

Human evolution

Patterns of evolution

Our recent history

Sociality

Learning about the past

Outline

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Context for evolution

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Primates

Apes

Hominins

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Humans as an example

- ▶ We are an example of a biological species that has evolved
 - ▶ Many of your friends are probably humans
- ▶ Humans seem unique:
 - ▶ How do they differ from other evolved organisms?
 - ▶ What do they share with other evolved organisms?



Similarities and differences

- ▶ What is different about people?
 - ▶ * Complex thoughts
 - ▶ * Culture
 - ▶ * Language
 - ▶ * Technology
- ▶ What is the same?
 - ▶ * Genetic code, biochemical processes
 - ▶ * We're here because our ancestors reproduced
 - ▶ * *If* our current reproductive success depends on heritable variation in traits, *then*:
 - ▶ * We're still evolving
 - ▶ * In what direction or directions?
 - ▶ * For how long will natural selection push us in the same direction as now?

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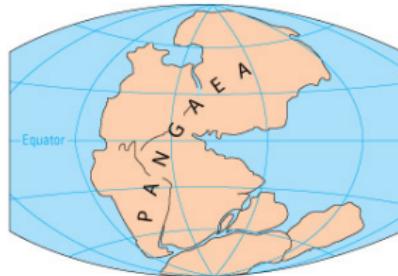
Learning about the past

Context for evolution

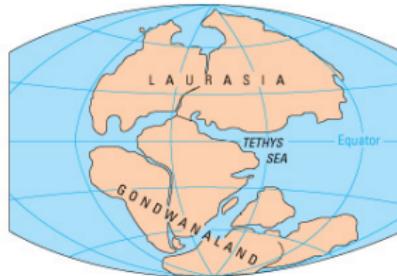
- ▶ Adaptations build on existing adaptations – often in unexpected ways
- ▶ Evolution does not know where it's going
- ▶ In a constant environment, species can only improve with gradual adaptations to the same environment
 - ▶ and will be in danger of getting “stuck”, e.g. vertebrate eyes
- ▶ A changing environment provides opportunities to try new combinations and build in unexpected directions

Physical changes

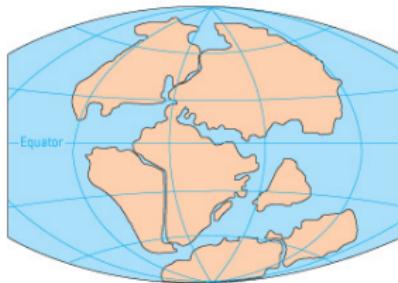
- ▶ Physical changes often provide species with new adaptive challenges and opportunities:
- ▶ Global climate change
- ▶ Continental drift
- ▶ Geological changes
 - ▶ New environments can arise (e.g., mountain ranges, desert basins)
 - ▶ Geology may also change connections between two populations without a large effect on how they live
 - ▶ Rivers changing course
 - ▶ Mountain ranges separating valley species
 - ▶ * Provides opportunities for allopatric speciation



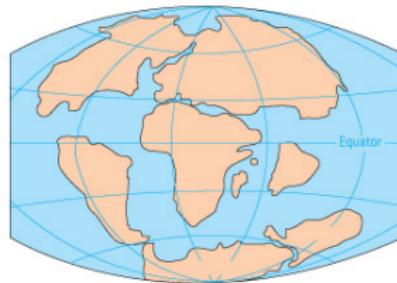
PERMIAN
225 million years ago



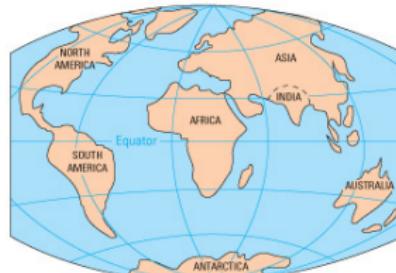
TRIASSIC
200 million years ago



JURASSIC
150 million years ago



CRETACEOUS
65 million years ago



PRESENT DAY

Changing ecosystems

- ▶ Taxa can be dramatically affected by changes in other taxa
 - ▶ Due to evolution or to colonization
- ▶ Interactions with other organisms are key to most ecological niches
 - ▶ Who do I eat? Who is trying to eat me? How do I reproduce?
- ▶ Co-evolution is a key driver of diversity. For example:
 - ▶ Plants evolve new ways to use insects for sex, or vertebrates for dispersal
 - ▶ Animals evolve new ways to benefit from plant resources





Mammalian ancestors

- ▶ Our ancestors, the **therapsids**, radiated and dominated many terrestrial environments *before* dinosaurs did
- ▶ Therapsids were largely replaced by dinosaurs in the age of dinosaurs
 - ▶ But some survived, and one radiated after a mass extinction

Radiation and contraction

- ▶ Many clades seem to go through periods of radiation and contraction
 - ▶ Gain and then loss of species diversity
- ▶ Examples:
 - ▶ Therapsids, apes, hominins (us)
- ▶ Radiation gives many chances for adaptation
 - ▶ Things that have had radiations may be more likely to persist
 - ▶ Even after periods of contraction

Reasons for contraction

- ▶ What are some reasons that a diverse clade suffer many extinctions?
 - ▶ * Changing conditions (climate change, continents moving)
 - ▶ * Competition from other clades (therapsids vs. dinosaurs)
 - ▶ * Competition from a successful member (people vs. other hominins)

Interpreting patterns

- ▶ We see a lot of clades with a history of radiations
 - ▶ Meaning, they radiated and then contracted again
- ▶ Does that mean most clades radiate more than once?
 - ▶ * Maybe we're more likely to notice certain clades
 - ▶ * Clades with a history of radiations may be more successful

Survivorship bias

- ▶ Bias arises from the fact that we're much more likely to observe successful taxa
 - ▶ * Unlikely adaptive mutations
 - ▶ * Weird speciation events (e.g., sunflower hybrids)
 - ▶ * Polyploidy and other duplications
 - ▶ * Organisms literally combining! mitochondria, chloroplasts

Advantages of previous radiation

- ▶ A clade that has radiated in the past may have advantages even after it contracts
- ▶ They've explored more kinds of environments
- ▶ They're found in more different specific places
 - ▶ e.g., marsupials in Australia
- ▶ They've had more chances to adapt
 - ▶ May have a few very successful species (like us)

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Primates

- ▶ Humans are **primates**, an “order” characterized by
 - ▶ Highly developed **stereoscopic** vision
 - ▶ Eyes are close together, face forward, and are used together
 - ▶ Allows 3-d visualization
 - ▶ Versatile limbs
 - ▶ Grasping hands and feet
 - ▶ Nails and fingertips (instead of claws)
 - ▶ Large brains
 - ▶ * Compared to related groups of mammals

Primates (present)

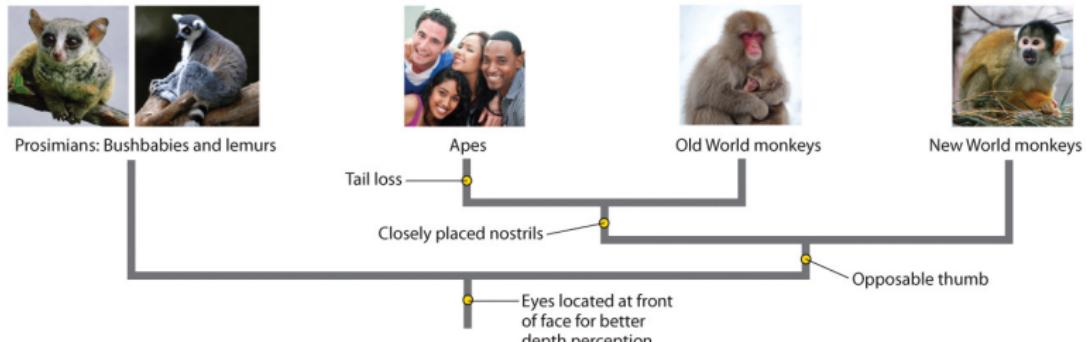


Figure 23.1
Biology: How Life Works
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(Left to right) George Holton/Science Source; Penelope Deaman/Getty Images; Yellow Dog Productions/Getty Images; Patrick Shyu/Getty Images; Lavan Pawson/ANL/REX/Shutterstock

Observing ourselves

- ▶ We used to think people were far from chimps and gorillas
 - ▶ * **Observer bias**
 - ▶ * Scientists are human, which gives us a particular perspective
 - ▶ * Phenetic approaches: humans have a lot of adaptations
 - ▶ * And we're good at recognizing them – more observer bias

The angiosperm explosion

- ▶ Flowering plants diversified very rapidly around 100 **mya** – million years ago
- ▶ This radically changed the ecology of the world, and opened up many new niches, apparently including space for primates





Primate adaptations

- ▶ There are a variety of theories for how characteristic primate adaptations evolved
- ▶ Each step was likely favored adaptively
- ▶ Likely something to do with processing and handling angiosperm fruit and flowers
 - ▶ Or else the insects that fed on these fruit and flowers

Adaptive theories

- ▶ There are many theories for why primate traits might have been adaptively favored in our ancestors
 - ▶ Leaping from branch to branch
 - ▶ Climbing and balancing on trees
 - ▶ Exploiting new plant resources
 - ▶ Catching insects
 - ▶ **Adaptive foraging:** the ability to switch between types of food, and to learn to use new types of food
 - ▶ This is a different use of the word “adaptive”
 - ▶ * Adaptive foragers can respond differently in different situations
 - ▶ * More analogous to acclimation

Adaptive looping

- ▶ Sometimes adaptations can reinforce each other:
 - ▶ Bigger brains may increase selection for adaptive foraging
 - ▶ Needing to process more types of food may increase selection for clever hands
 - ▶ More clever hands may increase selection for good stereoscopic vision
 - ▶ Ability to see and manipulate things in front of you may increase selection for bigger brains ...
- ▶ Which meaning of adaptive is at the top of this slide?
 - ▶ * The evolutionary one

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Apes

- ▶ Apes are more adapted for swinging through trees, whereas monkeys are more adapted for climbing and leaping
- ▶ More upright
- ▶ Better at hanging, and worse at sitting



Figure 33.11 (Part 2)
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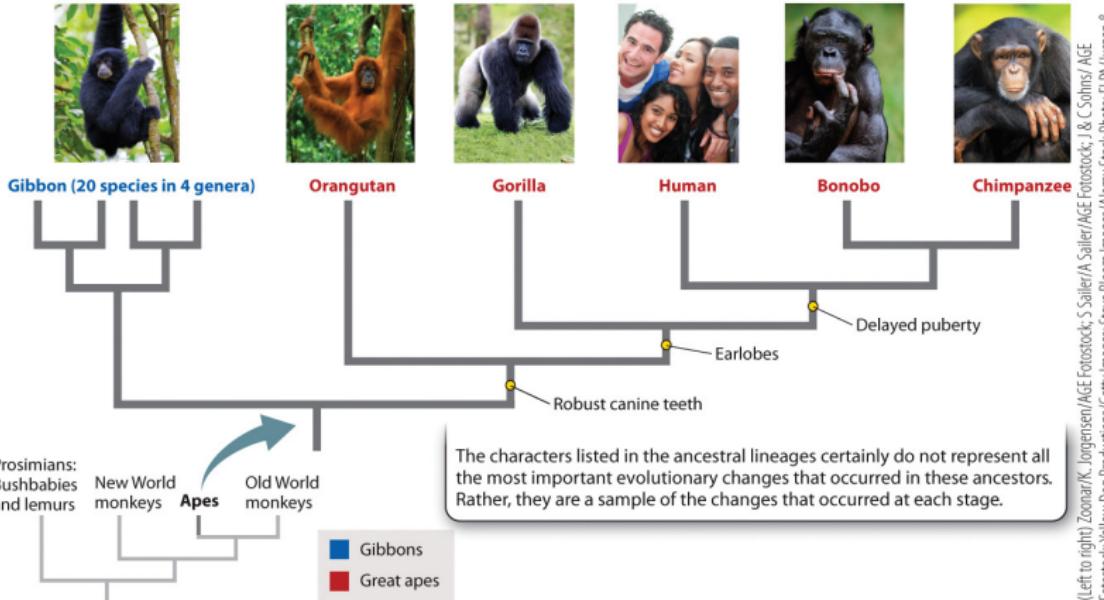


Figure 23.2
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Mobile arm joints

- ▶ New research suggests that apes' arm joints may have evolved to help heavy animals specifically climb *down* from trees
- ▶ This is another adaptation that likely led to further adaptations in a different direction
 - ▶ * Use of arms for other tasks, like adaptive foraging or tool use



Patterns of replacement

- ▶ Apes “radiated” into many habitats before monkeys did
 - ▶ Many ape species were apparently later replaced by Old World monkeys
- ▶ Why might apes have been replaced, if they were able to radiate successfully?
 - ▶ * Changing climatic conditions
 - ▶ * Changes in plants or insects
 - ▶ * Adaptive innovations by the monkeys
- ▶ What if the ape radiation had never happened?
 - ▶ * Less diversity between surviving apes
 - ▶ * Probably no people

Chimps vs. humans

- ▶ How much genetic difference?
 - ▶ * About 1% ...
 - ▶ * in homologous sequences!
- ▶ * About 4% overall
- ▶ Early results were very surprising, but maybe shouldn't have been
 - ▶ * Small changes can have large effects
 - ▶ * Changes aren't all that small
 - ▶ * A lot of genes about metabolic function: lungs, liver, immune system ... even basic cellular function

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Hominins

- ▶ **Hominins** refer to people and our upright ancestors
- ▶ Characterized by:
 - ▶ Walking upright (even more than apes)
 - ▶ Specific changes in chewing design: teeth, jaws and skull



Left to right) Uwe/Getty Images; iNTERD0/Alamy; Sylvain Entressangle & Eliabeth Daynes/Science Source; Alia Images/Shutterstock
Source: Sébastien Plailly/Science Source; Sylvain Entressangle & Eliabeth Daynes/Science Source

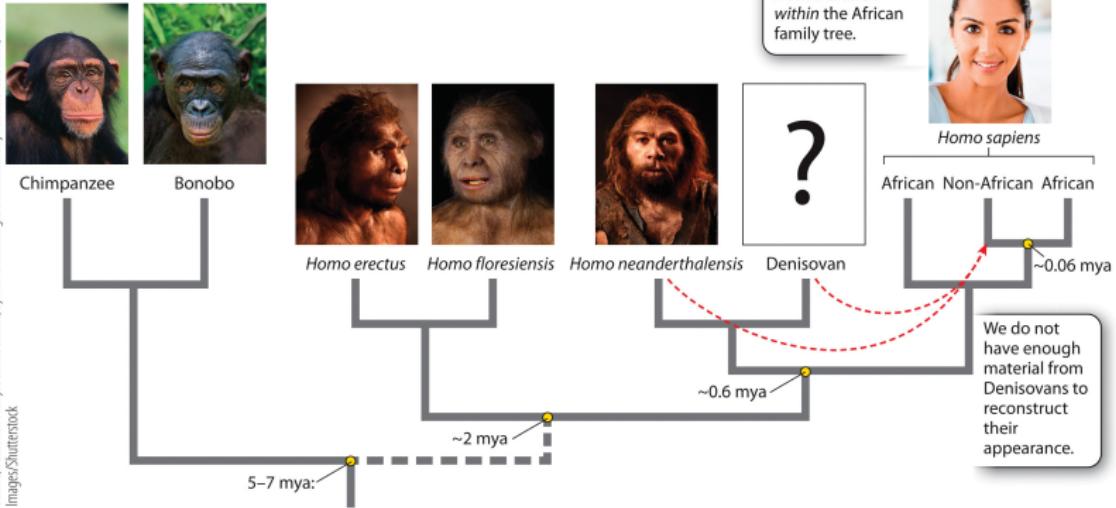
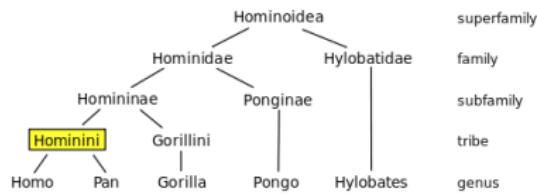


Figure 23.9
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Taxonomy



- ▶ Homonoidea, Hominidae, Homininae, Hominini, Hominina, Homo
- ▶ Why so much detailed splitting?
 - ▶ * We're a little bit full of ourselves
 - ▶ * We find things that make us different significant
 - ▶ * Observer bias

Upright posture

- ▶ How did upright posture and upright walking evolve?
- ▶ It's not known, but there are many theories:
 - ▶ Adaptation to walking on the ground instead of swinging through trees
 - ▶ Adaptation for keeping cool
 - ▶ Adaptation for harvesting food
 - ▶ Adaptation for carrying food

More radiation and contraction

- ▶ *H. ergaster* probably out-competed and replaced several related species, then radiated
- ▶ Modern humans replaced other descendants of *ergaster*

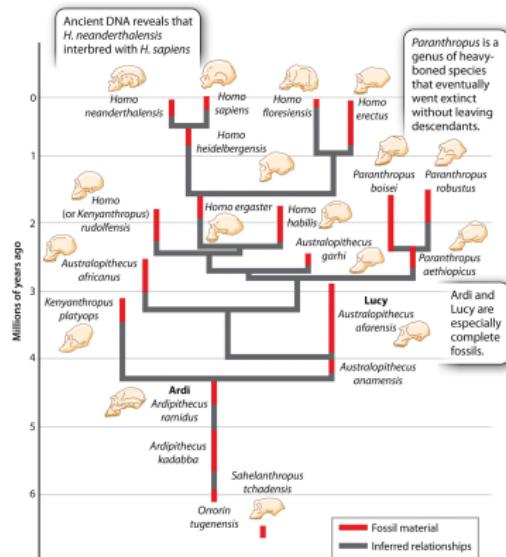


Figure 23.6
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[Data from R. G. Klein, 2009, *The Human Career*, Chicago, University of Chicago Press, p. 234; Homo floresiensis fossil from R. D. Martin, A. M. MacLennan, J. L. Phillips, L. Bussemer, P. F. Williams, and B. D. Bruns, 2006, Comment on 'The Brain of LB1, Homo Floresiensis', *Science* 312:994.

Modern humans

- ▶ Characterized by small face and teeth
- ▶ Less robust skeletal structure
- ▶ Evolved in Africa around 200 **kya** (thousand years ago)
- ▶ Took over most of the world in the last 50,000 years!
- ▶ Add picture?

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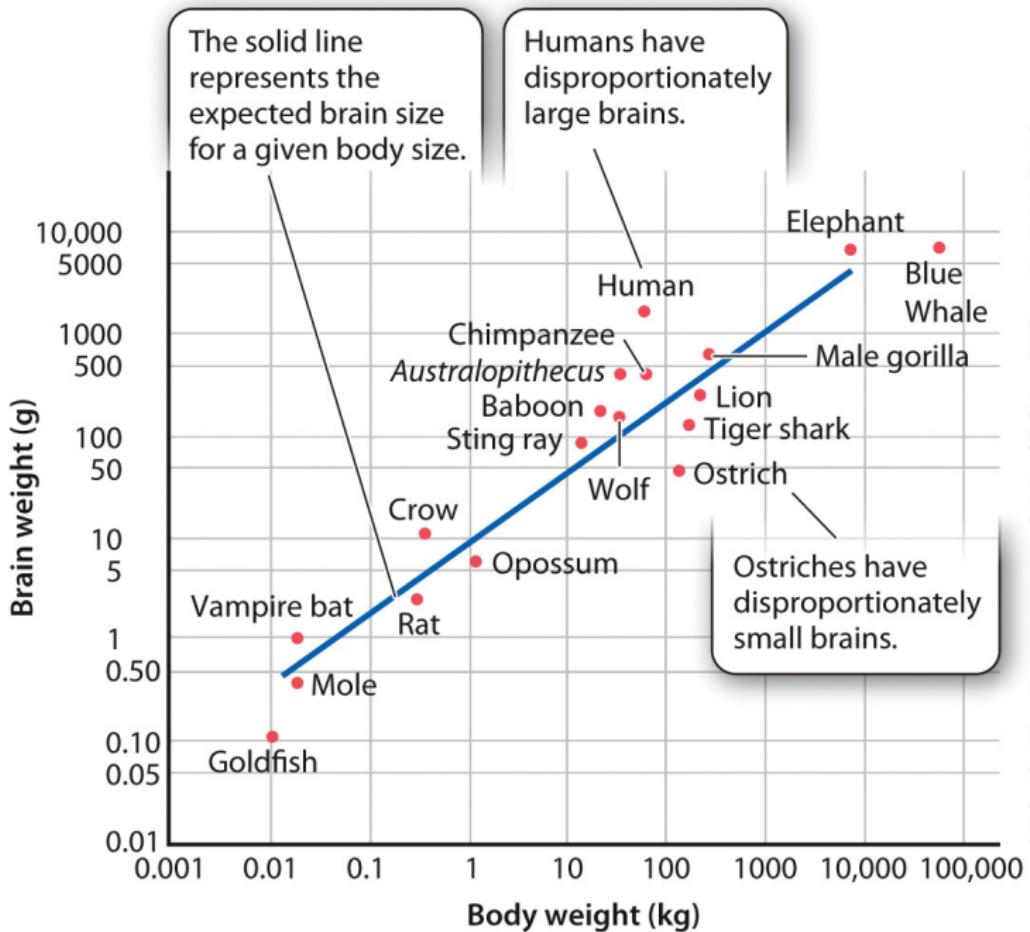
Learning about the past

Complex foraging

- ▶ Our ancestors went beyond the adaptive strategies of their relatives and found a tremendous variety of ways to feed themselves:
 - ▶ * Cooking and fire
 - ▶ * Weapons and hunting
 - ▶ * Tools and digging
 - ▶ * Selecting plants

Complex foraging

- ▶ These strategies likely built on, and also favored, existing traits:
 - ▶ Big brains, clever hands, mobile arms, stereoscopic vision, uprightness
- ▶ This is an example of:
 - ▶ * adaptive looping

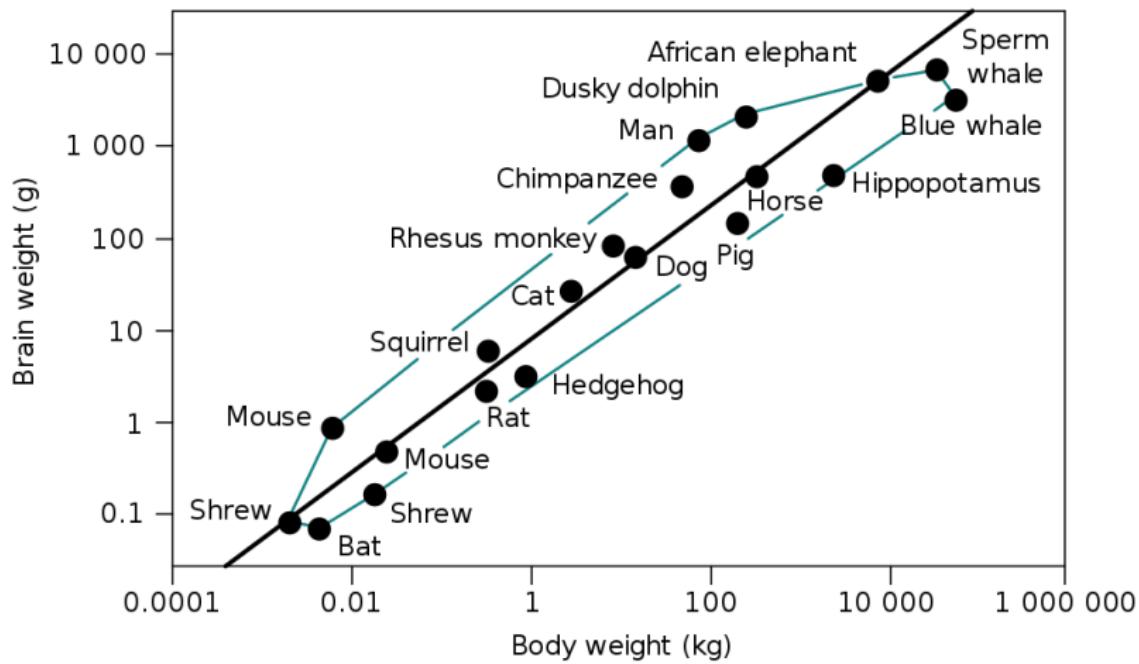


Data from Fig. 2.4, p. 44, in H. J. Jerison, 1973, *Evolution of the Brain and Intelligence*, New York: Academic Press.

Figure 23.14
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Brain and body size

- ▶ What is missing from the book's picture?
 - ▶ * Dolphins!
- ▶ What do we know about these animals?
 - ▶ * Brain size probably driven by sociality!



Co-operation and sociality

- ▶ Complex foraging can lead to selection for more co-operation
 - ▶ Different skill sets
 - ▶ Different tasks
- ▶ This can lead to new adaptive loops
 - ▶ Social interactions
 - ▶ Big brains
 - ▶ Communication
 - ▶ Culture
 - ▶ Long development period

Rate of development

- ▶ Why do human children develop *so* slowly?
 - ▶ * A lot to learn
 - ▶ * Social skills important to survival



Remark: 2-year-old

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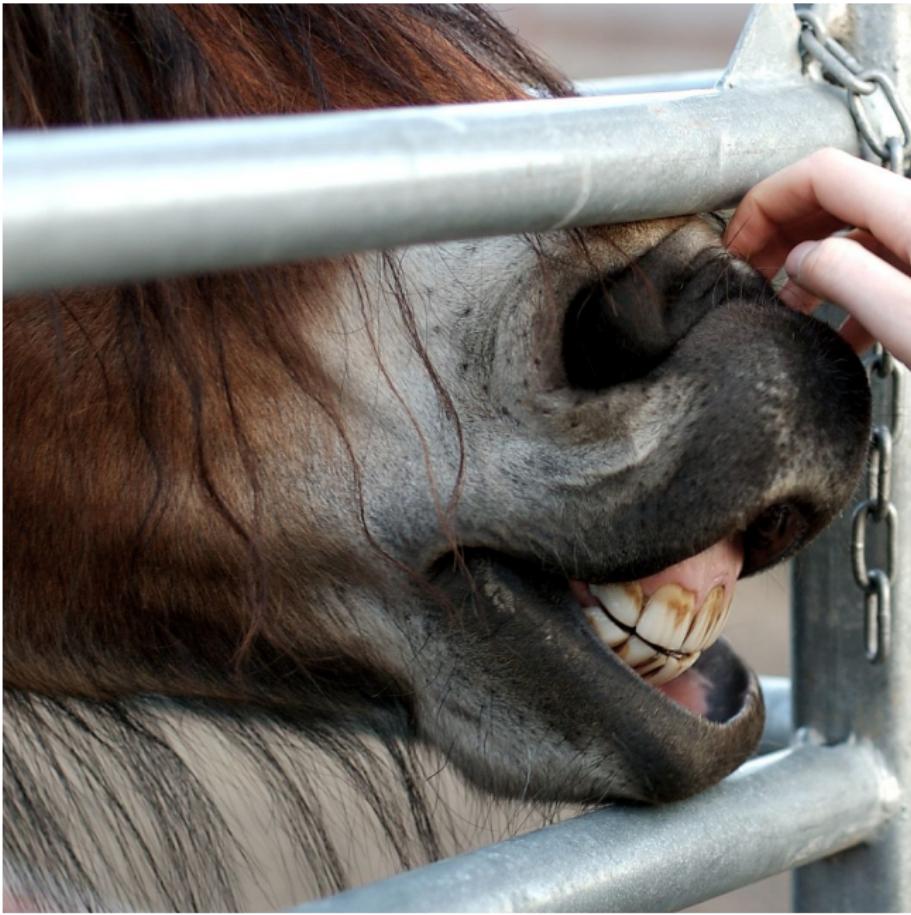
Getting fed

- ▶ A major factor in adaptation is food source.
- ▶ The most important strategies for early primates were:
 - ▶ **Frugivory**: eating fruits (and sometimes flowers)
 - ▶ **Folivory**: eating leaves
 - ▶ **Insectivory**: eating insects

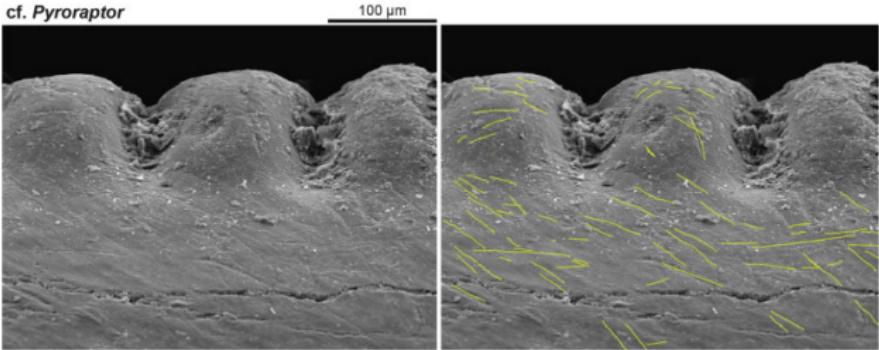
Teeth

- ▶ Teeth are very important for processing food
- ▶ Why do we have two sets of teeth?
 - ▶ * Makes it more likely our teeth will last for longer
 - ▶ * This is probably also why wisdom teeth come in late
- ▶ Teeth help scientists understand what extinct animals ate
 - ▶ Often preserved, highly adapted
- ▶ **Remark: Canadian research from 2018: insanely detailed study of dinosaur teeth and wear marks**

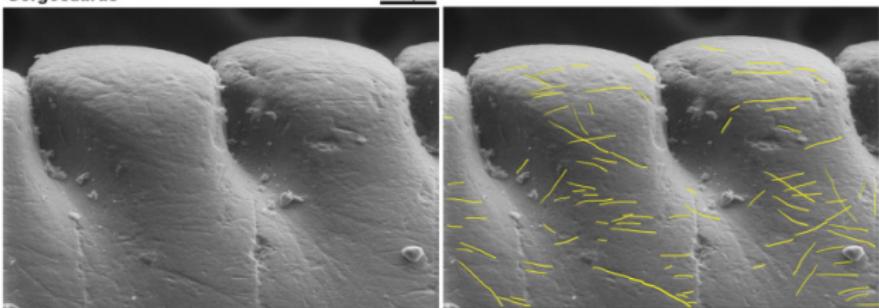




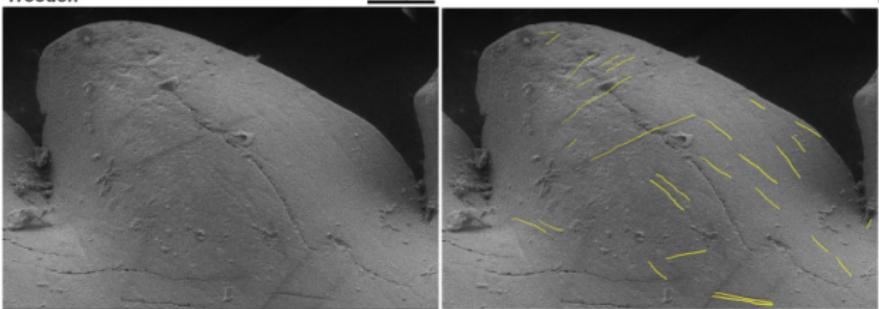
cf. *Pyroraptor*



Gorgosaurus

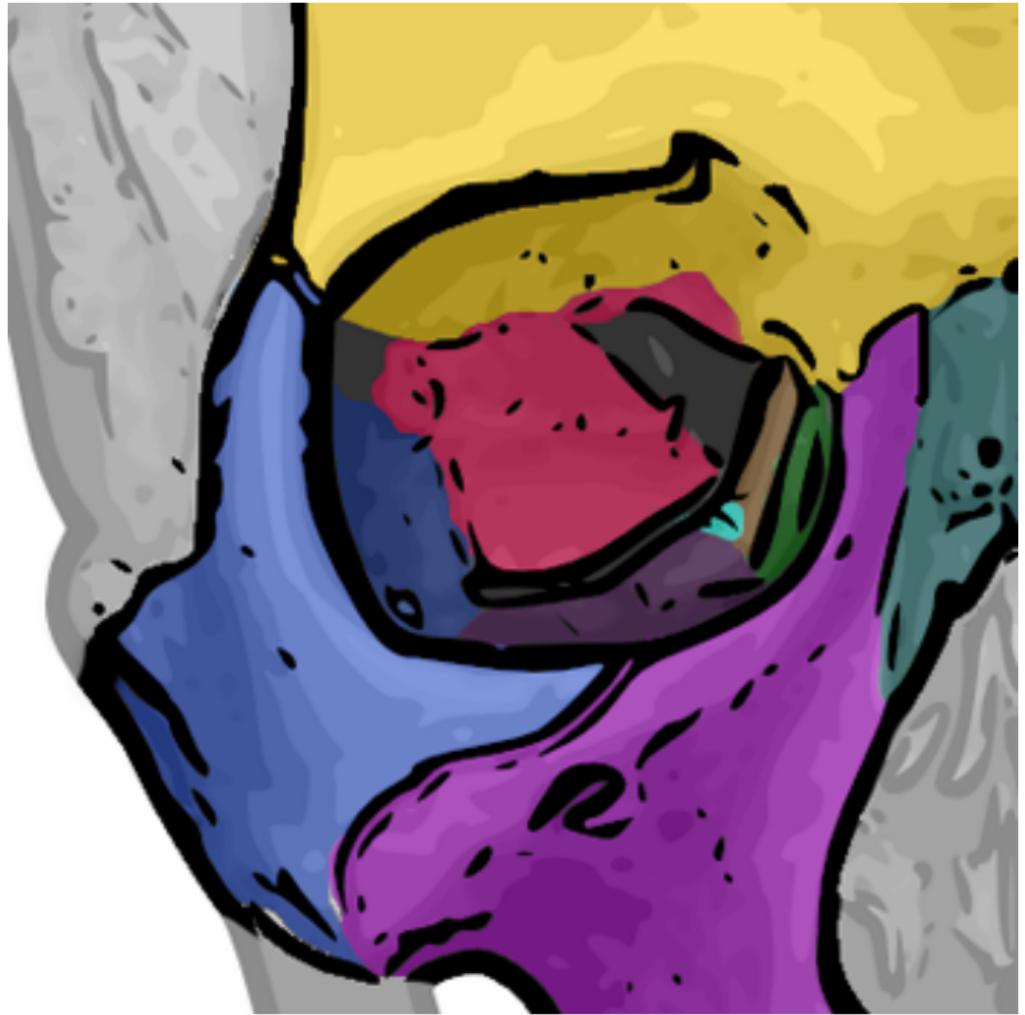


Troodon



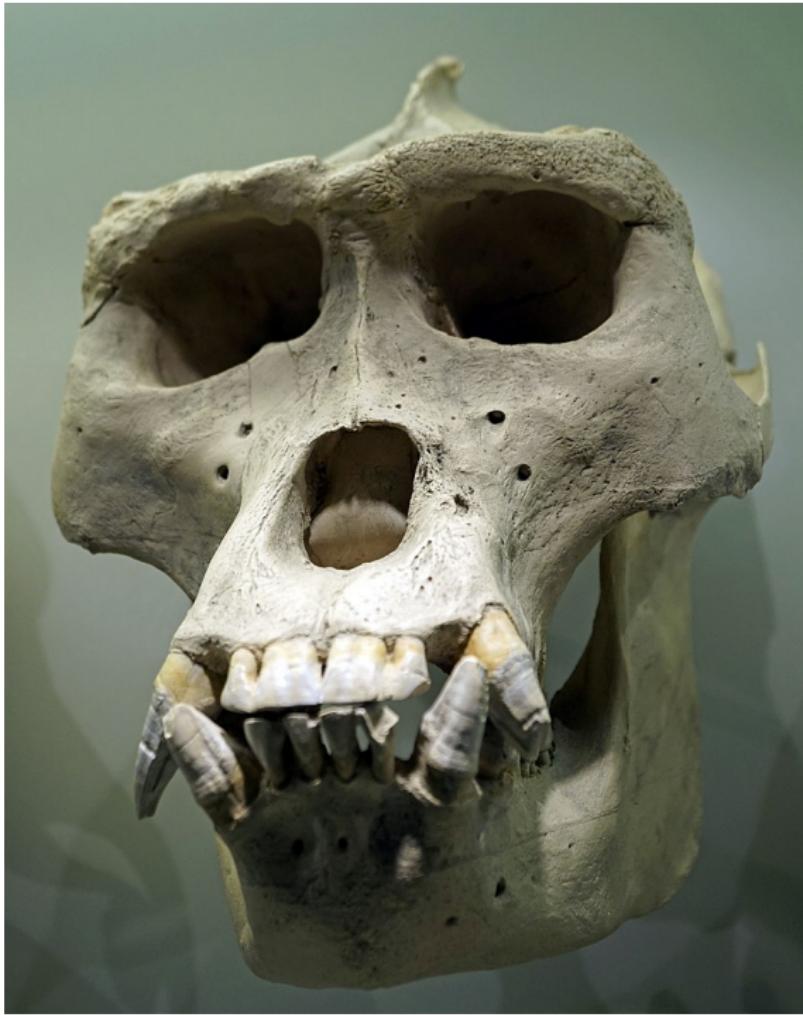
Eyes

- ▶ Eye **orbits** are the skeletal cavities where eyes are
- ▶ Orbit tell us size, shape and position of eyes from fossil animals
- ▶ What are the advantages and disadvantages of more forward-facing eyes?
 - ▶ * Better for precise tasks, three-dimensional visualization
 - ▶ * Not as good for looking around, being alert
- ▶ What are the advantages and disadvantages of larger eyes?
 - ▶ * Better for night vision
 - ▶ * More costly? Harder to protect?
 - ▶ * Are small (or deep) eyes better for day vision?









Sexual dimorphism

- ▶ Information about differences between males and females has implications about social structure and mating patterns
 - ▶ In species where there is more variation in male success (less bonding in pairs), we expect:
 - ▶ * More sexual dimorphism
 - ▶ * More competition between males for females





Dimorphism and sexual strategies

- ▶ Gorillas live in male-centered groups (one adult male, several adult females)
- ▶ Chimpanzees live in large, well-mixed groups with lots of interactions between males and females
- ▶ Which species should have more sexual dimorphism overall?
 - ▶ * Gorillas. Males are huge and strong and compete for females by displaying and fighting. A dominant male has exclusive access to a group of females
- ▶ Which species should have larger male genitals?
 - ▶ * Chimpanzees have much larger genitals.
 - ▶ * Gorillas don't use genitals as part of sexual competition

Human sexual competition

- ▶ Compared to other apes, humans have big penises and small testicles
 - ▶ * Genitals are likely important in competition for sexual access
 - ▶ * Probably less sperm competition than chimpanzees (more stable relationships)

Learning about evolution

- ▶ Understanding the course of evolution is an important part of understanding how things work now
 - ▶ How organisms work, and how ecosystems work
 - ▶ There are many challenges:
 - ▶ Timelines, identification, convergent evolution

Summary

- ▶ People have important differences from other organisms
- ▶ We got here using the same rules of natural selection as everyone else
 - ▶ Things may be different *now*, but even that is not so clear
- ▶ Adaptation does not move in a straight line
 - ▶ Changing conditions lead to opportunities for new adaptations
 - ▶ New adaptations *themselves* can be an important cause of changing conditions
 - ▶ Innovations, or co-evolution with other taxa

Summary

- ▶ People evolved by the same basic rules as other organisms
 - ▶ * Adaptation by natural selection
- ▶ Followed a very different path
 - ▶ * Strong loops that continually created new adaptive opportunities
- ▶ There is a lot we can learn about ourselves from biology
 - ▶ * We are affected by all of the same basic processes as other organisms
- ▶ And also a lot that we can't learn
 - ▶ * We are also strongly affected by our complex brains (and complex cultures)

Dobzhansky and Dushoff (Extra)

- ▶ “Nothing in biology makes sense except in the light of evolution.” — Theodosius Dobzhansky, 1973
- ▶ “Nothing in biology makes sense, period.” — Dushoff, 2005
- ▶ Biology is wild and wonderful; it's fun to do your best to make sense of it, but . . .