

Introduction to Biological Anthropology: Notes 2  
**What evolution is and how Darwin became convinced of it**

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- Announcements
  - how to get to class website
  - class user ID and password
- You will notice that I cover today’s material a little differently from the reading in the textbook
  - pay attention to both!
- The term “evolution” refers to at least two different things: a *fact*, and a *theory*
  - First, evolution refers to the observed *fact* that populations of living things change over time
    - this is an empirical, observable process in nature
    - contrary to what you sometimes hear, there are many well-documented cases of evolution
      - I’ll mention some examples shortly
  - Second, evolution also refers to a *theory* that explains how the observed process of evolution could occur
    - a theory is just a logical story that we hope helps to make sense of something
    - we can’t actually observe a theory
    - but we can use it to make predictions or test implications
      - that is, statements like “if the theory is correct, then we should expect to see x”
    - if a theory makes logical sense, and if the test implications fit the facts in case after case, we may be convinced that the theory correctly describes what is really going on
    - in fact, the theory of evolution is so well supported by so many cases and experiments that effectively all biologists and anthropologists believe that it is basically correct.
      - many scientists do argue about many of the details
      - but they do not dispute the general theory
      - once you understand it, you will probably agree, too
- The fact of evolution
  - Preliminary definition of **evolution** as an observable fact: change in the frequency or magnitude of heritable characteristics of a population of organisms over generations
    - later on, we will use a more precise definition of evolution in terms of genetics
    - but this one will do for now
  - A few of the many examples of evolution actually observed in nature:
    - the famous study of “Darwin’s finches” on one of the Galapagos islands
      - Peter and Rosemary Grant attached labels to the legs of almost every single member of the “medium ground finch” species on the island of Daphne Major, and recorded numerous measurements about each one
      - they kept updating this census of the birds over several years
      - over several generations, there was a significant increase in the average depth of the birds’ beaks
      - that is, the type of bird that was typical among “medium ground finches” changed over time: the population of finches evolved.
      - we’ll come back to the explanation for this later

- the point to notice now is that the average beak size at the end of the study was different from the average beak size a few years earlier. Evolution was observed to happen.
- Another famous example involves moths near Manchester, England
  - prior to the industrial revolution in England, the wings of most of these moths were patterned with dark gray and light gray mottles
    - but a small fraction of the moths were completely dark gray
  - after the industrial revolution, the very same population of moths was mostly dark gray, with only a few of the light, mottled type
  - The coloration of the typical, average moth of this species changed over time... evolution was observed in action.
- You may have heard about antibiotic-resistant bacteria
  - these are new, previously unknown variants of bacteria that cause illnesses such as tuberculosis, syphilis, strep infections, pneumonia, and many others
  - these new variants have developed the ability to survive doses of antibiotics that effectively killed these organisms just a few decades ago
  - this is evolution going on right before our eyes, with serious health implications
- And there are many more
- The preceding examples were observations of evolution in the wild. There are also many, many documented observations of evolution in animal breeding, farming, and laboratory settings, where people intentionally caused the evolution to occur
  - pigeons are a particularly well-documented group of examples
    - including not only new and bizarre physical forms
    - but also new, weird behaviors, like flight patterns with loops or rolls
  - the many dog and cat varieties you know are also recent creations
    - many are known to have been “created” by intentional breeding at particular times and places during historical times
    - these varieties simply did not exist before then
- Researchers at the Illinois Experiment Station caused evolution in corn
  - in 1896 the corn researchers planted a common variety of corn that had kernels with an oil content of 4-6%
  - each season, they selected the corn kernels that were richest in oil, and planted those
  - as the years passed, the average oil content of the corn increased
  - after 80 generations, the oil content was almost 19%
  - this is evolution caused by artificial selection
- There are many examples in laboratory populations of fruit flies, bacteria, etc.
  - some are cases where breeders intentionally caused evolution to occur
  - others are cases where scientists were observing a laboratory population carefully for some other reason, and happened to record evolutionary changes that occurred “accidentally” in the lab, without trying to make it happen
    - that is, with no artificial selection
- again, for more examples, see
  - <http://www.talkorigins.org/faqs/faq-speciation.html>
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- unlike observations in the wild, these cases of “artificial” evolution don't show that evolution actually occurs in nature
  - but they do confirm two things:
    - evolution does happen under certain circumstances
      - that is, species are not fixed and unchanging
    - evolution can result in large, rapid changes in populations of animals and plants
      - Chihuahuas and St. Bernards have evolved under artificial selection from a generic dog in under 10,000 years -- a very short time in geological terms
- Let's look more carefully at the parts of the definition
  - each word is there for a reason
  - Evolution is *change* in the *frequency* or *magnitude* of *heritable* characteristics of a *population* of organisms over *generations*
  - *change*: if there is no change, there is no evolution
    - lack of change is called **stasis**
  - a change in *frequency* would be like the moth example: the dark type became more common than the light type
  - a change in *magnitude* would be like the finches' beaks: the average beak depth increased
    - alternatively, we could look at a change in magnitude as a change in the frequency of different sizes
    - if larger sizes become more common, that is the same as the average size increasing
    - so technically, we could drop “magnitude” from the definition, and when we define evolution in terms of genetics, that is what we will do
  - evolution only refers to changes in characteristics that are *heritable* (inborn), that is, that are passed on from parents to offspring
    - like eye color
    - it does not refer to changes in individuals that are caused by the environment
      - for example, in the 19<sup>th</sup> century, it was fashionable for white Americans to have pale skin, while more recently, it has been fashionable to have suntanned skin
      - presumably, the average skin color of white Americans is darker now than it was then.
      - but a suntan is *acquired* by individuals; it is not *heritable*
      - babies born to tanned parents are just as pale as babies born to pale parents
      - so this change in average skin color, though real, is not an *evolutionary* change
        - because it is not a change in a *heritable* feature
        - so the color change cannot accumulate from one generation to the next
  - in a *population*: evolution refers to changes in *populations* of organisms
    - like the changing average beak depth of the finches
    - or the most common color of the moths
    - these concepts describe the *group* (or *population*) of organisms, not any particular individual
    - evolution does *not* refer to changes in *individual* animals or plants
      - an animal maturing, getting stronger, developing a tan, etc. is not evolving
      - that kind of change is interesting, but it is not *evolutionary* change
  - over *generations*

- the change must last across generations, rather than be within single generations
- for example, some sea turtles lay millions of eggs on certain beaches, once a year
  - when the eggs hatch, predators descend
  - only about 1 in 2000 baby turtles even make it to the sea, and a lot more die after that
  - so you could say that for a few days during the hatching season each year, the average size in this turtle population is quite small
  - it increases throughout the year, then drops again the next year
  - this is change in heritable features of the turtle population, but not the sort of change that persists across generations
  - so it is not *evolutionary* change
- Again, this is just a preliminary definition
  - once we have looked at genetics a little, we will use a more precise definition
  - Evolution, in this meaning of the term, is an amply documented fact
- The second common use of the word “evolution” is as a shorthand term for the *theory* of evolution
  - The *theory* of evolution is an *explanation* of how the *fact* of evolution occurs
  - the basics of the theory of evolution were proposed by Charles Darwin, who got it amazingly right in 1859, almost 150 years ago.
  - but the biological world is incredibly complex, and there are all sorts of interesting wrinkles and special cases that people are still working on today
  - so when people mention the “theory of evolution”, they are often referring not a single theory, but to an accumulation of interlocking ideas based on Darwin’s theory
  - using the word “evolution” to refer to the *theory* of evolution rather than the observable process of evolution often confuses matters
    - use “the theory of evolution”, or “evolutionary theory” instead.
- Let's set the stage for the theory of evolution
  - or more accurately, Darwin's “theory of adaptation by natural selection”
  - The starting point for the whole theory was the amazing variety of living organisms, and how well all these organisms are adapted to their environment
    - Just go to a zoo or an aquarium, or watch a few nature documentaries, to confirm how many varied, weird, and yet successfully functioning creatures there are in the world
  - Prior to Darwin’s theory of adaptation by natural selection, there was no good way to explain why organisms were so complexly, exquisitely adapted to their environment
    - One explanation was that God intentionally designed all organisms to be well adapted to their environments
      - how else to explain complex features like the eye, with all its interdependent parts?
      - in fact, this has been used as an argument for the existence of God:
        - if you find a watch, it implies the existence of a watchmaker
          - such a complex object could not have come about by the chance bumping together of bits of native metal; someone had to design and make it
        - so, according to this argument, if you observe marvelously complex living creatures with countless parts that work together perfectly, that must imply the existence of a designer who created them, that is, God.

- But if there was a designer, why are so many organisms so weirdly, even badly, designed?
  - why do people have an appendix that serves no purpose but is prone to fatal inflammation?
  - why do we have knees and backs that give out all the time, when it is easy to imagine better designs?
  - why are humans made so that without modern medicine, giving birth frequently kills the mother just when she is most needed?
  - if we were designed by a grand engineer, why did she do such a kludge job?
  - or to return to the watch argument, if there was a watchmaker who designed us, he must have been blind, lazy, or perverse
- Darwin showed that there was another possibility
  - that there was a way in which even complex features like knees and eyes could arise “all by themselves”, with no designer, through natural, understandable processes
- Who was this Charles Darwin guy?
  - Nothing less than one of the founders of modern science, one of the most influential thinkers of the last 200 years
  - Darwin figured out and publicized the essential features of the theory of evolution.
  - This is not a history class, and our focus will be on ideas, not investigators.
  - Nevertheless, Charles Darwin is one of the seminal figures of the modern world, and you really should know a little about him.
  - Born in 1809 to a wealthy, educated English family
  - Dropped out of medical school in 1827 at age 18
  - went to Cambridge University and become a minister
  - Graduated in 1831 and immediately went off on a 5 year journey as the volunteer ship’s naturalist on the scientific voyage of the HMS *Beagle*
  - Darwin observed geological features and collected plants, animals, and fossils
  - The common explanation for geological layers and fossils at the time (now known to be mostly incorrect) was **catastrophism**
    - the geological and biological world was the result of a series of catastrophes, usually envisioned as floods that covered the entire globe
    - these floods supposedly killed off many plants and animals, and left their remains as fossils in layers of rocks
    - different plants and animals would somehow arise, and then another catastrophe would wipe them out and preserve their remains in another layer
  - Just as Darwin was finishing university, the geologist Charles Lyell published a book arguing for an alternative model of **uniformitarianism**
    - uniformitarianism rejects the idea of hypothetical enormous events unlike anything we see today
    - uniformitarianism is the idea that the world was shaped by the action of the same forces we see around us today, but over a very long time
    - for example, large valleys could be formed by the gradual washing away of soil and rock by a river over a very long period of time, rather than by a single flood far bigger than any recorded in history

- the appeal of this idea is that we don't have to imagine any new, unknown processes; we just give the ones that we know actually exist more time to work
- Darwin read and was influenced by this theory.
- While on the *Beagle*, Darwin became convinced that plant and animal species were “adapted” to their environments
  - but he also noticed that species tended to be similar to other species nearby
    - as in the case of slightly different variants of birds, reptiles, and plants on each of the many islands of the Galapagos.
    - or the plants and animals on islands off Africa that are not exactly the same as anything on the mainland, but are more similar to them than to anything else
  - He concluded that the simplest explanation for this was that these variants could have arisen over time by gradual “evolutionary” change from shared ancestors.
    - for example, one group of finches might have somehow gotten to one of the islands, maybe blown there in a big storm
      - then as they spread to the other islands, each group would gradually change to fit the local environment
    - this would explain the general similarity of the finches on neighboring islands, as well as the specialized differences on each island
    - and if populations could develop these minor variations, then presumably with enough time the differences could become very great
    - different species could arise through the accumulation of many small, gradual changes
- This general concept of evolution was not original to Darwin.
  - it was already widely discussed, although not many people believed it was correct
  - the more common idea was that each species was “specially created” and then remained fixed, without changing over time
  - Darwin's view was a uniformitarian one, in that no unusual, “special creation” process was required
    - it would involve simply the accumulation of processes that we can observe happening today, but over a very long period of time
- So Darwin's observations on the *Beagle* got him started by convincing him of the “fact” of evolution (that populations change over time)
  - this was not nearly so well documented then as it is today
- The problem was to explain *how* evolution could occur.
  - We'll start explaining evolution next time.