

June 25, 2026

MRC Cognition and Brain Sciences Unit
University of Cambridge



From Vision to Semantic Cognition:

*How Primate Evolution
Made Human Language Possible*



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Institut des Maladies Neurodégénératives
Université de Bordeaux

Outline

- 1. The Primate Niche
- 2. Primate Vision
- 3. The Primate Temporal Lobe and the Ventral Stream
- 5. Hominoid Brain Expansion
- 6. Structural Reorganization
- 7. The Semantic Temporal Lobe
- 8. From Object Vision to Semantic Cognition



The Primate Niche



Larry Felder, National Park Service (NPS)
Eocene vegetation of the Clarno Nut Beds in John Day Fossil Beds National Monument



Sargis, E. J. (2002). Primate origins nailed. *Science*, 298(5598), 1564-1565.

Carpolestes simpsoni,
late Paleocene stem Primate

First Primates

Co-evolved with Angiosperms (flowering plants)

Fine terminal branches

Complex 3D environment

Grasping/leaping locomotion

Debate about fruit/flower vs insect predation

Primate visual specializations due to either foraging, predation, and/or 3D visual needs for arboreal locomotion (occlusion)





Our cousin, Colugo

Exclusively high arboreal gliding mammal (patagia)

Nocturnal

Highly folivorous

Poor climbers

Lack primate visual specializations



Primate Vision

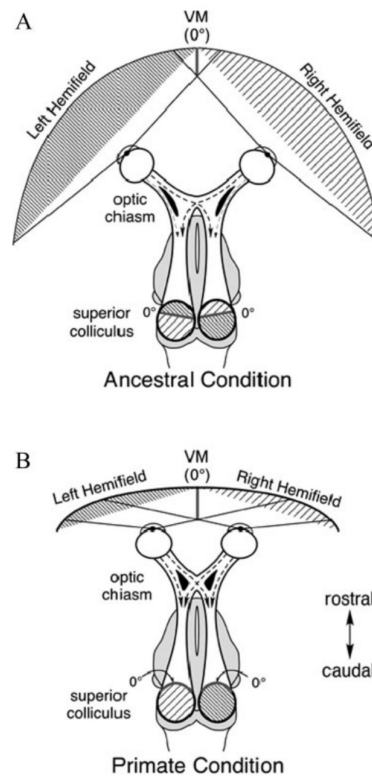


Primate Visual Specializations

Large Orbits

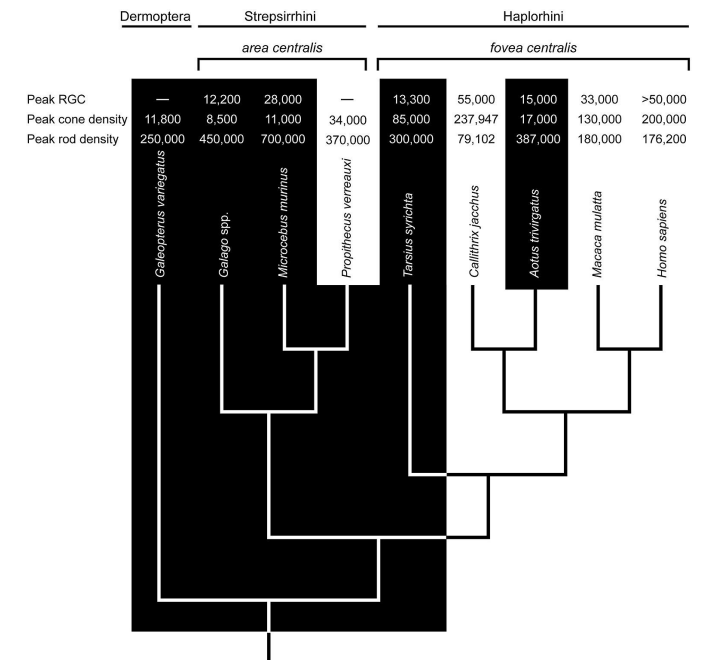


Stereopsis



Preuss TM. 2007. Evolutionary specializations of primate brain systems. In: Primate origins: adaptations and evolution. New York: Springer Science+Business Media. p 625-675.

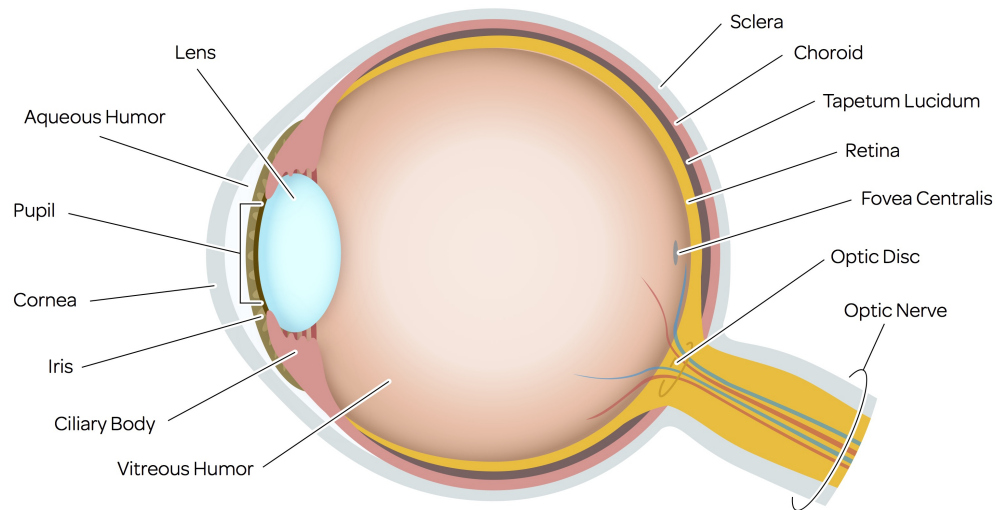
Fovea



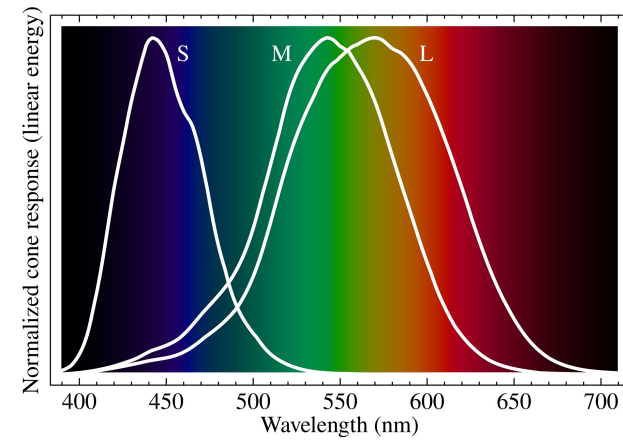
Moritz, G. L. et al. (2014). Niche convergence suggests functionality of the nocturnal fovea. *Frontiers in Integrative Neuroscience*, 8, 61.

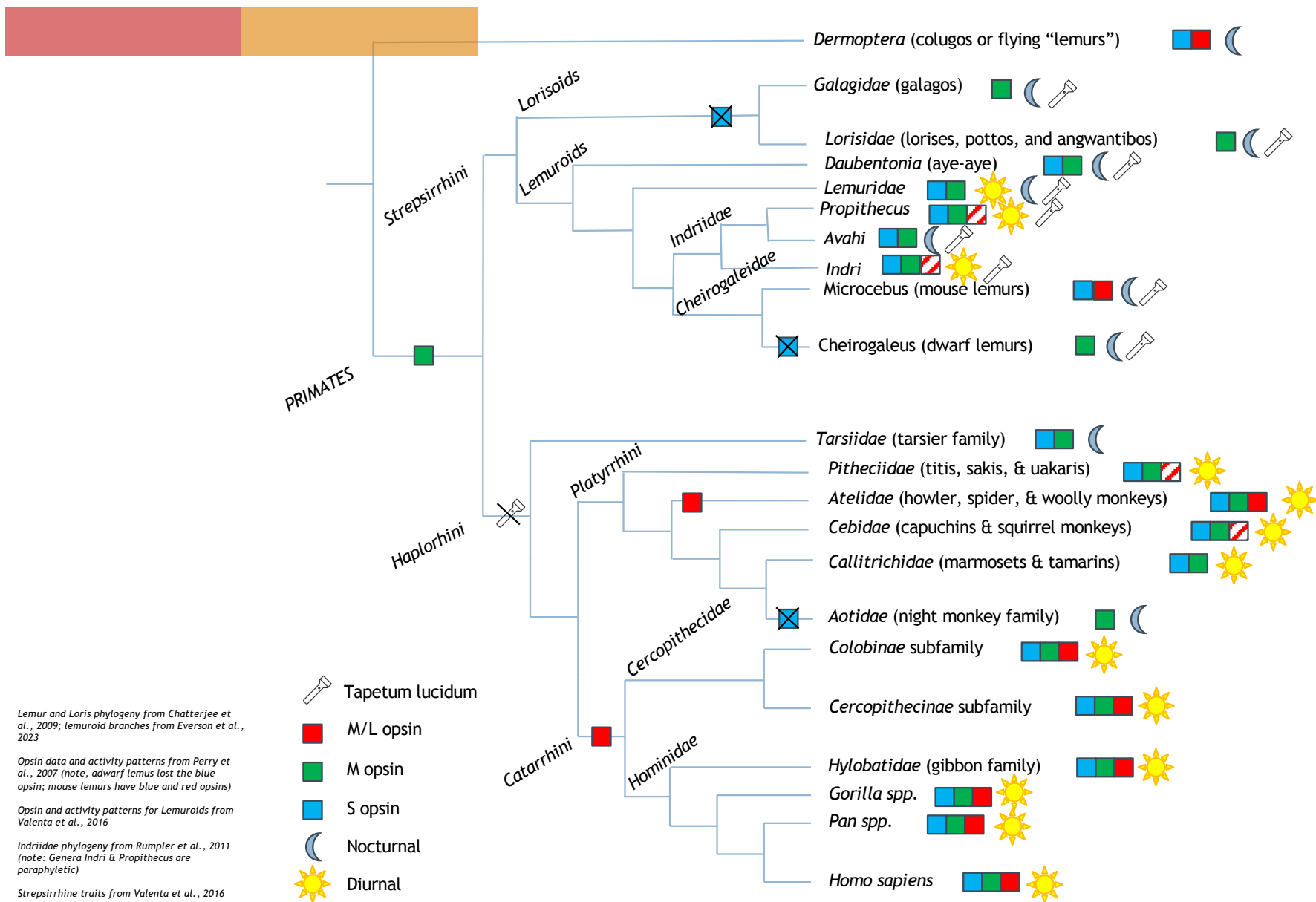
Primate Visual Specializations

- Loss of Tapetum Lucidum



- Trichromacy







Primate Visual Evolution

Strepsirrhines (Lemurs, Lorises, etc)

- Mostly nocturnal
- S opsin lost in some lineages
- Maintenance of tapetum
- M/L opsin evolved in diurnal lineages but X-linked

Haplorhines

- Loss of tapetum coinciding with diurnality



Platyrrhines (NWM)

- Trichromacy in females only
- Loss of S opsin in nocturnal lineages

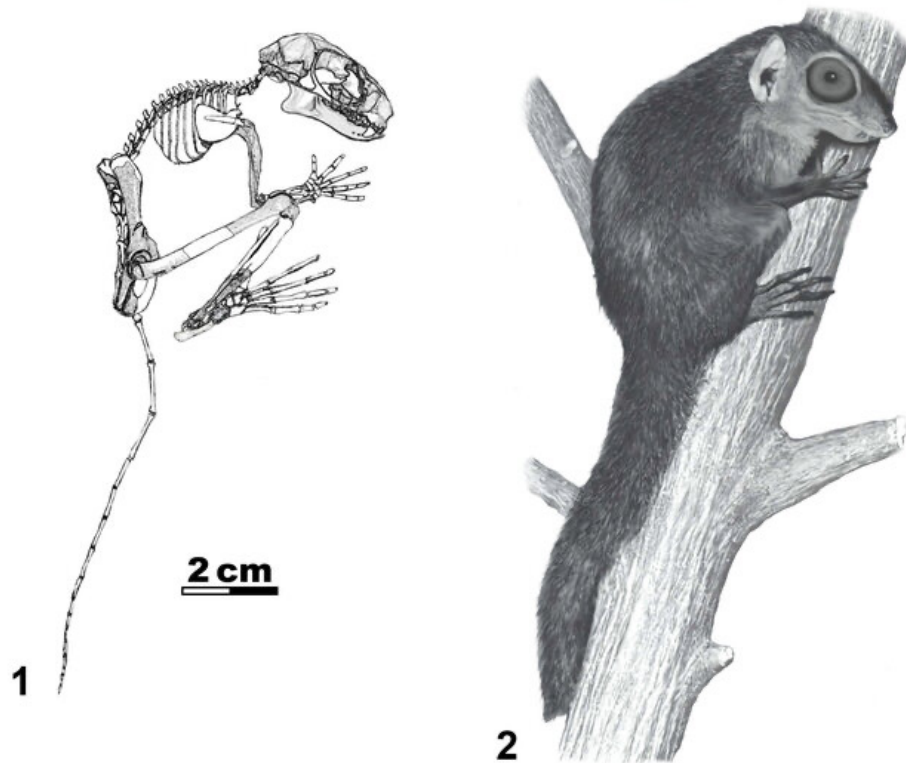
Catarrhines (OWM & Anthropoids)

- Trichromacy in males and females

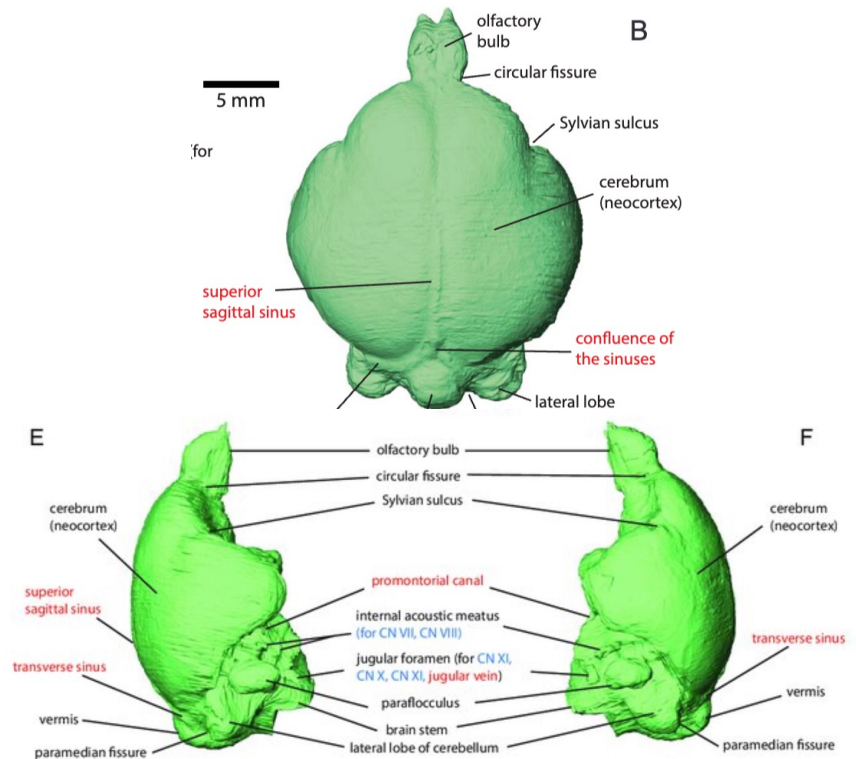
The Primate Temporal Lobe and the Ventral Stream



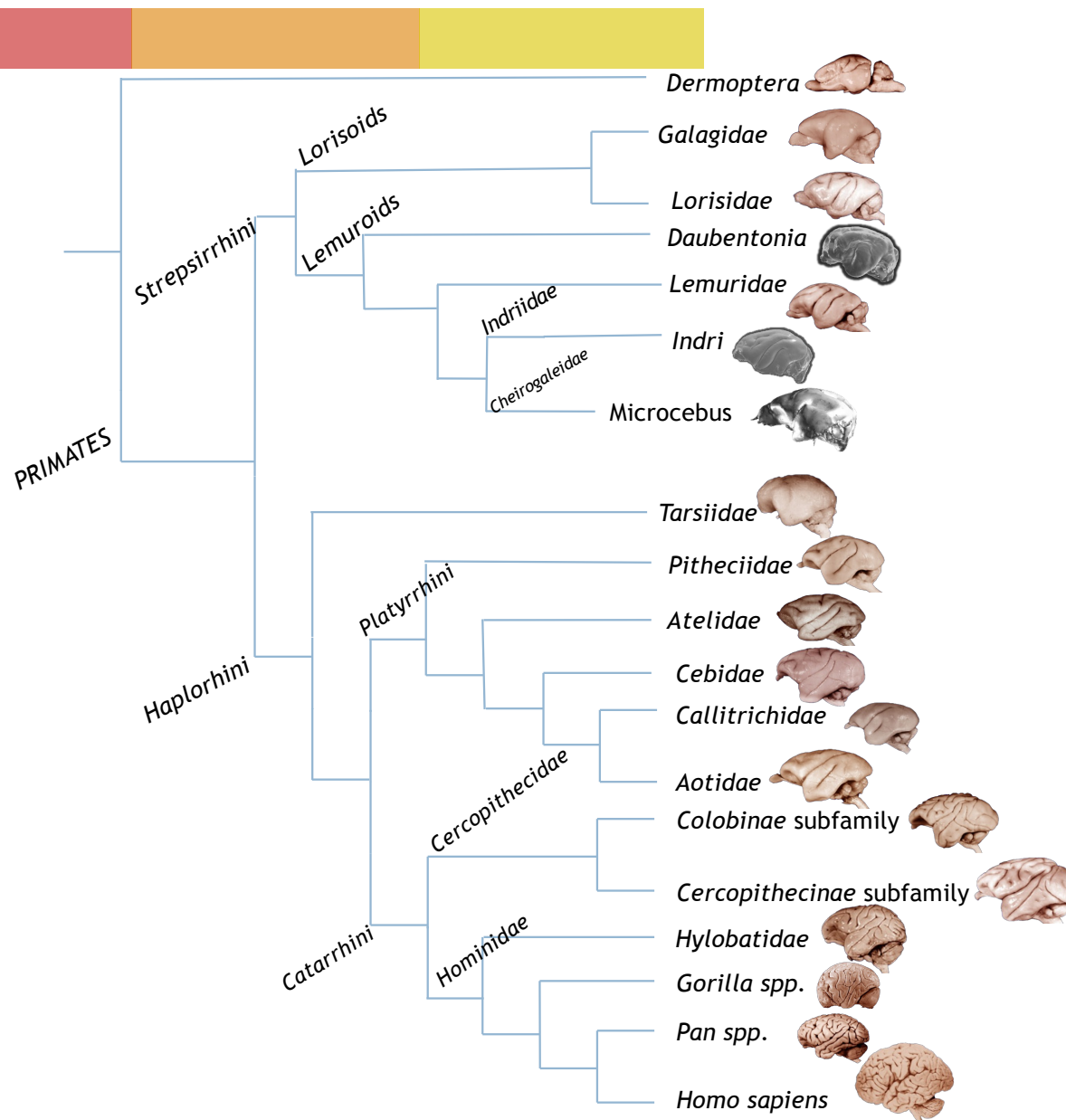
The Primate Temporal Lobe



Burger, B. J. (2010). Skull of the Eocene primate *Omomys carteri* from western North America. *Paleontological Contributions*, 2:1-192.



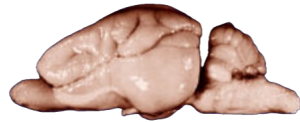
Harrington, A., Yapuncich, G., & Boyer, D. (2020). The digital endocast of *Necrolemur antiquus*. *Palaeovertebrata*.



The Primate Temporal Lobe is Unique

All extant primates share a distinctive temporal lobe morphology





Dermoptera

Strepsirrhine



Galagidae

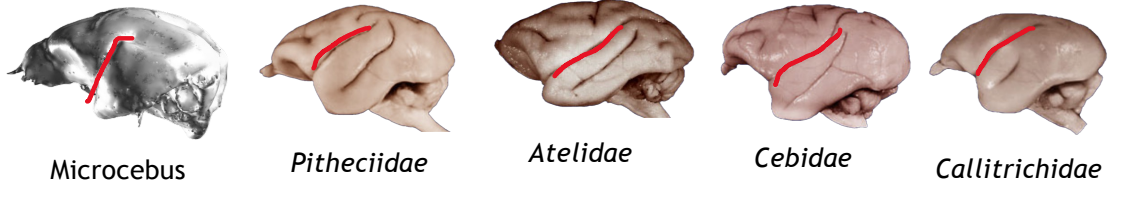
Lorisidae

Daubentonia

Lemuridae

Indri

Platyrrhine



Microcebus

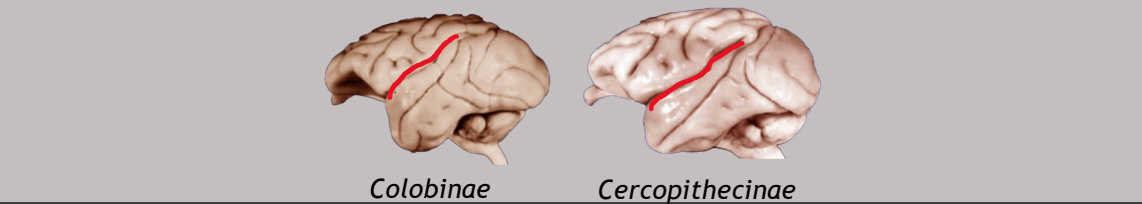
Pitheciidae

Atelidae

Cebidae

Callitrichidae

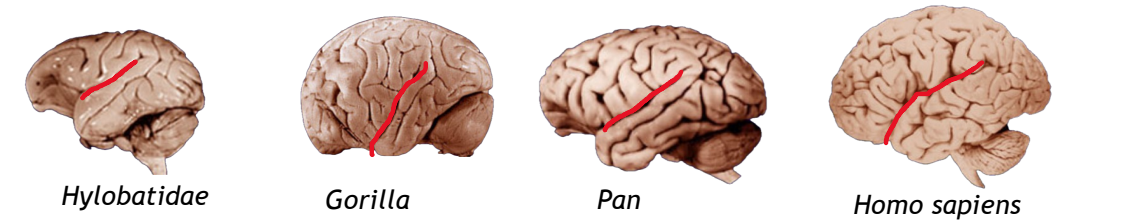
Cercopithecidae



Colobinae

Cercopithecinae

Hominidae



Hylobatidae

Gorilla

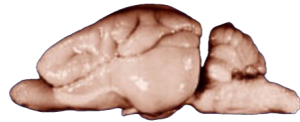
Pan

Homo sapiens

The Sylvian Fissure

Shared by all primates and not dermopteran outgroup (monophyletic)



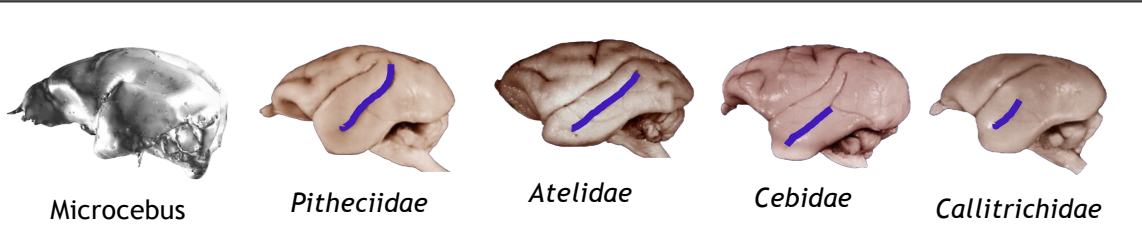


Dermoptera

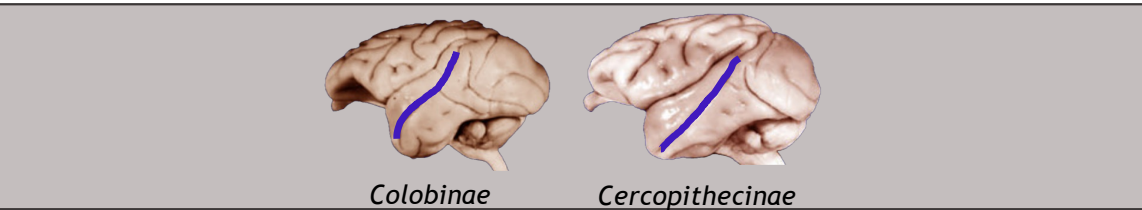
Strepsirrhine



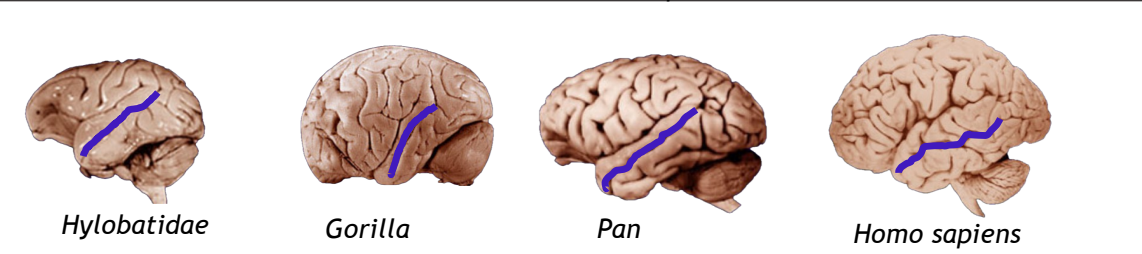
Platyrrhine



Cercopithecidae



Hominidae

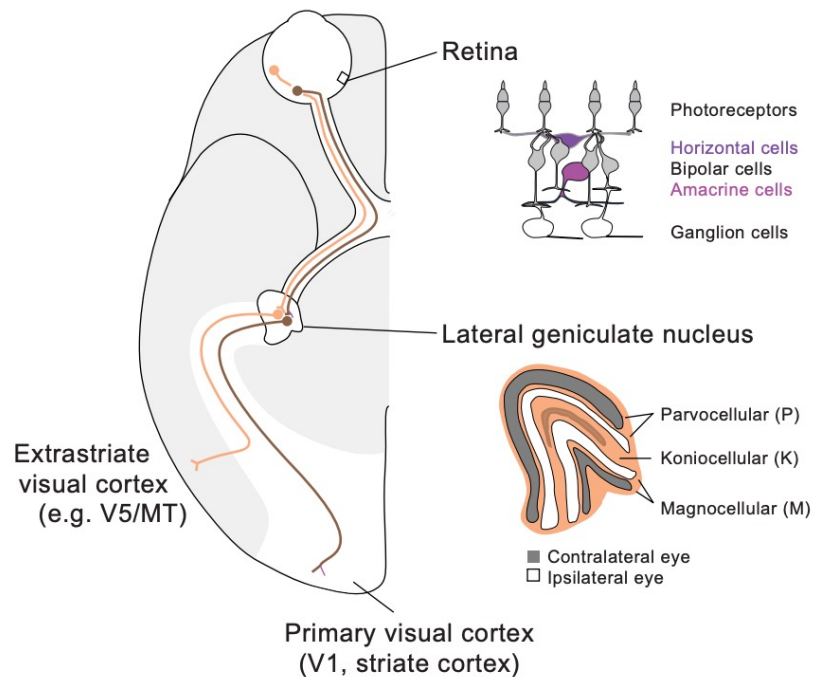


The Superior Temporal Sulcus

Delineating inferior temporal gyrus,
and roughly visual/auditory
processing



The beginnings of the ventral stream

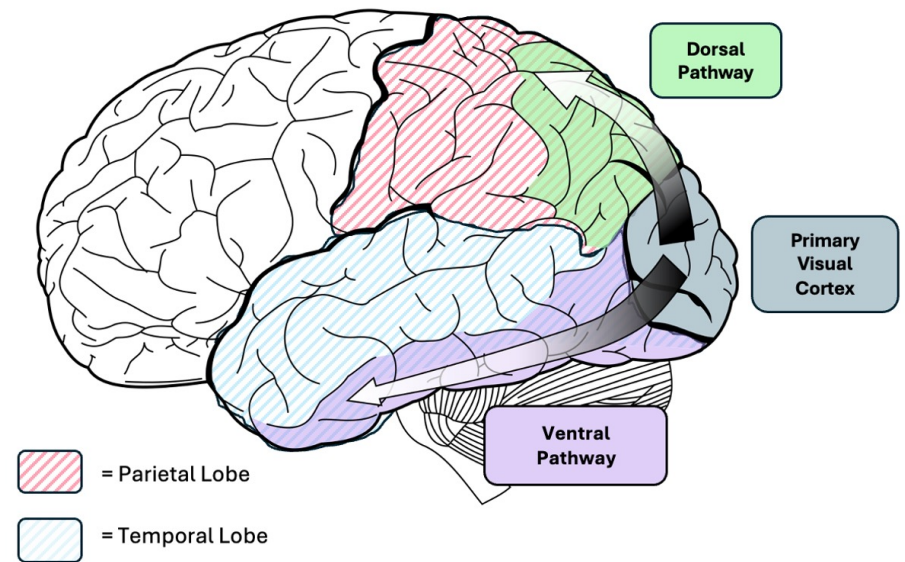
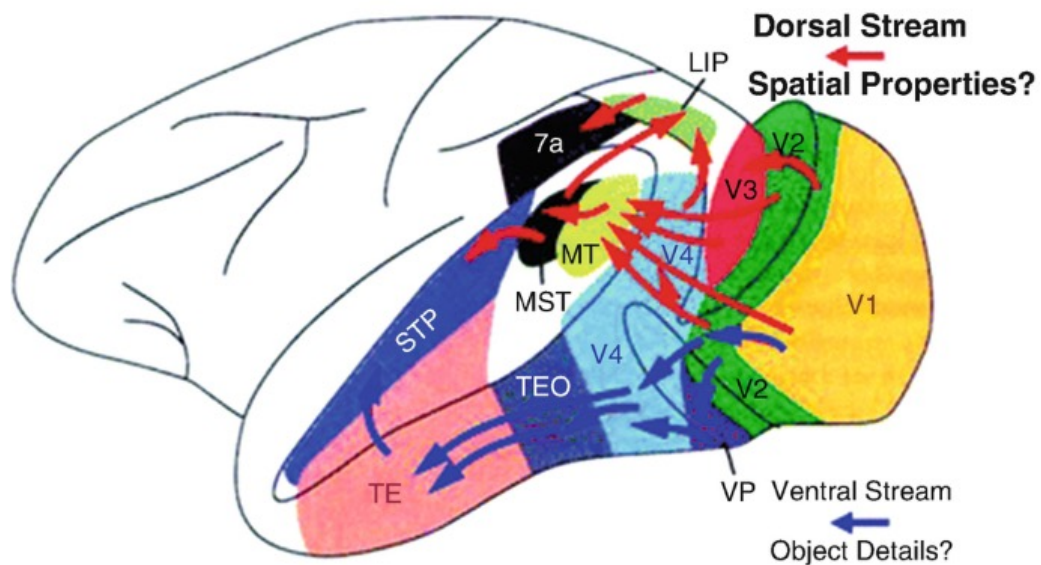


Pathway it's involved in	Parvocellular Pathway	Magnocellular Pathway
Cell body size	Small	Large
Dendritic tree	Less complex	Complex
Conduction rate	~2 ms	~1.6 ms
Function in visual system	"What" objects are according to fine detail	"Where" objects are; "How" to grasp the objects
Sensitivity to spatial frequency	Medium to high	Low
Temporal frequency	Low	High
Color opponency	Red-green opponency	Achromatic

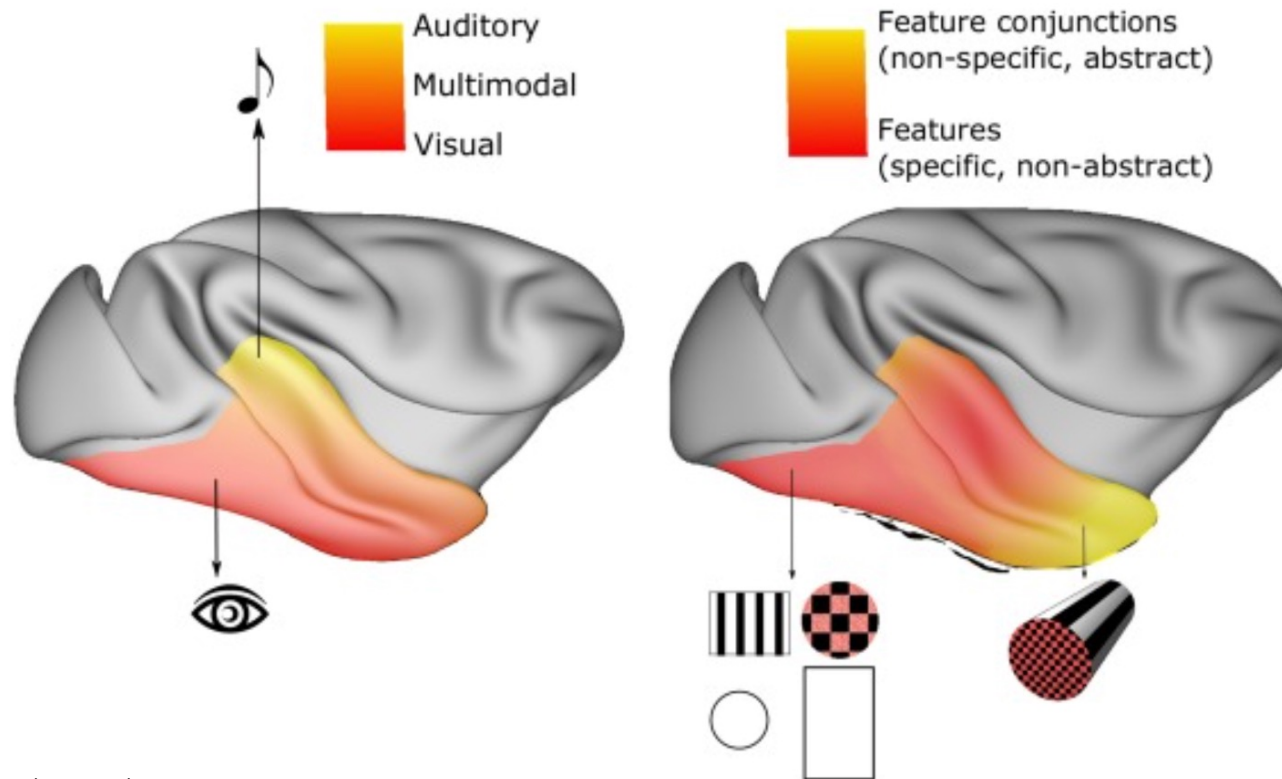
From: Solomon, S. G. (2021). Retinal ganglion cells and the magnocellular, parvocellular, and koniocellular subcortical visual pathways from the eye to the brain. In *Handbook of clinical neurology* (Vol. 178, pp. 31-50). Elsevier.

Primate temporal lobe houses the ventral visual stream

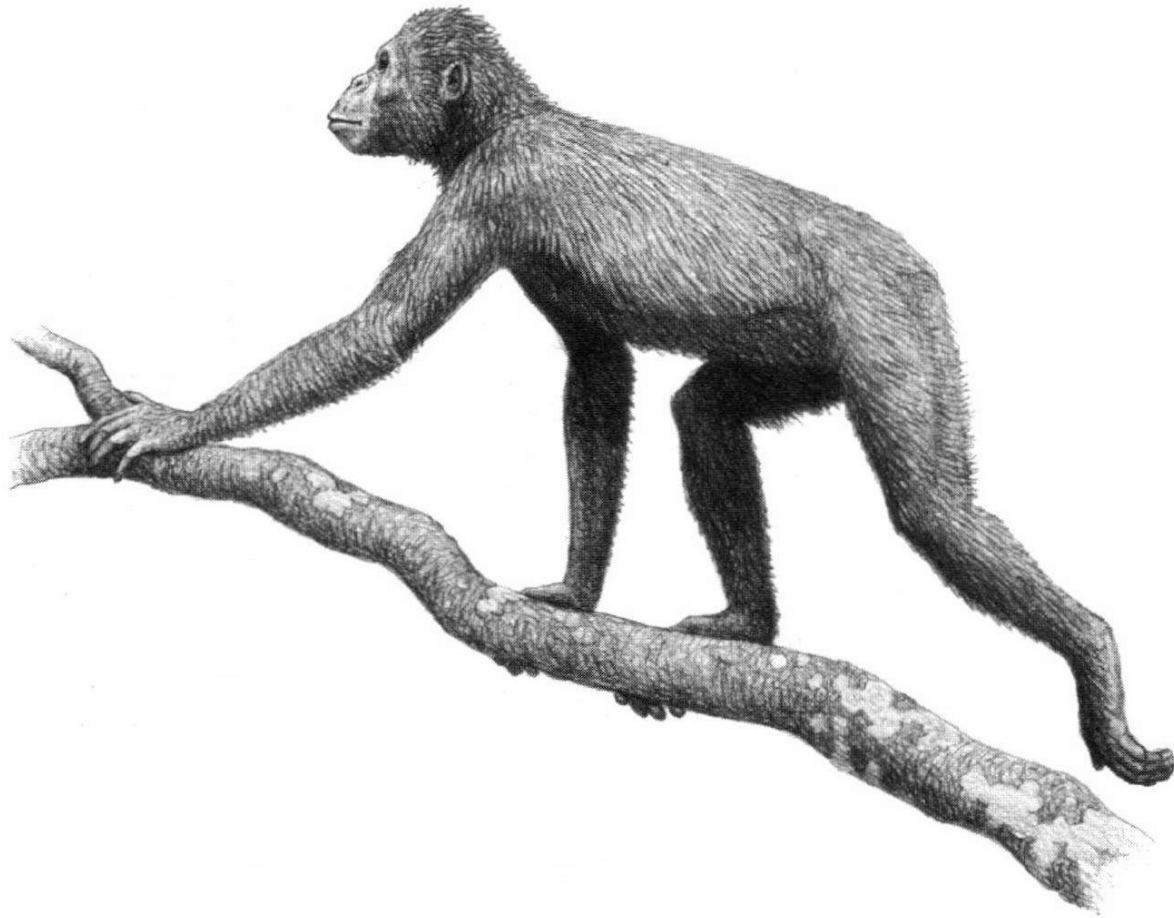
Dorsal and Ventral Streams in Monkey Cortex

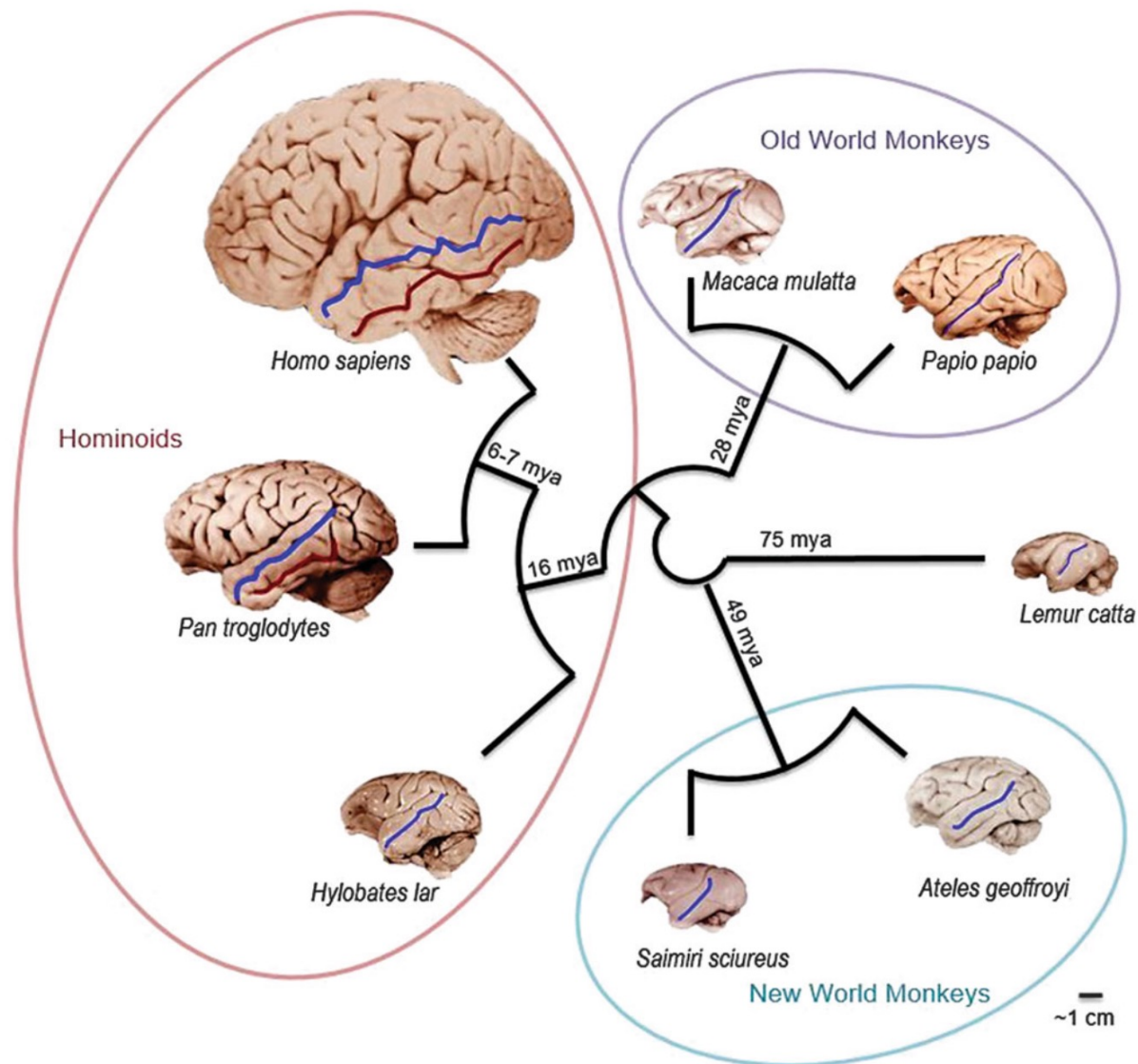


Ventral stream functions



Anthropoid Brain Expansion

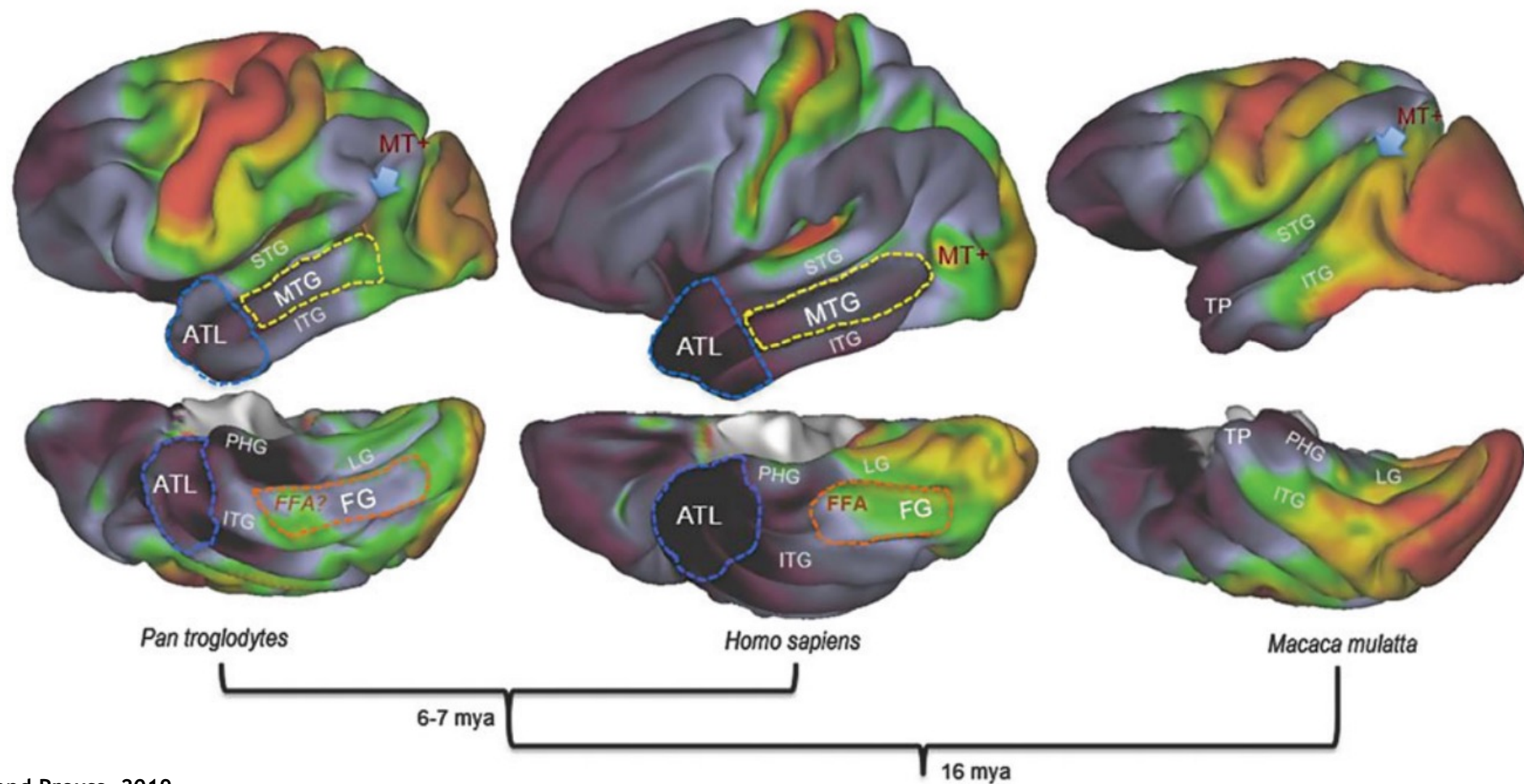


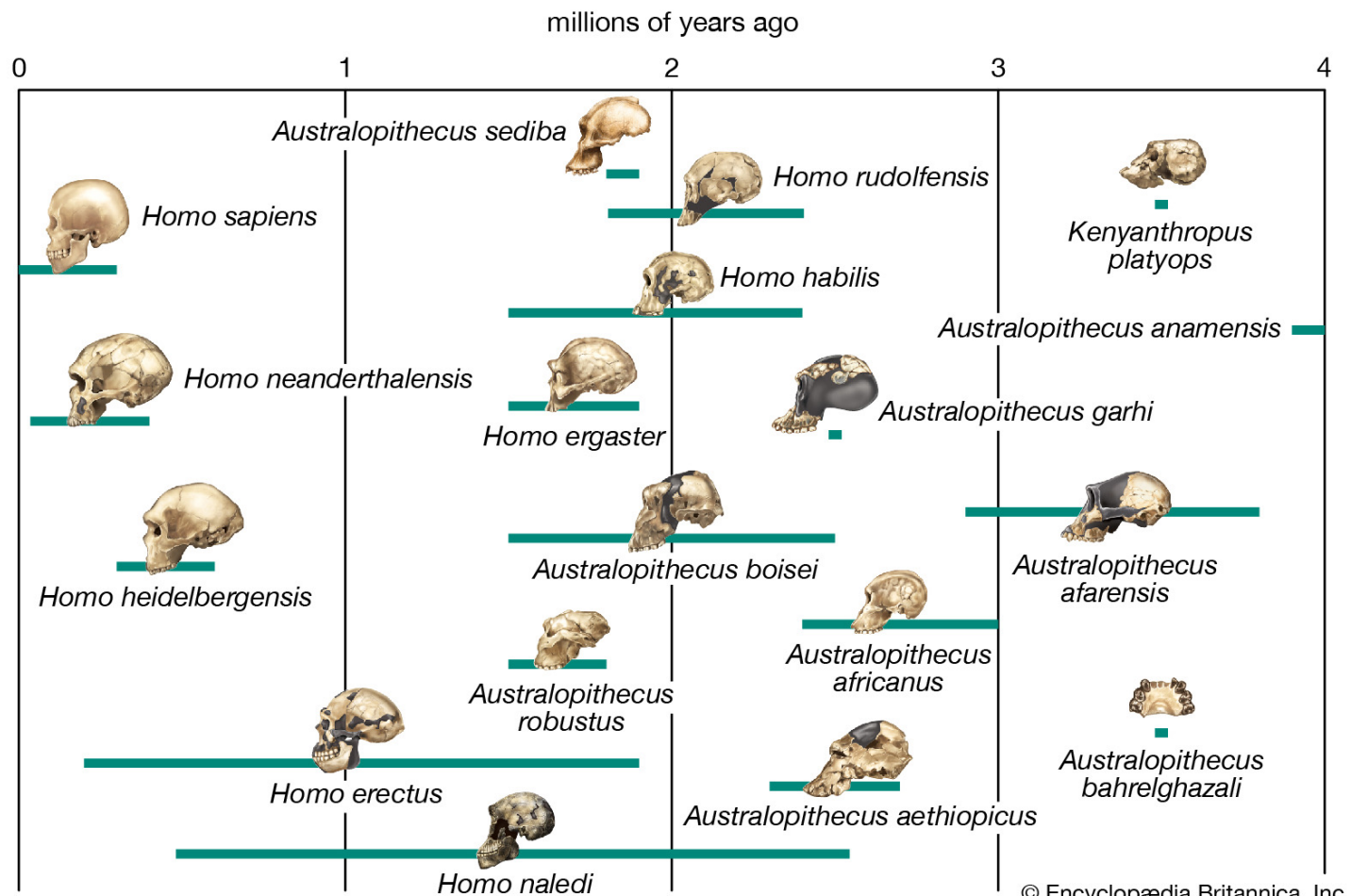


Brain expansion

Anthropoid trends





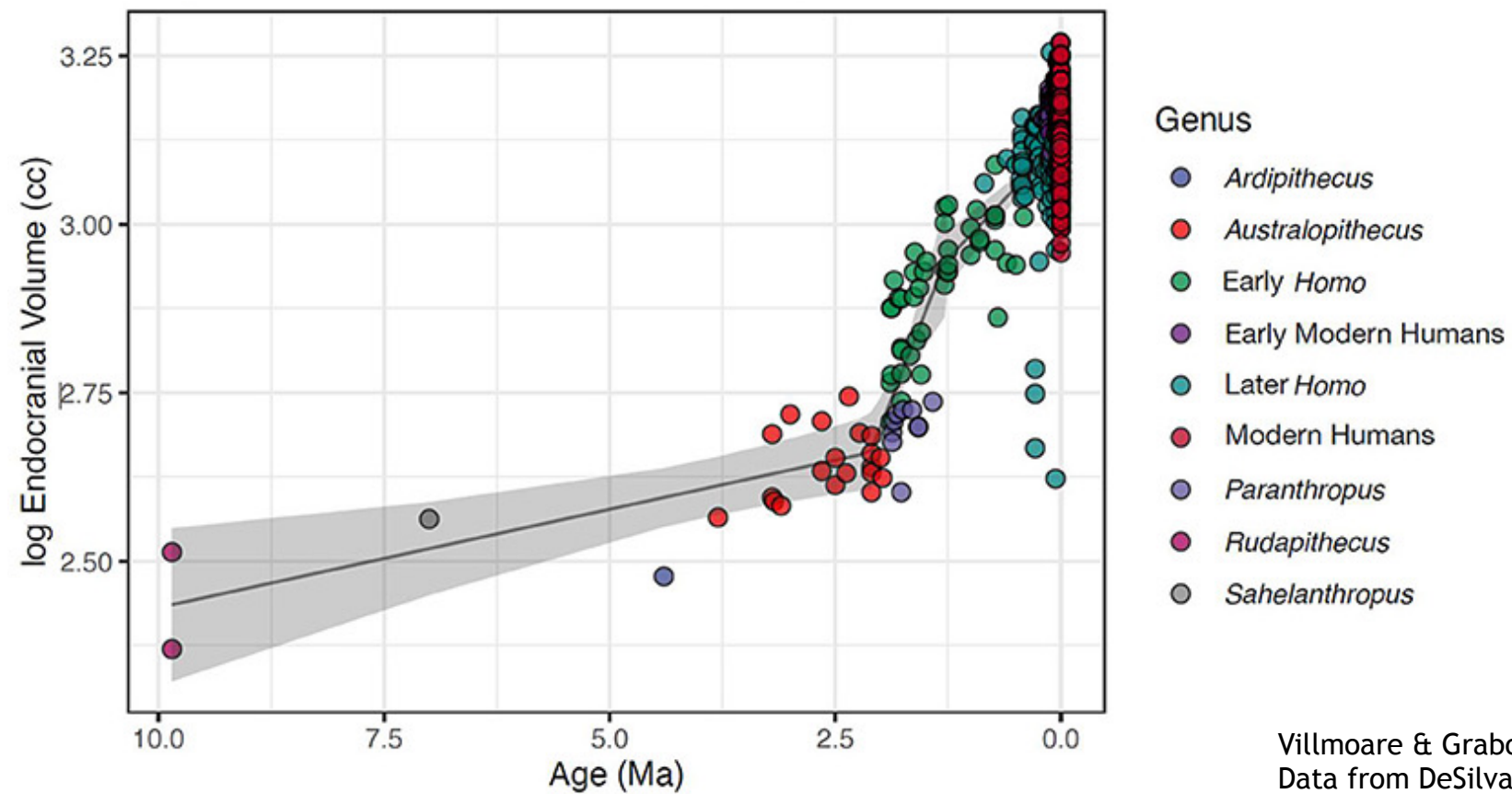


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Hominin Brain Expansion

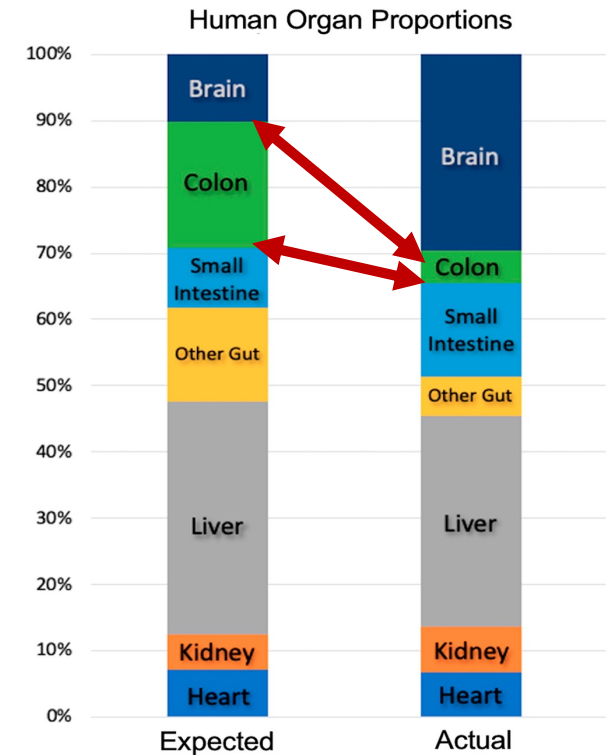
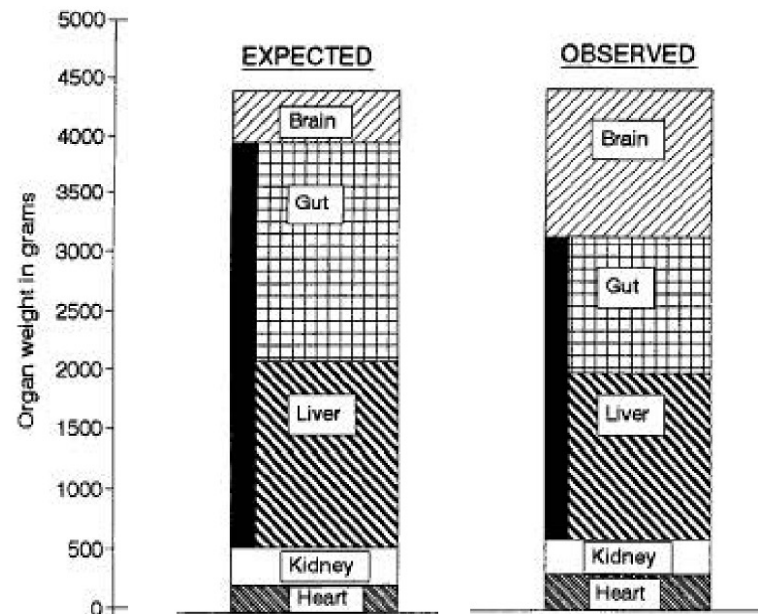
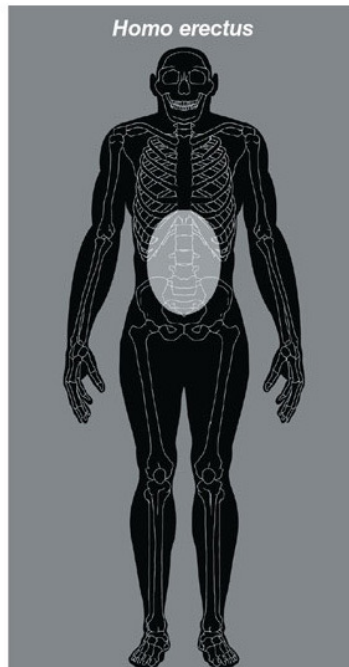
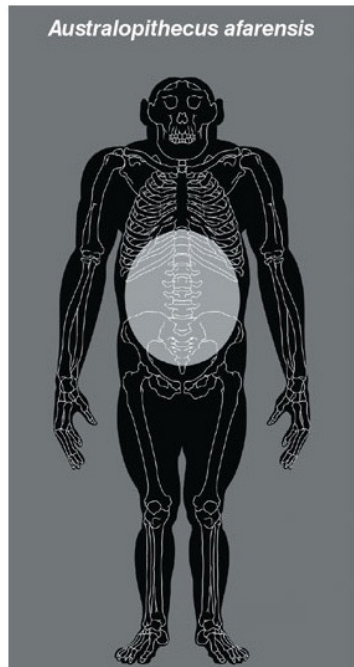


Hominin Brain Expansion



Villmoare & Grabowski 2021
Data from DeSilva et al. 2021

The Expensive Tissue Hypothesis



Aiello & Wheeler (1995). The expensive-tissue hypothesis. *Current Anthropology*, 36(2).

Bryant, Hansen, & Hecht (2023). Fermentation technology as a driver of human brain expansion. *Communications Biology*, 6(1), 1190.

External Fermentation Hypothesis

■ Meat

Published: 12 August 2010

Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia

Shannon P. McPherron , Zeresenay Alemseged, Curtis W. Marean, Jonathan G. Wynn, Dennis Reed, Denis Geraads, René Bobe & Hamdallah A. Béarat

Nature 466, 857–860 (2010) | [Cite this article](#)



■ Cooking

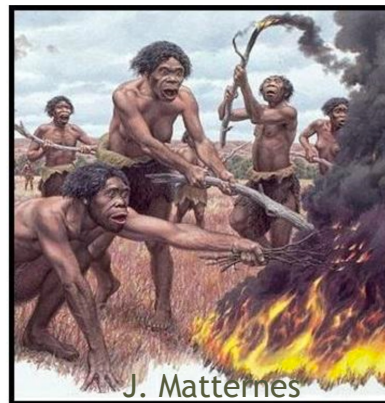
Review

‘Cooking as a biological trait’*

Richard Wrangham*, NancyLou Conklin-Brittain

Department of Anthropology, Harvard University, Peabody Museum, 11 Divinity Avenue, Cambridge, MA 02138, USA

Received 28 June 2002; received in revised form 16 January 2003; accepted 17 January 2003



■ USOs (roots, etc)

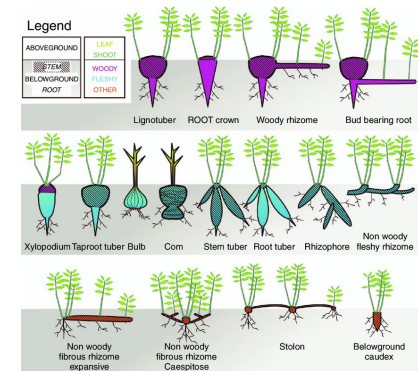
The rise of the hominids as an adaptive shift in fallback foods: Plant underground storage organs (USOs) and australopith origins

Greg Laden ^{a,*}, Richard Wrangham ^b

^a *Department of Anthropology, University of Minnesota, Twin Cities Campus, 301 19th Avenue S, Minneapolis, MN 55455, USA*

^b *Department of Anthropology, Harvard University, 11 Divinity Avenue, Cambridge, MA 02138, USA*

Received 5 July 2002; accepted 30 May 2003



■ Fermenting

communications biology

PERSPECTIVE

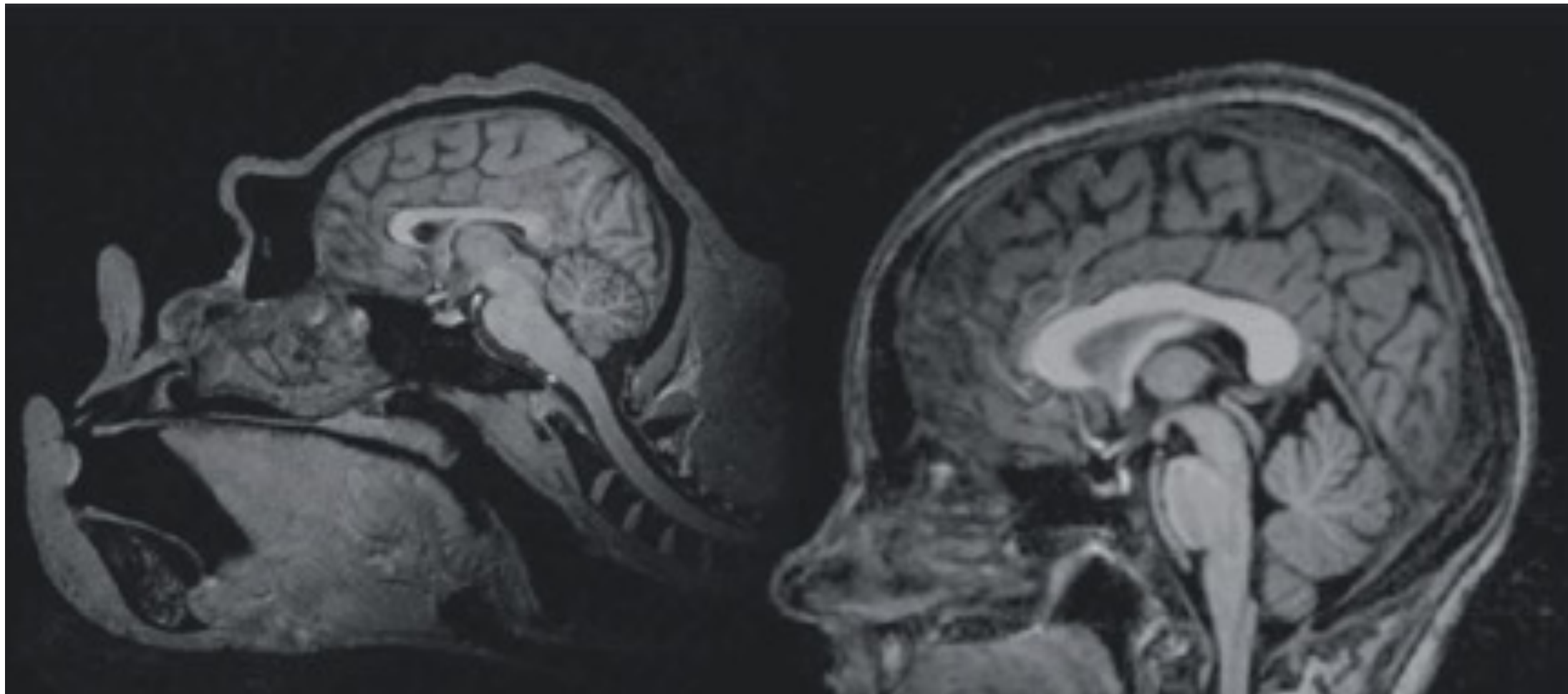
<https://doi.org/10.1038/nrn3003-023-00017-3> OPEN

Fermentation technology as a driver of human brain expansion

Katherine L. Bryant ¹, Christi Hansen² & Erin E. Hecht ³

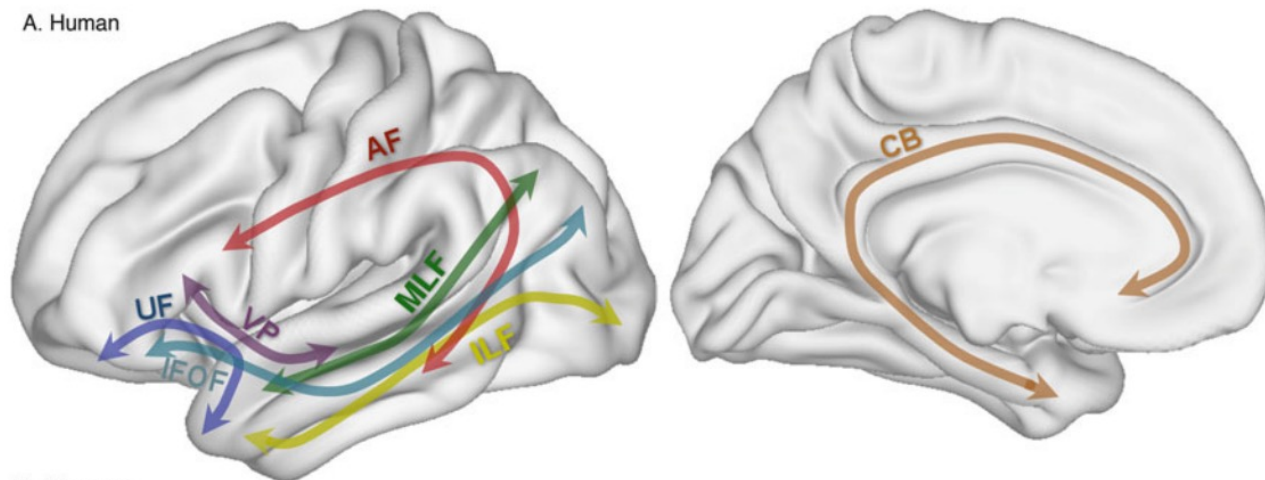


Structural Reorganization

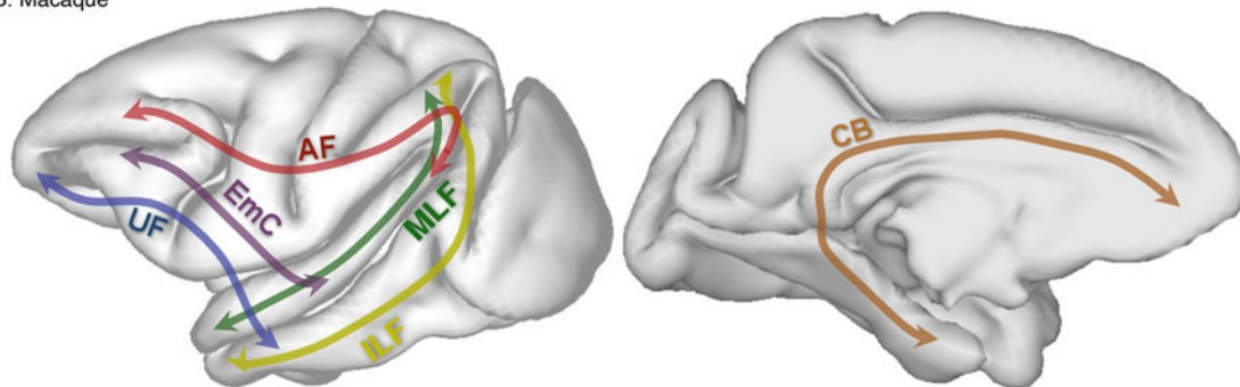


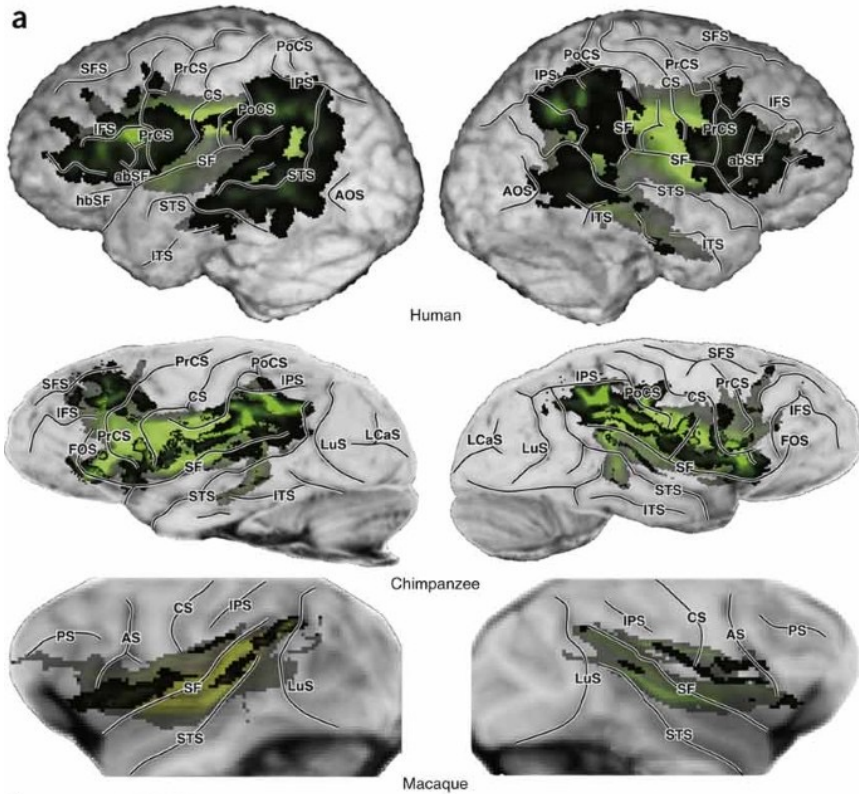
Simplified temporal white matter

A. Human

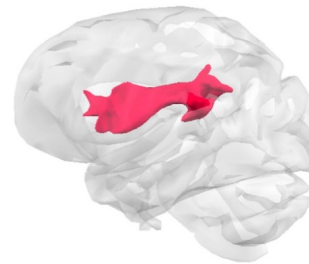
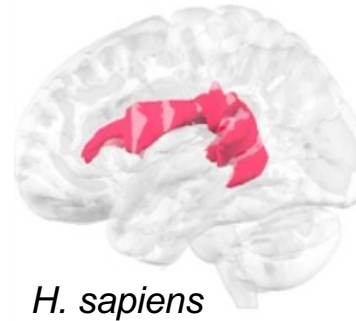


B. Macaque

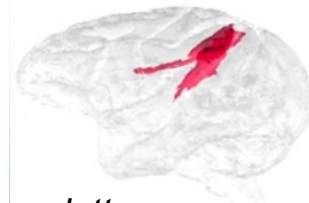




Adapted from Rilling, Glasser, Preuss, Ma, Zhao, Hu, & Behrens (2008). The evolution of the arcuate fasciculus revealed with comparative DTI. *Nature neuroscience*, 11(4), 426-428.



P. troglodytes



M. mulatta

Adapted from Bryant, Eichert, & Mars (2020). A comprehensive atlas of white matter tracts in the chimpanzee. *PLoS biology*, 18(12), e3000971.

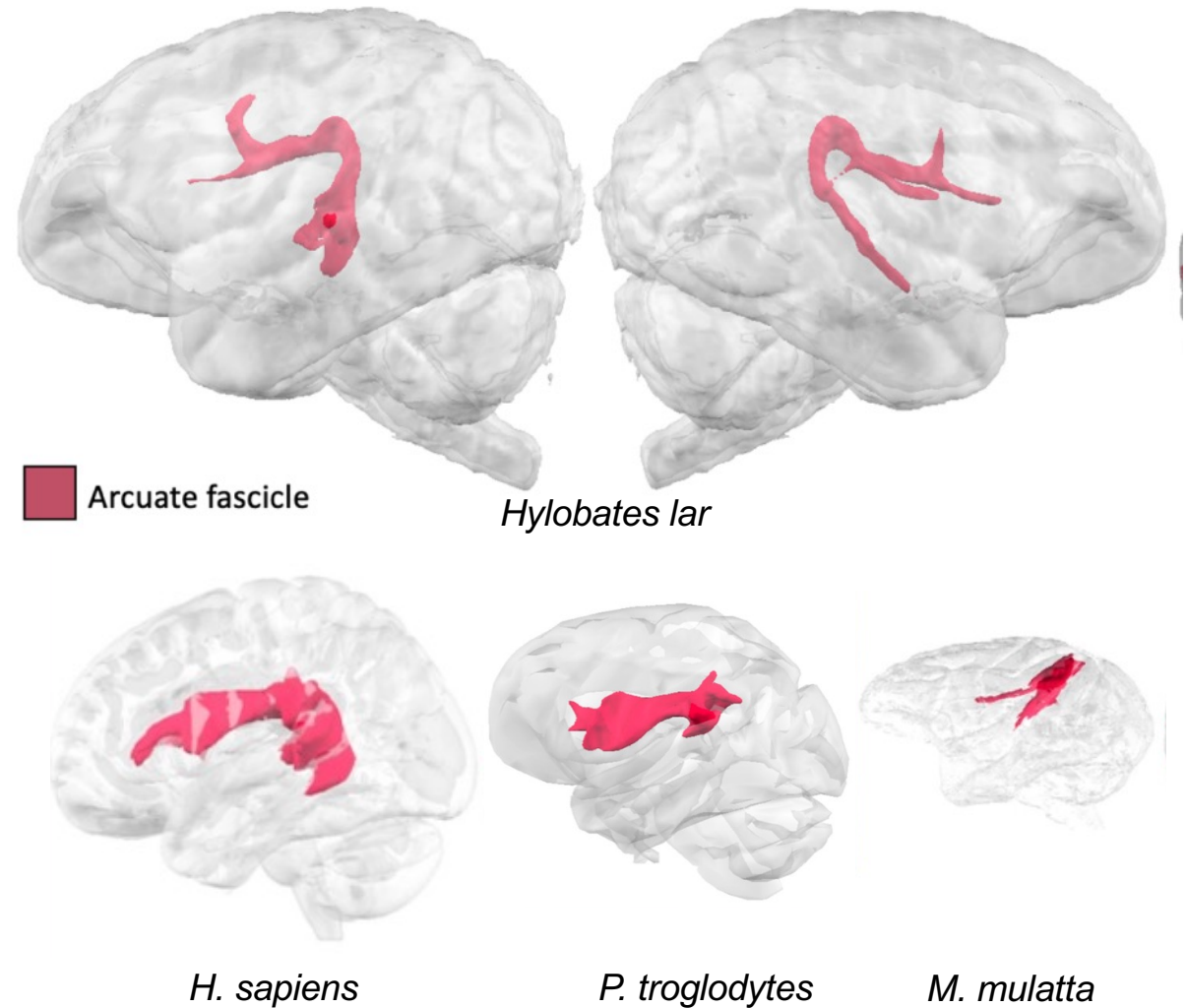
Arcuate evolution

Stepwise specializations

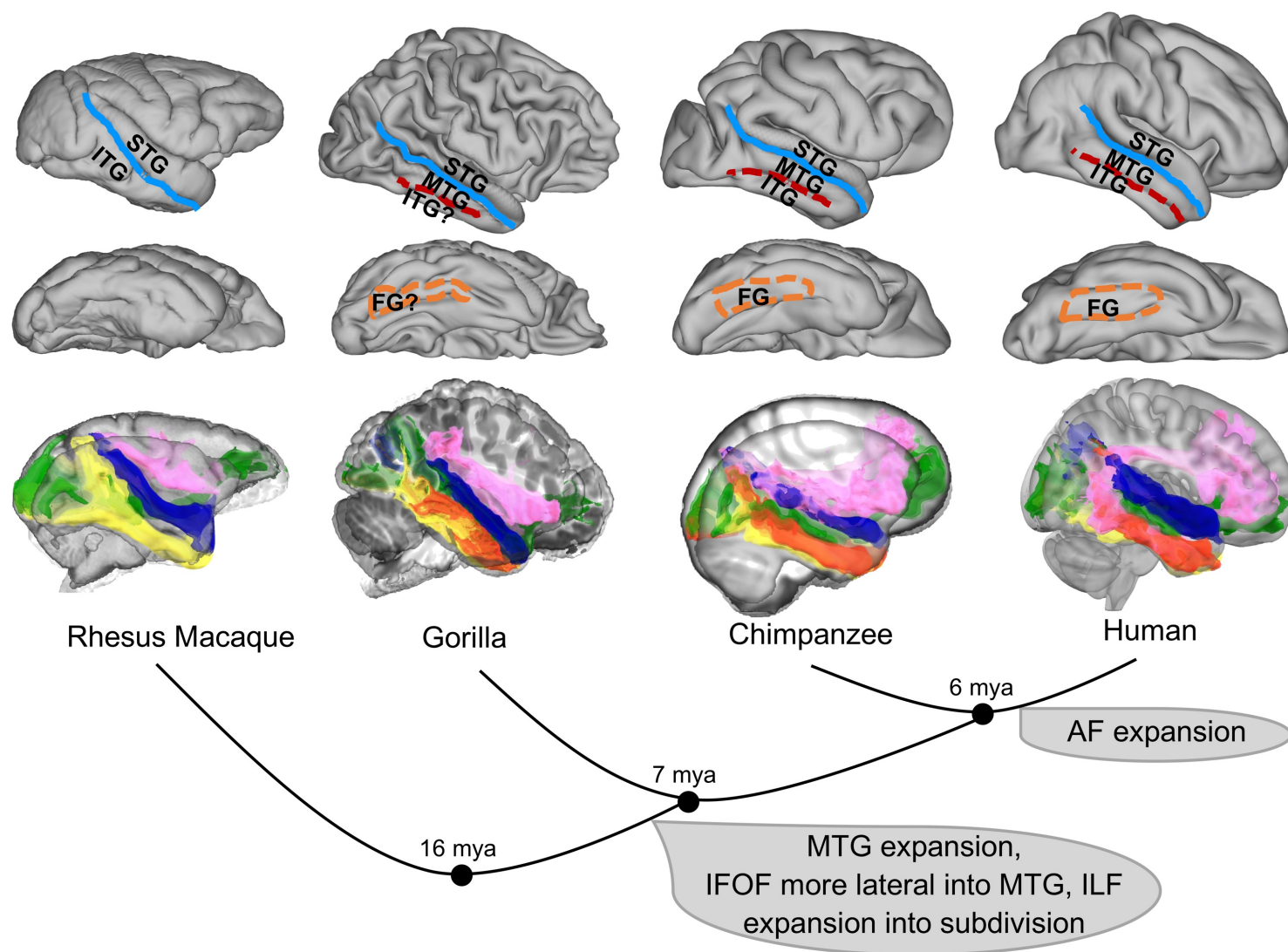


Lesser apes feature interesting arcuate specializations

Gibbons' flexible, complex, duetting vocalizations are unique among primates



Bryant et al. (2024). A map of white matter tracts in a lesser ape, the lar gibbon. *Brain Structure and Function*, 229(8), 1839-1854.



As cortex expands, ILF invades

Roumazeilles et al. (2020). Longitudinal connections and the organization of the temporal cortex in macaques, great apes, and humans. *PLoS biology*, 18(7), e3000810.



New ILF branch is in lesser apes, too

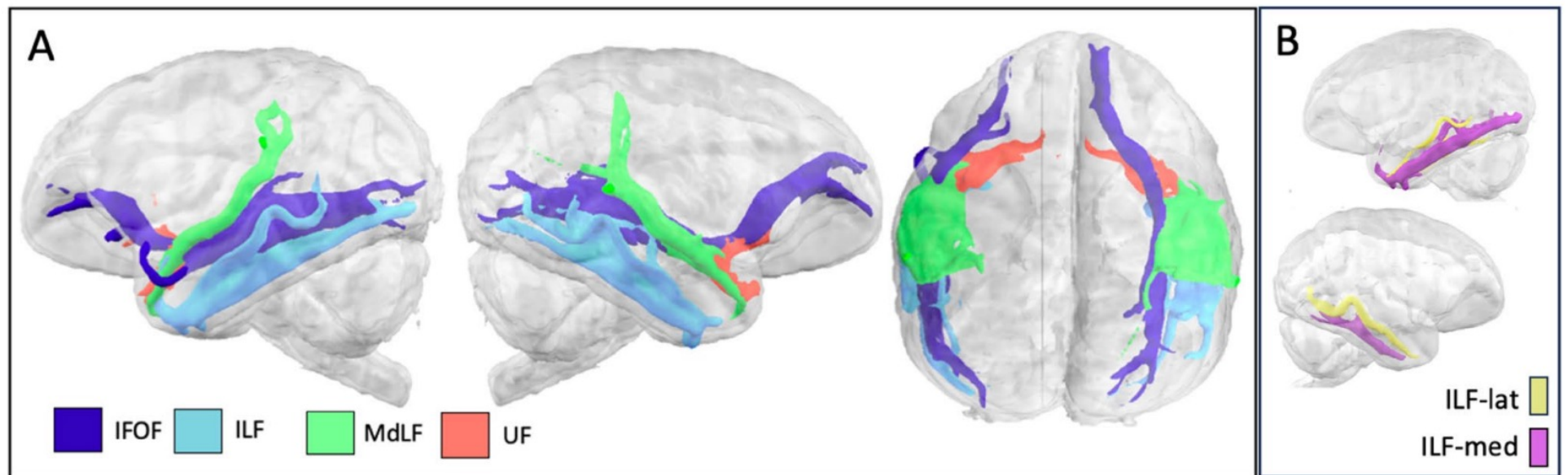
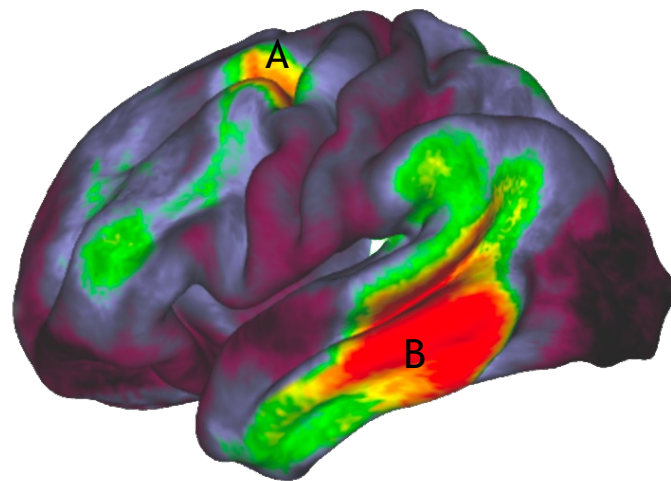


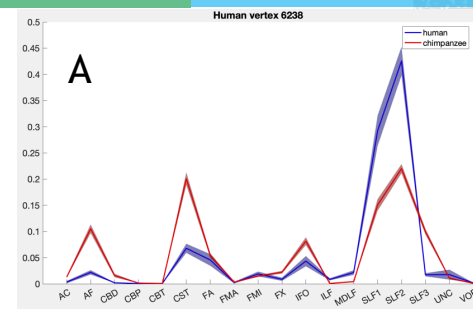
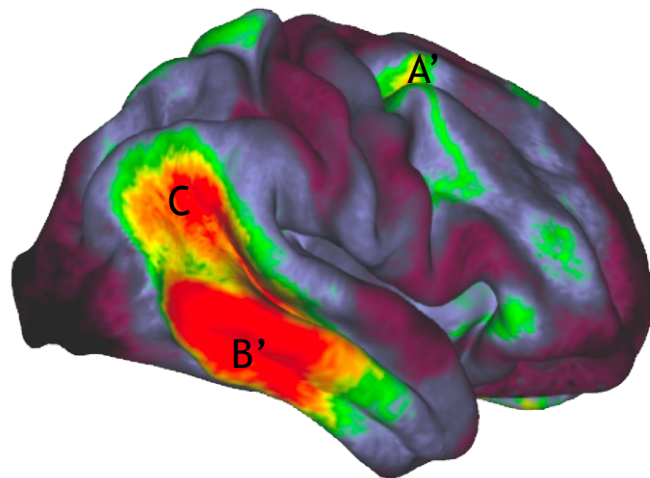
Fig.5 A Major fasciculi that course through the temporal lobe: (IFOF (inferior fronto-occipital fascicle), ILF (inferior longitudinal fascicle), MdLF (middle longitudinal fascicle) and UF (uncinate

fascicle) in the lar gibbon. **B** Lateral (ILF-lat) and medial (ILF-med) subdivisions of the ILF in the gibbon

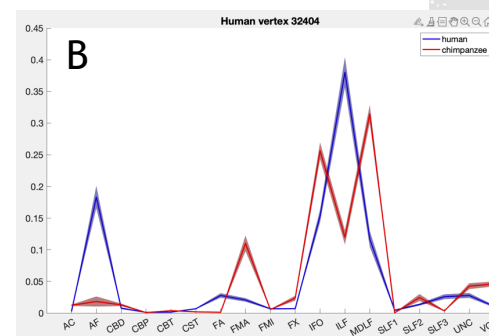
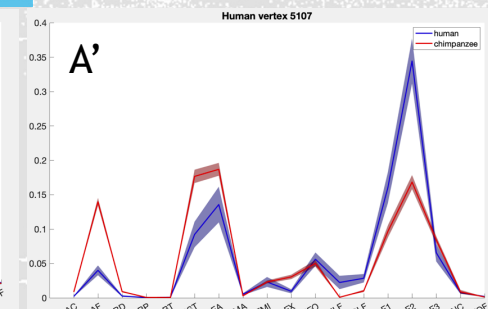
Bryant et al. (2024). A map of white matter tracts in a lesser ape, the lar gibbon. *Brain Structure and Function*, 229(8), 1839-1854.



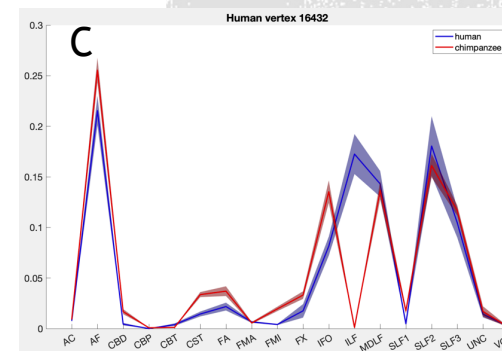
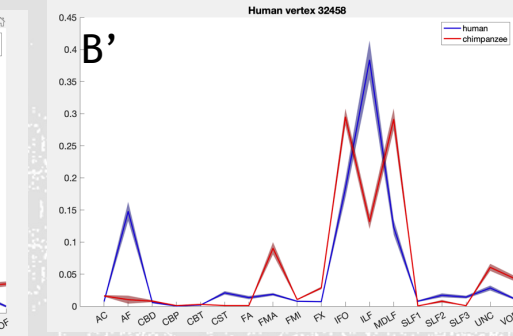
Human : Chimpanzee



Increases in SLF2 connectivity in dorsal PMG



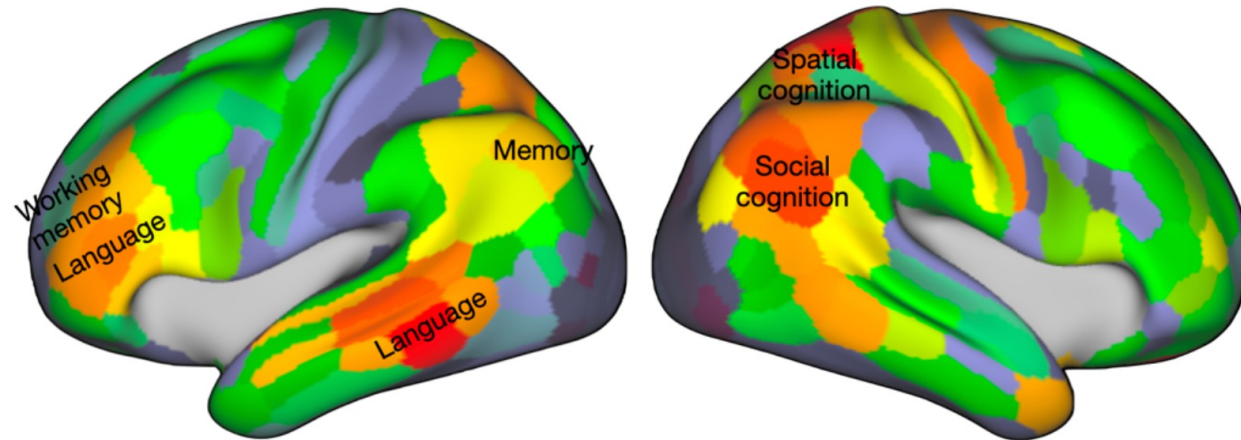
Increases in AF and ILF connectivity in pMTG



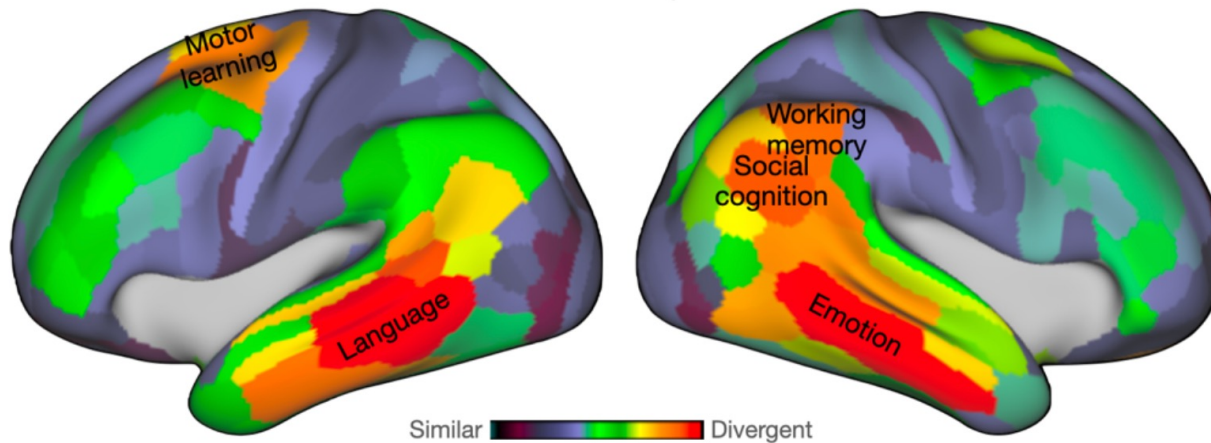
Increases in ILF connectivity in IPL



Human : Macaque



Human : Chimpanzee



Areas of High Divergence

Functional decoding reveals hotspots of evolutionary change since humans diverged from Old World monkeys and great apes

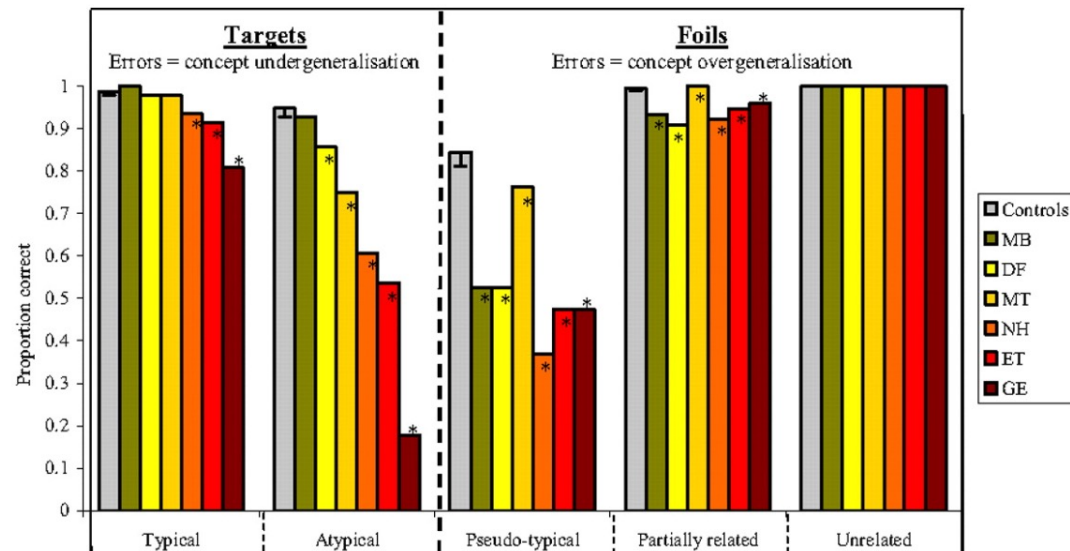
Hominoids feature a concentration of specializations in the temporal lobe uniquely

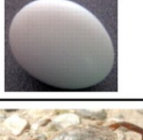
Bryant KL et al. (2025) Connectivity profile and function of uniquely human cortical areas. *Journal of Neuroscience*, 45(15).



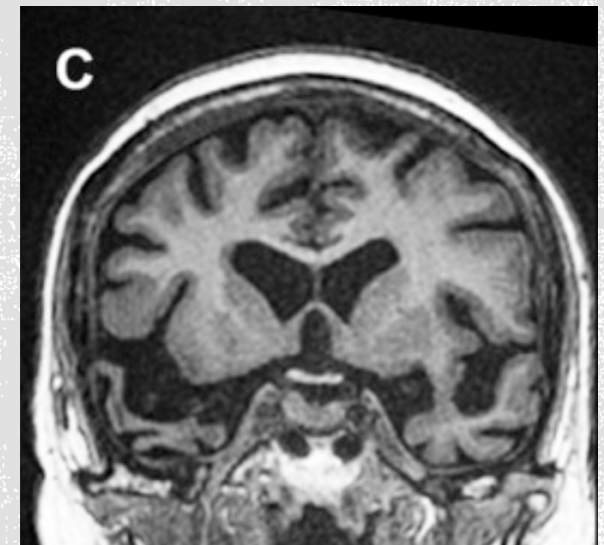
The Semantic Temporal Lobe





CAT					
BALL					
FISH					
HOOVER					

Anterior Temporal Lobe as Semantic Hub



Snowden, et al. (2018). Semantic dementia and the left and right temporal lobes. *Cortex*, 107, 188-203.

Lambon Ralph et al. (2010). Coherent concepts are computed in the anterior temporal lobes. *Proceedings of the National Academy of Sciences*, 107(6), 2717-2722.



The Anterior Temporal Lobe as Semantic Hub

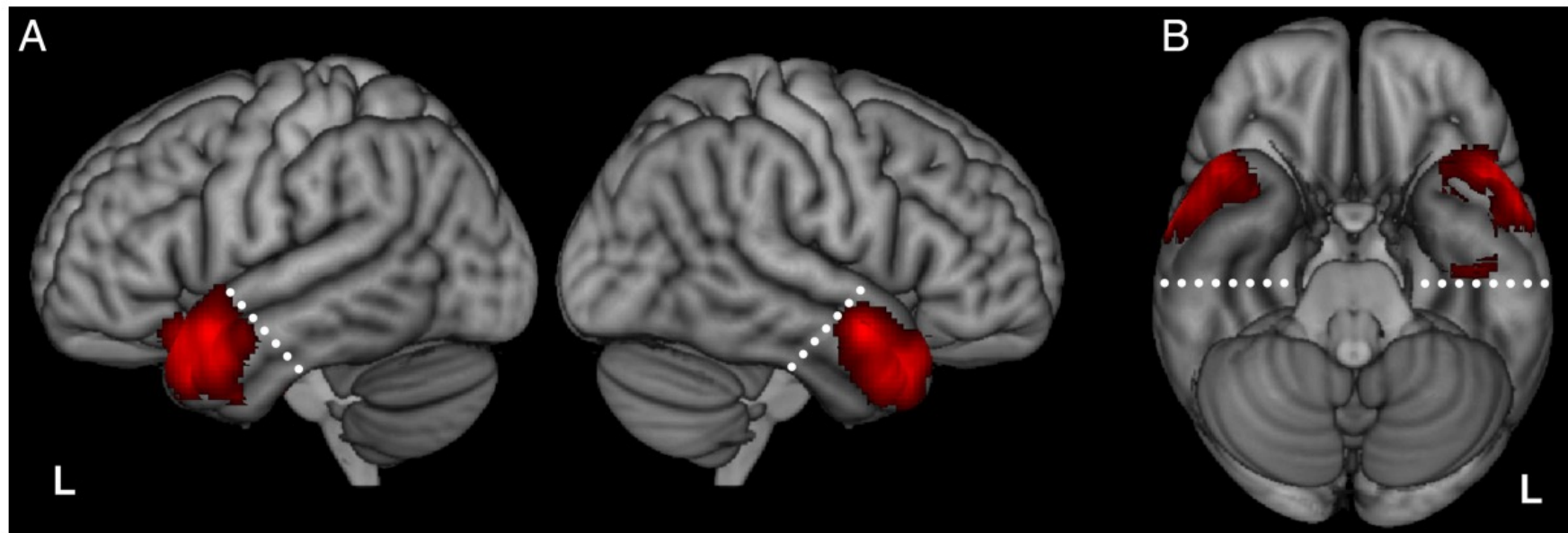
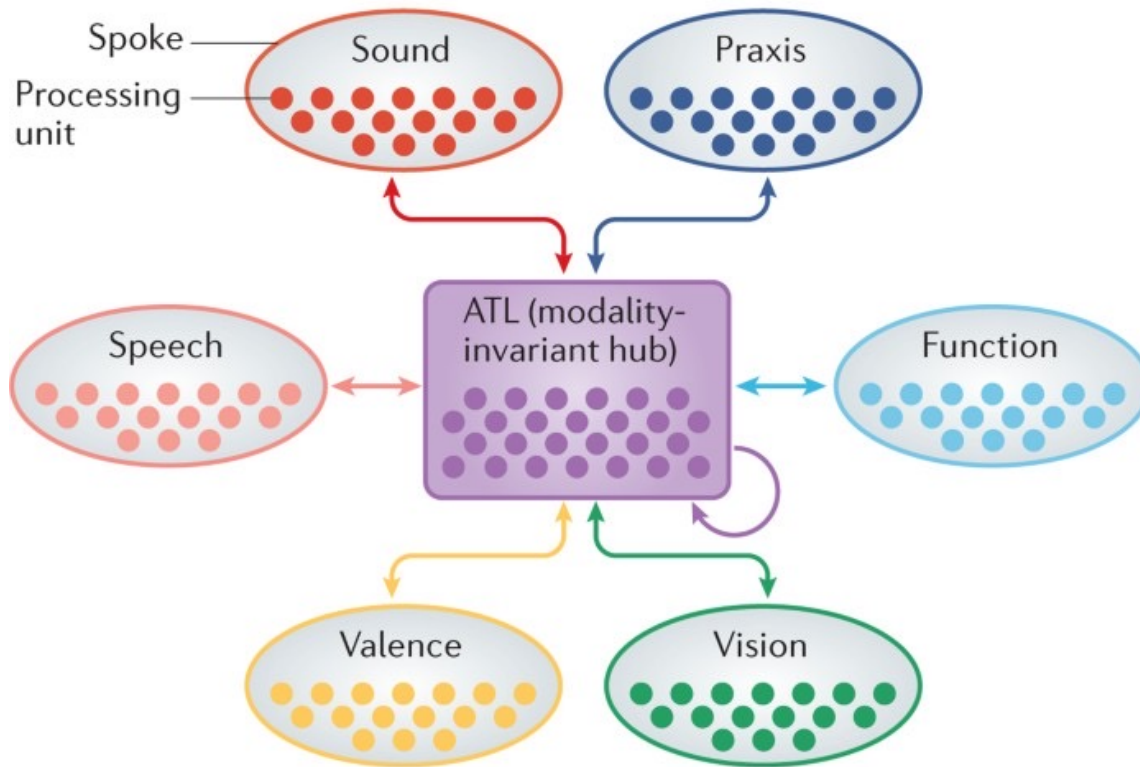


Figure 1. Activation likelihood map showing all 271 foci from 97 studies of conceptual knowledge, shown on the lateral (A) and ventral views (B). White dashed lines indicate the ATL cutoff; temporal voxels anterior to this plane were defined as falling within the ATL.

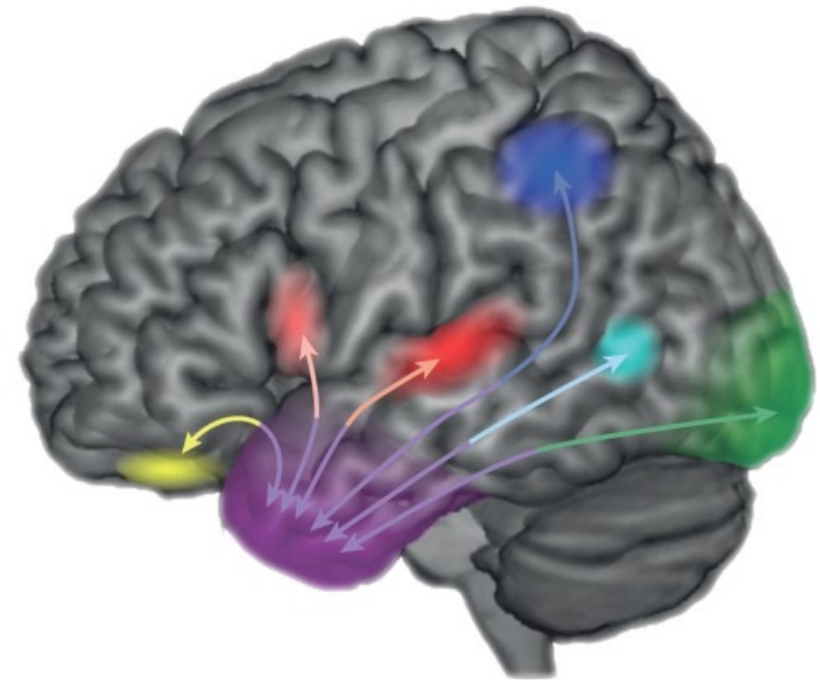
Rice, Lambon Ralph, & Hoffman (2015). The roles of left versus right anterior temporal lobes in conceptual knowledge: an ALE meta-analysis of 97 functional neuroimaging studies. *Cerebral cortex*, 25(11), 4374-4391.

The Anterior Temporal Lobe as Semantic Hub

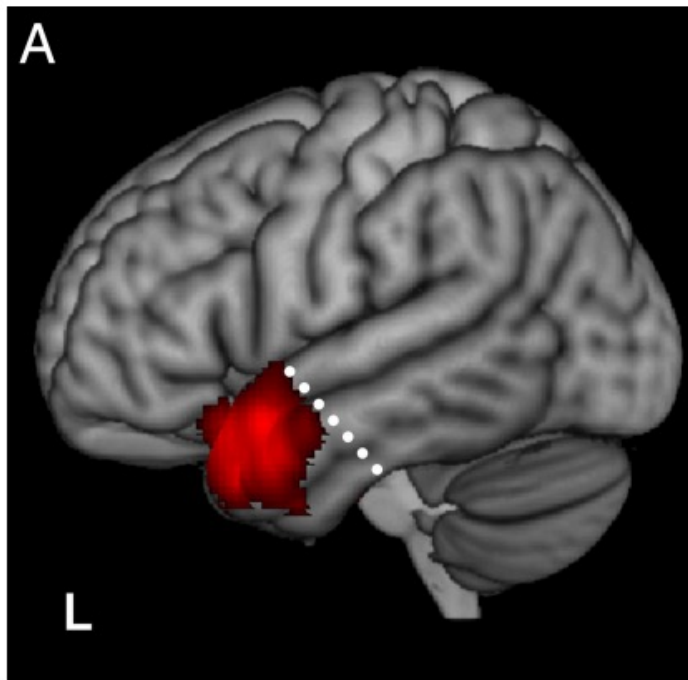
a Computational framework



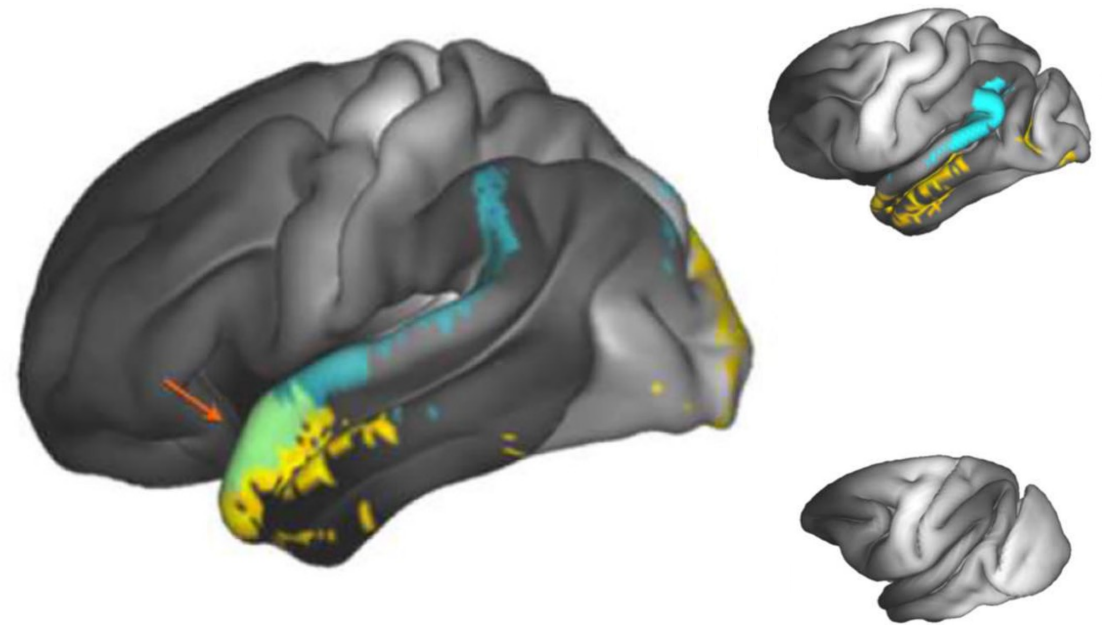
b Neuroanatomical sketch



Human Anterior Temporal Lobe has Multimodal Connectivity Unlike other Primates

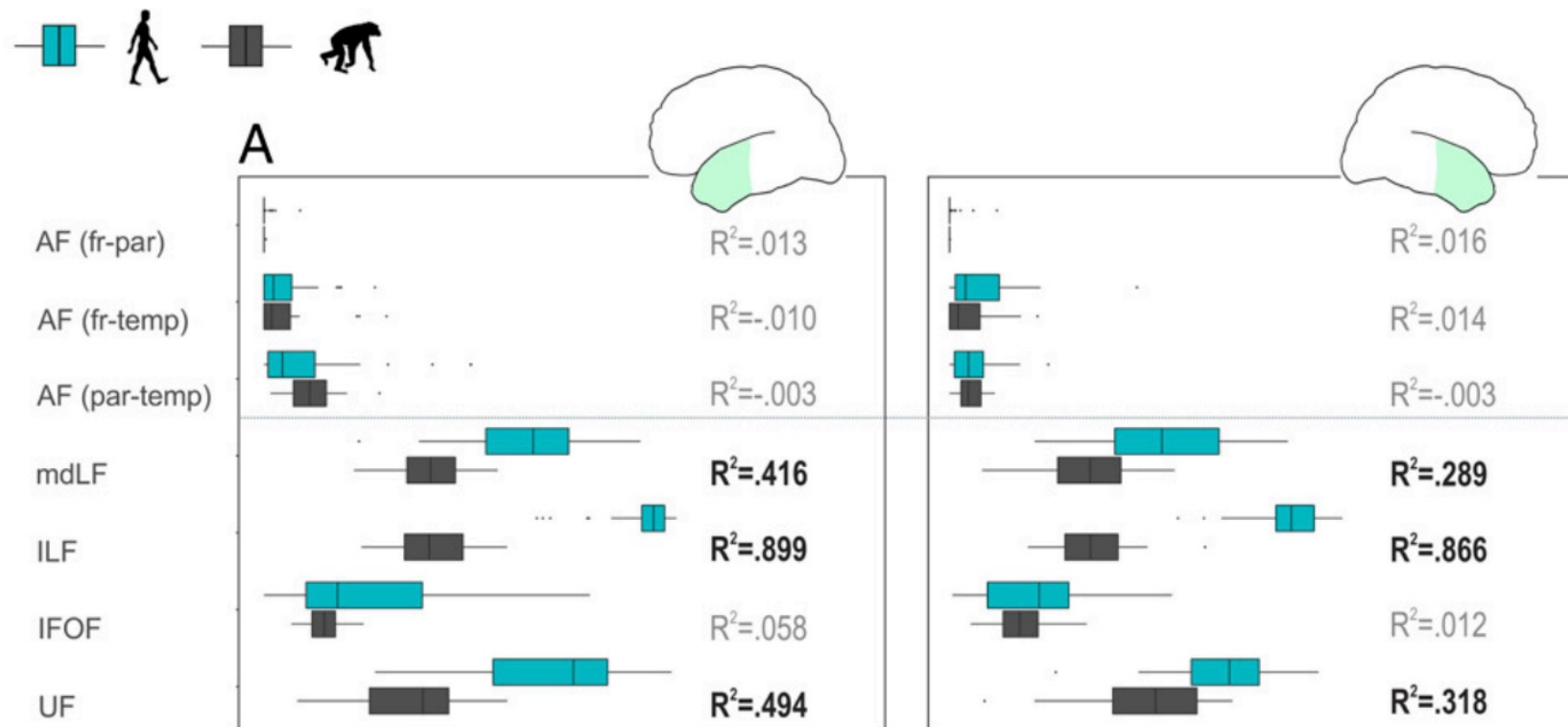


Rice, Lambon Ralph, & Hoffman (2015). The roles of left versus right anterior temporal lobes in conceptual knowledge: an ALE meta-analysis of 97 functional neuroimaging studies. *Cerebral cortex*, 25(11), 4374-4391.



Bryant, Glasser, Li, Bae, Jaquez, Alarcón, Fields & Preuss, (2019). Organization of extrastriate and temporal cortex in chimpanzees compared to humans and macaques. *Cortex*, 118, 223-243.

What if we examine ATL connectivity in humans and chimpanzees? -> ILF



Sierpowska*, Bryant*, et al. (2022)
PNAS, 119(28).

From Object Vision to Semantic Cognition: The Long View

- The temporal lobe is a primate specialization for visual object processing
- Haplorhine primates evolved specializations that increased fine-grain color vision
- Great apes evolved larger bodies and even larger brains with disproportionate association cortex expansion
- Our human lineage prominently features massive brain expansion, especially association cortex, since the Australopiths

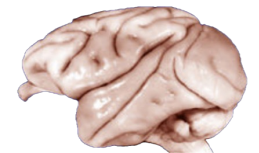
*Changes in size...
but are there changes in
architecture?*



Galago (Prosimian)



Squirrel monkey
(Platyrrhine/NWM)



Macaque
(Catarrhine/OWM)



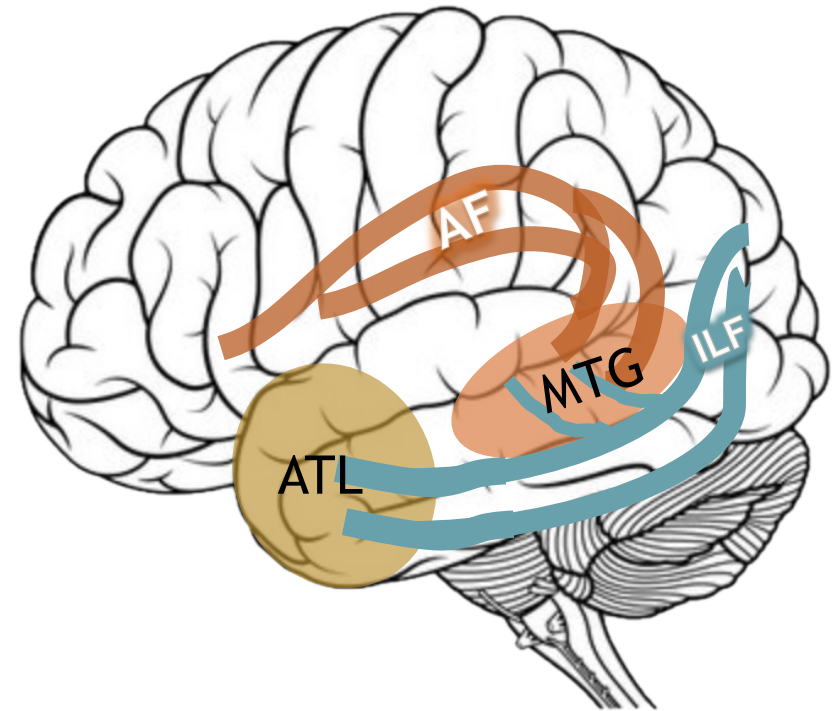
Human



Chimpanzee
(Homininae/Great Ape)

From Object Vision to Semantic Cognition: Human Neuroanatomical Specializations

- In hominoids (ancestor of great and lesser apes):
 - Arcuate expanded into PFC and the temporal lobe appeared in hominoids (the ancestors of great and lesser apes)
 - ILF duplicated
- In hominids (great apes), arcuate expanded further, into (new) MTG
- In humans only:
 - ILF and arcuate show coincident connectivity to MTG not found in our closest relatives
 - The ILF shows greater connectivity into ATL

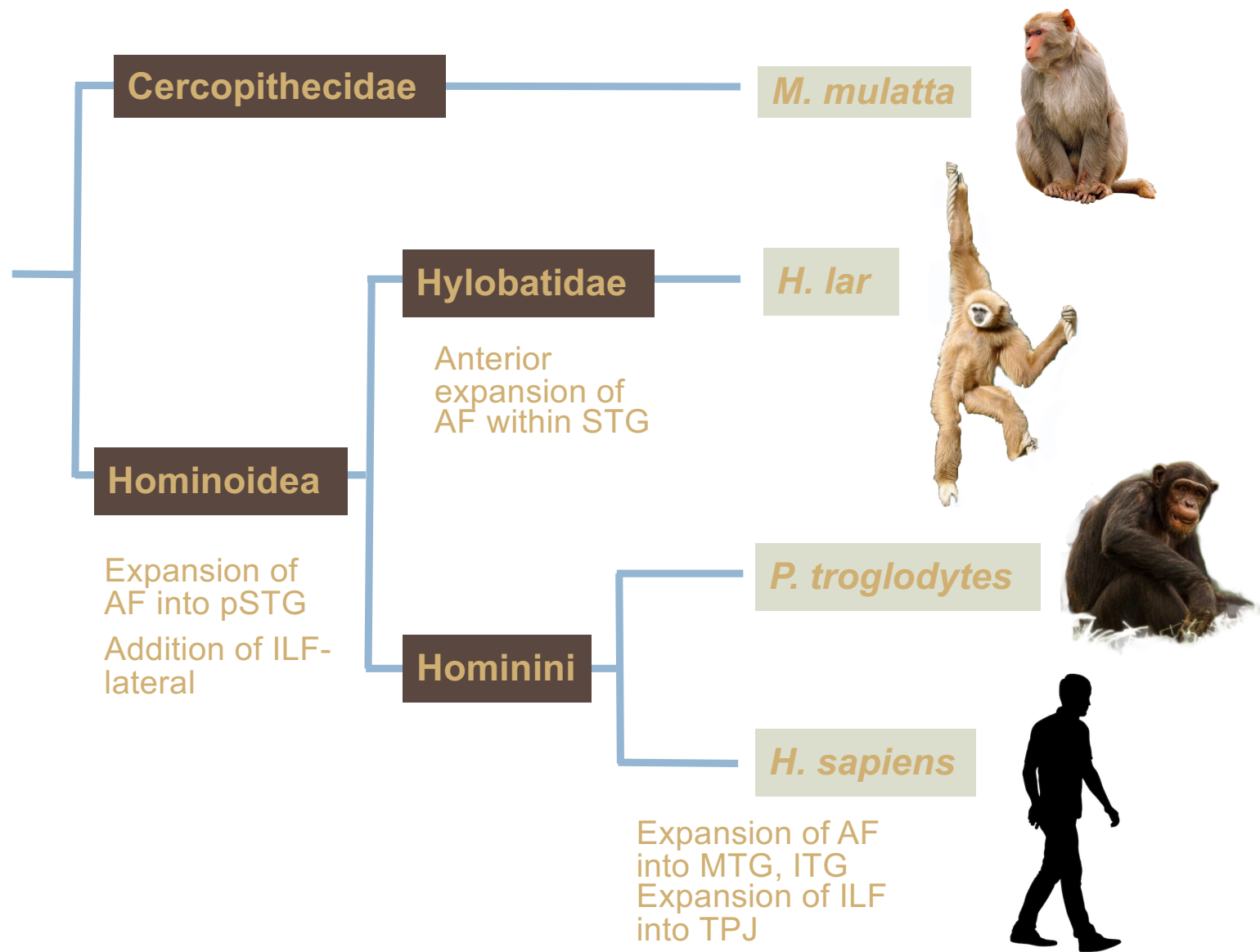


Originally a site of object vision processing in primates, human evolutionary modifications have co-opted the ventral visual stream to serve as a site for human semantic complexity

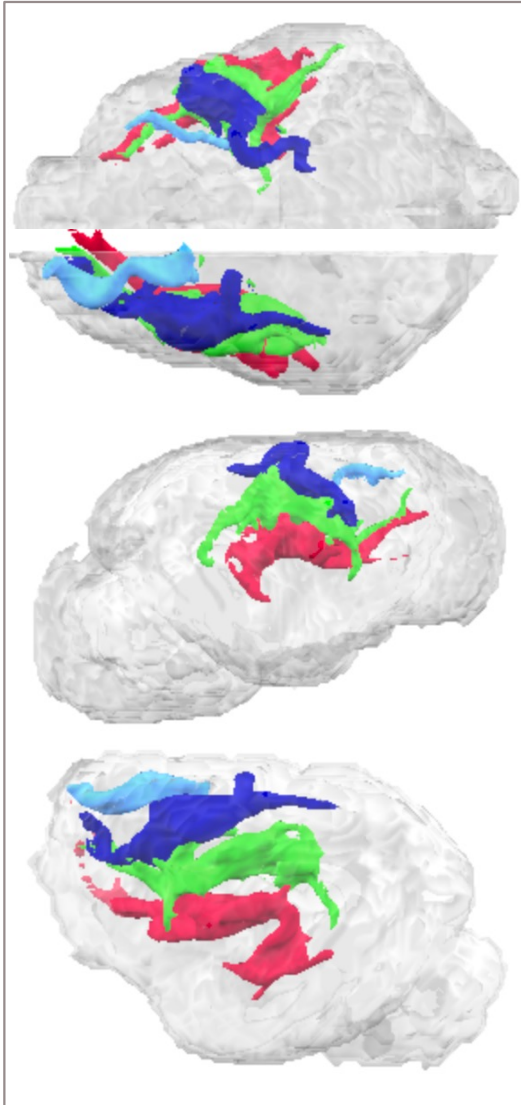
Thank you



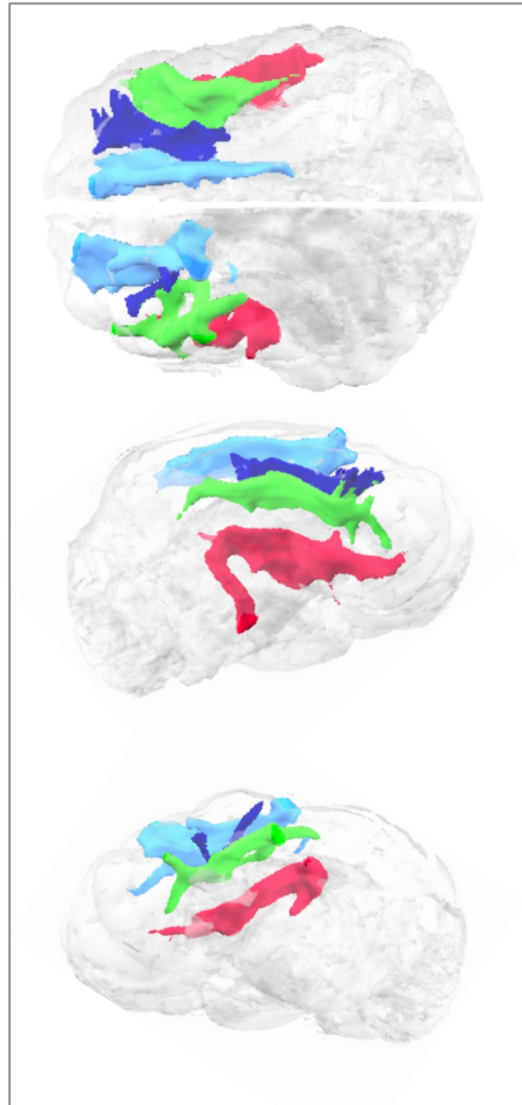
Find me @
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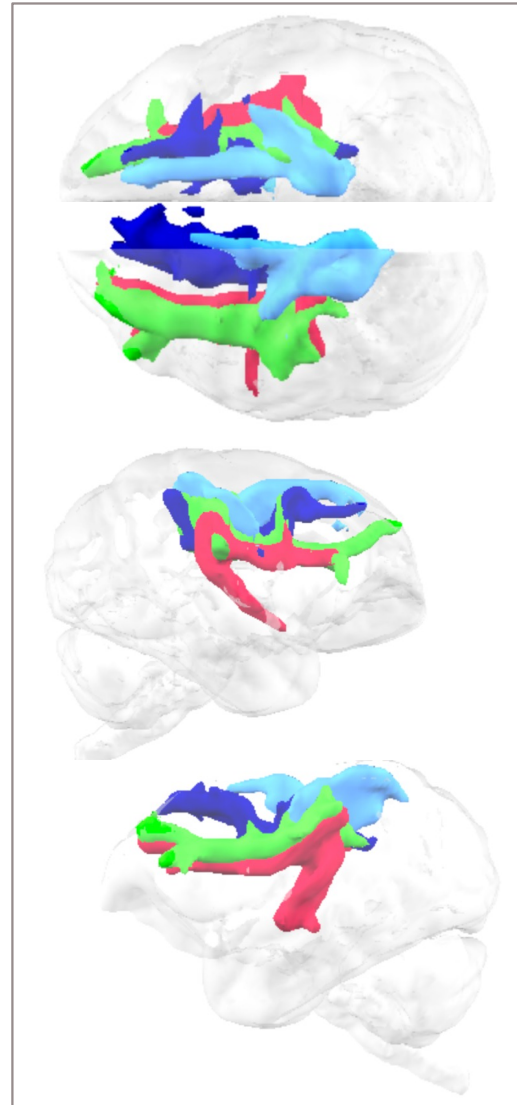
Dingo



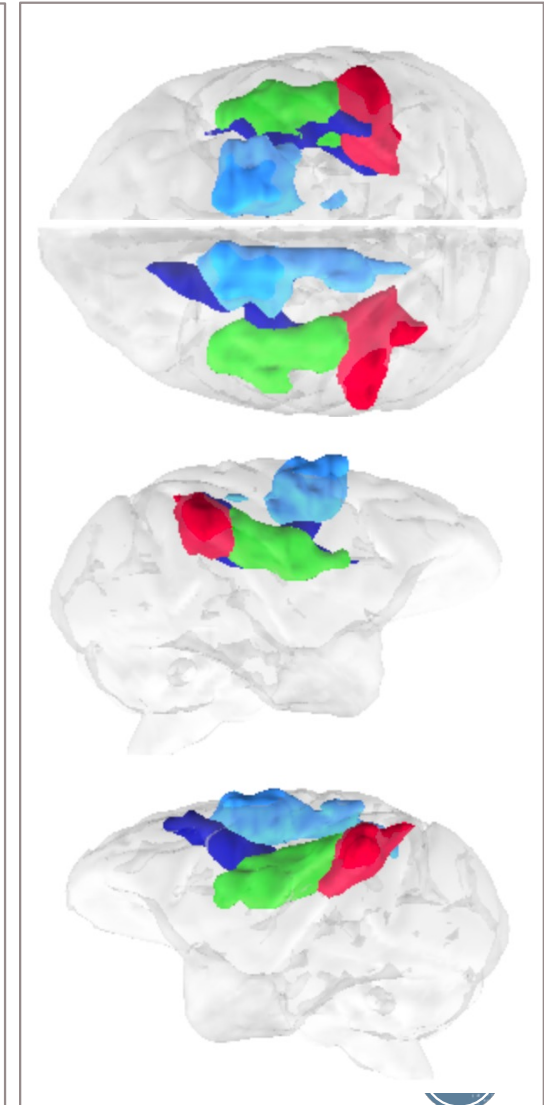
Red Panda



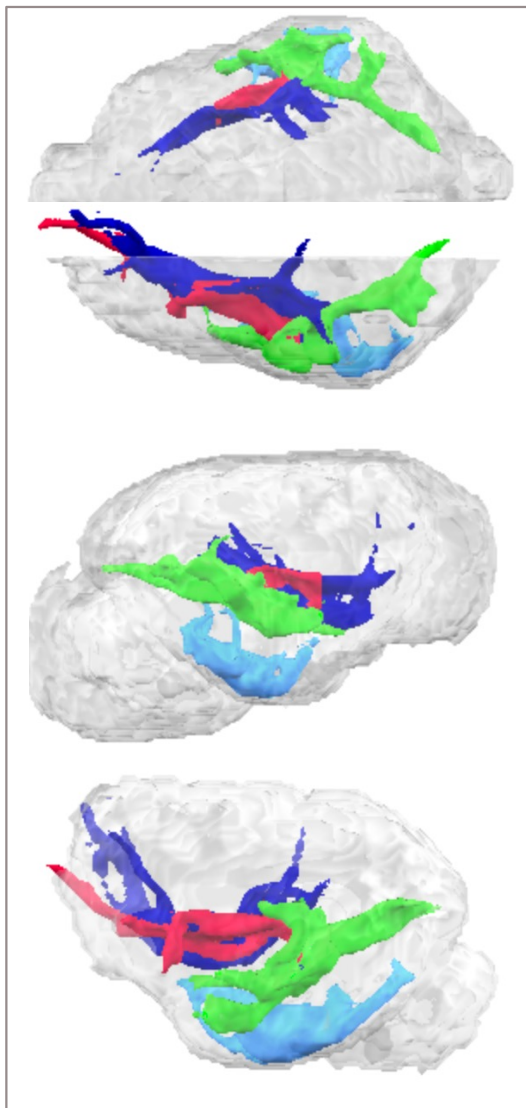
Gibbon



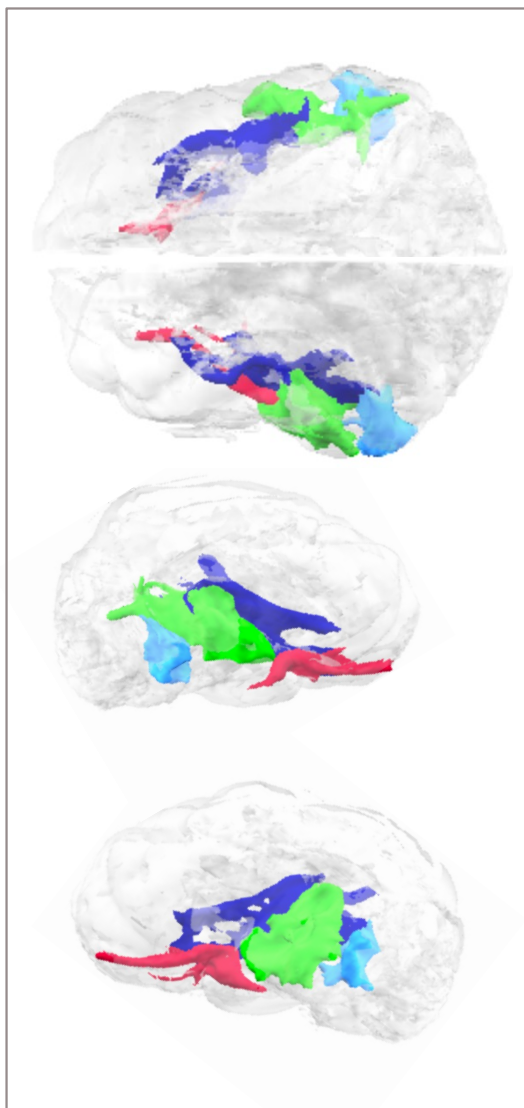
Macaque



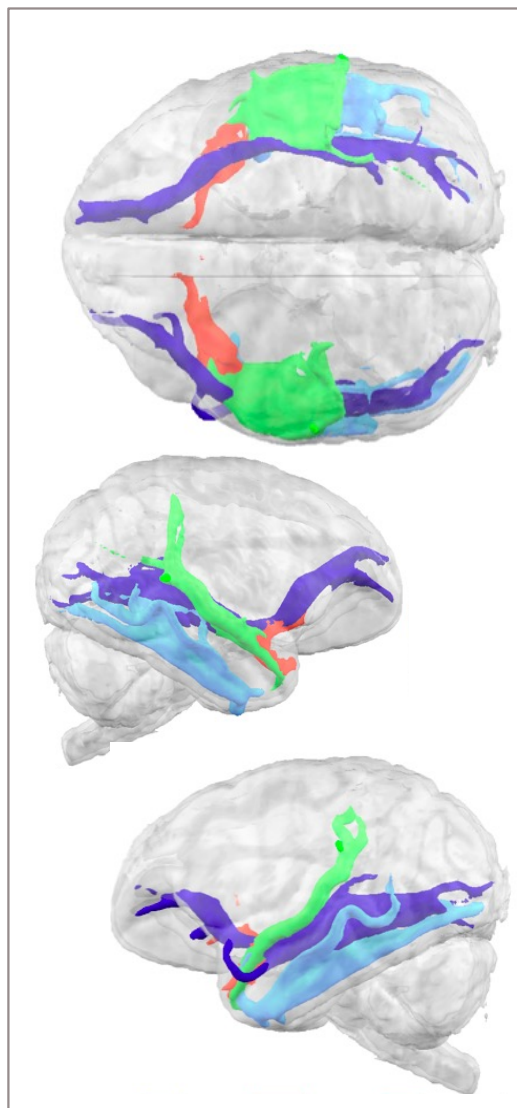
Dingo



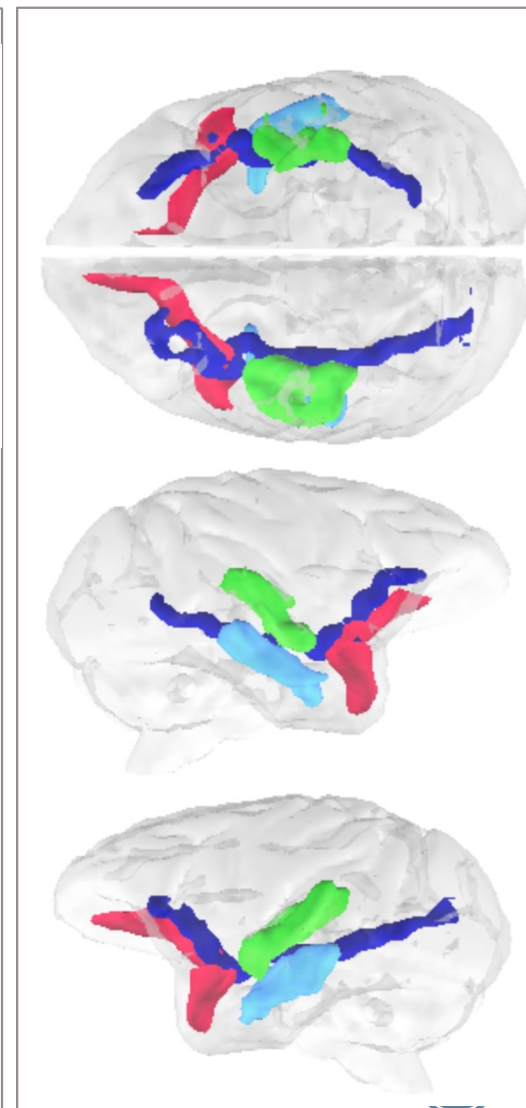
Red Panda

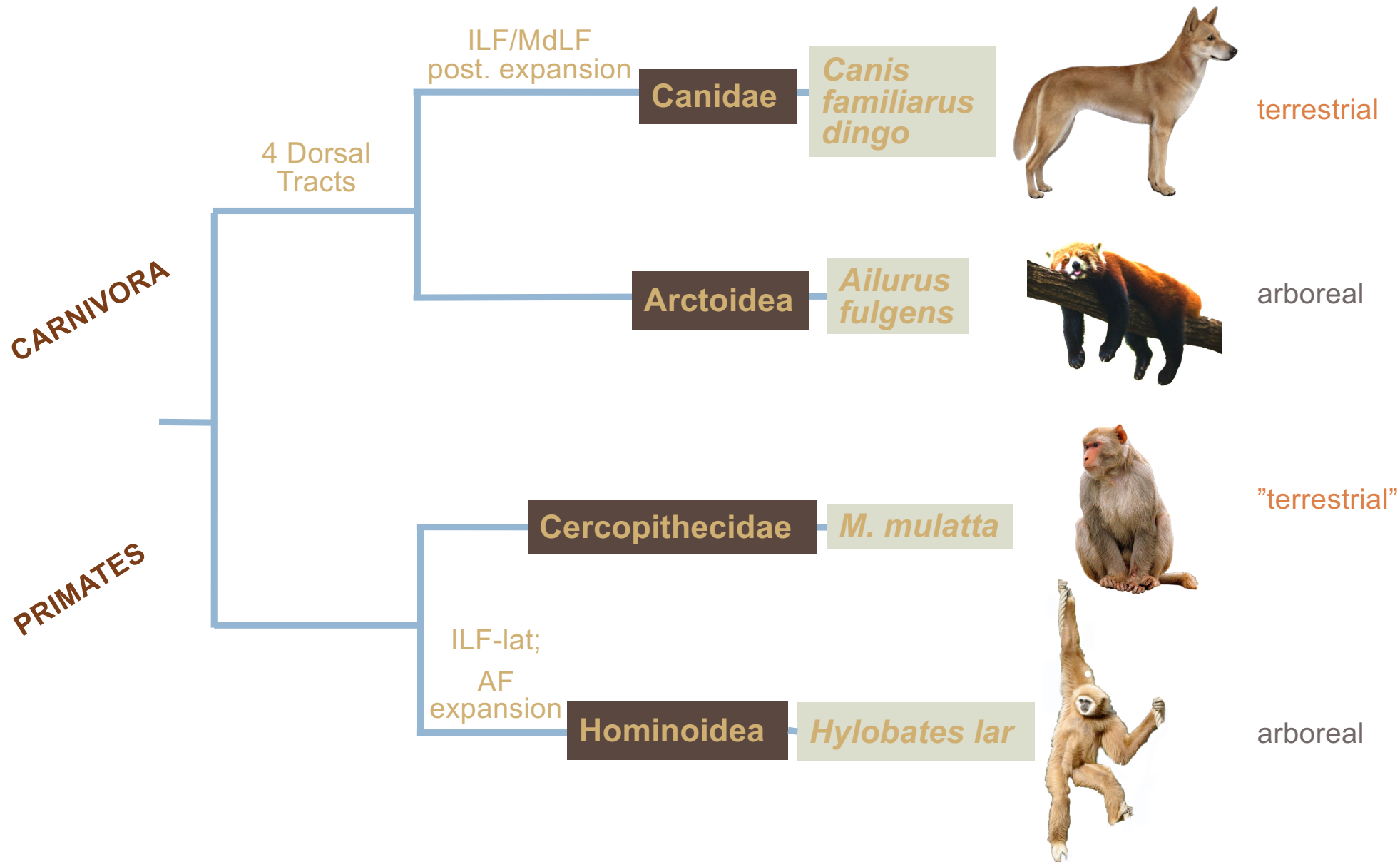


Gibbon

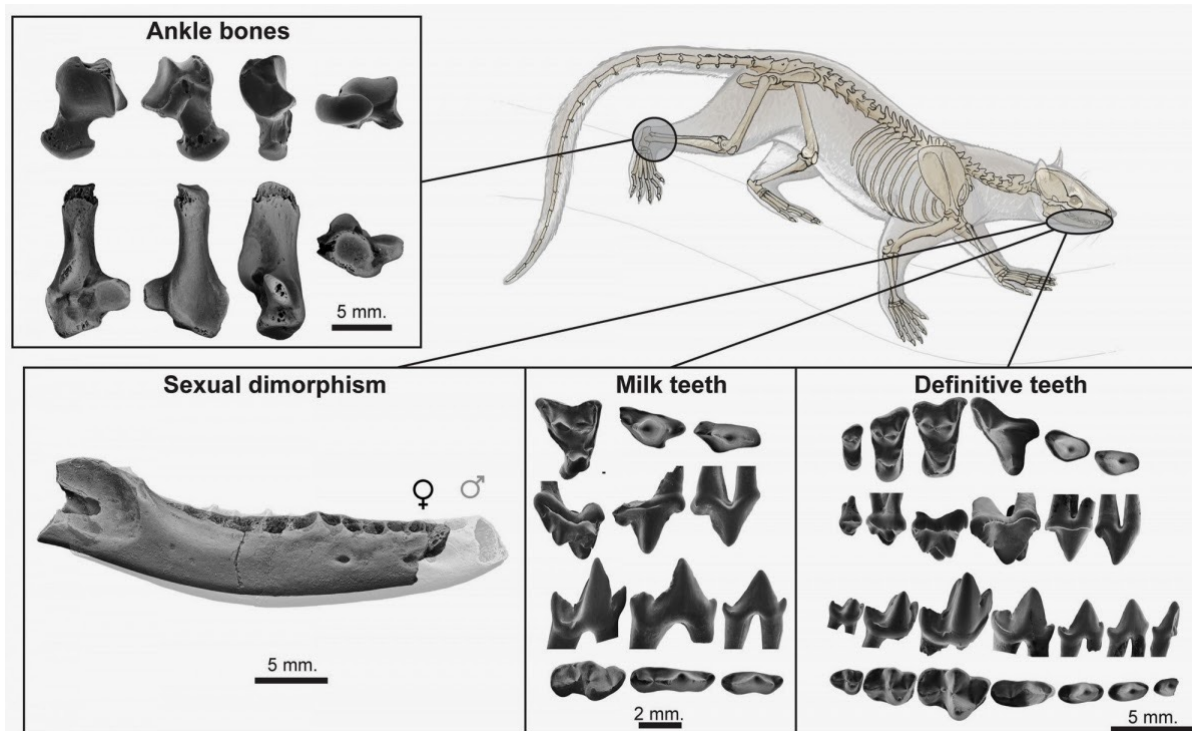


Macaque





First Carnivoran: *Dormaalocyon latouri*

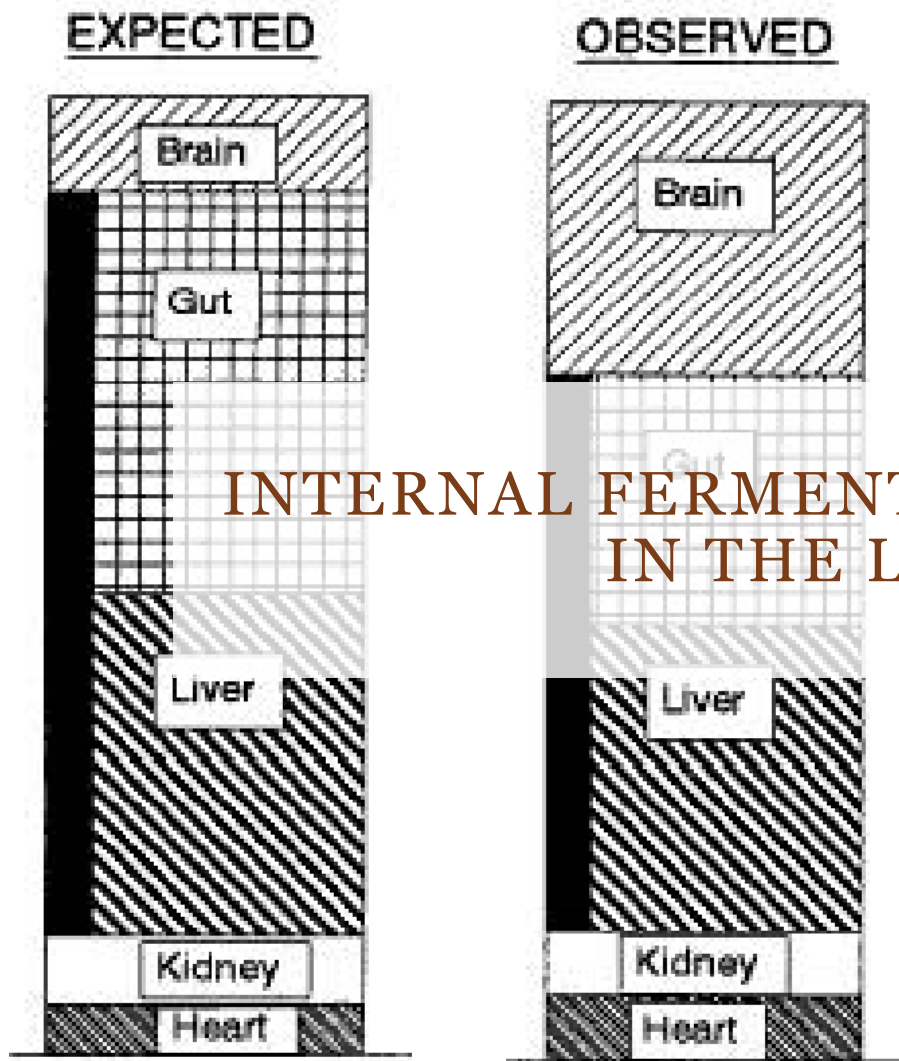


- Arboreal
- Genet-like
- Carnivores with tooth specializations (carnassials)
- Eocene
- Europe

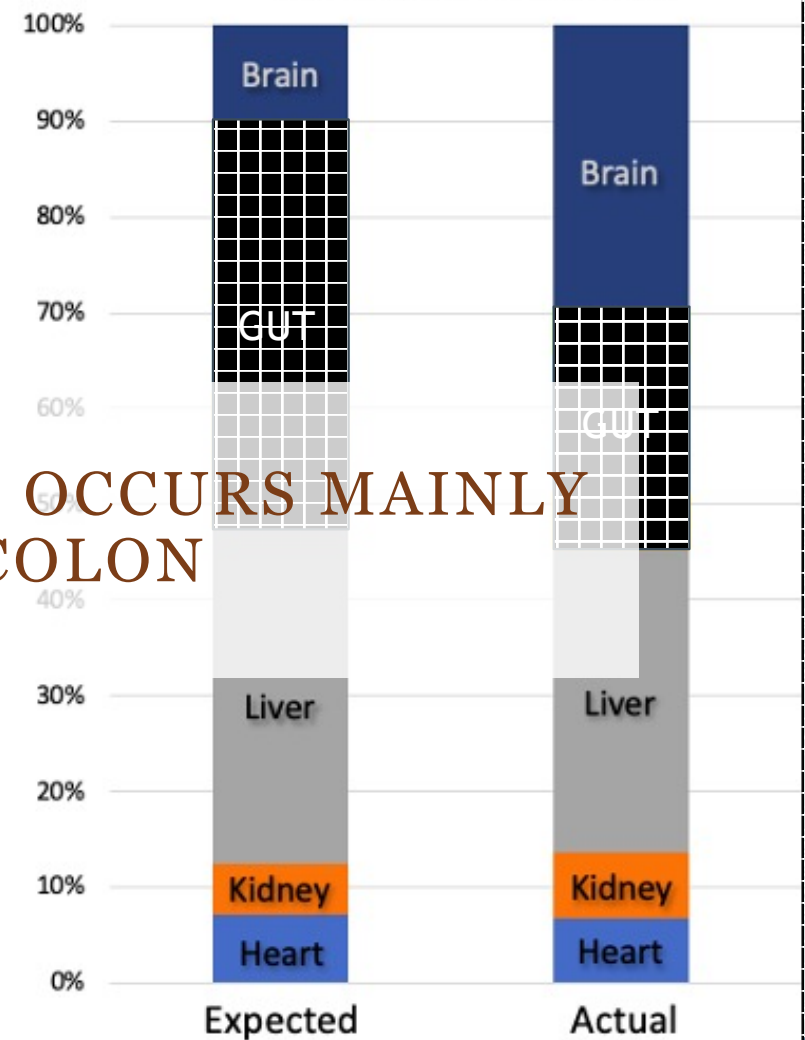
Solé, F. et al. (2014). Dental and tarsal anatomy of 'Miacis' latouri and a phylogenetic analysis of the earliest carnivoramorphs (Mammalia, Carnivoramorpha). *Journal of Vertebrate Paleontology*, 34(1), 1-21.

Supplemental slides

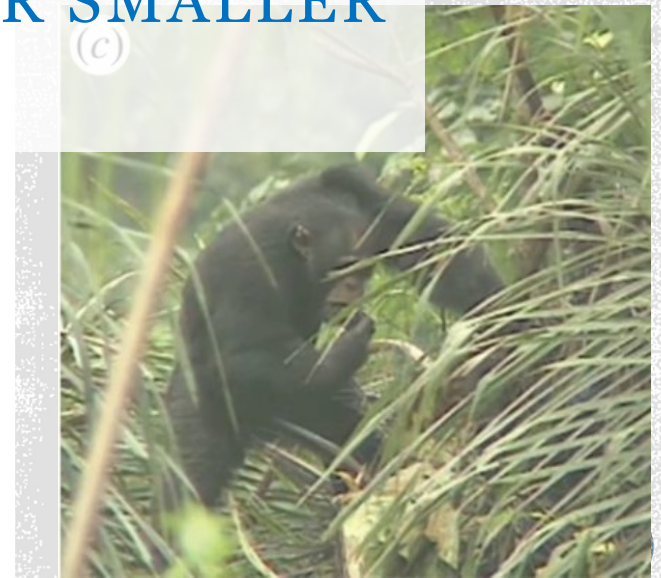




INTERNAL FERMENTATION OCCURS MAINLY
IN THE LARGE COLON



THE DISCOVERY OF EXTERNAL
FERMENTATION IS PLAUSIBLE FOR SMALLER
BRAINS



Hockings et al., 2015

Cooking vs External fermentation

- ❖ Clear mechanism for gut reduction (and jaw/tooth reduction)

- ❖ Cooking is universal among humans today

Fermentation

- ❖ Cooking renders food more digestible

- ❖ Modern-day humans tend to lose weight unsustainably on raw-only diets

Fermentation

- ❖ Controlling fire with a chimpanzee-sized brain?

- ❖ Earliest evidence for fire usage 1.5 mya (mid-*Homo erectus*)

- ❖ Brain expansion began in Australopiths before 2 mya

NO PROBLEM

Options for testing the hypothesis?



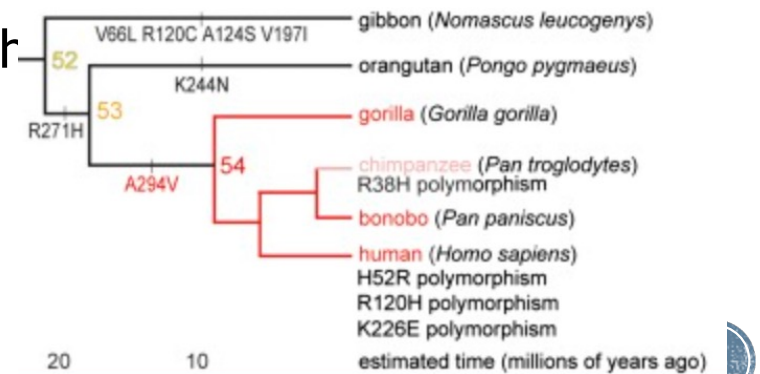
Summary of evidence for external fermentation

- ❖ Replaces fermentation functions in lost gut tissue
- ❖ Earliest traditional fermentations discovered accidentally
- ❖ Could be discovered via food caching
- ❖ Works for almost any food category (can complement existing theories)
- ❖ Promotes digestion and absorption of macro-and micronutrients
- ❖ Working memory, cooperation, strong executive functioning not needed → plausible for a human ancestor with a chimpanzee-sized brain

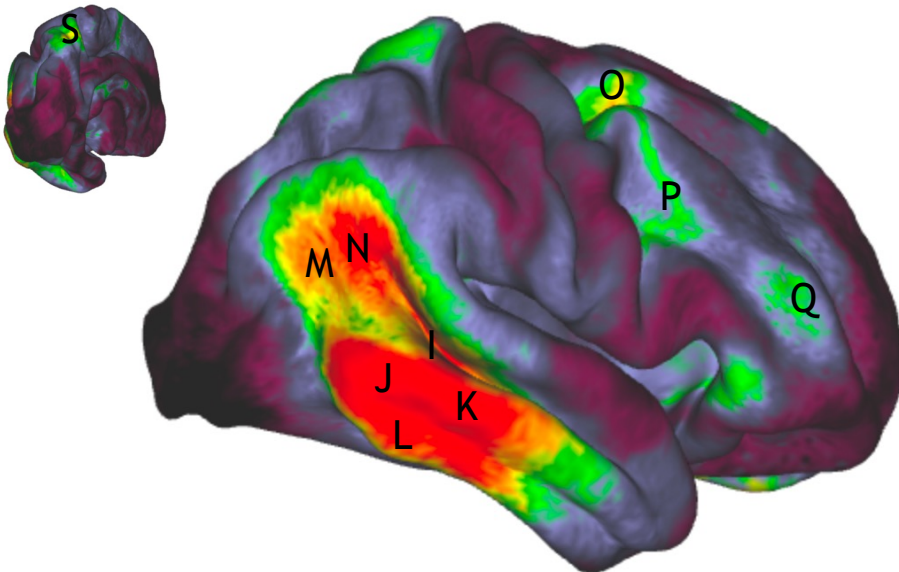
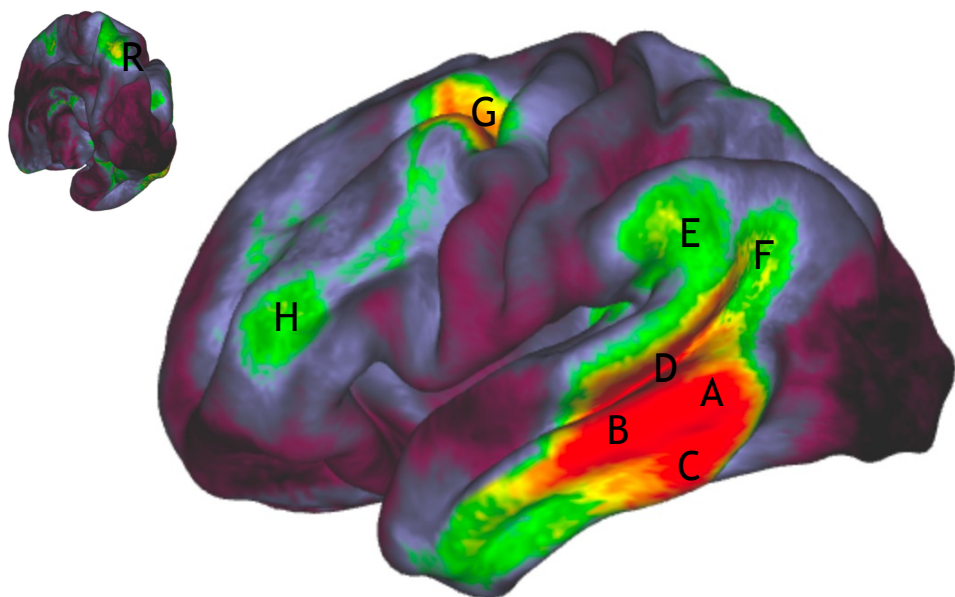


Additional Evidence for external fermentation

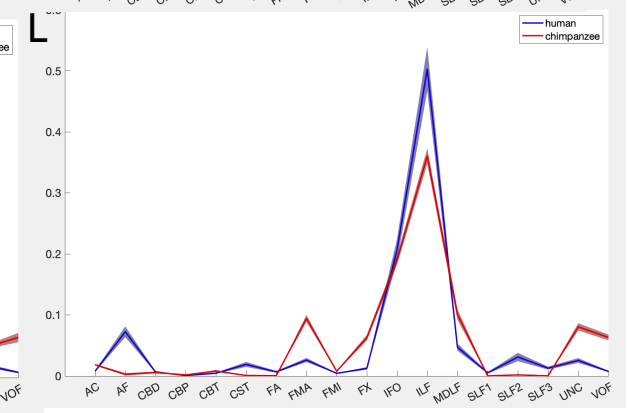
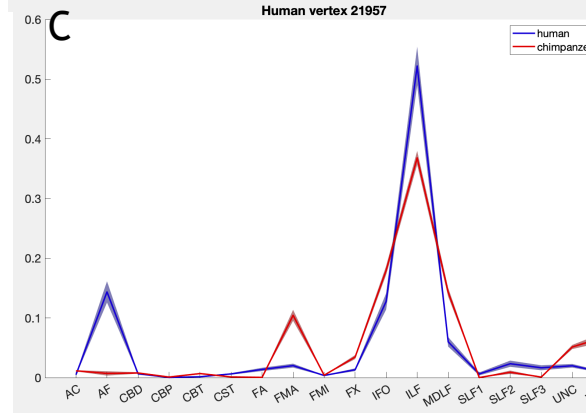
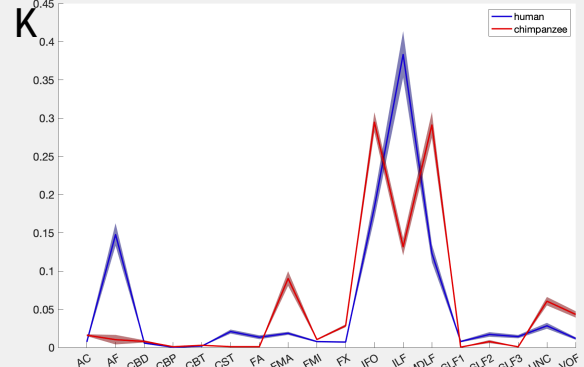
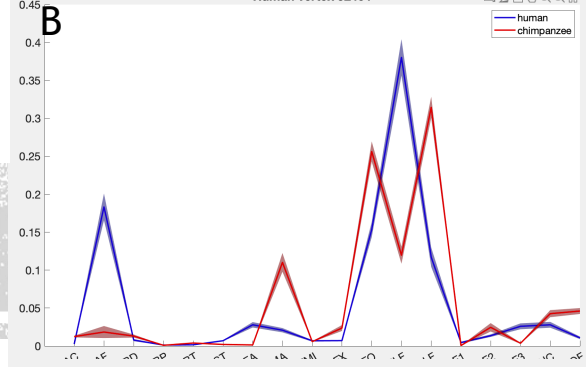
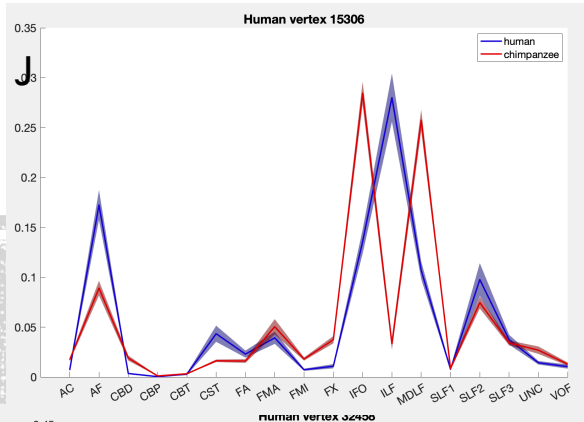
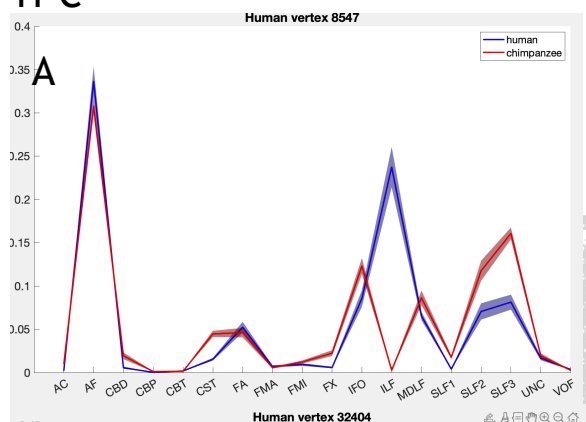
- ❖ Evidence for recent evolution of ability to metabolize fermentation metabolites (ADH4: alcohol/great apes) and taste preferences (apes' preference for sour flavors)
- ❖ Good strains could be fostered through reuse of caching sites
- ❖ Promote gut, immune, and brain health
- ❖ Tasty



Carrigan et al., 2016



H-C



H-C

