

## Astronomy 330



This class (Lecture 18):  
Origin of Intelligence  
**Lucas Guthrie**

Next Class:  
Cultural Evolution  
**Nathan Raichel**

HW #7 due Wednesday.

Music: *Intelligent Guy*– Butthole Surfers

## Paper Rough Draft



- Worth 1% of your grade, but really worth more.
- Due on or before April 15<sup>th</sup>! (Hard date!)
  - Beginning of class, else considered late.
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 6 to 8 pages double-spaced 12-point font, not including references.

## Astronomy 330



THE FLAKE EQUATION:

$$P = W_p \times (C_R + M_i) \times T_k \times F_o \times F_i \times D_r \times A_v \approx 100,000$$

Labels for the equation:

- $W_p$ : WORLD POPULATION (7,000,000,000)
- $C_R$ : FRACTION OF PEOPLE WHO IMAGINE AN ALIEN ENCOUNTER BECAUSE THEY'RE CRAZY OR WANT TO FEEL SPECIAL ( $\frac{1}{10,000}$ )
- $M_i$ : FRACTION OF PEOPLE WHO MISINTERPRET A PHYSICAL OR PHYSIOLOGICAL EXPERIENCE AS AN ALIEN SIGHTING ( $\frac{1}{10,000}$ )
- $T_k$ : PROBABILITY THAT THEY'LL TELL SOMEONE ( $\frac{1}{10}$ )
- $F_o$ : AVERAGE NUMBER OF PEOPLE EACH FRIEND TELLS THIS 'FIRSTHAND' ACCOUNT (10)
- $F_i$ : AVERAGE NUMBER OF PEOPLE THEY TELL (10)
- $D_r$ : PROBABILITY THAT ANY DETAILS NOT FITTING THE NARRATIVE WILL BE REVISED OR FORGOTTEN IN RETELLING ( $\frac{1}{10}$ )
- $A_v$ : FRACTION OF PEOPLE WITH THE MEANS AND MOTIVATION TO SHARE THE STORY WITH A WIDER AUDIENCE (BLOGS, FORUMS, REPORTERS) ( $\frac{1}{100}$ )

EVEN WITH CONSERVATIVE GUESSES FOR THE VALUES OF THE VARIABLES, THIS SUGGESTS THERE MUST BE A HUGE NUMBER OF CREDIBLE-SOUNDING ALIEN SIGHTINGS OUT THERE, AVAILABLE TO ANYONE WHO WANTS TO BELIEVE!

<http://xkcd.com/718/>

## Paper Rough Draft



- *Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 2007; Wikipedia: Mars).*
  - *I expect to see a few refs per page!*
- Holt, W., Smith, E., Rowe, T., & Jones, A. B. 2000, The Astronomical Almanac for the Year 1994, Vol. 2 (2nd ed.; Washington, DC: GPO)
- Smith, A. B., Thomas, J. R., Major, W., & Peebles, P. J. E. 2006, Astrophysics Journal, 450, 12
- Wikipedia: Mars, <http://en.wikipedia.org/wiki/Mars>, Accessed: March 25, 2010, Updated: March 24, 2010

## Presentations



- Lucas Guthrie: [Doomsday from Space](#)

## Outline



- Along comes oxygen!
- Development of intelligence.
- Brains. Brains.
- The rise of the primates!

## Drake Equation

Frank Drake



That's 5.8 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
	10 stars/yr	0.75 systems/star	$1.5 \times 0.11 = 0.165$ planets/system	0.47 life/planet	intel./life	comm./intel.	yrs/comm.

## 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.

## Picture Credits

Smithsonian Institute  
Field Museum  
NASA

University of California, Berkeley Museum  
<http://rainbow.ideo.columbia.edu/courses/v1001/7.html>  
<http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm>  
[http://www.uta.edu/geology/geol1425earth\\_system/images/gaia\\_chapter\\_11/ArcheanLandscape.jpg](http://www.uta.edu/geology/geol1425earth_system/images/gaia_chapter_11/ArcheanLandscape.jpg)  
[http://www.uta.edu/geology/geol1425earth\\_system/1425chap11.html](http://www.uta.edu/geology/geol1425earth_system/1425chap11.html)  
<http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm>  
<http://www.exhibits.lsa.umich.edu/Exhibits/Anthropology/Diaramas/Nat.Am./Copper/Copper.html>

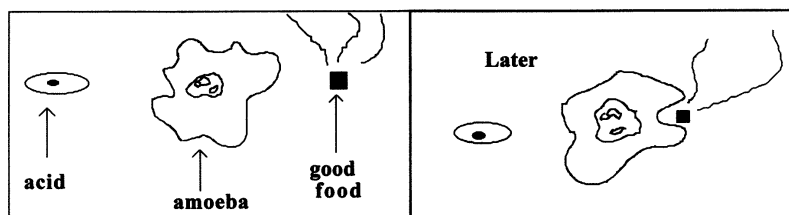


## Evolution of Intelligence

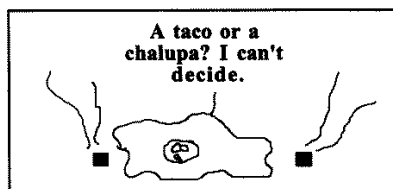


- Through diversity, evolution has resulted in an increase in the complexity of organisms on Earth.
- Can we associate complexity with intelligence?
- If intelligence is an advantageous trait, it is plausible that intelligence would increase over time.
- But, what is intelligence?

## An Amoeba Distinguishes



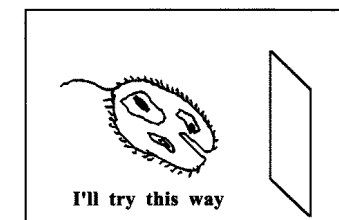
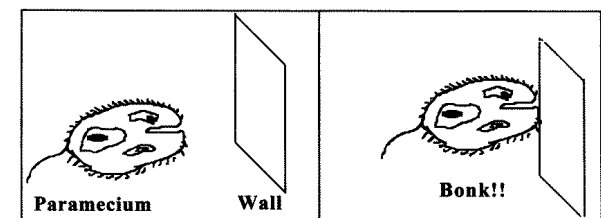
- Has a model of its environment.
- What if two pieces of food are placed nearby?



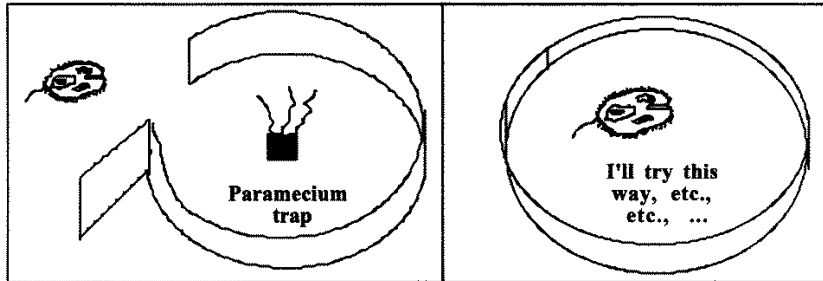
## The Intelligent Paramecium?



- 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.

## 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>



## 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?



## DNA Storage



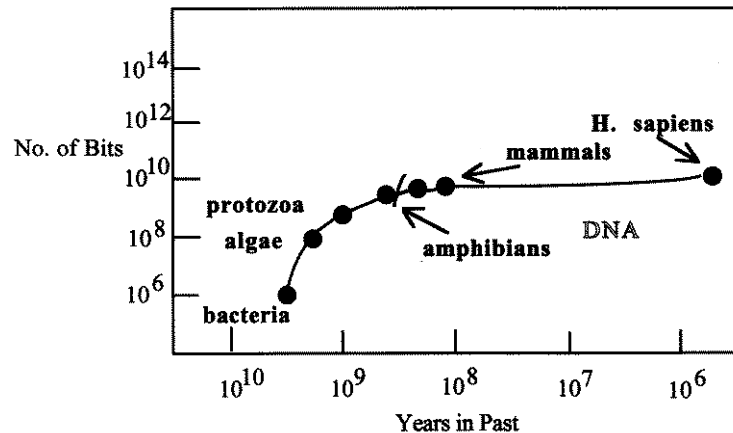
- We'll use bits of information
  - Yes = 1
  - No = 0
- Each DNA base has 2 bits of information— 4 options.
- Each codon has 3 bases or 6 bits ( $3 \times 2$ )
- Humans have  $(3 \times 10^9)$  bases  $\times$  2 bits per base =  $6 \times 10^9$  bits (~750 Mbytes), like 4000 books of 500 pages.



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  $1.2 \times 10^8$  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 with time led to some species with intelligence.



## 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



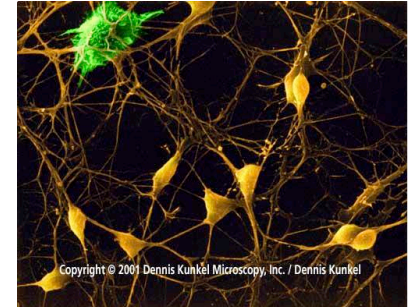
- What did life do?
- Evolution devised a new way (extra-genetic) to store information.
- Life developed a nervous system and brains.  
More bits of storage that are R/W. We can learn!



## Info Storage in Brains?

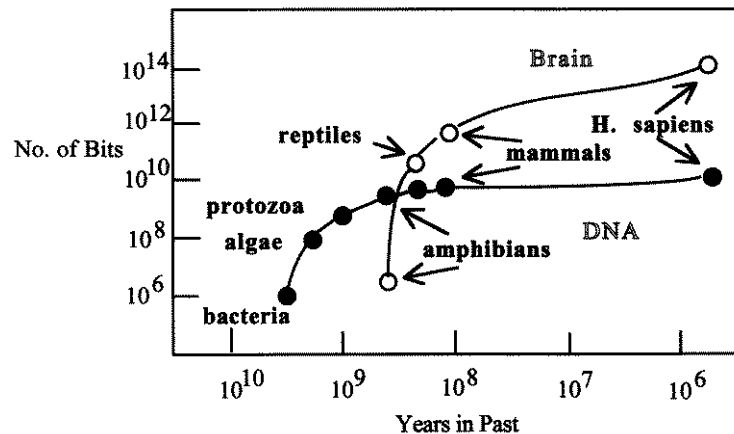


- Information storage in DNA is straightforward, but in the brain?
- There are  $10^{11}$  nerve cells (called neurons) in a human brain, but they do not work in binary form, more analog-based.
- And they are interconnected—a neuron can be connected (with synapses) to  $10^3$  other neurons.



- 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

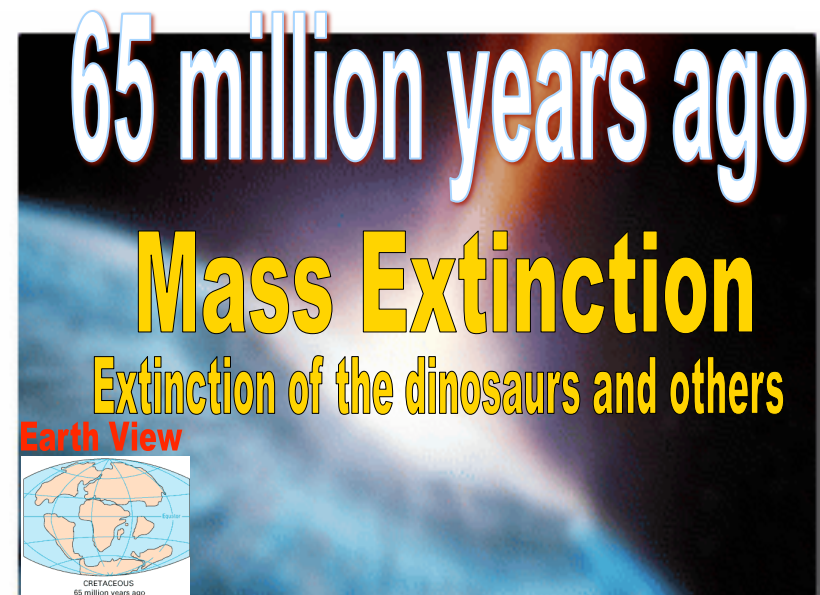


- Our species is the only one on Earth to have developed a technological civilization.
- How likely is that to happen on other planets?

## Human-Level Intelligence

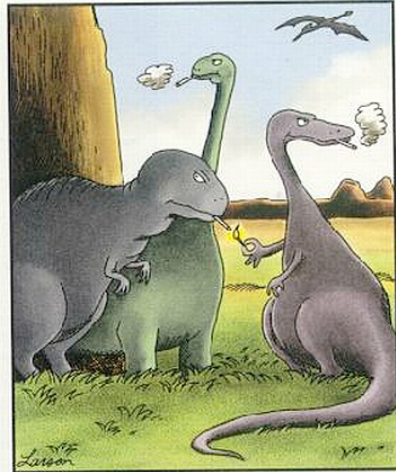


- Actually the development of humans is still controversial, even among anthropologists. New fossils are appearing that change our understanding.
- Mammals first appeared on the fossil stage about 200 Myrs ago, but were minor players until about 65 Myrs ago.





## 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

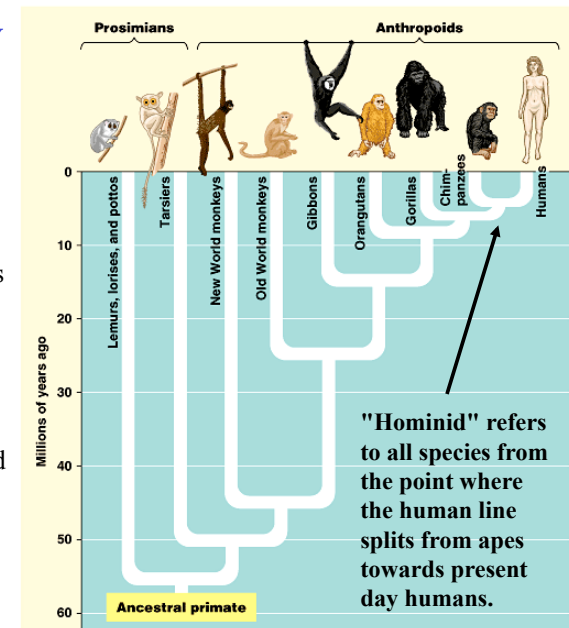


Not that one →



## Family Tree?

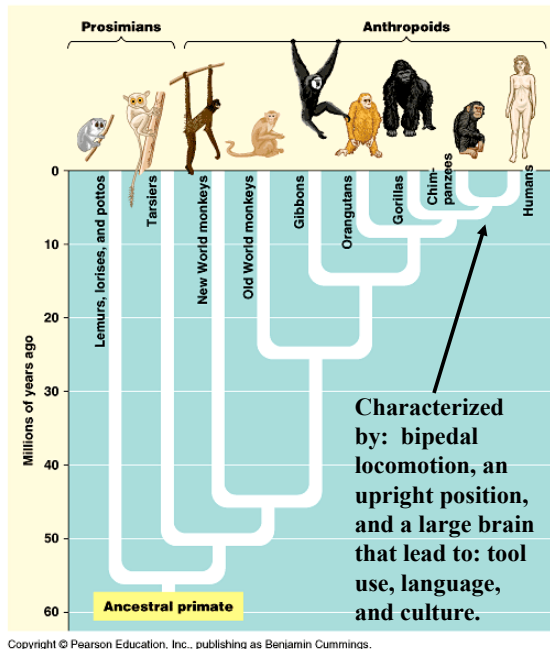
- General trend of adaptation to tree life.
- From toe claws to gripping with large toes or fingers (thumbs).
  - This allowed for tool use.
- From nocturnal to daylight.
- More vision– a rounded face with forward eyes and color vision.
- These mutations were random.



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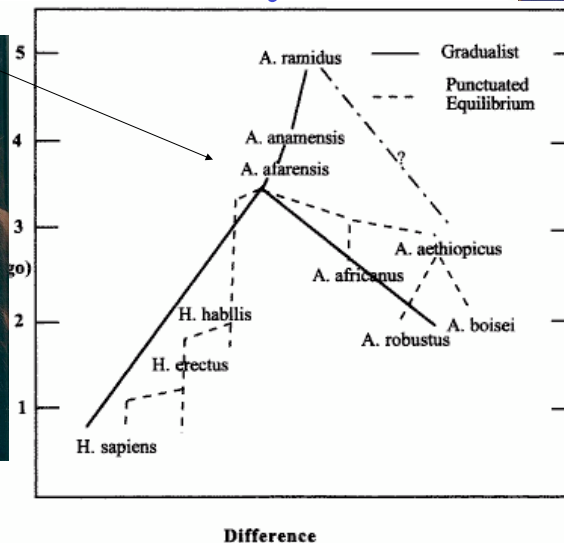
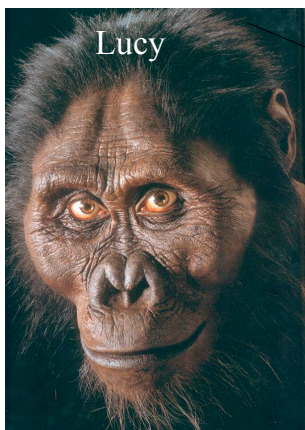
## Path to Intelligence



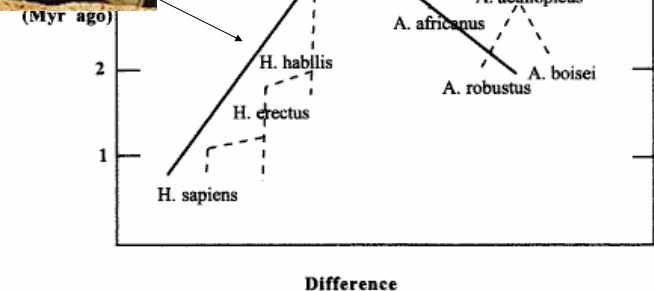
- Path to intelligence is not obvious, nor likely to happen the same way twice.
- On this planet it took ~4 billion years.
- Diversity is the key...
- The direct path to hominid evolution is interesting and controversial.



## The Last 5 Myrs



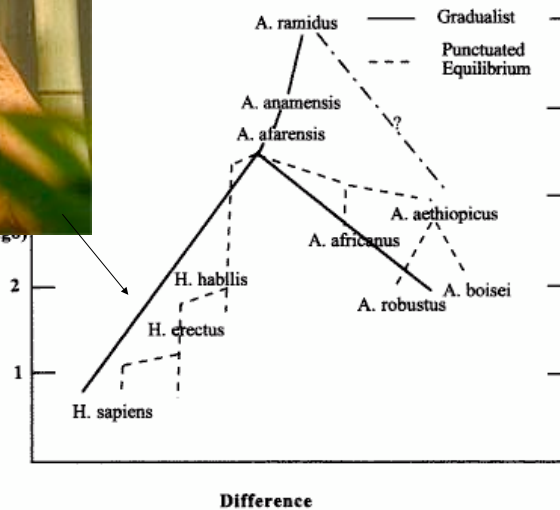
## The Last 5 Myrs



## The Last 5 Myrs



Java Man or Peking Man



## The Last 5 Myrs

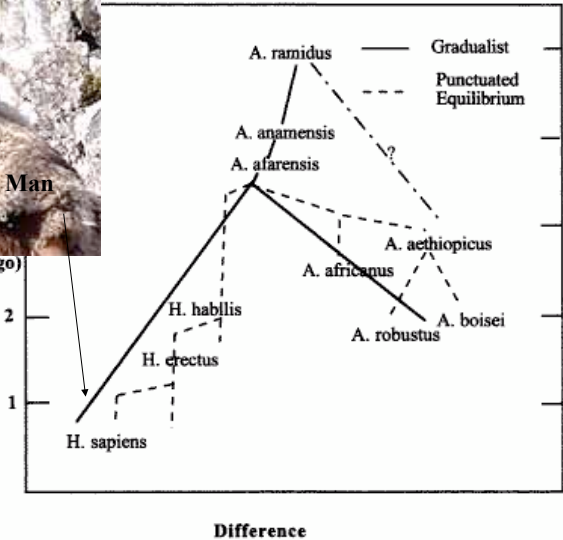


Neanderthal Man

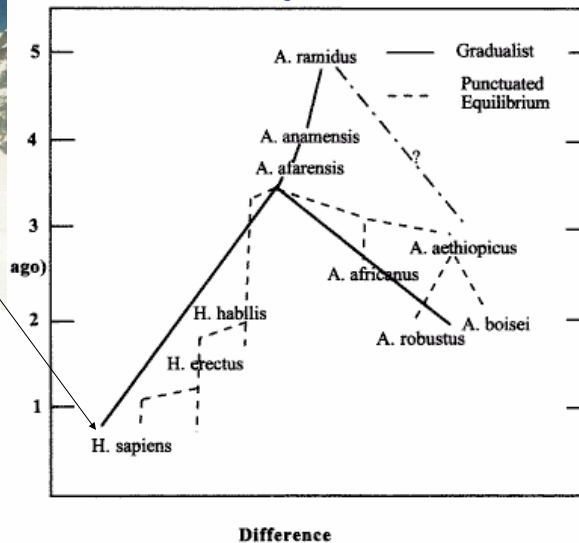
Was an earlier species that had larger brain volume and language.

Went extinct 28000 yrs ago.

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

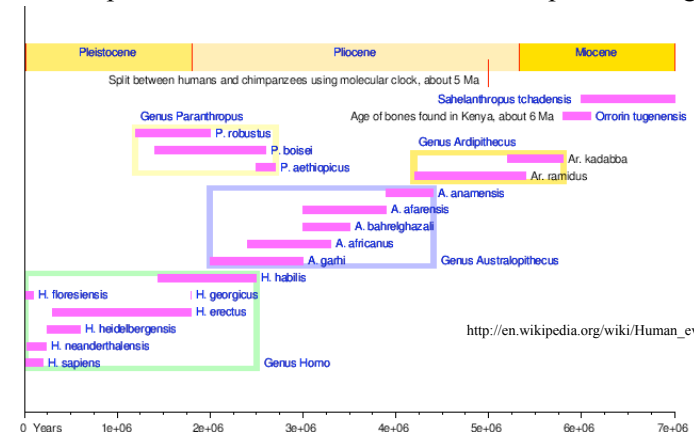


## The Last 5 Myrs



## 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.

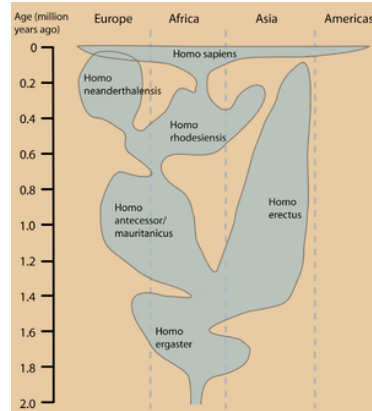


[http://en.wikipedia.org/wiki/Human\\_evolution](http://en.wikipedia.org/wiki/Human_evolution)

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

## f; Considerations



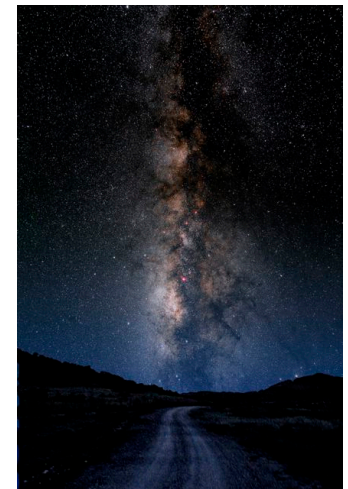
- Complexity leads to intelligence, but complexity seems to require a benign environment. Harsher environments tend to have simpler organisms.
- Perhaps life may exist on harsh planets, but more intelligent life?



## 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.





## $f_i$ 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.