Introduction to Biological Anthropology: Notes 17

Paleontology and the first primates

- So far, we have seen how evolution works in general, and how it has shaped our closest relatives, the non-human primates
- Now we will shift gears again, and look at the direct evidence of how our own kind evolved
  - we want to know basically two things
    - the *sequence of steps* that led from some kind of animal in the past to modern humans
    - and the *evolutionary reasons* for each one of those steps
      - why would our quadrupedal ancestors evolve into bipeds?
      - why would they develop language? … etc.
  - this is still an active field, with many questions left to be resolved
- this direct evidence comes from **paleontology**
  - the study of fossilized animal and plant remains
    - for animals, usually bones
    - occasionally, other body parts and evidence of them
  - usually, when an animal or plant dies, the bones and other parts rot, weather, and decay away
    - under some rare circumstances, bones can be preserved as **fossils**
    - the most common form of fossil is formed when the organic material gradually dissolves away and is replaced by minerals that crystallize out of ground water
    - this creates a rock in the exact shape of the bone
    - which is then very durable, and may last long enough to be found and studied
  - the study of fossils is **paleontology**, done by **paleontologists**
    - most paleontologists study extinct animals (and plants) that are not primates, as the evolutionary arm of biology
  - the study of fossils of animals ancestral to humans and our close relatives is a sub-specialty often called **paleoanthropology**, done by **paleoanthropologists**
  - by the way, **archaeologists** like me do not normally study fossils
    - we study the material evidence of *cultural activity* by *people*
    - that is, tools, houses, campsites, garbage dumps, burials, etc.
    - sometimes that includes the remains of human bodies or other animals
    - this stuff is usually much younger than any fossils
- We can often determine the age of fossils
  - The book explains briefly how some of these methods work, but we won't take the time to go through the physics of these methods here
  - **Potassium-argon dating** tells us how long ago lava or ash cooled to a solid
    - but works only on rocks (not the fossils themselves)
    - and the rocks must have cooled from liquid at least half a million years ago
    - used by dating a layer of basalt (lava) from above the fossil and another from below it, to bracket the fossil's age
  - **Radiocarbon dating** tells us how long ago a living thing died
    - but works only on organic material that is less than 70,000 to 50,000 years old

- most of human evolution occurred too long ago for the radiocarbon method to help
- and other methods…
- The point: we can tell how old fossils are, but with differing degrees of accuracy and precision, depending on the fossil's age and the conditions where it was buried

- Many of these extinct animals evolved in a world very different from the one we know
  - the continents were arranged differently
    - again, the book describes this briefly, but we won't pursue it here
    - the story of how "**continental drift**" was discovered, proven, and the ancient world reconstructed is fascinating - take a geology course!
    - the changing position of the continents and the oceans between them was important to primate evolution in two ways
      - it played a big role in forming the very different climates of the past, from tropical forest conditions that covered most of the globe, to the ice ages
      - it isolated some populations of primates from each other, like the New World monkeys from all the rest in Africa and Asia
    - but most of the primate evolution that will interest us happened after the continents had split up into roughly their modern arrangement
      - so for this class, continental drift is not a crucial part of the story
  - the climate differed drastically from today, and changed drastically during the evolution of the primates
    - we will have to take the climate and environment into account if we want to understand what was driving our ancestors' evolution
    - the dinosaurs disappeared around 65 mya (million years ago)
      - at the end of the Cretaceous period and the beginning of the Tertiary period
    - the first primates appeared around 55 mya
      - near the peak of recent global temperatures, about 25° C (77° F)
      - compare to the global average temperature now, about 5° C (41° F), cold but not freezing
      - Effectively the whole earth was tropical, hot, wet, and densely forested
    - Since then, the temperature has generally been dropping, very irregularly
      - eventually going into a series of ice ages (**glacial periods**) separated by warm **interstadial periods**
      - it was in this period of extreme climate swings and relative cold that our own genus *Homo* first appeared
      - We happen to live in one of the warm periods between glacial periods, or interstadials, which started roughly 12,000 years ago
      - there is no particular reason to think it is any different from the past few interstadials, which generally lasted 30,000 to 50,000 years
    - you might note: the difference between the cold parts of the ice ages and the warm interstadials (like the present) was only around 5° C (9° F)
      - think about that next time you hear global warming experts talk about a likely change of many degrees C in the coming century… that would be climate change on the same scale as the swings between ice ages and interstadials, but in the opposite direction…

- Let’s begin the story of the origin of humans
- Picking up the story in the early Cretaceous period, around 350 mya (million years ago)
- The Earth was covered by **gymnosperm** forests
  - gymnosperms are plants that
    - bear seeds, generally in cones
    - have no flowers
    - and no fruit
    - depend on the wind to blow their pollen around to fertilize another plant to produce seeds
    - most have needle-like leaves
    - generally have a single stem with minor branches, like a Christmas tree
  - modern examples are pines and redwoods
  - visualize the world covered by coniferous forests
    - straight trunks, twiggy branches, needles
    - difficult to move from one tree to the next, few arboreal animals
  - this was the environment in which the dinosaurs first evolved, diversified, and became the most prevalent kind of animal
  - mammals also first appeared in this kind of environment, but they remained relatively few compared to the reptiles
- About 100 mya, during the Cretaceous period, a new type of plant emerged: the **angiosperms**
  - this was the later part of the time that reptiles dominated the land
  - angiosperms are plants that
    - have flowers
    - many of which depend on insects or animals to pick up pollen and redeposit it in order to fertilize the same flower or a different one to produce seeds
    - produce seeds enclosed in fruits, rather than cones, many of which are edible
    - have broad, rather than needle-like, leaves
    - have complex branches, like most familiar trees
  - most familiar modern plants are angiosperms, except conifers and ferns
  - imagine the world largely covered by tropical and temperate broad-leaf forests
    - like the ones in the pictures we have been seeing of primates
- angiosperms offered new possibilities for animals
  - the angiosperms co-evolved with animals
  - evolved showy flowers with edible nectar and fruits to attract animals to pollinate them
  - evolved edible fruits to get animals to disperse their seeds
  - many animals evolved specialized features to find, eat, and digest the angiosperm fruits and leaves
  - for the first time, many animals also developed arboreal habits
    - because angiosperm forests form interlocking canopies that allow movement from one tree to the next without dropping to the ground
- various mammals adapted to these new niches, including the precursors to the primates
  - adapted to eat insects and possibly seeds

    - small bodies
    - teeth with pointy cusps
  - similar to modern tree shrews
  - imagine tropical deciduous forests, with dinosaurs prevalent on the ground, and little shrewlike mammals scurrying around in the trees and underbrush

- Something drastic happened at the end of the Cretaceous period, around 65 mya
  - this is the famous "Cretaceous-Tertiary boundary", or "K-T boundary"
  - many species of animals and plants abruptly went extinct
  - almost all of the dinosaurs disappeared
  - most geologists and paleontologists now believe that this was due to a massive meteorite striking the Earth
    - about 6 kilometers (3.5 miles) in diameter
    - the dust and vapor thrown up by the impact darkened the globe for several years
    - killing plants and plankton, temporarily cooling the climate, etc.
    - disrupting the food chain and driving many species extinct
  - but some of the small, nocturnal, rodent-like early mammals survived
    - these were our ancestors…

- About the same time that the dinosaurs went extinct, the first **plesiadapiforms** appeared
  - a late example: *Carpolestes simpsoni*
    - small, rodent-like variant of earlier mammals
    - but with opposable thumbs/toes with flat nails
      - retaining claws on the other digits
    - flattish molars suggest frugivorous diet
    - eyes are still on the side of the head, no overlapping stereo vision
    - no postorbital bar
    - hindlimbs still only slightly more powerful than forelimbs (locomotion not so hindlimb dominated as in primates)
  - so these animals had a few, but not all, of the suite of traits that define primates

- by about 10 million years later, some of these little mammals had evolved into the first definite primates
  - this was the Eocene epoch, about 55 to 36 mya
    - approaching the peak of recent global temperatures, about 25° C (77° F)
    - Effectively the whole earth was tropical, hot, and wet
    - most of the world was covered with tropical forest
  - there were two varieties of **Eocene primates**, both similar to modern prosimians
    - **Adapids**, like modern lemurs
      - larger
      - smaller orbits (and therefore, eyes)
        - thus probably diurnal
      - frugivores and folivores
    - **Omomyids**, like modern tarsiers
      - smaller

- larger eyes
  - thus probably nocturnal
- sharp teeth, probably for eating insects
- frugivores, insectivores and gummivores

- the full suite of basic primate features evolved in this environment
  - grasping hands and feet with opposable thumb/big toe
  - nails, not claws, with grasping pads on fingers
  - hindlimb-dominated locomotion
  - reduced snout and sense of smell
  - larger, forward-facing eyes with overlapping field of view
    - this is associated with a bar of bone behind the eye socket to support and protect the eyeball on the outside (post-orbital bar)
  - larger brain relative to body size

- What was it about this environment that caused selection to favor the features of primates?
  - **Arboreal hypothesis** suggests that
    - primate features were advantageous for living in trees
    - grasping hands for holding onto branches
    - binocular vision for depth perception
    - reduced smell because smell was not as important for moving around in trees
    - brain became complex to deal with balance and complex navigation in branches
    - problem with the theory
      - lots of modern, successful arboreal animals do not have these characteristics
      - so there must be something else that favored the primate characteristics
  - Matt **Cartmill's visual predation hypothesis** suggests that
    - primate characteristics were favored because they helped in catching insect prey
    - pro
      - stereoscopic vision is found in modern animals that use vision to locate prey, like cats
    - con
      - many living prosimians use sound and smell to locate prey
        - so it seems unlikely that the common primate ancestor was a visual predator, because many prosimian lineages would have to have lost those traits and reverted to a more ancient, generalized condition
      - plesiadapiforms (particularly *Carpolestes simpsoni*) evolved grasping hands and feet with neither stereo vision nor an insectivorous diet
        - so grasping hands/feet must have initially evolved for some other purpose
  - **Leaping hypothesis** suggests that
    - primate characteristics were favored because they helped in leaping locomotion
    - con
      - plesiadapiforms (particularly *Carpolestes simpsoni*) evolved grasping hands and feet without developing powerful leaping hindlimbs
        - so selection favoring leaping could not have led to the basic primate traits of grasping hands and feet
  - **Diet shift hypothesis** suggests that

- early primates focussed on insects
- then, with increasing radiation of angiosperms, acute stereo vision, larger brains, and grasping hands were favored in order to exploit more varied food sources
  - including fruit, flowers, gum
  - good stereo night vision would have been important if they had to handle varied, small, complex items at night
- con
  - plenty of animals have a varied diet and are nocturnal without selection having favored primate-like characteristics
  - plesiadapiforms (particularly *Carpolestes simpsoni*) ate fruit without selection favoring stereo vision

- **Two-step hypothesis**
  - the basic primate traits did not evolve all together as a package, but instead evolved separately in two stages, for different reasons
  - first, some mammals evolved to eat fruit, flowers, and nectar located at the ends of angiosperm branches (a "terminal branch" diet)
    - grasping hands and feet with flat nails helped to reach and collect this food
  - later, these animals expanded their terminal branch diet by hunting insects found around the fruit and flowers
    - stereo vision helped in hunting the insects
    - snout was reduced as improved vision increasingly replaced smell for locating food
  - this hypothesis fits with the fossils (for now!)
    - first, plesiadapiforms evolved grasping hands and feet
    - then, early primates added stereo vision

- So far, we have seen only prosimian-like early primates

- the first anthropoid (monkey-like) primates appeared in the Eocene
  - but are still very poorly known

- Much better evidence of anthropoids by the beginning of the Oligocene
  - 36 mya
  - lower temperatures, but still very warm by modern standards
  - more seasonal: wider temperature swings from winter to summer
  - Fossils of **Oligocene primates** are found in the Fayum depression (Egypt)
    - at that time, a swamp
    - adapids (lemur-like) and omomyids (tarsier-like) continued, as before
    - plus ten new genera of anthropoids
    - unknown whether anthropoids evolved from omomyids or adapids, or some other as yet unknown Eocene primates
    - later in the Oligocene (33 mya), a famous species: *Aegyptopithecus zeuxis*
      - post-orbital bar, as in of all primates
      - plus post-orbital plate, as in anthropoids
      - moderate sized eyes: diurnal
      - prognathic: jaws (snout) stick forward

        - foramen magnum (opening for the spinal cord) at back of head (not underneath): implies a quadrupedal posture, spine generally horizontal
        - larger brain, but still not very big
        - postcranial bones suggest arboreal
        - 13 pounds
        - large, wide, protruding ("procumbent") incisors plus large, sturdy canines: typical of frugivores
        - significant sexual dimorphism: probably multi-female groups with lots of male-male competition
    - Some of these Oligocene primates were probably ancestral to, or close relatives of ancestors of, modern Old World monkeys and apes
  - A few fossil anthropoids are also found in South America (Bolivia and Argentina)
    - also around 34 mya, about the same as the first anthropoids in the Old World
    - how did they get to the New World?
      - this presents some interesting problems that are covered in the reading
      - we don't have time to discuss them here

- The book also has an excellent discussion of how incomplete the fossil record is
  - again, we don't have time to cover this in class
  - the outcome is that we probably have seen fossils of only about 3% of all the primate species that have ever lived
  - real phylogenies are probably much bushier than the few fossils suggest
    - that is, more complex, more branches than we know
  - but even if fossils are not direct ancestors of particular living primates or other fossils, they are probably close relatives
    - so they give us a rough idea of what the actual ancestors were probably like

- the first known hominoids (apes) appeared in the late Oligocene, 27 mya
  - example early **Oligocene ape**: genus *Proconsul* (probably various species)
    - lived in tropical rainforest
    - fairly large, like a macaque
      - 33-110 pounds
    - hominoid traits
      - no tail
      - no "fleshy sitting pads" (ischial callosities)
      - larger body size
      - various subtle skeletal similarities to modern apes
      - slightly larger brain to body size ratio
      - short forelimbs and narrow chest indicate they were quadrupedal, walking on top of branches, as many monkeys do
        - rather than hanging by arms, as modern apes do
      - teeth indicate frugivorous diet
        - thin enamel on the molars: relatively soft foods
    - another Oligocene hominoid: *Morotopithecus bishopi*
      - similar to *Proconsul*, but with hints of more apelike posture and locomotion

      - evidence: scapula (shoulder blade) suggests that it climbed and hung from branches, maybe brachiated

- the middle Miocene (15-10 mya) saw a great radiation of hominoids (apes)
  - that is, the hominoids split into many different lines, with different species adapting to many different niches
  - why? We don't really know, but:
    - lots of climate changes in the Miocene
      - from the middle Miocene on, it got cooler and drier
      - tropical forests shrank, and there were greater areas of open woodland and savanna
      - the climate also began to change back and forth between warmer and cooler more rapidly, on a scale of just tens of thousands of years
        - maybe these rapid changes, rather than the climate itself, was the key
        - maybe something about apes made them well suited to handle changing environments
          - maybe the ability to get by on a range of different foods, rather than being strongly committed to just one category of foods
    - also, Africa and Eurasia got close and joined, cutting off the Tethys sea around 15-10 mya
      - leading to an exchange of animals and plants
      - probably changing the ecology in many ways
      - and allowing some species of early apes (genus *Proconsul*) to spread out of Africa to more varied environments
      - so populations of apes in different environments, surrounded by new varieties of plants and animals, evolved into many different species of apes
        - most of which went extinct by the end of the Miocene or slightly later
  - the many, varied **Miocene hominoids** (Miocene apes)
    - *Kenyapithecus*, *Oreopithecus*, *Dryopithecus*, *Sivapithecus*, *Ramapithecus*, etc.
    - general trend seems towards more chewing -- eating harder or more fibrous foods
    - presumably in response to the drying, more seasonal climate
      - which would have encouraged woodier, tougher plants compared to the tropical rainforest
    - Miocene hominoids (apes) had features for heavy chewing
      - molars of some species had thick enamel, allowing for more wear and more pressure to be applied to break hard seeds
      - molars had lower, rounded cusps, better for grinding, less designed for shearing leaves
        - that is, less specialized, more generalized for a varied diet
      - molars tend to be worn from lots of grinding
      - U-shaped **dental arcade**
        - typical of apes, different from hominids
      - more space for larger **temporal muscles** (that pull the lower jaw up against the upper jaw)
        - this is visible by looking at the space where the temporal muscle passes between the temporal bone of the brain case and the **zygomatic arch**
        - this whole space is filled by the temporal muscle
      - more massive **mandible** (lower jaw), to withstand the increased chewing forces

- at least two of the Miocene hominoids (*Dryopithecus* and *Oreopithecus*) were arboreal, adapted to hanging by their arms like quadrumanual or brachiating apes
  - they have the classic anatomical adjustments to brachiation or quadrumanuality
  - wide ribcage
  - shoulder blades at the back, not on the sides
  - long arms, short legs
  - long, curved fingers
  - this is the first definite appearance of these classically apelike features, which clearly led eventually to humans
    - although *Morotopithecus* may have had some or all of them
- unknown exactly how these hominoids relate to living primates
  - we may not have found the species that were ancestral to the various modern hominoids (humans, gorillas, chimps, orangs, gibbons, siamangs)
  - except *Sivapithecus*, which looks to be the ancestor, or a relative of the ancestor, of orangutans
- by the late Miocene and early Pliocene, many varieties of Miocene hominoids were going extinct
  - only a few lineages survived
  - leading to the modern apes, and to us
  - there used to be many more kinds of apes in the world; now just a few remain

- By the early Pliocene, between 5 and 4 mya, one of the surviving ape lineages was starting to show signs of resembling us
  - these were the first hominins -- the lineage that led specifically to us
  - we will look at them next time.