PHYSICAL ANTHROPOLOGY

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LibreTexts

Book: Physical Anthropology (Schoenberg)

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Licensing

A detailed breakdown of this resource's licensing can be found in ***Back Matter/Detailed Licensing****.*

Preface

The high cost of textbooks prevents many students from succeeding. Textbook prices have gone up 3 times the rate of inflation in the past 30 years. New textbook editions are a scam. The change in Jurmain's *Introduction to Biological Anthropology* from 2009 to 2011 was to search and replace the word “hominid” for the word “hominin”, and raise the price 20%. Many students will not buy their textbooks (Kingkade 2013), and struggle through class, reading at the library. Other students will order cheap copies online but get the wrong edition, or discounted shipping where it arrives halfway through the semester. Textbooks have become a barrier to student success.

Assigning free online textbooks is one solution. Much of the high cost of textbooks comes from color printing, but black-and-white and text-heavy books are poor options for our predominantly visual learners. Online textbooks allow for unlimited, large, color graphics. For the price of a new textbook, a student can buy a text reader (kindle, ipad, tablet, surface, etc.) or a used laptop. There may still be problems with students' access to high speed internet. The monthly fee for a cable modem service is expensive, but free WiFi is becoming more and more widely available. The new downtown San Diego library is a good example.

Unfortunately, in 2011 when I started this, there were no free online textbook available for Introduction to Physical Anthropology. Probably the closest were Dennis O'Neil's Biological Anthropology Tutorials from Palomar College, Wikipedia's Biological Anthropology and Introduction to Paleoanthropology textbooks, and I borrowed from these heavily. I have found most of these sources written in the style of an encyclopedia, and I've tried to compensate for that, to make the textbook more approachable, by including my own voice whenever possible.

Some students may lack the necessary computer skills to use an online textbook. Hopefully the recent increases in funding for basic skills will help. Gone are the good old days whence we scribed our homework on tablets of wet clay. Students must learn computer skills to survive academically and professionally, and the printed textbook is becoming a relic of a bygone age. The more students practice current electronic research techniques, the better prepared they will be for the rest of their academic and professional life.

I previously encouraged students to use their textbook as the main source for my take-home tests, but I found that many students start with the internet as their first source, and then fall-back on the textbook if the info doesn't show up immediately in a search engine. I've come to realize that this is not always bad, as they often discover more current information than the textbook. For rapidly changing issues, such as how many genes are in the human genome, how closely we are related to Neandertals, *Homo naledi*, or the Cerruti Mastadon, the information available on sites such as Wikipedia is often more accurate than the typical textbook written three to ten years ago.

For each major section I have tried to follow a typical textbook chapter format:

- *Introduction: an introduction and short summary of the section.*
- *Focus questions: intended to help students consolidate the disparate sources.*
- *Information: the bulk of the course content, my ideas and links to other sources.*
- *Vocabulary: key terms, useful for students to check their own knowledge*
- *Imagination questions: critical thinking and discussion questions*

The sources are linked directly and [most] included in the Bibliography. A glossary and index seemed superfluous, because of CTR-F on most browsers, online dictionaries, and search engines.

I've tried to keep the proportion of material consistent with most introduction to biological anthropology textbooks.

Weeks and Sections

1-2 Introduction

3-4 Evolutionary Biology

5 Cellular Biology

6-7 Primatology

8-10 Paleoanthropology

11-13 Human Variation

14 Conclusion: the Future

One difference in the ordering is that I'm attempting a more chronological approach to human taxonomy than most other textbooks. I introduce human evolution in the order of speciation: from DNA, vertebrates, mammals, primates, hominids, to anatomically modern *Homo sapiens.* I introduce paleontology as the method to understanding primate evolution, and in turn, living primates.

Much of this textbook is just a bunch of links to other articles; almost like a reader. If I found a source that said it better than I could, I just copied the link. I have chosen only articles that are freely available, with no login required. I've tried to include a mix of both the most basic and well-written introduction to the subject, and examples of the most primary and current sources available online. The textbook mixes internet memes, peer review journal articles, encyclopedic entries, video clips, gifs, radio podcasts, games, and VR. There is some justification for a multimodal approach to teaching anthropology (Chin 2017), but there are also drawbacks.

One disadvantage of this reader format is that sometimes students may get bombarded by obscure details. Michelle Field and Tori Saneda describe a similar critique in the introduction to their Wikipedia Biological Anthropology textbook, where they argue for presenting a brief outline of the information online and using class time to fill in the details:

> *As you peruse the reading material in the course module pages you might find that they contain less detail than what you would see in a "normal" textbook. This is intentional. One thing we find incredible about higher education is that the student often reads the textbook only to go into class and have the professor lecture for two hours on the exact same material. Because of this repetition of the material, students often become exasperated and either stop reading the material or stop paying attention in class. We've also found that students in the introductory anthropology courses frequently struggle with picking out the basic concepts from among the myriad of material from the textbook. We think that students in introductory anthropology courses such as this one, most of whom are not going to be anthropology majors, should read the basic information outside of class. This allows the instructor to focus on providing more explanatory details and help students work through critical thinking about the material in class. Therefore, the readings in the course modules have the basic information. Through in-class activities, discussions, and homework assignments, the job of the instructor is to help students move deeper into and synthesize the material. [Field 2011]*

I have tried to address these problems with a short outline to the subjects in my own words, but my textbook emphasizes links to original sources in order to maximize the depth of critical thinking outside of class, and I hope to review the basic concepts during class. Also, repetition is not a waste of time for an introductory class. I believe the risk of losing a few blurry-eyed students to the frustration of obscure websites, is worth the benefits of pushing students to work directly with more primary sources and often the most current research available.

This project is ongoing: links go out of date, better articles become available, permissions are granted, and peer-review is an ongoing process. The quality of a big name textbook is admittedly superior, but I believe that in the context of our community college, overall student success will improve with the mediocre -- but free -- textbook that follows.

Forward

“Can't beat the price!” –Jo Student

Student User Guide

For the full online version of this textbook I don't recommend printing this entire document because so much of the information is in the hyperlinks that you need to click on to get to. The forthcoming *Study Guide for the Introduction to Physical Anthropology* will be formatted for printing, but in the meantime this LibreTexts version is more printer friendly, then the full version.

It's most efficient to read this with a fast internet connection to minimize the frustration of waiting for links to load. If you don't have a fast connection at home, many browsers have settings that will cache or save pages and let you read them off-line, so you may be able to click all the links here when you have a good connection and then read the pages later.

Experiment with different browsers and try the Reader Mode, you should be able to adjust the font and size so this is not so hard on your eyes.

The WiFi at our college is sketchy, so you should try different locations and times, or find a computer with a direct connection. The new downtown public library has excellent WiFi.

For navigation, the table of contents has hyperlinks to the sections. An index is unnecessary because most internet browsers have a "search" or "find" function within this webpage, trying pressing CONTROL or COMMAND and the letter F at the same time.

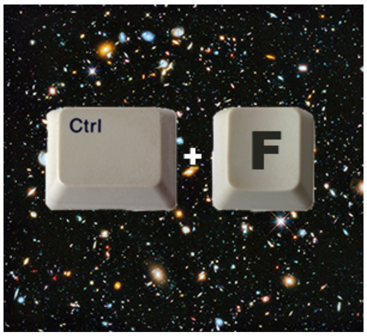


Figure 1: "Take Control + F to find your place in the universe" by Arnie Schoenberg, remix of 2014 NASA Hubble photo and 2015 Tracy Watanabe ctrlF (CC BY-NC 4.0)

This is a work in progress so for any problems you find, please send me an email or let me know in class. If a link is bad you can often find the correct one through a search engine, but please email me the broken link and I will fix it.

I've labeled required links and assignments in GREEN CAPITALS, please consider this part of your required course work; I expect you to do the assignment or click on the link and read it. When I say to skim a link, you want to go to the link with the question of "How is this relevant to physical anthropology?" in mind and scroll thorough quickly looking for answers. If you haven't had much experience skimming before, here is a quick description of skimming scientific articles.

If I just include the link, then you can consider it recommended but not required. Many of the recommend links can be written up as Critical Reviews, which I've labeled with a teal asterisk *. Please consult the instructions for critical reviews in your syllabus for more information.

The *Imagination Questions* are extra credit assignments that you can answer in a journal format, see your syllabus for details.

Please contact me with specific questions and feedback.

CHAPTER OVERVIEW

1: Introduction to Physical Anthropology

This chapter will introduce you to the field of anthropology, define basic terms and concepts and explain why it is important, and how it can change your perspective of the world around you.

1.1: Science

Science is a specific way of looking at the universe.

science : empiricism :: religion : faith

Anthropology is mostly based on science. Anthropology is holistic. The four main subfields of anthropology are cultural anthropology, physical (biological) anthropology, archaeology, and linguistics. It is worthwhile to back up and introduce both science and anthropology. And before talking about science, we should back up even farther, and talk about *epistemology*, the study of how we know things.

The word science comes from the Latin for “knowledge”, but in modern English it means a very specific kind of knowledge, and implies a method of obtaining knowledge.

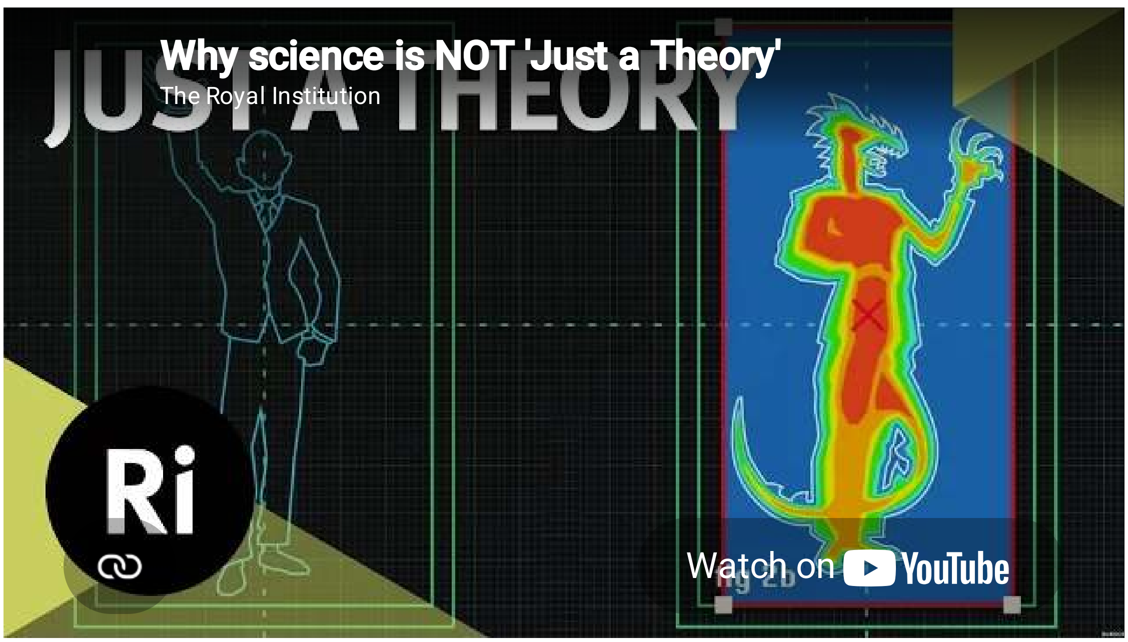
Scientific Method

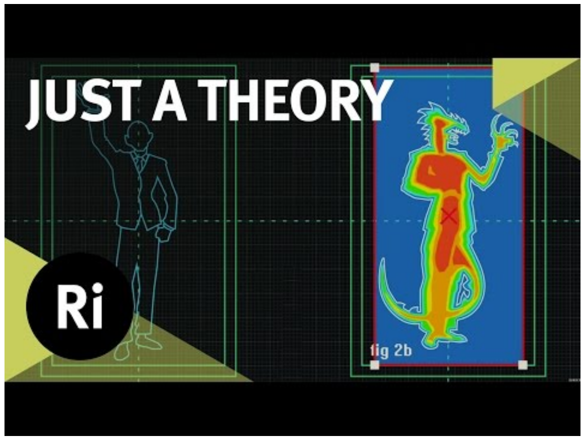
Note

Another good summary of the scientific method

Here are a few terms to clarify: law vs. theory, quantitative vs. qualitative, inductive vs. deductive

A scientific "Law" is just an archaic term for an accepted theory; we could talk about Newton and his theory of gravity, or Darwin and the Law of Evolution, and what we mean is that neither hypothesis has been disproven yet.





Anthropology uses both quantitative (statistics) and qualitative (detailed description) methods, but leans towards qualitative research.

Other good terms to understand are induction and deduction. Induction is where you take what you can observe and make generalizations, like hypotheses and theories. Deduction is where you start with the general laws of the universe and you use them to predict how a specific event will play out. Both are important aspects of science: the ability to make generalizations, and the ability to predict future events. For example, Sherlock Holmes kept a notebook of all his previous cases, and from this he made inductive generalizations about human nature. When a client came to see him, he would deductively apply his criminal theories to solving the specific case.

Quantitative versus qualitative is another pair to distinguish, and have to do with what kind of data you use. Quantitative science is based on a large quantity of objects, qualitative science is based on intensive scrutiny of a small number of objects. For example, sociology tends to use quantitative methods – studying humans by asking many people a few questions; while anthropology tends to use qualitative methods – studying humans by asking a few people many questions.

All this terminology is relatively new in human history, but the foundation of science, empiricism, is ancient. I don't want to back up too far into philosophy, so let me just say that science is based on what you can experience. Scientists use what you can see for yourself with your own two eyes (or some extension of your eyes, like an electron scanning microscope). If a scientist makes an argument that a fossil belongs to an ancestor of *Homo sapiens*, they need to point out the same details that led them to that conclusion, and as scientists they are required to explain their ideas in a way that anyone else could see the same thing they are seeing and come to same conclusions. This is also an example of how science is "reproducible". Scientists don't get so excited about the **first** person to discover cold fusion, what makes it science is the **second** person to verify the results, or better said, fails to disprove the original hypothesis. Science is about disproving hypotheses. Science can say you´re wrong, but it can´t say you´re right. The goal of science is not about establishing Truth, and for that reason it is often not as satisfying as other branches of knowledge such as religion or art that can claim Truth with a capital "T". Try not to get too frustrated with statements that hedge their conclusions, or just admit that we just don´t know yet: this is a characteristic of good science.

Exercise 1.1.1

Read Deduction vs. Induction

How to Critically Review Scientific Articles

Scientific writing can be pretty dry. If you're chatting about a movie, probably the first thing you say is whether you liked it or not, and you'll build up an emotional story without any spoilers.

You need to shift gears for science. This may be disturbing to your self-esteem, but busy scientists usually don't care about how a scientific article makes you feel or whether you liked it or not. They want to know how much the data supports or disproves the hypotheses they are working with. They don't need spoiler alerts, they want as much spoiling as possible. There are more scientific articles than minutes in a human life, so scientists need the conclusion in the first paragraph, so they can decide whether to keep reading or not. The process of doing science entails communicating several necessary components. With good scientific articles you should be able to easily find all of the following elements:

The Citation

A citation is how the article you are reviewing would look in a long list of references, works cited, or in a bibliography. It functions as a link between how you use the ideas in the article, and how the reader can get ahold of the article and read it themselves. It's important to stay anal-retentive about the format of a citation, so people can find the article. MLA and APA are popular formats, but much of anthropology uses the Chicago Style.

The citation functions as the title of your review and goes on top, like the format of an annotated bibliography.

This is the main difference between an essay and a critical review. An essay has a topic and a title, a critical review (or an annotated bibliography) just has a source, and then your thoughts about it below. So what goes below the citation? read on...

The Introduction to Your Review

Even though this is the order of elements in the final version, as you're working on your review, you want to skip ahead and come back here after the Conclusion.

Cover all the following sections and then summarize them into a single paragraph, like the annotation in a typical annotated bibliography, or an abstract that summarizes a longer work. If you organize your review with a paragraph for each section, and each paragraph begins with a topic sentence, then you can pretty much just copy the topic sentences word-for-word and you're done with the Introduction.

Because the introduction is basically a summary of your critical review, you need to do the critical review first, before the introduction.

Why all this jumping around between the article, introduction, and the rest of the critical review?

Your job as the writer is to make it easy for the reader to find the information they need as quickly as possible, and decide if they need to keep reading.

The Hypothesis

Don't waste time! Go straight to the core of the article. What is the author trying to prove? Hypotheses come from “Problems” and “Research Questions” but they are reworded as answers. The hypothesis shouldn't end in a question mark – it's the answer, stated as a concise declarative sentence that is either descriptive ("This is that.") or causal ("This causes that."). The question you and the scientists want to answer is how well was the hypothesis supported or disproved.

A Background

Now that you've stated the hypothesis, you can back-up and put it in context. Why is it important? How does the hypothesis connect to other research? For this class you want to refer to the other articles in the same section and explain how this research fits into those broader topics. Why did Arnie put this article in this section? What other sections might it fit into? What does this article have to do with physical anthropology?

This is sometimes called the “Problem” or “Research Question”. In a larger scientific write-up you might make this section into a “Literature Review”, which is a summary of everything that has been written about the subject before your contribution.

The Methods

Now that you've given the essential hypothesis, and given its background, you can add more details about the article itself. What did the scientist do? What techniques or technology were used? How did they look at something? What empirical senses were involved? This is very different from what the scientist thinks–which you find in the hypothesis or the conclusion.

Some Data

If methods are **how** the scientists looked at something, then data are **what** they saw. What did they see? feel? hear? touch? sense? What senses they used are methods, how their senses responded are data. Data are often reported as “Findings” or “Results”.

Scientists are obligated to make their data public so that other scientists can attempt to reproduce their conclusions. An article is already summarizing the data, and a review of an article should summarize it even more. In the humanities and social sciences, hypotheses are rarely completely falsified or overwhelmingly supported, how "true" a hypothesis is, depends on the quality and quantity of the data that supports it.

You want to give enough details to connect the hypothesis to the conclusion.

The Conclusion

The conclusion has two parts: yours and the author's. You want to present the conclusions that the article came to, and you want to wrap your review up, summarizing what you've done so far. In the conclusion, the scientists let us know what they think. How well did the data support the hypothesis? Was the hypothesis testable? Was it reliable (usually a review of the methods)? Was it valid (usually a critique of the background)? Was it verifiable; would it be possible for someone to repeat the same process? How did the sources cited or the "Literature Review" connect to the data? What further research do the scientists suggest?

In a *critical* ***review***, you want to present how the scientists answered these questions. As a ***critical*** *review*, you also want to answer these questions yourself, evaluating the strengths and weaknesses of the article. If this were a ***peer*** *review* you would be a peer of the author, a colleague, you would have the same background knowledge as the author, and be more likely to thoroughly understand the article and be able to evaluate it. But, you're taking an introductory class, you're not an expert yet, so try not to get cocky and feel like you are supposed to attack the author.

Science thrives on criticism. The goal of a peer review is to help the author fix their mistakes and get better.

> **Note**
>
> Here's a great video of Austin's Butterfly: Building Excellence in Student Work, that reflects the ideal way the scientific community comes to consensus.
>
> 
>
>
> Austin's Butterfly: Building Excellence in Student Work from EL Education on Vimeo.

Now that you're done with the body of your review, go back and write a short introduction to YOUR work in the form of an abstract or annotated bibliography.

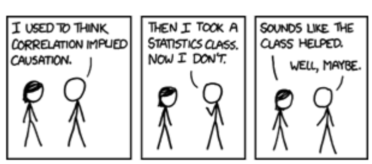


Figure 1.1.2 - http://xkcd.com/552/ (CC BY-NC 2.5)

- a good source for critically evaluating articles
- Twenty tips for interpreting scientific claims
- Science can't prove anything: how scientists define *theory, proof, uncertainty*
- The Research Methods Knowledge Base provides a good introduction to these concepts and terms

A Rough Guide to

SPOTTING BAD SCIENCE

Being able to evaluate the evidence behind a scientific claim is important. Being able to recognise bad science reporting, or faults in scientific studies, is equally important. These 12 points will help you separate the science from the pseudoscience.

1. SENSATIONALISED HEADLINES

Article headlines are commonly designed to entice viewers into clicking on and reading the article. At times, they can over-simplify the findings of scientific research. At worst, they sensationalise and misrepresent them.

2. MISINTERPRETED RESULTS

News articles can distort or misinterpret the findings of research for the sake of a good story, whether intentionally or otherwise. If possible, try to read the original research, rather than relying on the article based on it for information.

3. CONFLICTS OF INTEREST

Many companies will employ scientists to carry out and publish research - whilst this doesn't necessarily invalidate the research, it should be analysed with this in mind. Research can also be misrepresented for personal or financial gain.

4. CORRELATION & CAUSATION

Be wary of any confusion of correlation and causation. A correlation between variables doesn't always mean one causes the other. Global warming increased since the 1800s, and pirate numbers decreased, but lack of pirates doesn't cause global warming.

5. UNSUPPORTED CONCLUSIONS

Speculation can often help to drive science forward. However, studies should be clear on the facts their study proves, and which conclusions are as yet unsupported ones. A statement framed by speculative language may require further evidence to confirm.

6. PROBLEMS WITH SAMPLE SIZE

In trials, the smaller a sample size, the lower the confidence in the results from that sample. Conclusions drawn can still be valid, and in some cases small samples are unavoidable, but larger samples often give more representative results.

7. UNREPRESENTATIVE SAMPLES USED

In human trials, subjects are selected that are representative of a larger population. If the sample is different from the population as a whole, then the conclusions from the trial may be biased towards a particular outcome.

8. NO CONTROL GROUP USED

In clinical trials, results from test subjects should be compared to a 'control group' not given the substance being tested. Groups should also be allocated randomly. In general experiments, a control test should be used where all variables are controlled.

9. NO BLIND TESTING USED

To try and prevent bias, subjects should not know if they are in the test or the control group. In 'double blind' testing, even researchers don't know which group subjects are in until after testing. Note, blind testing isn't always feasible, or ethical.

10. SELECTIVE REPORTING OF DATA

Also known as 'cherry picking', this involves selecting data from results which supports the conclusion of the research, whilst ignoring those that do not. If a research paper draws conclusions from a selection of its results, not all, it may be guilty of this.

11. UNREPLICABLE RESULTS

Results should be replicable by independent research, and tested over a wide range of conditions (where possible) to ensure they are consistent. Extraordinary claims require extraordinary evidence - that is, much more than one independent study!

12. NON-PEER REVIEWED MATERIAL

Peer review is an important part of the scientific process. Other scientists appraise and critique studies, before publication in a journal. Research that has not gone through this process is not as reputable, and may be flawed.

Figure 1.1.3 - *2014 CompoundChem.com* (CC BY-NC-ND 4.0)

Faith

I introduced this section by discussing epistemology, the theory of knowledge. Science is one kind of knowledge, faith is another kind of knowledge. What you know can come from what you experience with your own empirical senses, or you can believe something that someone told you. Faith is complex and varies from person to person, but a concise definition can be found on the popular bumper sticker that reads: “God said it, I believe it, that settles it.”

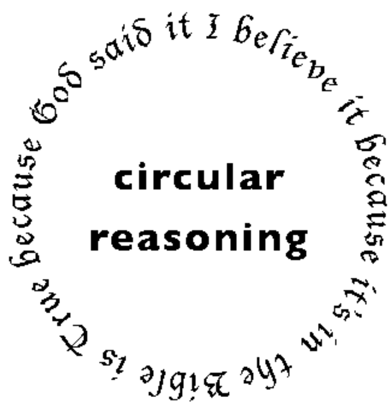


Figure 1.1.3 - *Circular Reasoning* (CC BY-NC 4.0)

Radical fundamentalist Christianity in the US makes what should be a parlour room discussion between science and religion into a political debate with real educational consequences for all us. Scientists struggle to understand the complex mechanisms of evolutionary theory, but for many, the struggle is made more difficult by ideological barriers set up by faith-based opposition to science.

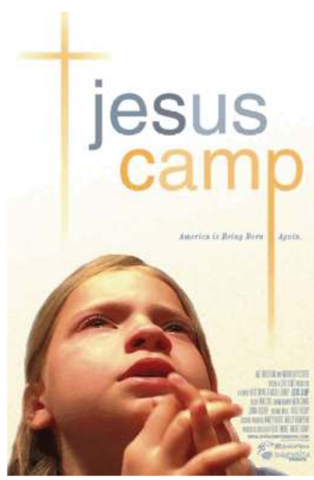


Figure 1.1.4 - *Jesus Camp. good 2006 documentary on radical fundamentalism*

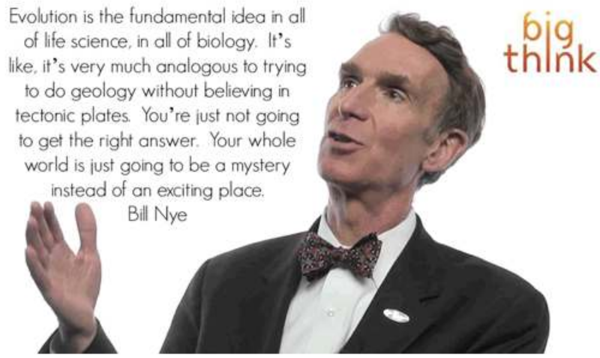


Figure 1.1.5 - *Big Think*

We need to stress evolutionary theory because it is a fundamental explanatory device in biology. There is a famous quote by geneticist Theodosius Dobzhansky where he states “nothing in biology makes sense, except in the light of evolution.” Trying to make sense of biological systems, including human beings, without evolution is like trying to understand physics while claiming that the force of gravity doesn't exist. There are very few belief systems in the world that deny evolution, and it is totally compatible with most religions around the world, even the Pope has come out supporting evolution (* 2014), so you have no conflict if you are a Catholic. But unfortunately, we happen to live in a culture that prefers faith over science. Our technology has changed rapidly in the last couple of millennia but our mindset has not quite kept up. Many fierce battles are fought today in school boards around the country over the separation of church and state, and whether faith-based ideas (Creationism/Intelligent Design) should be taught in public schools. The battles have spilled out onto the streets with people declaring their beliefs with little symbols on the backs of their cars.

Figure 1.1.6 - *Al Seckel, John Edwards 1983*

Personally, I wish I didn't have to dwell on the issue so much, I have friends who are Creationists and we get along fine. But, in my role as professor of physical anthropology, I cannot accept Creationism or Intelligent Design as anything more than dangerous fallacies that interfere with students' ability to learn the required curriculum. For me to teach "both sides" would be a form of repressive tolerance (Marcuse 1965). I'm not leading any crusades to banish Medieval thinking from society, but I get worked-up about the issue. It's like professional frustration – that I've failed at my job as an educator – when I see people who are proud of their ignorance. They act like being stupid is somehow cool or something. It reminds me of how Cornel West describes the problem of nihilism in society today.

It bothers me too how religion is used reinforce socioeconomic class. Many of you are smart enough to transfer to Harvard with a scholarship and get six-figure jobs in the budding genetics industry in major cities around the globe, but if during your job interview, you start spouting Intelligent Design ideology, your scientific credentials go down the drain, and you're back to flipping burgers at In-and-Out.

So, if you think Creationism/Intelligent Design is a load of crap, fine, so do 99.9% of the scientists in the world. But, if you are Christian, you don't have to abandon your faith for this class. I would get in trouble if half the class reasoned, "Well since my teacher has proven that a few poetic lines written thousands of years ago can't be interpreted literally, now I should do the exact opposite of all the moral precepts in the Bible, and become a Satanic mass-murdering tweeker." There are millions and millions of scientists who believe in Christ and evolution and find no contradiction between the two. If that doesn't console you, maybe it'll help to think of this class as an exercise in "know thyne enemy". You don't have to sign a "God is dead!" pledge, and you don't even have to actually believe in evolution to pass this class, you just have to understand it well enough to be able to regurgitate a few of the things I want to hear. But, be forewarned, I'm not a minion of the Devil; it's in my job description to test your faith and proselytize the wisdom of evolutionary theory.

There are very, very few people who actually take The Bible literally. Almost everyone interprets the meaning of the words in The Bible relative to their own language, historical milieu, and personal circumstances. Biblical scholars use the word *hermeneutics* to talk about the different ways that passages in The Bible can be interpreted. For example, there are several passages in the King James' version that says it's harder for a rich man to get to heaven than a camel to go through the eye of a needle. Some Biblical scholars think that the passage was poorly translated from the Aramaic to the Greek, and the mistake continued to Latin, and then English. They have found similar sayings from around that historical period that refer to the difficulty of threading a needle with a camel **hair**, or thread or rope made of camel hair, because camel hairs are so thick. Another interpretation is that Jerusalem had a small gate, called the Camel **Gate**, that was difficult to pass through if you were rich and carrying all your stuff. For me the metaphors of a camel hair through a needle or a rich guy with gear squeezing through a small door make a lot more sense than this image of an actual camel floating through some giant needle. Stuff gets lost in translation. Have you ever played that game, "telephone", where you get a big circle with your friends and one person makes up a complicated sentence and whispers in the ear of the person next to them, who whispers it in the ear of the person next to them, and as the message gets passed around the circle, people miss-hear things, or forget things, and the message changes. And, when you compare the original message to how it ended up, it often sounds silly.

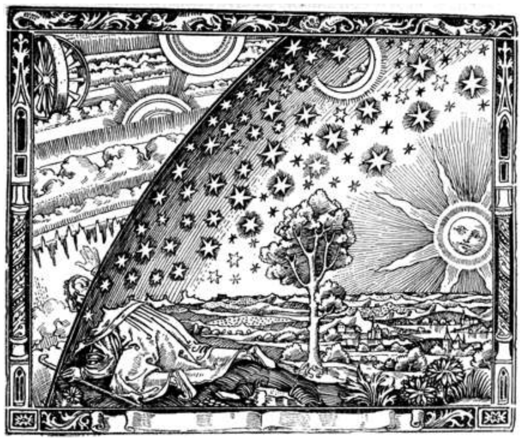


Figure 1.1.7 - *Flammarion engraving 1888, notice the pillars that hold up the heavens*

Some of the few people who take the Bible literally have been ridiculed into the closet. The Flat Earth Society took literally a passage from The Bible that said the heavens are held up by four pillars at the corners of the earth, and the image of the sun "rising" literally. They actually believed that if you walked far enough to some corner of the earth you would bump into a big pillar. Nowadays, it's hard to find an honest proponent of the Flat Earth theory, but they were around by the 1950s. Now, everyone just laughs at them, like you would probably laugh at someone one who claims the sun revolves around the earth. But on February 17, 1600, this was no laughing matter, when in the Campo di Fiore, Rome, Giordano Bruno was burned at the stake for advocating the heretical belief proposed by Copernicus known as *heliocentrism.*

Figure 1.1.8 - *Statue of Giordano Bruno, Campo di Fiore, Rome, Italy* (CC BY-NC 4.0)

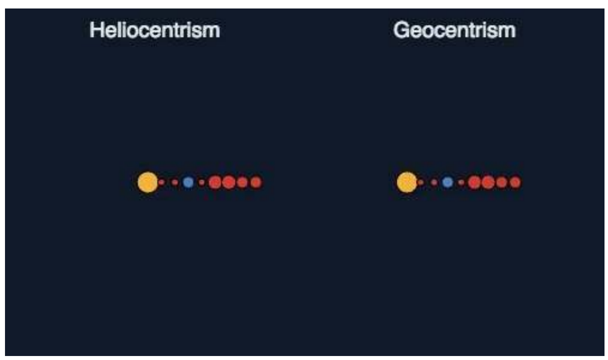


Figure 1.1.9 - *http://i.imgur.com/AReqgfP.gif*

I'm glad that we're at a point in history where I don't have to worry about being burned at the stake for teaching the theory of evolution, and I'm glad that we're at a point where we can just poke fun at Creationists through Darwin fish on our cars, or spoofs such as The Church of the Flying Spaghetti Monster. But I don't think the battle is over. Obama undid many of attacks on science that characterized the Bush administration, but the Trump administration promises a radical attack on science, and an era of "alternate facts". We'll see...

Notes

- A TED talk video of how science can help cure cancer
- A primer on logic and arguments

Vocabulary

- literature review
- abstract
- research question
- epistemology
- anthropology
- archaeology

- biological anthropology
- Creationism
- deduction
- empiricism
- faith
- hermeneutics
- hypothesis
- induction
- Intelligent Design
- laws
- linguistics
- physical anthropology
- qualitative
- quantitative
- science
- taxonomy
- theory

Imagination Questions

- What would happen to science if radical Christian fundamentalists organized a military coup and took control of education in the US?
- What if artificial intelligence advances to the point where robots can do their own science?
- How strong is your belief in science or faith? If you are religious and someone convinced you your religion was wrong, would you give it up? If you believe in science, and you saw God, would you give up your scientific beliefs?

1.2: Anthropology as a Science

Anthropological Imagination

The anthropological imagination (anthropological perspective) is how anthropologists see the world. Anthropology differs from other sciences because it emphasizes holism and genealogy. The emphasis on genealogy for cultural anthropology implies a focus on the family (domestic structure). The emphasis on genealogy for physical anthropology extends the metaphor of the family tree from an individual and their family, to a family tree writ-large that uses phylogenetic taxonomy to contextualize the human species. Anthropology's emphasis on holism implies a balance between different approaches and many subfields. The four main subfields of anthropology are cultural anthropology, physical (biological) anthropology, archaeology, and linguistics. Anthropologists balance objective and subjective epistemologies.

I think the best way to get a sense of how anthropology differs from other branches of science is to understand the anthropological imagination. I borrowed the concept of the anthropological imagination from one of my professors, Dr. Wade Pendleton, who in turn borrowed it from an introductory anthropology book (Dimen-Schein 1977), who based it on an important sociology book, *The Sociological Imagination* by C. Wright Mills (1959).

There isn't much published about the anthropological imagination, but it is basically the same thing as what most anthropologists call the "anthropological perspective" (Jurmain 2011:19-20; Field 2011). I like the connotations of "imagination" in the way it has been used by John Lennon and recent social movements to recognize the agency that people have to go beyond their cultural constraints. Franz Boas (1858-1942), one of the founders of anthropology, described this as people's need to break the "shackles of tradition" (* *Franz Boas: Shackles of Tradition*). It is especially related to cultural anthropology, where "the world is as you see it", the idea that if people believe in ghosts, then you as a scientist need to start with the hypothesis that those ghosts really exist. That might seem weird to many scientists, but anthropologists need to balance a detached, objective, way of seeing, with the subjective reality of the people they join to study.

Anthropologists balance several seemingly contradictory philosophies. I like to see the anthropological imagination as tendencies between two extreme poles, and though they may lean towards one side or the other, they can never really go to the extreme in any direction.

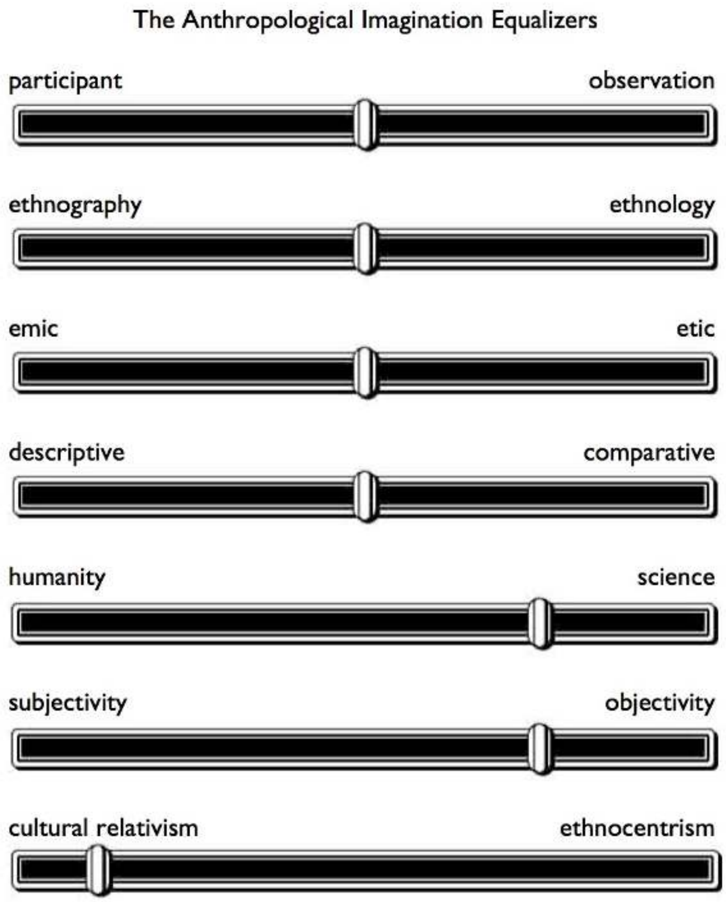


Figure 1.2.1 - *The anthropological imagination balances extremes* (CC BY-NC 4.0)

The principle method of fieldwork in cultural anthropology is called participant-observation, and participant observation exemplifies the balance of anthropology. Anthropologists must objectively study people as an outsider, but they also become part of that culture. They must be culturally relative, and not judge a foreign culture by the standards of the researcher's culture, but they also have their own ethical principles that come from the anthropologist's own culture, and there are limits to how dogmatic anthropologists can be about cultural relativism, and scientists (myself included) need to be a little bit ethnocentric to support things like the *United Nations Declaration of Human Rights and tell another culture that they're doing it wrong. Because our science is so tied to humans we can't avoid asking ethical questions, or as Sir Raymond Firth put it "Cui bonum?" *For Whose Good?(Schepher-Huhges1981)* What is the purpose of doing anthropology?

This is true to a lesser extent in our class, regarding physical anthropology. We are objectively discussing some aspects of a biological species that has been around hundreds of thousands of years, and has a few distinct characteristics from other animals, but at the same time, we are talking about ourselves, my relatives, the people who gave me the genes I have now, that enable me to think, and type, and wish that this font was easier to read on this crappy screen.

I think the two most distinctive characteristics of anthropology are that it is holistic and it emphasizes genealogy. Holism means that it tries to understand all facets of the human condition. This has many implications. Anthropology is multi-disciplinary, it involves many branches of knowledge. By the early 1900's Franz Boas solidified anthropology into four interrelated subfields: cultural anthropology, physical anthropology, archaeology, and linguistics. As anthropologists began solving real world problems, some advocated for a fifth subfield: applied anthropology. For each of these sub-fields you can combine practically any other branch of science to make sub-sub-fields, depending on your specialization. Don't get too hung up about the correct taxonomy for these branches of knowledge. It can be rewritten in many forms depending which branch you want to emphasize. But in anthropology, all specialists need to have a broad overview to fit their research into the larger questions of what it means to be human, and this incorporation of specific issues into broad questions requires a holistic approach. A good example for physical anthropology is the concept of *biocultural evolution*, the idea that to understand human evolution we need to look at both biology and culture.

If you take a cultural anthropology class you will see the study of culture requires a holistic approach in its own right because culture is integrated and all-encompassing; you need to study all the elements of culture together and their interaction. Another consequence of holism, and the multi-disciplinary approach of anthropology, is that anthropologists tend to be skeptical of unicausal arguments. A unicausal argument is something like "people have wars because they have an aggressive nature." Anthropologists understand that human nature is supremely complex, and that culture can drastically change any human characteristic that people try to claim is biologically determined. Sure, people are aggressive, you can look at chimpanzees and hominid weapons, but humans are also peaceful, you can look at bonobos and the amazing art of the Upper Paleolithic. Try to keep this point in mind when you´re writing for this class: avoid unicausal arguments, give all sides of an issues, avoid oversimplification, explore the evidence that supports each position.

Exercise 1.2.1

Compare ETHNOGRAPY to ETHNOLOGY

Another general emphasis in anthropology is on genealogy. In cultural anthropology, the structure of the family is usually a core element of a culture. In physical anthropology, I like to view our emphasis on classification and taxonomy as just an attempt to better understand the branches of our own family tree.

The anthropological imagination is also something that you as an individual will use to better understand yourself and your place in the world. Biological and cultural explanations can be useful in solving your own problems. Having an answer to "Why am I sweating right now?" means understanding the cooling mechanisms that our ancestors evolved over tens of millions of year, and the fight-or-flight response in response to stress that involves putting your own personal financial problems into a cultural context where education is touted as the method of class mobility, yet restricted by public policy that raises tuition, textbook prices, and limits financial aid.

Subfields of Anthropology

Exercise 1.2.1

Read Dennis O'Neil: The Subfields of Anthropology and Wikipedia's Explanation

Many anthropologists consider applied anthropology as a fifth subfield. I prefer to think of it as a research goal or purpose that cross-cuts all of the four subfields. For example, there are projects that can be considered applied linguistics [language renewal], or applied archaeology [Incan agronomy]. There are many applications for physical anthropology, especially in medicine. The word *forensic* means "legal", but most forensic anthropology tends to be a subfield of physical anthropology - we use what we know about human biology to help solve crimes.

Notes

- The Argentine Forensic Anthropology Team is a good example of forensic anthropology. They have been recently working to identify the 43 missing students from Ayotzinapa, Mexico.
- Check out careers in genetic counseling
- The Health and Medicine chapter from a cultural anthropology textbook
- Desmond Morris' The Language of the Body: a good video combining physical anthropology, cultural anthropology and linguistics

Conclusion: Anthropology and Science

In conclusion, anthropology is mostly a science, but has many aspects of humanism. For a more traditional introduction to anthropology and science read the Dennis O'Neil overview of anthropology.

Epistemology for Physical Anthropology

Epistemology means the study of how we know what we do. *Taxonomy* comes from the Greek word for "branches". Here is a taxonomy of knowledge for this class:

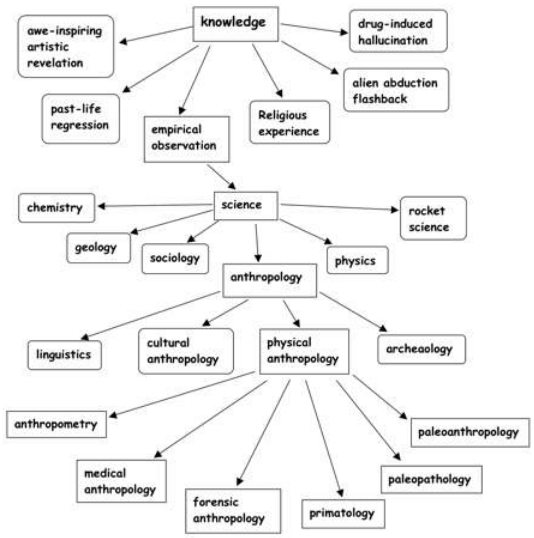


Figure 1.2.2 - *An epistemology for physical anthropology* (CC BY-NC 4.0)

You add or subtract boxes, and draw the arrows differently depending on what you want to focus on, and because anthropology is holistic these charts don't make much difference; anthropologists include all relevant aspects of knowledge. We will focus on the bottom part of the flowchart, but always keep the bigger picture in the back of your mind.

Vocabulary

- anthropology
- archaeology
- biology
- culture
- epistemology
- ethnography
- ethnology
- linguistics
- participant-observation
- phylogenetic
- taxonomy

Imagination Question

How does the anthropological approach to understanding human beings differ from other classes you've taken?

CHAPTER OVERVIEW

2: Introduction to Biology

Physical anthropology is also called biological anthropology. You need to understand the basics of biology before you apply it to humans. We are going to use these ideas as the basis for explaining phenomena in later sections, such as: Why primates scream at each other? How are those two fossils related? Why do people look different from each other? What are people going to look like in a million years? Now is a great time to review your notes from your High School biology class.

Thumbnail: Darwin's finches (also known as the Galápagos finches) are a group of about fifteen species of passerine birds.[1][2][3][4] They are well known for their remarkable diversity in beak form and function. From "Voyage of the Beagle." (Public Domain).

2.1: Introduction

Physical anthropology is also called biological anthropology. You need to understand the basics of biology before you apply it to humans. We are going to use these ideas as the basis for explaining phenomena in later sections, such as: Why primates scream at each other? How are those two fossils related? Why do people look different from each other? What are people going to look like in a million years? Now is a great time to review your notes from your High School biology class.

Biology is a broad field that ranges in scale from the microscopic to the geographical. Evolutionary theory is crucial to biology. Charles Darwin's theory of natural selection came from a historical context where many other scientists were contributing to evolutionary theory. Natural selection means that individuals compete for resources and those with the variations that make them more fit to survive in a certain environment tend to survive and reproduce more. Sexual selection is the part of natural selection that focuses on competition for reproduction. Darwin understood the importance of variation.

Gregor Mendel used math to explain how variation is inherited. Population genetics used math to show how inheritance works in large populations. The modern synthesis combined Mendelian genetics and population genetics, to codify evolutionary theory into four forces: mutation, natural selection, migration, and genetic drift. Inheritance, mutation, and other sources of variation can now be understood through cellular biology and genetics. Humans are made up of cells. Cells have DNA. DNA is the code that directs protein synthesis. Proteins direct the functions of life.

Sickle cell anemia is an example of how the holistic approach of anthropology can use many subfields, mostly from biology, to understand the origins and consequences of an important human disease.

2.2: Scale, Human Space, Powers of Ten for Physical Anthropology

Anthropology is a broad field that incorporates many sub-fields and borrows from many other disciplines, so the space that is relevant to physical anthropology is also vast. It ranges from the atomic particle that causes genetic mutation—the primary cause of evolution—to the plasticity of the human body because of our need to adapt to seasonal changes caused by the elliptical orbit of the planet in the solar system. Anything bigger or smaller is beyond the scope of physical anthropology. Why atomic particles behave the way they do is a question of physics. Whether life exists on other planets is a question of astrobiology. Both are good themes for philosophy and science fiction, but are beyond the scope of this class.

Meters	Common Measurement	Abbreviation	Relevance
10^{-10}	1 ångström	1 Å	Size of an atom
10^{-9}	1 nanometer	1 nm	Diameter of DNA helix, size of a base
10^{-8}	10 nanometers	10 nm	Size of a codon (3 base pairs)
10^{-7}	100 nanometers	100 nm	Locus, length of a typical gene
10^{-6}	1 micron	1 µm	Cell nucleus, *Plasmodium falciparum*
10^{-5}	10 microns	10 µm	Typical primate cell
10^{-4}	100 microns (micrometer)	100 µm	Patch of melanin, width of hair, human egg
10^{-3}	1 millimeter	1 mm	The height of a cusp on a Y-5 molar
10^{-2}	1 centimeter	1 cm	Human ear bones,*Anopheles* mosquito
10^{-1}	10 centimeters	10 cm	Length of a human's opposable thumb
10^{0}	1 meter	1 m	Space that an individual primate occupies
10^{1}	10 meters	10 m	Typical sleeping area of a primate social group
10^{2}	hectare/ 2.5 acres, football field	100 m	Typical core area of a primate social group
10^{3}	10 hectares, 1 kilometer	1 km	Typical territory of a non-human primate social group
10^{4}	100 hectares	10 km	Typical home range of a non-human primate social group
10^{5}	100 kilometers	100 km	
10^{6}	1,000 kilometers, continent	1000 km	Typical range of a non-human primate species; range for most of human evolution
10^{7}	10,000 kilometers, the surface of the planet Earth	100000 km	The range of all biological evolution
10^{12}	1 billion kilometers, 1 terameter	1 Tm	The Earth's orbit in the solar system, includes meteors and solar radiation

Notice that most of the larger ranges are relevant for hominid evolution and primate behavior, the medium sizes are used in osteology and to compare human and hominid variation. The smaller sizes can describe human variation and genetics. Refer back to this chart as we cover those relevant sections.

Exercise 2.2.1

Use this chart and watch the movie POWERS OF TEN

> *"Recognize that the very molecules that make up your body, the atoms that construct the molecules, are traceable to the crucibles that were once the centers of high mass stars that exploded their chemically rich guts into the galaxy, enriching pristine gas clouds with the chemistry of life. So that we are all connected to each other biologically, to the earth chemically and to the rest of the universe atomically. That's kinda cool! That makes me smile and I actually feel quite large at the end of that. It's not that we are better than the universe, we are part of the universe. We are in the universe and the universe is in us."*
> *-Neil deGrasse Tyson*

Note

More on scale and measurements: human scale

Imagination Question

When you look in the mirror do you see yourself as a trillion cells, or a trillion, trillion atoms which came from stardust, or a collection of selfish genes, or an individual?

2.3: Evolutionary Theory (Part 1)

Don't go to a dictionary and look up the definition of "evolution". Most of the definitions are just going to reinforce your confusion. For this class we are using the **biological** definitions of evolution: the splitting of a lineage into two new species, or the change in allele frequency in a breeding population from one generation to the next. For this class an individual can never evolve in their lifetime, a cell phone operating system can never evolve, only a population or a species can evolve. Darwin understood the problem with the word "evolution" and preferred the phrase "descent with modification", but that obviously never caught on.

Understanding evolutionary theory is crucial for all the chapters that follow. For example, in the paleoanthropology section we will make arguments about how natural selection gave our ancestors advantages in different environments, and we will argue how gene flow kept our recent ancestors from becoming separate species. If you don't learn about the forces of evolution now you won't understand the arguments we're going to make later.

Evolutionary theory is a difficult concept. In the last section we discussed the ideological barriers that extremely dogmatic religious people have that might keep them from understanding evolutionary theory. Another common misconception of evolution is that there is inherently something good about it, that to evolve means to progress. The simple definition of *evolution* is just “change”. It doesn't mean change for the better, or change for the worse, just that a species is different than what it used to be. It's important to separate how a word is used on the street from the very specific definition we are using here in our biological context. The main reason people have problems with a neutral definition of evolution is that we've had thousands of years of cultural baggage that clouds our empiricism. The philosopher Aristotle stressed the importance of finding the essence of a thing, and from this we get the concept of essentialism. People often think of humans as diverging from or progressing towards some ideal form, but these are cultural constructs, not what we empirically see in biology. We carry baggage around that makes simple concepts seem counterintuitive. Understanding the incorrect ideas helps us accept the correct ones.

Exercise 2.3.1

Read more about Darwin and design.

History of Evolutionary Theory, up to Darwin

It helps to understand evolutionary theory if you understand how it “evolved”. I put “evolved” in quotes because for this class I want to reserve the word *evolution* to mean “biological evolution” and not confuse it with historical and cultural changes. There are different ways to study history, and for this section we need to be careful not to fall into the trap of thinking of history as a series of Great Men – important people who change the world through their personal actions. This way of looking at history is very convenient for an introductory class, because you just need to make a handful of flashcards with the names on one side, and what they're famous for on the other. But, try to look beyond the individuals, and imagine the broader movements that were going on at the time these individuals lived.

It helps sometimes to put people and concepts into two columns: did they contribute to evolutionary theory or did they detract from the development of evolutionary theory? But, many historical figures can be put in both columns, depending on their effect on history, and what stage of their life you look at. For example, Linnaeus made amazing strides in biological taxonomy, but opposed evolutionary theory, at least until the end of his life; Lamarck created a great theory of evolution, but it was wrong; Cuvier contributed to our understanding of extinction, but argued against evolution and fixity of species, Lyell argued against biological evolution until after Darwin convinced him; Wallace's evolutionary theory was mixed with quirky spiritualism; Darwin's theory of Natural Selection was revolutionary, but his emphasis on blending made it more likely to ignore important contributions from scientists like Mendel, and gradualism made it harder to accept punctuated equilibrium. Just realize that for an introductory class, we only have time to give you a cardboard cut-out of these fascinating and complex individuals and their historical milieux.

Exercise 2.3.2

Read Dennis O'Neil's Intro

The Fixity of Species

In this modern world, we are so used to change that it's hard not be ethnocentric and imagine a time when things were pretty much the same as it was for your grandparents, and you expected things to be pretty much the same for your grandkids. Imagine growing up and liking the same music as your great-grandparents. Most religions around the world are conservative. God creates a world and some people to interact with it. And the reasoning often goes that if your deity is all-powerful, His creations would be perfect and He wouldn't need to keep tinkering with them. When people looked around at all the living creatures on the planet, they assumed that everything was stuck the way they saw it. This concept is called *the fixity of species,* and "fixity" in this case refers to being in a fixed position; unchanging.

> *Evolutionary theory is diametrically opposed to the fixity of species.*

The Great Chain of Being

The Great Chain of Being incorporates the concept of the fixity of species but ranks life into better or worse, noble animals like eagles and lions go towards the top, slimy animals like worms and eels go down to the bottom. Noah's Ark usually boards the same way, first-class passengers first. When applied to humans, the Great Chain of Being has always functioned to perpetuate political oppression such as racism, sexism, and classism. The dominance of the Great Chain of Being in Eurasian philosophy makes it hard at first for many students to accept the complete absence of any system of ranking or progress in evolutionary theory.

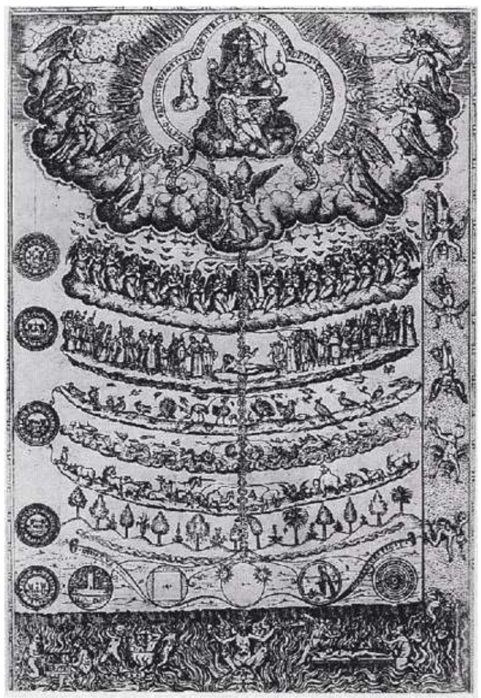


***Figure** 2.3.2 - Wikipedia;1579 drawing of the Great Chain of Being from Didacus Valades, Rhetorica Christiana.*

John Ray

John Ray (1627-1705) is important to us because he invented the concept of the species (the word "species" is one of those Latin words that doesn't change between the singular and plural; "one species, two species"). Species are the most fundamental way of grouping life forms. You might ask how a book entitled "The Wisdom of God Manifested in the Works of Creation" could contribute to evolutionary theory but a common theme in all science is how scientists get some things right and some things wrong. In Ray's book *History of plants* he grapples with how to group the varieties of life, and he comes up with a concept that is still useful today – individuals that can reproduce are from the same species:

> *no surer criterion for determining species has occurred to me than the distinguishing features that perpetuate themselves in propagation from seed. Thus, no matter what variations occur in the individuals or the species, if they spring from the seed of one and*

> *the same plant, they are accidental variations and not such as to distinguish a species… Animals likewise that differ specifically preserve their distinct species permanently; one species never springs from the seed of another nor vice versa *[Ray 1686; Ray 1686]*

A species is something that exists over time and is capable of perpetuating itself, and variations within a single species occur. The Notice at the end of the quote how he insists on the fixity of species, and denies speciation, but we still use Ray's species concept today.

Carolus Linnaeus

Linnaeus is the father of taxonomy. Taxonomy was different from the Great Chain of Being because instead of grouping animals into biblical categories, he grouped them by biological characteristics: how they give birth, what they eat, aging, exterior movement, internal propulsion of fluids, diseases, death, glands, skin, and the shape of the inner ear (Foucault 1970). This list is very arbitrary compared to how today we compare the DNA of a species to classify it, but Linnaeus' taxonomy was radically different from the more poetic groupings of his time. Linnaeus was able to distinguish bats from birds, and snakes from eels and worms. His taxonomy changed over his lifetime and has been an important concern of biology to this day.

His approach to classifying humans codified scientific blunders regarding race that have continued over two centuries.

> **Exercise 2.3.3**
>
> Read this Introduction to Linnaeus

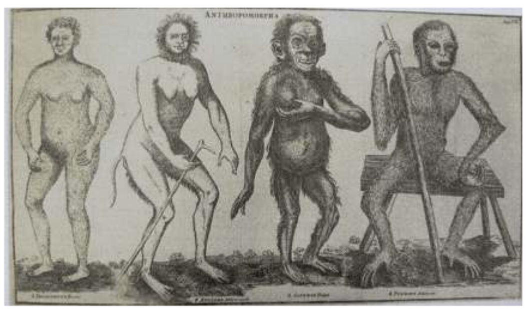


***Figure** 2.3.5 - 1760 Hoppius based on Linnaeus, left to right: Troglodytes, Lucifer/Homo caudatus, Satyr, Pygmie*

> **Exercise 2.3.4**
>
> Briefly scan Linnaeus' system of nature 1740
>
> Skim the pages on humans from this 1757 version

Buffon

George Louis Leclerc, Comte de Buffon wrote about how life changes according to the environment but didn't explain how.

Erasmus Darwin

Erasmus Darwin was the grandfather of Charles Darwin and his poetic writing about how life forms might change influenced his grandson, Charles.

* if you like prose, skim his chapter on generation

Jean-Baptiste Lamarck

Lamarck is known for his theory of Acquired Characteristics, also called the Use-Disuse theory. The theory goes that the physical traits you change during your lifetime get passed on to your kids. So if you believe in Lamarck's theory then you would expect Arnold Schwarzenegger's babies to be born with lots of muscles.

Of course, Lamarck was wrong. Physical characteristics acquired during an individual's lifetime are **not** transferred to its offspring (with a few epigenetic counterexamples). We'll show why he was wrong in the section on cellular biology. The reason Lamarck's theory sounds so plausible is because **culture** is transmitted this way; what you **learn** during your lifetime can be taught to your children. But biological inheritance has very specific mechanical processes that we can now see in a microscope. You have to give Lamarck credit for coming up with an elegant theory of evolution. It has been disproven, but it was still a great theory for its time. Understanding why Lamarck was wrong will help you understand natural selection.

Exercise 2.3.5

Look at the classic example of Giraffes

Skim this Biography of Lamark

Georges Cuvier

Cuvier is important to evolutionary theory in promoting the concept of extinction. He saw fossils of animals no longer on the planet, such as giant elephants, and he correctly explained their disappearance as extinction, the big elephants just died out.

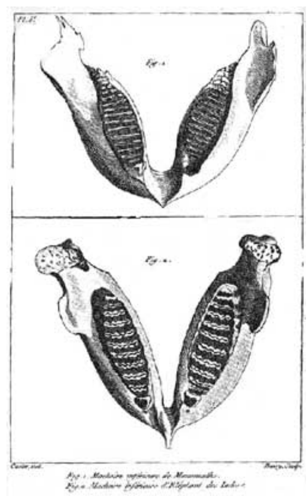


Figure 2.3.8 - *evolution.berkeley.edu/evolib...cle/history_08*

His views on extinction contributed to evolutionary theory but his attempts to reconcile geology with The Bible did not. Cuvier is also known for his theory of Catastrophism: extinctions in the fossil record are only because of sudden changes in the environment, such as worldwide floods, like Noah's flood.

Geologists: James Hutton and Charles Lyell

Geology has always had a profound impact on evolutionary theory. Most of the scientists of the 18th and 19th Centuries called themselves "naturalists" and didn't distinguish between fields such as geology and biology. James Hutton and Charles Lyell were two of the most important scientists to use empirical observations to guide theories of how the Earth arose and became what we see today. Their two main contributions to evolutionary theory are the concept of geological time and the principle of uniformitarianism.

Geology is important to biological anthropology in many ways, such as dating and environmental context in paleoanthropology. In archaeology, Lyell's Law of Superposition is crucial – the deeper you dig, the older things are.

Geological Time

How long are you going to live? 50 years? 100 years? The length of time that you can perceive is limited by your own biological expiration date. The neat thing about geology is you start thinking like a rock. Imagine 1,000 years passing, 10,000 years, 100,000 years, 1,000,000 (a million) years, 1,000,000,000 (a billion) years… Lyell proved that the Earth is old, that rocks have been around for a long time. This was important to biologists and paleontologists because it showed that fossils are very old too. If life has been around for billions of years we can more easily accept that drastic changes could happen over that long a time span. Geological and astronomical time is sometimes called **Deep time,** and it is one of those very disturbing nonhuman concepts that science often forces us to think about.

> **Note**
>
> Bishop Ussher dates the world at 4004 BC.

The Principle of Uniformitarianism

What happened in the past continues to happen today. Most cosmologies around the world have some concept of a mythical past, where different laws of nature applied. Lyell demonstrated that huge geological formations can be explained by the same simple forces that we see today, such as erosion, wind, earth moved by earthquakes. We can explain something as awesome as the Grand Canyon with two simple processes that can be seen today: uplifting and erosion.

In biology, we can find simple processes that differentiate me from a banana slug. Both, the biological and the geological require huge quantities of time.

> **Exercise 2.3.6**
>
> Skim the 1830-3 Table of Contents of Lyell's Principle of Geology (10 pages)

Thomas Malthus

Malthus studied demography, how populations change. Overpopulation creates competition for limited resources. This idea of competition within a population is similar to the idea of competition within a species, and creates change. According to Malthus, humans can increase their population faster than they can increase their food supply. Having more people than food leads to starvation and competition for limited resources.

For example, imagine that Octamom has 8 daughters who each have 8 daughters who each have 8 daughters who each have 8 daughters, and in 5 generations you have a population of around 32,000. When Octamom works a plot of land she can produce one bushel of food per month, with her daughters helping she can produce 2 bushels, with her grandkids helping, 3 bushels, but by the time her great-great-grandkids have exhausted the nutrients in the soil, and run out of fertilizer made from non-renewable resources, her descendants are back to producing about 3 bushels a month, except it's like a Mad Max dystopia with thousands fighting over those few bushels, and most starving to death.

Darwin took Malthus' very specific observations of how humans compete for limited resources and generalized them to the broader field of biology.

Mary Anning

Mary Anning was the most famous fossilists of 19th century. A fossilist is someone who gathers fossils. A fossil is the imprint of a biological form, and we will come back to fossil in the sections on paleontology and paleoanthropology. Fossils represent biological data. If we go back to section 1.1 and consider the scientific method, it's important to remember that hypotheses are based on empirical observations, things we can see with our own senses. With a phenomenon like gravity you see the apple falling from the tree, but seeing evolution is more difficult. What many of the evolutionary thinkers of the 19th century got to see were the fossils collected by Mary Anning.

* Watch this puppet show of Mary Anning's life

Imagination Questions

- How big is life?
- How old is life?
- The line "same as it ever was", from the Talking Heads song "Once in a Lifetime" always reminds me of uniformitarianism and the song makes make think of deep time. Do you ever freak out about how short your lifespan is compared to how long the planet has been around?

2.4: Evolutionary Theory (Part 2)

Charles Darwin

One of the most profound impacts Darwin had was to change how we ordered life, from a ladder (like the Great Chain of Being) to a tree.

Exercise 2.4.1

Read Dennis O'Neil's Darwin and Natural Selection

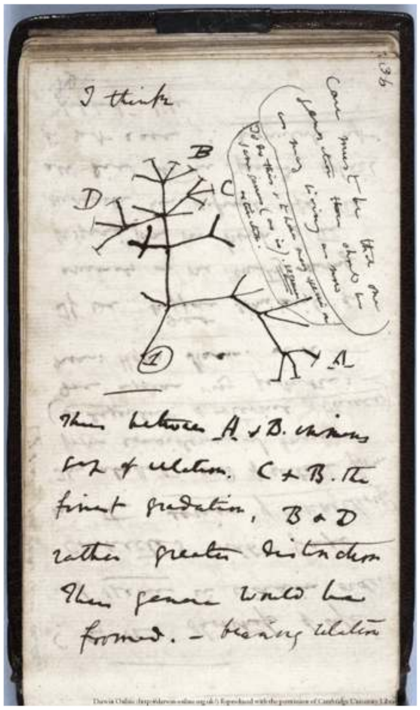


***Figure** 2.4.10 - The page from Darwin's 1837 private notebook ("Notebook B on the transmutation of species," 1837–1838)*

Darwin's main Eureka! moment with evolutionary theory was that species (1) evolves into species A, B, C, and D, and everything in-between goes extinct:

> *"I think ... Case must be that one generation then should be as many living as now. To do this and to have many species in same genus (as is) requires extinction. Thus between A & B immense gap of relation. C & B the finest gradation, B & D rather greater distinction. Thus genera would be formed.—bearing relation."*

This is barely legible, confusing, and poorly written, so please don't use this as an example of anything you want to turn in for my class. Darwin's genius comes from translating this sketch into a 500 page bestseller by 1859, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, which thoroughly explained Natural Selection and supported it with voluminous evidence. We remember Charles Darwin's not for the Aha! moment in 1837, but for the two decades of work he did afterwards to finish *On the Origin of Species* by 1859. The media tends to sensationalize scientific discovery (e.g. Isaac Newton gets hit by an apple and suddenly understands the mathematical equation that describes gravity), but for most scientists, it's more about hard work.

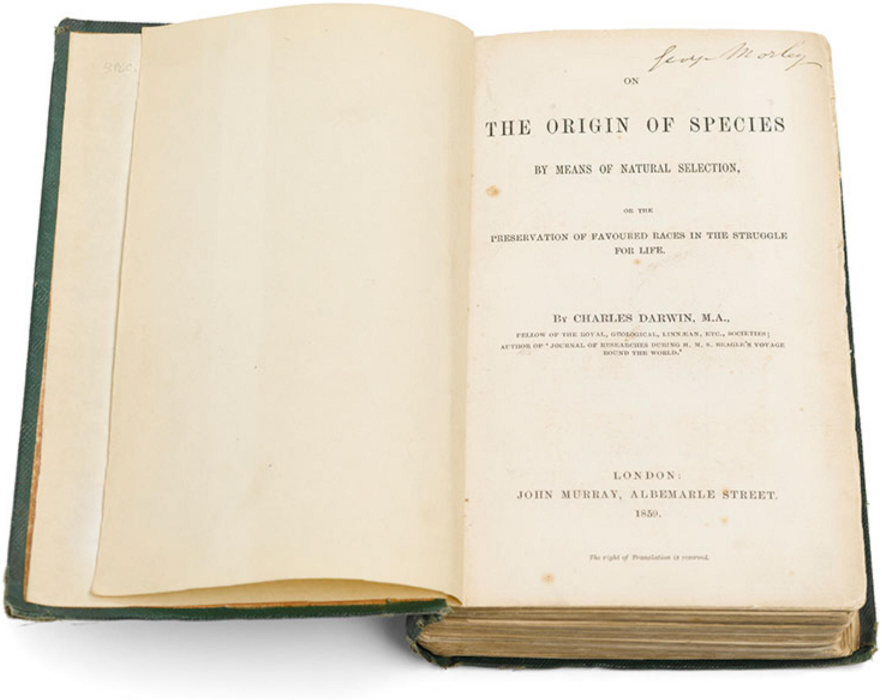


Figure 2.4.11 - *On the Origin of Species 1859*. Photo by Wellcome Collection (CC-BY-4.0)

Exercise 2.4.2

Open Charles Darwin's 1859 *ON THE ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION, OR THE PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.*; Read the description of the chapters carefully (page V to page X), then skim the rest for a few minutes

* A more readable version of On the Origin of Species, and more of Darwin's writtings,

Darwin had an unremarkable personal life. He wasn't a great student, he didn't have strong philosophical, political, or religious views.

* Good summary of Darwin's personal life

> *Darwin did not use evolution to promote atheism, or to maintain that no concept of God could ever be squared with the structure of nature. Rather, he argued that nature's factuality, as read withing the magisterium of science, cannot resolve, or even specify, the existence or character of God, the ultimate meaning of life the proper foundations of morality, or any other question with the different magisterium of religion. [Gould 1999]*

He wasn't oblivious to the social consequences of his findings, and was reluctant to publish.

Exercise 2.4.3

Watch *Creation*: a pretty good Hollywood movie about Darwin's personal and ethical problems; the story of how the movie was censored in the US says a lot about how this is still an important political issue.

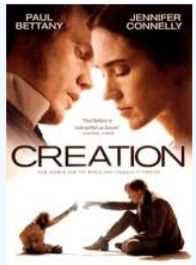


Figure 2.4.12 - *Creation 2009*

Understanding Natural Selection

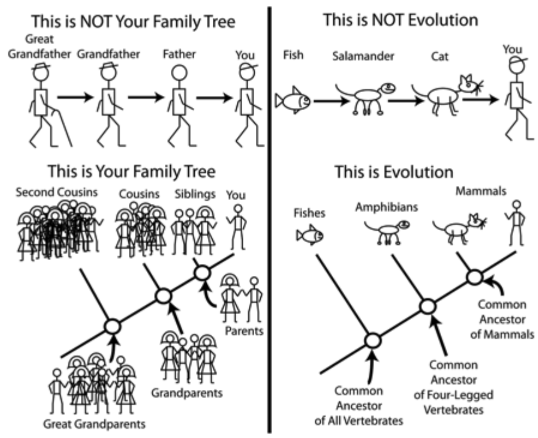


Figure 2.4.13 - "Evolution is no different than your family tree … except over a much longer period of time." by M.F. Bonnan/Florida Citizens for Science © 2010

A classic example of natural selection is the industrial melanism of the peppered moth. The same species of moth has black moths and white moths which can interbreed. When they land on white tree bark, the black moths tend to be eaten, and they become rare. Because of industrial pollution, the bark turned black, and now the white moths became rare. They cleaned up the pollution, the bark became lighter, the white moths survived more than the black moths. There are a few problems with the research but it is still a great example of how evolution works.

Note

- A video game that simulates Kettlewell's research
- Scientists may have found the gene that determines the color change of the moths.

Unfortunately, very few of us have grown up on a farm, so it's hard for us to understand where Darwin got the phrase "natural selection" from. We don't ever use the phrase "unnatural selection" but that's what human selection is. After every harvest the farmer notices the tastiest, biggest, or most fruitful plants and keeps their seeds until next season to plant, and animal breeders mate their best stock together. The farmers and breeders are selecting desirable characteristics and increasing the chance that they will be passed on to the next generation. From this process of selection we get all the food we eat today and an amazing range of domesticated pets.

Figure 2.4.13 "Big and Little Dog" By Ellen Levy Finch CC-BY-SA-3.0

We see In the archaeological record of Mesoamerica how teosinte was selected over thousands of years and became corn.

Figure 2.4.16 - *http://teosinte.wisc.edu/index.html* photos by Hugh Iltis (left) and John Doebley (right), © The Doebley Lab, Department of Genetics, University of Wisconsin-Madison

Part of Darwin's genius was to recognize that the process farmers and animal breeders use to change a species, was also a natural phenomenon, that competition in an environment of limited resources would select those individuals who were more fit for that environment, and he coined the phrase "natural selection".

When we use the word "fit", don't think of 24-Hour Fitness, think of square peg fits into square hole, round peg fits into round hole. Some individuals fit into an ecosystem or an environment better than others.

Note

- Research on the origins of corn
- Article on genes and dog size

Sexual Selection

Darwin didn't stop with natural selection, he continued to expand evolutionary theory throughout his lifetime. Darwin avoided a few difficult ideas in *The Origin of Species* and left them for his 1871 work:* THE DESCENT OF MAN, AND SELECTION IN RELATION TO SEX**. This book tackled both a difficult scientific question – sexual selection, and a difficult social question – the origins of humans.** And within the book, Darwin left his most controversial chapters at the very end:* Part II Sexual selection of man (316-84) and General summary and conclusion (385-405).

Peacocks gave Darwin a headache. Natural selection says you are more likely to survive and reproduce if you are camouflaged, if you stay hidden and avoid predators. But, what gave Darwin, and the male chauvinist scientists of his time, the most trouble was the idea that the female was responsible for choosing the mate and driving evolution.

Figure 2.4.18 - *Female peahen and chick* (CC BY-NC 4.0)

Figure 2.4.19 - *Male peacock* (CC BY-NC 4.0)

Wallace was almost famous, but Darwin published before him.

Exercise 2.4.4

Read Dennis O'Neil's Darwin and Natural Selection

Watch the 'Animated Life of A.R. Wallace'

Skim Wallace's early, 1855, article on evolutionary theory: *On the Law Which Has Regulated the Introduction of New Species,* skip to the end and read the comments by Bernard Michaux who argued that Wallace probably believed in something close to natural selection because his article contains all the important themes of Darwinism: "gradualism, utility, adaptation to different environments, allopatric speciation, imperfection of the fossil record" (Michaux 2000).

Imagination Question

1) Natural Selection
In the novel *Cryptonomicon,* Neal Stephenson presents the origin of his protagonist as a series of survivors:

> *Like every other creature on the face of the earth, [he] was, by birthright, a stupendous badass, albeit in the somewhat narrow technical sense that he could trace his ancestry back up a long line of slightly less highly evolved stupendous badasses to that first self-replicating gizmo—which, given the number and variety of its descendants, might*

> *justifiably be described as the most stupendous badass of all time. Everyone and everything that wasn't a stupendous badass was dead.*

In the movie *Beast of the Southern Wild*, the teacher describes a mythical predator depicted in the Lascaux cave paintings as

> *a fierce, mean creature that walked the face of the earth back when we all lived in caves. They would gobble the cave-babies down right in front of their cave-parents. And the cavemen couldn't do nothing about it, because they were too poor, too stupid, too small.*
> *Who up in here think the caveman was sitting around crying like a bunch of pussies? Y'all gotta think about that.*
> *Any day now, the fabric of the universe is coming unraveled. Ice caps gonna melt, water's gonna rise, and everything south of the levee is going under. Y'all better learn how to survive now.*

Do you think of yourself as a badass? Do you give your ancestors credit for making you what you are? Do the hardships your ancestors overcame, inspire you to overcome the problems of the future?

2) Money talks

A) If Wallace's family had more money, evolutionary theory might have gone down a different path. Wallace was more spiritual than Darwin. Jonathan Marks defines "Atheistic Darwinism" as the use of Darwin to support atheism (2011:57-9). Maybe the backlash against evolutionary theory would have been less with Wallace at the helm?

B) The fictional protagonist of Elizabeth Gilbert's novel The Signature of All Things comes up with a "theory of competitive alteration" almost identical to Darwin and Wallace, through the same methods of empirical research and world travel, but she never publishes it, mostly because of her gender. How does power influence science?

3) Great Chain of Being

Below is a tongue-and-cheek reference to the Great Chain of Being from Margaret Atwood's novel *Life Before Man*:

> *Auntie Muriel is unambiguous about most things. Her few moments of hesitation have to do with the members of her own family. She isn't sure where they fit into the Great Chain of Being. She's quite certain of her own place, however. First comes God. Then comes Auntie Muriel and the Queen, with Auntie Muriel having a slight edge. Then come about five members of the Timothy Eaton Memorial Church, which Auntie Muriel attends. After this there is a large gap. Then white, non-Jewish Canadians, Englishmen, and white, non-Jewish Americans, in that order. Then there's another large gap, followed by all other human beings on a descending scale, graded according to skin color and religion. Then cockroaches, clothes moths, silverfish and germs, which are about the only forms of animal life with which Auntie Muriel has ever had any contact. Then all sexual organs, except those of flowers. [Atwood 1979]*

There has always been implicit racism in the Great Chain of Being; social inequalities were created by God. But there are broader questions. Why do humans feel the need to rank things? Why do we make top ten lists? Facebook started as a facial ranking network, Hot or Not. The grade you get in this class is basically part of a ranking system for employers and other schools. The difference in salaries between full-time and part-time faculty separates professors into two socioeconomic classes.

In the primate behavior section coming up, we'll see other primates similarly obsessed with dominance hierarchies. Perhaps ranking is human nature?

2.5: Evolutionary Theory (Part 3)

Science doesn't stop with a founder. Creationists blame Darwin for evolutionary theory, but most biologists wouldn't call themselves “Darwinists”, any more than most physicists wouldn't call themselves “Newtonists.” Natural selection is just one factor of evolutionary theory. People know much more about evolution today than they did during Darwin's time. That doesn't mean that Darwin was wrong, just that science has progressed.

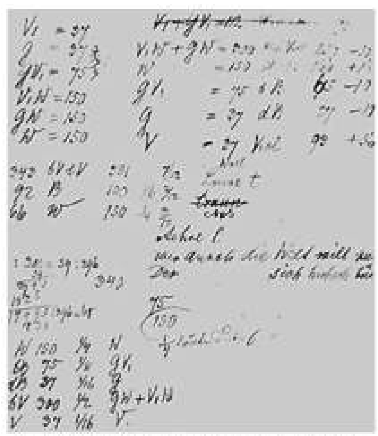
Darwin often gets blamed for *Social Darwinism*, the political ideology that extends "survival of the fittest" to justify exploiting the poor, but Darwin didn't come up with this phrase nor did he apply Natural Selection to human society. Social Darwinism was invented and promoted by others such as Herbert Spencer, Thomas Huxley, and Francis Galton. Charles Darwin objected to the application of his biological model to human social structure, and he definitely would have objected to the "Darwin Project" battle royale game, and "Darwin Awards" given out in his name.

So far, our overly broad unifying theories haven't been worth much more than interesting metaphors, so please try to separate nature from nurture: biology from culture.

Gregor Mendel

Even though neither Darwin nor Mendel knew about how heredity worked at the cellular level, it's almost impossible to talk about the consequences of their work without referring to what we know now. So we will introduce a few terms in this section that are anachronistic, and we'll wait to explain them in depth until the section on cellular biology.

The genius of Mendel is how he used mathematics to show how inheritance worked.



Courtesy of the Mendelianum, Moravian Museum, Brno.
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Figure 2.5.22 - *Mendel counted peas*

Dominance and Recessiveness

Remember that Gregor Mendel (1822-1884) didn't know about DNA when he did his experiments, he didn't see meiosis in the microscope, he wasn't directly involved in the debates over evolution, but he found one of the sources of variation that Darwin's theory of natural selection relies on, and he discovered two important principles that are the foundation of genetics: The Principle of Segregation and The Principle of Independent Assortment. Darwin knew that variation was crucial to his theory, but he didn't know the source of variation.

The pea plant has variation. Some seeds are smooth, some wrinkled; some yellow, some green. Some pods are inflated, some constricted; some green, some yellow. Some flowers are purple, some white; some along the stem, some at the top. Some stems are tall, some are short. Mendel was careful to exclude other kinds of variation: how some plants are eaten by snails, some don't get enough water, some too much sun, some are cooked in soup, some peas are overcooked, some shot through straws. Mendel ignored all these things that happen to peas and only paid attention to this first set of variations, the either/or inherent characteristics that can be seen.

Mendel was rediscovered around 1900. Theories of inheritance at the time of Mendel focused on blending, for example, one parent with extremely dark skin and one parent with extremely light skin have a child who is neither very light, nor very dark, but a color that is in between the extremes. But when Mendel bred purple flowers with white flowers, he got only purple flowers, and then when he bred those purple flowers together, in the next generation he got mostly purple but some white ones. The white flower trait disappeared and then came back. The purple color dominated the white one, but the recessive white color was not gone for ever, it came back in a later generation. If you cross a purple flower with a white flower, Darwin would have expected a whitish-purple flower. What happened to the blending?

If you don't remember from your high-school biology class, here are some basics that we got from Mendel:

- Children resemble their parents.
- Genes come in pairs.
- Genes don't blend.
- Some genes are dominant.

The Principle of Segregation

Good science can come from unlikely sources. Mendel would momentarily escape from the duties of a monk in a cold monastery.

> *Mendel frequently took sanctuary in the little two-room building nestled into a corner of the monastery courtyard right up against the brewery next door. It gave him not only blessed warmth but also the space to engage in his scientific pursuits -- which would, he believed, prove important enough in time to earn him a place in the annals of horticulture. He had filled the glasshouse's long tables with pots of pea plants, each carefully labeled as to seed source and variety. His immediate goal was to breed these peas, thirty-four different seed types in all, after allowing them to self-fertilize for two full years. In the speeded-up growing seasons of the glasshouse, two years of growing meant perhaps six full generations -- enough to assure Mendel that the seeds were indeed what they appeared to be. [Marantz Henig 2000:14]*

Mendel isolated and bred different pea plants together and observed the characteristics of their offspring, and what really amazes me is that he counted them--and looking at the numbers he noticed patterns, and used simple math to work out the ratios of different traits.

First, he crossed true breeding plants (P) to get heterozygous plants, called hybrids (F_1), and then he crossed those hybrids with each other (F_1 x F_1 = F_2) and counted:

> *Expt 1: Form of seed. — From 253 hybrids 7,324 seeds were obtained in the second trial year. Among them were 5,474 round or roundish ones and 1,850 angular wrinkled ones. Therefrom the ratio 2.96:1 is deduced.*
>
> *Expt 2: Color of albumen. — 258 plants yielded 8,023 seeds, 6,022 yellow, and 2,001 green; their ratio, therefore, is as 3.01:1.*
>
> *[...]*
>
> *Expt. 3: Color of the seed–coats. — Among 929 plants, 705 bore violet–red flowers and gray–brown seed–coats; 224 had white flowers and white seed–coats, giving the proportion 3.15:1.*
>
> *Expt. 4: Form of pods. — Of 1,181 plants, 882 had them simply inflated, and in 299 they were constricted. Resulting ratio, 2.95:1.*

> *[...]*
>
> *Expt. 5: Color of the unripe pods. — The number of trial plants was 580, of which 428 had green pods and 152 yellow ones. Consequently these stand in the ratio of 2.82:1.*
>
> *Expt. 6: Position of flowers. — Among 858 cases 651 had inflorescences axial and 207 terminal. Ratio, 3.14:1.*
>
> *Expt. 7: Length of stem. — Out of 1,064 plants, in 787 cases the stem was long, and in 277 short. Hence a mutual ratio of 2.84:1. In this experiment the dwarfed plants were carefully lifted and transferred to a special bed. This precaution was necessary, as otherwise they would have perished through being overgrown by their tall relatives. Even in their quite young state they can be easily picked out by their compact growth and thick dark–green foliage. [Mendel 1865]*

Notice that the ratios of the F_2 generation work out to about 3:1 which means that three plants have the dominant phenotype for every one plant that has the recessive phenotype. Mendel showed that each trait (seed color, seed shape, pod shape, pod color, flower color, flower position, stem length) is determined by a pair of characters, and they get them from their parents, one from the pollen cell and one from the egg cell, which come together to form the embryo. When the pollen and egg cells are made, these two characters are "segregated" so each egg and pollen cell has only one character. In genetics we now call these traits, *genes*, and the pair of characters is called a pair of *alleles*. From cellular biology, we now know that the segregation of alleles during the production of eggs and sperm is called *meiosis*. We'll come back to this in the sections on genetics and cellular biology.

The Principle of Independent Assortment

If you take true breeding plants with two different traits, like form of seed and color of seed-coat, cross them together, you first get all of the dominant trait. Then if you cross those new versions again, you get some interesting numbers 9:3:3:1 The numbers reveal that there's no connection between the traits; the traits are independently assorted. We can now explain this with cellular biology because the two traits are on different chromosomes.

Punnett squares

A Punnett square is a grid or matrix that represents the outcomes of different combinations. They are often presented as proofs of Mendel's Principle of Segregation and Principle of Independent Assortment, but Punnett squares came after Mendel, and I think it's important to understand the steps Mendel went through in his research: empirical observations of pea plant variations, breeding true-breeding plants, crossing specific traits, getting weird results, counting them, working out simple ratios, explaining the ratios as biological Principles as to how the peas (and all life, including humans) reproduce and transmit the information using traits from parent to offspring. Punnett squares are graphic representations of sexual reproduction: all the possible sperm are one axis, all the possible eggs on the other, and in the middle are all the possible combinations of fertilization – the individual zygotes (fertilized egg) who develop into fetuses, babies, and then adults. About a hundred years after Mendel's experiment we got to look in a microscope to confirm Mendel's mathematics and we continue to explore Mendelian traits in humans.

Exercise 2.5.1

Read: "MENDELIAN LAWS APPLY TO HUMAN BEINGS"

Here is an example using Tay-Sachs disease. The * HEXA gene on chromosome 15 makes part of an enzyme that is important for maintaining your central nervous system. If you have one or two normal alleles, you're OK, but if both your alleles have a Tay-Sachs mutation, then you'll have different neurological problems usually starting as an infant. If you are a genetic counselor and a couple comes to you planning to have kids, and they are both carriers (heterozygotes), you want to be able to tell them what is the chance their baby will have Tay-Sachs. If we assign symbols to alleles, "t" = a Tay-Sachs mutation, and "T" = normal HEXA allele, then we can diagram the possible outcomes of fertilization.

	T	t
T	TT	Tt
t	Tt	tt

Statistically, 25% of their children will be normal (TT), 50% of their children will be carriers (Tt), and 25% of their children will be born with Tay-Sachs (tt). This principle works with most recessive diseases.

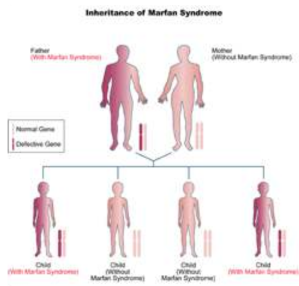


Figure 2.5.23

Mendelian Traits Laboratory

Your phenotype results from the interaction of your genotype and the environment. Most traits are polygenic, meaning several genes contribute to how they are expressed. Even though your genes guide your development, the environment where you grow up influences how those genes are expressed. The combination of polygenic and environmental influence leads to an amazing variety of individuals. However, humans have a small number traits that are readily observable because they are: 1) Mendelian (determined by a single gene) so their expression is on/off, 2) tend not to be effected by the environment, 3) have high enough allele frequencies that someone in the class probably expresses them, and 4) are visible without genetic testing.

For each of the traits described below, your assignment is to: 1) record your phenotype, 2) assign letters to represent the alleles of the gene, and 3) list your possible genotypes. Your phenotype is best described in a complete sentence: "I can ____.", "I cannot ___."; "I have ____.", "I don't have ____." Include only the trait that you express. Mendelian genetics assigns letters or combinations of letters to represent alleles. For two-allele genes, often a single letter is used, the capital letter for the dominant allele and the lowercase letter for the recessive allele. For a two-allele gene, you can have three possible genotypes: heterozygous, homozygous dominant, and homozygous recessive. Depending on your phenotype, you may have more than one possible genotype that leads to the phenotype that you observed. [text adapted from Mendelian Traits Laboratory; missing source]

Example 2.5.1: PTC tasting

PTC, or phenylthiocarbamide, is a human-made chemical. While the majority of people find PTC to have a bitter taste, many find this substance tasteless. To discover your phenotype, chew a strip of filter paper that has been soaked in a concentrated solution of PTC. The ability to taste PTC is inherited as a dominant. There are some studies that compare tasting PTC to tasting broccoli. There are several genes and environmental influence involved but "PTC tasting is largely determined by a single gene, TAS2R8, with two common alleles, and the allele for tasting is mostly dominant over the allele for non-tasting" (McDonald 2012).

You would write:

> *PTC Tasting*
>
> *My phenotype:* Broccoli tastes bitter to me, and I can taste PTC.
>
> *Alleles:* B= the allele that codes for tasting PTC; b= the allele that codes for not tasting PTC

My possible genotypes: BB or Bb

or depending on your phenotype you might write:

PTC Tasting

My phenotype: Broccoli tastes good to me, and I can't taste PTC.

Alleles: B= the allele that codes for tasting PTC; b= the allele that codes for not tasting PTC

My possible genotypes: bb only

Earwax

Earwax, or cerumen, occurs in two basic forms. The dry form is gray and brittle while the wet form is brown and sticky. The dry form is inherited as a recessive. The gene is located on *chromosome 16

Figure 2.5.24 - *"Mimikaki -- Japanese Ear Picks" © 2014 Dr. Timothy C. Hain*

Figure 2.5.25 - "Cotton swab" by Aney. (CC BY-SA 3.0)

Mid-Phalanx Hair

Look at the middle segment (phalanx) of your fingers. Note the presence or absence of hair. Complete absence of hair reflects a homozygous recessive genotype. Note that some types of work may wear the hair away.

Lactase Persistence

The ability to digest milk as an adult is a dominant trait. This is good example of biocultural evolution: a biological trait intertwined with cultural factors (how people produce food).

* more info at Wikipedia

Relative Finger Length

Lay your right hand on a piece of lined paper with the fingers perpendicular to the lines. Note the relative lengths of the second (index) and fourth (ring) fingers. There are three possible situations: the second finger is longer than the fourth, the second finger is shorter than the fourth, or the second finger is the same length as the fourth.

Individuals who are homozygous for the allele for short index finger have a shorter index finger. Individuals who are homozygous for the allele for long index fingers have longer index finger. Individuals whose index and ring fingers are equal length are heterozygous. However, this is not a true Mendelian trait because the expressions of the two alleles in the heterozygous individual show that this trait is influenced by at least one other gene on the 23rd chromosome. Heterozygous males express an index finger that is equal to or shorter than the ring finger. But heterozygous females will have an index finger that is equal or longer than the ring finger.

Exercise 2.5.2: IS YOUR RING FINGER LONGER THAN YOUR INDEX FINGER?

Figure* 2.5.26*5 -"Index finger longer than ring finger" by Arnie Schoenberg, adapted from "Gaye Holud and Mehendi" by Russell eee from Wikimedia Commons (CC BY-SA 4.0)

If so, you're up to three times more likely to develop arthritis of the knee than women whose ring fingers are the same length as or shorter than their pointers. The British scientists who discovered the link speculate that it may have to do with hormones. This finger pattern is more common in women with low estrogen levels. Another clue: Men are more likely to have longer ring fingers, but for them, there's less of an arthritis link. [*Good Housekeeping* 2008:37]

* Article on cave art and relative finger length

ABO Blood type

Read Dennis O'Neil on Human Blood

Remember not to confuse the ABO blood type, a gene located on the ninth chromosome, with the Rhesus factor (Rh^+, Rh^-) a gene located on the first chromosome.

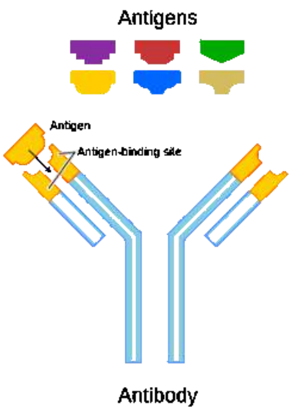


Figure* 2.5.27 *public domain

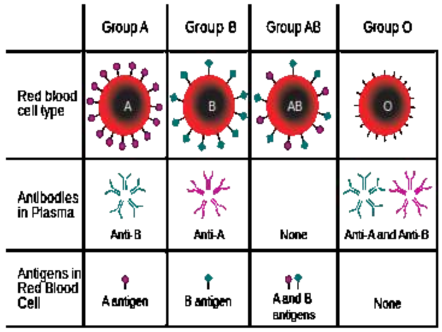


***Figure** 2.5.28* - *en.Wikipedia.org/wiki/ABO_blood_group_system*

Try to shift your thinking from Dominant means good/strong/prevalent, and Recessive means bad/weak/rare. Recessive just means it takes two alleles to expressive the trait. Dominant means you can have 2, or just 1 allele to express the trait. Don't conflate dominance with fitness. Dominance has to do with Mendel and inheritance, fitness is from Darwin's theory of natural selection.

Exercise 2.5.3

Review Dennis O'Neil's Mendelian Genetics

*Skim Mendel, Gregor. 1865. "Experiments in Plant Hybridization"

*Play around with the Online Mendelian Inheritance in Man database. Try typing in the name of a disease, or body part into the search engine, and follow the link.

Population Genetics

By the 1920s, a new definition of evolution became popular: "a change in allele frequency". We're looking at how many people have a trait in one generation and how it might change in the next generation.

To translate a Punnett square into math, just replace the sperm and eggs with variables that represent allele frequencies, and you get a pretty simple algebraic equation, that can be used to study how populations change over time. It was discovered independently in 1908 by two scientists: Hardy and Weinberg.

	p	q
p	pp	pq
q	pq	qq

A frequency is just another word for a percentage except we write it as a decimal e.g. p = .5 is the same thing as saying 50% are *p*, or that half the alleles are *p*. This implies that the other half are q, because with a two-allele gene, the percentages have to add up to 100% (the frequencies add up to 1.00), so

$$p+q=1 \tag{2.5.1}$$

we can square both sides to get:

$$(p+q)^2=p^2+2pq+q^2=1 \tag{2.5.2}$$

Now compare this to the Punnett square: *pp* is p^2, *qq* is q^2, and the two *pq* are 2*pq*. The p^2 and q^2represents the frequencies of the homozygotes and *2pq* represents the frequency of the heterozygote. So you can take a population, count the total alleles, and count the phenotypes of the individuals and compare them to see if anything looks weird. Mathematically, you expect the numbers to work out, and when they don't, you know some kind of evolution is occurring.

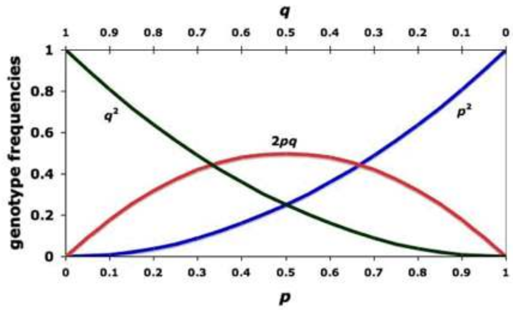


Figure 2.5.29 - *How the allele frequencies are supposed to work without evolution; the null hypothesis*

Exercise 2.5.4

Read the Dennis O'Neil Intro to the Hardy-Weinberg Equation.

*and here is a longer introduction to Population Genetics, if the math freaks you out, just skim to later sections.

The Modern Evolutionary Synthesis

By the 1920s, evolutionary theory had synthesized the macroevolution of Darwin, with the microevolution of Mendel and population genetics, and came up a short list of factors that cause evolution. They tested populations with the Hardy-Weinberg equation, and when they failed to get a null hypothesis, they started trying to figure out which of the four forces of evolution caused the change in allele frequency: mutation, natural selection, genetic drift, and migration. The theories have been refined in the last hundred years, the four forces of evolution is still a useful way to think of evolution.

Vocabulary

- antibodies
- antigens
- codominant
- dominant
- fixity of species
- Great Chain of Being
- Hardy-Weinberg Equation
- macroevolution
- microevolution
- population
- the Principle of Independent Assortment
- the Principle of Segregation
- Punnett Square
- recessive

2.6: "Forces" of Evolution

One of the elegant things about evolutionary theory is it can describe phenomena on both the small scale and the large scale. We can use these same forces to explain microevolution – the change of an allele frequency of a population of the same species from one generation to the next; and we can use them to explain macroevolution – the change of one species into another species over long periods of time. This is similar to the way the theory of gravity can be used to describe the motion of molecular particles or large galaxies.

We use the word "force" to refer to a process that drives change, but thinking about evolution as a set of forces can be dangerous because it's easy to fall into the trap of thinking of evolution as a directional agent, pushing organisms towards an ultimate goal.

Mutation

Mutation is the prime mover, the creator of all new alleles. We'll learn more about how mutations happen in the section on cellular biology.

Exercise \(\PageIndex{1}\)

Review the last section on Darwin.

Read Dennis O'Neil's description of Natural Selection with an Emphasis on Population Genetics.

Note

- Article on carcinogenic traditional medicine, notice the kinds of mutations this plant causes

Migration

Migration (also called "gene flow") is where someone physically moves alleles from one population to another. When people move from one population to another they pack all 23 pairs of chromosomes inside the nuclei of their cells, and bring it all with them. If this changes the allele frequency of either population then it is by definition a kind of evolution. It can bring new alleles to a population that hadn't had that mutation recently, or just bring or remove a significant quantity of a certain allele to change the frequency of either population.

The individual doesn't actually have to migrate to the new population, they can just leave or pick up a few alleles. The stereotype that sailors have kids in every port, is probably better represented by today by the traveling businessman, soldier on leave, sexual tourist, or the sex trafficked. Migration is the geographic movement of alleles from one population to another. We'll come back to migration in future sections as an important point in understanding human origins and human variation. It is why there is only one species of hominid on the planet today.

Note

Article on coywolves and other hybrids which can be understood as a kind of gene flow and loosening of the species concept.

Genetic Drift

Random genetic drift, or genetic drift, is about statistics. The "drift" part has nothing to do with geographical movement (that would be migration/gene flow), what drifts is the allele frequency, like when you look at a graph of a complex system changing over time, and from a distance it looks like a straight line, but as you zoom in, the line becomes jagged, jumping up and down; the smaller your field of view, the more drastic the changes become.

A good way to understand genetic drift is to plan two trips to Viejas Casino, the first with $1,000,000,000 and the second with $100. Sit down at the cheapest table or slot machine you can find and start playing. For your first trip, your money will go up a little ($1,000,000,135) and down a little (down a little more because the House sets the odds $999,999,564) but after a few hours, you'll get bored and go home with around $1,000,000,000. Ok now go back with $100, your money will go up a little ($135) and down a little ($64), then up a little ($68), then down a little ($24) then up a little ($26) then down a little ($4) then up a little ($6) then down... whoops! no more money ($0), time to go home broke. The analogy here has to do with population size and alleles. Every generation alleles are shuffled and with a huge population statistically the allele frequency will stay pretty much the same, but with a small population, the random fluctuations are more drastic, and allele frequencies can drop to zero. If an allele frequency drops to zero, the game's over, and it's gone from the gene pool.

Here's a statistics exercise called the *Gambler's Fallacy* that also shows the difference between flipping a few coins and flipping a thousand coins.

A bottleneck is where the population shrinks to the point where lots of alleles drop out like this. The founder's effect is where a small group of people move to a new area and start a new population. The new population may grow quickly, but even though the number of people grows, if there is no other force of evolution, the allele frequencies of the new population is determined by the small number of founders who might happen to not represent the population they left. There's no way a small number of people can represent the diversity of a large population. In statistics this is known as sampling error. When comparing the old and new population, they have different allele frequencies, so by definition, evolution has occurred, and we attribute this kind of evolution to genetic drift.

Exercise \(\PageIndex{2}\)

- Read Dennis O'Neil's Small Population Size Effects
- Read Stanford's Encyclopedia of Philosophy: Random Drift

The "drift" in genetic drift comes from statistics, called *stochastic drift*. *Stochastic* just means "random", so stochastic drift is a fancy way to say that random stuff tends to happen with a small sample size.

Vocabulary For 2.3

- founder's effect
- gene flow
- genetic drift
- migration
- mutation
- stochastic drift

2.7: Genetics, Cellular Biology, and Variation (Part 1)

By the middle of the 20th century, microscopes were good enough to actually see the "characters" that Mendel discovered, and by the end of the turn of this century, an outline of the human genome was completed, and now new alleles are discovered daily, and some even intentionally created.

We could easily do a whole class on this section, but you should focus on trying to understand the mechanisms of human variation, which we'll be dealing with for the rest of the class. What is the cause of human variation? How does it happen at the cellular level? Darwin knew that variation was essential for the functioning of natural selection, but he had no clue how it worked. Mendel's research in heredity suggested principles of simple variation, but failed to explain 90% of what you see in life. In order to understand where most of variation comes from you need a microscope, and understand basic cellular biology and genetics.

I find it helpful to get an overview of the scale of human variation. How big is the thing we're talking about? Go back and watch the 10 minute Powers of Ten movie, and focus on the cellular section.

Even the pictures can get confusing until you get a sense of how everything fits together. The same chromosomes can look different at different stages. During protein synthesis it's hanging loose, and during cell division it's all wound up like a dreadlock. Here's another graphic that goes from small to big and mentions a few stages:

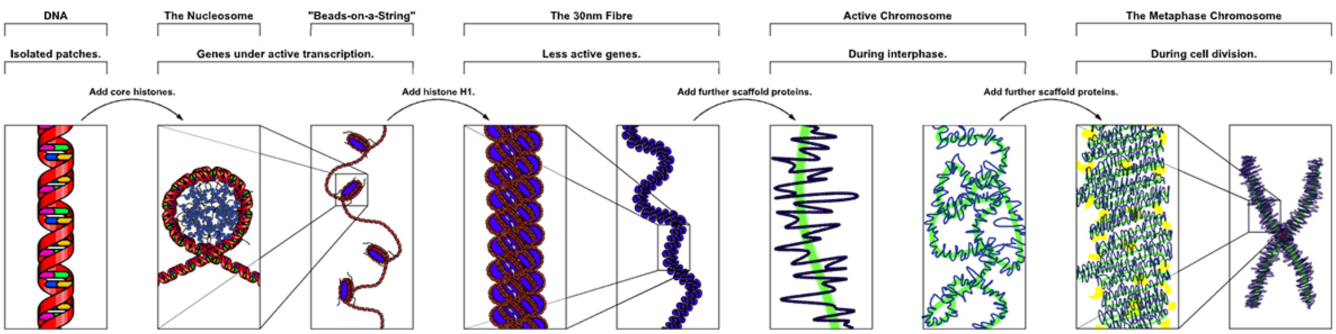


Figure 2.7.2 - *Chromosomes are made of DNA.* Chromatin Structures By Richard Wheeler via Wikipedia (CC-BY-SA-3.0)

Cell size can vary drastically, but ova are big and sperm are small

A pair of sister chromatids and centromere and a pair of homologous chromosomes are about the same size; you get two chromatids because of DNA replication in preparation for cell division; you get two homologous chromosomes because of fertilization, one from Dad, and one from Mom.

All cells arise from pre-existing cells.

Cells

You are made up of about a trillion cells. Each cell has organelles inside them. A very important organelle is the nucleus. Inside the nucleus are your chromosomes. Your chromosomes direct protein synthesis, which determine how the cells interact with each other, and how you as an individual function.

Organelles

The ribosomes manufacture proteins. The mitochondria convert and store energy so the cell can use it. There are many others, but these are the most important to understanding human variation.

Nucleus

The nucleus contains the DNA, and is metaphorically like the brain of the cell.

Chromosomes

There are 23 pairs of chromosomes inside the nucleus of most human cells for most of the time. You have a pair, because as Mendel discovered, you get one from your dad and one from your mom. There are two kinds of chromosomes, autosomes and sex chromosomes. The 22 pairs of autosomes are named for *auto* which means "self"; they're the chromosomes that stay with yourself. They are numbered from biggest to smallest. The last pair, the sex chromosomes, are named because they tend to determine the sex of an individual. The number of chromosomes doesn't make much difference. For an analogy, think of hard drive that can be formatted into different sectors.

A genome is an entire set of genes.

Different species have different number of chromosomes. Humans have 23 pairs, other apes have 24 pairs, hermit crabs have 127 pairs. Compare humans to a table of different species according to their number of chromosomes

Mitochondria

Mitochondria are the power plants of the cell, and they have their own separate DNA. The history of how mitochondria came to be is fascinating. We think they used to be independent living creatures swimming around, until 2 billion years ago, an ancestor of eukaryotic cells swallowed one, but instead of digesting it, that mitochondrion survived and began a symbiotic relationship with the host cell, reproducing inside the host's cytoplasm and being passed on to the next generation as the cell divided.

mtDNA

Mitochondrial DNA (mtDNA) can be used for genealogy and for dating the migrations of pre-historic populations.

Mitochondria are like cells within cells. Because, our cell's DNA is in the nucleus, and the mitochondrion in the cytoplasm, the mitochondrial DNA (mtDNA) was separated from the nuclear DNA of the host cell during reproduction. When sexual reproduction began, the eggs were bigger and they were almost always the source of mitochondria for the zygote. This means that you get your mtDNA from your mom, and it is inherited through matrilineal descent. Your mtDNA come:

from your great-great-great-great-great-great grandmother,

to your great-great-great-great-great grandmother,

to your great-great-great-great grandmother,

to your great-great-great grandmøther,

to your great-great grandmøther,

to your great grandmøther,

to your grandmøther,

to your møther,

to yøu.

And because of matrilineal descent, if your great-great-great grandmother had a mutation (o→ø) in the mtDNA of an egg, that mutation would be passed down to all of the descendants of that egg, and you would share the mutation with your mom, and your siblings, all those aunts and uncles, and fourth cousins on your great-great-great grandmother's side. The mutations in mtDNA accumulate and become markers to show ancestry, as well as demonstrate the evolutionary forces of migration and genetic drift. Because mitochondria are so simple, they have almost no functional variation – they either work or they don't – and without variation, natural selection doesn't happen. When you control for natural selection, the rate of neutral mutations of mtDNA becomes like a constant (one or two mutations every half-a-dozen millennia), and you can count how many different mutations two individuals have, and approximate how many generations ago they had a common ancestor. And by comparing large samples of indigenous populations, you can approximate where the mutation took place. We can correlate the genetic "when" and "where" with archaeological and historical data to test fascinating hypotheses of how humans moved across the globe.

Notes

National Geographic's Genographic Project

Skim Wikipedia: Mitochondria

Mitochondrial diseases

Cell Division

Explore Sex cells have one set of chromosomes; body cells have two.

Mitosis

Mitosis is the production of body cells for growth and healing. In mitosis, cells copy their chromosome and copy themselves, so that each daughter cell has the same number of chromosomes as the parent cell. Variations in the body cells can continue to be copied through mitosis (*e.g.* cancer), but the variations will not be passed down to the next generation.

Watch an 8 second Mitosis Movie (Try manually moving the cursor to see it slowly)

Meiosis

Meiosis is the production of gametes for sexual reproduction. In meiosis, cells copy themselves twice, but only copy their chromosomes once, so each of the viable daughter cells ends up with half the number of chromosomes as the parent cell. Individuals get the full number of chromosomes when two gametes combine during fertilization. Variations in gametes will be passed on the next generation. This is why when you get an x-ray, they put a lead blanket over your gametes – to block the radiation, and decrease birth defects.

Watch a quick Meiosis Movie

Oogenesis

Oogenesis makes ova or eggs.

Spermatogenesis

Spermatogenesis makes sperm.

Recombination

Meiosis is important because it increases variation by recombining your parents' genetic information.

Your genetic information comes in a small number of little packets, called chromosomes, and they were passed down from grandparent to parent to child. They come in pairs. One from one parent, one from the other. Meiosis splits the pairs, and shuffles them randomly so for example you might get one of your 3rd chromosomes from your paternal grandmother and one of your 4th chromosomes from your maternal grandfather.

My genome approximates my ancestry. If you know what to look for you can see which chromosomes came from my Mom and which from my Dad. My maternal grandparents were mostly descended from Britain and Ireland, and show up as light and dark blue on this chart. My paternal grandparents were mostly descended from Ashkenazim and show up as dark green. So for the first chromosome pair, the top one came from Dad and the bottom one from Mom. For chromosome pair 22, the top one is from Mom and the bottom one from Dad. For the sex chromosomes I got the Y from my Dad, and the single X from my Mom.

If I had my grandparents DNA, I could figure out whether the X chromosome that I got from my Mom, came from my maternal grandmother or my maternal grandfather. I definitely know that my Y chromosome came from my paternal grandfather. Each of my 46 chromosomes came from some great, great, great, ... grand-parent up in my family tree.

Crossing Over

Notice that that most of the chromosomes above aren't solid colors. The interspersed segments come from *crossing over*. During meiosis the homologous chromosomes are brought very close to each other. Because they are the same chromosome and have the same genes, pieces of one chromosome can "cross-over" to the one next to it.

Recombination includes the shuffling of chromosomes that you're getting from each parent, and a specific kind of recombination, called *crossing over*, where the chromosomes themselves can change, and genes can cross over from one grandparent's chromosome to another's. The discrete packages of chromosomes don't stay the same every generation, they open up and traits move from one to another.

Non-disjunction

While meiosis sorts and delivers the packets of genetic information we call chromosomes, one part of the process where variation can occur is that meiosis can deliver an **extra** packet, and we call this *non-disjunction*.

During meiosis the homologous chromosomes are brought together, and then pulled apart, but sometimes they aren't pulled apart hard enough and they stick to each other, and both chromosomes are pulled into one gamete, and the other gamete gets none. This is called non-disjunction; the junction between homologous chromosomes that is usually broken during meiosis is not. Having the wrong number of chromosomes is usually lethal, and the fertilized egg just doesn't reproduce, and you just don't get pregnant that month. Many people survive and do fine with more or fewer than 46 chromosomes. Chromosomes are numbered by size, so non-disjunction with higher numbered chromosomes tends to be less lethal. Down syndrome is also called Trisomy 21, having three of the somatic chromosome number 21.

Note

- Read the Down Syndrome Association of San Diego, Down Syndrome Facts
- New treatments for people with Down syndrome

2.8: Genetics, Cellular Biology, and Variation (Part 2)

DNA

Deoxyribonucleic Acid is the chemical name for DNA we use to talk about its chemical structure. It comes in packages, called chromosomes which we can see in the microscope when it's all natted up as big dreadlocks inside the cell nucleus, when the cell is about to divide. Try not to confuse the doubling-thing in DNA and chromosomes because there are four very different kinds of doubling that happen at different times and scales, listed here from big to small:

1. First, the biggest scale of doubling is the pairing up of duplicated homologous chromosomes at the beginning of meiosis (metaphase I), but this doesn't last long. Karyotype pictures are often taken during this phase, so you see what looks like four chromosomes for each of the 23.
2. Second, for most of cell's life it has two of each of the 23 chromosomes, in what are called homologous pairs. The pair comes from fertilization, you get one from your mom and one from your dad; this is what Mendel was studying. Another pairing at this same scale is the duplicated sister chromatids after replication, and before the beginning of meiosis mentioned above.
3. Third, if you compare the upper and lower part of each of the 23 in a karyotype, you see the sister chromatids are joined in the center by a centromere, and the upper and lower parts of each side are called *arms*. The centromere is never exactly in the middle, so every chromosome has a shorter arm, p (for *petit*), and the longer arm, q. So, the X chromosome was named because after replication it has two sister chromatids joined in the middle by a centromere, and it looks like an "X", a dot with four arms.
4. Fourth, the smallest scale of doubling is at the structural level: the complementary strands of DNA wound together in a double helix. So if you have an A on one side, you have a T on the other; if you have a G on one side, you have a C on the other. These complementary strands are like the two sides of a zipper that come apart for protein synthesis and replication.

Replication

DNA likes to make copies of itself.

Protein Synthesis

There are two main stages in protein synthesis: transcription and translation. It starts in the nucleus with transcription, where enzymes take the message from the DNA and transcribes it into messenger RNA (mRNA). The mRNA takes the message out of the nucleus into the cytoplasm to the ribosome.

Translation occurs when the ribosome reads the message and puts the right amino acids in the right order. The ribosome needs help to gather and place the amino acids and uses transfer RNA (tRNA). The tRNA has an amazing property that a combination of three bases (codon) will stick to a particular amino acid, and as the ribosome reads the message from the mRNA it use the tRNA to transfer the correct amino acid in the correct order to make a protein.

After protein synthesis, the protein can leave the cell and do whatever it needs to do to keep the individual alive.

Check out this groovy example of hippy science from Stanford University in 1971: protein synthesis reenactment (the trip kicks-in at around 3:13)

A gene is a discrete sequence of DNA nucleotides.

Often one gene makes one protein, but not always. The expression of genes is influence by the enivorment. Some proteins require many gene. Some genes produce more than one protein.

Polygenic Traits

Polygenic traits are determined by a combination of many genes. For example, the hemoglobin protein takes 4 genes (6 for fetuses) and we'll look at a tiny change in one of the four genes that causes Sickle Cell anemia.

Pleiotropic Genes

Pleiotropy is where a single gene can effect multiple traits.

Locus > Gene > Allele

The words *locus*, *gene*, and *allele* can be very confusing, especially since people (including myself) get lazy and use them interchangeably, but technically they are distinct and you may as well get in the good habit of using them correctly. *Locus* has the same root as "location", and it refers to a place on a chromosome where a string of bases will fit. If that string of bases codes for a protein (a functional product), then that spot is also a *gene*. But in many cases, there can variations as to what bases fit in that same spot, and each of those possible variations is called a different *allele*, and often codes for different proteins and change the organism. In summary, if a *locus* does something it's a *gene*, all the different versions of the *gene* are *alleles*.

Introns and Exons

One of the ways to increase variation is have genes modify other genes, and there are many stages of protein synthesis where that can happen, one of them being during transcription where parts of the code are cut out.

Notes

- Read S-cool's description of introns and exons.
- The RNA message is sometimes edited.
- Some DNA does not encode proteins.
- Article "Exon Skipping: Borrowing from Nature to Treat Rare Genetic Diseases"

Codons

DNA words are three letters long.

Cells and the Source of Variation

The origin of all variation is mutation. Mutations can occur at many different scales. The smallest is the Single Nucleotide Polymorphism (SNP, called a "snip") that changes a single base.

If we think of meiosis as sorting and delivering genetic information to our kids in packets that we call chromosomes, there are many parts of the process where variation can occur, including: 1) meiosis shuffles the packets of informations in recombination as Mendel proved in his Principle of Independent Assortment, 2) meiosis moves traits from packet to packet in crossing over, and 3) meiosis can deliver an extra packet in non-disjunction.

Another possibility is that two different packages can stick together, like the chromosomal shifting that fused the greater ape chromosome 2a and 2b, into *Homo sapiens* chromosome 2. The same genes are there, just on one chromosome instead of two. These big changes are important for macroevolution (speciation), and makes it impossible for humans to reproduce with other apes (apologies to Jerry Springer and the *Weekly World News*).

The use of the word *recombination* can be confusing because most of the recombination that makes you different from your siblings is Mendel's principle of independent assortment, the shuffling of chromosomes, but there is also a type of recombination called *crossing over* that is a very different specific process on a smaller scale where genes jump between homologous chromosomes. Also, recombination is technically not a separate force of evolution, it's an aspect of all of them.

Because this is an introduction we have skipped many other processes that influence variation, such as genes that don't produce proteins directly, but just effect other genes that do. But, most genes make proteins, so lets get the basics down first.

for another review read Dennis O'Neil's description of mutation and recombination

Notes

- Single Nucleotide Polymorphisms (SNiPs)
- Some viruses store genetic information in RNA.
- Genetic disorders

***Figure** 2.8.5 - La Plasmogenia (in Spanish) Alfonso Luis Herrera introduced Darwin to Mexico*

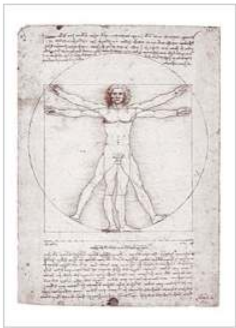


***Figure** 2.8.6 - Leonardo DaVinci notebook*

Imagination Activities

- **Extract your own DNA**

Follow the instructions on this video, and take a selfie with your own DNA.
For each cell, how many membranes does the soap have to break down to release the DNA?

Imagination questions

- **Your tax dollars at work**

The Human Genome Project is federally funded. Do you think it's worth it?

- **Exploration**

Take a few minutes to explore the human genome with MapViewer at the National Center for Biotechnology Information. How is exploring our genome different from exploring unknown jungles, or the bottom of the sea, or outer space?

- **Life**

Is a virus alive? A DNA molecule?

What of humans is mechanistic? Where does free-will exist?

- **The whole is greater than the sum of its parts**

What is a person? A bunch of cells. Each individual is made up of about a trillion cells (1,000,000,000,000). Most of those cells have 46 chromosomes. Each chromosome has about a million and a half base pairs, and the human karyotype has about 3.2 billion base pairs total. The information in the 3,200,000,000 base pairs makes sure the 1,000,000,000,000 cells all work together. 3.2 billion seems like a lot of base pairs, but if you take computer memory as a metaphor it's not that much. If you think of a base pair like something between a bit and a byte, then all the genetic information fits on a 3.2 gigabyte (3.2 GB) thumbdrive. It's like the basic install of a video editing program. Not something you could attach to an email, but it wouldn't take that long to download. So what makes people so complicated, if their code is so small?

- **Multiple identities**

Here's an introduction to chimerism, the idea most of us are conjoined twins to a small extent. Does this change how you think of yourself?

Genetics and Ethics

Remember that the anthropological imagination avoids scientism: putting science on a pedestal protected from all criticism, and valuing science and scientific knowledge above people. Anthropology is the science **of** humans, so there is no way to avoid humanistic questions. The field of genetics has grown in a political context where world economic systems have loosened many ethical guidelines. It's like the wild, wild, west.

Identity and Ownership

If you think the government reading your emails is bad, think of having scientists steal your genetic code without your consent and owning you in your afterlife.

Exercise 2.8.1

- Read an update on Henrietta Lacks' genome
- New HBO movie

One of the great things about Obamacare is that it headed-off a growing problem of insurance companies using genetic information as a way to screen out members with a propensity for expensive medical conditions.

Our reliance on genetics in forensic anthropology (using anthropology for legal, usually police, situations) can lead to problems such as this case which seems straight out of the Jerry Springer show: * Man Fails Paternity Test Because Unborn Twin Is The Biological Father Of His Son

Stem Cells

Stem cells are undifferentiated, that means they divide and grow into many different kinds of cells. When you think of yourself as a trillion cells, once upon a time, you used to be one cell: a tiny, cute, little zygote (what happened!??!!). Stem cells are left over from that transition from one cell to billions of cells. They are great for medicine because if you are missing cells in your body, you tell the stem cells to become them.

The controversy was much worse a decade ago when the major source of stem cells was aborted fetuses, but today, they can be harvested from your own baby teeth, your blood, even from your left over liposuction.

Notes

- Article on stem cell therapy for Crohn's disease
- Article on stem cell therapy for diabetes, protein synthesis is how a cell produces insulin

Cloning

Figure 2.8.7 - *stuffistumbledupon.com*

To me, human cloning is no big deal. We're already dealing with the ethical issues that cloning raises.

Genetically identical humans? It's what we get with identical (monozygotic) twins, when the zygote divides and then separates into two embryos who become two individuals. They may be identical genetically, but variations in how they interact with their environment will make them physically distinct, and most importantly, their different cultural experiences will make them different people.

Exploiting people to harvest their organs? The demand for kidneys has led to transplant tourism and black markets in places like India and the Philippines, and a legal kidney market exists in Iran.The 1% are already playing God and cannibalizing the bodies of the 99%.

(Full disclosure: my tolerance for cloning may be biased because I am currently raising several clones of my own of various ages on a secret organic ranch in southern Utah which I plan to use to for parts as I get older. Here's a home video of my favorite "Little Arnie", AS0983-2342, getting in shape for his transplant surgery.)

GMOs

I think recombinant DNA, or genetically modified organisms (GMO) are a bit scarier... Will it kill you to eat them? No! Are they poisonous? No! Should you try avoid them? Yeah, it's probably a good idea to eat as much organic produce as as you can afford.

*Read this article that examines a historic period in agronomy known as the "Green Revolution"and how we might be able to use lessons learned from this technocratic disaster, to avoid potential disaster from the current GMO revolution.

We look at hackers today as some kind noble outlaw, or social bandit, but we need to keep asking ourselves, what are our limits, and how far we are willing to go to hack ourselves and the code that makes us who we are.

***Figure** 2.8.8 - Frank Miller and Geof Darrow 1993. Hard Boiled*

The mad scientist trope in biology has a long history, from the Jewish golems, the alchemists of the Middle Ages, Mary Percy Shelly's *Frankenstein; or, the Modern Prometheus*, or some of my recent favorites, the Larry Fessenden 1991 movie, *The Telling*, and Margaret Atwood's 2003 novel, *Oryx and Crake*. But, another worry with the rapidly expanding technology of genetic modification is the chaos theory idea from *Jurassic Park*, or what I like to call the Homer Simpson effect – shit happens – genes can move around out of our control, and I think this next section is even scarier:

Lateral Gene Transfer

Lateral gene transfer (LGT), also called horizontal gene transfer (HGT), is distinguished from the kind of up-and-down verticalness of heredity that we represent with a family tree. It's important that you understand the classic Standard Evolutionary Theory of Darwin, Mendel, and the Modern Synthesis, because that's how things work 99.999999% percent of the time, but there are rare exceptions. Some evolutionary scientists have advocated including new research into an Extended Evolutionary Synthesis, others say that the old paradigm works fine.

Some consider LGT to be a kind of gene flow, but classic gene flow happens within the same species through migration. LGT is about genes that can be moved from one nucleus to another in ways other than meiosis. Humans have learned to do this intentionally as shown in the previous section, but it can also happen naturally.

I think the scariest thing about all the genetic engineering going on today is the combination of GMOs and LGT. Nature has dealt with LGT for billions of years and you can expect that we've evolved to deal with whatever genes are floating around in the environment. When you create a new gene, you can test how it will influence a certain organism in the laboratory, but when you release the gene into the environment, there is no way to test every possible combination of that gene inserted into every other species. So for example, you make a gene that allows leaf cells to produces their own pesticide and you put it in corn. Fine, the corn is great, no bugs, no need to spray pesticides. But, what happens if that gene moves to bacteria that live in your stomach. Whoops! Now you don't have to bother drinking pesticide, because you're producing it in your stomach already.

On the bright side, LGT does make a great back-story for horror movies.

Notes

- You are what you eat; a good introduction to LGT
- A recent editorial about "GMOs, Herbicides, and Public Health"
- An article on genomic infection.
- Scare tactics: Genetic Roulette movie trailer
- Good rebuttal to Genetic Roulette
- Article on Monsanto suing farmers for saving seeds
- Article on human embryo editing
- Website for the FDA's Cellular, Tissue, and Gene Therapies Advisory Committee
- An article on human babies with a two mothers and a father (a mitochondrial donor) or just two mothers, which the FDA is considering

Imagination Questions

- Designer Babies
  - 1) My niece was screened for chromosomal abnormalities *in utero*, and I've been avoiding asking my sister if she would have gotten an abortion if the fetus tested positive for Down syndrome. Would you abort your child if you found out it was going to be born with a disease? Would you like time to prepare? Would you even want to know?
  - 2) an article on a sperm donor clinic who filters out "the donor matches with an elevated risk of rare recessive paediatric conditions."
- Do you think births should be natural? Do you have limits on how far people should go to provide for the future of their children?

Imagination Actions

GMOs

Using what you've learned, find a recent campaign calling for the labeling of genetically modified foods (e.g. Just Label It), and write a letter to the appropriate policy maker, arguing for, or against, the legislation/action.

Vocabulary

- allele
- autosome
- cell
- centromere
- chromatid
- chromosome
- codon
- crossing-over
- double helix
- gamete
- gene
- individual
- karyotype
- locus
- meiosis
- mitochondria
- mitosis
- nucleotide
- nucleus
- ovum
- population
- somatic cell
- species
- sperm
- zygote

2.9: Summary Example- Holism in Anthropology, Sickle Cell Anemia and Malaria

Exercise 2.9.1

Read the section called "Selection Against Both Homozygotes" from Dennis O'Neil Natural Selection

Anthropology is holistic because it covers many branches of knowledge. To understand sickle cell anemia we need look at the smallest change in a base pair, and at the global migration of alleles. We need to look two thousand years back in time to a transition from hunter-gatherers to horticulturalists, to the racial discrimination of the 20th Century. We apply the knowledge to the most deadly disease on the planet, and to mixology.

Mutation starts the process. In the sperm or egg on the 11^{th} chromosome, at the 17th nucleotide of the gene for the beta chain of hemoglobin, there is a point mutation where an A is replaced by a T, which changes the codon GAG (for glutamic acid) to GTG (which encodes valine). Thus the 6th amino acid in the chain becomes valine instead of glutamic acid. The beautiful architecture of the hemoglobin molecule collapses, as if you took the capstone off of an arch, and the red blood cell takes on a sickle shape. The sickled cells get caught in blood vessels and don't carry oxygen as well.

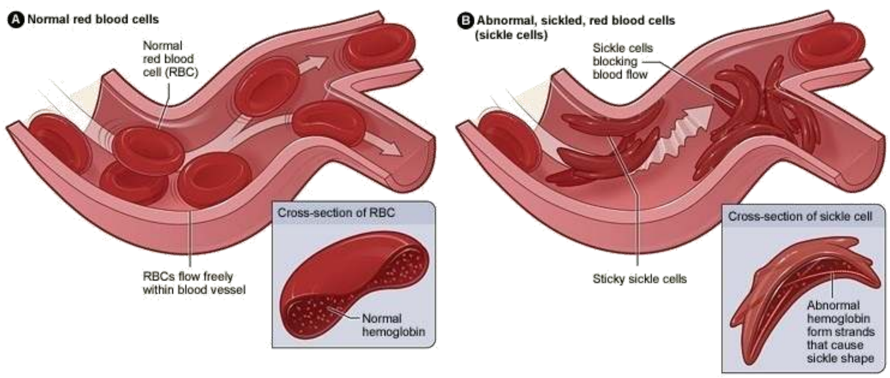


Figure 2.9.1 National Institute of Health Sickle Cell Disease (public domain)

Exercise 2.9.2

Skim the medical literature on sickle cell anemia and click on the location to get a sense of what a gene is

This new allele is called the S allele, and as a Mendelian trait, you get one from each parent.

AA=normal hemoglobin
AS=sickle cell trait, sickle cell carrier
SS=sickle cell anemia

The allele frequency of any Single Nucleotide Polymorphism (SNP) is about 1 in 100,000, so you might expect the allele frequency of the S allele to stay at that rate: S=0.00001 But in some places the frequency of the S allele gets as high as 1 in 5, or S=0.2 When population geneticists see changes in allele frequencies they know that evolution is occurring, and the connection to malaria makes it clear that this is a case of natural selection.

The sickled cells are bad for blood flow and carrying oxygen, but they are good because they protect you from the parasites which cause malaria.

Malaria is an infectious disease caused by the parasite, *Plasmodium falciparum*, and is carried by mosquitoes, and easily spread. One little parasite gets into one of your red blood cells, reproduces 30,000 times, pops the cell, and then go on to infect thousands of other cells, which then go on to infect thousands more, until you are really sick.

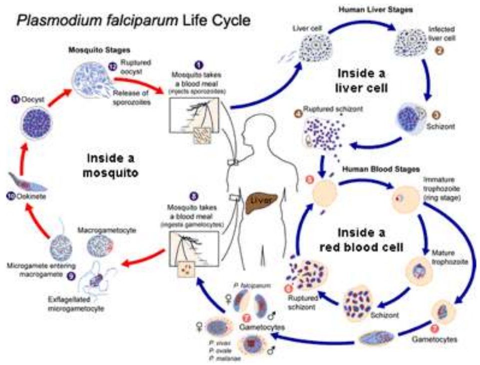


Figure 2.9.3

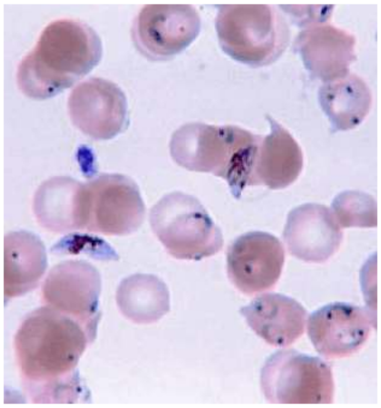


Figure 2.9.4

But, when the parasite infects a sickle-shaped cell, there is less room to reproduce, and it doesn't pop the cell, so it's not spread. Sickle Cell Anemia is bad, but it gives you immunity to Malaria.

Natural selection acts on the mutation to change its allele frequency.

Fetuses produce a special kind of hemoglobin (HbF) that helps pull mom's oxygen across the placenta. Once born, the fetuses normally stop producing HbF, but some adults inherit a gene that tells their body to persist in producing fetal hemoglobin all their lives. The correlation between people with blood diseases like Sickle Cell anemia and hereditary persistence of fetal hemoglobin suggests that natural selection may have selected for the persistence of fetal blood to mitigate the effects of sickle cell anemia. Malaria makes it advantageous to have Sickle Cell, and then Sickle Cell makes it advantageous to have hereditary persistence of fetal hemoglobin.

Sickle Cell Anemia is an example of biocultural evolution because human cultural activity was the cause of people's genetic change. People in West Africa developed a new subsistence practice that produced more food by clearing land and planting crops. But it also created open spaces for mosquitoes to breed, and higher population densities that made it easier for malaria to spread. As malaria became endemic it became more advantageous to have the S allele.

Other cultural factors range from racism to mixology. Because of racism, and the misconception of Sickle-Cell Anemia as a racial disease, the US military initially prohibited African-Americans from flying planes fearing that all African-Americans would suffer sickling events at high altitudes. British Colonialists lacking malaria resistance turned to the bark of a tree from South America called quinine, and they preferred to drink this bitter tonic with gin for good measure. Unfortunately, because of natural selection, most malaria parasites are now resistant to quinine, and drinking gin & tonics in the tropics is more likely to cause dehydration than prevent malaria.

The holistic approach of anthropology allows us to understand sickle cell anemia through a wide range of disciplines including archaeological research on sites in West Africa, the genetics of humans, plasmodium parasites, and mosquitoes, racism in the US, and even mixology.

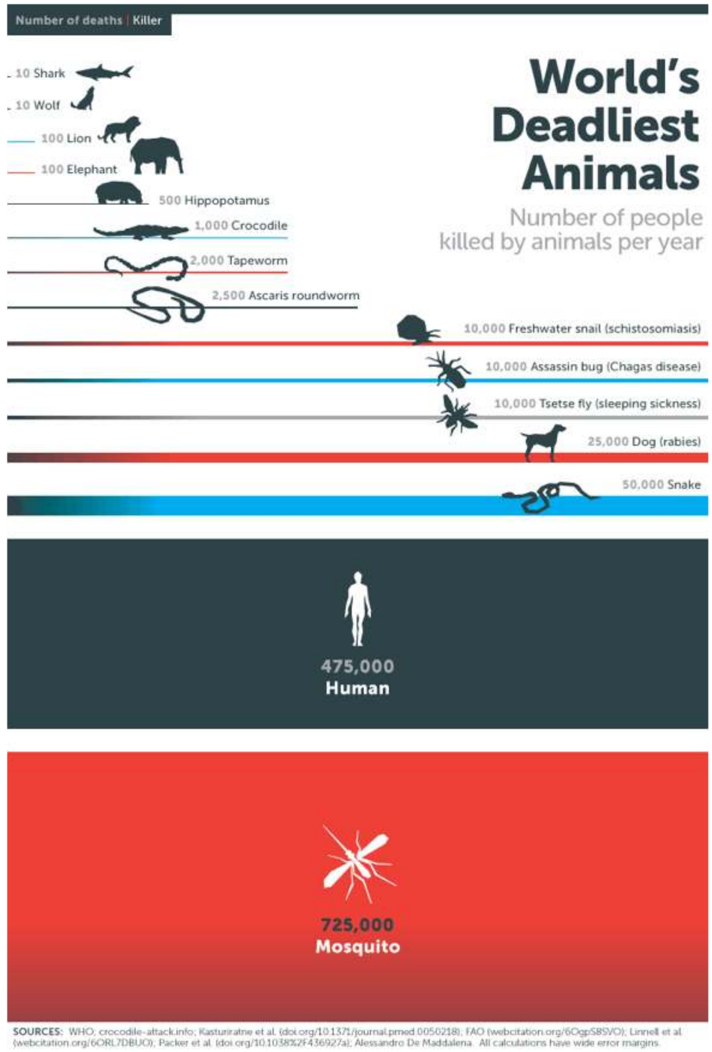


Figure 2.9.5 - *Bill Gates notes* © Copyright The Gates Notes, LLC

Notes

- History of the gin and tonic
- Exploring the use of fetal hemoglobin as a treatment for sickle cell anemia
- A 360º VR 3D video [you need VR goggles] on malaria, and how to prevent it:

Imagination Question

- Now that you understand natural selection, why are pesticides, malaria killing drugs, and a new insect repellent not as good in the long term as a new vaccine for malaria and a campaign to provide mosquito nets?
- What could go wrong with a genetically modified mosquito?

- People with Sickle Cell Trait may suffer during heavy exertion, and have been discriminated against because of their condition, and there is debate in sports and different branches of the US military as to whether to keep their condition confidential to protect them from discrimination, or publicize their condition to * protect them from the health risks.

Imagination Actions

- Read through the Nothing but Nets website, or Against Malaria, and take action to support providing mosquito nets to people from areas with endemic malaria.

Vocabulary

- malaria
- sickle cell anemia
- *Plasmodium falciparum*

3: Osteology

Osteology is the study of bones. Osteology is important to studying human variation, and primatology. Paleoanthropology relies on osteology because most fossils come from bones. Forensic anthropology uses osteology to solve crimes. Like most other physical traits, the bones we see are a consequence of genes and environment. There is nothing particularly profound about bones compared to other biological systems, but their durability makes them special for anthropology because they are the main source of data for paleoanthropologists, important to archaeology, and before DNA testing, they were important to the study of human variation.

We tend to think of bones as dead, dry, and brittle, and when you leave them out in the sun for a few years they do get old. Their hardness comes from a calcium-based crystal structure of hydroxyapatite $(Ca_{10}(PO_4)_6(OH)_2)$, which interconnects like columns of Lego blocks.

In a biology class you tend to think of a bone as a living organ, like your heart or your lungs, but in anthropology we are used to looking at dead bones, outside of the body, when they are just shells of the functions they had when they supported living organisms.

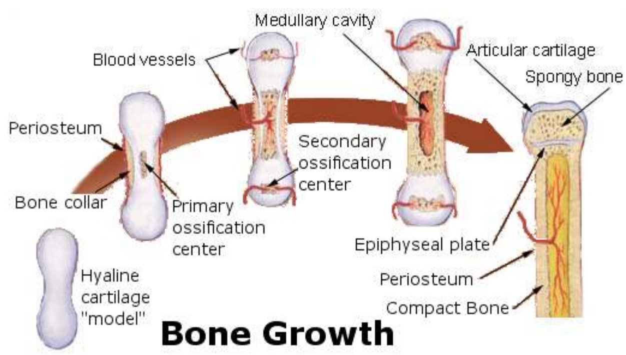


***Figure* 3.2** - *Bone Growth rozwój kos´ci*

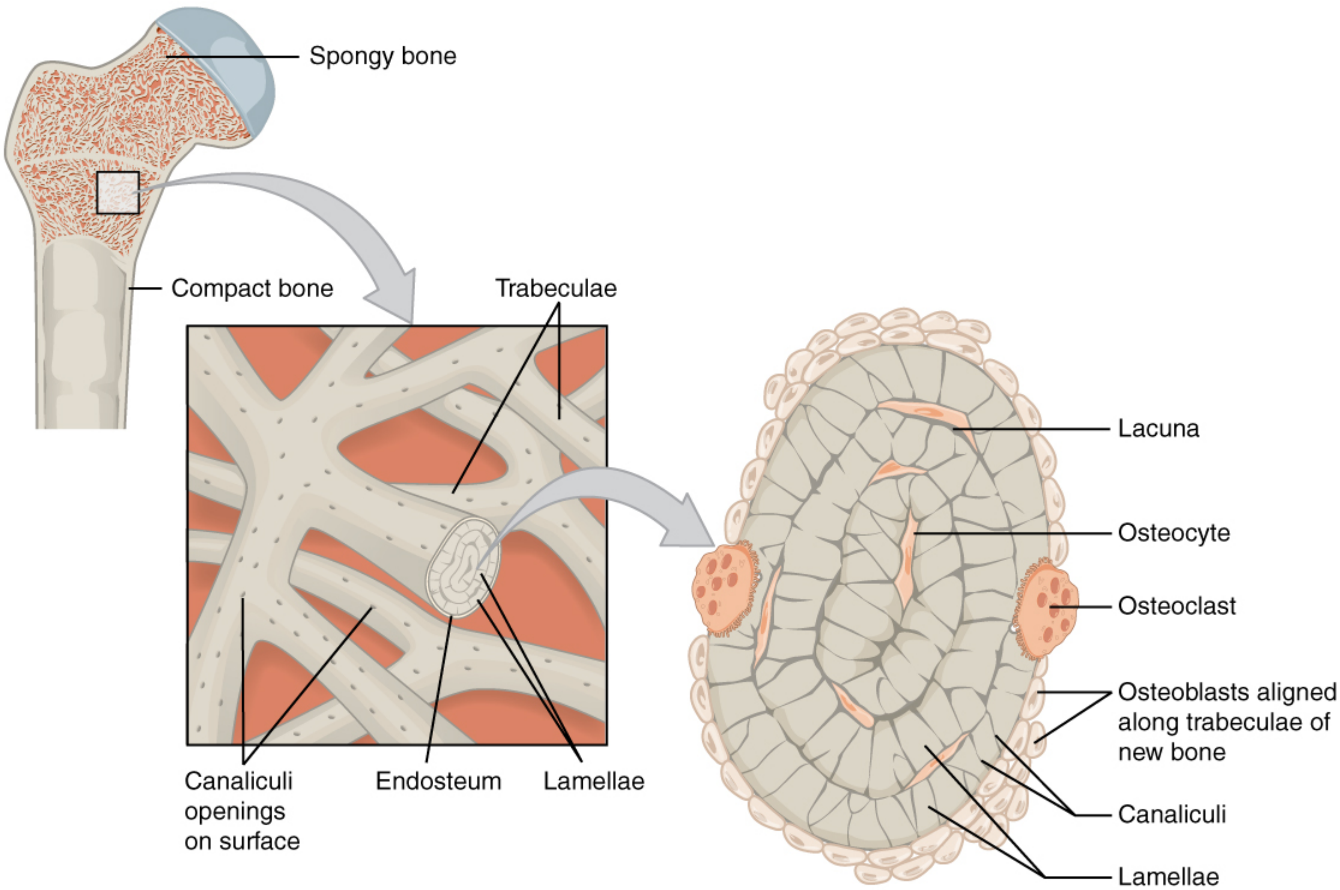


Figure 3.3 - *By OpenStax College - Anatomy & Physiology, Connexions Web site.*

Genetics determines most of what your bones look like, for example, your 23rd chromosomes determine several shapes that are commonly used to say whether someone looks male or female, and when forensic anthropologists use these differences to identify skeletons.

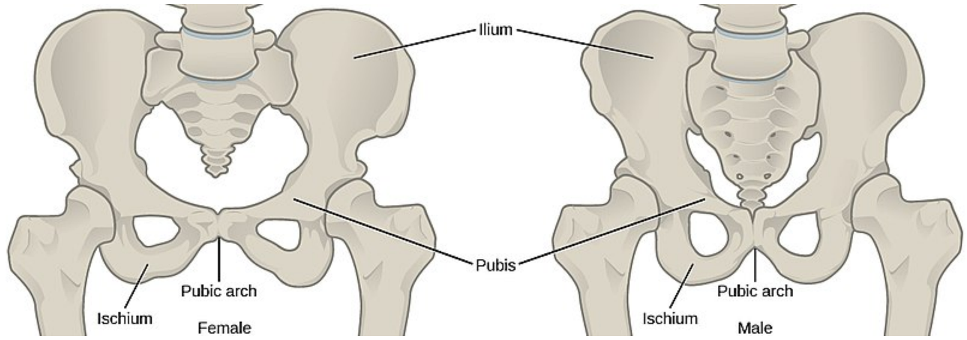


Figure 3.4 - *By CNX OpenStax [CC BY 4.0 (http://creativecommons.org/licenses/by/4.0)], via Wikimedia Commons*

However, like the rest of your body, the environment also effects your physical structures. The muscle attachments on your bones suggest your activities during your life, and stress, i.e. malnutrition, can be read in cross-sections of your teeth like tree rings. It's important that we have a basic shared vocabulary so that we can compare humans to other vertebrates, to evaluate fossils, and to understand several aspects of human variation. Learn the bones of the human skeleton below:

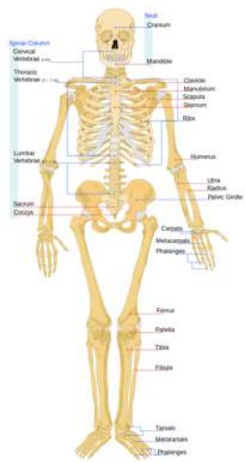


Figure 3.5 - *Mariana Ruiz Villarreal, 2007*

Make sure to learn the scientific name!

Common Name	Scientific Name
skull	cranium
jawbone	mandible
collarbone	clavicle
shoulder blade	scapula
breast bone	sternum
funny bone	humerus
spine	vertebrae
hip(s)	pelvis
wrist	carpals
thigh bone	femur
kneecap	patella
shin bone	tibia
ankle	tarsals

Here's an online practice quiz with more detail then you need for this class, but good to know if you're going on in anything health related.

Exercise 3.1

Skim animal skeletons

Skim Primate Skeletons and More Primate Skeletons

Vocabulary

- carpals
- cervical vertebrae
- clavicle

- coccyx
- cranium
- epiphyseal
- femur
- fibula
- frontal bone
- humerus
- hyoid
- lumbar vertebrae
- mandible
- manubrium
- metacarpals
- metatarsals
- occipital bone
- parietal bone
- patella
- pelvic girdle
- periosteum
- phalanges
- phalanges
- radius
- ribs
- sacrum
- scapula
- sternum
- tarsals
- temporal bone
- thoracic vertebrae
- tibia
- ulna

Imagination Questions

- Go to Balboa Park and visit the San Diego Natural History museum, it's free with a resident ID on the first Tuesday of the month. How are we constrained by our skeleton?
- Compare and contrast primate anatomy. Why is it different? Why is it the same?

Thumbnail: Catacombs of Paris. Image taken in October 2007. (Djtox).

CHAPTER OVERVIEW

4: Paleontology

Paleontology is the study of old life forms. Now that we've introduced a few basic concepts in biology, we are going to start mapping our family tree. With genetics we've seen that all life shares DNA, that the origin of life is this molecule and its ability to direct the activities of the individual, to accumulate changes, and to copy itself. With DNA at the base of our tree, we'll continue to trace the branches and connect them to our own family.

Thumbnail: Tyrannosaurus rex, Palais de la Découverte, Paris. (CC BY-SA 3.0 David Monniaux).

4.1: Paleontology → Paleoanthropology → Archaeology → History

The roots “paleo” and "archae" mean *old*. We saw the word “ontology” already when talking about “the origin of how things became” and the different ontologies that religions and science have. Paleontology looks at life in the past, and the most popular branch is dinosaurs. Closely related human ancestors get their own subfield, paleoanthropology, and the dividing line paleontology and paleoanthropology is usually when they start walking on two feet. Confirmed human ancestors get another field called archaeology, and the line between paleoanthropology and archaeology is usually set at anatomically modern *Homo sapiens*. History starts with written records. For this class, we focus on paleoanthropology and use paleontology to give an early context.

Although the line between the paleontology and paleoanthropology, and the line between paleoanthropology and archaeology can be blurry, there is a fairly distinct line between paleontology and archaeology. So, if you ever find yourself passing by an archaeological site, and you stop to chat with the archaeologists, if you want to make yourself seem really stupid, ask them “Have you found any dinosaur bones?”

Pay special attention to the information and figures about brains and teeth because these are going to be trends of human evolution all the way through to the end of this class.

If you are curious about dating techniques and how fossils form, you could jump forward in the textbook and skim the section on paleoanthropology methods too.

Exercise 4.1.1

- Skim the Early History of Life on Planet Earth
- Skim a good review of geology and speciation
- Skim How Old is Old?
- Skim Wikipedia's Paleontology
- Go to Balboa Park and visit the San Diego Natural History Museum, it's free with a resident ID on the first Tuesday of the month.

4.2: Macroevolution

Another word for macroevolution is speciation, the production of species, this is the level of evolution that Darwin studied, the kind that occurs over immense periods of time, where small changes accumulate to make life diverge into often drastically different forms. Now that we've introduced Mendel and cellular biology we can explain the two main pieces that Darwin was missing, heredity and variation.

Hox genes

Hox genes are a good example of one mechanism that enables drastic biological changes. Minor variations in the same small set of genes direct a zygote to grow into the shape of a worm, fly, mouse, or a human.

Exercise 4.2.1

- Read Hox gene intro
- Review Micro and Macro Evolution
- Living things share common genes.
- *Read about Human Accelerated Regions
- *Article on the genes for arms and legs coming from fish

Allopatric

“-patric” refers to geography. “allo” is Greek for *other*. Allopatric speciation happens when two populations are separated geographically; if you can't meet, you can't breed; in the absence of gene flow, variations accumulate through mutation and natural selection effects the two populations differently until they become separate species.

Punctuated Equilibrium

Darwin saw evolution as the gradual accumulation of changes, but looking closer at the fossil record, especially shellfish, later paleontologists began to question Darwin's ideas of phyletic gradualism, and proposed the theory of punctuated equilibrium, where the equilibrium of stasis or lack of change, is punctuated or broken by rapid evolutionary change. Remember that we are using the word "rapid" in a geological sense, usually it means hundreds of thousands of years.

Exercise 4.2.2

Skim this intro to punctuated equilibrium

4.3: Species vs. Paleospecies

The definition of a species is something we can demonstrate very clearly: if two individuals can have grandkids, then they're part of the same species. With fossils it's tricky to test this. If you bang two fossils together, they don't make baby fossils. In the next section on paleoanthropology, we will lump fossils into groups and label them with an official-looking genus and species designation written in Latin and in italics, but it's really important for you to remember that this designation is not a concrete fact, it's just a hypothesis that will continue to be tested (and often contested). Understanding that paleospecies are hypotheses will help you to understand the context for many of the debates in paleontology and especially paleoanthropology.

Exercise 4.3.1

Skim species for evolutionary biology

READ EVOLUTIONARY SPECIES VS. CHRONOSPECIES

*Lygers, Zonkeys, Jaglions… skim examples of hybrids

4.4: Interspecific vs. Intraspecific Variation

When you lump a bunch of fossils together and call them a paleospecies, you are saying that all the differences between the fossils are *intraspecific variation*, variations within a species. If you split all the different looking fossils into separate species then you are seeing *interspecific variation*, variation between species; *intra*- means "among" and *inter*- means "between"

4.5: Plate Tectonics

Plate tectonics can cause macroevolution. If a species roams over a continent and that continent splits into two, the evolutionary force of migration is prevented, and the two population will accumulate variations over time until they eventually become separate species.

4.6: Adaptive Radiation

When given the opportunity, a group of species will move into available ecological niches. A classic example is when around 65 million years ago, mammals took on ecological roles formerly held by dinosaurs after the northwest top of the Yucatán Peninsula was hit by a giant asteroid which left the Chicxulub crater, a rain of fire, mega-tsunamis, and a cloud that cooled the Earth for tens of thousands of years.

Figure $4.6.1$ - *The impact of meteors can change the weather*

When the dust cleared, the surviving mammal species radiated into the ecological niches formally occupied by dinosaurs. One species' misfortune is another's opportunity.

A good article on *dinosaur paleoecology. Morphospace is from *morphology* meaning the study of shape and space implies a landscape, or in this case an ecosystem where a particular shape is more or less adaptive.

4.7: Analogy vs. Homology

When I'm swimming in the ocean and see a vertical fin above the water in the distance, I always freak out and think it's a shark even though it always turns out to be dolphins. Dolphins evolved from a four-legged mammal that might have looked something like a hippo, and the dolphin's fin and the shark's fin are coded for by totally different genes, and have totally different evolutionary pathways. Traits that look the same but evolved separately are called *analogies*.

Homologies are traits that share a common evolutionary pathway and the same genes that code for them. The range of morphology of vertebrate forelimbs is incredible, but they all have the same genetic source, and thus share most of the same bones.

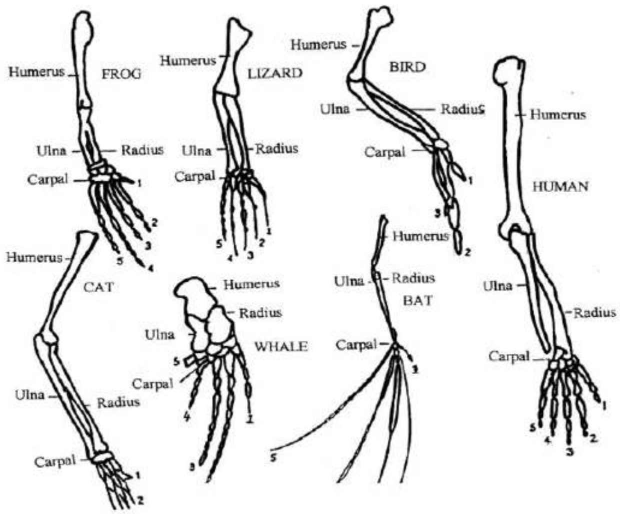


Figure 4.7.1 - *Homologous vertebrate forelimbs*

When you see two species with similar traits, the first question is are they similar because they had the same ancestors (parallel) or they had different ancestors and evolved in similar environments.

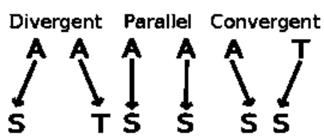


Figure 4.7.2 - *Parallel vs. convergent evolution*

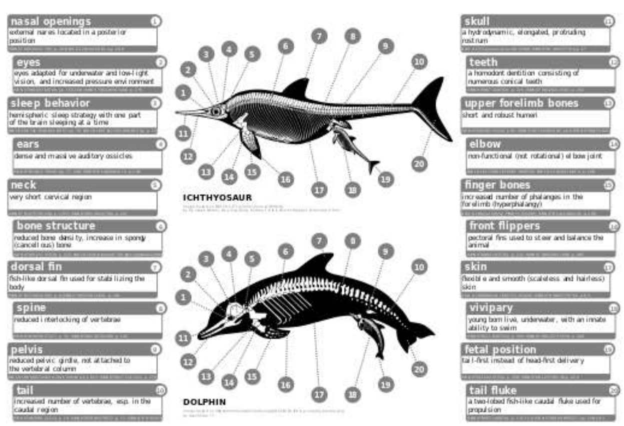


Figure 4.7.3 - *Convergent evolution for water, ichthyosaur vs dolphin by Sceptic view from Wikimedia Commons (CC BY-SA 4.0)*

Example 4.7.1:

Convergent evolution: echolocation in bats and dolphins

4.8: Taxonomy

The two classic lines of evidence have been comparative anatomy and fossils. Recently, genetics has almost completely taken over comparative anatomy research, because it's like going to the primary source, the gene is what codes for the anatomy. It used to be that using fossils was the only way to get dates, but recently, the differences between the mutations in the mitochondrial DNA (mtDNA) of a species can be used to calculate the time when that species split off from another species with different mtDNA.

The fossil evidence gives us a picture that looks like this:

***Figure** 4.8.1: "The Geologic Time Spiral: A Path to the Past" by Joseph Graham, William Newman, and John Stacy (USGS) 2008) (Public Domain)*

The genetic evidence looks like this:

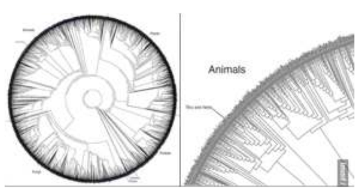


***Figure** 4.8.2 - Genealogy of life by genetic distance , "The Tree of Life" by David M. Hillis, Derrick Zwickl, and Robin Gutell, University of Texas © 2003*

Both imply the differences between living forms and the time when they branched off from each other. The genetic evidence is more concrete about living forms, the fossil evidence is more concrete about extinct life forms and gives more accurate dates.

Taxonomy is another way to think of your family tree. Biologists use different methods to make taxonomies, such as cladistics (better science) and evolutionary systematics (includes dates of speciation events) but as an anthropologist, I tend to emphasize the "genealogy" of classification – how a particular life form fits into my family tree. I try to figure out what part of my DNA I share with that organism, and probably inherited from a common ancestor. With mitochondrial DNA dating, we can get pretty close to calculating when the common ancestor between two life forms lived and when the split started.

For this class you can use most terminology interchangeably: taxon = clade = branch = phylum = group.

The whole family tree metaphor has recently come under attack by the evolutionary implications of processes like lateral gene transfer, and fuzzy hybrids, and we are learning more and more that evolution doesn't always follow a nice clean straight line. As we saw in the section on lateral gene transfer, there have been examples of two species interchanging DNA without having sex. Also, the concept of a species is not as rigid as we'd like to make it. Every once in awhile the normal sterile hybrid offspring of two different species can be fertile (Horse + Donkey = normally sterile mule).

These events are rare, so it's still worth learning classic evolutionary theory, but we can extrapolate from Charles Lyell's principle of Uniformitarianism that small changes can cause big effects over long periods of time. Call me stubborn, but I'm still not ready to give up on the family tree metaphor. LGT is good evidence that evolution doesn't follow the kind of clean branches that Darwin first sketched, but I think we can still go back to trees to save the metaphor and illustrate how life separates over time into distinct species, but can still occasionally come back together to share genetic material. Have you ever seen how when two separate roots or branches grow right next to each other for a long time that they sometimes fuse and become one root or one branch?

Exercise 4.8.1

SKIM THIS PAGE OF TREES OF LIFE

The theme of separation and reconnection plays an important part in the interpretation of our own recent evolutionary history.

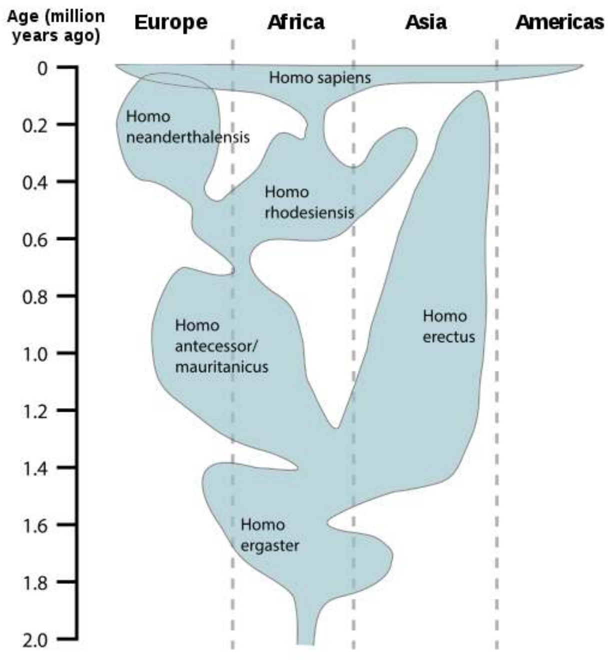


***Figure** 4.8.4 - Reed DL, Smith VS, Hammond SL, Rogers AR, et al. (2004) Genetic Analysis of Lice Supports Direct Contact between Modern and Archaic Humans. PLoS Biol 2(11) (CC BY 4.0)*

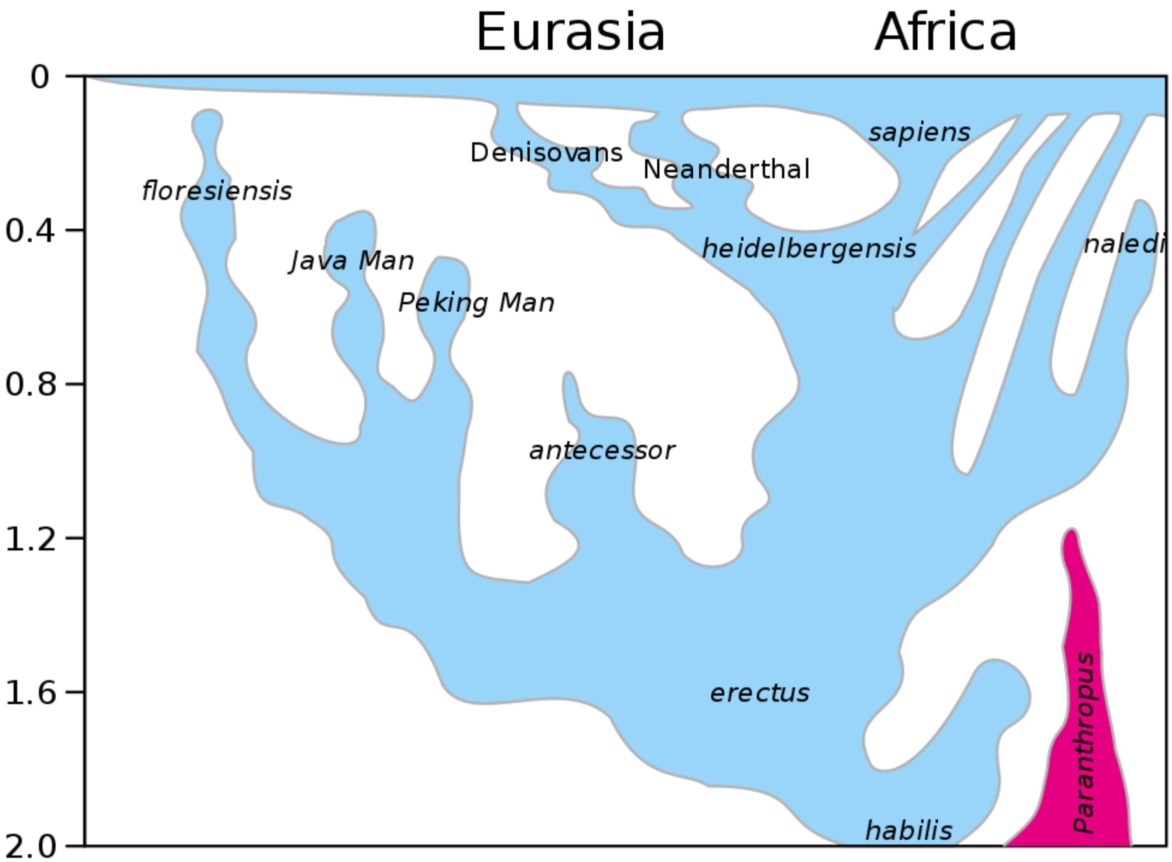


Figure 4.8.5 - *Human taxonomy, based on Stringer, C. (2012). "What makes a modern human". Nature 485 (7396): 33–35. (CC BY 4.0)*

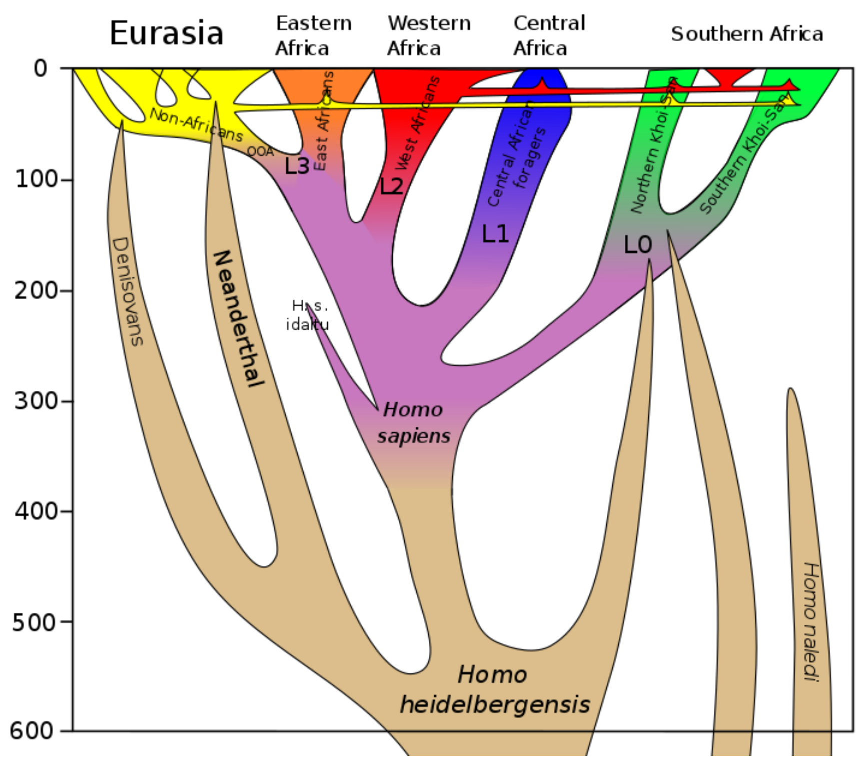


Figure 4.8.6 - *Extension to 600 kya (Homo sapiens). (CC BY 4.0)*

Note

Another good article about the "tree of life" metaphor

Astrobiology

This class focuses on the planet earth where humans evolved and share ancestry with all known life. But, it's fascinating to think of what life on other planets may be like. There are some serious hypotheses that some evolution may have taken place on other planets and been brought to the earth through meteors

Note

Life in extreme environments.

4.9: Human Taxonomy

The classic Linnaean taxonomy is basically part of your family tree without drawing in all the branches. Linnaeus was great for the 1700s, but can be very misleading today if you try to cram all the different branches of life into arbitrary horizontal categories like: Kingdom, Phylum, Class, Order, Family, etc. All of these categories are arbitrary and the only way to make them work is through lots of "sub-" and "super-". But, it's still useful to ask why the split between two taxa is being made: What do they have in common? How are they different? Especially as it relates to us. So if I want to compare and contrast myself to a frog, I go up the tree to the place where vertebrates split into amphibians and mammals. I will share all the characteristics of other vertebrates with frogs, and I will be different from frogs in all the ways mammals are. This helps you determine who is a closer relative, and this is useful in many different ways, e.g., if you want to predict how pollution might effect humans, it is usually better to look at mammals rather than amphibians, if you test a drug on pregnant rhesus monkeys, it might act differently on human mothers because we have a different placenta.

- Kingdom: Animalia
- Phylum: Chordata
  - Subphylum: Vertebrata
    - Class: Mammalia
      - Subclass: Theria
        - Infraclass: Eutheria
          - Order: Primates
            - Suborder: Anthropoidea
              - Superfamily: Hominoidea
                - Family: Hominidae
                  - Genus: *Homo*
                    - Species: *sapiens*

[from Dennis O'Neil 2012]

> **Note**
>
> Article on fish with legs, and the evolution of vertebrate limbs.

4.10: Mammals

There are three main branches of mammals alive today, classified mostly on their reproductive system:

- monotremes lay eggs,
- marsupials have pouches, and
- placental mammals keep the kids inside for longer.

Much of what it means to be human is shared with all mammals.

> **Note**
>
> Humans who can wiggle their ears share the same vestigial auricular muscles with other mamas.

Protomammals

Dinosaur-like mammals existed around hundreds of millions of years ago. They evolved into reptiles, mammals, dinosaurs, and birds.

> **Note**
>
> A new protomammal fossil.

Examples of living mammals

The split between the three groups of mammals living today happened while they were dodging huge dinosaurs in the Triassic period (250-200 mya). The three types of mammals:

Monotremes

The monotremes, or protheria, were once a large group of mammals that roamed the world, but today there are only two surviving species: the echidna and the duck-billed platypus. They lay eggs, have poison glands, and have other features we commonly consider reptilian.

Figure 4.10.3 - *Duck-billed platypus egg*

Marsupials

Marsupials, also called metatheria, are animals where newborns must crawl to their mother's pouch to nurse until developed.

Figure 4.10.5 - *Koala (Wikipedia)*

Figure 4.10.6 ***Possums***

Placental Mammals

Placental mammals, also called eutheria, are known for carrying their fetuses inside a protective placenta until birth.

Imagination Questions

Does taxonomy make you feel more part of the animal kingdom? Try the exercises below to broaden your family tree.

1) How does the Linnaean taxonomy of humans compare to other life? For every branch in the Linnaean taxonomy of humans, find another species that fits into the categories above ours, but not those below it. For example, for "Order" you might pick cats, which have the same Kingdom, Phylum, Subphylum, Class, and Infraclass as us, but belong to a different Order.

Kingdom: Animalia

Phylum: Chordata

Subphylum: Vertebrata

Class: Mammalia

Subclass: Theria

Infraclass: Eutheria

Order: Carnivora

2) Take the first five to ten letters of your name and pick an animal that starts with each of those letters. Find the most recent common ancestor by looking up the origin of their common groups, and draw a taxonomy that connects all the animals and gives the dates when they split from each other. For example: Aardvark, Rhinoceros beetle, Newt, Ibis, Elephant. Insects first arose about 400 million years ago (mya), amphibians around 300 mya. Mammals split around 260 mya from the reptiles that became dinosaurs and then birds. The oldest fossil ancestors of Elephants and Aardvarks have been found only about 10 million years apart, about 60 mya and 50 mya, which is around when the first primate ancestors were found too, because of the adaptive radiation of mammals after 65mya. So Aardvarks and Elephants are my closest cousins, and Rhinoceros beetles probably don't get invited to many family functions.

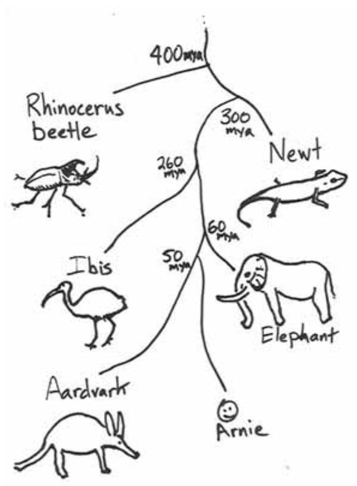


Figure **4.10.9**

3) Draw your family tree back to the Big Bang. Follow your maternal line back, skipping generations in powers of ten. Look up what ancestor was around at times below in the column "years ago" and briefly describe your sample "grandmothers".

I calculated the "years ago" column by multiplying the number of generations by the average generation length. I estimated the average time between generations by taking the average age of fertility, from menarche (first menstruation) to menopause (last menstruation)/death.

Power of ten	Generations	Average age of menarche (First menstruation)	Average reproductive lifespan or age of menopause	Average generation length (years)	**Years ago**	**Who was my Great, Great […] Grandma?**	Arnie's example:
1	1	13	50	25	**25**		Mom
2	10	17	40	20	**200**		great, great, great, great, great, great, great, great, great, great, grandmother, probably an Irish peasant
3	100	?	25	18	**1800**		great, [x100], great grandmother, possibly a Celtic peasant
4	1,000	?	?	17	**17,000**		great, [x1000],great grandmother, an anatomically modern *Homo sapiens* hunter-gatherer possibly in the Iberian Peninsula with Maternal Haplogroup H3 (I happen to know this because I had my mitochondrial DNA tested) See image below.
5	10,000	?	?	16	**160,000**		
6	100,000	?	?	15	**1,500,000**		
7	1,000,000	9	?	12	**12,000,000**		
8	10,000,000	N/A		6	**60,000,000**		
9	100,000,000	N/A		4	**400,000,000**		
10	1,000,000,000	N/A		0.7	**700,000,000**		
11	10,000,000,00	N/A		0.1	**1,000,000,000**		

Power of ten	Generations	Average age of menarche (First menstruation)	Average reproductive lifespan or age of menopause	Average generation length (years)	**Years ago**	**Who was my Great, Great […] Grandma?**	Arnie's example:
	0						
12	100,000,000,000	N/A		0.017	**1,700,000,000**		
13	1,000,000,000,000	N/A		0.002	**2,000,000,000**		great, […],great grandmother, an algae-like eukaryote
14	10, 000,000,000,000	N/A		0.00036	**3,600,000,000**		great, […],great grandmother, a cyanobacterium in a stromatolite
15	100,000,000,000,000	N/A		0.000044	**4,400,000,000**		great, […],great grandmother, a strand of self-replicating molecule swirling in primordial ooze
16	etc.				**13,800,000,000**		stardust

Vocabulary

- allopatric
- ancestral
- convergent evolution
- derived
- divergent evolution
- homoplasy
- mammal
- marsupial
- monotremes
- parapatric
- peripatric
- placental
- primitive
- shared

CHAPTER OVERVIEW

5: Primatology

Primatology is the scientific study of primates. Primatologists study both living and extinct primates in their natural habitats and in laboratories by conducting field studies and experiments in order to understand aspects of their evolution and behavior.

5.1: Introduction to Primatology

We are primates. One way to learn about humans is to study them as a kind of primate. This works especially well to explain how we got the physical structure that we have. It works a little bit to explain a few of our behaviors. It doesn't work at all to explain our culture. The Darwin tubercle is a projection on the helix of the ear resulting from a thickening of the cartilage. The actual size of the tubercle varies. It is one of many vestiges of our primate ancestry.

Figure 5.1.1 - *http://en.Wikipedia.org/wiki/Darwin's_tubercle*

A broad research question in primatology is to compare and contrast primates to other mammals, and then compare and contrast primates to themselves.

Note

KATHRYN ORZECH'S INTRO: WHAT MAKES A PRIMATE A PRIMATE?

Exercise 5.1.1: One goal of primatology is to use it to help us understand ourselves.

REVIEW PRIMATE SKELETONS AND MORE PRIMATE SKELETONS

- Jane Goodall is famous for studying chimpanzees. Watch this JANE GOODALL: WHAT SEPARATES US FROM CHIMPANZEES?
- Skim the first chapter of Augustín Fuentes *Race, Monogamy, and Other Lies They Told You Busting Myths about Human Nature*

5.2: Primate Evolution

There is a direct correlation between primate evolution and primate taxonomy. Our goal in evolutionary systematics is to make a taxonomy of living organisms and trace their ancestors and provide the dates when the groups of species split apart from one another.

> **Exercise 5.2.1**
>
> SKIM O'NEIL ON PRIMATE EVOLUTION

Video on primate evolution:

Prosimians

Linnaeus named this group of primates as the ones "before apes", and it happens to work well in an evolutionary framework, as they happen to be the most primitive. If you saw the first "Madagascar" movie, the primates there were all prosimians, and most of the world's prosimians are found on Madagascar. Madagascar is an island off the east coast of Africa. A variety of prosimian fossils are found all over Africa and Asia, but they were replaced by other primates most everywhere but Madagascar.

> **Exercise 5.2.2**
>
> SKIM STREPSIRRHINES. Evolution of Lemurs

Tarsiers

Tarsiers used to be classified as prosimians, because they look and move like prosimians, but they turned out to be genetically more similar to monkeys and apes. So, scientists had to come up with a new division that was named after the differences in their noses.

> **Exercise 5.2.3**
>
> READ ABOUT HAPLORHINES

Anthropoids

Anthropoids are monkeys, and apes (which includes humans). Anthropoids are primates, but not prosimians. Fossil found in Thailand suggest anthropoids evolved in Asia first (~45mya), and then migrated to Africa (~38mya)

Hominoids

Hominoids are apes. Hominoids are Anthropoids but not monkeys. The Miocene (23-5mya) was an important a time period for hominoid evolution and the adaptive radiation of apes led to extreme variation, and the ones in our clade were relatively generalized compared to *Gigantopithecus* for example.

Vocabulary

- Eocene
- Miocene
- *sivapithecus*
- *gigantopithecus*
- genetics
- Strepsirrhines
- anthropoids
- hominoids
- haplorhines

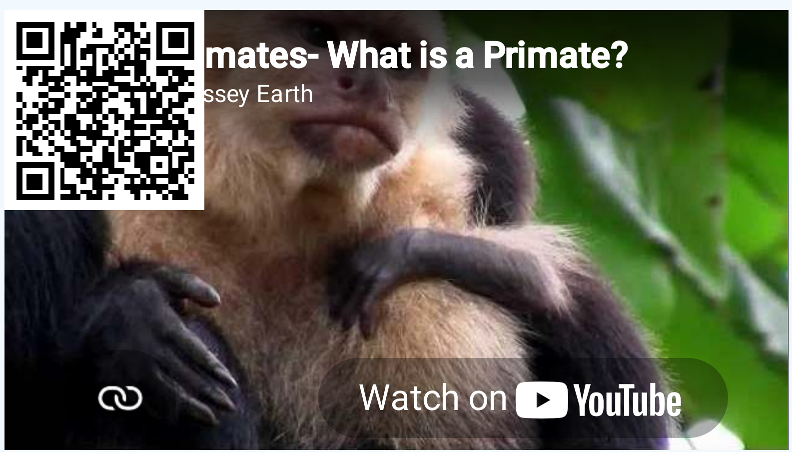
5.3: Primate Taxonomy

Primates are characterized by large brains relative to other mammals, as well as an increased reliance on stereoscopic vision at the expense of smell, the dominant sensory system in most mammals. These features are more developed in monkeys and apes and noticeably less so in lorises and lemurs.

Figure 5.3.1 - *Primates*

Exercise 5.3.1

WATCH THIS 5 MINUTE VIDEO OVERVIEW OF PRIMATES:

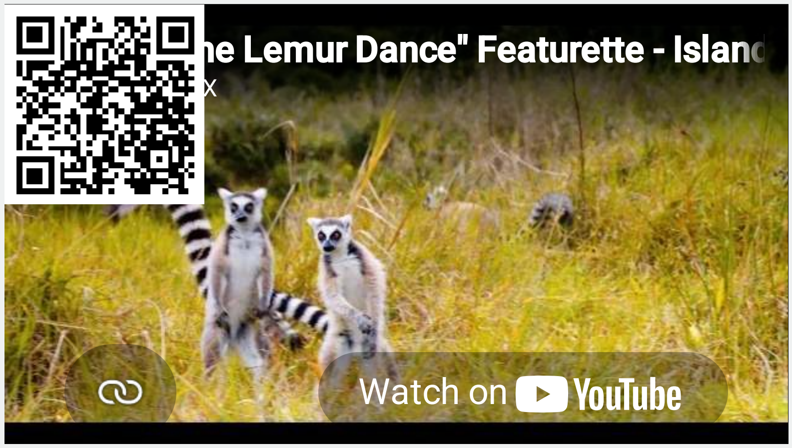


Primate Locomotion

Humans are the only primate that is habitually bipedal, but primates have a tendency towards vertical orientation. The small clingers and leapers hang upright on the trunk, the brachiators hang vertically from their arms, many prosimians jump bipedally, most apes go on two feet for a more dramatic display.

Note

WATCH THESE JUMPING LEMURS:



5.4: Ethology

Ethology is the study of animal behavior. Don't confuse it with "eth**n**ology" the study of "ethnos", ethnicities, the comparative study of human cultures. I think videos are the best way to get a sense of both primate behavior and our place in the primate continuum. Captivity is a bad place to study behavior because the behavior has evolved in a certain environment, to solve problems in that environment, and you can't expect to see natural behavior outside of a natural setting, and I hate zoos because they justify the destruction of natural habit. But, some of these psychological experiments are useful to blur the line between human and non-human primate.

Note

Reintroducing Lemurs into Madagascar (7 part series with John Cleese)

2014 "Inside Ape Minds"

Behavioral Ecology

- Baboon adaptations to the savanna
- Safety in numbers, boa constrictor eats Purús red howler monkey
- The Monkey and the Snake: How the Primate Brain Reacts to Serpents

Primate Culture

Exercise 5.4.1

WATCH ORANGUTAN BEHAVIOR

- Orangutans plan ahead and share trip plans a day before leaving: Wild Apes Communicate Their Travel Plans for Tomorrow
- Chimp vs. Children
- Capuchin Monkey tool use:

Exercise 5.4.2

Watch Chimpanzee's from Bossou tool use

Article on social transmission of tool use, Sonso chimp leaf sponges

Ape Language?

Apes don't speak but they can learn sign language and symbolic keyboard languages. Book on Koko, a gorilla who was taught sign language

Ape Music?

Language is often defined as an exclusively human form of communication, but the line between human language and animal communication is not so sharp, as we see with Koko, Kanzi, and the dozens of other apes taught to use languages. Can the same be said about music? Gorillas make up little songs when they are eating. When we find regional variations of sounds produced by chimps, can we say they are like musical styles?

Exercise 5.4.3

Watch Chimpanzee's from Bossou clip leaves because they like the sound it makes, and they are bored, frustrated, or want to attract a mate (you need to turn the sound up on the video to hear it)

- Review of Chimpanzee drumming styles
- Article on Gorilla eating songs

Theory of Mind

Theory of mind refers to an individual's ability to think about what other individuals are thinking. The term has various definitions which can range from mirroring, copying another's actions, to mentalizing, predicting how another will react. Humans are definitely the best at this, but other animals demonstrate this behavior, including dogs, dolphins, elephants, some birds, and of course primates. Dogs are actually better at recognizing human pointing than chimpanzees.

* John Rubin "The Gap Between Humans and Apes"

Exercise 5.4.4

Watch a lecture by Tetsuro Matsuzawa, "Mind Reading" in Chimpanzees

Skim Charles Darwin's1872 "The Expressions of the Emotions in Man and Animals", especially look at the pictures:

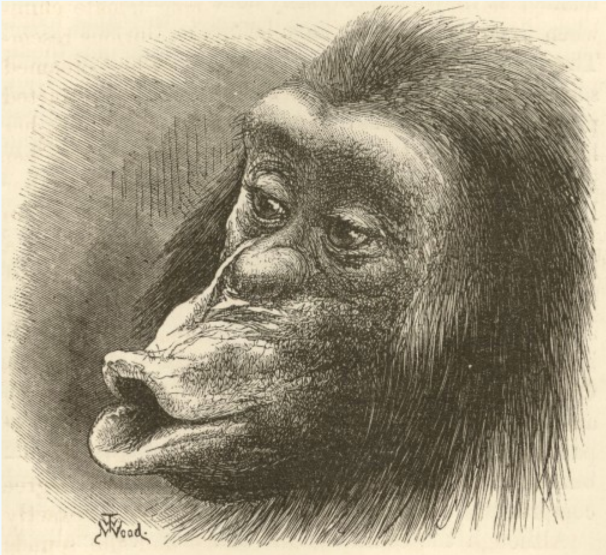
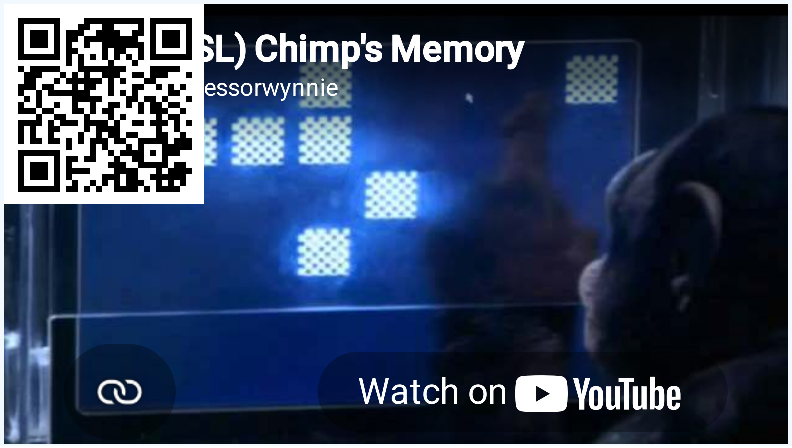
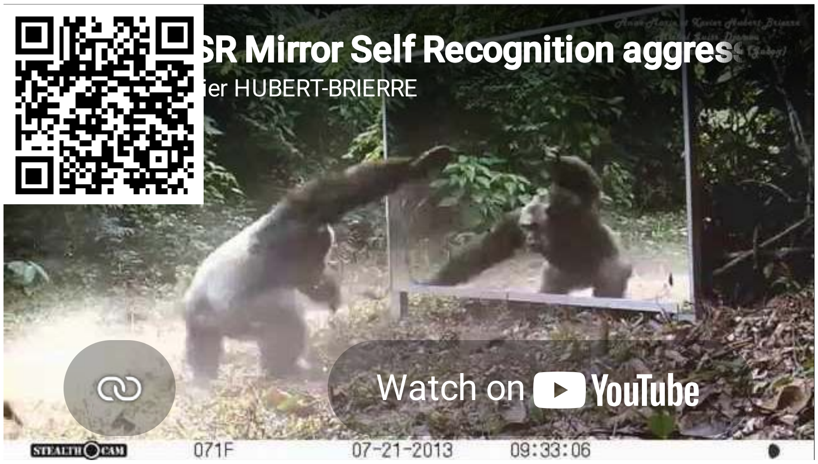


***Figure** 5.4.2 - "Chimpanzee disappointed and sulky. Drawn from life by Mr. Wood."*

Watch an amazing test of chimp short term memory:



* Apes and mirrors:



* Ape self-awareness:

Exercise 5.4.5

Read an article on contagious yawning in chimpanzees

Read an article on Chimp attitudes towards death

The three clips are arranged from agonistic (aggression) to affiliative (grooming and sex).

Agonistic Behavior

Agonistic means "aggressive", but it is usually more bluff and intimidation than physical violence. Natural selection is going to generally select for conflict resolution that avoids members of the same species injuring each other. Many primates are aggressive, but they don't kill each other very often. They learn hierarchies to avoid injury. But when push comes to shove, primates make bad pets.

- Watch a Violent Chimp Attack

Affiliative Behavior

Affiliative means "social". There is a push and pull of conflict and resolution in primate societies. Primates fight to see who's on top, and then make-up to keep the group together. Agonistic behavior helps to establish dominance hierarchies, and is usually followed by reconciliation, a kind of affiliative behavior. The most common primate affiliative behavior is grooming. We tend to think of grooming as keeping clean, but its main function for primates is social bonding.

- Read about Bonobos comfort each other
- James Fowler research on how humans chose their friends based on genetic closeness

K-selection vs. r-selection

If you say something is r-selected or K-selected, you are comparing a species or group of species to another, and comparing their strategies for growing their population. The terms come from variables in a math equation that describes how populations grow:

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right) \tag{5.4.1}$$

where

- N = the population density,
- r = the reproductive rate,
- K = the carrying capacity.

r-selected animals have plenty of habitat to grow into, so they crank out lots of kids and hope a few survive. K-selected animals have limitations on their resources, so they have few infants per birth, and longer birth spacing, and invest more parental care in making sure they survive. K-selection follows the human phylogenetic continuum closely. Vertebrates are more K-selected than invertebrates. Mammals are more K-selected than other vertebrates. Primates are more K-selected than other mammals. Anthropoids are more K-selected than prosimians. Hominoids are more K-selected than monkeys. Humans are one of the most K-selected species on the planet.

* Jane Goodall on chimpanzee motherhood:

* Verhulst equation of population growth or logistic growth equation

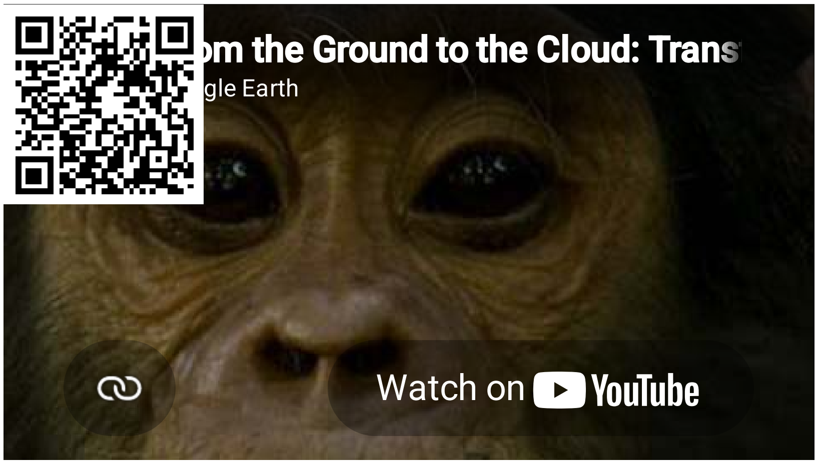
Vocabulary

- altruism
- language
- violence
- sexual dimorphism
- sexuality
- anthropomorphism

5.5: Conservation

"Are primates going extinct?" This is a trick question. One answer is "no". The total world primate population has skyrocketed in the last 10,000 years and especially in the last 200 years. But, another answer is "yes". The total number of primate *species* has declined drastically and primate extinction is expected to continue. One primate is doing really well, at the expense of all the other primates. The primary cause is habitat loss, but a significant and very symbolic factor is that one primate is literally eating all the others.

* Jane Goodall video on conservation:



Research on Primates

Primates are valued as research subjects because their physiology is so similar to ours, but the same similarity makes captive breeding and research unethical. The Russians are good at sending primates into space, but haven't quite figured out how to get them back alive.

Habitat Loss

When we cut down forests we push primates towards extinction. This is happening to all primates around the world. The bulk of deforestation is to provide luxury food products (like hamburgers or palm oil) to meet consumer demand in the US.

> Note
>
> GRASP statement on palm oil plantations

Anthropozoonotic Diseases

Eco-tourism is generally good for primates because it adds monetary incentives for conservation, but because human and non-human primate biology is so similar (~98%), the diseases that infect us can often jump species and infect the primates we came to watch.

> Note
>
> Ecotourism can transfer disease from humans to primates

Bush Meat

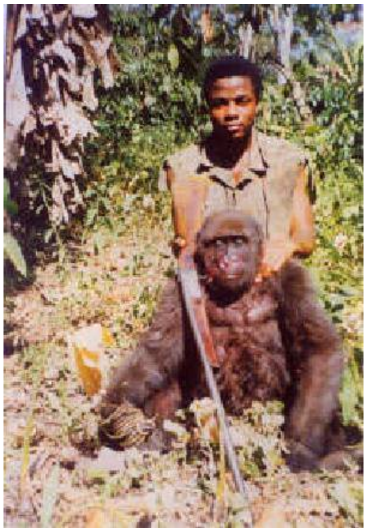
I think the story of primate extinction is better told in pictures. What is important to remember is the root cause of why people resort to eating other primates: colonialism. The reason people are hungry is because of how resources are distributed. Even with overpopulation, there is enough food in the world to feed everyone. It is a question of distribution. There are the rich and the poor. Colonialism exacerbated existing class distinctions to better extract natural resources and send wealth to Europe. Colonialism led to post colonialism, where even after “independence”, patterns of corruption continue today.

It's easy for us to judge people and say we need to stop eating bush meat, but as anthropologists we strive for cultural relativity. Imagine your family was starving, and you had to choose between your children or another primate on the verge of extinction. Would you let YOUR family starve for the sake of another animal?

One of the most paralyzing factors in this issue is the history of Europe, the US, and Africa is so long and sordid, that our most well-intentioned actions often backfire. Look at the backlash to the recent Kony 2012 campaign. How can the US claim any moral superiority when they perpetuated slavery and racism? How can we claim that we have Africa's best interests at heart, after what what we did in the Congo in 1960--sending the CIA to assassinate the democratically elected leader? The sadness of these pictures goes way beyond the extinction of primates in our generation. It reflects a very difficult political situation, where everyone, especially the primates, loses.

Warning: Graphic Images

I was getting very depressed gathering these photos, but I stumbled on an innovative program that is trying to substitute beekeeping for the hunting of bushmeat, and it cheered me up for a moment. There is a crisis and we need to all do something about it, but things aren't hopeless, we just need to work quickly and do more.



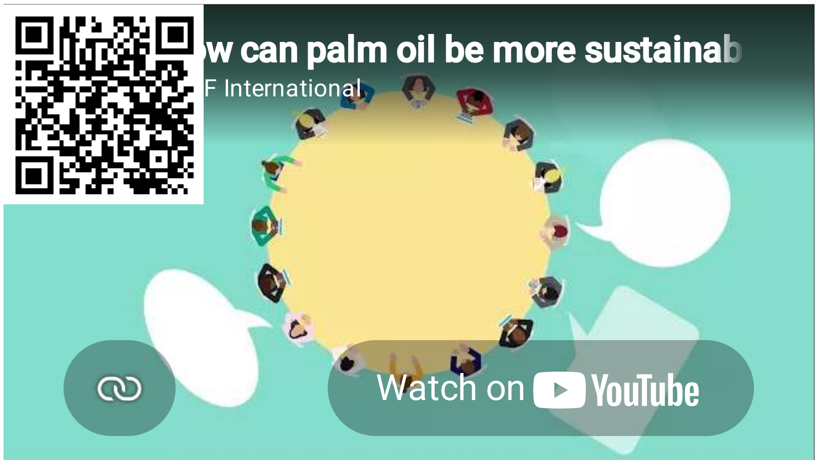
- * Article on alternatives to bush meat
- * Mountain Gorilla census over 100
- * Article: Outlook is grim for mammals and birds as human population grows.
- * Legal rights for chimpanzees in the US
- * Vaccinating Lemurs:

* The Green Corridor Project includes research and reforestation to connect isolated chimpanzees to larger reserves, and help them coexist with humans:

Imagination Actions

- Participate in the latest Eyes on Apes action alerts
- Sign the Pledge not to torture slow lorises:

- Write letters to stop palm oil plantations to Herakles Farm, TIAA-CREF, another TIAA-CREF, Sara Lee, Pepsi on land used by thousands of orangutans, chimpanzees, and other primates:



- Sign this petition to ask Russia to stop sending primates into space.
- Sign this petition asking the Korea Central Zoo to stop giving cigarettes to chimps, and explain why chimps would be likely to get addicted to nicotine and suffer the same health problems as humans?
- Write a letter asking the NY Blood Center to not abandon chimps in Liberia, and sign this petition to ask IBM to pressure them.
- Comment on whether Naruto the selfie monkey should own the rights to the photos he took.

Figure 5.5.1 - *Self Portraits ©2008 Naruto the Celebes crested macaque, used without permission.*

CHAPTER OVERVIEW

6: Paleoanthropology

In previous sections, we compared ourselves to living creatures that you can see running around in their natural habitat, but in the paleoanthropology section, most of our knowledge is based on data gathered through archaeology, and we focus on hominid fossils, and how to interpret them.

6.1: Introduction to Paleoanthropology

Anthropology asks the broad question: “Who are we?” Paleoanthropology asks a more specific question: “How did we get to be what we are?"

In this part of the class we go back in time to follow the branch of the tree of life that leads to us. In the previous sections, we compared and contrasted ourselves to other vertebrates, then to other mammals, then to primates, and mostly to hominoids (apes). In paleoanthropology we start from the split that separates apes from humans and continue on that branch, and all its side branches, until we get to us.

Paleoanthropology deals with hominids (bipedal hominoids). In previous sections, we compared ourselves to living creatures that you can see running around in their natural habitat, but in the paleoanthropology section, most of our knowledge is based on data gathered through archaeology, and we focus on hominid fossils, and how to interpret them.

The next few sections are going to bombard you with specific dates, exotic places, hard to pronounce names, and plenty of Latin. Please try not to miss the forest for the trees. We need to sweat the details. The details are what paleoanthropologists use to support their very tenuous hypotheses. But make sure that when you hear a specific factoid, that you put it in context with a larger framework. So if you hear "Toros-Menalla" you should think "that´s kinda northwest of where most of those other hominid fossils were found." If you hear a species called *Homo ergaster*you think "well it's later than the australopithecines because it's of the genus *Homo*, but it's not quite us because the species name is different than *sapiens*." If you see a date for Lucy is 3.7-3.5mya you think: "Well she didn't use stone tools because those only appear around two and a half million years ago." If you read that *Sahelanthropus tchadensis* had a cranial capacity of 320-380 cc, you think "before australopithecines hominids had about the same size brain as chimps do now"

We have found hundreds of thousands of hominid fossils which represent tens of thousands of individuals. When someone claims that there is no "missing link" between apes and humans they are ignoring that huge body of evidence gathered by thousands of scientists. The real debates are about how to include those ten thousand individuals in our family tree, because these thousands of fossils are just a tiny fraction of the billions of hominid ancestors that have lived rich and important lives, but left no physical traces. A genealogical analogy is that you may know from your last name that you belong to certain clan, but you might not be able trace all your relatives back to that apical ancestor; in paleoanthropology there are many gaps.

Important factors for fossils are: dates, where found, morphology (shape), and associated tools.

hominid or hominins?

> The confusion over taxonomic terminology gets worse. Recently, many scientists have redefined the term "hominid" to include great apes along with humans. This better reflects our genetic similarity to great apes. To distinguish humans and their bipedal ancestors from great apes they now call us "hominins". I don't really care which terms you use as long as you are consistent. It's always a good idea to define your terms anyway.

You don't want to get lost in the details, and always bring it back to the context of time, place, and relation to the major trends.

6.2: Trends

Some paleoanthropologist see the icon of humanity as footprints, some left by an australopithecine some 3,500,000 years ago, which led to footprints on the moon.

Figure 6.2.1 - Laetoli footprints by Momotarou2012 (CC BY-SA 3.0) .

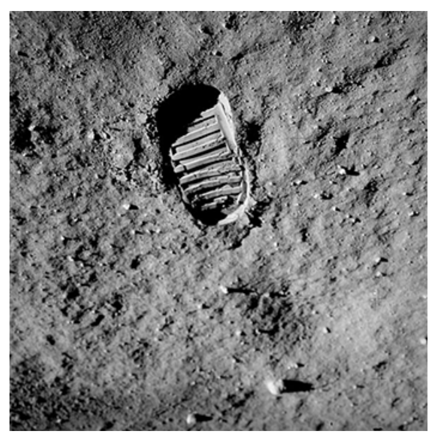


Figure 6.2.2 - lunar footprint NASA (public domain)

Feet are important, but another way to look at humanness, is the hand.

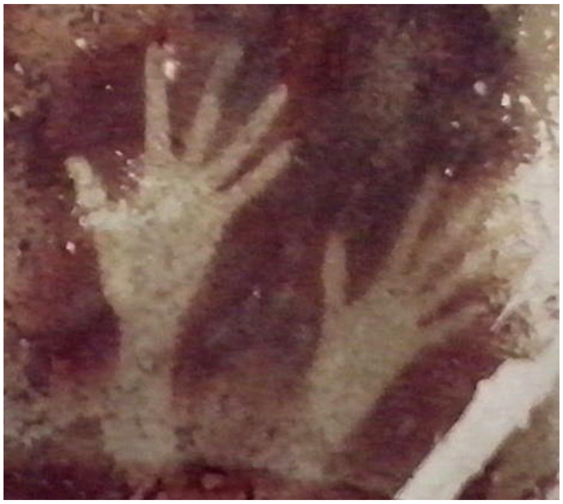


***Figure** 6.2.3 - Hands in Pettakere Cave by Cahyo Ramadhani (CC BY-SA)*

What makes us different from any other lifeform is this ability to leave our handprint. Of course the two go together, because to make art with your hands, you first need to walk upright on two feet.

It's convenient for us to summarize the evolution of our species into a few broad trends that fit on the back of flash-cards: two feet, smaller teeth, big brains, culture, tools, language, large body size, wide geographic range... This is how evolution made us different from our closest living relatives bonobos, chimpanzees, and gorillas. But at the same time it's important to remember that evolution is not directional. Life doesn't progress towards an ultimate goal. There is no human essence that our species strives to become. This is more of that philosophical baggage we have left over from Aristotle.

Scientists do use a creation metaphor, the concept of *mosaic evolution* to describe how evolution creates a picture out of many different pieces.

"Mosaic evolution" is a metaphor for how the picture of a living species can be seen as the evolution of many characteristics, or pieces of colored stones that work together to form a pattern, even though each of those pieces may have evolved at a different rate, and in our case, we can see a picture of modern human beings as a composite of many trends in hominid evolution, which are listed as column headings, roughly chronological from left to right. With locomotion we are concerned with the development of bipedalism. A fancy way to talk about an increase in brain size in the evolution of a clade (branch) is encephalization. The reduction of dentition is another trend. Toolmaking behavior is the only direct evidence we have for culture in early hominids. A good example of biocultural evolution are the trends in dentition and tool use: as we developed better tools we no longer relied on our teeth to process food.

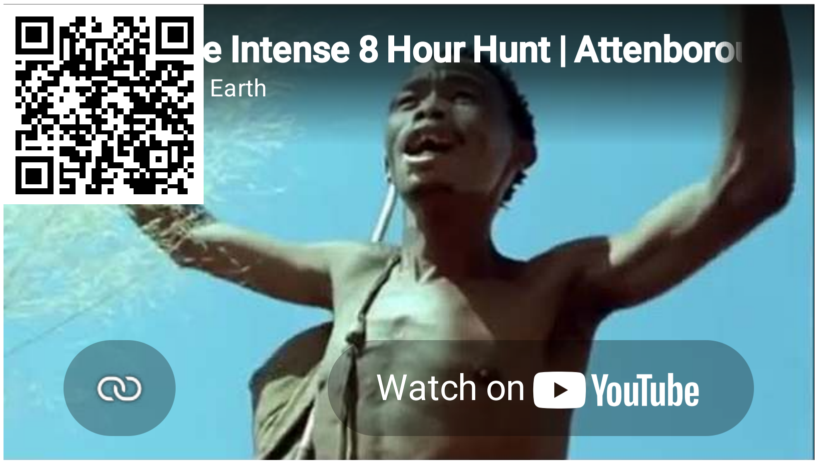
Bipedalism

We are the only primate to walk on two feet. All primates can walk bipedally if carrying something or injured, but it's not their normal mode. This is a trend that goes back to primate evolution and our arboreal adaptation. Natural selection selected for being comfortable while vertical, both for vertical clinging and leapers with their torsos aligned with the vertical trunks of trees, and brachiators, where gravity pulls us into a vertical position as we swing from tree to tree.

There are several hypotheses for why evolution selected for bipedalism in basal hominids. Using two feet instead of four is more efficient for traveling long distances. Walking on two feet freed our hands for tools and communication. Walking tall meant we could see over the tall grass of the savanna to notice food and predators, and it could have help intimidate rivals or predators, and some claim that it would have helped us wade through shallow water. Getting up off the ground could have kept us cooler in hot savanna heat, but moving our head farther away from the hot ground, and decreasing the amount of sun our bodies got when it was at its strongest. Anthropology's acceptance of multi-causal arguments means we don't have chose one, and we can evaluate the likelihood of each in different situations.

* Locomotor Energetics in Primates: Gait Mechanics and Their Relationship to the Energetics of Vertical and Horizontal Locomotion

* Human versus horse races



Kung San persistence hunting

Encephalization

cepha is Greek for head, encephalization is the head getting bigger, but we're really more concerned with the brain. Paleoanthropologists used to take skulls and fossil skull casts and pour rice into the foramen magnum until it was full, and then pour it out and you got the individual's cranial capacity. Now we use 3-D scanners instead of rice, but it's the same principle: how much brain did the individual have. It's usually measured in volume, like cubic centimeters, abbreviated as cc'. Both the absolute and the relative brain volume tends to grow as time goes on with hominid evolution, with a few exceptions. Neandertals actually had on average bigger brains than anatomically modern *Homo sapiens*.

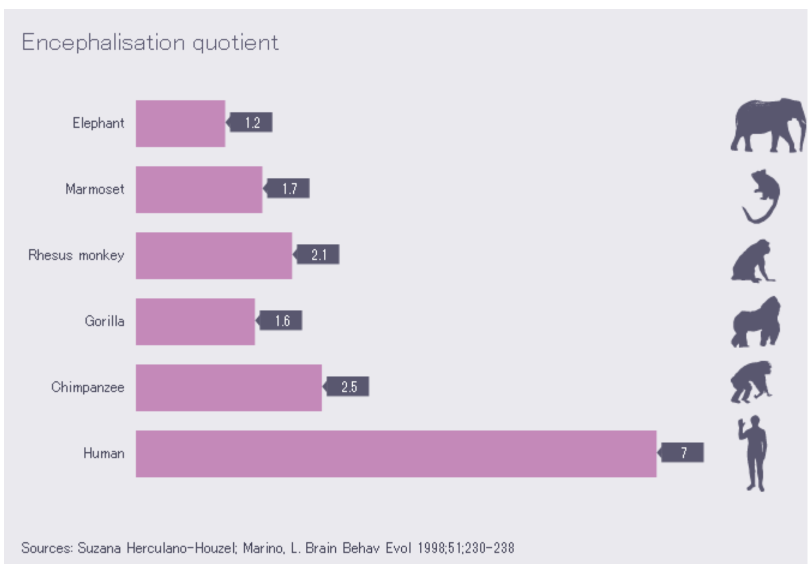


***Figure* 6.2.4** - the ratio of brain to body size by Peter Aldhous, Wikimedia Commons (CC BY 4.0)

Note

Marino 2000. Article on the SRGAP2 gene associated with brain development

Culture/tools

The classic theory is that bipedalism freed the hands from locomotion and allowed them to specialize in tool use, and this was supported by the correlation between complexity in stone tools and encephalization in hominids such as *Homo habilis*. Recent discoveries are pushing the dates of the first stone tools back before significant encephalization had occurred, but this is consistent with our observations of living primates. If we can see primates today make tools with a 400cc brain, we can imagine our ancestors doing the same with 450cc brain.

Note

* Radio interview on the origin of the precision grip:

T.L. Kivell & M. Skinner

npr

Share

Shots - Health News

Maybe Early Humans Weren't The First To Get A Good Grip

Listen

2:40

© 2015 NPR

Exercise 6.2.1

COMPARE THE TOOL SECTIONS OF THESE PAGES: OLDOWAN TO THE ACHEULIAN TO THE MOUSTERIAN TO THE UPPER PALEOLITHIC

* Article that maps brain patterns to the hands and feet of primates suggests the dexterity required for tool used evolved before bipedalism

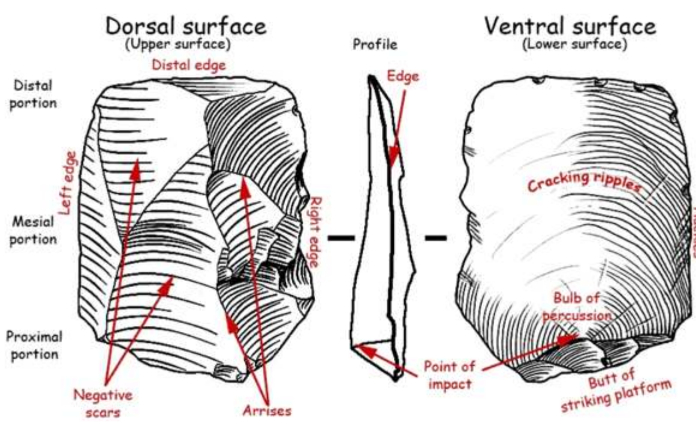


Figure 6.2.5 - flake attributes by José-Manuel Benito Álvarez from Wikimedia Commons (CC BY-SA 2.5)

Language

The evolution of the human capacity for language is tied to the development of encephalization and culture. You need a brain to process language, and language enables complex cultural transmission. Unfortunately, the evidence for the evolution of human language is scanty. The study of the evolution of human language was even banned by the French linguistic society in the 1800s.

- Approaches towards the origin of language

- Article and video on an orangutan's capacity for producing human sounds

Dentition

The evolution of hominid teeth is basically reduction, with a few counter examples. Teeth are the hardest bone in the body, and so they tend to fossilize more than other bones.

Exercise 6.2.2

SKIM THE EVOLUTION OF HOMINID DENTAL MORPHOLOGY

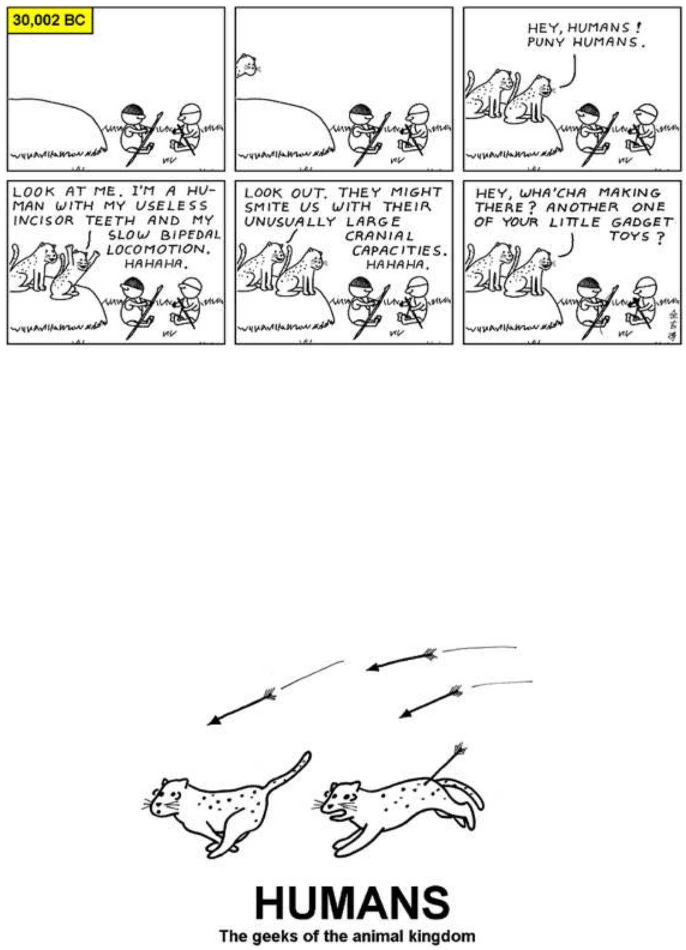


Figure 6.2.6 - "Puny Humans" by Abstruse Goose (CC BY-NC 3.0 US)

6.3: Methods

The methods of paleoanthropology are basically the same as paleontology: find a fossil or a gene, and then compare and contrast it to every other fossil, bone, or gene currently known. It is very detail oriented work on all fronts, with surprisingly few "aha!" moments, and many of the debates often come down to the interpretation of statistics.

Taphonomy

Taphonomy comes from the Greek “taphos” or death, and it basically means the study of what happens to you after you die. The study of rotting and decay, and especially important for us, the study of how fossils are formed. This is a big problem because when we try to recreate an image of the past our data is sketchy. For example, we have a ton of pig fossils, and can talk in exhaustive detail about the evolution of pigs, but when it comes to human ancestors we have less to work with. We would love to find DNA from early hominids but the same capacity for unzipping for replication and protein synthesis makes it a fragile molecule that is unlikely to survive more than 100,000 years.

Fossils

Remember that fossils are not bones, they are casts of bones.

> **Exercise 6.3.1**
>
> READ DENNIS O'NEIL ON FOSSILS

Dating

Getting the dates right is crucial, but we hardly ever get an exact date, like something you could use for a time machine, usually it's just a statistical approximation.

> **Exercise 6.3.2**
>
> - READ DENNIS O'NEIL ON DATING OVERVIEW
> - READ DENNIS O'NEIL ON RELATIVE DATING
> - READ DENNIS O'NEIL ON CHRONOMETRIC DATING 1
> - READ DENNIS O'NEIL ON CHRONOMETRIC DATING 2

Paleoecology

Along with the hominin species that we find, we want understand what kind of world it lived in. We try to recreate the ecology.

- Human ancestors had many predators, including crocodiles CSI: Olduvai Gorge. The work of Jackson Njau [scroll through the different pages]
- Hyenas crushed human skulls

Paleoclimatology

- Read Dennis O'Neil's intro to climate change and hominin evolution
- Climate change and paleoanthropology

Molecular Paleontology

Genetics gives us two major lines of evidence, existing and ancient. Our own DNA gives us many clues to our evolution. We can compare ourselves to other living primates, and other humans, and the differences will suggest pathways to evolution. Ancient DNA has only been found in the most recent hominids

- Review of molecular paleontology

In several recent hominids (such as Neandertals and Denisovians), DNA is preserved, and we can see more than just the skeleton. The DNA tells us what proteins were produced and hints at soft tissue and behavior.

- Article on genetic evidence for the difference in brain size between humans and other apes

Vocabulary

- anthropogeny
- absolute dating
- relative dating
- site context
- in situ
- paleospecies
- chronospecies

Taxonomy

Linnaeus put all life into a huge family tree and correctly included humans on the primate branch. One of the goals of paleoanthropology is to fill-in as many details as possible for all the twists and turns of how that branch leads to us. The family tree metaphor can sometimes be misleading, Stephen J. Gould described taxonomy as more of "luxuriant bush", but for this introductory class, it is useful to minimize the groupings so we don't get overwhelmed. When paleoanthropologist find a fossil they try to fit it into the existing taxonomy, and there a two broad strategies: 1) f you call it another example of an existing group, you are a "lumper" (you're lumping them all together) or 2) if you call it a brand new species you are a "splitter" (you're splitting the branch into two). Splitters tend to get more attention on the news, but for this class we'll lean towards lumping hominid fossils into fewer manageable groups: pre-australopithecines, australopithecines, the genus *Paranthropus*, early genus *Homo*, later genus *Homo*, anatomically modern *Homo sapiens* (us).

6.4: Pre-australopithecines

For lack of a better name, we can define this group as primate fossils that date before the known group of australopiths, that show evidence of bipedalism, or dentition similar to later hominins who show bipedalism. One of the major frustrations of paleoanthropology is that this represents a huge time period, and we're trying to answer some of the most important questions of hominid evolution centering around our coming down from the trees with just a handful of fossils.

Exercise 6.4.1

READ DENNIS O'NEIL'S EARLY HOMININS

6.5: Australopithecines

Australopithecines currently come in two flavors, gracile and robust.

$$\text{australopithecines } = \text{australopiths} \tag{6.5.1}$$

The robust australopithecines were re-grouped into a separate genus, *Paranthropus*, because they are so different from the hominins that came after them.

Exercise 6.5.1

READ DENNIS O'NEIL ON AUSTRALOPITHECINE VS. PARANTHROPOID SPECIES

Gracile

Gracile australopiths have a wide range of dates and can be grouped into several species.

Robust

We've had problems figuring out where to put the robust australopiths in our family tree. Kind of like that distant cousin that you have to invite to the wedding, but can't find a seat for. They are bipedal, so they are definitely closer to us than bonobos, chimps or gorillas, and they have many morphological similarities to other australopiths. But they look much different, with huge mandibles and molars, and a big muscle-head (sagittal crest) like the rest of the great apes. They were nicknamed "Nutcracker Man" because of the huge mandibles, and there is probably some truth to that because we can tell from their teeth and jaws that they had a hard diet. So far, we haven't found any stone tools associated with them. The robust australopiths have had their genus renamed a few times, from *Titanohomo*, *Zinjanthropus*, to *Australopithecus*, and now most paleoanthropologists have settled on *Paranthropus*.

6.6: Early Genus Homo

We originally defined the genus *Homo* because of two interrelated factors: the first evidence for stone tools and significantly bigger brains.

Exercise 6.6.1

READ DENNIS O'NEIL ON EARLY GENUS HOMO

Homo habilis

Homo habilis was the first example of the genus Homo, and was named for the dexterity required to make stone tools.

6.7: Homo erectus

Imagine an awards ceremony at the end of the universe, judging all the hominids that have ever existed, "...and for the most successful hominid... " and then our hopes are dashed as *Homo erectus*takes the stage, with a big prognathic smile from its parallel dental arcade, jabbing an Acheulian hand axe towards the sky in a triumphant gesture. *Homo erectus* is significant for many reasons, but one of the most important is because unlike so many contested hominid paleospecies, we have found so many *Homo erectus* that almost all paleoanthropologists agree that there was such a thing. *Homo erectus* was important for its longevity, more than any other hominid so far,it will take us another million years to beat their record.

Homo erectus was also important as the first documented hominid to leave Africa, and they definitely got around, because their geographical ranges covers Africa, Europe and Asia (but not Australia or the Americas). *Homo erectus* begins the human trend of globalization and makes migration (gene flow) one of the important evolutionary forces for humans.

Africa

Some African hominids at the same were more gracile, enough different from Eurasian to warrant another species name for some paleoanthropologists, *Homo ergaster*.

> **Note**
>
> A range of hominids from different periods have been found at Lake Turkana in Northern Kenya

Asia

- Eugene Dubois found the first Homo erectus on the island of Java in Indonesia.
- Classic Zhoukoudian fossils were found near Beijing, and they were originally sold in apothecary shops as "dragon bones"
- Article on very early *Homo erectus* in China

Europe

- Tautavel man from Arago Cave

Dmanisi hominids

The Dmanisi fossils are special for how old they are (1.77mya), how small they were, how small their brains are, and how simple their tools are, and that they're found in Europe. The old theory is that *Homo erectus* was the first hominid to leave Africa, enabled by their large overall size, large brains, and complex tools. But, the Georgian hominids were small, had small brains, and used simple tools, they were similar to australopithecines in many ways.

- Article on Skull 5: variations within the Dmanisi suggest that all hominids can be lumped into *Homo erectus*
- Article on Dmanisi toothpick use

Acheulian Tool Industry

We want to ask what kind of intelligence to work stone with this amount of symmetry and precision?

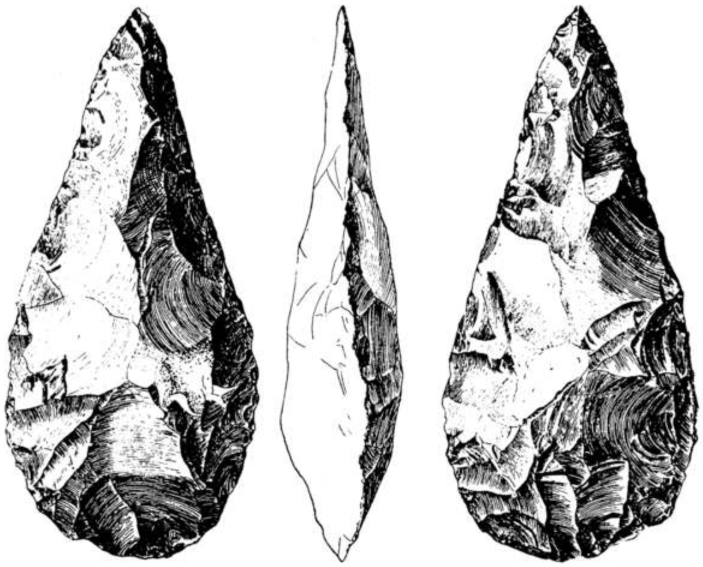


Figure $6.7.1$ - Lanceolate hand axe from the acheulean site of San Isidro, Madrid, Spain. Hugo Obermaier (1925): *El Hombre fósil*. Madrid (public domain)

6.8: Around Homo erectus

Almost all paleoanthropologists acknowledge *Homo erectus* as a category of hominin in between Australopithecines and anatomically modern *Homo sapiens*. The transition from Homo erectus to Homo sapiens is less clear. extreme lumpers consider *Homo erectus* a

Homo antecessor

A hominid found in Europe from around 1.2mya to 800,000 ya, with a morphology very similar to *Homo ergaster*.

- Article on *Homo antecessor* dentition

Homo heidelbergensis

- DENNIS O'NEIL ON *HOMO HEIDELBERGENSIS*

Imagination Questions

The animal rights movement among other factors has politicized the human diet. Paleoanthropological evidence can be used to support both veganism and raw steaks. Would scientific evidence about our evolutionary propensity for a certain diet effect what you eat?

6.9: Neandertals

For the hominids in the last section, paleoanthropology hasn't settled on a single name so it gets a little confusing. Some lumpers just call them all "humans", some splitters come up with taxonomies of dozens of species. There are different ways to group these hominids: by geological period, glacial period, tools (from broad lithic periods to the more specific archaeological industries), and names of paleospecies (mostly based on bone morphology), and they don't always fall in neat categories. This means that weather, tools, and osteology don't always go together.

The Pleistocene is defined by repeated events of glacial advance and retreat, which meant radical weather changes. Geologists have pushed the the boundary between the Pliocene and the Pleistocene back to 2.5 mya to account for new data on early glacial periods. This date happens to fit pretty well with the first stone tools found, and hence our definition of the genus *Homo*. Section 6.9 focuses on hominids in the Middle Pleistocene, especially the transition from *Homo erectus* to the very noncommittal term "Premodern Humans". The "human" part acknowledges that they were a lot like us. The "premodern" part recognizes that there are enough differences in their bone morphology and cultural attributes to question whether they had a mind different enough to think of ourselves as different from them. I'm not sure myself. A famous paleoanthropologist said that if a *Homo erectus* sat down next to you on a bus you might want to change seats, but if it were a Neandertal (also called a European Middle Pleistocene hominid) you just might stare a little. We'll continue this kind of "us" or "them" debate into the next section.

Some of the most fascinating recent research are the advances in decoding the Neandertal genome, especially that some were redheads and had an allele (FOXP2) involved with language . You will definitely hear more details about this in your lifetime.

Exercise 6.9.1

READ DENNIS O'NEIL'S INTRO TO NEANDERTALS

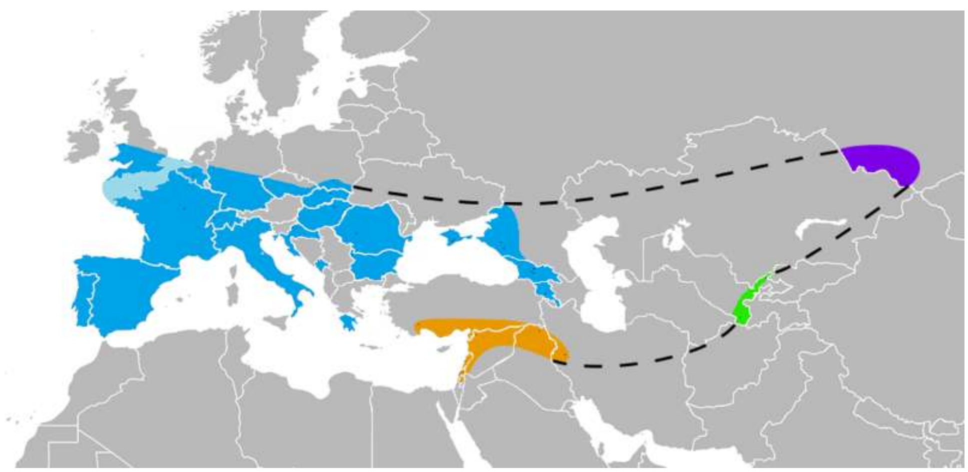


Figure 6.9.1 - Figure 121 Known Neanderthal range in Europe (blue), Southwest Asia (orange), Uzbekistan (green), and the Altai mountains (violet), as inferred by their skeletal remains (not stone tools) by Nilenbert, Nicolas Perrault III (GFDL, CC-BY-SA-3.0, CC BY-SA 2.5)

* A good introduction to Neandertals by Svante Pääbo, one of the scientists responsible for working out the Neandertal genome,

* Read the first 5 pages of this article on Bone tools made by Neandertals What is a *lissoir?* What was it used for? How do the archaeologists know that it is a tool and not just food remains?

* Article on Neandertals eating pigeons a good example of the range of foods that hominids were exploiting.

Neandertals in Popular Culture

Our fascination with Neandertals in popular culture is a reflection of the paleoanthropological debates of our relation to Neandertals. Are they us? Are we them?

Chatelperonian

Chatelperonian is a tool industry used be Neandertals.

6.10: Denisovians

The Denisovians were another group of hominids that most group with *Homo sapiens*, but they have slightly different DNA. They have a combination of big teeth, which we usually associated with older hominids, but some complex tools and symbolic behavior that we associate with anatomically modern *Homo sapiens.*

Exercise 6.10.1

READ THIS NAT GEO INTRO TO DENISOVIAN DNA

- Another overview of Denisovians
- Genes found in Tibetans that help them survive high altitude shared with Denisovians

6.11: The Cerutti Mastodon

Wow! San Diego is on the map as a game changer in hominid evolution! Evidence that 130,000 years ago, someone cracked open the bones of mastodons with hammerstones.

VISIT THE SAN DIEGO NATURAL HISTORY MUSEUM'S EXHIBIT.

Why were they breaking bones? To get to the marrow? To shape the bone into other tools? Who were they? *Homo sapiens*? A middle Pleistocene hominid? *Homo erectus?* We didn't find any remains of the people using the tools, so we wait on future discoveries. Most evidence points to the first settlement of the Americas reliably at 15,000 years ago, or possibly as old as 30,000. But this find is so much earlier, 130,000 years ago, it really is a game changer.

6.12: Homo floresiensis

Homo floresiensis is a hominid found on Flores island in Indonesia that lived around 50,000 years ago. It is unusual for its overall small size and small brain size, but its very recent dates. Because of its small size it has been nicknamed the "hobbit".

- An explanation from 2014 of the questions about *Homo floresiensis*

Scientists often use Law of Parsimony (Occam's Razor or the Keep It Simple, Stupid principle) to interpret limited data. So since *Homo floresiensis* co-existed with both *Homo erectus* and anatomically modern *Homo sapiens*, an early research question was whether *Homo floresiensis* were descended directly from *Homo erectus* or if they are within the range of variation of *Homo sapiens*. But, recent evidence suggests the last common ancestor with *Homo floresiensis* may be much earlier, closer to *Homo habilis* than to either *H. erectus* or *H. sapiens*.

- Research from 2017 suggesting *Homo floresiensis* may be a sister species to *Homo habilis*

One of the arguments to include them as a variation of *Homo sapiens* is all of the examples of animals with smaller versions on islands. Here on the Channel Islands we find fossils of pygmy mammoths that were about the size of a pony, and today there is a species of pygmy fox. This could help explain the small stature of *Homo floresiensis*.

Exercise 6.12.1

Read about insular dwarfism

6.13: Homo naledi

Homo naledi is an amazingly large number of hominid fossils found in a cave in South Africa. The dates haven't been determined but the morphology shows fairly small brains compared to the development of their lower bodies. Also amazing is the difficult of getting bodies to the location, which implies the cultural practice of burial.

- Original article on *Homo naledi*
- The geological and taphonomic context

6.14: Anatomically Modern Homo sapiens

The phrase "anatomically modern *Homo sapiens*" is the scientific consensus for the group of hominid skeletons that everyone agrees to call "us".

Out of Africa vs. Regional Continuity Model

Chris Stringer Talk, first 18 minutes: What is the Coalescent African Origins model?

This is the end of paleoanthropology section. It brings us up to what most scientists agree is all the same species as what we are now, with no significant biological differences. There are obviously cultural differences, and you can study those if you take the Introduction to Archaeology class, but when scientists say "anatomically modern", they are saying that these hominids are biologically the same as us, and excuse the science fiction scenario, but if you somehow extracted enough DNA from one of these anatomically modern *Homo sapiens* bones found around 100,000ya, cloned it, raised it in a typical family, he or she would end up an indistinguishable member of our society.

When reading about the different models for recent human origins, you continually need to be asking yourself the question: "What is the evidence that supports this model?" Get into the nitty-gritty details. Don't worry that there is conflicting evidence, that's OK, in fact, that's typical of science. We try to keep an open mind and see both sides of an issue; it's ok to hold multiple hypotheses. This is similar to the idea I mentioned the Anthropological Imagination where anthropologists are skeptical of unicausal explanations. More evidence comes from the DNA of at least three groups of Neandertals, and another coexisting group, the Denosovians.

Even though this debate has been pretty much resolved, it is still a good example of the scientific process and complex and varied forms of evidence that anthropologists use to answer questions.

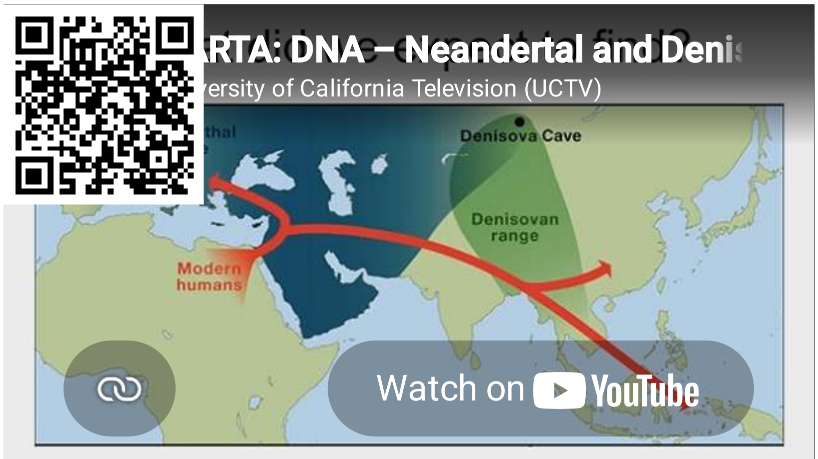
Figure 6.14.1 - *Results from Arnie Schoenberg's Genographic test*

Exercise 6.14.1

Skim Dennis O'Neil on the origins of modern humans

Watch Svante Pääbo talk about Neandertal DNA

We are still debating how much genetic material the regional continuity of hominids contributing to our modern DNA, but we don't think it's very much. We mostly come from Africa very recently. The genetic evidence points to a bottleneck event between around 50,000 to 100,000 years ago for everyone who left Africa. Genetic Drift made all non-Africans extremely homogeneous.



Upper Paleolithic Revolution

To get a sense of the Upper Paleolithic revolution try taking some of the virtual tours available for the cave art, e.g. Chauvet-Pont-d'Arc Cave. Also, compare the Lower Paleolithic and Middle Paleolithic to the Upper Paleolithic. Count how many years it takes for people to invent a way of making stone tools so different from before that it justifies a new name for the assemblage.

Exercise 6.14.2

Watch the movie: *Cave of Forgotten Dreams* Werner Herzog, 2010:

- An author searches for the origin of consciousness
- Cave painting in Indonesia
- This course really stops at the Upper Paleolithic, and you would normally take an archaeology class to learn about more recent humans:
- Ötzi the Iceman (5,000 ya in the alps)
- An update on Kennewick Man (9,000 ya in Washington state)

CHAPTER OVERVIEW

7: Human Variation

The previous paleontology and paleoanthropology sections tried to answer the question: How are humans different from other life? This section on human variation asks the question: How are humans different from each other?

Thumbnail: iwanticewater.wordpress.com/...animated-gifs/

7.1: Introduction to Human Variation

The previous paleontology and paleoanthropology sections tried to answer the question: How are humans different from other life? This section on human variation asks the question: How are humans different from each other?

Go back and review the Mendelian traits lab. Should we take everyone in class with attached earlobes and call them a race? This sounds silly, but what I hope you can appreciate is that from a biologist's perspective, assigning a race to people based on an arbitrary range of skin colors and facial features is even sillier. Anthropologists have a kind of dissociative identity disorder when it comes to race. When you ask people about human variation, the first thing that usually comes to mind is race – they acknowledge the concept. So race exists, and cultural anthropologists study it as a learned behavior. Physical anthropologists split between denying the existence of race, and seeing it empirically in bones. Forensic anthropologists still like to talk about being able to "race a bone", which means establish the ancestry of an individual from the morphology of skeletal remains. Since the early 1900s, most anthropologists in all subfields have actively opposed racism.

More biologically significant kinds of human variations include our practically invisible co-evolution with disease, and solving important riddles such as 1) If men are from Mars, and women from Venus, does that make Earthlings intersexual? and 2) What walks on four legs in the morning, two legs in the afternoon, and three legs in the evening?

7.2: Age

Humans have the longest life span of any primate. Orangutans live to be about 60 but we average another third of a life on top of that. We are the longest living out of any mammal and most life on the planet. It makes us ask why natural selection selected so many old people.

Epigenetics

Epigenetics refers to changes beyond the four forces of evolution. Your chromosomes can change during your lifetime. The term genetic mosaic refers to a group of cells in the body with variation in their DNA. Don't confuse mosaic evolution with genetic mosaicism.

Notes

DNA responds to signals from outside the cell.

Article on Genetic Mosaic in the Brain

Article on Mother's diet can lead to alterations in her child's DNA

Evo Devo

Evo Devo went beyond the Modern Synthesis and focused evolutionary theory on the development of the embryo (Stanford 2012).

Embryology

People who don't understand evolution often struggle with trying to explain why human fetuses have things that look like tails and gills.

***Figure** 7.2.2 - Embryonic stages of a bat, a gibbon and a human. Ernst Haeckel. 1905.*

But if you understand our ancestry it makes perfect sense that our DNA is just a bunch of variations away from fish DNA. There is a grandiloquent phrase to describe this phenomenon, which you can use to impress people at cocktail parties: "Ontogeny recapitulates phylogeny." Ontogeny is the development of the individual through various life stages. To recapitulate is to briefly summarize. Phylogeny is the evolution of a species, that we studied in the paleontology section. So, this idea is that the development of the individual is a brief summary of the development of the species. The idea goes way back to Lamarck's time, and has been abused and misused for a long time, and you should not think of it as a scientific law that applies to all cases, and be very vary of people who talk about our "reptilian brain", for example, because our brain is not just a fish brain, enclosed by a

reptile brain, enclosed by a human brain, and that kind of simplification can be very misleading. But, I think the idea is useful as a metaphor, something not true, but just a good reminder that we share relatives with fish, and that evolution tends to build on structures that are already there.
(see: Gould, Stephen Jay. 1977. *Ontogeny and Phylogeny*. Cambridge Mass.: Belknap Press of Harvard University Press. for more info.)

Human Life Cycles

We can use apply evolutionary theory, cellular biology, primatology, genetics, and most of the other subfields we've studied so far to better understand how humans change over our lifetimes.

Childhood

During childhood body growth slows slightly until adolescence, but brain growth peaks around age 5.

* Article on peak glucose use in childhood brains

Adolescence

Hypotheses for risk taking; insurance companies

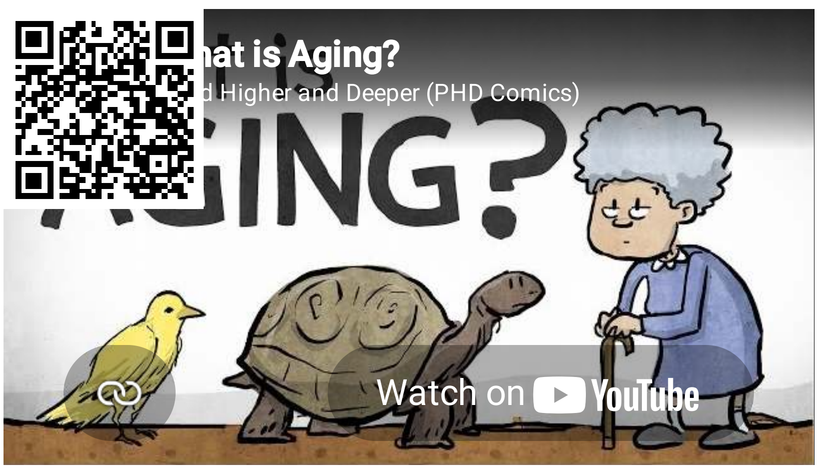
Research on Bonobo thyroid hormones and life stages vocabulary: ontogenetic

Secular Trend

The average age of menarche has continued to fall since the 1800s, and as good anthropologists we should beware of unicausal arguments and consider all the possible contributing factors, like improved diet and health, and environmental contaminations such as hormones (from discarded birth control pills and animal products) and similar chemicals found in plastics.

Senescence

One factor in both aging and epigenetic change are the ends of your chromosomes, your telomeres which tend to wear out when they get bumped around.



Grandmother Hypothesis

Most animals reproduce until they die. Natural selection selects against a"wasted" life. So why do humans live so long? Why do women tend to live so long after they stop reproducing?

> **Notes**
>
> Testing the grandmother hypothesis in Utah
>
> * with killer whales

Vocabulary

- birth
- conception
- grandmother hypothesis
- k selection
- life cycle
- menarche
- menopause
- puberty
- R selection
- secular trend
- weaning

7.3: Disease

A disease is just what it says: a “dis” - “ease”; meaning something is keeping you from being at ease, or your normal state. From a system theory approach, disease is a stressor that moves the body out of homeostasis. There are many kinds of diseases that are important to human evolutions. We've already discussed genetic diseases in section 2, but here we are going to look at human variation as a response to infectious disease.

via GIPHY

With infectious diseases, the concept of coevolution is important to understand. While humans are evolving, our diseases are also evolving (and unfortunately, usually faster than we do).

The study of diseases on a large scaled is called epidemiology.

* Article on the epidemiological transition

Looking at the history of humanity most of our genetic diseases were dealt with through natural selection. For most of history the most important disease we suffered from was malnutrition. People were more worried about starving to death than anything else. If a small band of hunter-gatherers got a bad infectious disease, they just all died, and took the disease with them. As population density increases we are are exposed to more diseases.

Most of the selection for disease resistance is at the molecular level. * Watch this example of evolution of immunity:

Paleopathology

Paleopathology is the study of the effects of disease on human remains from archaeological sites.

* “Black death skeletons reveal pitiful life of 14th-century Londoners”

Altitude Sickness

Anything that takes us out of our biological comfort zone can cause natural selection. High altitude is associated with several stressors including less available oxygen, cold, and resource scarcity. Highlanders tend to be different than lowlanders, both genetically and culturally.

Exercise 7.3.1

Read Wikipedia's description of altitude sickness

* Genes found in Tibetans that help them survive high altitude shared with Denisovians

The Epidemiological Transition

We can see human history as changes in the prevalence from one class of diseases to another.

Starvation to Infectious Disease

As hunter-gatherers the main thing that killed us was starvation. If a typical isolated band of 25-50 people caught a nasty disease, the entire band would die, and the disease would die with it.

When we started agriculture we increased population density, and became sedentary, and basically started living in our own shit, not to mention that of all our domesticated animals. Agriculture was a big trade off: we had more food and didn't starve as much, but we had to deal with more infectious diseases. Most archaeological research shows that when agriculture was introduced the population went up, but the health and life expectancy of the individual went down.

* "The Worst Mistake In The History Of The Human Race" by Jared Diamond, Prof. UCLA School of Medicine *Discover*-May 1987, pp. 64-66

Zoonosis

A vector in epidemiology refers to something that transfers the disease to the human. Many infectious diseases are transferred to humans through other animals.

Figure *7.3.1 - "Little Boy & Pig"*

One reason bats have been an important vector in diseases like Ebola is because they can fly long distances and spread the pathogens to a wide geographic area. The other reason has to do with understanding our taxonomy, our place in the animal kingdom. As mammals, bats are so similar to us that they provide almost identical environments for the pathogens to live, evolve, and then easily cross over to humans, with only small modifications necessary. This is same reason why it's especially bad for humans to eat primates. For example, earthworms get all kinds of diseases, but their anatomy is so different from ours, that you can eat a worm and the pathogens that have evolved to live in earthworms won't be able to live inside of you.

Mosquitos don't get the same diseases as we do, they function like a shared needle, in passing blood and pathogens from one person to another.

* Mosquitos decide who to bite based on your genetics

Figure *7.3.2 - Female Aedes aegypti mosquito used in the experiment to test attractiveness to odors from the hands of identical and non-identical twins. doi:10.1371/journal.pone.0122716.g001* (CC BY)

Infection to Lifestyle Diseases

We didn't evolve to sit motionless at a computer screen for hours a day. Millions of years of evolution set us up to be climbing or running around gathering and hunting for food. And for most of that time there wasn't enough food to go around. When food is too fast and too cheap we get fat. High density calories were once rare and expensive.

Most hunter-gatherers were getting most of their calories from fruits and vegetables. Meat was scarce, and the rest hadn't been invented yet.

When medicine and abundant food kept us fed and free of infectious disease, we started dying from type II diabetes and heart disease.

The idea of a "paleo diet" is to try to recreate the pre-agriculture diet.

* Too tired to chew; meat and evolution

* Article on Paleo diet

* Graph of relative cost of food worldwide

The Evolution of Infectious Disease: Pathogens Evolve Too

Remember that when we take antibiotics, we don't kill everything, and when the new population multiplies, natural selections means that they tend to have the variations that make them resistant to the antibiotics. You might expect this evolution to be slow because the variation from sexual reproduction (meiosis) is mostly absent, but you have to take into account the length of time of each generation. Human evolution is slow because it takes about 20 years from when you're born to when you reproduce, whereas baby *E. coli* bacteria are fissioning (mitosis) about 20 minutes after their born. Go back and watch the video of bacteria evolving resistance in the Mutation section.

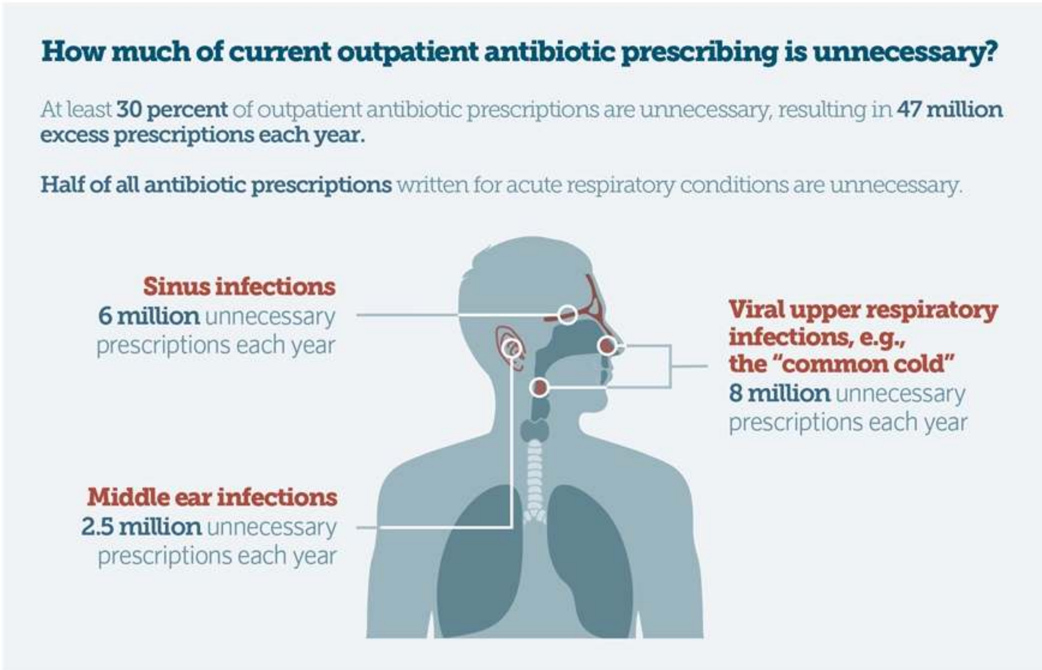


***Figure** 7.3.3 - "National Goals for Reducing Inappropriate Antibiotic Use in Outpatient Settings" 2016 Pew Charitable Trust, Antibiotic Resistance Project*

* 2014 World Health Organization report on antimicrobial resistance

* New Type of Antibiotic Resistance Raises Alarm

* Understanding sex, drugs and HIV

But not all pathogens are evolving faster that our culture can keep up with. Many viruses are slow to change, and we can actually get ahead of them if we all work together.

Should you vaccinate your child?

YES!

It's amazing to think of humans actually driving some viruses into extinction. Let's pat ourselves on the back! Vaccines have an exponential effect because of a phenomenon known as "herd immunity". When the percentage of immunized people reaches a critical level, there is hardly anyone around to spread the disease to.

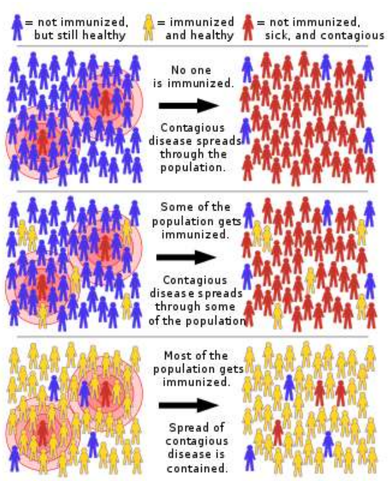


Figure 7.3.4 - Herd Immunity by Tkarcher (CC BY-SA 4.0)

* Vaccines and Autism: A Tale of Shifting Hypotheses

Pharmagenomics

Even though pathogens continue to evolve, medicine seems to be getting better because our cultural progress continues at a fast pace too. One area of growth is applying our understanding of genetics to medicine and develop individualized treatments based on a patient's genome.

* Pharmagenomics and personalized medicine

* Obama's initiative for Precision Medicine

Lactose Intolerance

Look back at our discussion of lactase persistence as a Mendelian trait. Lactase persistence means you keep producing lactase as an adult, lactose intolerance is the opposite, you can't digest milk In this section we are examining the same trait, except that we are trying to explain how natural selection may have caused it. What are the selective advantages and disadvantages to being able to digest milk as an adult? How does culture effect our biology? It's amazing to think of Nigeria the different rates of lactose tolerance of different people within the same country.

Notes

DENNIS O'NEIL ON Nutritional Adaptation

Article on the genetics of smell

Article on European Lactose Intolerance

Third epidemiological transition: new infectious diseases

New diseases are coming back with a vengeances.

Imagination Action

- Tell MacDonalds to stop overusing antibiotics
- Tell the FDA to ensure appropriate antibiotic use in animal agriculture

Vocabulary

- endemic
- epidemic
- epidemiological
- dizygotic
- infectious
- lactase
- lactose
- lifestyle disease
- monozygotic
- pandemic
- pathogen
- vector
- zoonotic

7.4: Sex

The difference between sex and gender is a great example of biocultural synthesis, but the terms can get confusing, so I've included a glossary below. Although language changes and there are gray areas, it's better to get the commonly used definition down first, and then go into to the controversies.

Sex

Sex in biological anthropology refers to whether or not when you peek inside the nucleus of each of your cells at the 23rd pair of chromosomes you see a stumpy Y chromosome or a second X chromosome (XX or XY). The 23rd chromosome codes mostly for genitals and secondary sexual characteristics like robusticity, pelvic shape, hair patterns, mammary gland function, fat distribution, and a bunch of others we're still figuring out, including maybe the structure of the brain. You can ask a forensic anthropologists what their plans for the weekend are, and with straight face, they might say, "I'm going to sex that bone on the table." We often use the terms male and female to refer to sex.

Things get confusing because cultural anthropology often borrows the other popular definition of sex, which should probably be more specifically referred to as love, affection, eroticism, coitus, genital rubbing, mounting, penetration, fertilization, insemination, or whatever is specifically being described, but our Puritan heritage tends to get in the way, and we usually blush and use a general euphemism to avoid embarrassment.

Gender

Humans tend to take biological phenomena and shroud them in all kinds of very complicated cultural trappings. Gender refers to the cultural patterns associated with sex. The fact that girls wear pink and boys wear blue is not genetically hardwired on our 23rd chromosomes, it's a cultural rule that we are taught from the first moment we're born and wrapped in a blanket that codes our respective gender, and we're taught the scripts that go along with that gender. We often use the terms man and woman to refer to gender. There is a statistical tendency for most males to be men (XY & wears blue), and most females to be women (XX & wears pink), but this is not a rule; there are also male women (XY & wears pink), and female men (XX & wears blue), and all kinds of variations between those extreme examples.

Identity

How you think of yourself.

Expression

How you express yourself to other people.

Binary

Humans like to think in twos; perhaps because 2 almost the first whole number you get to when counting, perhaps because of our bilateral symmetry that we share with all vertebrates, perhaps because of dualistic cosmologies popular around the world, such as Manichaeism. Because of the duality inherent in meiosis, your sex is mostly determined by whether your father contributed an X or a Y 23rd chromosome.

Spectrum

A continuum, the opposite of binary. Polygenic traits are expressed as clines, like the way a meteorologist doesn't just tell you it's cold here and it's hot there, but they show a map with concentric smooth polygons with temperatures. Even though your biological sex is mostly binary, it is also on a continuum.

Sexual Dimorphism

"Sexual" refers to male or female. "di" means two. "morph" means shape. The term refers to the biological differences between males and females of the same species.

Sexual Orientation

"Sexual" refers to eroticism. Whom your body feels attracted to.

Sexual Preference

"Sexual" refers to eroticism. Whom you prefer to be erotic with. "Orientation" implies more biological determinism than "preference", and since most people don't have conscious control over whom they're attracted to, "orientation" is usually more accurate.

Sexual Selection

"Sexual" refers to eroticism and male or female. This is Charles Darwin's term for the kind of natural selection that was more about reproduction (which implies fertilization)

Homosexual

"Homo" means same, like our genus name, which refers to how these hominids are the same as us. The "sexual" part is very ambiguous, and includes both definitions of sex mentioned above and often gender. A more accurate term might be "homosex(gender)sexuality" but please don't start using it. "Hetero" means different. "Bi" means both. This term is being phased out because of its use in portraying sexuality as mental illness.

Gay

A man or male who is erotic with men or males, can be broadened to someone who is erotic with the same sex/gender (also, someone who is happy)

Lesbian

A woman or female who is erotic with women or females (also, someone from the Greek island of Lesbos)

Transgender

A general term for males who adopt women's culture, and females who adopt men's culture.

Crossdresser

Men or males who wear women's clothes; women or females who wear men's clothes, without any implications of eroticism. Crossdressers are often heterosexual.

Transvestite

"Trans" means across, "vest" means clothing. An older term with the same word roots as crossdresser but has more of an erotic connotation.

Transexual

"Sexual" here refers to male or female. Someone who is in the wrong body, and may take hormone supplements and have sexual reassignment surgery to change sexual characteristics of their body. The term is being phased out because it sounds too clinical. "Cissexual" is the opposite, people who feel they were born in the right body.

Trans*

A catch-all term for gender variation

Intersexed

"Sex" here refers to male or female, "inter" means in between. Non-disjunction of the 23rd chromosome, crossing over of the SRY gene, genes that interfere with sex determining hormones, and other factors can effect the genetic coding and expression of genitals and secondary sexual characteristics, so that many individuals are born not fitting neatly into the extreme biological stereotypes of male and female. The old term for this was “hermaphrodite” (from a Greek myth about the child of Hermes and Aphrodite).

Queer

A once derogatory term that has been reclaimed as a catch-all for variations of the terms above. (>also, someone who is strange)

-phobia

"fear of [...]"

You might expect something like sex and eroticism to be wrapped-up with fear and anxiety. Many anthropologists such as Margaret Mead have argued that the fear of sex is culturally determined and is not universally present in all societies and we can find many variations of sexual and gender roles, such as the Twin Spirits, Hijra, Etoro and Sambia warriors, etc. This suggests that our own culture's transphobias, homophobias, and genderphobias are not biologically determined, and can be easily changed through education and political action.

The glossary was adapted from the National Center for Transgender Equality and Gay Alliance

It's important to remember that most of these terms are adjectives that make small qualifications to the main identity of the subject; most of these terms should be followed by the most important word, "person", and we need to remember how small (if any) a genetic variation we are talking about; we may make a big deal about this part of someone's social identity, but on the genetic level it represents an insignificant difference between people.

Notes

5 part video series by Desmond Morris “The Human Sexes” 1997

Blog post on sex as a social construct

Watch Alpha male, non human primates and humans

The Mask You Live In, America's narrow definition of masculinity

Sex differences in how cold to set the air conditioner

Article on atrazine and chemical castration

An article about South African athlete Caster Semenya and how sports struggles with the grey areas between and within, sex and gender.

The International Association of Athletics Federations releases new rules for "female classification" based mostly on hormone levels

Museum of Menstruation and Women's Health

Guevedoces: girls who become boys during puberty

Article on variable expression of the SRY gene

Theories for why men have descended testicles.

Correlation between testes size and child nurturing: "Evolutionary Life History Theory posits that evolution optimizes the allocation of resources toward either mating or parenting so as to maximize fitness."

Why men have nipples

Neurosexism: Male and female brains

Article on gay genes

Imagination Questions

- Does thinking about the biology of humans affect your views on gender identity and sexual orientation?
- Read the article describing how stem cell advances may allow gay and lesbian couples to have biological children.

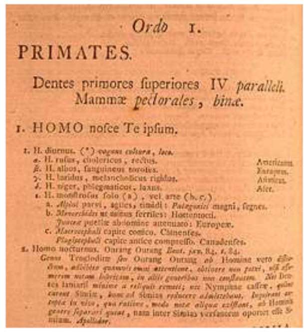
Why would gay men be able to have sons and daughters, but lesbian women only be able to have daughters?

How much of what it means to be a man or a woman is based on biology, and how much is culture?

7.5: Race

All the categories of human variation in this section (age, sex, disease, race) have some basis in biology, but this last one is the most arbitrary out of all of them. The decision to group people based on superficial visual characteristics is not founded in absolute biological difference, but in a long history of cultural difference. Race is culture, not biology. We have a cultural tendency to cram human variation into racial categories.

We are stuck with lots of baggage from scientists who got it wrong.


Ordo I.

PRIMATES.

Dentes primores ſuperiores IV *paralleli.*
Mammæ *pectorales*, *binæ.*

1. HOMO noſce Te ipſum.

Figure 7.5.1 - *Linnaeus on human races*

In this schema Linnaeus sets up categories based on geography and cultural stereotypes, and mixes them in with biological taxonomy. This error of conflating culture and biology has been repeated for centuries, and continues to this day.

Physical anthropology is great at explaining why biological divisions between human races don't exist, but we can also suggest how we got into this mess in the first place, and why humans might be predisposed to getting it wrong. Race is an optical illusion, and our dependence on creating the world based on what we see can be explained in terms of the evolution of primates and our shift in sensory priorities from olfaction to vision. Compared to most mammals primates see better than they smell. The visual predation hypothesis suggests how the forward facing eyes of small carnivores predisposed them towards the binocular vision required by life in the trees. The consequences of failing to predict the correct distance of a branch can be deadly, and genes for visual acuity tend to get passed on to the next generation. Millions of years adapting to life in the trees led to primates generalized diet, including fruits. Color distinctions, especially in diurnal primates, are useful to discern whether fruit is ripe from a long distance. As we came down from the trees, the neocortex used in vision was re-purposed for increased cultural complexity such as social structure and tool use, and although encephalization has tripled the sized of our brains, we retain the vestigial primate emphasis on vision over smell. We emphasize the visually apparent differences between people because that's what our species is biologically set up to do. Dogs judge other dogs by their smell. Whales judge other whales by their songs. Bats judge other bats through echolocation. Spiders judge other spiders by their vibrations. Duck-billed platypuses judge others by their electromagnetic radiation. Trees judge other trees through mycelial networks. We look at skin color, body type, and facial features. These visual markers may seem critical to us, but they don't represent enough biological difference to separate people into significant groups.

Racism

Racism is the belief that there are discrete racial groups that can be ranked from good to bad. I have a pure-bred dog with an AKA pedigree and all, and it kind of creeps me out a little to see how seriously some of these dog breeders take their work, it reminds of the eugenics movement. Eugenics is the application of racial ideas to public policy. We blame Hitler for the most horrible atrocity in history while striving to create the master race, but many of his ideas came from the eugenics movement in the United States.

Eugenics

- Article about California's role in the eugenics movement
- It was also popular in Latin America, here's an example of eugenics in Veracruz, Mexico
- Update on Racial profiling in NYPD stop and frisk policy
- Traffic enforcement in San Diego, California An analysis of SDPD vehicle stops in 2014 and 2015
- Op Ed about Census racial categories

Eugenics and Donald Trump

Race Without Racism?

I don't think it's possible to study race without taking sides, either for or against racism, but the study of human variation does lead to some "neutral" generalizable rules about the visual characteristics we use to determine race. Most forensic anthropologists argue that they can empirically determine the race of a bone, and they get it right about 2/3 of the time.

Exercise 7.5.1

- SKIM THE AMERICAN ANTHROPOLOGICAL ASSOCIATION COMPANION SITE TO THEIR EXHIBITION ON RACE.
- READ DENNIS O'NEIL ON HUMAN VARIATION
- Review Dennis O'Neil on Non random mating, an argument against people tending to choose mates from within their own race is the research on HLA and the immune system

- Distribution of Y chromosomes among Native North Americans: A study of Athapaskan population history Question: Why does Y chromosome analysis reveal a greater admixture with Europeans than MtDNA analysis?
- Red hair is a good example of convergent evolution, people in many different regions around the world have different kinds of red hair, and our culture deals with it in radically different ways. Read Wikipedia on red hair
- Genetic diversity in Latinos enables chromosome mapping

Gloger's Rule

Mammals tend to have darker skin towards the equator and lighter skin towards the poles.

Exercise 7.5.2

READ THE WIKIPEDIA ENTRY ON GLOGER'S RULE

Read Peter Elias' research on filaggrin mutations, another protein like melanin that helps protect the skin.

Remember, the fact that we can study skin color scientifically doesn't mean that races are scientifically valid categories. Races are cultural defined, not biologically. Humans, as primates, tend to be visually oriented, so it makes sense how we might create folk taxonomies based on colors.

- Article on different genes that cause skin color

Allometry

Other visual ways of categorizing humans is by body types and features, and many variations can be explained through natural selection. Allometry is the change in body shape when a population gets bigger or smaller depending on environmental condition. We've already had a great example in paleoanthropology of *Homo floresiensis*, the "Hobbit", a small hominin found on a small island in Indonesia. We attribute the small size to insular dwarfism, a principle seen in other island species; the limited island resources select for small body size.

Exercise 7.5.3

Read more about allometry

Bergman's Rule

To understand Bergman's rule think of the best and worst radiator design, and ways to maximize and minimize the surface area to mass ratio which allows heat to dissipate or be conserved. A car radiator is made with lots of flat fins for the air to pass through and wick the heat away. Some of the most efficient igluit are almost spherical to minimize the area that will dissipate heat. Natural selection tends to make humans and other mammals that way too. If you live in a hot place and need to dissipate heat, you tend to have more surface area and less mass; you're gracile. If you live in a cold place and need to conserve heat, you tend to have more mass and less surface area; you're robust. This is the best explanation for the robusticity of Neandertals: they evolved during the ice ages. The principle also explains some differences between modern regional populations.

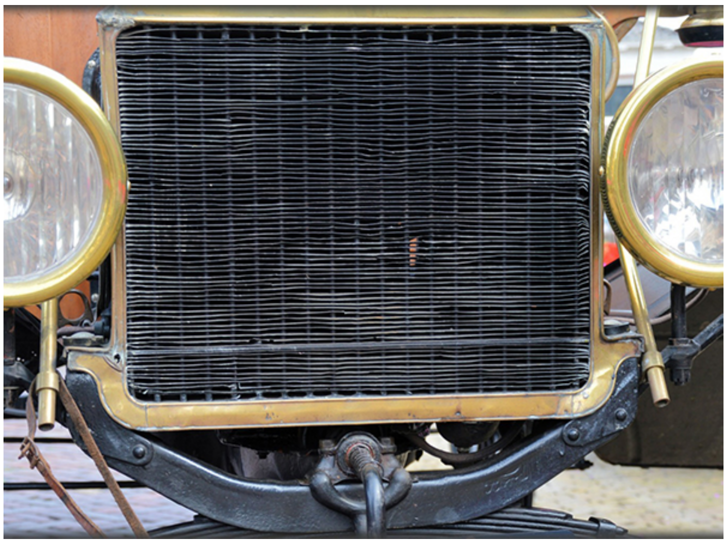


Figure $7.5.2$ *- A car radiator*

Figure $7.5.3$ *- igluviak in Oopungnewing from Charles Francis Hall's* Life with the Esquimaux*, 1865 (public domain)*

Allen's Rule

The radiator analogy works for Allen's rule too, the longer the appendages the better they work to release heat, and the shorter the appendages, the more heat is conserved. So people who live in cold climates for long periods of time, tend to have shorter arms and legs than people who live in hot climates.

These rules apply to most animal. Bears are great example: compare the long-legged tropical Sun Bear to the short-legged Polar bear. Human populations tend to follow this, for example the arctic Inuit tend to be stocky with short arms and legs compared to the Woodabe of sub-Saharan Africa who tend to be tall and thin. But there are some counterexamples as well, the Aka live fairly close to the Woodabe, but they tend to be short. This counterexample is probably best explained as part of the amazing human diversity on the African continent, where human evolution has occurred for the longest.

Exercise 7.5.1: Imagination Actions

Take this quiz about the history of slavery in the US, and write about what you learned.

Vocabulary

- allometry
- Allen's rule
- Bergman's rule
- blood types
- cline
- endogamy
- essentialism
- exogamy
- eugenics
- Gloger's rule
- haplogroup
- race
- racism
- Y chromosome

7.6: Culture

Now that we've almost finished introducing physical anthropology, it is a good time to remember how small the effect of our biology is on who we are. Yes, I'm telling you that everything you've learned up to now about the biological origins of humanity is mostly insignificant. Most research into human behavior finds biology as a almost insignificant causal factor compared to culture. We didn't evolve to be who we are, as much as we learned to be who we are. Most of who we are is determined by how we grow up: what language we speak, our religion, our favorite flavor of ice cream, our views on existentialism, what we laugh about, what we cry about.

We can accept that we are both: that biology got us most of way in the past, but by now culture has mostly taken over. The holistic approach of anthropology lets us avoid extreme views of cultural determinism or biological determinism, and we can hold seemingly contradictory views, such as bio-cultural evolution. Anthropology's skepticism of unicausal explanations makes it reluctant to force a broad unifying theory on situations where there are too many counter examples.

Biologically analogies of culture are often misused. Recapitulation theory ("ontogeny recapitulates phylogeny") notices that human fetuses have proto gill slits, but that doesn't make us fish, and the analogy breaks down even more when applied neurology or art criticism. **Social Darwinism** says that poor people deserve to die because they're not fit for society, and Darwin never said or implied this. The theory of Mimetics claims that internet memes follow the same principals of Natural Selection that genes do, but they don't. They don't reproduce in the same way, they don't have introns and exons, and the way they changes is more like what Lamarck described than Darwin. Have you ever heard that expression that people use to talk about how much they like a certain sports team that “it's part of our DNA”? I'd like to say that people who use that phrase are genetically stupid, but the research fails to show causation between genetics and IQ at this level. It's not in their DNA. It's in their brain. They learned it. These are examples of a general tendency to abuse biological principles and try to apply them metaphorically to cultural situations, and a kind of logical fallacy often known as a *weak analogy*; trying to compare apples and oranges.

As we have seen in previous sections on human variation, culture is more important than biology. Whether you get an infectious disease depends mostly on your access to clean water. Your 23rd chromosomes do NOT determine your gender; it's about your clothes, and what pronouns you use. Biological human races do NOT exist, but many cultures reify them as folk taxonomies.

Most anthropology programs separate physical (biological) anthropology from cultural anthropology because the methods and the data tend to be different, but the goal is the same. The holistic approach of anthropology is good at balancing these multiple causal factors of nature versus nurture, biology versus culture. Other branches of science do this as well, such as in behavioral ecology.

Exercise 7.6.1

- Go back and review the epigenetics section.
- Read a good review: "Culture Is Essential" the first chapter of *Not By Genes Alone: How Culture Transformed Human Evolution*, by Peter J. Richerson and Robert Boyd, 2005.

Class

How much money your family has effect you biologically. Your DNA directs your cells to produce proteins to maintain normal functions, but if you lack the energy and building blocks to produce the proteins, there is no way to reach your genetic potential. The human body has an amazing plastic to survive starvation, and this is a testament to evolutionary forces acting on our ancestors. The most significant stressors on the human body have to do with class: malnutrition, lack of clean water, exposure to harsh weather, exposure to pollution.

Notes

Stress can permanently effect your DNA

Cesarean delivery may provoke methylation that changes the genetics of a baby

Intersectionality

The intersection between biological and cultural identities can a cumulative effect.

* Traumatic stress changes brains of boys, girls differently

Art

Much of what we think is beautiful is determined by genetic factors that can be explained through natural selection and our evolution. The *kawaii* (cuteness) of manga and anime that elicits that sigh of "ahhh", happens because of our nurturing instinct towards neotony.

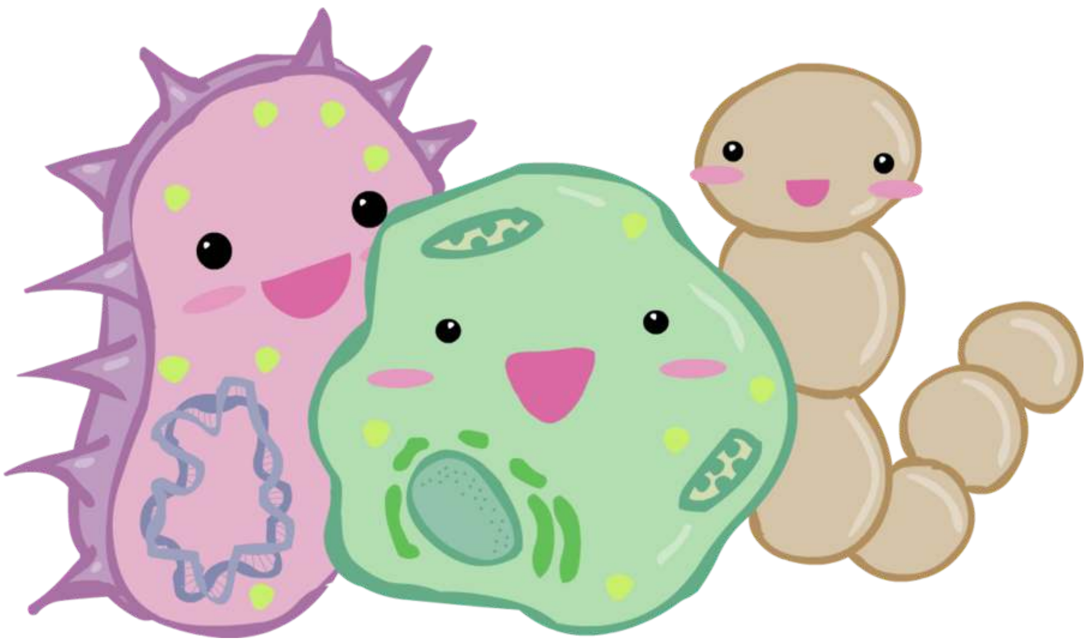


Figure 7.6.1 - *Bacteria by* pngimg.com (CC BY-NC)

The presence of trees in beautiful landscapes, both in paintings and gardens, happens because the arboreal past that we share with primates triggers some set of neurons that were determined by genes to makes us feel good.

These pathways from gene to neuron to behavior are very difficult to trace, and this makes for exciting research in the years to come.

Notes

Denis Dutton article on Evolutionary Aesthetics

Creativity in Human Evolution and Prehistory, an edited book with several good articles

Evolutionary Approaches to Creativity

Sexy Handaxes

Music

Music is a good example of a complex response to the nature vs nurture question. What kind of music you like is determined by the culture you grow up with. The fact that every culture around the world has music suggests that humans are biologically determined to be musical.

An overview on *singing and human evolution.

Cyborgs

Popular culture thinks of cyborgs as the extreme half-robot, half-human, but thinking about human dependence on culture to augment their physical bodies, we can see that the human cyborg is not science fiction, but part of a continuum that spans our primate tool-using ancestors to the amazing interfaces of today. Human evolution, cultural progression, and the history of technology can be thought of not as some line we've crossed between "natural" and "machine" but just a question of degree, how sophisticated are the tools.

Humans use their bodies to modify the natural world, as we saw in the art of the Paleolithic revolution, but humans also use the natural world to modify their bodies. The Bafia of Cameroon believe that without scarification they are no better than monkeys or pigs (Pitt-River's Museum, Body Art). Modification sets us apart from other animals.

> **Notes**
>
> Brain machine interface
>
> Donna J. Haraway Simians, Cyborgs, and Women: The Reinvention of Nature 1989

Terraforming

Homo sapiens have transformed Earth to meet their culture needs. Since prehistoric times, our subsistence practices have changed ecosystems on a planetary scale: industrialism, deforestation, agriculture, domestication.

* 33,000 years of Man's best friend in southern East Asia

CHAPTER OVERVIEW

8: Homo sapiens Futures - Doom, Gloom, and Hope?

Thumbnail: cjohnson7 from Rochester, Minnesota

8.1: Introduction

I don't know a better way to say it, but as a species we've pretty much permanently screwed-up our planet. The real question is "What now?" Do we continue our nihilist craze to destroy the rest before going extinct, or do we try to salvage and restore as much we can? Most people in the Abrahamic Western tradition (Judeo-Christian-Islamic) have been enculturated to regard nature as something that needs to be dominated. Many Christians believe the hastened destruction of our world should be encouraged because it is a prerequisite for The Second Coming. Our current capitalist economy translates the domination of nature into the inalienable rights of the individual to exploit natural resources, even non-renewable ones, without taking into consideration the consequences for future generations. And to better use up those natural resources, capitalism creates a culture of consumerism, where our happiness is measured by conspicuous consumption.

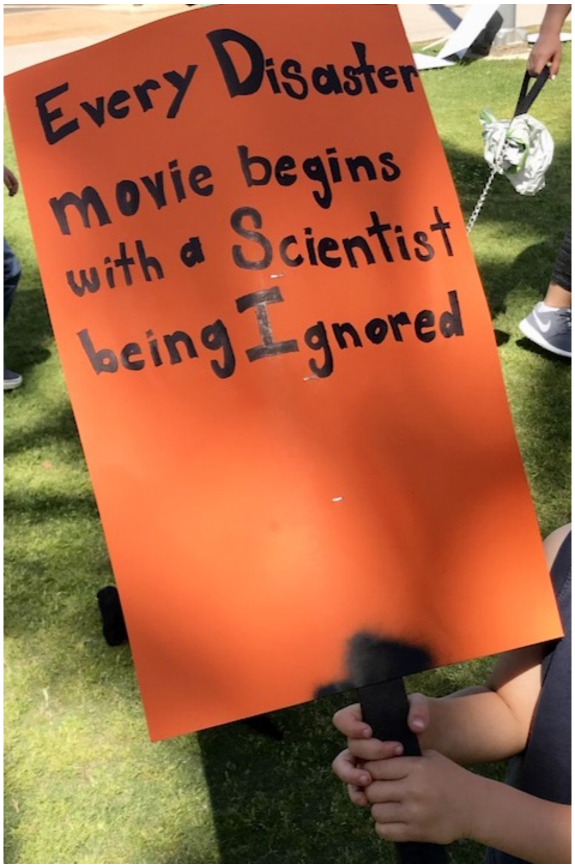


Figure 8.1.1 - *2018 San Diego March for Science*

How could a sane hominid have such low self-esteem that they would take a credit card to a shopping mall to buy things they don't really need, from a factory in China that uses slave labor and bribes its way out of pollution controls, to the point where they're in debt and need to burn non-renewable fossil fuels sitting in rush hour traffic for hours every day to pay off the interest on their card, to the point where if you asked them to help solve some of the problems that effect their fellow hominids, they would respond that they don't have any free time, or they're afraid of getting fired if they speak up?

So where's the hope?

I hope you got a sense in this class of the difference between culture and biology, and in this case, the difference between biological change and cultural change, especially in terms of time, the rate of change, how much faster culture can change compared to biology. When we talk about drastic biological change we can talk about evolution and the adaptive radiation of large groups of species into ecological niches over millions of years. When we talk about drastic cultural change we are talking about revolution. In an instant of geological time, our species went from crude tools to stunningly beautiful cave art in what we studied as the Upper

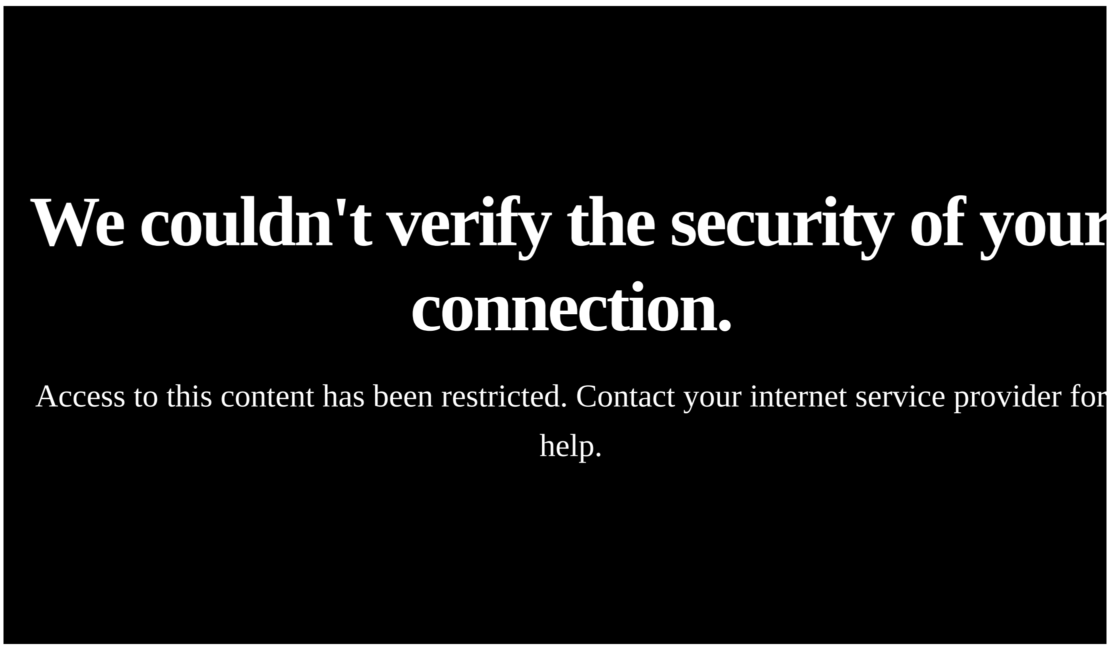
Paleolithic revolution. I find hope in knowing how fast culture can change, that in the blink of an eye, the crude ideology of our dominant hominid could be replaced by something much more beautiful.

8.2: Doom and Gloom

> *we must acknowledge, as it seems to me, that man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his god-like intellect which has penetrated into the movements and constitution of the solar system—with all these exalted powers—Man still bears in his bodily frame the indelible stamp of his lowly origin. [Darwin 1871:405]*

Overpopulation

The word *overpopulation* is very subjective. There is no scientific way to decide how many people is too much. It is more of an aesthetic question: like would you prefer to live in a huge mansion all by yourself, or in a one-bedroom apartment with 10 roomates? Most people would choose something in between, probably leaning towards the mansion. The science of population change is called *demography*, literally a "map of people/districts", and the science has mapped a population explosion in the last eye-blink of human evolution. We are rapidly heading towards the one-bedroom apartment with 10 roomates, and the ensuing drama is taking place on a global scale.



Notes

World Population from Population Education on Vimeo.

Population growth

Where do you fit into the 7 billion?

Bioanthropological perspective: McKee, Jeffery 2012 “The Human Population Footprint on Global Biodiversity”

Video on transhumance

Loss of Biodiversity

Should we care about any other species besides our own? This question is like asking "Should I care about anyone else besides myself?" on a larger scale. Most people care about at least some of their family members. Through the genealogical emphasis of anthropology, many people can extend their altruism to include broader categories of people they're not related too, people of different "races", and hopefully other species.

To me biodiversity is an aesthetic question. Complex ecosystems are beautiful. Do you want kids to grow up in a world where the only other life they know is cockroaches, mosquitos, rats, and pigeons? Review the section on primate extinction

> **NoteS**
>
> Megafauna extinction due to humans
>
> Humans as super-predators

Global Warming

If you compare a graph of population growth and average temperature you can see the correlation between human overpopulation and climate change. How much CO2 was produced by 6,000,000 (6 million) hunter-gatherers sitting around campfires? Almost nothing! That's about the equivalent of one campfire every two hundred square miles. How much CO_2 is produced by 6,000,000,000 (6 billion) people who are driving, consuming, deforesting? Our ecological footprint is massive compared to our hunter-gatherer ancestors, and there are thousand times more of us.

We should expect both massive extinction and some evolution as variations in populations are selected for in the new ecological niches caused by extreme weather, drought, flooding, acidification of the oceans. Global warming will cause more people to die of starvation and infectious disease. Many plants and animals will go extinct, humans will use cultural adaptations to survive, but it will be very painful and expensive, and the longer will put our heads in the sand and ignore the problem, the worse it will be.

> **Notes**
>
> Comparing human caused extinction to other mass extinctions
>
> An economic approach, the environment as an "externality"

Pollution

Geological periods are usually bracketed by climate change and major extinction, and they are based on empirical evidence that a geologist with a rock hammer can go out and find. Human effects on the environment have begun to show up in the field of geology:

- "An anthropogenic marker horizon in the future rock record"

8.3: Hope

Is there hope for the human species? I think so. We have a millions of years before the sun engulfs us. One of the lessons of evolutionary psychology is that we do have free-will and we are not slaves to our instincts. The *Upper Paleolithic revolution* is an example of how quickly we can change. Skim the section on primate ethology. I believe understanding the primate origin of human behaviors helps us make cultural choices about how to suppress or embrace them.

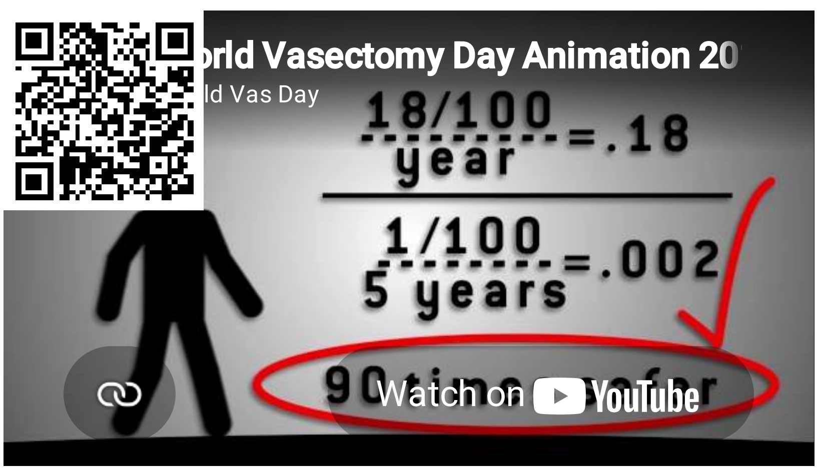
We are starting to grant legal rights for non-human primates, Here's an example in Argentina. If you haven't already, read the the bee keepers for primate conservation article

* Primate have a sense of justice and reconciliation:

Exercise 8.3.1

WATCH THIS JANE GOODALL INTERVIEW

* "Get Whacked for Wildlife" 2016 campaign:



> *"Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has." -Margaret Mead*

Imagination Actions

- Take this World Population Knowledge Quiz
- Volunteer with a non-profit group working to increase hope in the world

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