Human evolution

Patterns of evolution

Our recent history

Sociality

Learning about the past

Outline

Humans as an example

- Humans are an example of a biological species that has evolved
- Humans are relatively familiar
  - 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?


Exit
Madison Avenue
& 42 Street
Open M-F 6:30am-7:30pm
Track

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?

Outline

Context for evolution

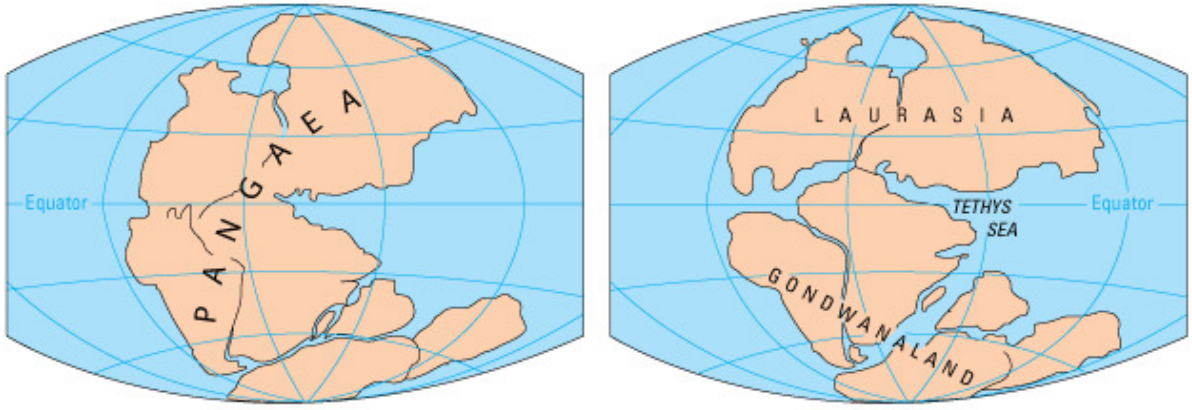
- Adaptations build on existing adaptations – often in unexpected ways
- Evolution does not know where it's going
- In a constant environment, species can only improve with gradual adaptations to the same environment
  - and will be in danger of getting "stuck", e.g. vertebrate eyes
- A changing environment 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
  - Many dramatic examples
- Continental drift

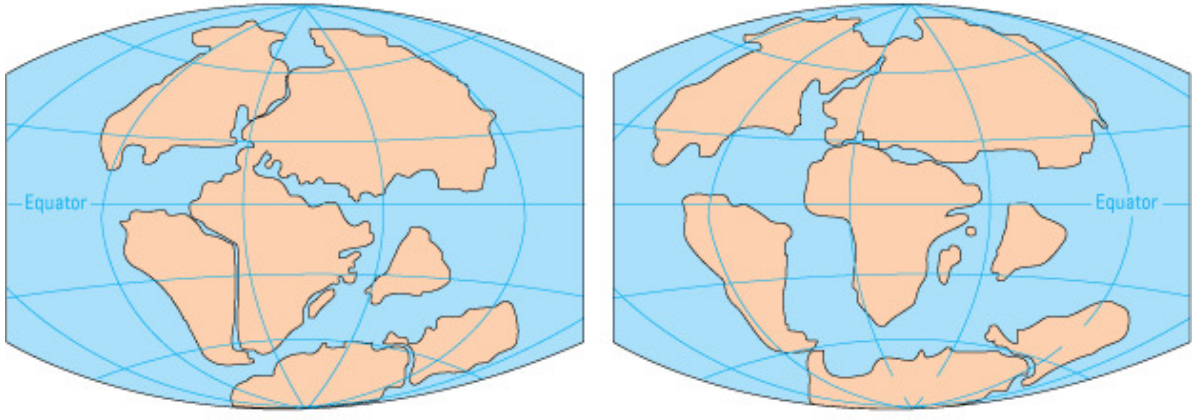
Physical changes

- 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
    - * Vicariance
    - * Provides opportunities for allopatric speciation



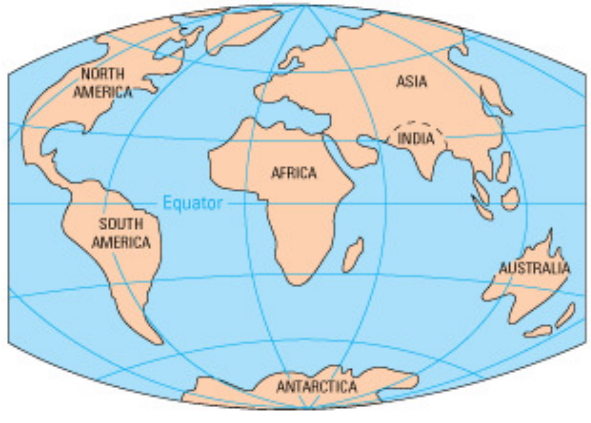
PERMIAN
225 million years ago

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

Remark: These are examples of co-evolution

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?
  - * 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

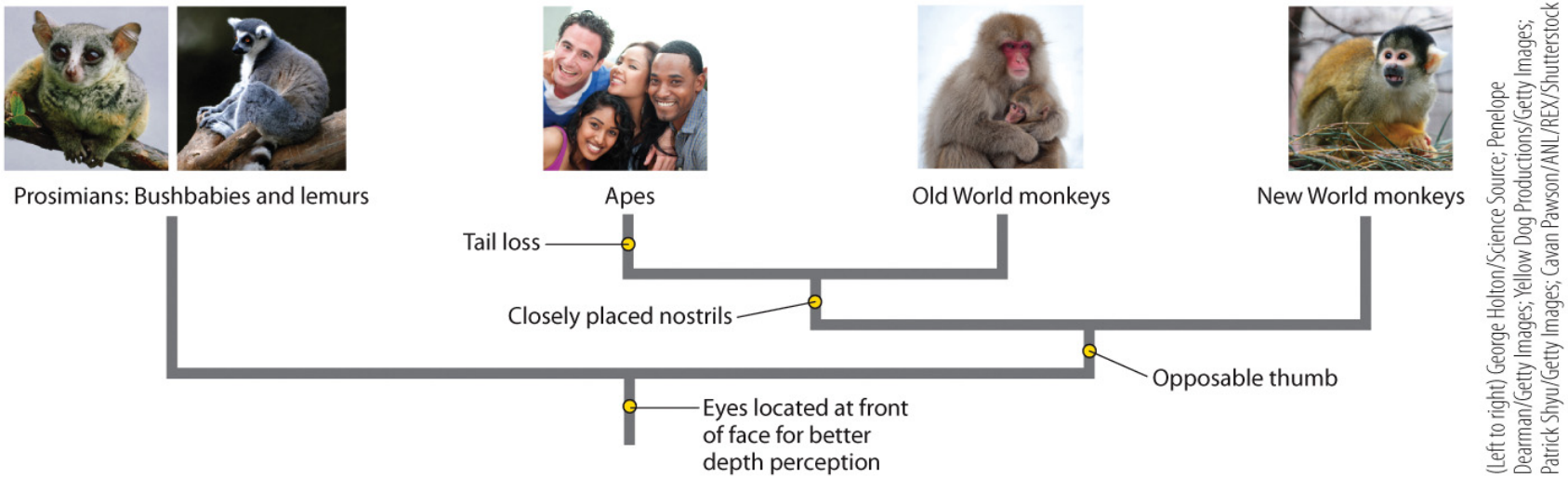
Outline

Outline

Primates

- Humans are **primates**, an "order" characterized by
  - Highly developed **stereroscopic** 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)



(Left to right) George Holton/Science Source; Penelope Dearman/Getty Images; Yellow Dog Productions/Getty Images; Patrick Shyu/Getty Images; Cavan Pawson/ANL/REX/Shutterstock

Figure 23.1
Biology: How Life Works

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 (**angiosperms**) 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
- Huge diversity of fruit and flowers
- Co-evolving with:
  - * A huge diversity of insects

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
    - * An example of ability to acclimate

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 natural-selection one
  - * Not the foraging one

Outline

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

Russell Watkins/Shutterstock

Figure 23.13 (Part 2)
Biology: How Life Works

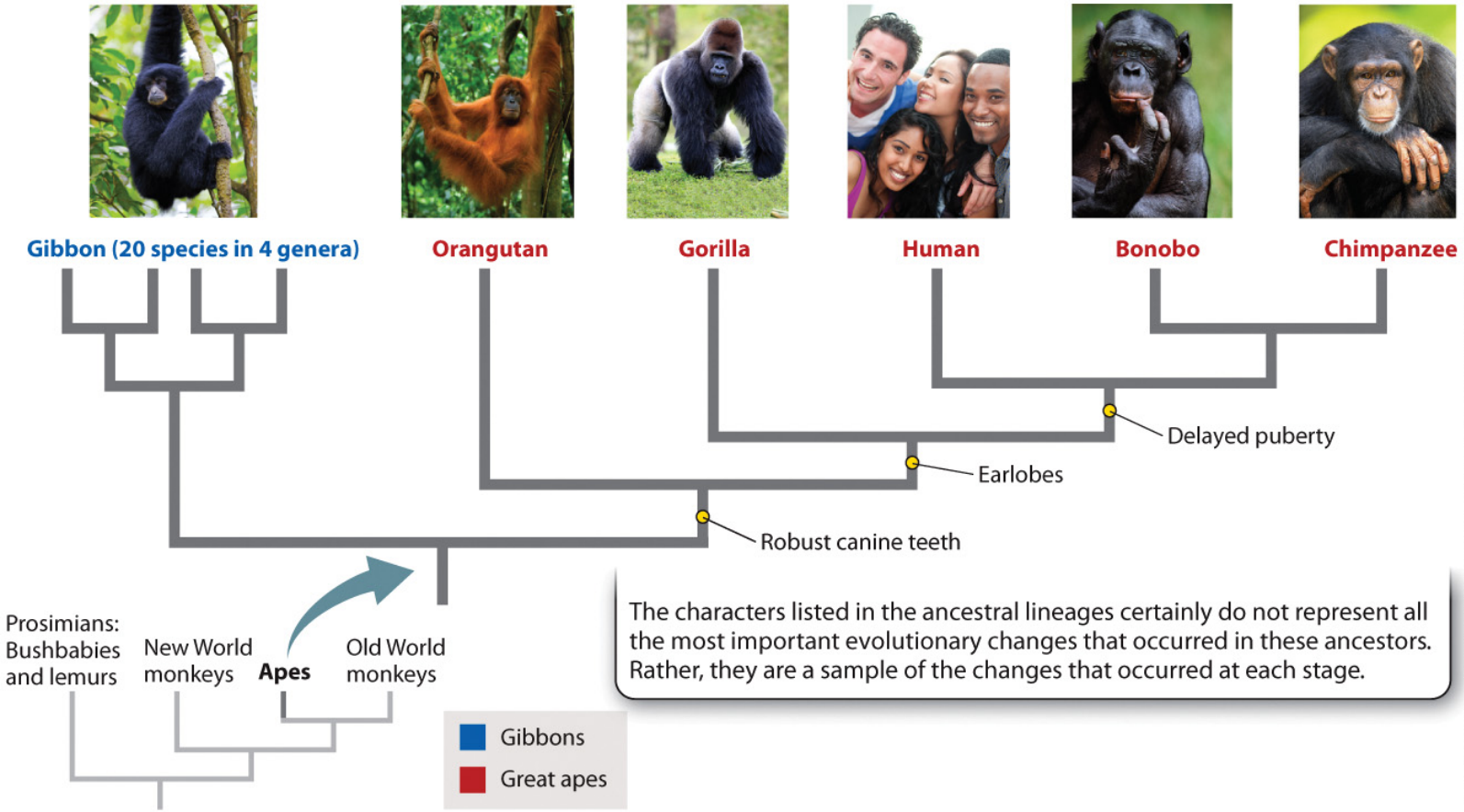


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Figure 23.2
Biology: How Life Works

Endangered gibbons

PalmOilDetectives.Com

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

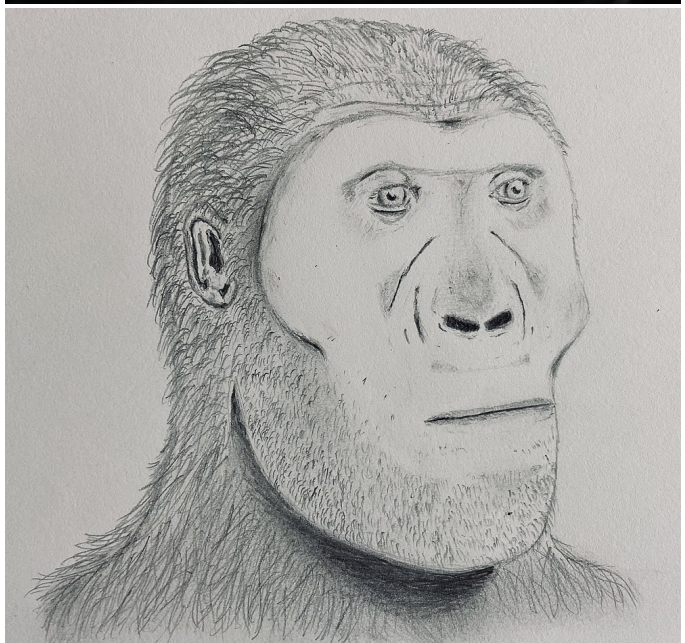
Chimps vs. humans

- 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

Outline

Hominins

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



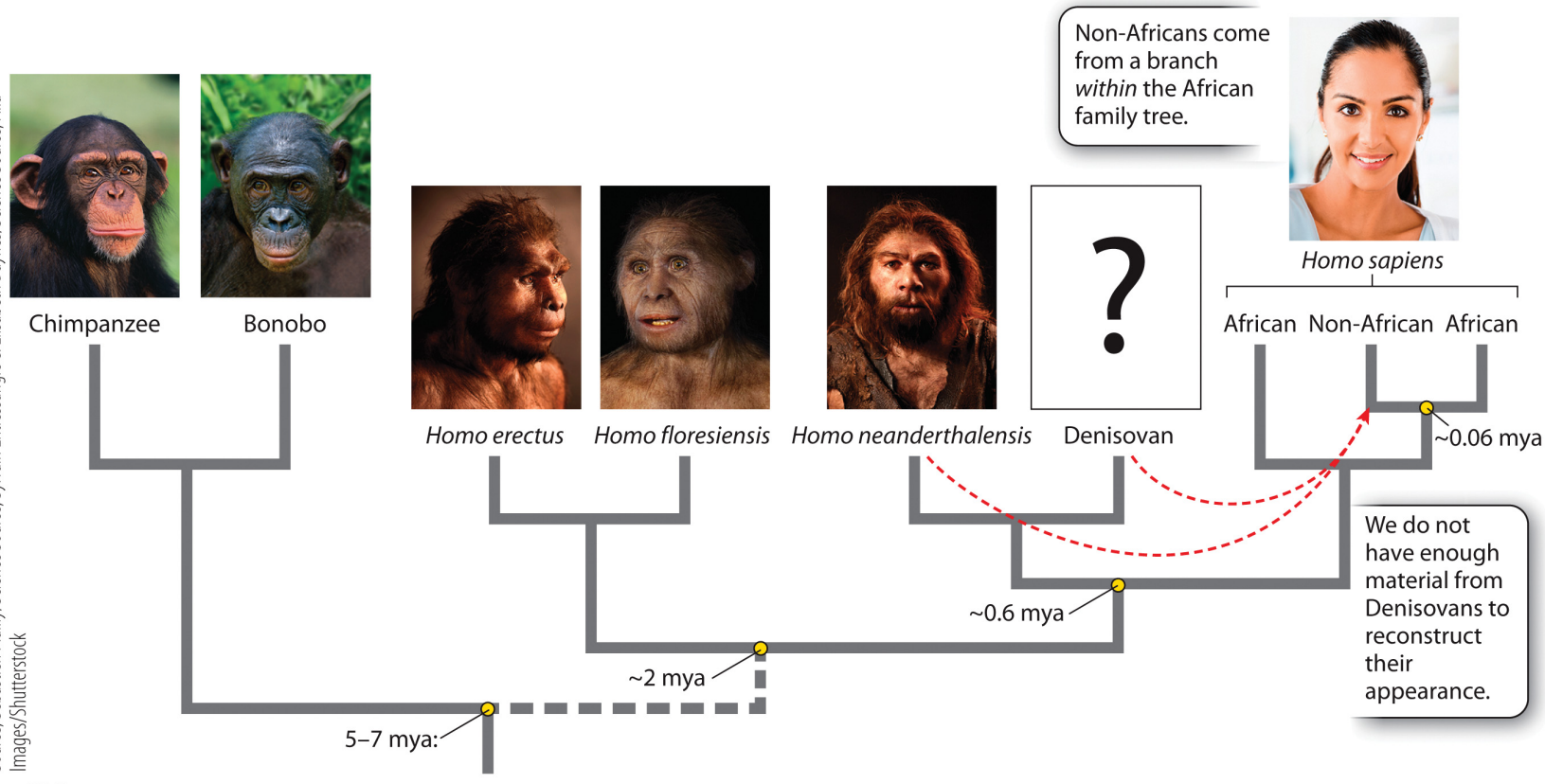


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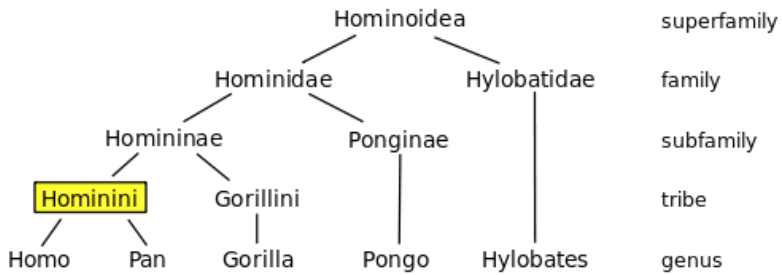
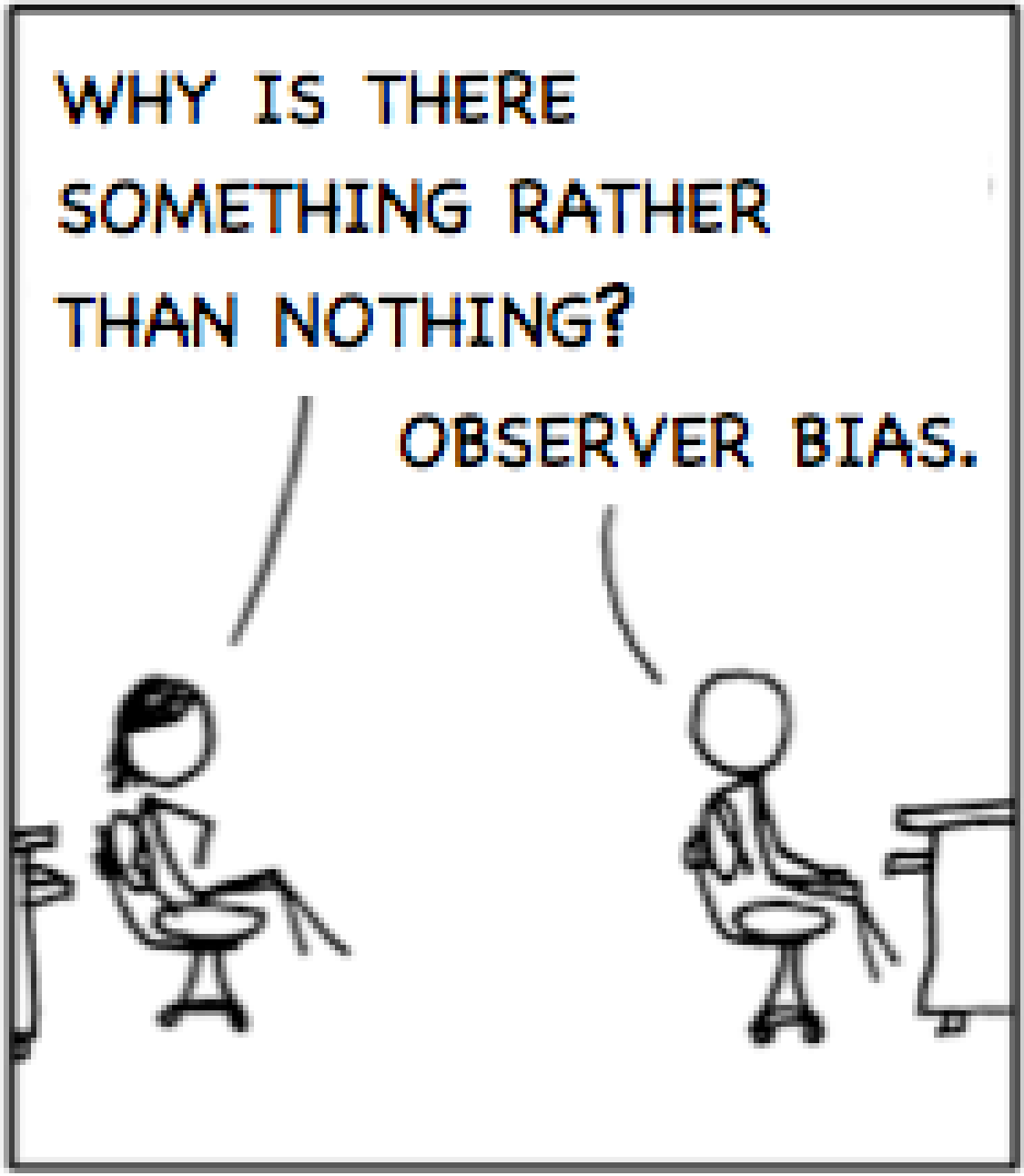
Figure 23.9
Biology: How Life Works

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

Observer bias is everywhere! (Extra)



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*

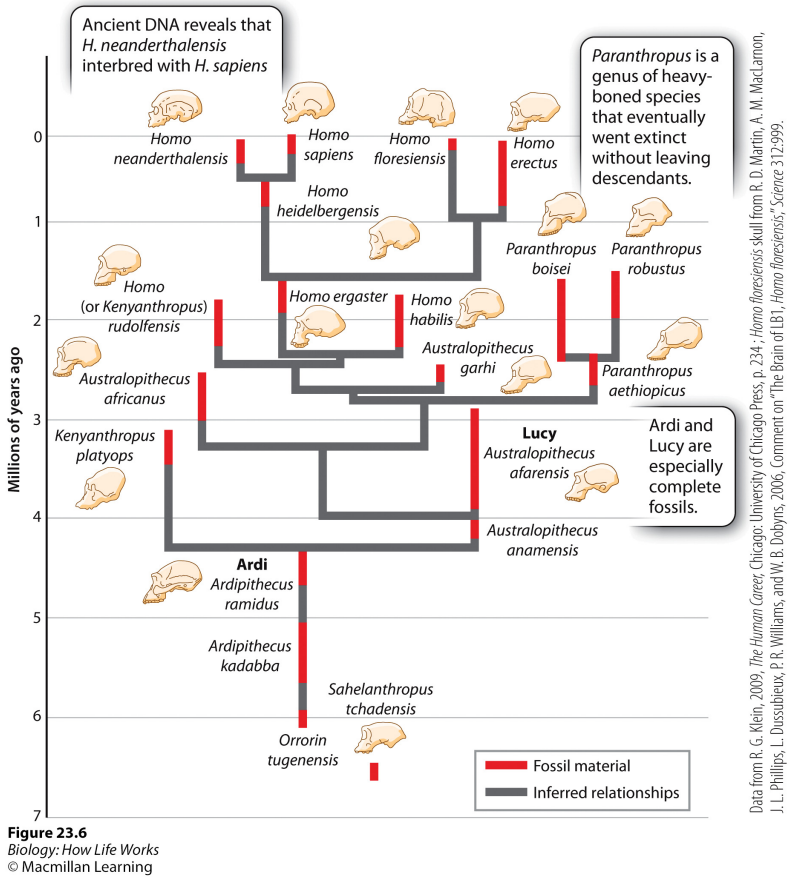


Figure 23.6
Biology: How Life Works

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!
- Aadd picture?

Outline

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
- A more advanced version of adaptive foraging

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

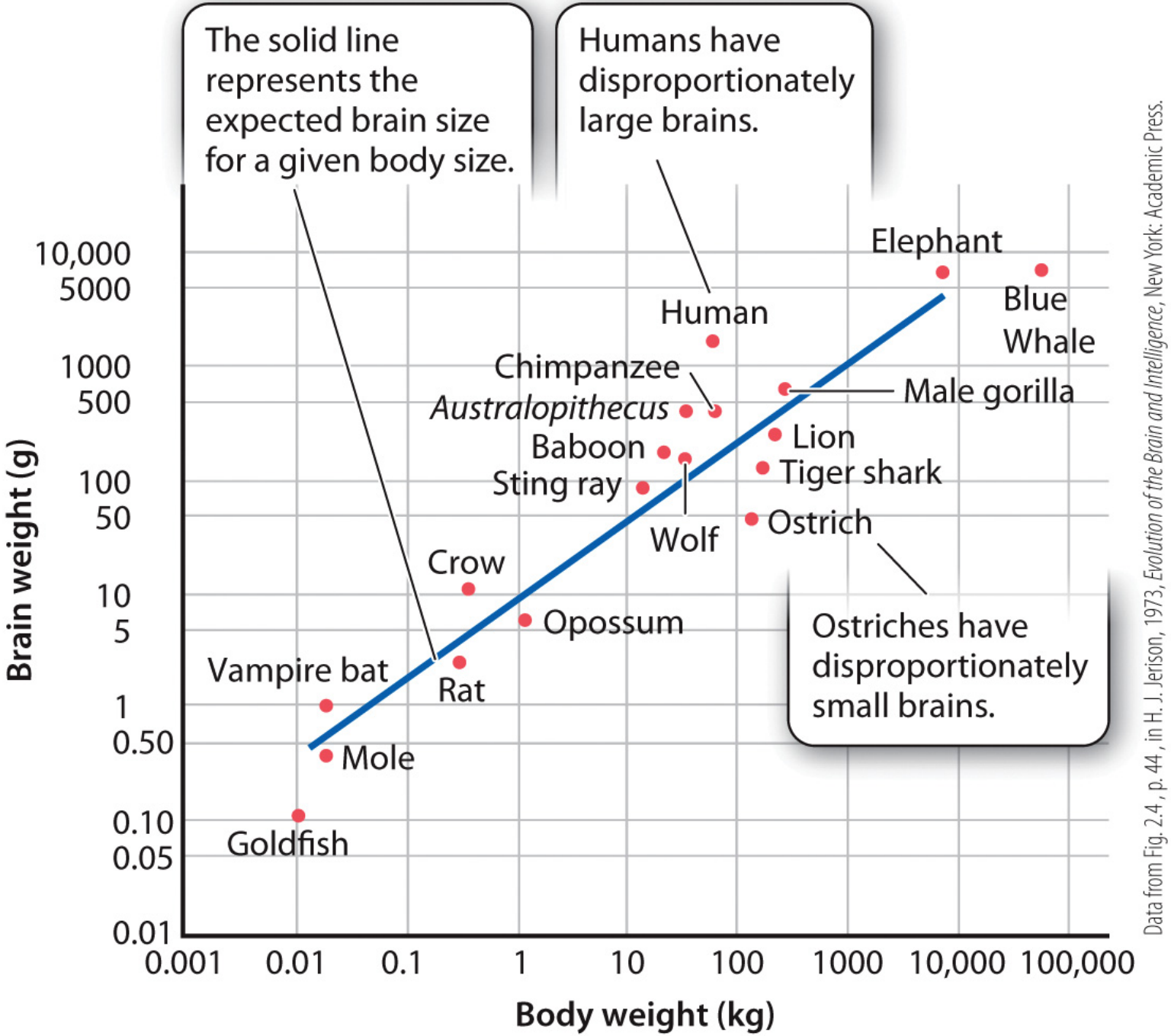
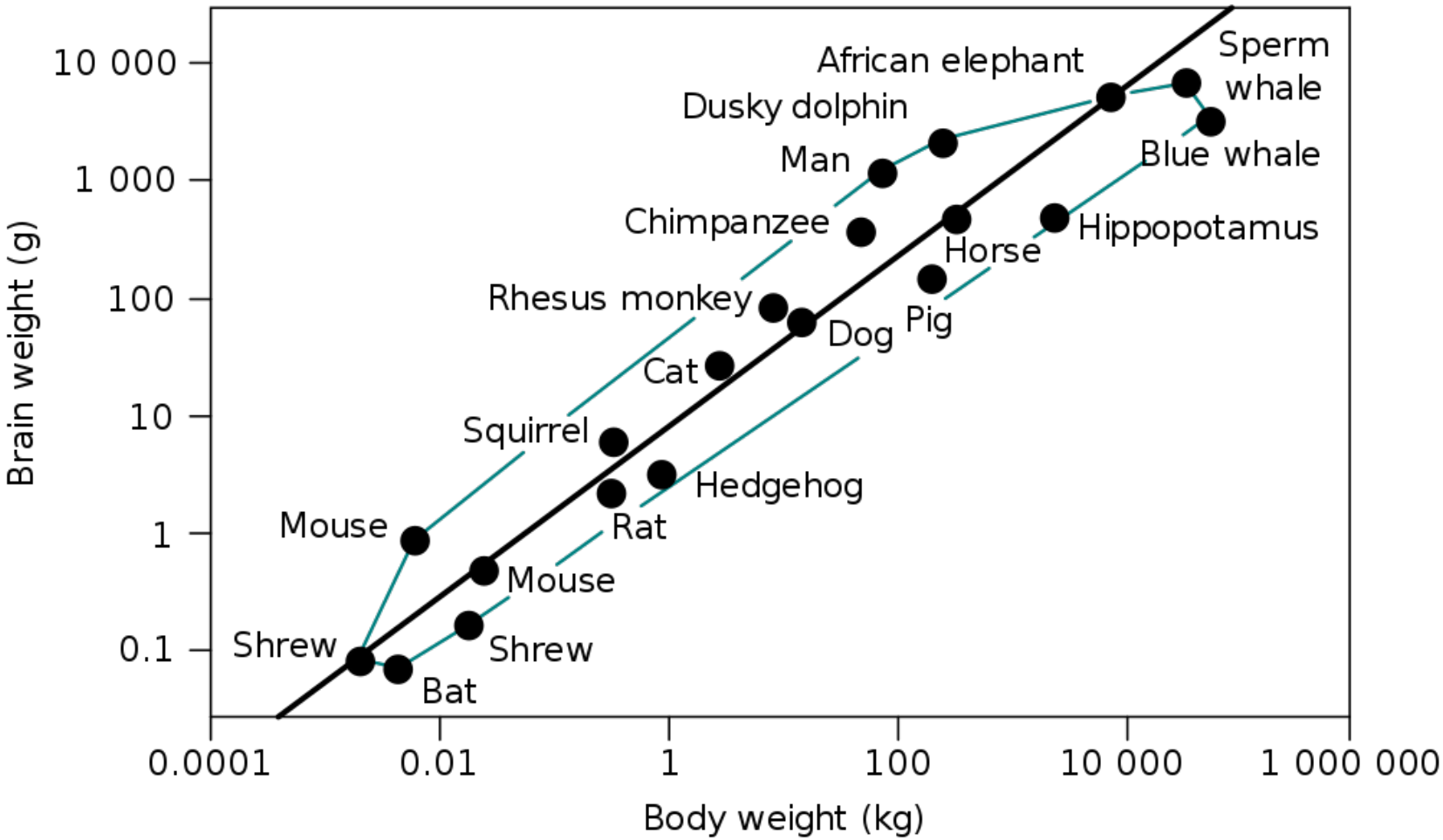


Figure 23.14
Biology: How Life Works

Brain and body size

- What is missing from the book's picture?
  - * Dolphins!
- What do we know about these animals?
  - * Highly social
  - * Sociality may be an important component for us as well


Brain weight (g)
10 000
1 000
100
10
1
0.1
Body weight (kg)
0.0001
0.01
1
100
10 000
1 000 000
African elephant
Sperm whale
Dusky dolphin
Blue whale
Man
Chimpanzee
Hippopotamus
Horse
Rhesus monkey
Pig
Dog
Cat
Squirrel
Hedgehog
Rat
Mouse
Mouse
Shrew
Shrew
Bat

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

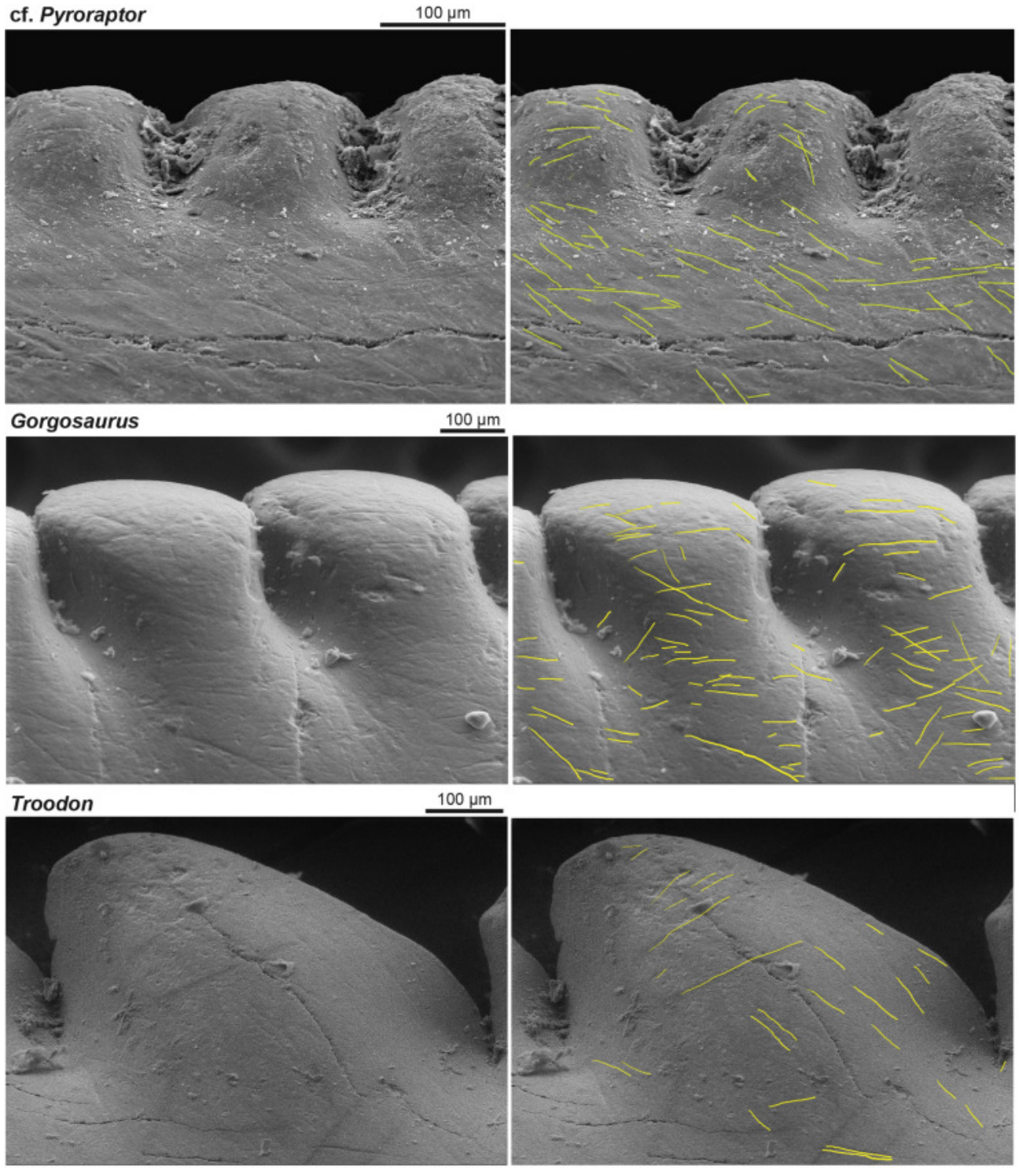
Outline

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

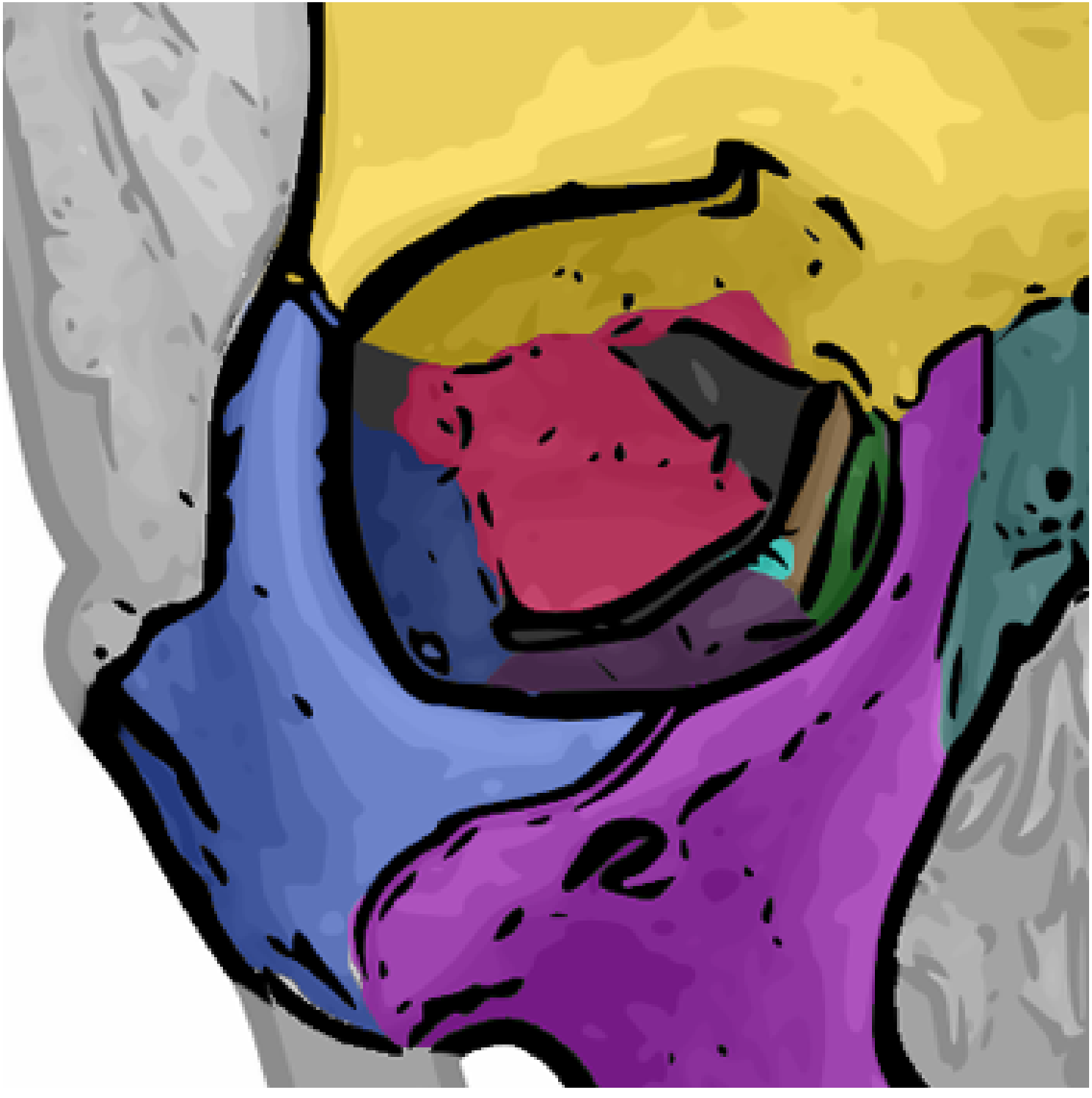
Teeth

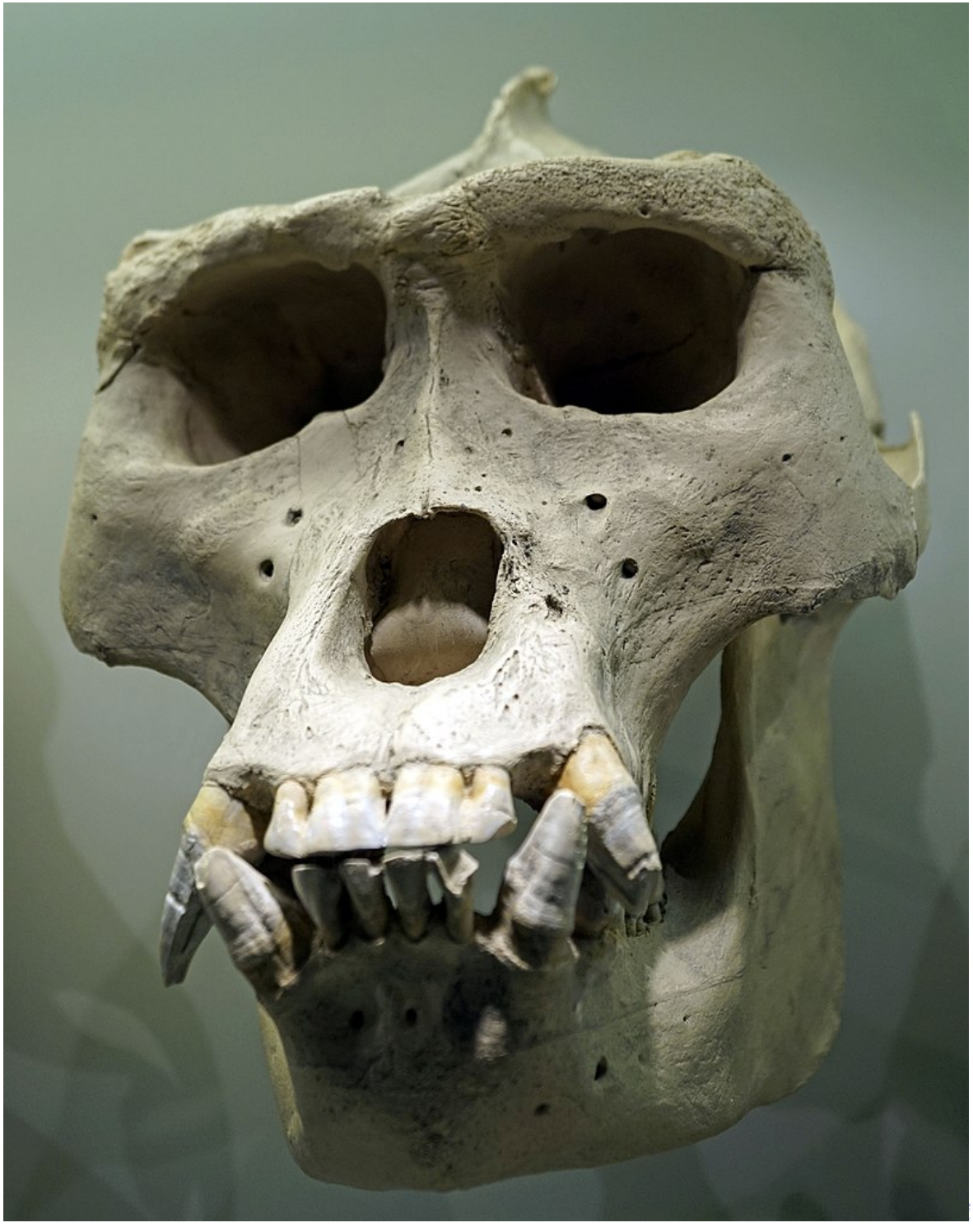
- Teeth are very important for processing food
- Why do we have two sets of teeth?
  - * Makes it more likely our teeth will last for longer
  - * This is probably also why wisdom teeth come in late
- Teeth help scientists understand what extinct animals ate
  - Often preserved, highly adapted
- **Remark: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


cf. Pyroraptor
100 µm
Gorgosaurus
100 µm
Troodon
100 µm

Eyes

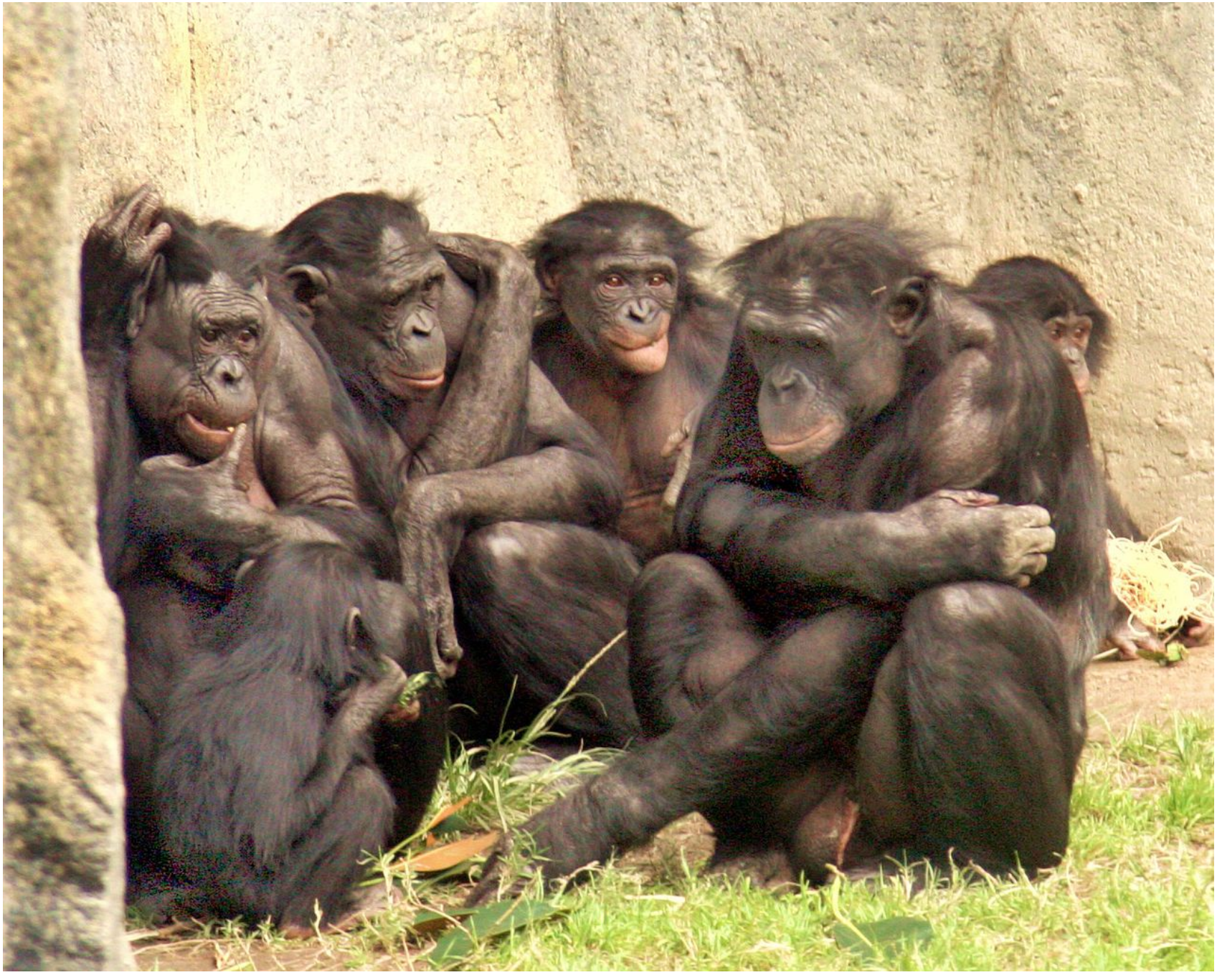
- Eye **orbits** are the skeletal cavities where eyes are
- Orbits tell us size, shape and position of eyes from fossil animals
- What are the advantages and disadvantages of more forward-facing eyes?
  - * Better for precise tasks, three-dimensional visualization
  - * Not as good for looking around, 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
  - * Sexual dimorphism can sometimes be seen or inferred from fossil remains



Dimorphism and sexual strategies

- Gorillas live in male-centered groups (one adult male, several adult females)
- Chimpanzees (and bonobos) 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)
  - * Unfortunately hard to track from fossils

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 . . .
  - it will always surprise you