Megadontia and bipedalism

Did habitual bipedalism evolve in early hominids to reduce the energetic costs of increasing head weight?

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Many theories for the evolution of habitual bipedalism

- Tool use (Darwin, Washburn)
- Food carrying, male provisioning, on the savanna (Etkin, Lovejoy)
- Energy efficient locomotion (Rodman & McHenry, Isbell & Young)
- Thermoregulation (Wheeler) Increased viewing distance (Dart)
- Threat display behavior (Livingston)
- Wading (Hardy, Verhaegen, Kuliukas)
- Suspensory feeding (Tuttle)
- Postural feeding (de Brull, Hunt, Jolly)

It is fair to say there is no consensus on a correct theory

Whatever their other merits, many are difficult to prove or disprove

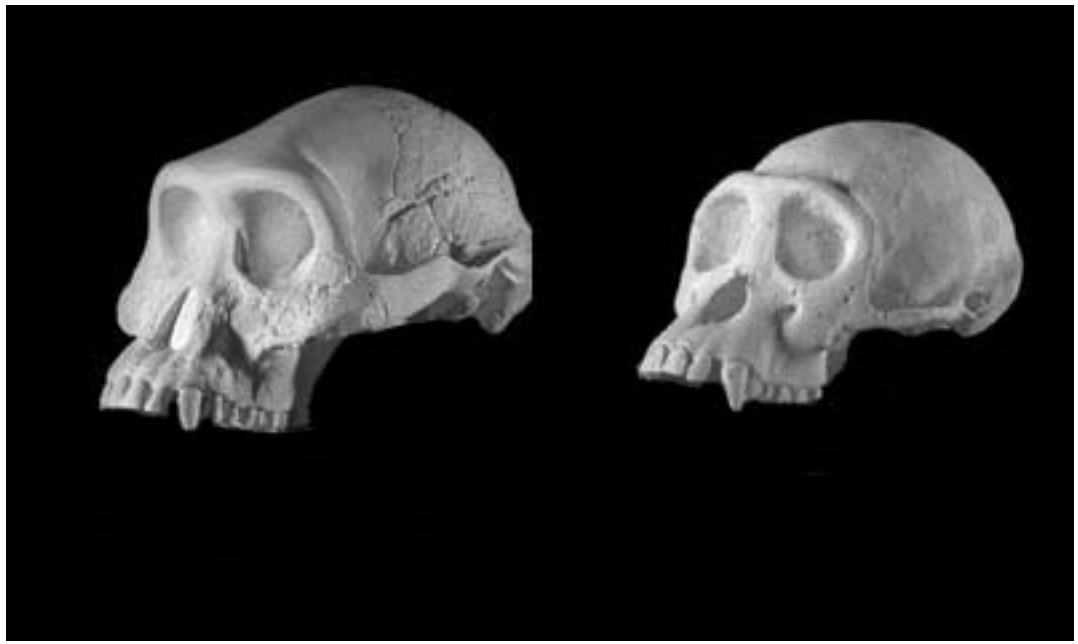
Yet another theory!

Whatever its other merits, this one should be relatively easy to disprove…

Could the evolution of three distinctly hominid morphological traits be causally linked?

- Megadontia
- Reduced canines
- Bipedalism

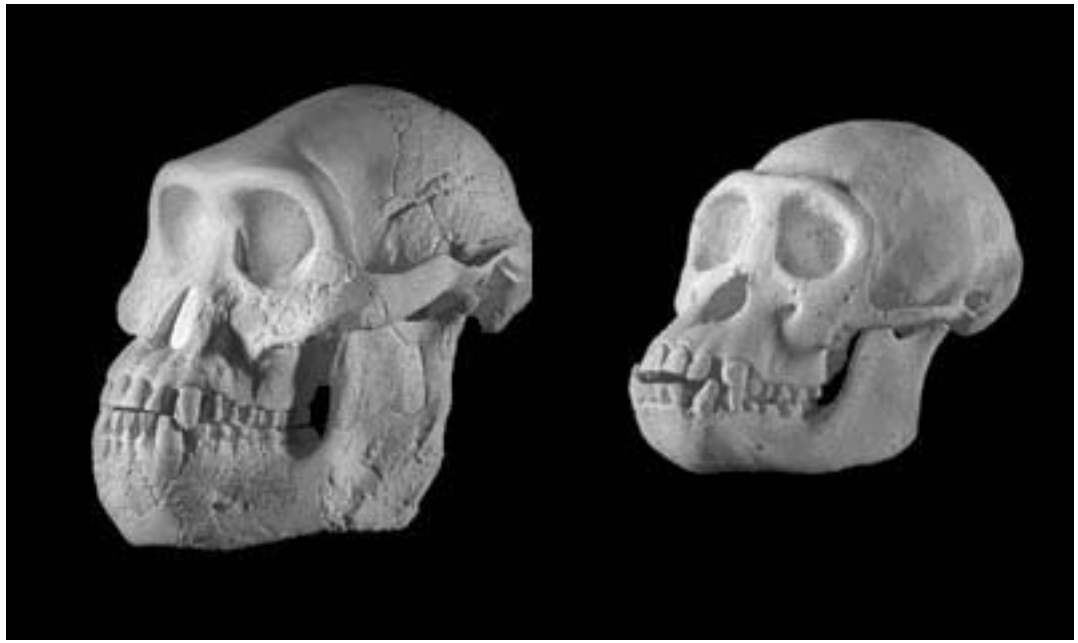
Brain size is about the same…



***A. afarensis* composite** **Chimp**

To scale

But that's a HUGE jaw!



***A. afarensis* composite** **Chimp**

To scale

But that’s a HUGE jaw!

***A. afarensis* composite** **Chimp**

Not to scale

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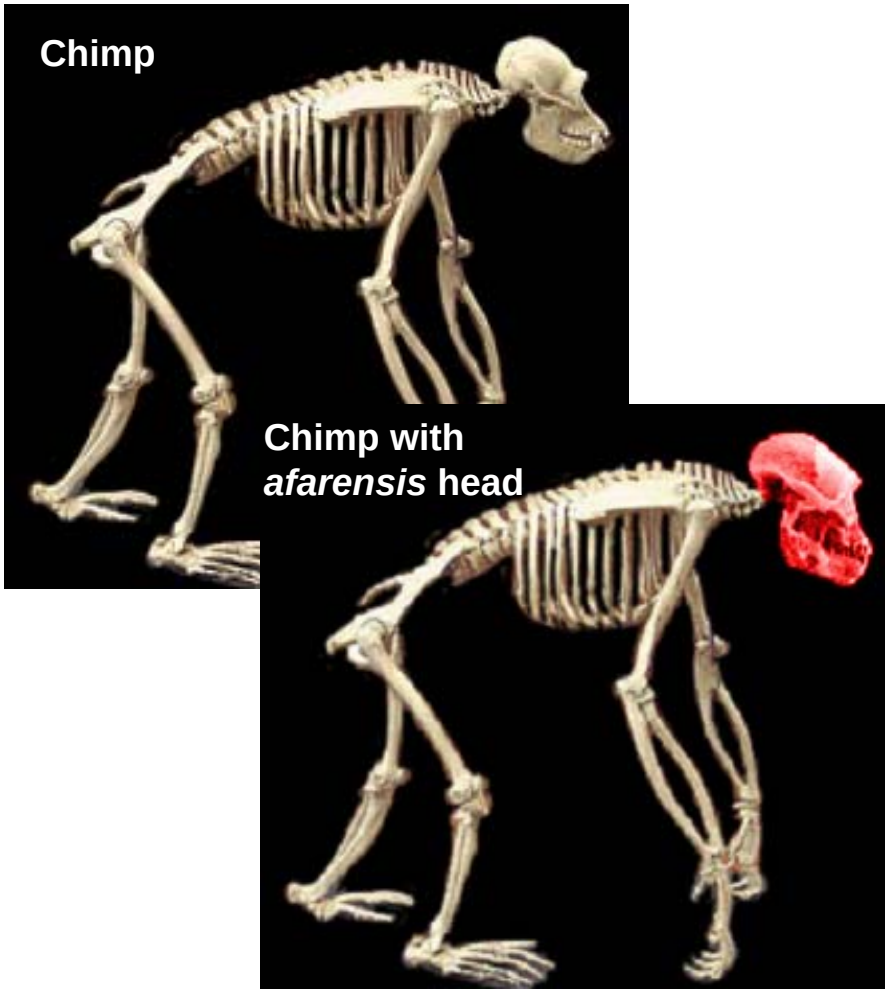
Given the weight of the huge jaw plus its associated chewing muscles, was there an energetic advantage to habitual bipedalism?



Heavier head is dynamic load

Heavier head is static load

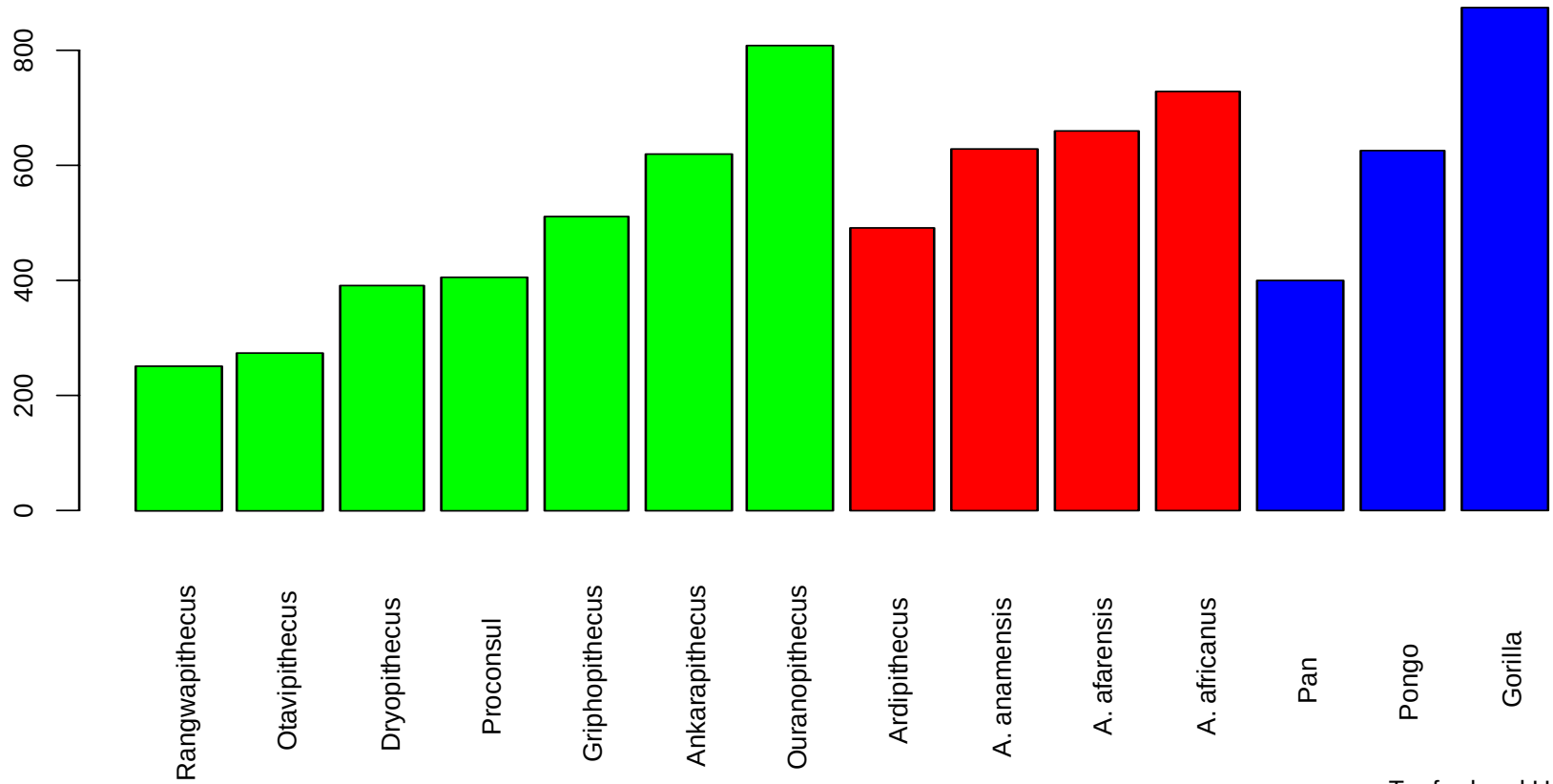
Energetic advantages of bipedalism given huge jaw

- Head is static load (cheap), not dynamic load (costly)
- Neck muscles can be reduced
  - Lower development cost
  - Lower maintenance cost
- Tradeoff: neck muscles vs. chewing muscles (costly to have both)

Bipedalism is well-suited for carrying large weights atop the spine

But, e.g, gorillas have large jaws and heavy heads…

Was hominid dentition exceptionally large?



Teaford and Unger 2000

Mandibular postcanine area (P4-M3), not corrected for body size

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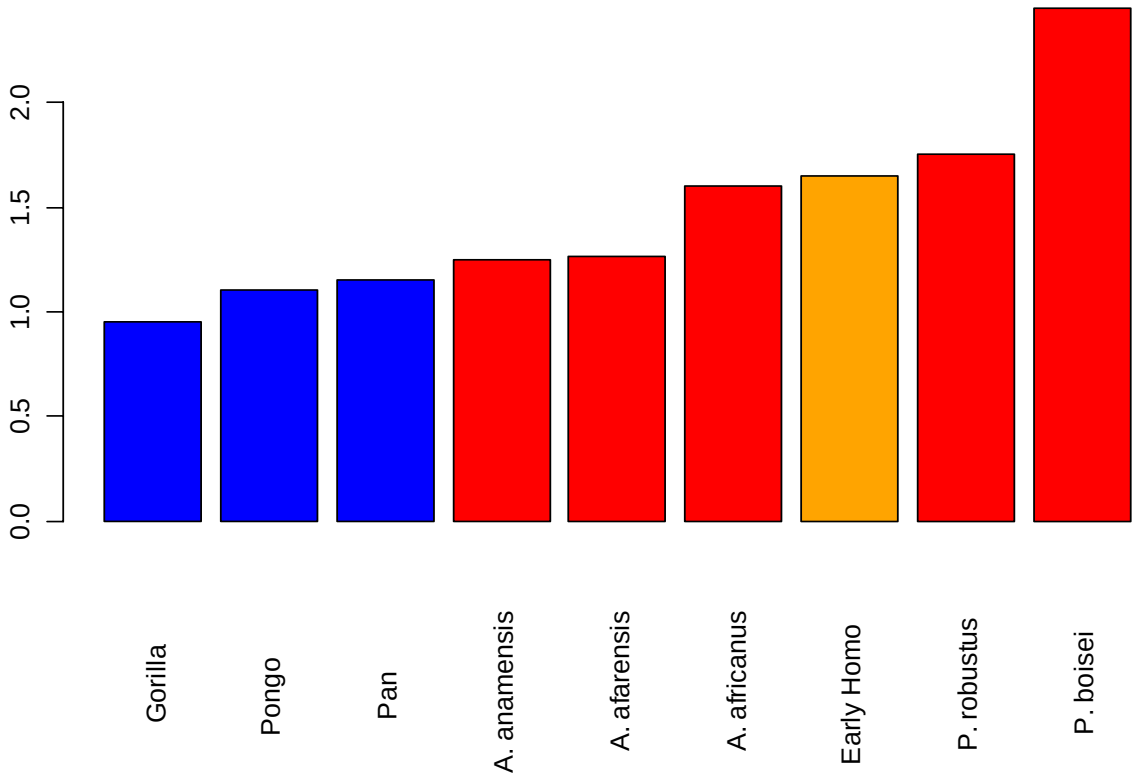
Hominid dentition was exceptionally large



Teaford and Unger 2000

Megadontia quotiont: postcanine size corrected for body size

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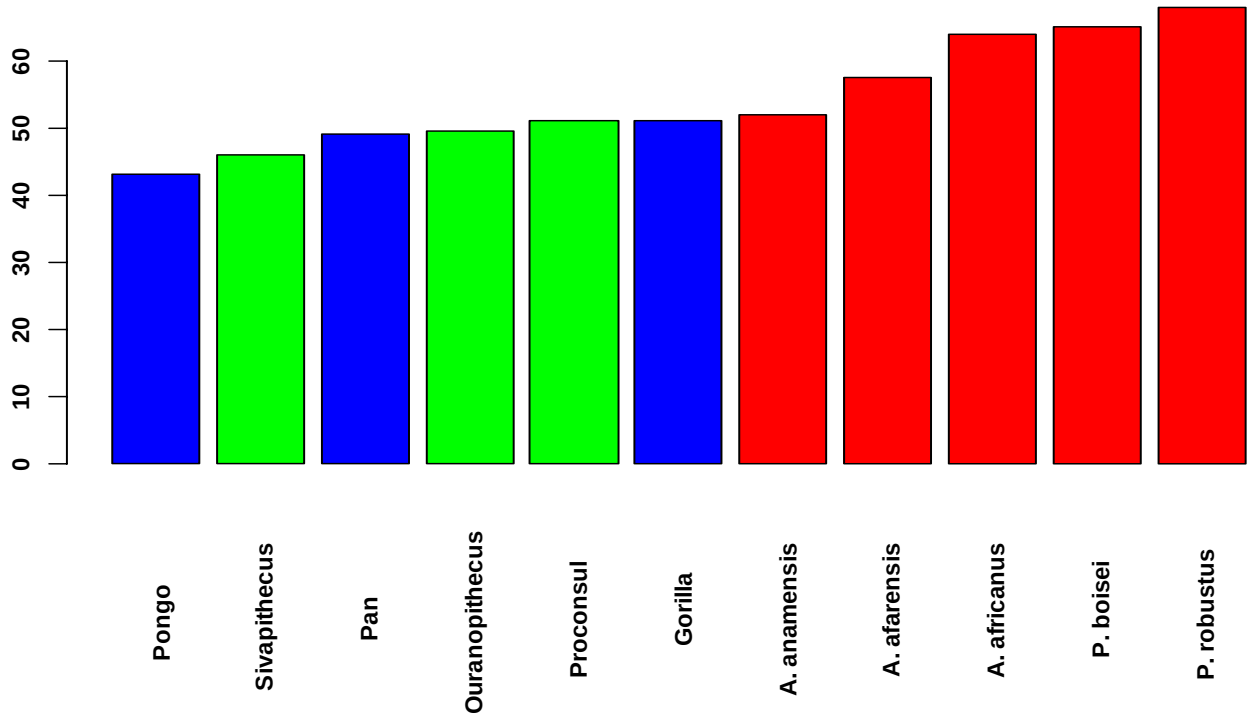
Hominid jaws <u>were</u> exceptionally large



Teaford and Unger 2000

Mandibular corpus index: breadth/height

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But other animals have large heads…

Why this cost-saving strategy could evolve in apes but not many other taxa

- Apes were pre-adapted for habitual bipedalism.
- Apes had grasping forelimbs that could bring food to the mouth, enabling a flexible feeding strategy.
- A habitual biped would have been especially vulnerable to foot injuries, but apes could reduce this vulnerability:
  - Many apes have complex social organization that provided pre-adaptations for the mutual care possibly necessary to buffer foot injuries.

Canine reduction linked to reduced neck muscles

Powerful chewing muscles do increase puncturing ability, but if neck muscles are weak, can't fight effectively using canines

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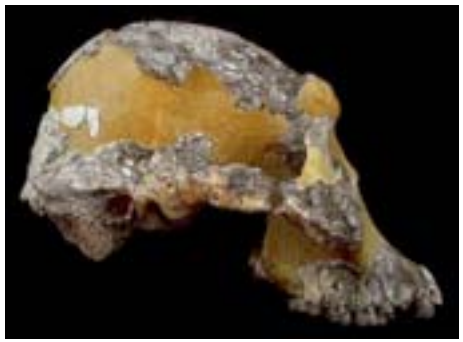
The jaw-size/head-weight theory is easy to falsify

- Were bipedalism and megadontia linked in the earliest hominids?
  - *Sahelanthropus tchadensis*
  - *Orrorin tugenensis*
  - *Ardipithecus ramidus (*Teaford and Unger: megadontia quotient similar to *afarensis?)*
  - *Oreopithecus?? (Rook et al. 1999)*
- Was head weight significantly greater?
- Were energetic costs therefore significantly increased in a quadruped?
- Would bipedalism have significantly decreased costs?
- Is direction of causality in the other direction (bipedalism permits a large jaw)?

Final speculation



Divergence from chimps (c. 7-5 mya)

Emergence of Homo (c. 2 mya)

Modern Human (c. 0.25 mya)

Human evolution can be characterized by an increase in brain size and a corresponding decrease in jaw size

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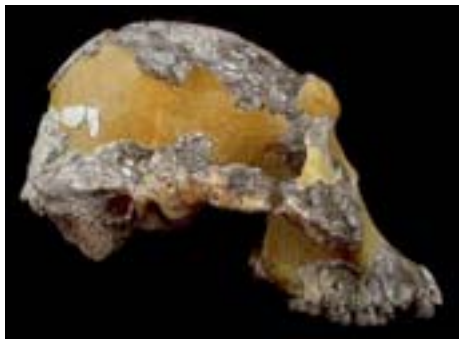
Final speculation



Divergence from chimps (7-5 mya)

Emergence of Homo (2 mya)

Modern Human (0.25 mya)

By enabling the carrying of an exceptionally heavy head, did bipedalism ‘open the door’ to a larger brain?

Cf. Stedman et al. 2004

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Could carrying increased head weight be at least one selection pressure for bipedalism?

Did bipedalism therefore permit the evolution of an exceptionally large brain?

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