Human evolution

Patterns of evolution

The evolution of primates

Apes

Learning about the past

Hominins

Sociality

Outline

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?

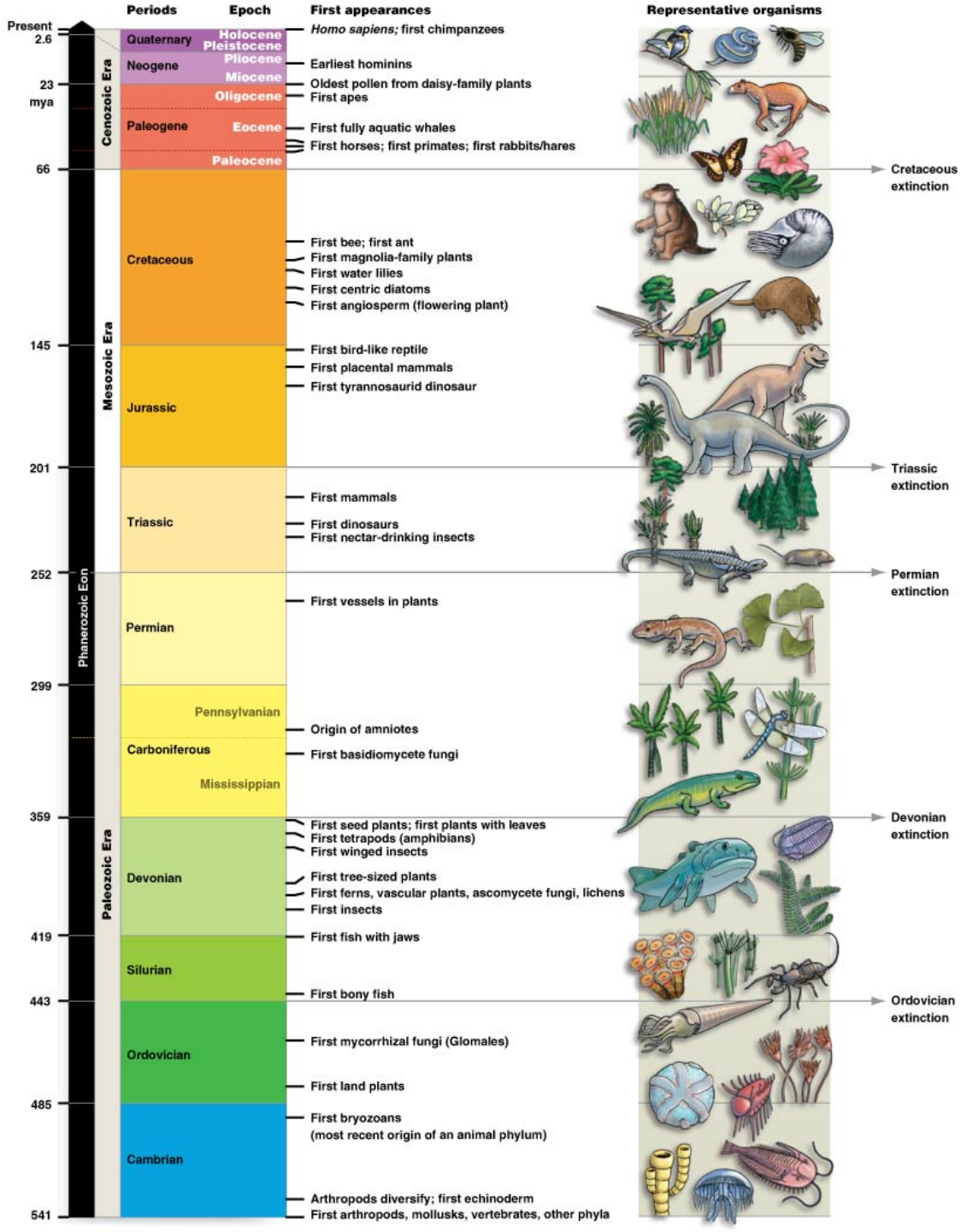

Exit
Madison Avenue
& 42 Street
Open M-F 6:30am-7:30pm
Track

Similarities and differences

- What is different about people?
  - * Complex thoughts
  - * Culture
  - * Language
  - * Technology
- What is the same?
  - * We're here because our ancestors reproduced
  - * If reproductive success depends on heritable variation in traits . . .
    - * We're still evolving
    - * In what direction or directions?

History

- There are a *lot* of steps (and a lot of divergences) between us and the last universal common ancestor of life
- More than 3 billion years ago!
- Some key steps:
  - **Eukaryotes**
  - **Animals**
  - **Vertebrates**
  - **Mammals**
  - **Primates**
  - **Apes**



Timeline

- Why not just say how long ago?
  - Periods may be punctuated by major events
    - Radiations, mass extinctions
  - People started talking about periods before they had good measures of how long ago things happened
  - Periods have cool names
    - * Connections help people think clearly

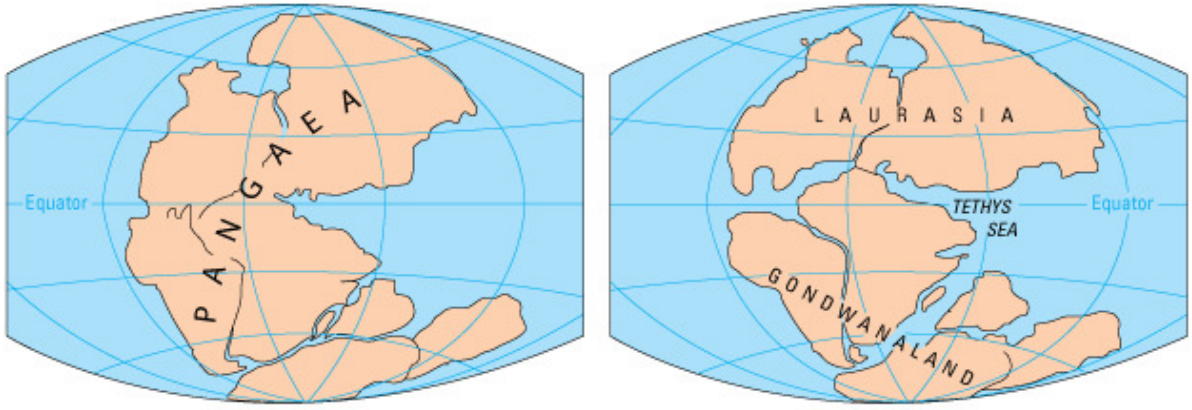
Outline

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

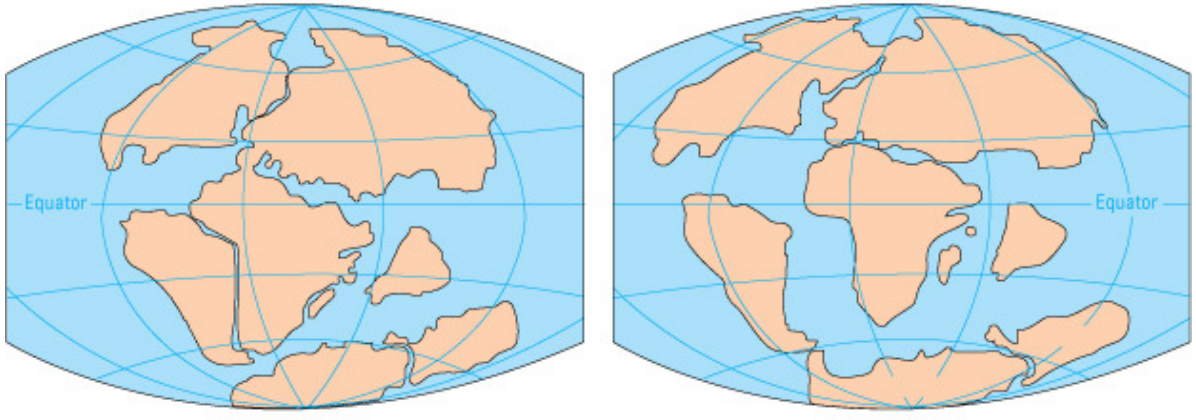
Physical changes

- Physical changes often provide species with new adaptive challenges and opportunities:
- Global climate change
- 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



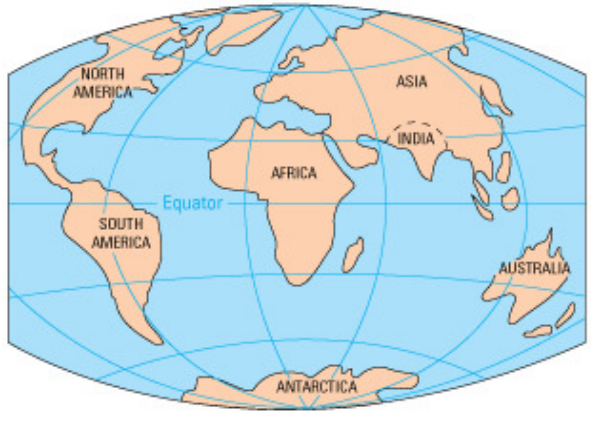
PERMIAN
225 million years ago

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)

Observer bias

- We see a lot of clades with a history of radiations
- Does that mean most clades radiate?
  - * Maybe it's just the ones see
  - * Clades with a history of radiations may be more successful

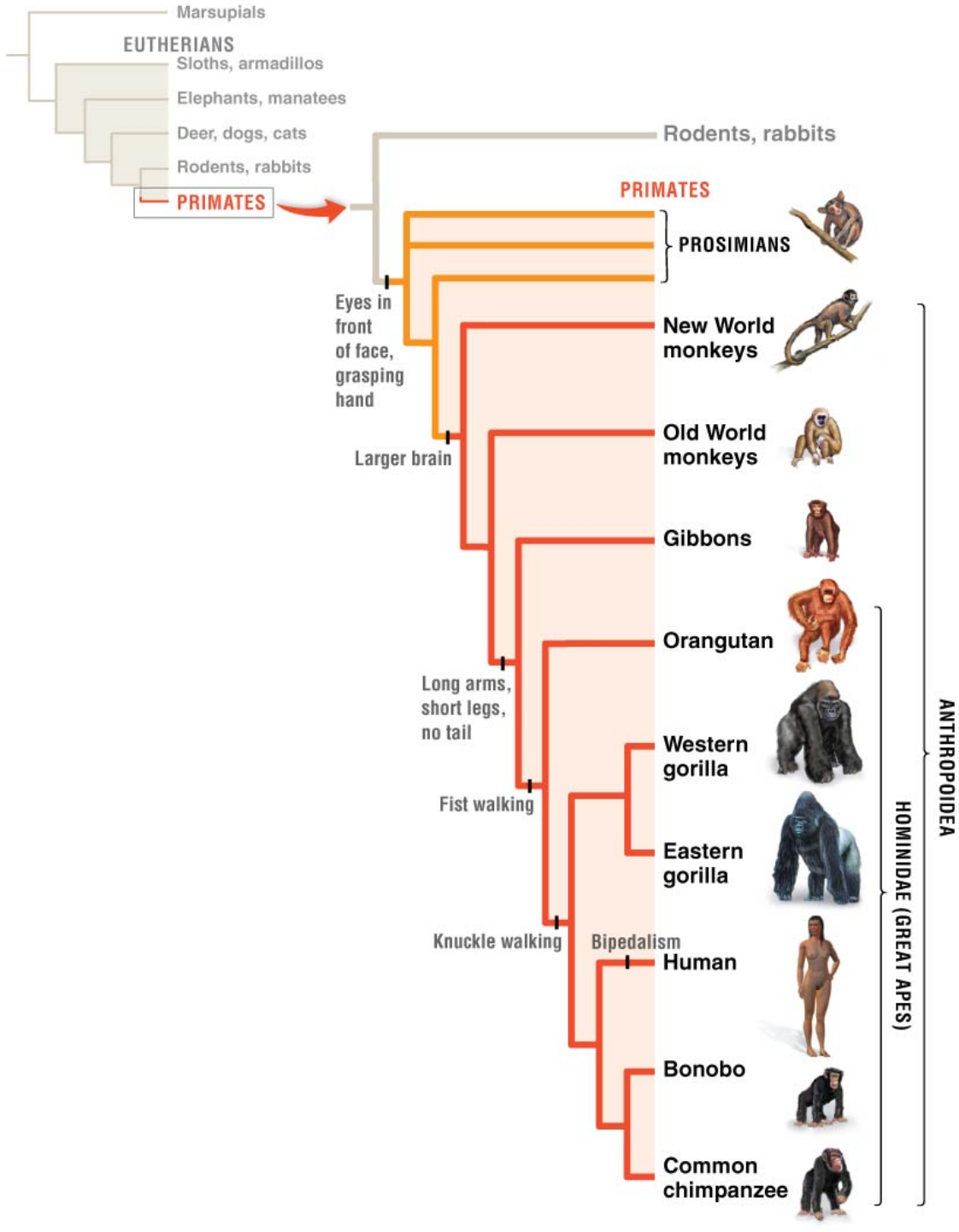
Advantages of previous radiation

- 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)

Outline

The evolution of 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



Traits

- What sort of traits do biologists use to characterize a group?
  - * Derived traits
- How would you interpret the fact that humans don't have grasping feet?
  - * Our ancestors lost the trait
  - * It takes many traits to make an accurate phylogeny

Changing models

- Does swinging through trees provide evidence that bonobos are closer to orangutans than to humans or gorillas?
  - * Depends on the ancestor: in this case it seems hard to say
  - * Even if there is evidence, there's more evidence that they're closer to us
- We used to think people were far from chimps and gorillas
  - * Observer bias
  - * 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

Patterns of adaptation

- These strategies may have evolved sequentially
  - Maybe exploiting tree resources came first, but similar traits helped some species later catch insects
  - Maybe traits which evolved for one specific purpose later became useful for adaptive foraging

Outline

Ape adaptations

- 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
- Lots of missing pieces of the puzzle
  - There may be a lot of convergent evolution and secondary loss going on

Patterns of replacement

- Apes "radiated" into many habitats before monkeys did
  - Many ape species were apparently later replaced by monkeys
- Why might apes have diversified, and later been replaced by monkeys?
  - * Changing climactic conditions
  - * Changes in plants or insects
  - * Unpredictable adaptive innovations
- What if the ape radiation had never happened?
  - * Less diversity between surviving apes
  - * Probably no people

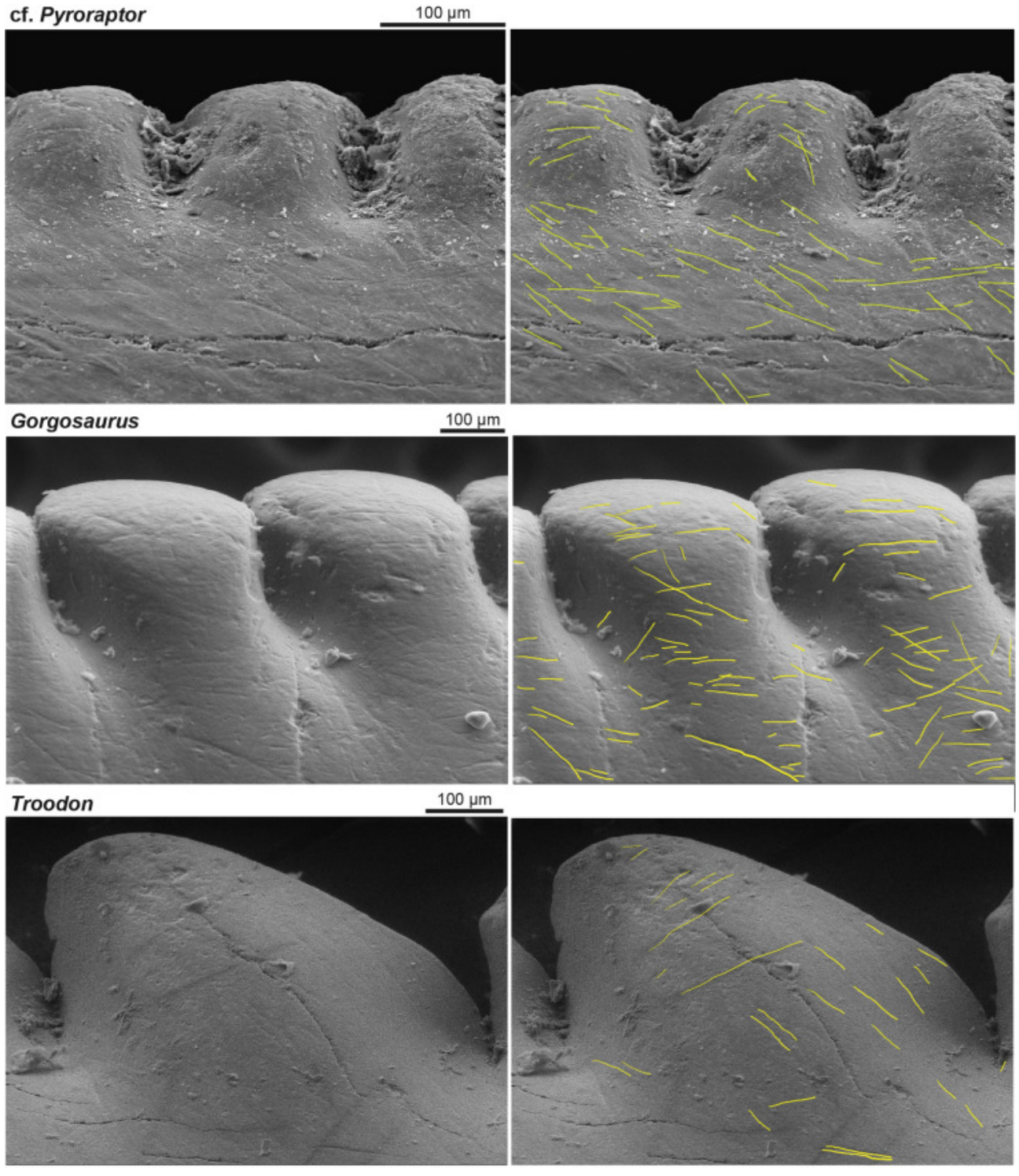
Outline

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

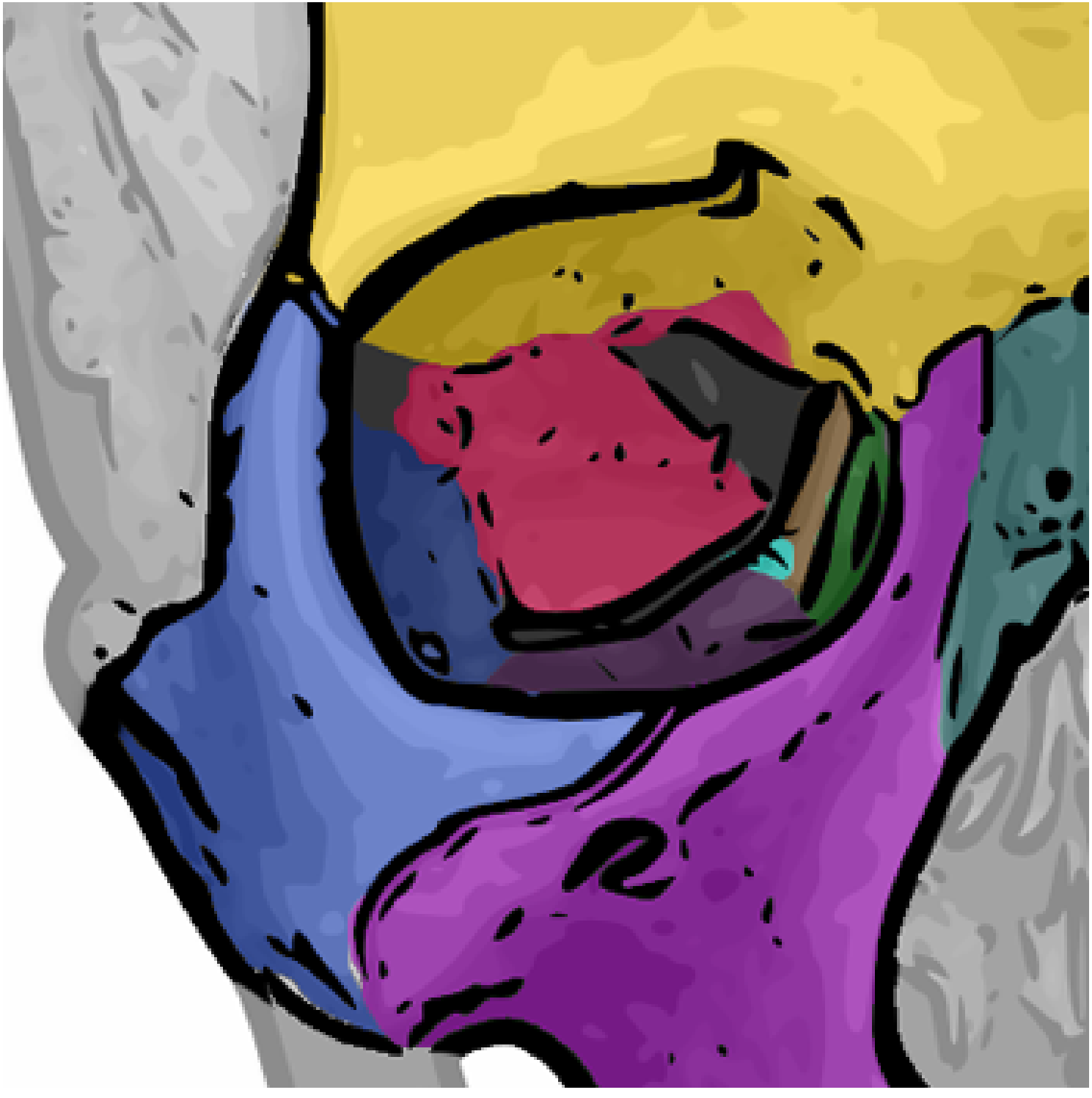
Teeth

- 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

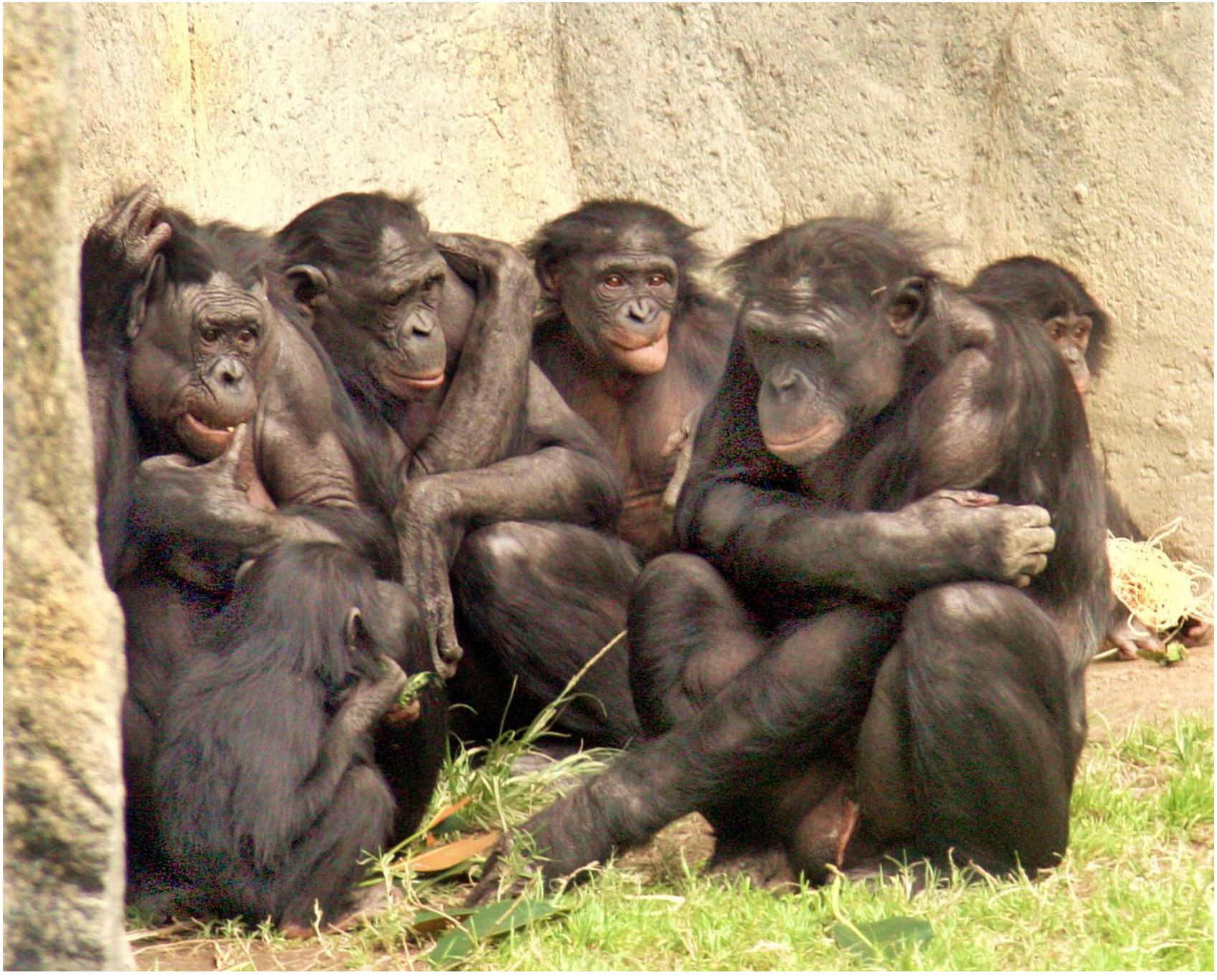
Eyes

- 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



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
- What about humans?
  - **Remark: Big penises and small testicles**

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
- **Remark: : Skip a summary slide**

Summary

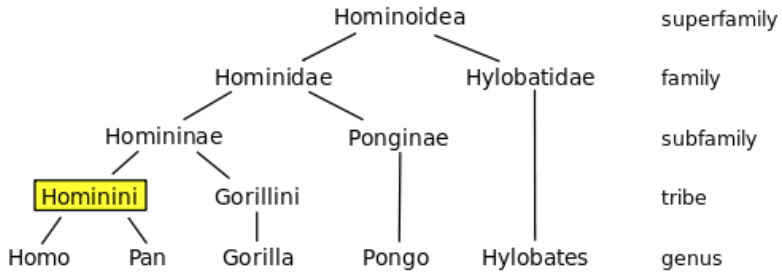
- People have important differences from other organisms
- We got here using the same rules of natural selection as everyone else
  - Things may be different *now*, but even that is not so clear
- Adaptation does not move in a straight line
  - Changing conditions lead to opportunities for new adaptations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

Outline

Hominins

- **Hominins** refer to people and our upright ancestors
- Characterized by:
  - Walking upright
  - Specific changes in chewing design: teeth, jaws and skull

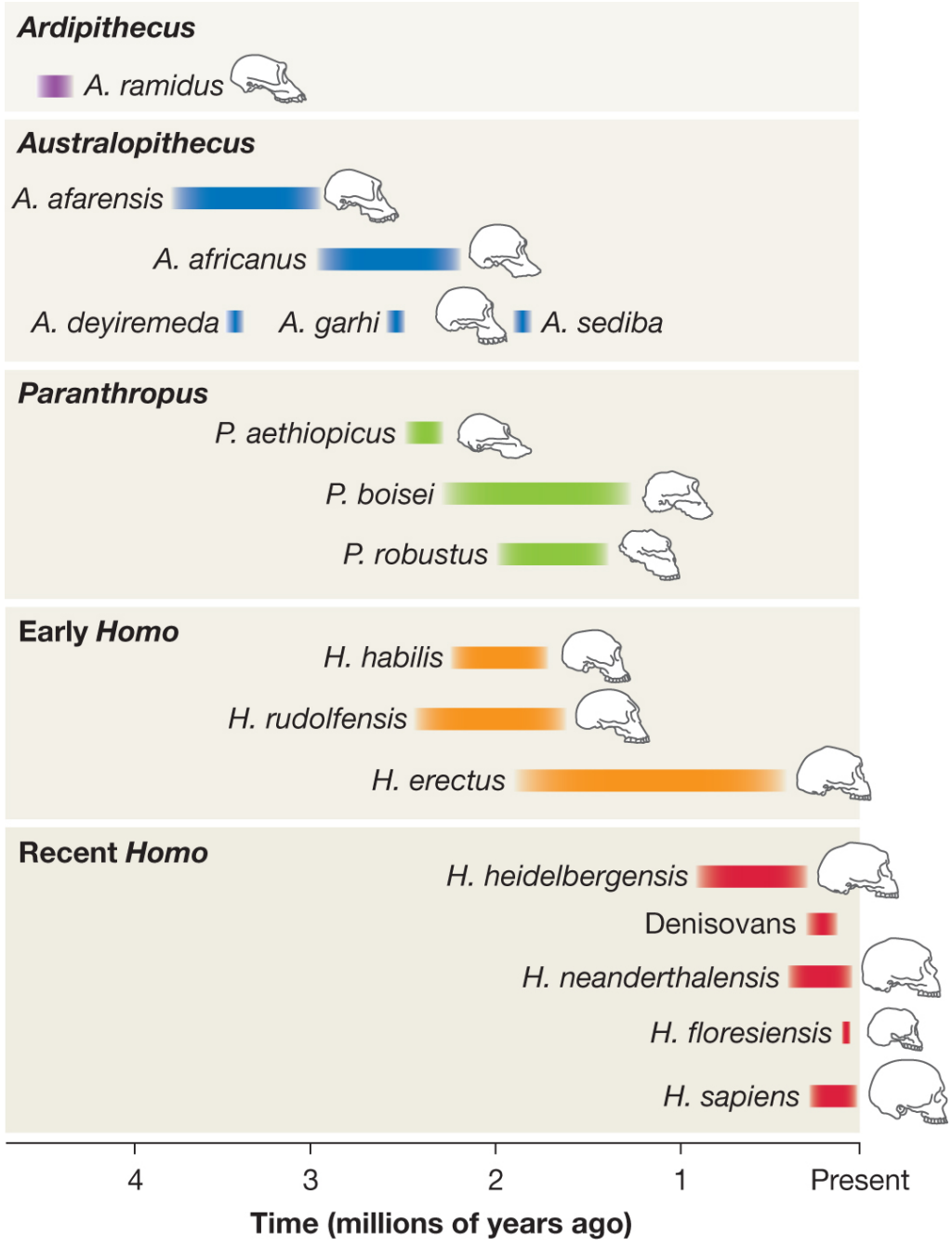
Taxonomy



- **Remark: Taxonomy from wikipedia**
- Homonoidea, Hominidae, Homininae, Hominini, Hominina, Homo
- Why so much detailed splitting?
  - * We're a little bit full of ourselves
  - * Observer bias

Putting together the puzzle

- What did our common ancestor with chimpanzees look like?
- Which fossils are related to which other fossils?
- The key is which features are reliable indicators of relatedness?
  - * How do we tell the difference between convergence and homology?
  - * It's all in the details
  - * And it's not always clear


Ardipithecus
A. ramidus
Australopithecus
A. afarensis
A. africanus
A. deyiremeda
A. garhi
A. sediba
Paranthropus
P. aethiopicus
P. boisei
P. robustus
Early Homo
H. habilis
H. rudolfensis
H. erectus
Recent Homo
H. heidelbergensis
Denisovans
H. neanderthalensis
H. floresiensis
H. sapiens
4
3
2
1
Present
Time (millions of years ago)

Competition and replacement

- *H. erectus* replaced everything that came before it
- *H. sapiens* replaced everything that came before *it*

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

Why are we here?

- Modern humans arose around 200 kya, but took over the world around 50 kya
- What happened?
  - Cultural change?
  - Evolutionary change?
    - Sudden or gradual?
  - Why don't we see evidence?
    - * Might be about our brains, and not reflected in fossils

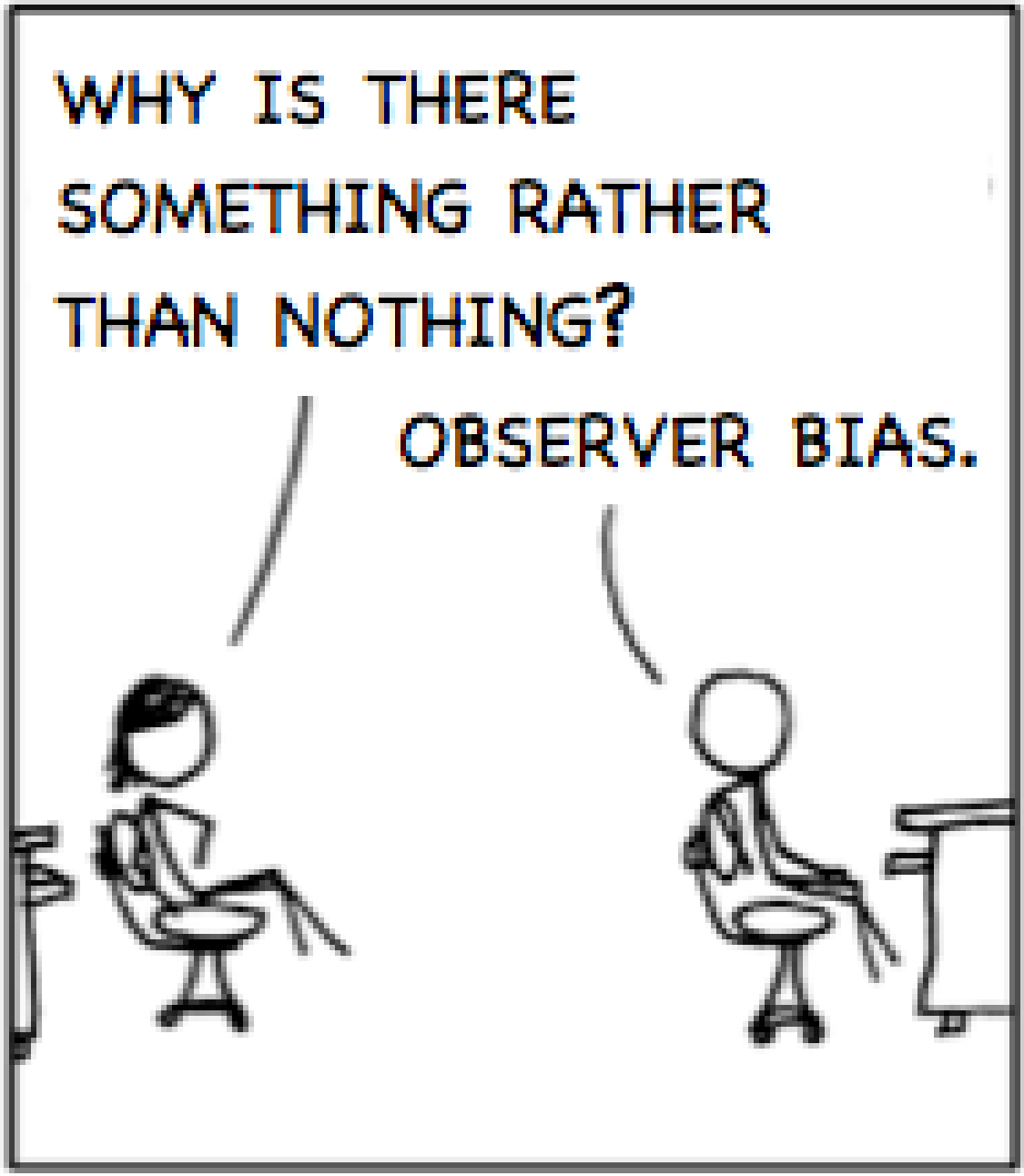
Evaluating evidence

- There are a lot of theories and a great deal of expertise
- But expertise can also lead to over-confidence
- As with other examples, we try to make and test theories
  - * Make predictions about things that haven't been seen yet

Apelike ancestors

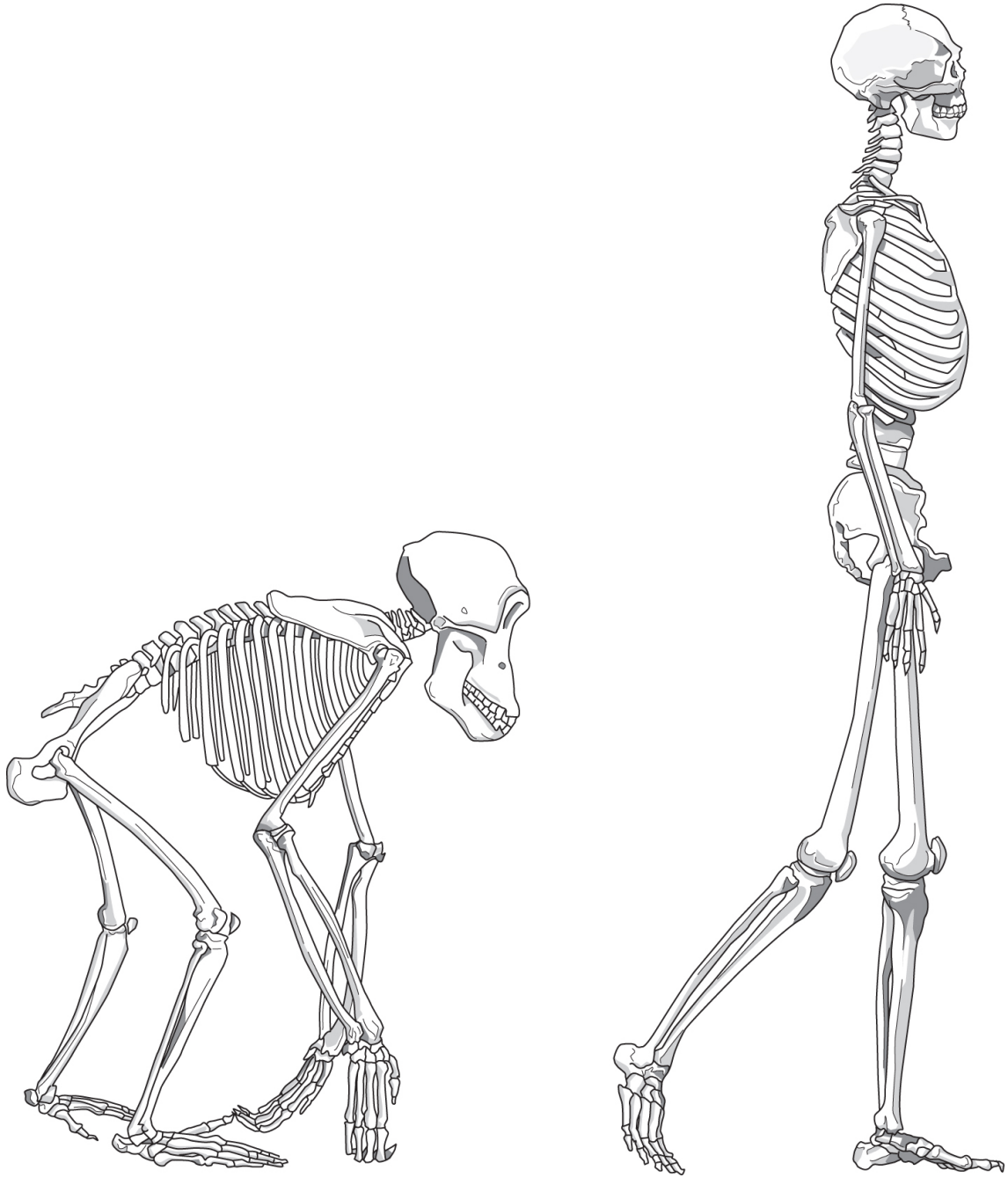
- Were our ancestors more like us, or more like apes?
  - * Trick question: we *are* apes, if apes are a clade
  - * Among living apes, the closest *relatives* of our ancestors is us
  - * In some important ways, we have evolved more than chimpanzees have
  - * But chimpanzees have probably evolved more than we think
    - * Observer bias
    - * Our ancestors are less like chimps than we thought

Observer bias (present)



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
    - * If so, probably dependent on **gradual** evolution from existing form
  - Adaptation for keeping cool
  - Adaptation for harvesting food
  - Adaptation for carrying food



Gradual evolution

- Hominins' evolution of upright posture was likely dependent on evolutionary history and circumstance
  - Built on previous adaptations
- Evolution of upright posture almost certainly led to further evolutionary change:
  - Carrying and storing things
  - Making and using tools
- Given the dramatic amount of evolution, there were likely a lot of adaptive "loops"
  - Changes in one area set the stage for changes in another area

  ...

Studying evolution

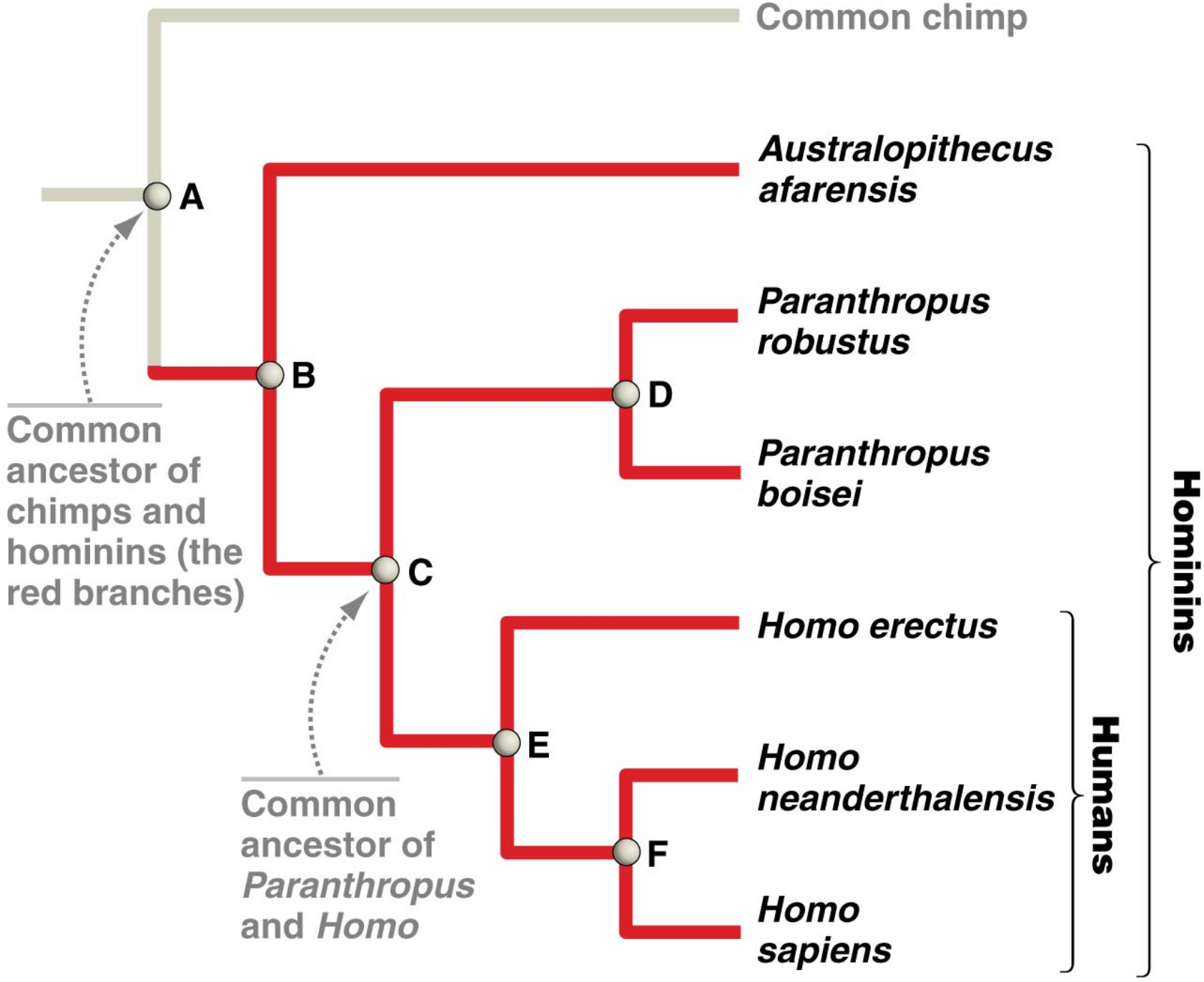
- Evidence from fossils
  - knees, hips, backs, skulls all provide evidence about posture
  - teeth and jaws provide evidence about diet
- Evidence from archaeology
  - hominin fossils may be found in particular placess
  - associated with fossils from things that hominins used to eat
  - or with tools

Back and forth evolution

- Many very early hominins (6 mya) had facial and dental features that were similar to later hominins (2 mya)
  - Less similar to chimpanzees
  - But also less similar to *Australopiths* (3 mya)
- Is this surprising?
  - * Radiation and contraction
    - * The hominins we found may not be directly related to the Australopiths
  - * Evolution is not goal-oriented
    - * Changing conditions can lead to changing directions of evolution

Hominin phylogenies

- Hominins had a large number of speciation and extinction events
  - Consistent with radiation and contraction
  - Likely provided more opportunities for adaptation in the long run
- The tree is not well understood, despite intensive study
  - * Changing environments and convergent evolution



Outline

Complex foraging

- A key part of human evolution was shaped by **complex foraging** strategies of our ancestors – they relied on many types of food, including types of food that are difficult to get or process
- What adaptations likely favored this strategy?
  - * Clever hands, upright walking
- What further adaptations might this strategy have favored?
  - * Big brains
  - * co-operation, including male-female co-operation
  - * Social behaviour

Looping

- Lots of adaptations may be partly explained by adaptive loops
  - * Complex foraging $\Longrightarrow$ more sociality $\Longrightarrow$ bigger brains $\Longrightarrow$ more opportunities to adapt complex foraging techniques ...
  - * More communication $\Longrightarrow$ more complex social interactions $\Longrightarrow$ bigger brains $\Longrightarrow$ more opportunities to evolve better communication or language

Complex foraging and co-operation

- Complex foraging may have promoted co-operation between females and males, since primate child care is not well suited to a hunting life style
- It may have promoted co-operation between people with different skills, since they might have access to food at different times
- It may have promoted co-operation among hunters, since hunting success is highly variable
- It may have promoted co-operation in teaching and learning

Complex foraging and thinking

- Complex foraging favors large brains that can learn a lot
- It also favors a long learning period
  - Sensitivity vs. crystallization
    - Time periods when we learn, vs. time periods when we have fixed behaviours
- It also favors communication

Complex foraging and gender roles

- How might complex foraging affect child care and sexual dimorphism?
  - * If males and females co-operate, then pair bonds might be more stable
  - * If pair bonds are more stable, we expect sexual dimorphism to be less

Social behaviour

- As behaviour becomes more social, a wide variety of other adaptations may become available
  - Mostly related to thinking and communication
- Leading to more opportunities for looping:
  - * Bigger brains may facilitate more food-gathering and survival strategies
  - * Communication may favor co-operation

How social were early hominins?

- What kind of clues might be available?
  - * Sexual dimorphism
  - * Physical structures consistent with vocal communication
  - * Dental enamel! Preserves amazingly detailed history of growth and growth rate

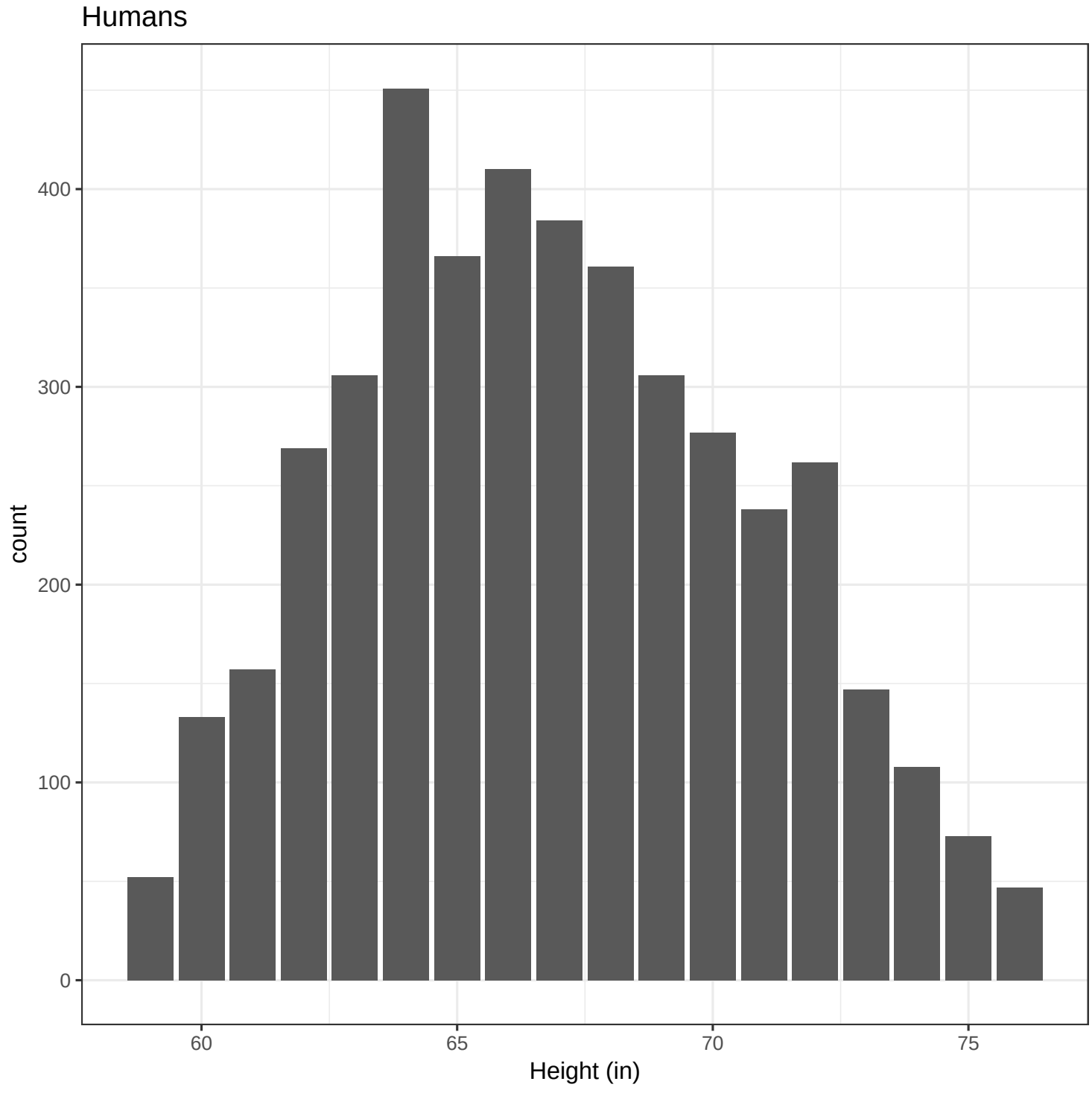
Sexual dimorphism

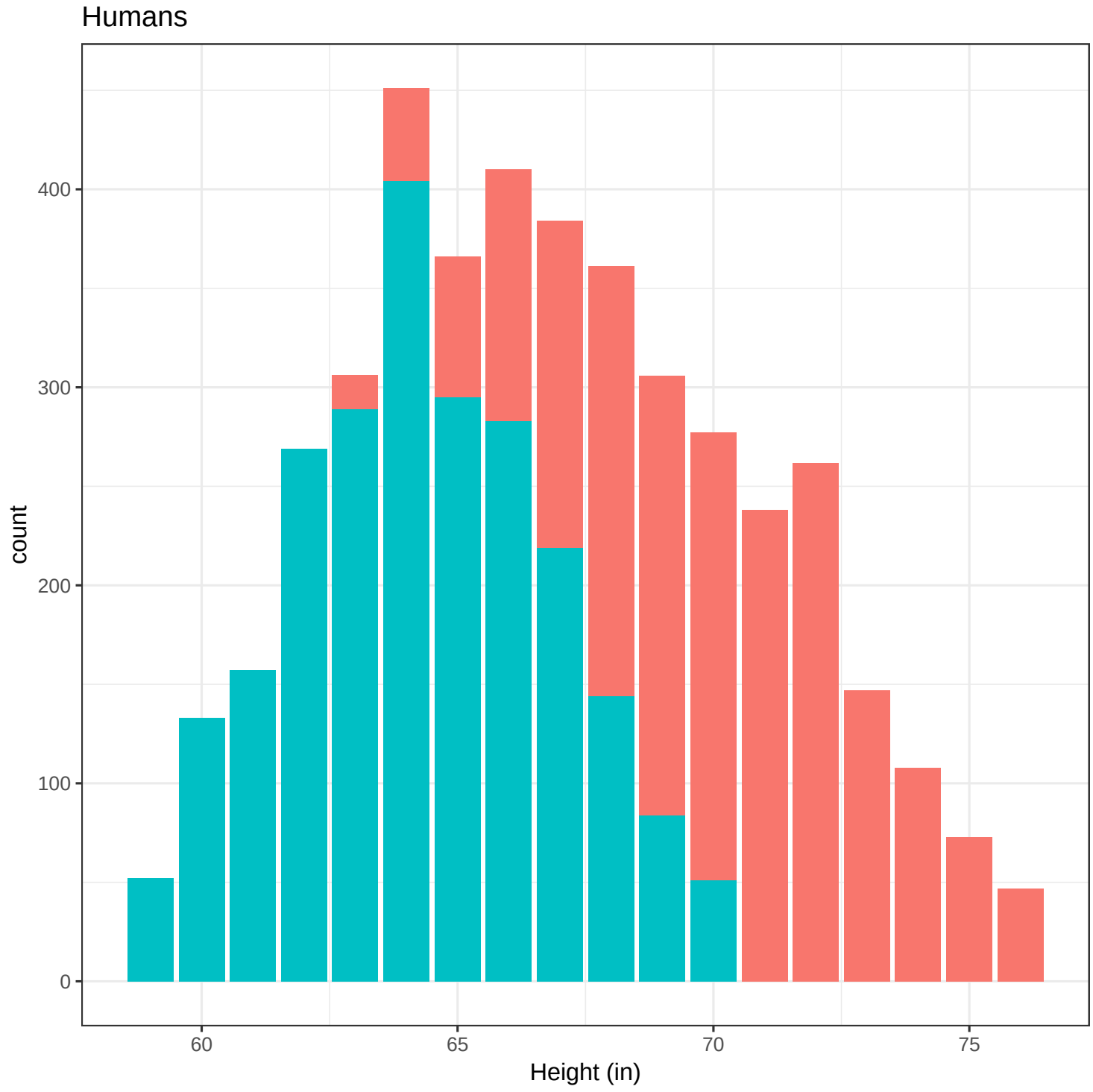
- The extent of sexual dimorphism tells us at least something about social structures
  - * Large amounts of sexual dimorphism probably mean less sociality and co-operation
  - * At least among adult males
- How do we know whose bones are male and female?
  - * **Pelvises** (hip bones) are very different in all of our ancestors
  - * Because childbirth
- How do we know whose teeth are male and female?
  - * We don't, usually
  - * Bimodality can tell us about dimorphism anyway

Bimodality

- Bimodality means having two peaks in a distribution
  - For example, a modern human height distribution would have a peak for men, and a peak for women

- If traits are strongly dimorphic, we should be able to tell by sampling, even if we don't know which fossils come from males and which from females

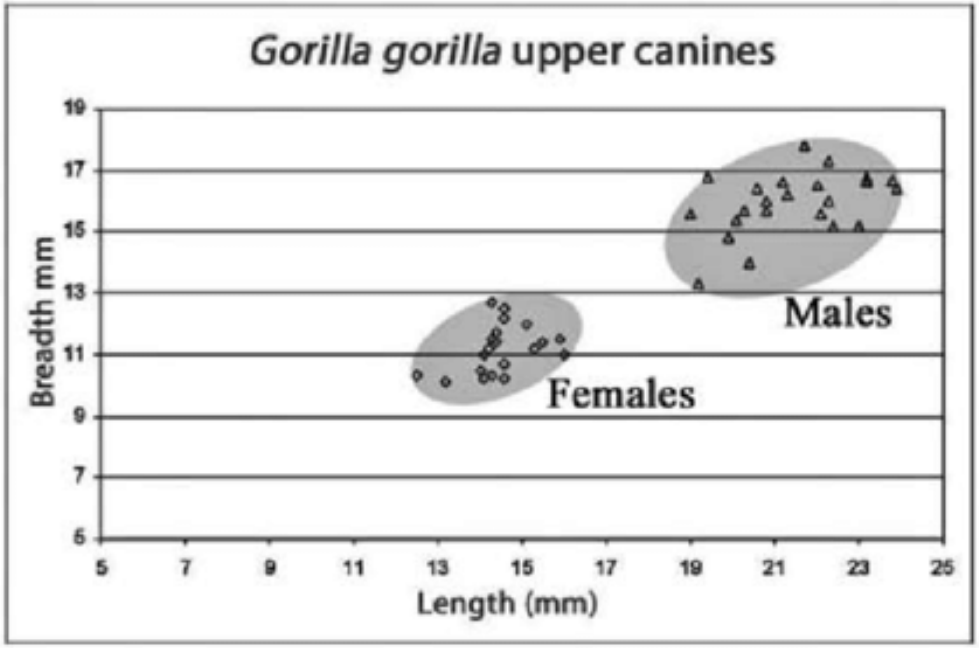

Humans
count
400
300
200
100
0
60
65
70
75
Height (in)

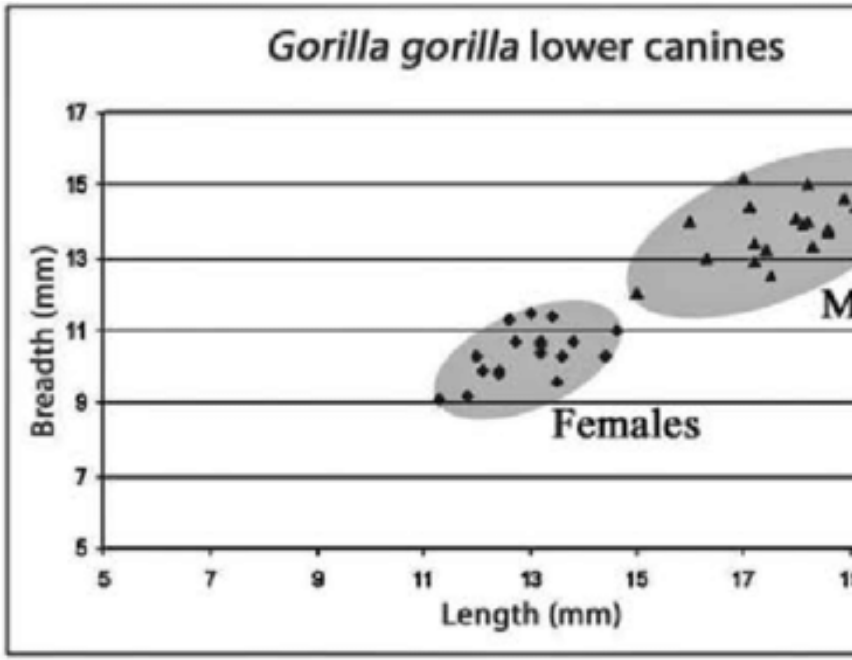

Humans
count
400
300
200
100
0
60
65
70
75
Height (in)

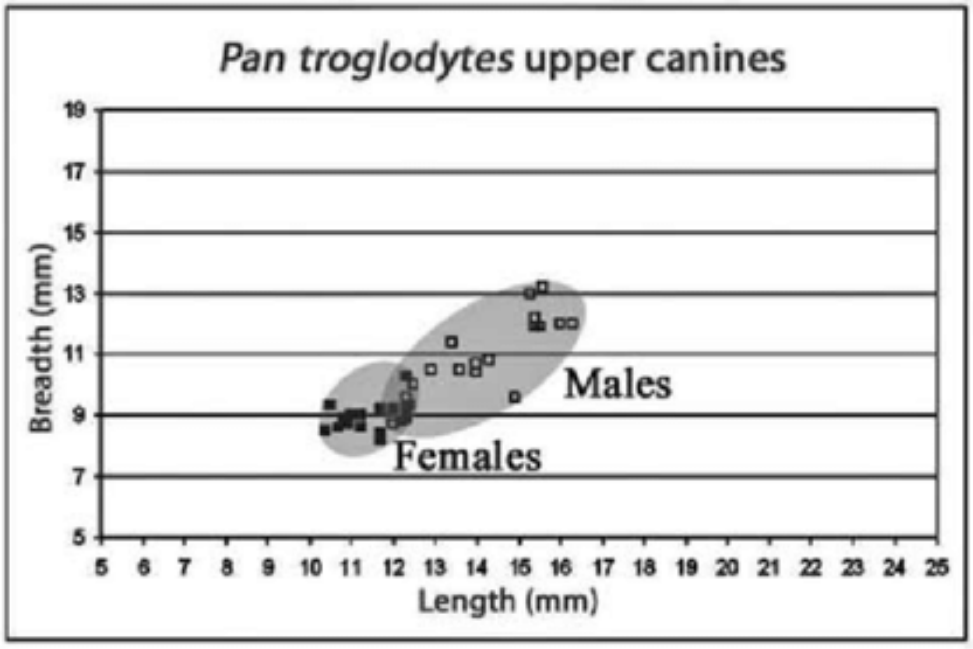
Teeth

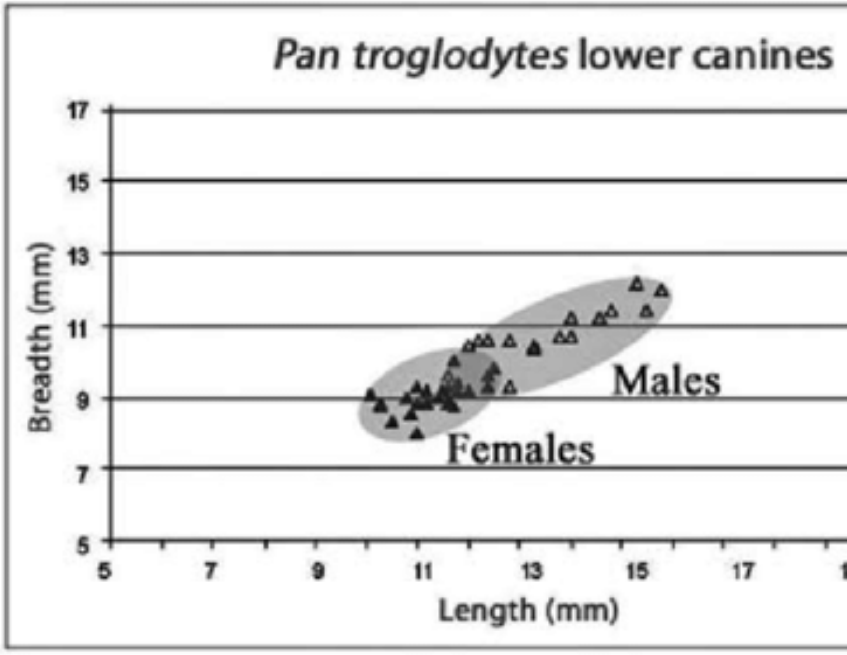
- Chimpanzees and (especially) gorillas have extreme sexual dimorphism in tooth size

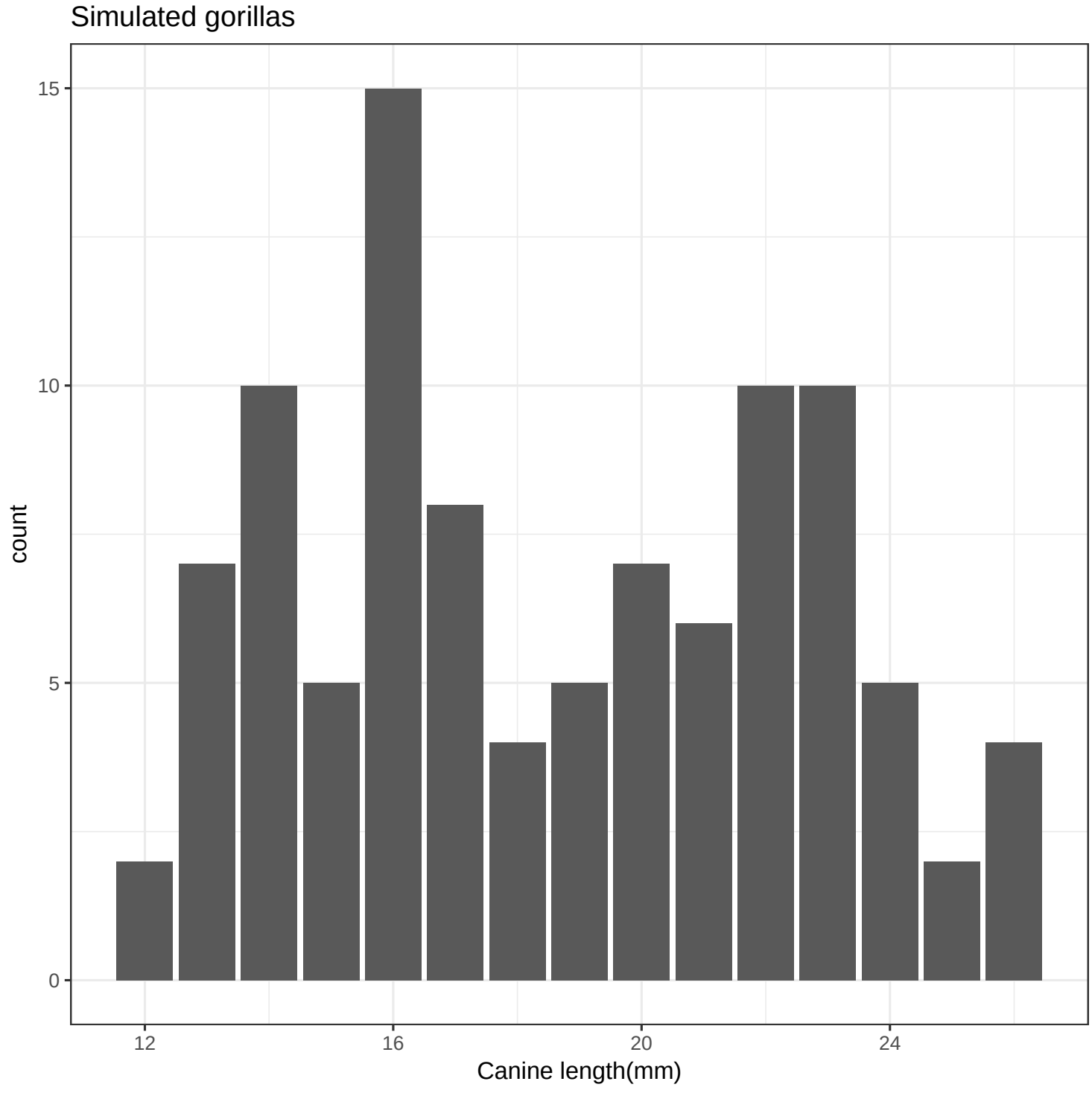
- We can tell our ancestors have less dimorphism than that *even if we can't tell the males from the females*
  - * We would expect to see two clear peaks in the distribution

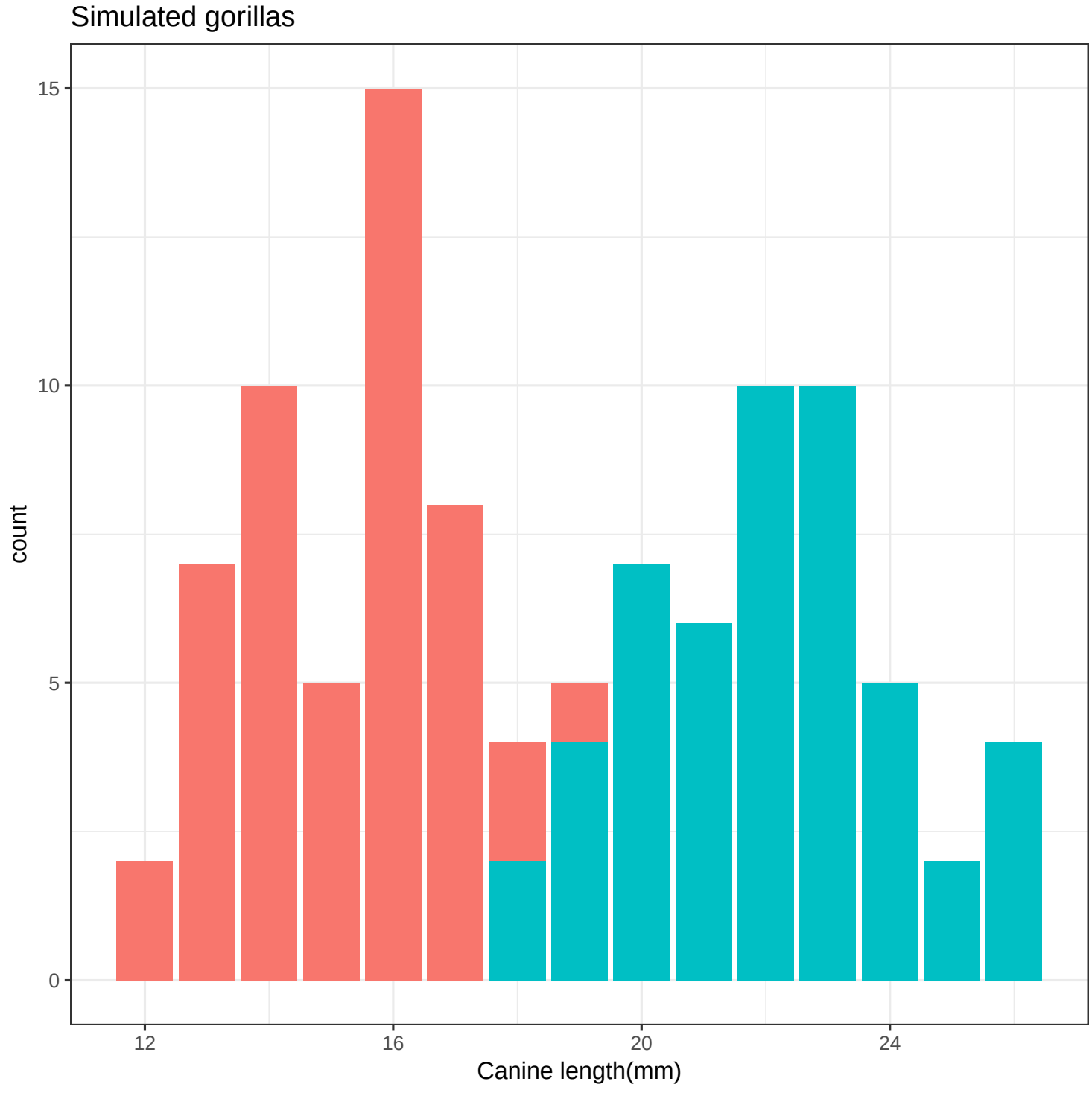

Gorilla gorilla upper canines
Breadth mm
Length (mm)
Males
Females


Gorilla gorilla lower canines
Breadth (mm)
Length (mm)
Females


Pan troglodytes upper canines
Breadth (mm)
Length (mm)
Males
Females


Pan troglodytes lower canines
Breadth (mm)
Length (mm)
Males
Females


Simulated gorillas
15
10
5
0
count
12
16
20
24
Canine length(mm)


Simulated gorillas
15
10
5
0
count
12
16
20
24
Canine length(mm)

Rate of development

- Why do human children develop *so* slowly?
  - * Presumably related to elaborate sociality
- We are therefore very interested in how long it took our ancestors to mature
- Clues are available
  - Dental enamel
  - Molar development
- But it's a hard problem

Remark: 2-year-old

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)