

Astronomy 330



This class (Lecture 19):
Origin of Intelligence
Lauren Yang

Next Class:
Cultural Evolution
Kevin Homann

HW7 is due Thursday

Music: *Intelligent Guy*– Butthole Surfers

Outline



- Genetic diversity leads to diversity of life.
- Evolution on Earth leads to complexity.
 - As measured in stored info and in brains
- Intelligence an outcome of this diversity

Presentations



- Lauren Yang
[Aliens in Pop Culture](#)

Drake Equation

Frank Drake



That's 1.59 life systems/decade



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

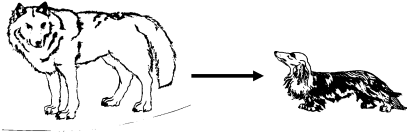
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that communicate	Lifetime of advanced civilizations
	15 stars/yr	0.65 systems/star	1.3 × 0.1 = 0.13 planets/system	0.125 life/planet	intel./life	comm./intel.	yrs/comm.

Does Mutant Sex take a long time?



Cabbage, kale, kohlrabi, brussels sprouts, cauliflower and broccoli have same common ancestor– wild mustard. All bred by humans on a very short time scale.

This is selective breeding, but still the potential is in the DNA.



Or domestic lap dogs from wolves in about 5000 years.

Question



Sex in space, or on Earth, is important because

- a) sex, although fun, also stimulates gene mutations.
- b) it allows the genetic material of the better organisms to survive.
- c) mutations can only occur in sexual reproduction.
- d) it leads to greater genetic diversity and an increase of positive mutations in the offspring.

Comparing Ages

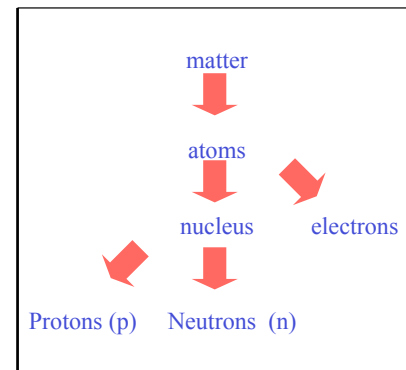


- Important to understand history of Earth life is the ability to age different components
- Can be difficult
- Radioactive dating....
 - ^{14}C for the last 60,000 years
 - ^{40}K and ^{235}U for 100's of millions of years

Radioactive Dating



Recall:



- Most atomic nuclei stable
 - But some nuclei are unstable.
⇒ decay to new nucleus
“radioactive”
-
- Energy
- Radiation
- Particle
- Radioactive Atom

The Law of Radioactive Decay



As radioactive “parent” decays, the number of decay product or “daughters” increases

Decay Rule
Start out with N parents, 0 daughters

Time t since start	# parents	# daughters
0	N	0
$t_{1/2}$	$\frac{1}{2} N = \text{half as much}$	$\frac{1}{2} N \text{ have appeared}$
$2t_{1/2}$	$\frac{1}{4} N = \text{half again as much}$	$\frac{3}{4} N$
$3t_{1/2}$	$\frac{1}{8} N$	$\frac{7}{8} N$
$30t_{1/2}$	About $N/10^9$	$99.999999\% N$

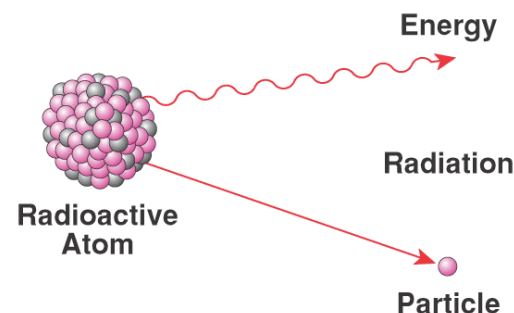
Decay is a good “clock”

- Each radioactive species has different “tick”
- Rate= ”half-life”
- Exponential decay from original population of n_0

Radioactive Decay Examples



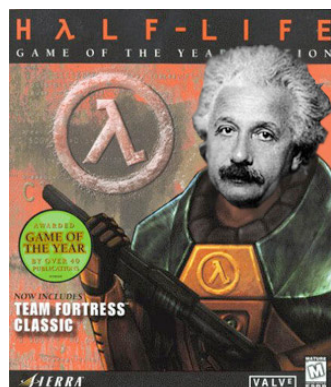
http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html



Carbon-14



- Cosmic rays from space are constantly hitting the Earth.
- React with ^{14}N in atmosphere to create ^{14}C .
- Decays back to ^{14}N with half life of 5730 years.
- But, there is an equilibrium in abundance
- In atmosphere, the ^{14}C is mostly in $^{14}\text{CO}_2$.



http://bbspot.com/Images/News_Features/2003/12/half-life.jpg

Carbon-14



- Plants take in $^{14}\text{CO}_2$ with the $^{12}\text{CO}_2$ and other animals eat the plants.
- So, every living creature has a equilibrium ratio of $^{14}\text{CO}_2/^{12}\text{CO}_2$.
- When the organism dies, the ^{14}C decays to ^{14}N . By measuring how much ^{14}C remains, you can date the fossil.
- This works well to about 60,000 years.
 - Viking remains in Newfoundland– 500 yrs before Columbus.
 - Shroud of Turin to 1330 AD

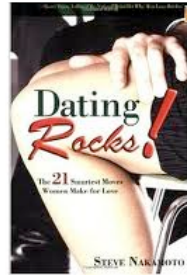
<http://web.mit.edu/smcguire/www/newfoundland/newf16.html>



Dating Rocks



- First you ask them out?
- No, you need a radioactive decay that has a longer half-life than ^{14}C .
- Potassium-argon
 - ^{40}K decays to ^{40}Ar with a 1200 Myr half-life.
- Uranium-lead
 - ^{235}U to ^{207}Pb with 700 Myr half-life.



Dating Rocks



- But these only work with volcanic layers.
- So, the ages of fossils are interpolated from ages of volcanic layers above and below them.



<i>Era</i>	<i>Period</i>	<i>Myr Ago</i>	<i>Life Forms</i>	<i>Events</i>
Cenozoic	Quaternary	2	H. Sapiens	Ice ages
	Tertiary	65	Primates	Extinction of Dinosaurs
Mesozoic	Cretaceous	136	Birds	S. Atlantic open to 1900 miles
	Jurassic	190		N. Atlantic open to 600 miles
Paleozoic	Triassic	225	Mammals	Continental drift
	Permian	280	Reptiles	Pangaea breaks up
	Carboniferous	345	Amphibians	Formation of coal
	Devonian	395	Insects	
	Silurian	430	Land Plants	
	Ordovician	500	Fish	
Precambrian	Cambrian	543	Trilobites	
		545	Small Shelly Fossils	
		580	Ediacarans	
		600-800	Multicellular life	Snowball Earth episodes

Increase of Complexity



- Last table showed only the last 800 Myrs.
- The more complex and intelligent organisms appeared towards the end.
- For many years it was thought that life originated in the Cambrian era, then Precambrian fossils were found.
- Then, it was realized that there were single-celled fossils that required microscopes.

<i>Myr Ago</i>	<i>Era</i>	<i>Event</i>
Now	Cenozoic	
	Mesozoic	
	Paleozoic	Macroscopic life/Snowball Earth
	Precambrian	
1000		Worm tracks
		Multicellular algae
		Eukaryotes certain
		Sexual reproduction
2000		Eukaryotes possible
	Protozoic	Oxygen-rich atmosphere
		Snowball Earth
		Formation of continents
3000	Archean	Life begins?
4000		Formation of Oceans
		Bombardment decreases
		Frequent impacts
	Hadean	Earth formed

Concepts



- As prokaryotes are simpler than eukaryotes, we expect them to exist first.
- Identifying fossil prokaryotes is difficult: they're tiny!
- But there is enough evidence that before 1500-2000 Myrs ago there are only prokaryotes fossils.
- Note: the oldest fossils (3800 Myrs ago) are under some dispute, but the 2800 Myr old fossils are universally accepted.
- All of the macroscopic life only arose in the last 600 Myrs– 1/6th of the history of life on Earth.



<http://www.earth.ox.ac.uk/research/geobiology/geobiology.htm>

Early Earth

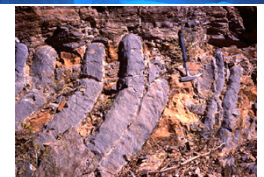
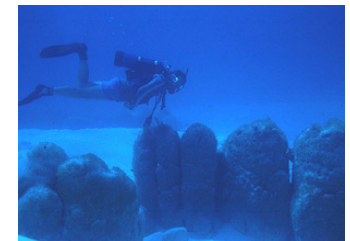


- We've talked about the Early Earth's atmosphere– mostly N and CO₂, which dominated the atmosphere for the **first 3 billion years!**
- But life was polluting the planet even then.



Making Oxygen!

- The early prokaryotes played a crucial role for life on Earth by producing oxygen through photosynthesis.
- Cyanobacteria (also called blue-green algae) changed the world!
- Lived in colonies that formed mats or films, growing into large structures called stromatolites.
- Still around, but much more common before 700 Myrs ago.



Making Oxygen!

- About 2 billion years ago atmosphere became oxygenated!
- Probably killed off many species.
- But, oxygen was new and important step in intelligence
- It allowed a new energy extraction method
 - Aerobic (using oxygen) metabolism
 - More complex life
 - Created ozone layer (dry land now an option for life on Earth!)



Question



The Early Earth's oxygen in our atmosphere came from

- a) trees.
- b) colonies of cyanobacteria.
- c) comets.
- d) colonies of plankton.
- e) outer space.

Relationship to ETs



- Would evolution on other planets have a similar time-scale?
- Evolution is not a deterministic process.
- Selection seems to be mostly luck, rather than adaptation.
- On the other hand, many traits have developed in several lineages– warm blood and eyes.
- Some say that intelligence seems to increase in many lineages, so it is likely that if life exists then intelligent life exists.
- On the other hand, the plant kingdom never developed neurons.

Summary



- This following slides are from:
<http://www.udayton.edu/~INSS/>
- Nice timeline of life on Earth.

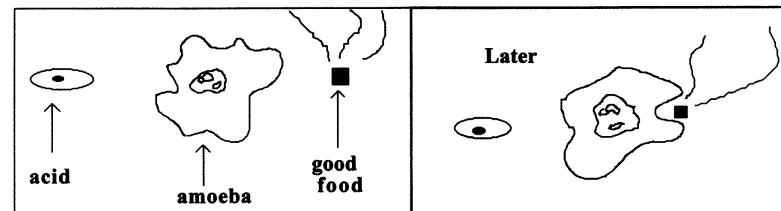


Evolution of Intelligence

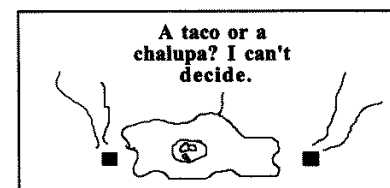


- Through diversity, evolution has resulted in an increase in the complexity of organisms on Earth.
- Can we associate complexity with intelligence?
- If intelligence is an advantageous trait, it is plausible that intelligence would increase over time.
- But, what is intelligence?

An Amoeba Distinguishes



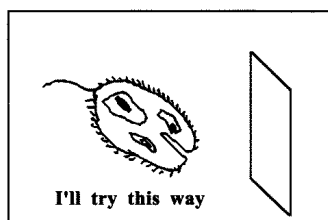
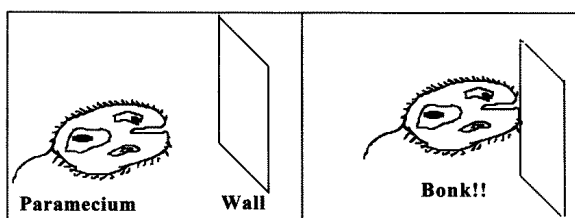
- Has a model of its environment.
- What if two pieces of food are placed nearby?



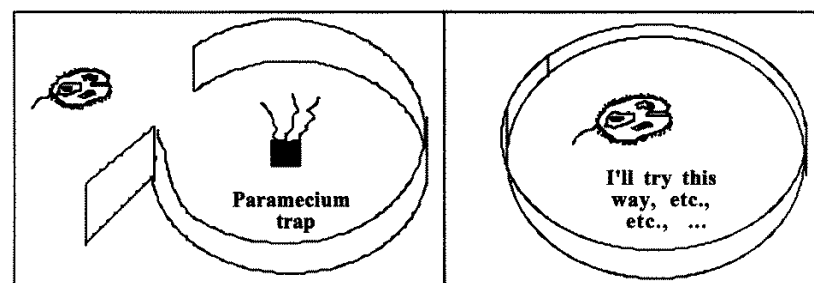
The Intelligent Paramecium?



- Still one celled, but more complex.
- Has a kind of primitive memory.



Intelligence Breakdown



- Doesn't realize to give up.
- Smarter than the amoeba, but no genius.
- With complexity does come some intelligence.
- There seems to be a continuum of intelligence.



Evolution of Intelligence



- A general definition is “the ability to model the world, including the organism’s own self”.
- But even single-celled animals seem to be able to do that to some degree.
- Can think of intelligence as a continuum, not a unique aspect of humans.
- Why then, does there seem to be a gap between us and the rest of life on Earth?



Origin of Human Intelligence



- If we view intelligence as a continuum, then we are not essentially different than other organisms.
- Still need a quantitative measure of intelligence.
- Intelligence could be defined by the amount of information stored in the organism. DNA storage.



Spottet Dolphins sounds
<http://neptune.atlantis-intl.com/dolphins/sounds.html>

DNA Storage

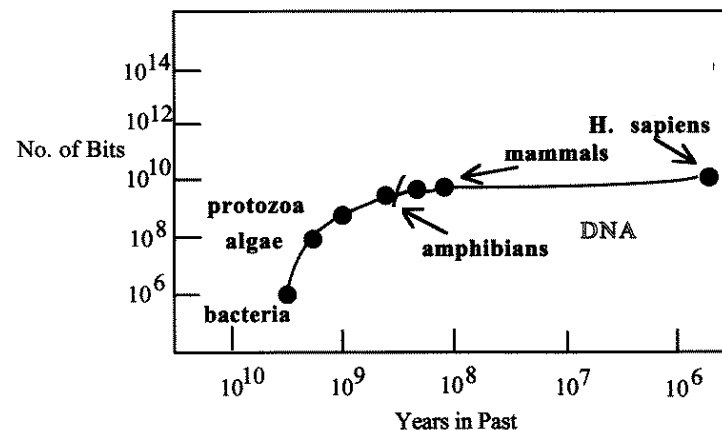


- We'll use bits of information
 - Yes = 1
 - No = 0
- Each DNA base has 2 bits of information– 4 options.
- Each codon has 3 bases or 6 bits (3×2)
- Humans have (3×10^9) bases $\times$ 2 bits per base = 6×10^9 bits (~750 Mbytes), like 4000 books of 500 pages.



Spottet Dolphins sounds
<http://neptune.atlantis-intl.com/dolphins/sounds.html>

Development of Intelligence



Caveats



- Existence of large amount of “junk DNA” makes it problematic to measure intelligence by number of DNA possibilities
 - Only about 2% of human DNA seems to actually code proteins, then humans have 1.2×10^8 bits (15 MB), or 800 books
 - For some organism the “junk DNA” is significant: Newts and lilies would have more than 10^{11} bits (12.5 GB).



Caveats



- Keep in mind that less intelligent organism did not disappear, so there is no trend for organisms to get smarter.
- The **diversity** of life (i.e. diversity locked in the DNA) with time led to some species with intelligence.
- A niche is found where intelligence is preferred..



Limited Pockets in Genes



- There are limits to how much info genes can store.
- If you try to store too much info, mutations can wipe you out.
- For eukaryotes, the error rate is about 10^{-9} , limiting the amount of storage to about 10^{10} bits.



Limited Pockets in Genes



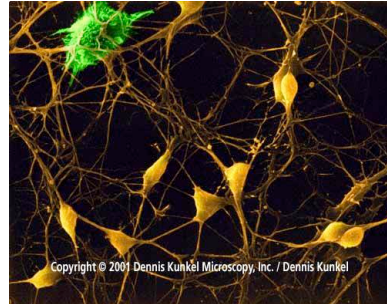
- What did life do?
- Evolution devised a new way (extra-genetic) to store information.
- Life developed a nervous system and brains. More bits of storage that are R/W. We can learn!



Info Storage in Brains?

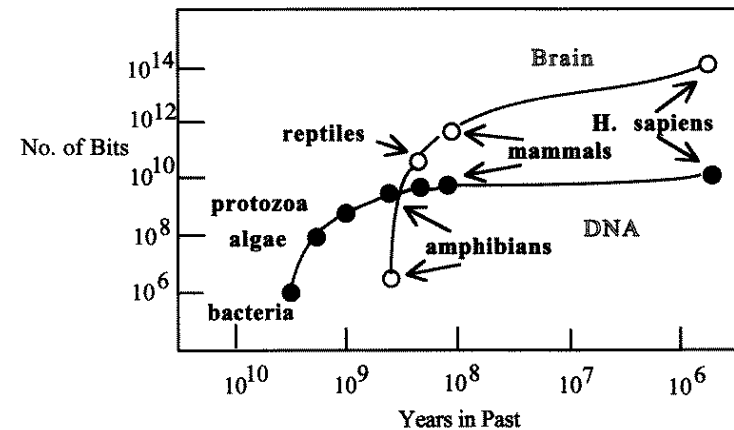


- Information storage in DNA is straightforward, but in the brain?
- There are 10^{11} nerve cells (called neurons) in a human brain, but they do not work in binary form, more analog-based.
- And they are interconnected—a neuron can be connected (with synapses) to 10^3 other neurons.



- An impulse triggers a chain of neurons to “fire” causing a reaction. So, really the information is stored in synapses. $10^{11} \times 10^3 = 10^{14}$ bits (12.5 Terabytes)

Development of Intelligence



Intelligence



- It seems that intelligence is a desirable trait.
- And we can argue for a rough connection between the rise of complexity and intelligence.
- Increased genetic diversity is the key. With more organisms of all types, a more intelligent species is reasonable.



<http://www.cartoonstock.com/lowres/shr09451.jpg>

Intelligence



- Still, the point of the Drake equation is to find civilizations with which to communicate, so we need to think about developing human-like or better, intelligence.



<http://www.newenglandfilm.com/news/archives/03march/reviews.htm>

Human-Level Intelligence

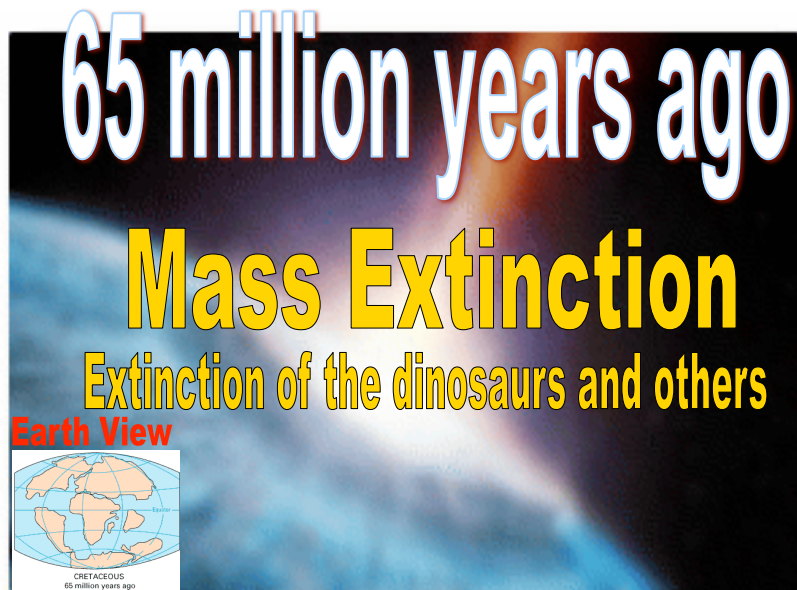


- Our species is the only one on Earth to have developed a technological civilization.
- How likely is that to happen on other planets?

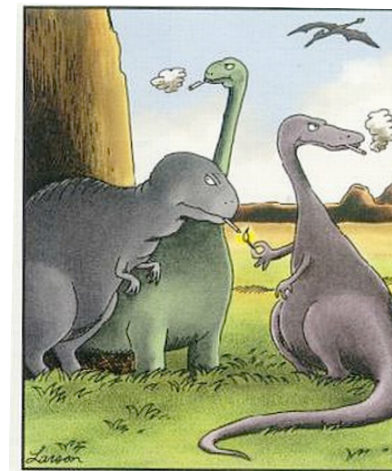
Human-Level Intelligence



- Actually the development of humans is still controversial, even among anthropologists. New fossils are appearing that change our understanding.
- Mammals first appeared on the fossil stage about 200 Myrs ago, but were minor players until about 65 Myrs ago.



Less Credible Theories



The real reason dinosaurs became extinct

<http://www.boundaryschools.com/fws/snidsmk.htm>

Primates



- Main characteristics:
 - Flat fingernails
 - Eyes in front of face
 - No sharp teeth or claws
 - Some have large brain-to-body ratios, but most do not.
 - Primarily adapted to life in trees



<http://saldf.stanford.edu/Projects.htm>

Primates



- Basically, with **one** large exception, primates have not been very successful.



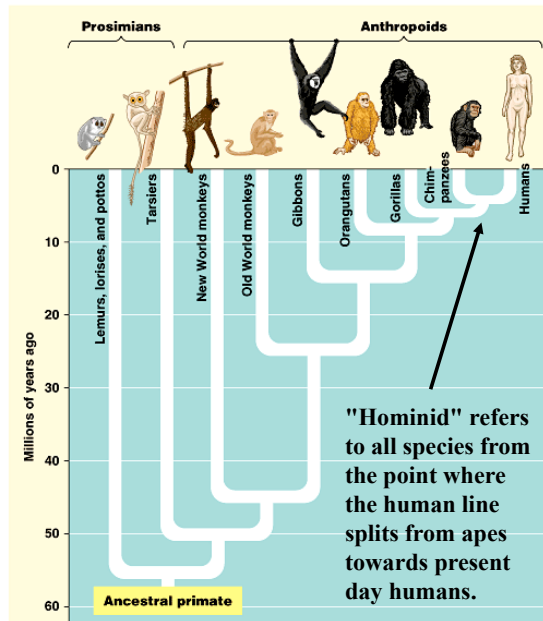
← That one



Not that one →

Family Tree?

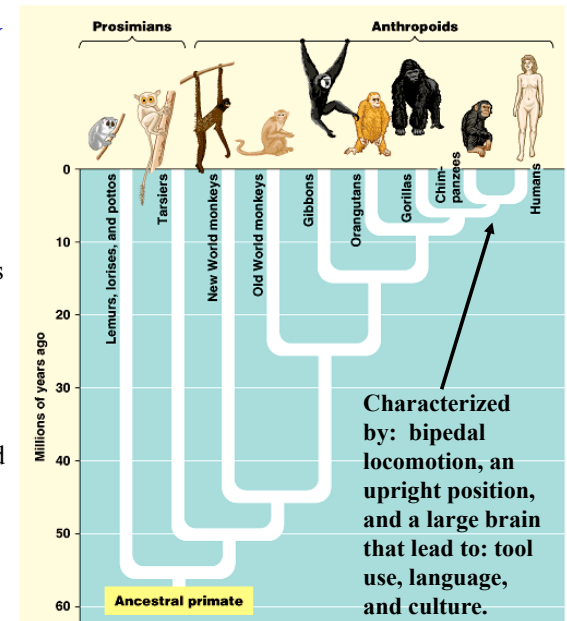
- General trend of adaptation to tree life.
- From toe claws to gripping with large toes or fingers (thumbs).
 - This allowed for tool use.
- From nocturnal to daylight.
- More vision– a rounded face with forward eyes and color vision.
- These mutations were random.



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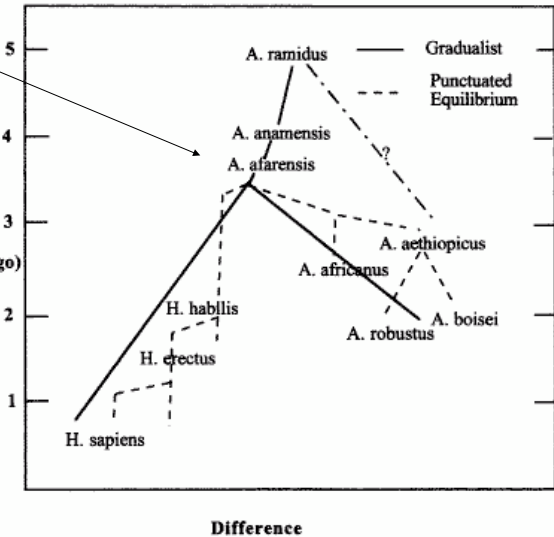
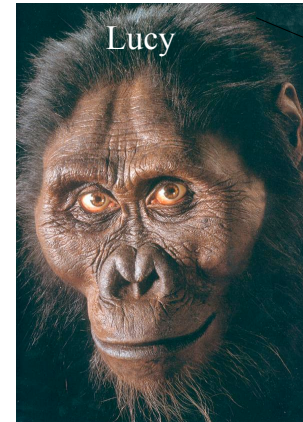
Path to Intelligence



- Path to intelligence is not obvious, nor likely to happen the same way twice.
- On this planet it took ~4 billion years.
- Diversity is the key...
- The direct path to hominid evolution is interesting and controversial.



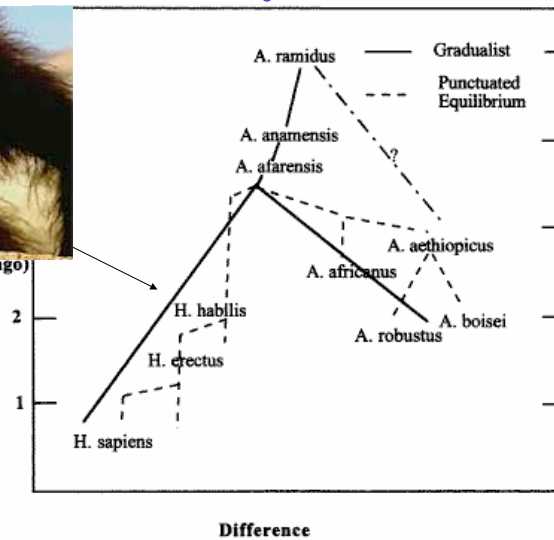
The Last 5 Myrs



The Last 5 Myrs



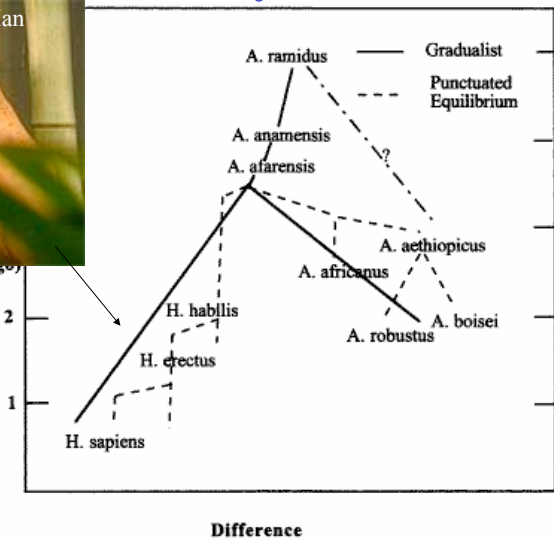
(Myr ago)



The Last 5 Myrs



(Myr ago)



The Last 5 Myrs

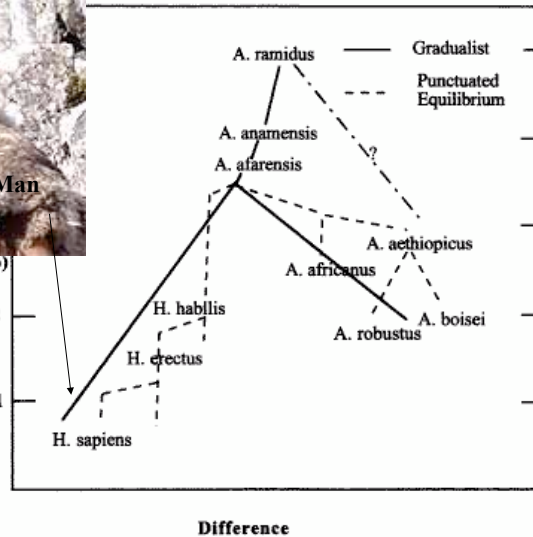


Neanderthal Man

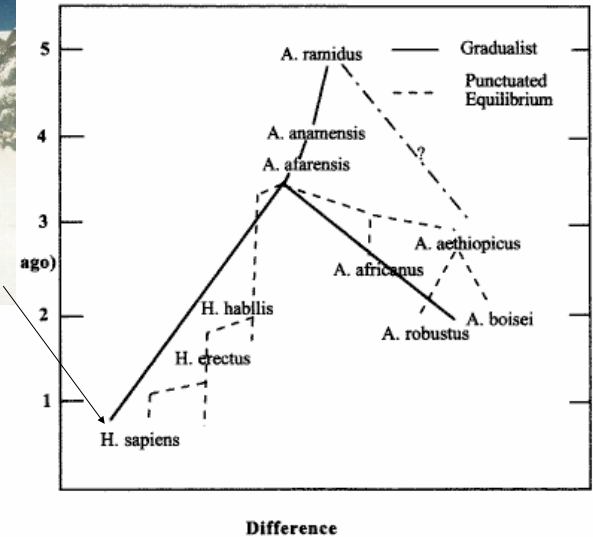
Was an earlier species that had larger brain volume and language.

Went extinct 28000 yrs ago.

New mDNA comparison shows that they are not related to us.

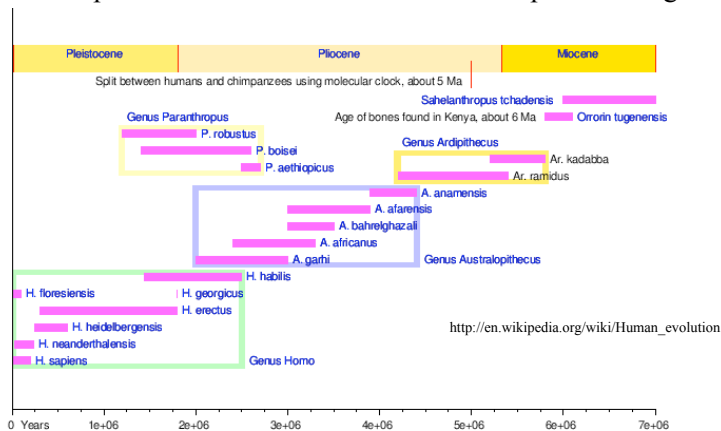


The Last 5 Myrs



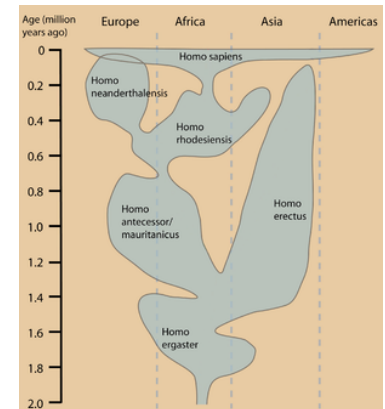
Ancestors

- Overall, the evolution leading to *H. sapiens* was not a smooth and steady path.
- At some points there were 4 distinct hominid species living.



Ancestors

- Modern humans emerged from a situation with many variant species adapting to fill different environmental niches.
- Only one path lead to much larger brains, and we do not truly understand what environmental factor favored it.
- It seems likely that something like this will happen on other planet with enough time.



Question



Overall, the evolution of H. Sapiens was

- a) a smooth and direct path.
- b) simple and inevitable, after the extinction of the dinosaurs
- c) depended only upon the local environment in Africa.
- d) an awkward path of evolution with many surprises.
- e) likely orchestrated by aliens.

f; Considerations



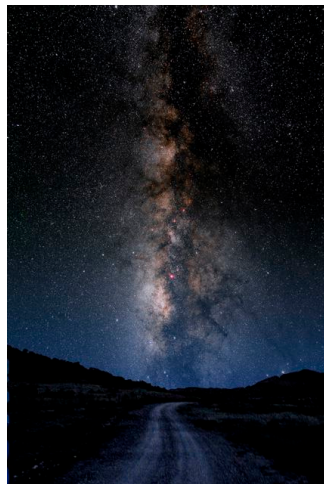
- Complexity leads to intelligence, but complexity seems to require a benign environment. Harsher environments tend to have simpler organisms.
- Perhaps life may exist on harsh planets, but more intelligent life?



f; Considerations



- Remember, human intelligence took 4.5 billion years.
- Systems very near the center of the galaxy are more likely to be hit with supernovae event in that time.
- 4.5 Byrs is about half the age of our Galaxy. Were we fast or slow? Fast: severely limits ETs. Slow: there can be multiple ETs.



f; Considerations

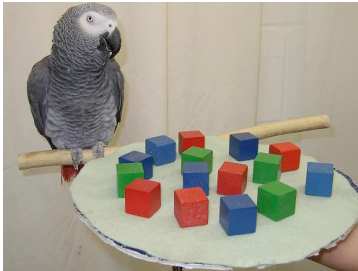


- Intelligent life is a very recent development on Earth with the emergence of the primates, hominids, and H. sapiens.
- Everyone agrees that this particular evolution will not occur on other planets.
- But, will the characteristics of H. sapiens be common to human-like intelligence?
 - Manipulative organs– hands
 - Walking upright?
 - Is tool use and larger brains associated with walking upright?
 - Pair bonding?
 - Human brains quadruple in size after birth compared to other primates which double.

f_i Considerations



- How unique is our intelligence?
- Teaching sign language to chimps and gorillas have shown they are more intelligent than we thought.
- Don't forget [Alex the parrot](#)!



Alex (1976 - September 6, 2007)



Dr. Patterson persuades Koko not to smoke. "Kitten hates it, Koko!"

f_i Considerations



- Whales and dolphins are speculated to be of high intelligence, but communicating is difficult.
- With all of this in hand, we are ready to make the next estimate in the Drake equation.
- This term is only intelligent life that can communicate abstract thought to each other, not technological able to communicate.



What is f_i



- What is the fraction of life that forms human or better intelligence in less than about 4.5 billion years?
- If you think that it always does, then $f_i = 100\%$
- If you think that it is a statistical fluke or required supernatural invention then you could use 1/billion or $10^{-7}\%$.
- Anywhere in between is fair game.