Bio 1M: Human evolution (complete)

1 Patterns of evolution

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?
  - **Answer:** Complex thoughts
  - **Answer:** Culture
  - **Answer:** Language
  - **Answer:** Technology
- What is the same?
  - **Answer:** We're here because our ancestors reproduced
  - **Answer:** If reproductive success depends on heritable variation in traits ...
    - **Answer:** We're still evolving
    - **Answer:** 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
    - **Answer:** Connections help people think clearly

1.1 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
    - **Answer:** Provides opportunities for allopatric speciation

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?
  - **Answer:** Changing conditions (climate change, continents moving)
  - **Answer:** Competition from other clades (therapsids vs. dinosaurs)
  - **Answer:** 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?
  - **Answer:** Maybe it's just the ones see
  - **Answer:** 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)

2 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?
  - **Answer:** Derived traits
- How would you interpret the fact that humans don't have grasping feet?
  - **Answer:** Our ancestors lost the trait
  - **Answer:** 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?
  - **Answer:** Depends on the ancestor: in this case it seems hard to say
  - **Answer:** 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
  - **Answer:** Observer bias
  - **Answer:** Phenetic approaches: humans have a lot of adaptations
    - **Answer:** 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

3 Apes

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?
  - **Answer:** Changing climactic conditions
  - **Answer:** Changes in plants or insects
  - **Answer:** Unpredictable adaptive innovations
- What if the ape radiation had never happened?
  - **Answer:** Less diversity between surviving apes
  - **Answer:** Probably no people

4 Learning about the past

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?
  - **Answer:** Makes it more likely our teeth will last for longer
  - **Answer:** This is probably also why wisdom teeth come in late
- Teeth help scientists understand what extinct animals ate
  - Often preserved, highly adapted

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?
  - **Answer:** Better for precise tasks, three-dimensional visualization
  - **Answer:** Not as good for looking around, being alert
- What are the advantages and disadvantages of larger eyes?
  - **Answer:** Better for night vision
  - **Answer:** More costly? Harder to protect?
  - **Answer:** 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:
    - **Answer:** More sexual dimorphism
    - **Answer:** 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?
  - **Answer:** 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?
  - **Answer:** Chimpanzees have much larger genitals.
  - **Answer:** Gorillas don't use genitals as part of sexual competition
- What about humans?

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

5 Hominins

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

Taxonomy

- Homonoidea, Hominidae, Homininninae, Hominini, Hominina, Homo
- Why so much detailed splitting?
  - **Answer:** We're a little bit full of ourselves
  - **Answer:** 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?
  - **Answer:** How do we tell the difference between convergence and homology?
  - **Answer:** It's all in the details
  - **Answer:** And it's not always clear

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?
    - **Answer:** 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
  - **Answer:** Make predictions about things that haven't been seen yet

Apelike ancestors

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

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
    - **Answer:** 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?
  - **Answer:** Radiation and contraction
    - **Answer:** The hominins we found may not be directly related to the Australopiths
  - **Answer:** Evolution is not goal-oriented
    - **Answer:** 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
  - **Answer:** Changing environments and convergent evolution

6 Sociality

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?
  - **Answer:** Clever hands, upright walking
- What further adaptations might this strategy have favored?
  - **Answer:** Big brains
  - **Answer:** co-operation, including male-female co-operation
  - **Answer:** Social behaviour

Looping

- Lots of adaptations may be partly explained by adaptive loops
  - **Answer:** Complex foraging $\implies$ more sociality $\implies$ bigger brains $\implies$ more opportunities to adapt complex foraging techniques ...
  - **Answer:** More communication $\implies$ more complex social interactions $\implies$ bigger brains $\implies$ 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?
  - **Answer:** If males and females co-operate, then pair bonds might be more stable
  - **Answer:** 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:
  - **Answer:** Bigger brains may facilitate more food-gathering and survival strategies
  - **Answer:** Communication may favor co-operation

How social were early hominins? (not covered)

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

Sexual dimorphism (not covered)

- The extent of sexual dimorphism tells us at least something about social structures
  - **Answer:** Large amounts of sexual dimorphism probably mean less sociality and co-operation
  - **Answer:** At least among adult males
- How do we know whose bones are male and female?
  - **Answer:** **Pelvises** (hip bones) are very different in all of our ancestors

- **Answer:** Because childbirth

- How do we know whose teeth are male and female?
  - **Answer:** We don't, usually
  - **Answer:** Bimodality can tell us about dimorphism anyway

Bimodality (not covered)

- 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

Teeth (not covered)

- 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*
  - **Answer:** We would expect to see two clear peaks in the distribution

Rate of development

- Why do human children develop *so* slowly?
  - **Answer:** 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

Summary

- People evolved by the same basic rules as other organisms
  - **Answer:** Adaptation by natural selection
- Followed a very different path
  - **Answer:** Strong loops that continually created new adaptive opportunities
- There is a lot we can learn about ourselves from biology

  - **Answer:** We are affected by all of the same basic processes as other organisms

- And also a lot that we can't learn
  - **Answer:** We are also strongly affected by our complex brains (and complex cultures)

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