

Introduction to Biological Anthropology: Notes 2
What evolution is and how Darwin explained it

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- 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 #1 of **evolution** as an observable fact: change in the characteristics of a population of organisms over generations
 - A few of the many examples:
 - 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 the first examples, these 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 major, 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
- Notice that evolution does *not* refer to changes in *individual* animals or plants
 - an animal maturing, getting stronger, developing a tan, etc. is not evolving.
- instead, 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
 - the individuals themselves do not change during their lifetimes
 - but the average characteristics of the *population* change from one generation to the next
- Also, evolution only refers to changes in characteristics that are *heritable* (inborn), that is, that are passed on from one generation to the
 - it does not refer to changes in individuals that are caused by the environment
 - for example, in the 19th century, it was fashionable for white Americans to have pale skin, while more recently, it has been fashionable for them 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
- Preliminary definition #2 of **evolution** as an observable fact: change in the frequency or magnitude of heritable characteristics of a population of organisms over generations
 - 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
 - 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, over 140 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 "Darwin's theory of evolution" or "the theory of evolution" 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 have to 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 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
 - 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 widely discussed, although not many people believed it was correct
 - the more common idea was that species were “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.

- There was already a theory for this, originally proposed by Jean Baptiste Lamarck in several volumes from 1815-1822, when Darwin was still a child
 - Like Darwin and some others, Lamarck also believed that evolution occurred
 - he explained it by proposing that animals changed over their lifetimes
 - body parts that they used a lot developed more, and ones that they used less developed less
 - for example, a giraffe that spent its life straining to reach high leaves would develop a longer neck than it would have if had grazed on grass
 - Lamarck also suggested that these acquired characteristics would then be inherited by the animal's offspring
 - so that the next generation of giraffes would start with a slightly longer neck to begin with, and would develop it even further if they kept reaching for high leaves
 - this sounds reasonable, but there was no good evidence of acquired characteristics actually being inherited
 - you can observe that tanned parents have kids who are just as pale as any other kids
 - animal breeders did not succeed in creating faster horses by vigorously training them, generation after generation, or fatter cows by overfeeding them over several generations
 - it just didn't work
- Darwin (like many people at the time) was aware of how animal breeders actually did develop variants by controlling mating
 - breeders would select the individual animals that had the desired characteristics and allow them to mate
 - then pick the best of their offspring and breed those, and so on
 - controlling mating is what worked in animal breeding
 - not creating acquired characteristics by training, special feeds, etc.
 - this method is now sometimes called **artificial selection**
- But artificial selection obviously had not happened in nature...
- In 1838, two years after returning from the voyage of the Beagle, and at the ripe old age of 28, Darwin read *An Essay on the Principle of Population*, by Thomas Malthus
 - Malthus's book had been published 40 years before, in 1798
 - Malthus argued that human populations grow geometrically (they double every so many years), while food production grows more slowly
 - so population eventually outstrips food supply
 - and some correction inevitably occurs: famine, disease, or war, which reduces the population back down to what the food supply can support
- Darwin realized that the same thing happens with populations of plants and animals
 - more individuals are born than survive to adulthood
 - so some kind of selection – **natural selection** – would take place as some survived and reproduced, while others did not
 - the characteristics of the ones that reproduced would become more common in the following generations, just as if an animal breeder had artificially selected them
- The theory of adaptation by natural selection was born.
- Darwin was a perfectionist, so he spent the next twenty years working on his collections and refining the evidence to support his arguments

- When Darwin learned that a younger naturalist named Alfred Russel Wallace had come to the same conclusions that he had, and was planning to present a paper about them, he finally had to go public or become a forgotten footnote in history
- Fortunately, both Darwin and Wallace were honest, civil people, and they agreed to both present papers at the same conference in 1858.
- Darwin then quickly finished the book that outlined and defended his theory, and published it in 1859. The title was *On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life*.
 - The *Origin* was an instant bestseller. It sold out on the first day, and it eventually went through five more editions.
 - It was aimed both at specialists and the educated public
 - It laid out a logical, scientifically supported theory of evolution and popularized it at the same time
 - it was controversial; some people accepted it, and others blasted it
 - Today, the *Origin* seems a bit too detailed and the writing is old-fashioned, but it is clear and understandable. If you can read Charles Dickens, you can read Charles Darwin. There are lots of copies around, and I highly recommend it.
 - The class web page has a link to the full text online
- Darwin got it right
 - Although some important details could not be filled in until almost a century later, Darwin's basic theory is still at the core the model of evolution that virtually all biologists believe explains the nature and origins of life on earth – and other things, too.
- Darwin's theory of adaptation by natural selection
 - **Adaptation** has at least two meanings:
 - Adaptation as a feature: a physical or behavioral *feature* of an organism that helps it survive and reproduce in its environment
 - examples of adaptations in cats: good vision, sharp teeth, and speed that make them good hunters
 - Adaptation as a process: a *process* of biological change by which a population of organisms becomes adjusted (“adapted”) to its environment over many generations.
 - as in "The species adapted to its new environment."
 - this usage of "adaptation" refers to *heritable* change over generations (that is, evolution) that makes the organisms better suited to their environment
 - adaptation is a *subset* of evolution
 - not all evolution results in better adaptations!
 - this usage of "adaptation" does *not* refer to the adjustments that an individual organism makes during its lifetime, like developing stronger muscles or a tan
- Darwin's theory rests on three simple postulates:
 - 1. Organisms produce many more offspring than can survive and reproduce
 - This is easy to observe, even in human populations.
 - Prior to modern medicine, a large percentage of infants did not make it to adulthood
 - In a litter of kittens, unless people intervene, usually only some survive
 - Darwin called this "the struggle for existence"

- 2. Individuals vary in ways that affect how successful they are at surviving and reproducing
 - All individuals are different
 - Some of these differences affect how successful they are at surviving and reproducing
 - This is sometimes expressed as: "There is variation in fitness"
 - note that "fitness" does not mean speed, beauty, intelligence, etc. -- it means only the ability to survive and reproduce
- 3. Offspring tend to resemble their parents
 - not in all ways, of course, but many traits do tend to be inherited
 - Short, blonde parents are likely to have short, blonde children
 - relatively more "fit" individuals will tend to have relatively more "fit" offspring
 - This is sometimes expressed as: "Some variation is inherited"
- The logical, necessary result is natural selection
 - Some parents leave more offspring than others
 - those offspring tend to be similar to their parents
 - so the traits of the successful parents become more common in the next generation
 - this is NOT "survival of the fittest"!
 - surviving counts for nothing if you don't reproduce!
 - the bottom line is leaving the most offspring (that themselves survive and reproduce)
- Darwin called his theory "natural selection" by analogy to the "artificial selection" practiced by animal breeders who created all those new types of pigeons, dogs, cattle, etc.
 - But instead of a animal breeder who intentionally picks the desired traits, in nature it is the "struggle for existence" that does the selecting
 - many individuals don't survive, or if they do, don't reproduce as much as others
 - The variants that are most "fit" survive and reproduce most
 - The traits they have are passed on to the next generation
 - over time, the most "successful" traits become more and more common, and the least "successful" traits become rare and disappear
- So where is "evolution" in this picture?
 - natural selection *may* cause evolution
 - say the parents that leave the most offspring are taller than average for the population
 - and tallness tends to be inherited
 - then there will be more tall offspring in the next generation
 - so the average height will be greater
 - evolution will occur
 - this is **directional selection**: selection that causes change in some direction
 - but natural selection does not *always* cause evolution
 - say the parents that leave the most offspring are the height that is already average in the population
 - then they will leave lots of offspring with that same average height
 - and the average height of the population will remain unchanged
 - the average height is already optimal, so there is no selective advantage for those who are taller or shorter

- in this case, natural selection is maintaining the status quo, and no evolution occurs
- this is **stabilizing selection**: selection that keeps the features stable
- So, let's go back to the watchmaker analogy
 - when you see an intricate, functioning watch, you assume there was a watchmaker
 - when you see an intricate, functioning organism, what is the difference?
 - living things reproduce themselves
 - but they reproduce themselves with some variation
 - this makes life a whole different ballgame
 - it makes evolution possible
 - now, consider that we are beginning to make artificial things that reproduce themselves
 - computer viruses
 - genetically engineered organisms
 - perhaps, eventually, machines
 - if they do not reproduce themselves perfectly, and they vary in the number of "offspring" that they produce, then these things will evolve too...
- And finally, let's think briefly about science and morality
 - I said that the bottom line in natural selection is leaving the most offspring
 - the traits of those that leave the most offspring become more common in the next generation
 - we often say that organisms act in ways that maximize their reproductive success
 - does this mean that it is *good* to maximize reproductive success?
 - am saying that you should all go out and have lots of children?
 - does it mean that the most successful survivors and reproducers (the most "fit" individuals) are *better* than the others?
 - does it mean that evolution causes organisms to get *better* over time?
 - of course not.
 - evolutionary theory simply explains what happens, without assigning any moral value to it.
 - maybe the "fittest" of some species are strong and colorful
 - we might consider them better than the others
 - or maybe the "fittest" are those that kill their neighbors and feed them to their offspring
 - we presumably think this is bad
 - either of these strategies might maximize reproductive success, but we approve of one and condemn the other
 - the "fittest" are not necessarily "better" than the others
 - they simply leave more offspring
 - whether or not natural selection favors something has nothing to do with our moral judgement of it
 - a scientific question is "what kind of world *is* it?"
 - a moral question is "what kind of world do we *want* it to be?"
 - the answer to one tells us nothing about the other
 - but we need to think about both.