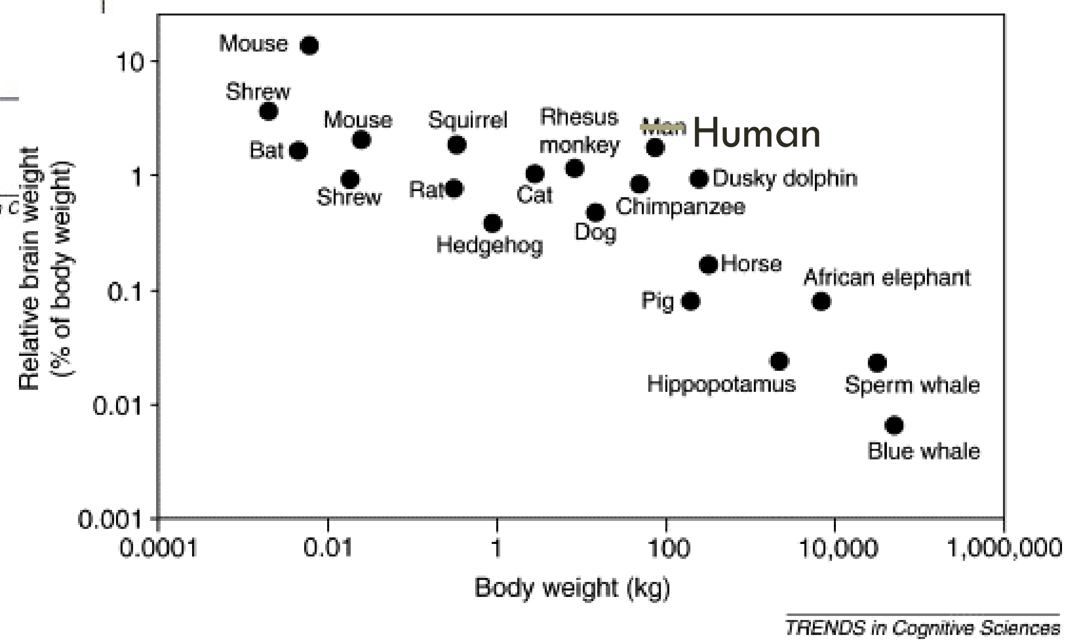
Humans do not have the largest brains, in either volume or cortical surface area



G. Roth & U. Dicke (2005). Evolution of brain and intelligence. *Trends in Cognitive Sciences, 9,* 250-257.

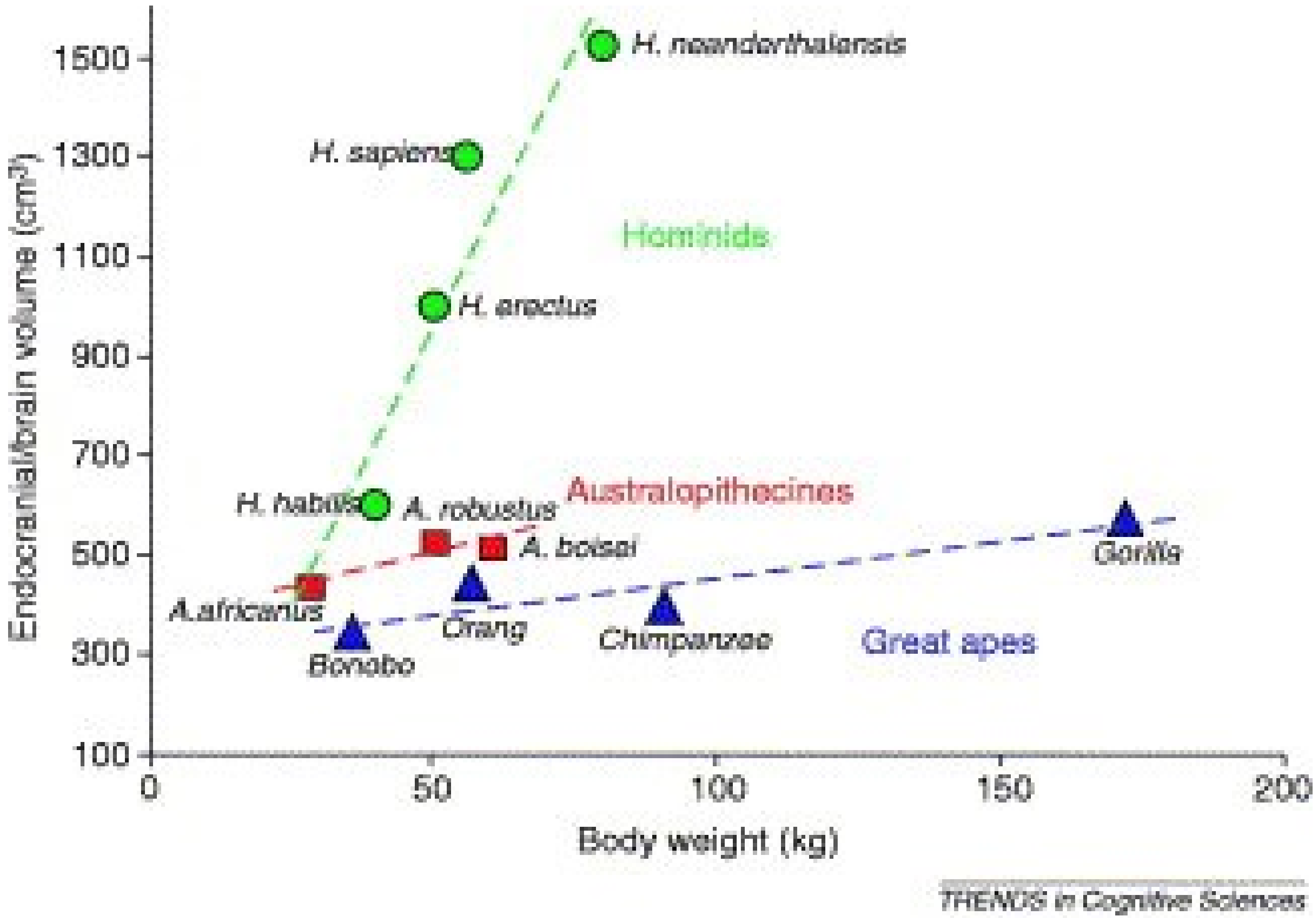
BRAIN SIZE & BODY SIZE





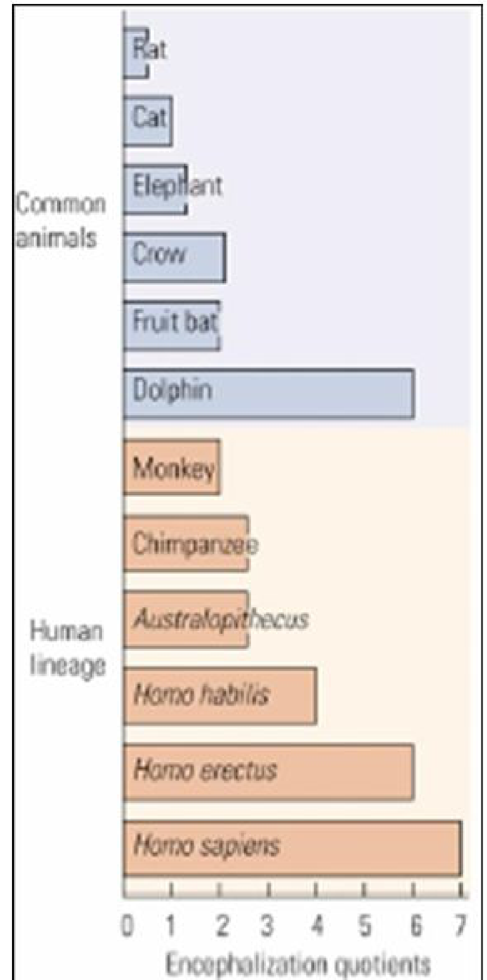
TRENDS in Cognitive Sciences

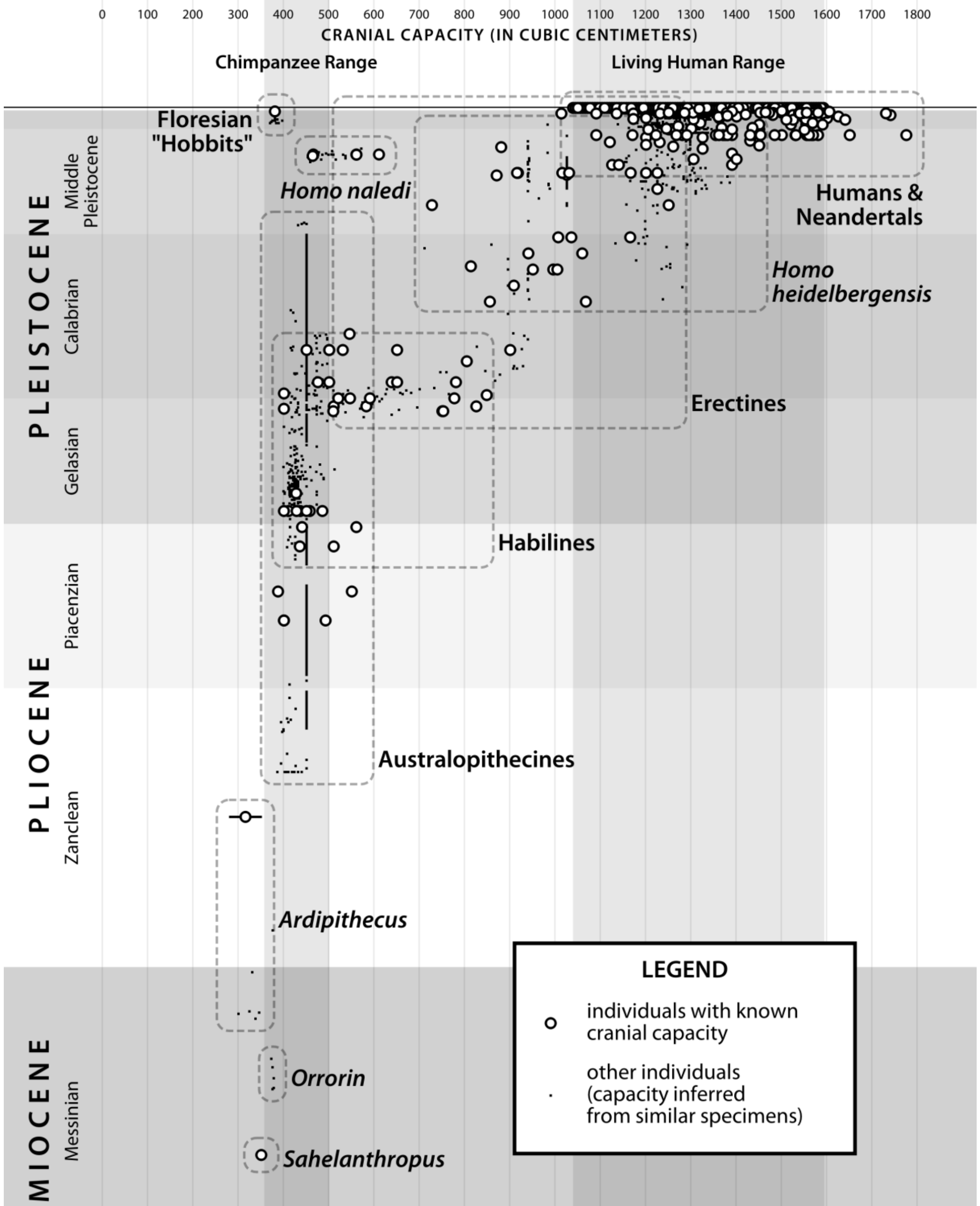
EVOLUTION OF HOMINID BRAIN SIZE



ENCEPHALIZATION QUOTIENT

Encephalization Quotient (EQ):
– Measure of brain size obtained from the ratio of actual brain size to the expected brain size for an animal of a particular body size
• *H. sapiens* have the largest EQ





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1200
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1400
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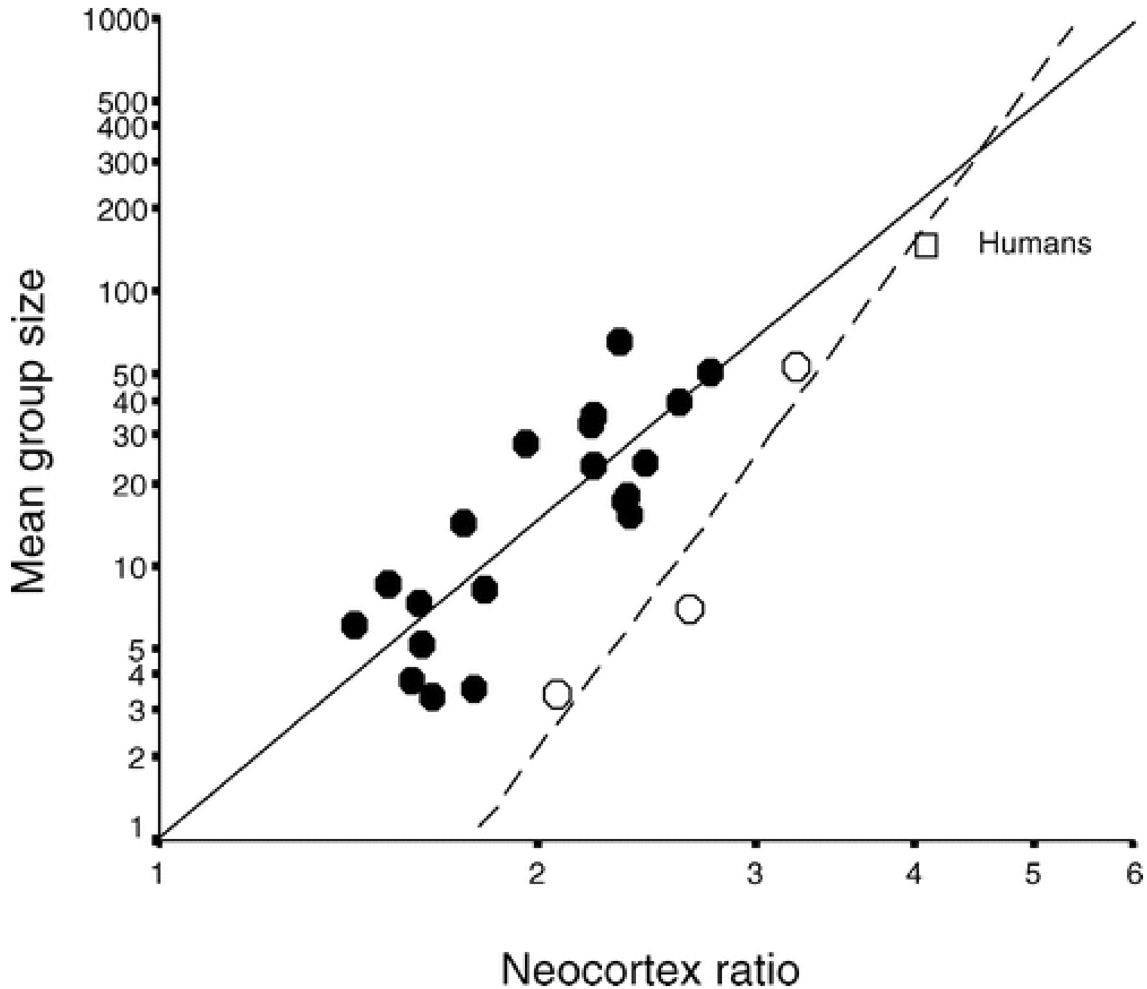
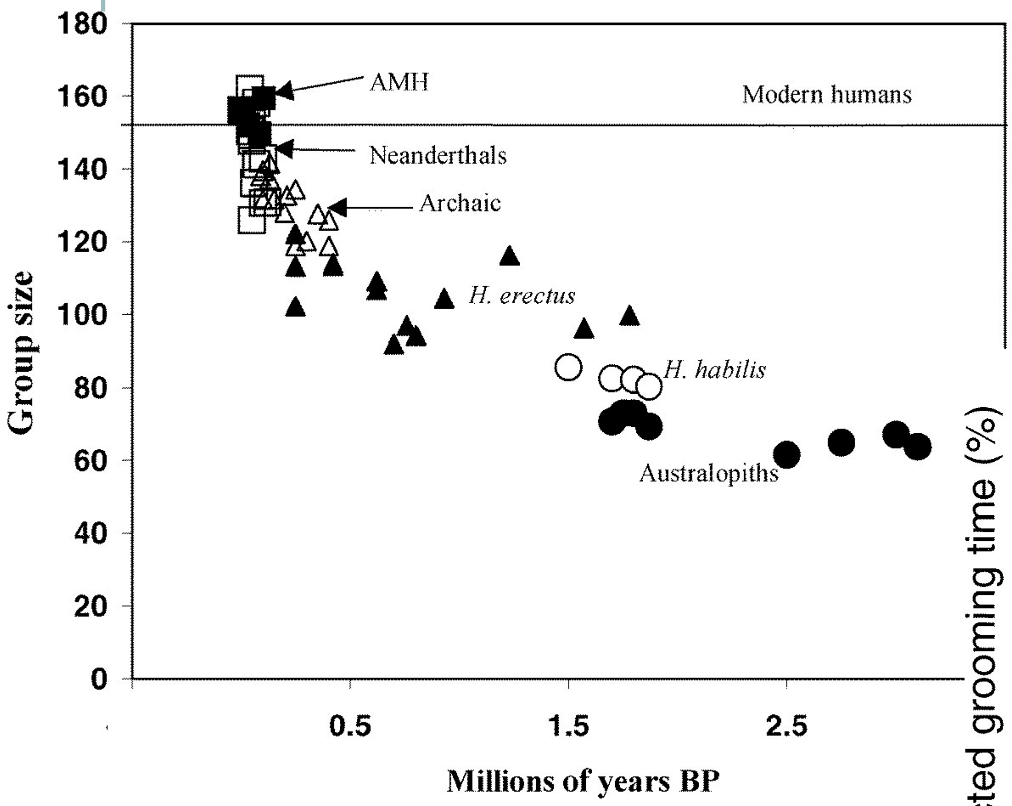
1600
1700
1800
CRANIAL CAPACITY (IN CUBIC CENTIMETERS)
Chimpanzee Range
Living Human Range
PLEISTOCENE
Middle Pleistocene
Calabrian
Gelasian
PLIOCENE
Piacenzian
Zanclean
MIOCENE
Messinian
Floresian "Hobbits"
Homo naledi
Humans & Neandertals
Homo heidelbergensis
Erectines
Habilines
Australopithecines
Ardipithecus
Orrorin
Sahelanthropus
LEGEND
individuals with known cranial capacity
other individuals (capacity inferred from similar specimens)

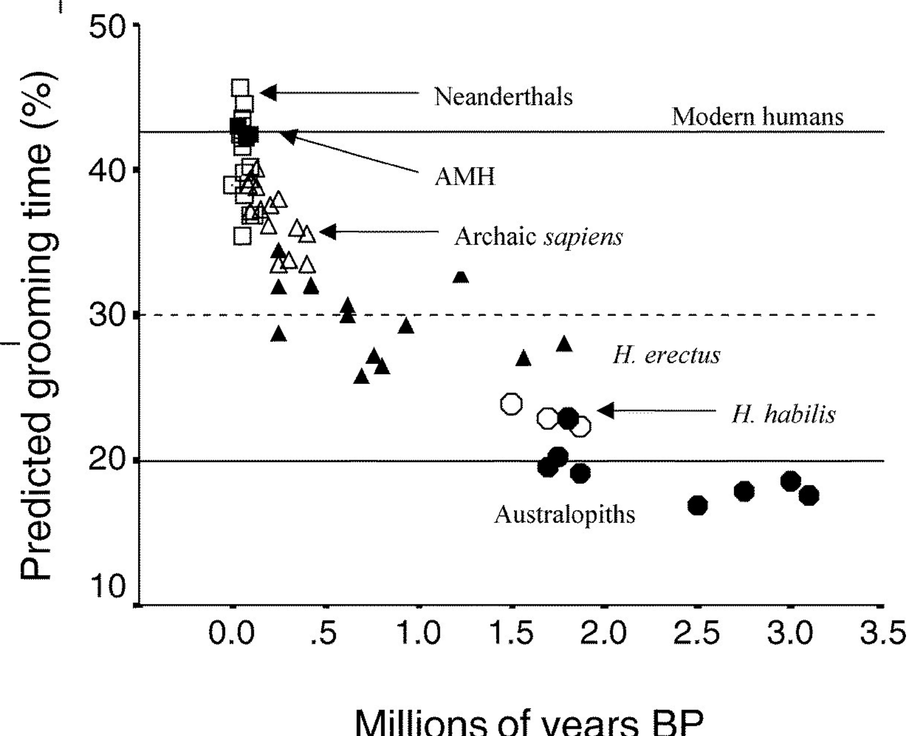
NEOCORTEX SIZE AND GROUP SIZE

Dunbar, R. I. M. (2003). The Social Brain: Mind, Language, and Society in Evolutionary Perspective*. Annual Review of Anthropology, 32*, 163-181.



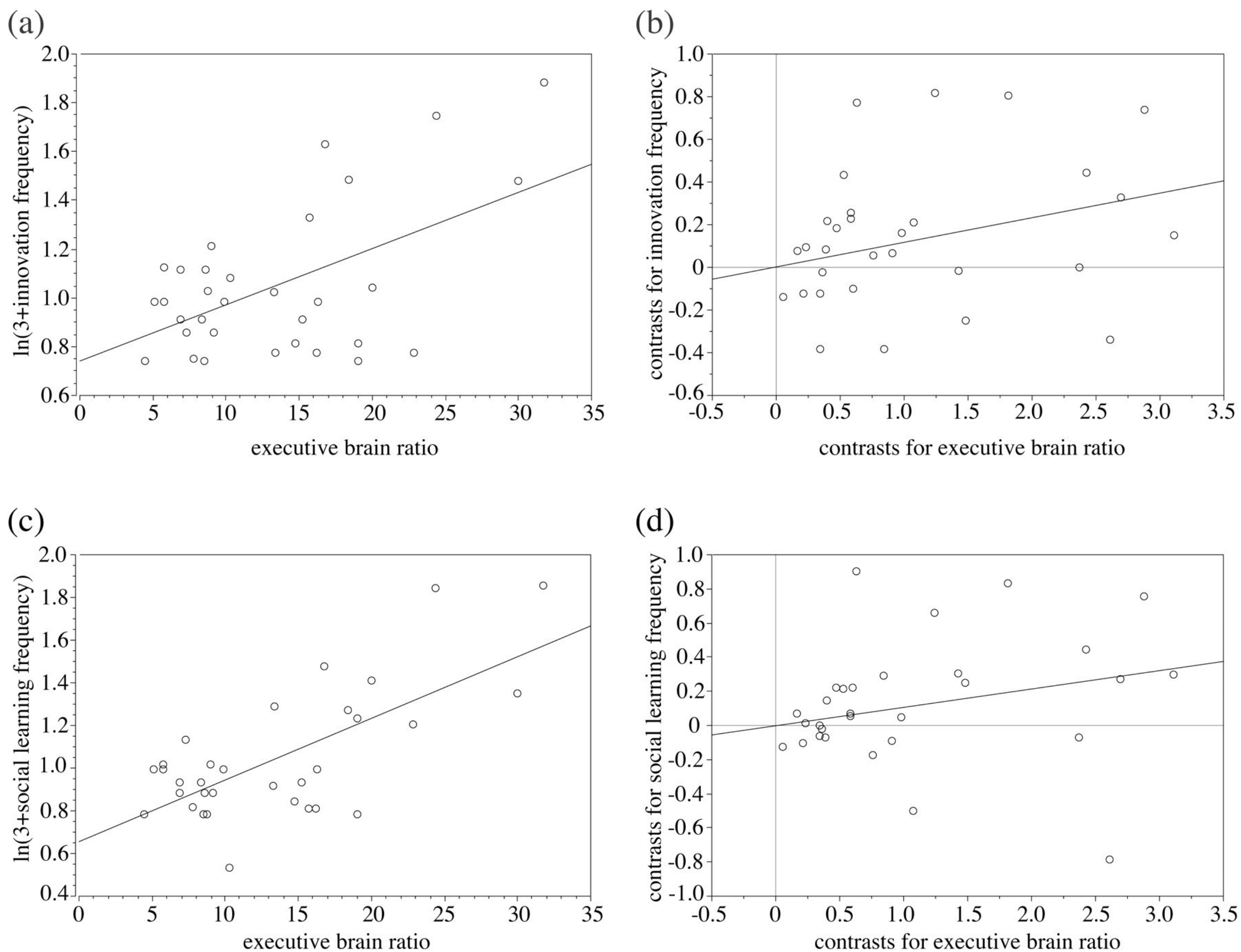
BRAIN SIZE: GROUP SIZE, GOSSIP, AND LANGUAGE

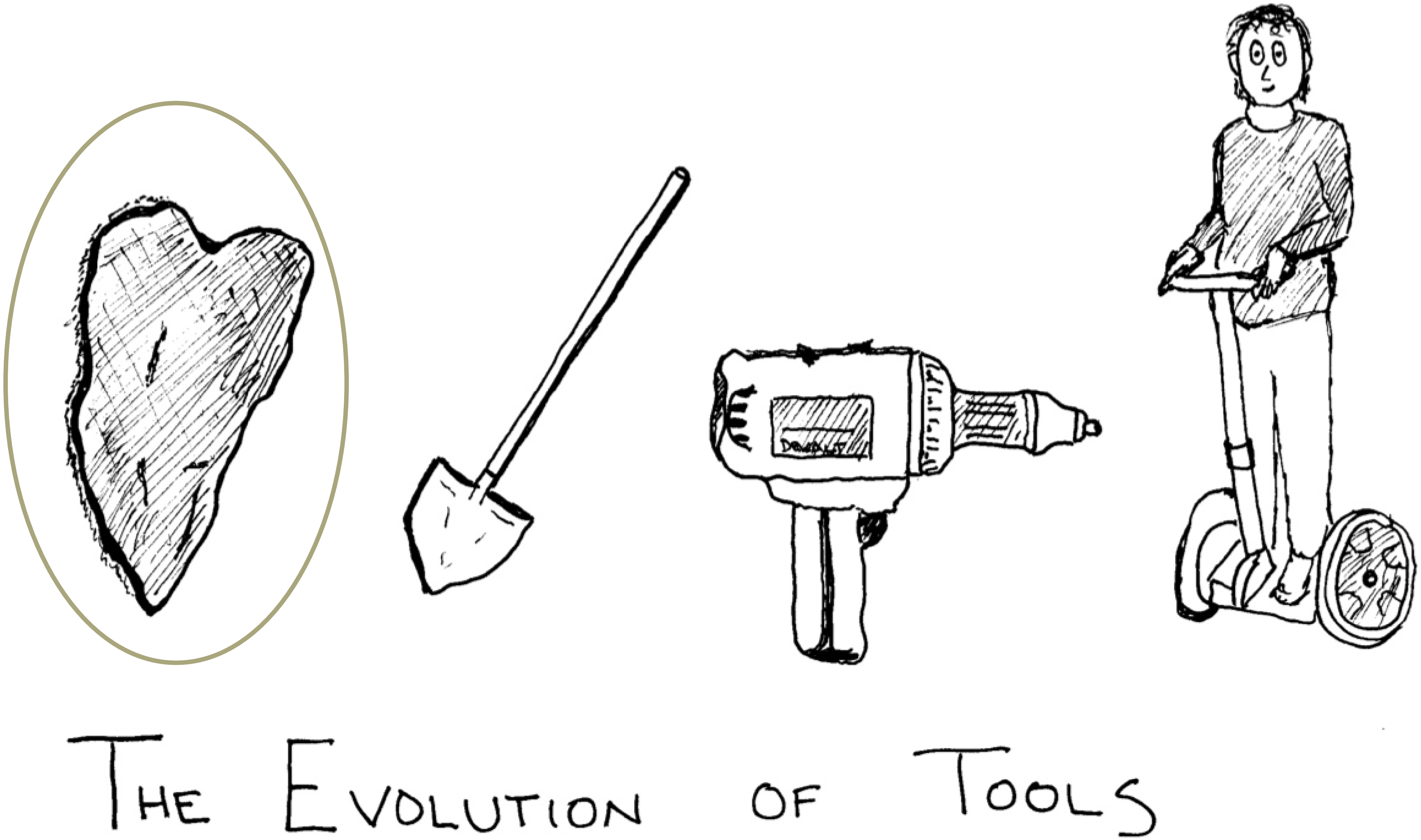




BRAIN SIZE: SOCIAL LEARNING, INNOVATION AND TOOL USE

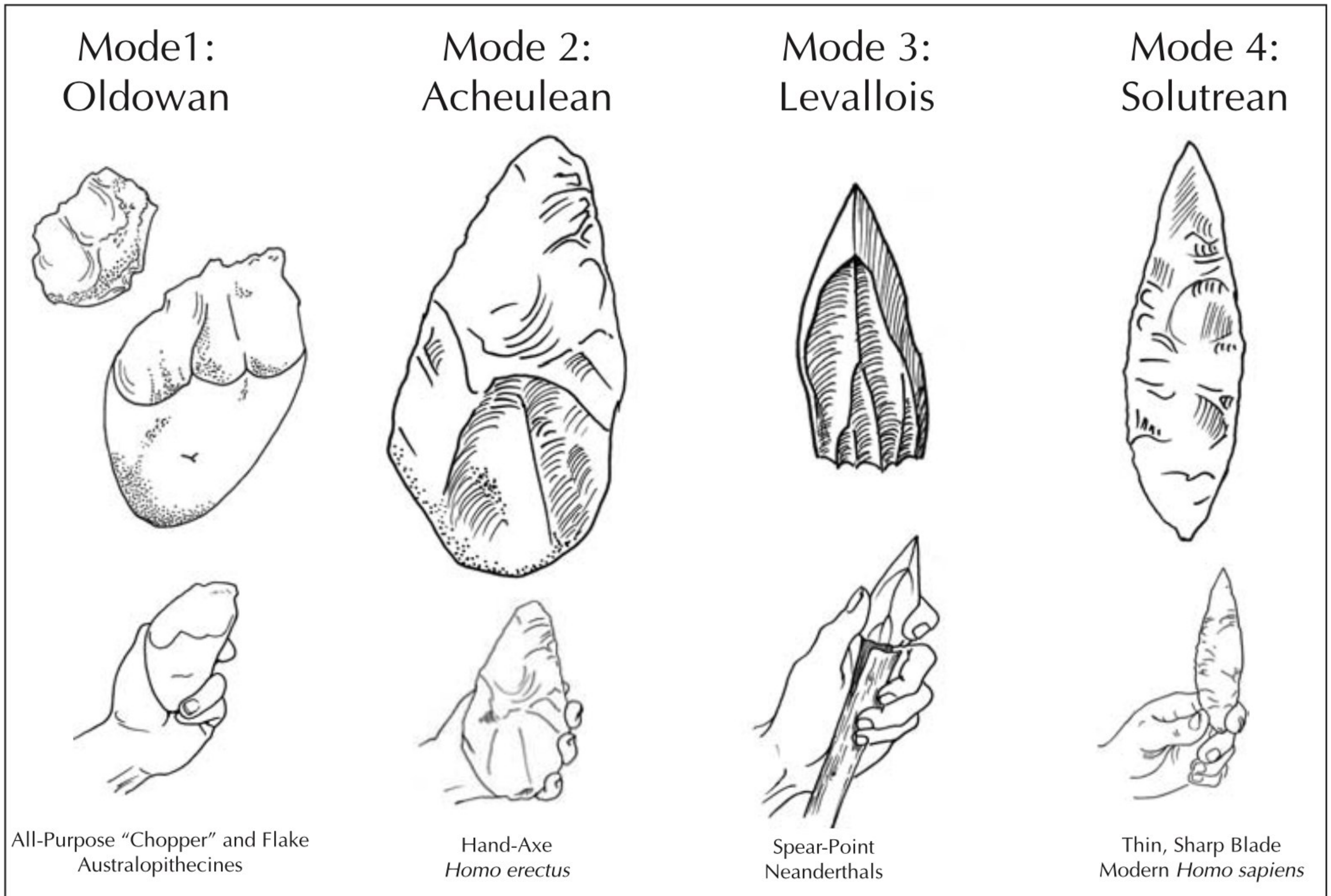
S. M. Reader & K. N. Laland (2002). Social intelligence, innovation, and enhanced brain size in primates. PNAS, 99, 4436-4441.





http://thenervousbreakdown.com/tmccagg/2010/07/the-evolution-of-tools/

HOMINID TOOLS



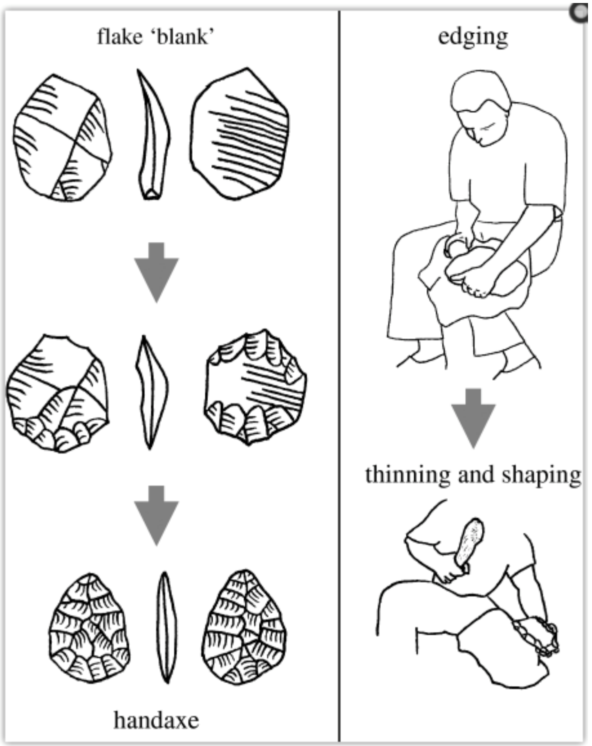
~2.6mya ~1.7mya ~300kya ~22kya

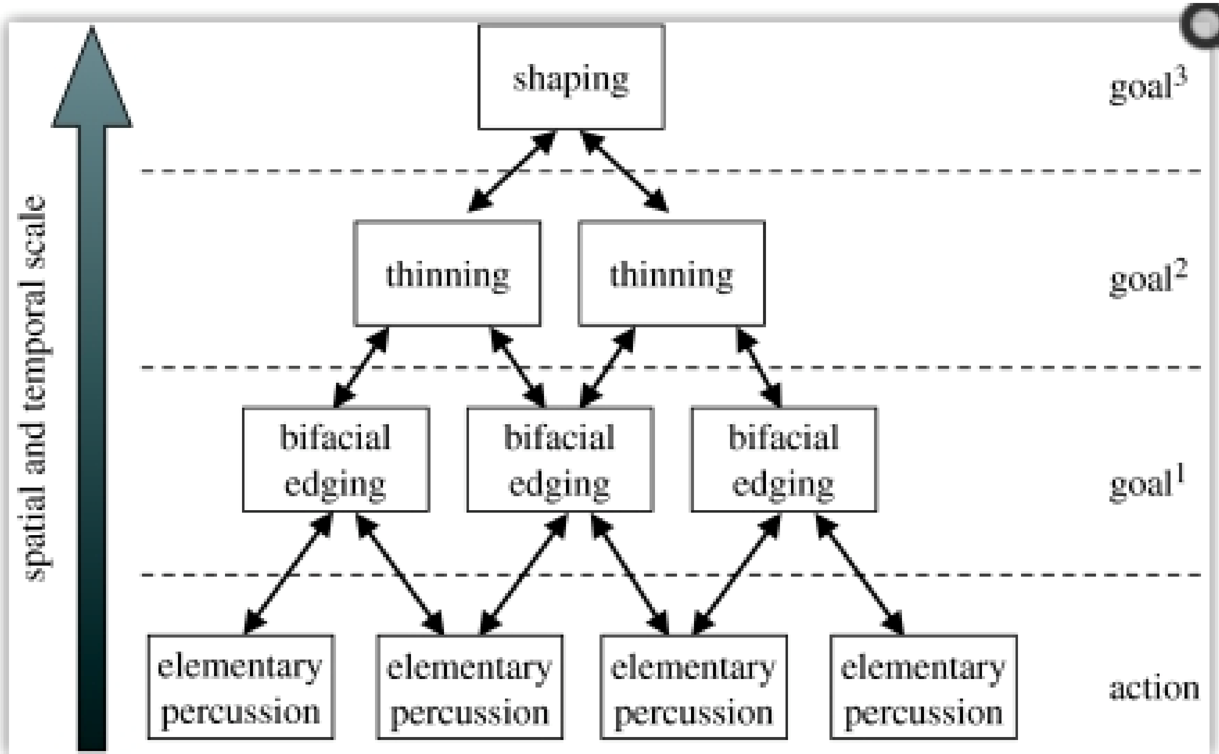
HOMINID TOOLS: NEW EVIDENCE

Harmand, S., Lewis, J. E., Feibel, C. S., Lepre, C. J., Prat, S., Lenoble, A., ... & Taylor, N. (2015). 3.3-million-year-old stone tools from Lome

COGNITION OF TOOL MAKING

D. Stout, N. Toth, K. Schick, & T. Chaminade. (2008). Neural correlates of Early Stone Age toolmaking: technology, language and cognition in human evolution. *Philosophical Transactions of the Royal Society B, 363*, 1939-1949.





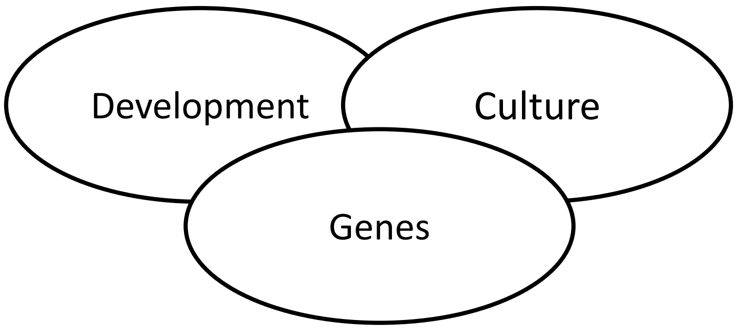
"toolmaking and language share a basis in more general human capacities for complex, goal-directed action" (Stout et al., 2008, p. 1939).

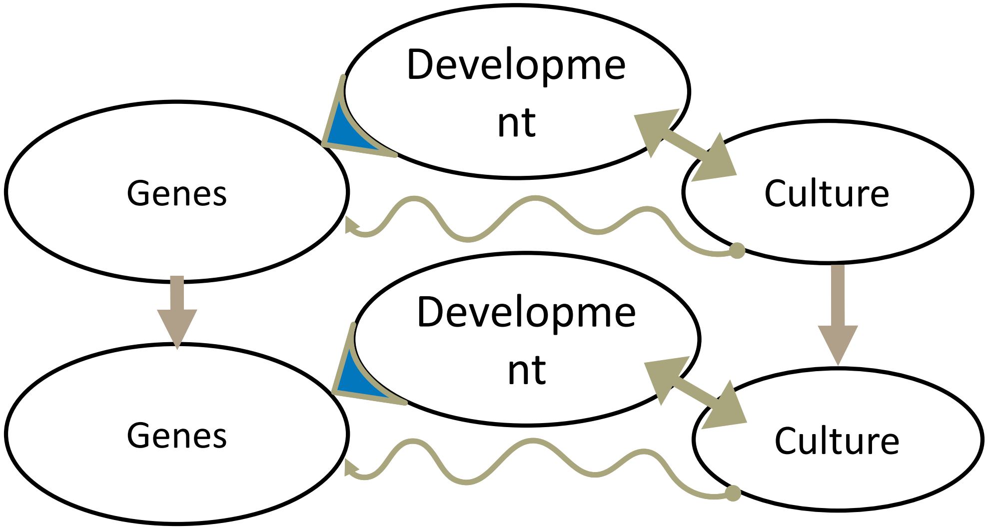
CULTURAL TRANSMISSION/SOCIAL LEARNING

Evolution requires transmission of information, with a high-ish degree of fidelity (inheritance of traits)

- Biology: accomplished through DNA replication

Information can also be transmitted culturally/socially





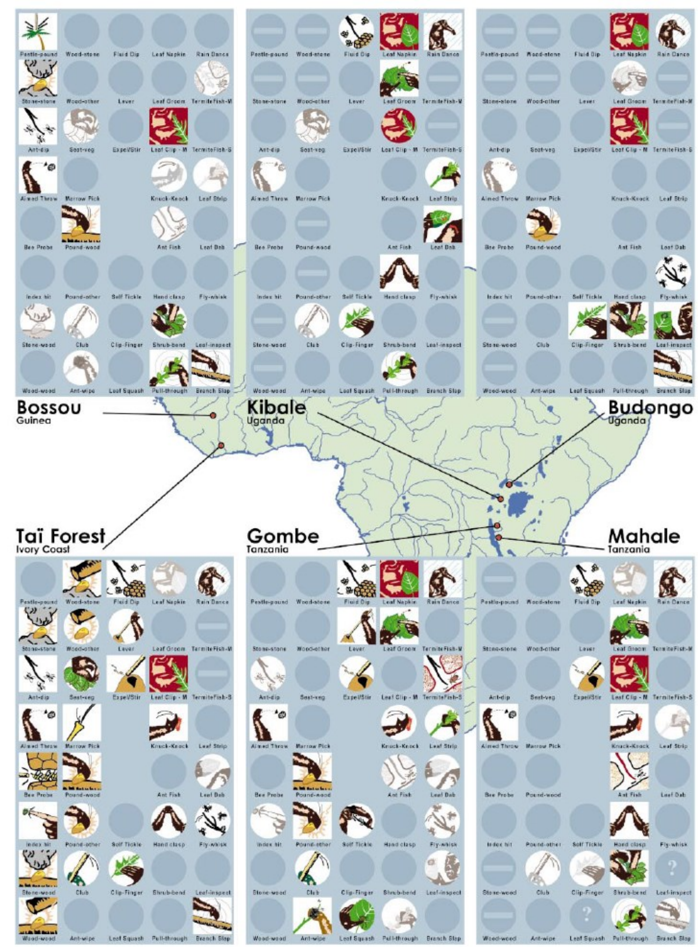
CULTURE IN CHIMPANZEES

Behavioural variation

- e.g., crack nuts, fish for termites

Some variation due to environment (e.g., availability of nuts)

Some variation due to culture



Whiten, A., Goodall, J., McGrew, W. C., Nishida, T., Reynolds, V., Sugiyama, Y., et al. (1999). Cultures in chimpanzees. *Nature*, *399*, 682–685.

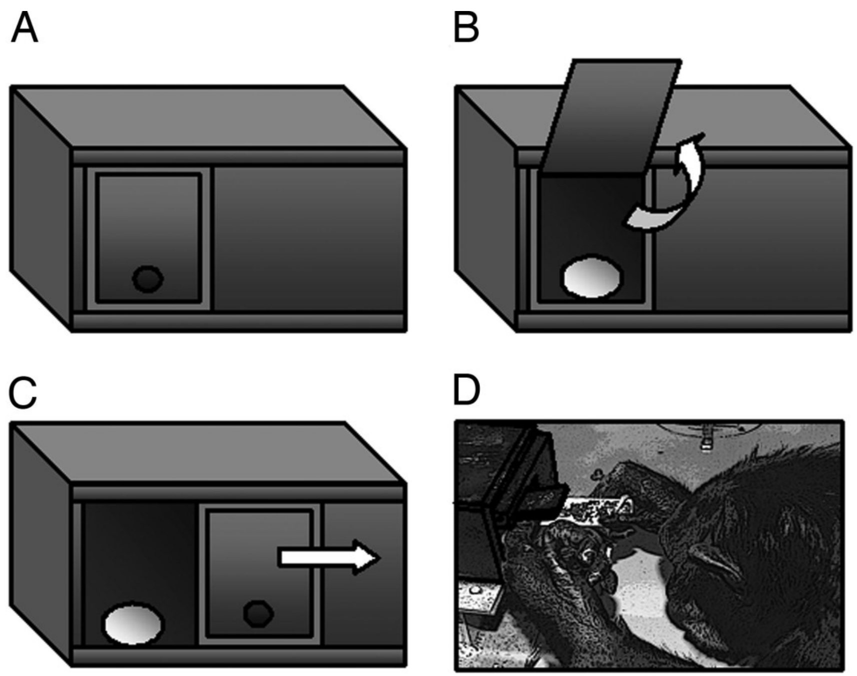
TESTING CULTURAL TRANSMISSION

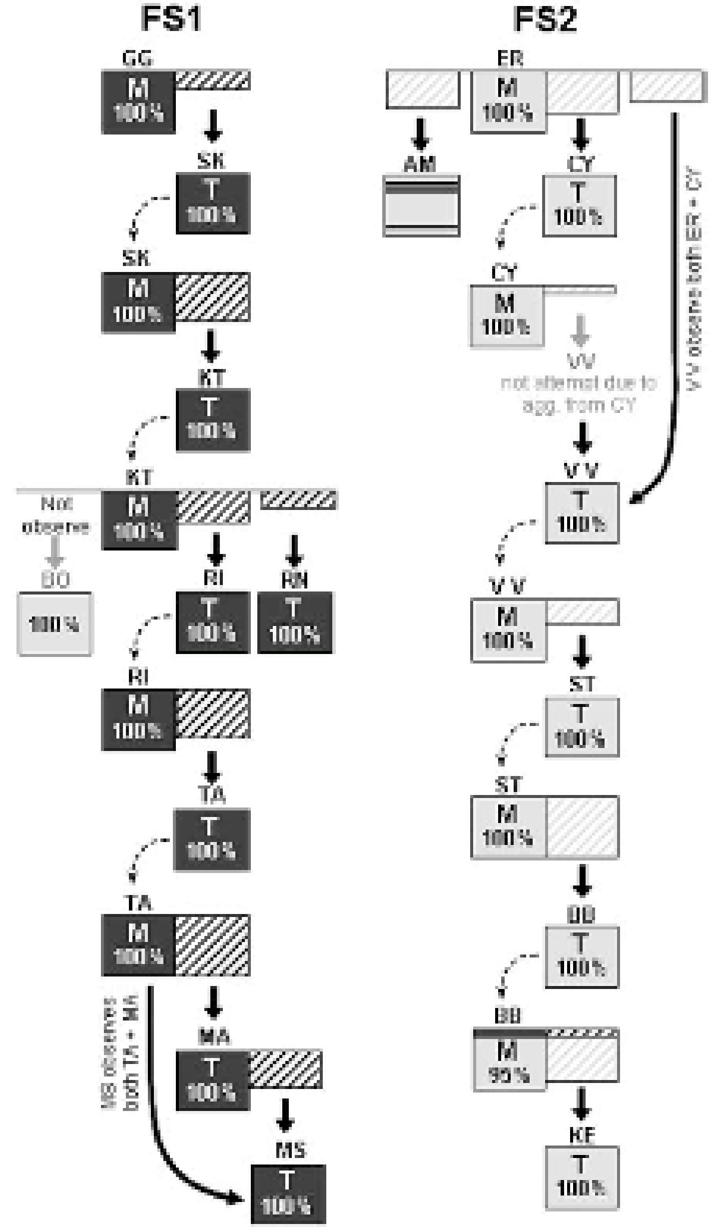
We can observe this in natural populations, but this is hard.

Seed captive and wild populations with foraging strategies/paths

Create food puzzles

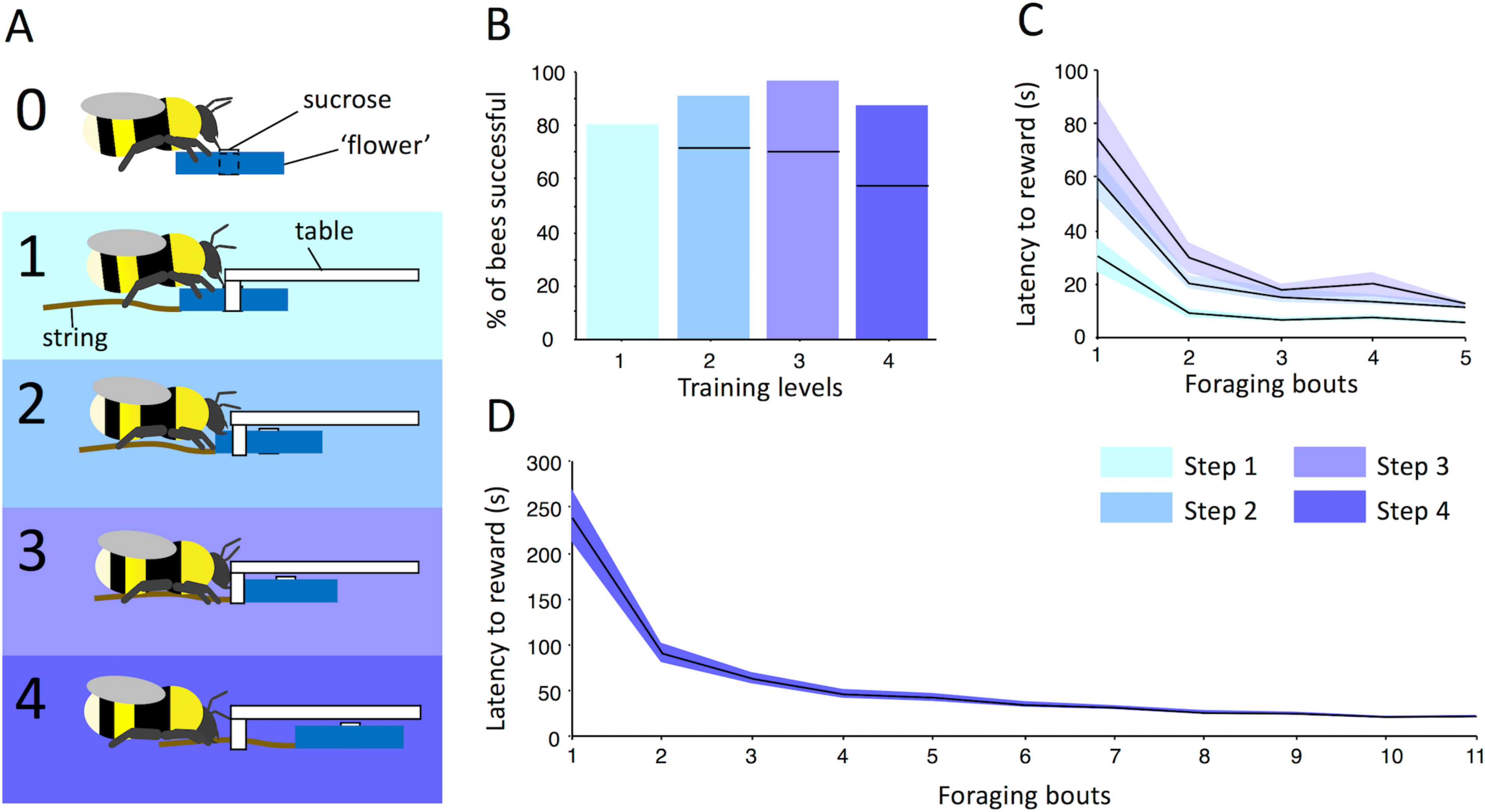
CHIMPANZEE FOOD PUZZLES

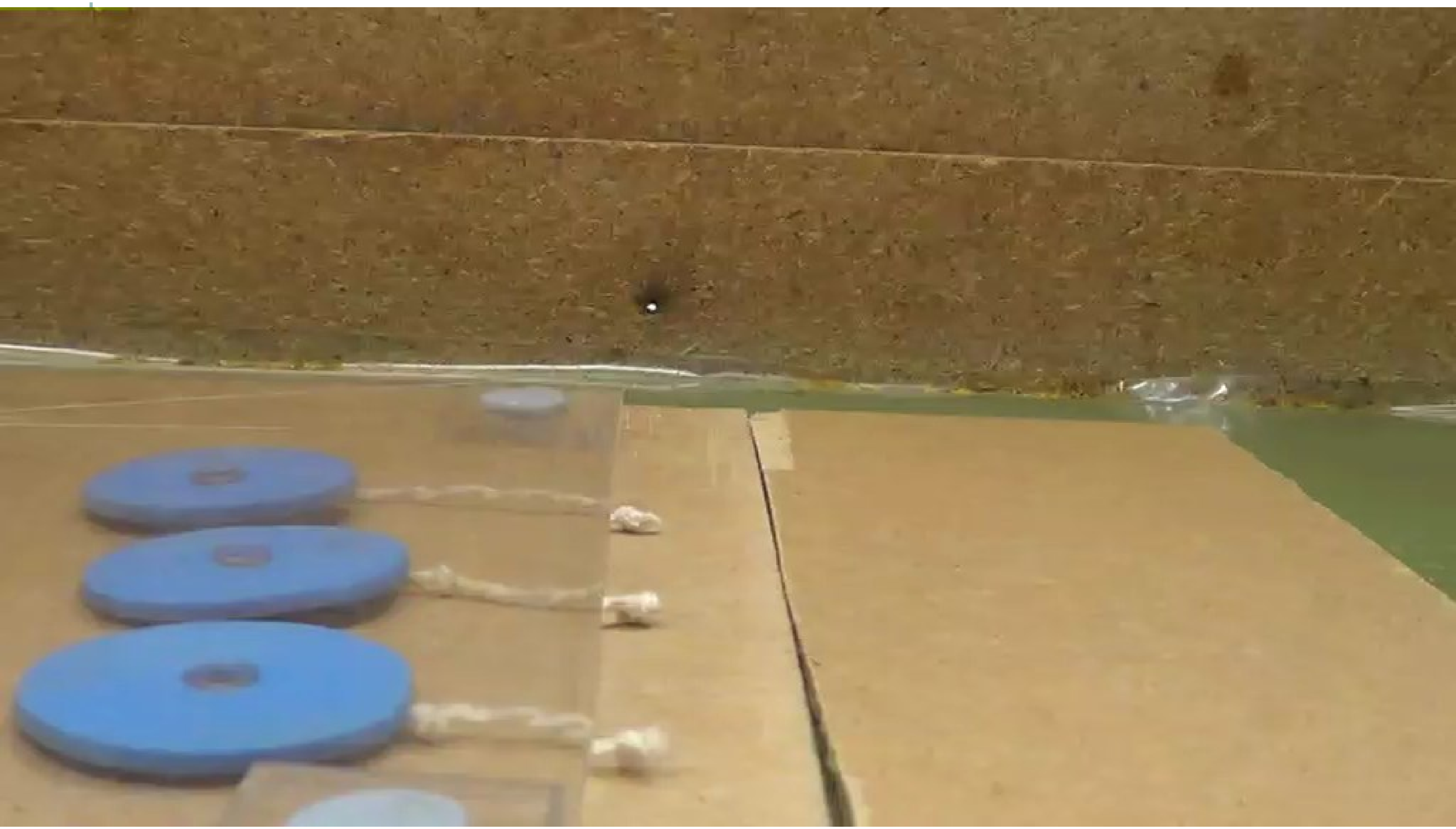


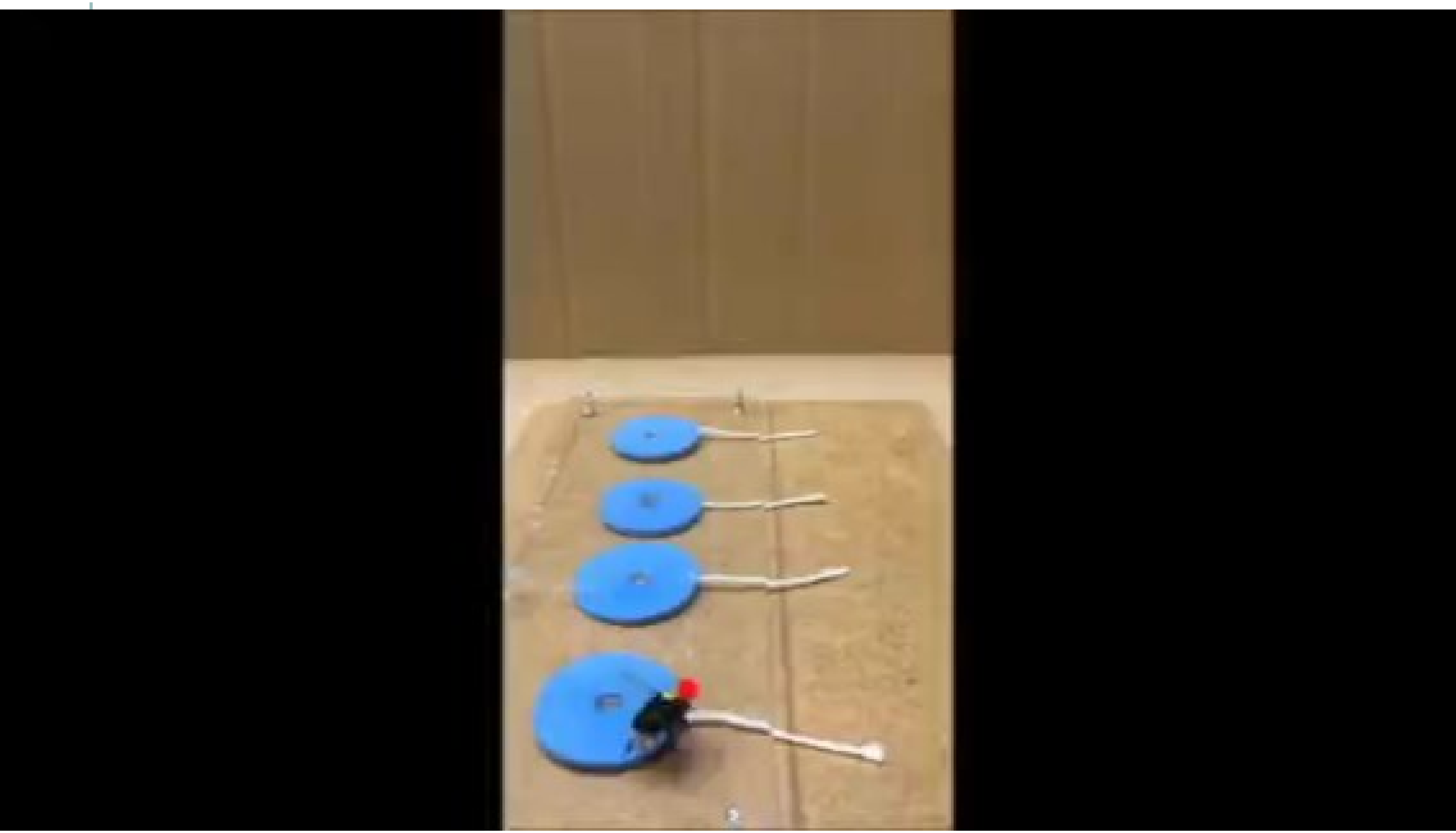


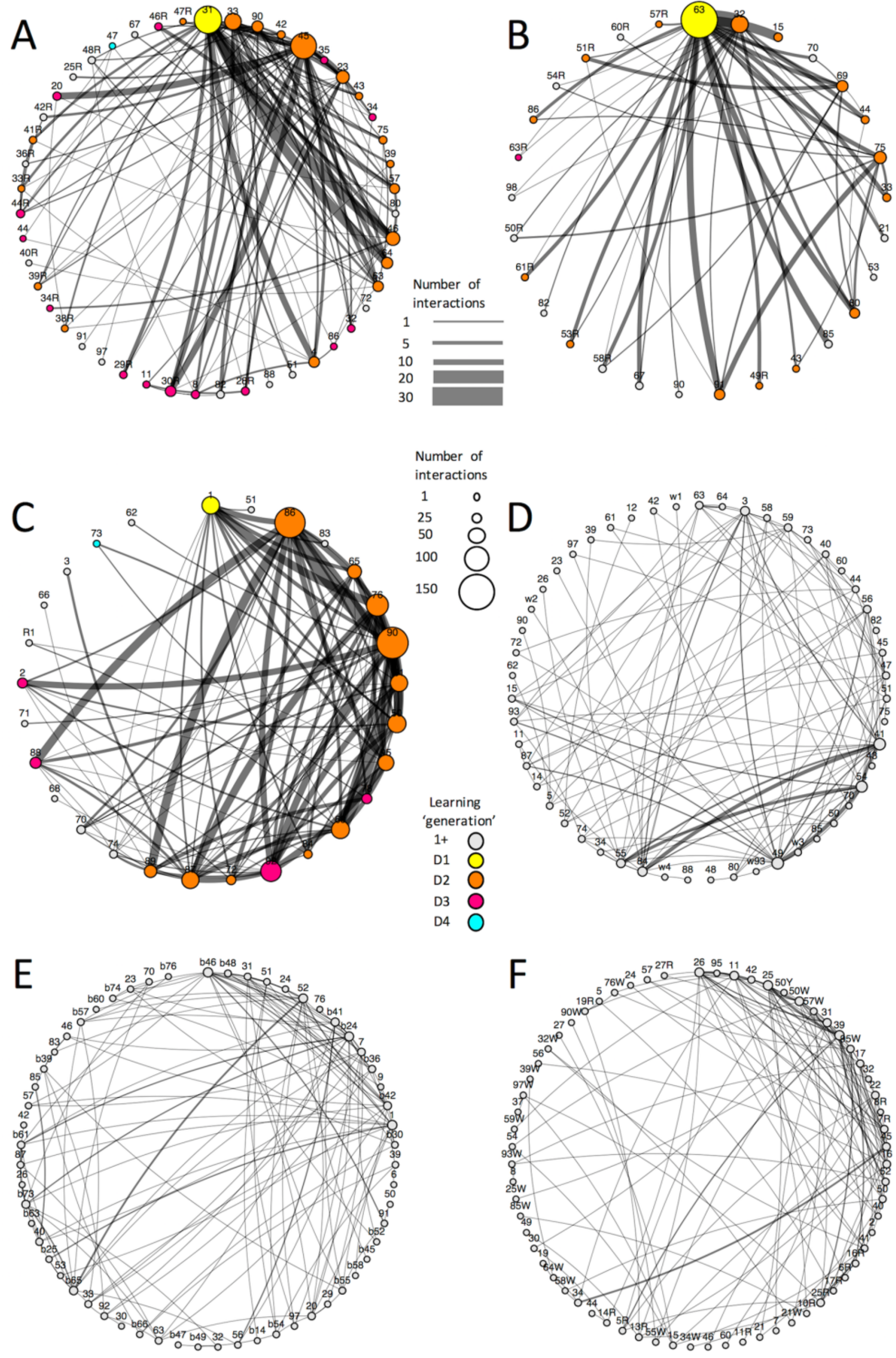
Horner, V., Whiten, A., Flynn, E. & de Waal, F. B. M. (2006). Faithful replication of foraging techniques along cultural transmission chains by chimpanzees and children. *Proceedings of the National Academy of Science, USA, 103,* 13878-13883.

CULTURAL TRANSMISSION IN BEES





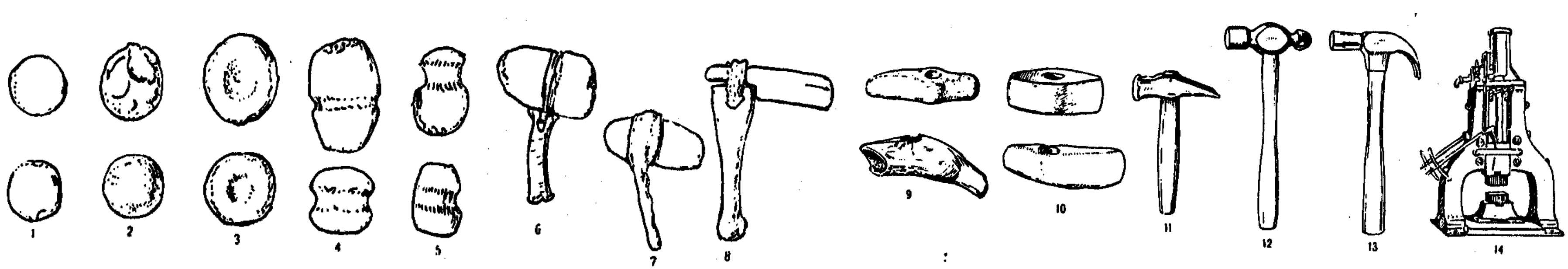



A
B
C
D
E
F
Number of interactions
1
5
10
20
30
Number of interactions
1
25
50
100
150
Learning 'generation'
1+
D1
D2
D3
D4

CUMULATIVE CULTURAL EVOLUTION (CCE)

Information isn't simply passed down culturally, but systems accumulate information (i.e., it can be added) at each generation

- Results in systems with complexity that could not be supported by a single individual (e.g., technology, language)



CCE: UNIQUELY HUMAN?

"the human attributes that are described as 'cultural' in ordinary discourse, seem to be a good deal more complex than, for example, potato washing and termite-fishing…and it is plausible that their greater complexity derives from the accumulation of modifications" (Heyes, 1993)

Heyes, C. M. (1993). Imitation, culture and cognition. *Animal Behaviour, 46,* 999-1010.

CCE UNIQUELY HUMAN

"Undoubtedly, given the investigative and manipulative tendencies of the young chimpanzee and his ability to learn through trial and error, almost all of the feeding and tool using behaviours I have described could be invented anew by each individual" (Goodall, 1970)

Goodall, J. (1970). Tool using in primates and other vertebrates. *Advances in the Study of Behaviour, 3*, 195-250.

TYPES OF SOCIAL LEARNING

- Three types of social learning
  - **Emulation:** aiming for the *outcome* of someone else's action.
  - **Imitation**: copying the *form* of another's actions precisely to reach the same outcome.
  - **Teaching**: transmission of goal-oriented information via interaction

The end result of these is often indistinguishable

Humans imitate, allowing for **accumulation**

AIRPLANES: CCE IS NON-TRIVIAL

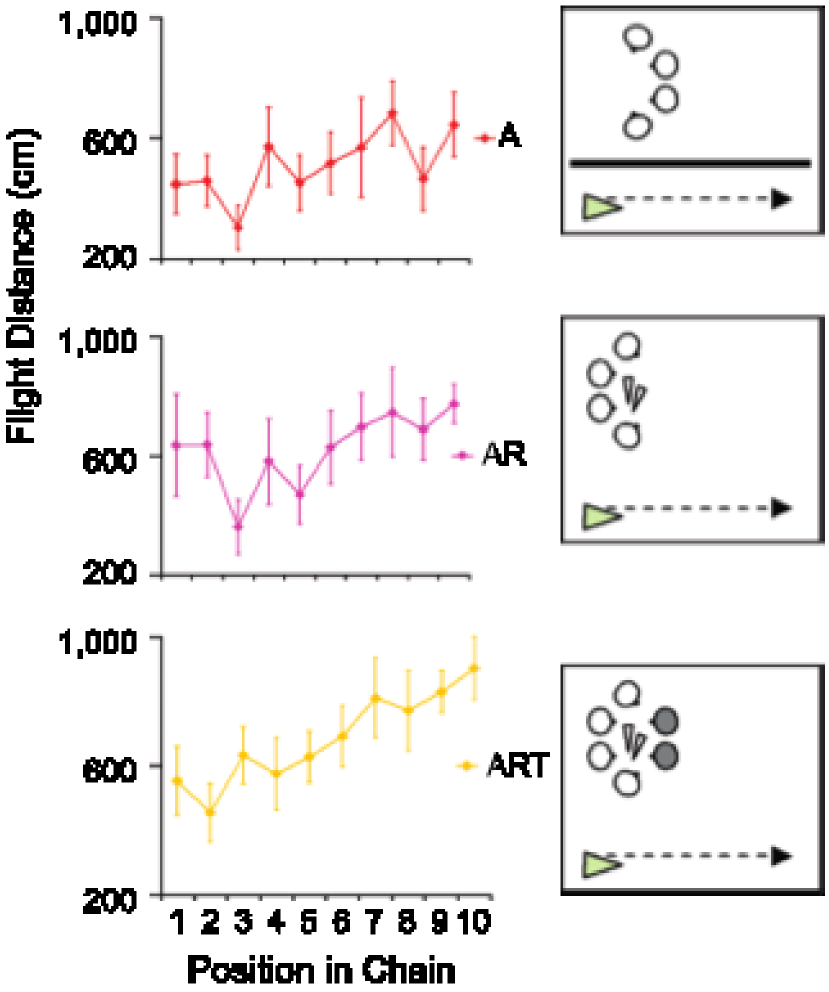
Is teaching an improvement?

actions (A—i.e., opportunities to observe actual building of paper airplanes, allowing for imitation);

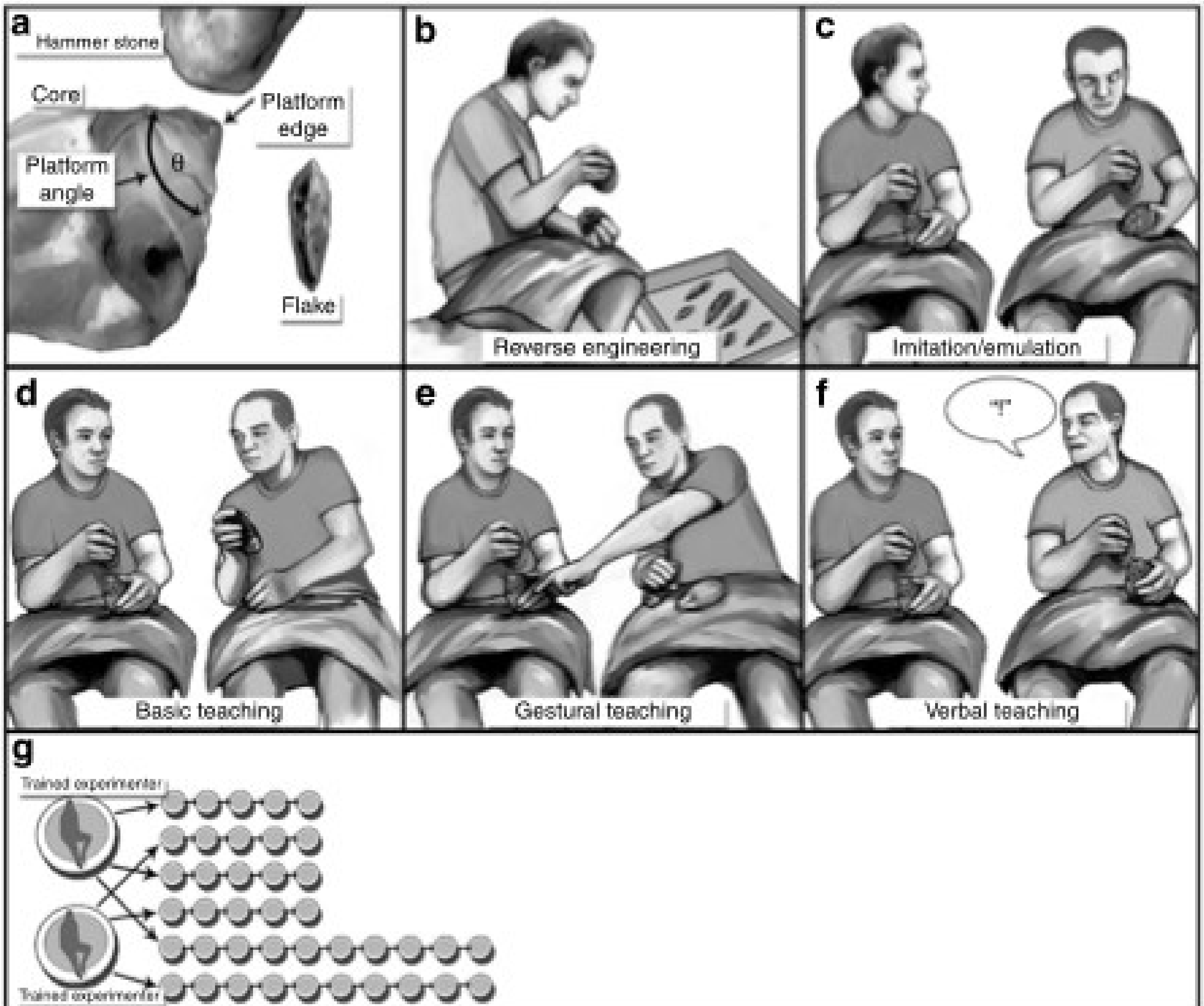
results (R—i.e., opportunities to inspect completed planes and observe their flight distances, allowing for emulation)

teaching (T—i.e., opportunities to communicate verbally with other participants, including those who had already completed the task).

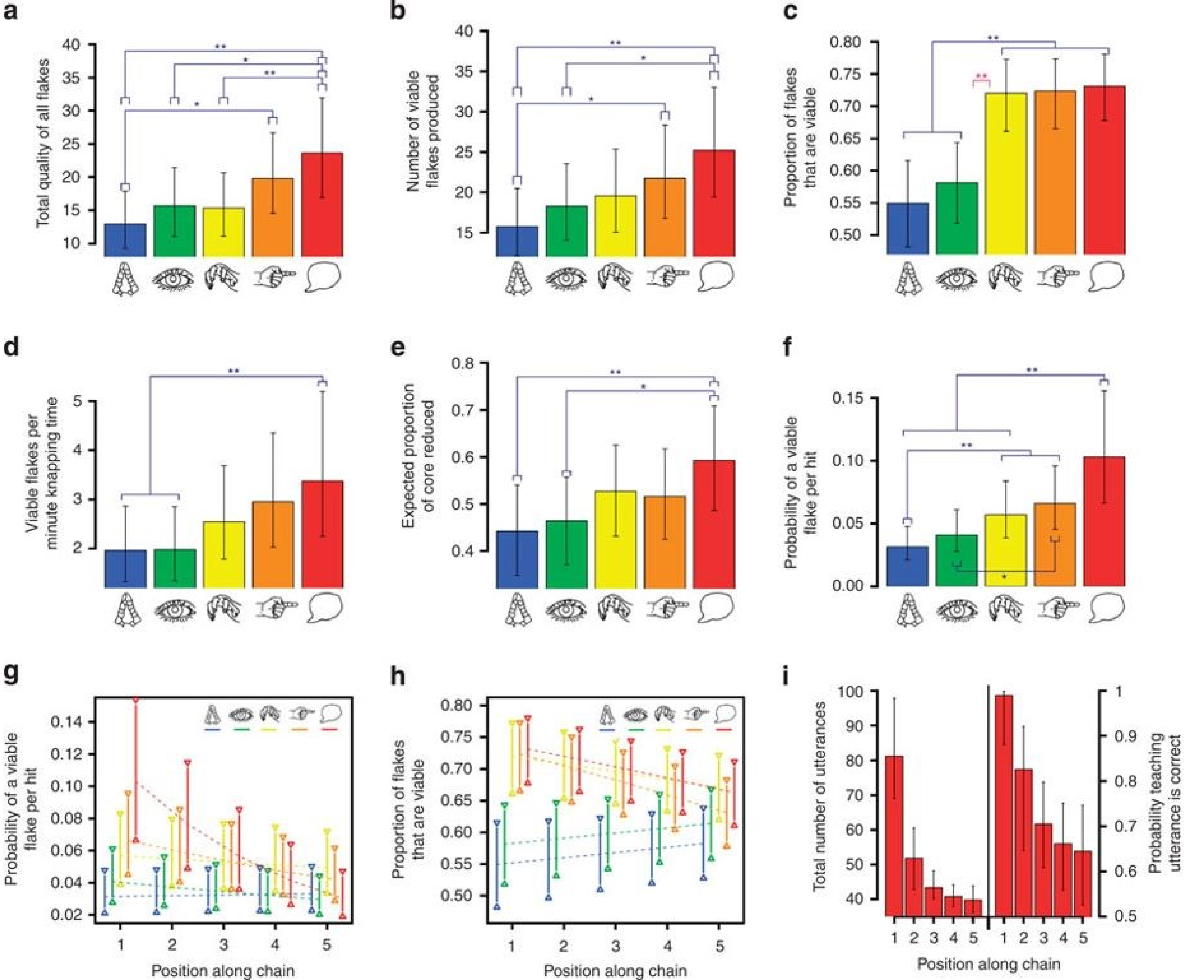
Caldwell, C. A., & Millen, A. E. (2009). Social Learning Mechanisms and Cumulative Cultural Evolution: Is Imitation Necessary? *Psychological Science, 20*(12), 1478–1483. https://doi.org/10.1111/j.1467-9280.2009.02469.x



TOOLS: CCE IS NON-TRIVIAL



Morgan, T. J., Uomini, N. T., Rendell, L. E., Chouinard-Thuly, L., Street, S. E., Lewis, H. M., ... & Whiten, A. (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature communications*, *6*, 6029.



a
Total quality of all flakes
b
Number of viable flakes produced
c
Proportion of flakes that are viable
d
Viable flakes per minute knapping time
e
Expected proportion of core reduced
f
Probability of a viable flake per hit
g
Probability of a viable flake per hit
Position along chain
h
Proportion of flakes that are viable
Position along chain
i
Total number of utterances
Probability teaching utterance is correct
Position along chain

"…assuming that the transmission of more complex technologies also benefits from more complex means of communication, later technologies would have reinforced [a] gene-culture co-evolutionary dynamic. Such a process could have lasted for millions of years (and may be ongoing), with more complex communication allowing the stable and rapid transmission of increasingly complex technologies, which in turn generate selection for even more complex communication and cognition, and so forth. Although this places little necessary constraint on when teaching and language may have evolved, our central contribution is to provide evidence that Oldowan tools, produced by hominins since at least 2.5 mya, were involved in this dynamic." (Morgan et al., 2015)

LANGUAGE: A TOOL FOR THE COMMUNICATION OF COMPLEX INTERNAL STATES?









SUMMARY

Hominid evolution is bushy, not linear, incl. many recent new discoveries

Brain size evolved rapidly - what does this mean?

Material cultural evolution can be a proxy for language evolution (or can it? more in tutorial)

Vertical cultural transmission is possible alongside genetic

Cumulative cultural evolution requires sufficiently high fidelity for over & above innovations