Astronomy 330

This class (Lecture 19):
Biological Evolution

Next Class:
Cultural Evolution

Exam 2 is next Thursday!

Music: *Space Oddity* – David Bowie

Exam 2

- Exam 2 is coming up– April 8th!
- Will be similar to Exam 1 (class voted for 40 questions).
- Cover from last exam up to today's lecture.
- Again, 1 sheet of notes will be allowed.

Paper Rough Draft

- Worth 1% of your grade, but really worth more.
- Due on or before April 14th! (Hard date!)
  - Beginning of discussion 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.
- Can work in the same groups as your presentations.

Outline

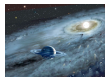
- Along comes oxygen!
- Development of intelligence.
- Brains. Brains.
- The rise of the primates!

Drake Equation

Frank Drake

That's 2.7 life systems/decade








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

N	R_*	f_p	n_e	f_l	f_i	f_c	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 commun-icate	Lifetime of advanced civilizations
	9 stars/ yr	0.29 systems/ star	1.03 x 0.22 = 0.23 planets/ system	0.46 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Early Earth

- We've talked about the Early Earth's atmosphere– mostly N and CO_2, 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!)



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 live exists then intelligent life exists.
- On the other hand, the plant kingdom never developed neurons.

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.

Summary

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

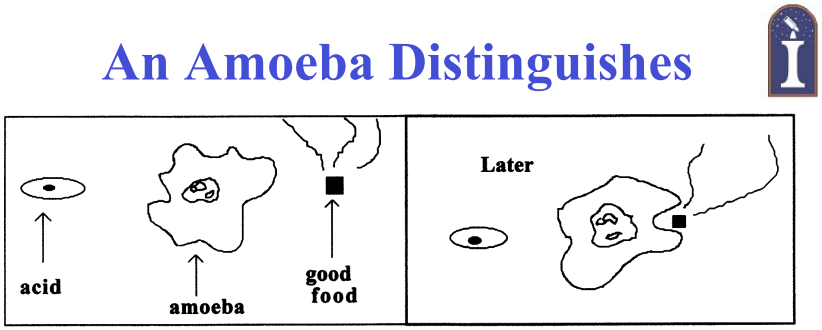
Picture Credits

Smithsonian Institute
Field Museum
NASA
University of California, Berkeley Museum
http://rainbow.ldeo.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/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

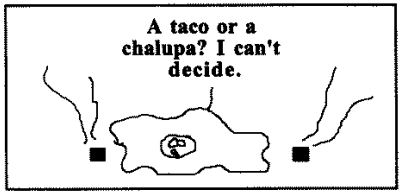
Evolution of Intelligence

- 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

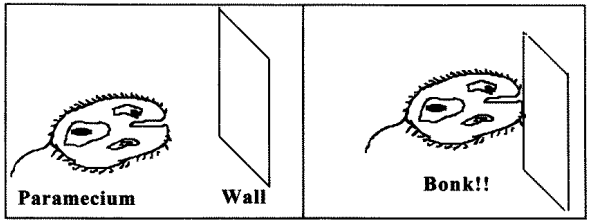


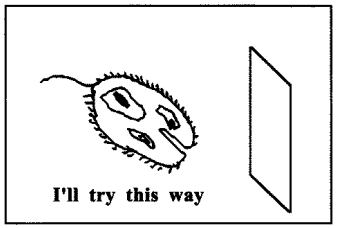
- Has a model of its environment.
- What if two pieces of food are placed nearby?



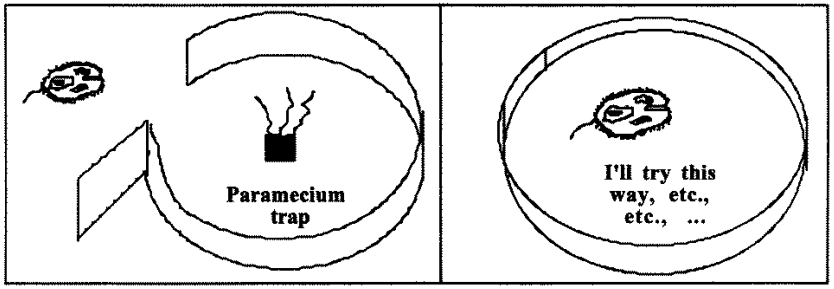
The Intelligent Paramecium?

- 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.

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 x 2)
- Humans have (3 x 10^9) bases x 2 bits per base = 6 x 10^9 bits (~750 Mbytes), like 4000 books of 500 pages.

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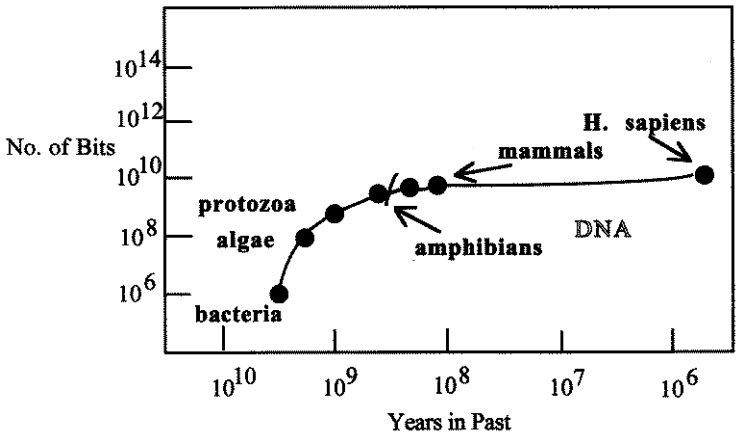
Development of Intelligence



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 x 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).

http://www.eeingeorgia.org/eic/images/landfill.jpg

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.

http://www.eeingeorgia.org/eic/images/landfill.jpg

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

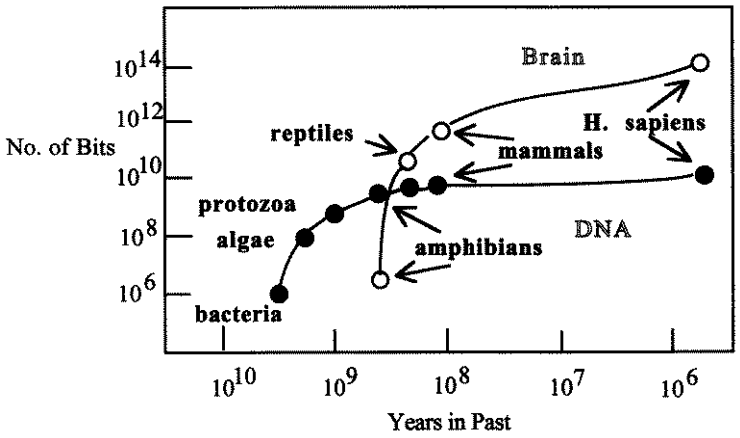
- What did life do?
- Evolution devised a new way (extra-genetic) to store information.
- Life developed a nervous system and brains. More bits of storage that are R/W. We can learn!

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/shr0945l.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

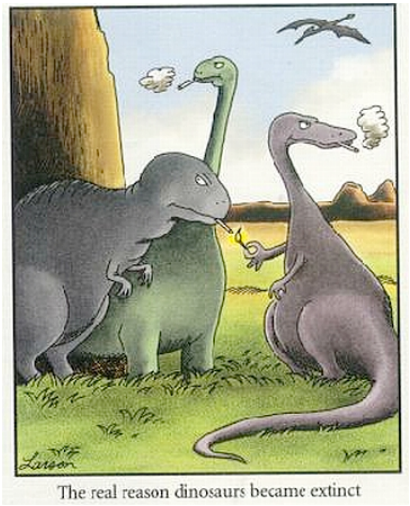
Human-Level Intelligence

- 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 rations, but most do not.
  - Primarily adapted to life in trees

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

Primates

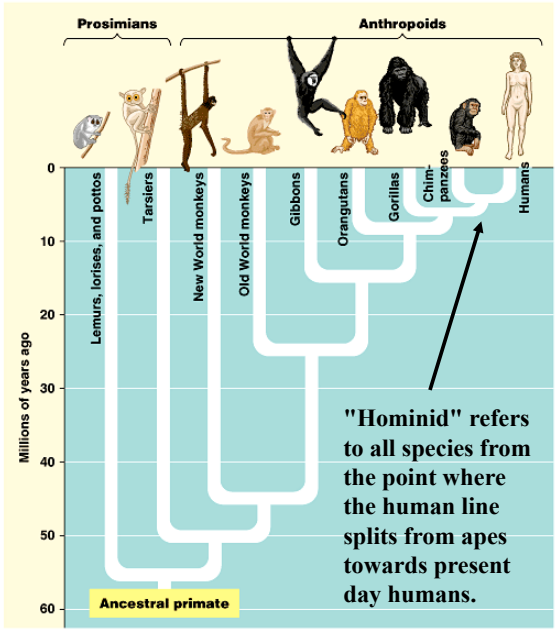
- Basically, with **one** large exception, primates have not been very successful.

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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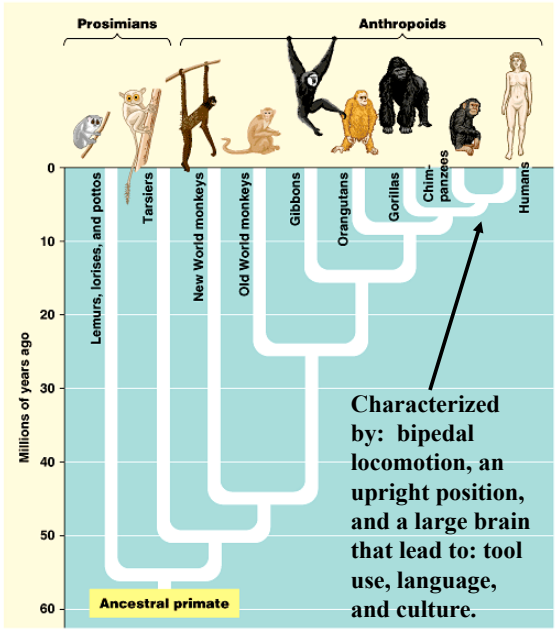
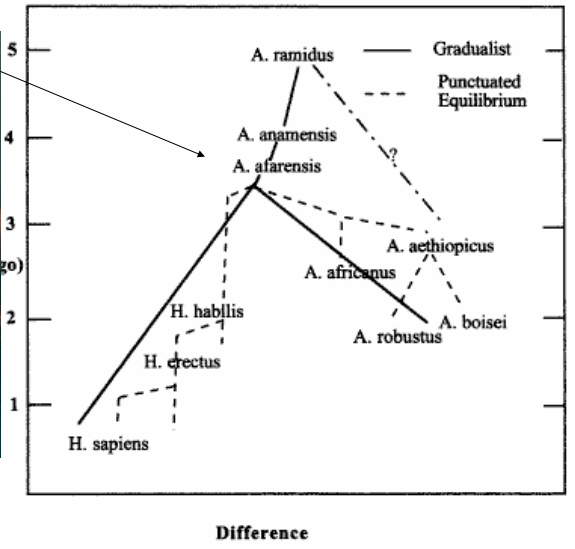


Path to Intelligence

- 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



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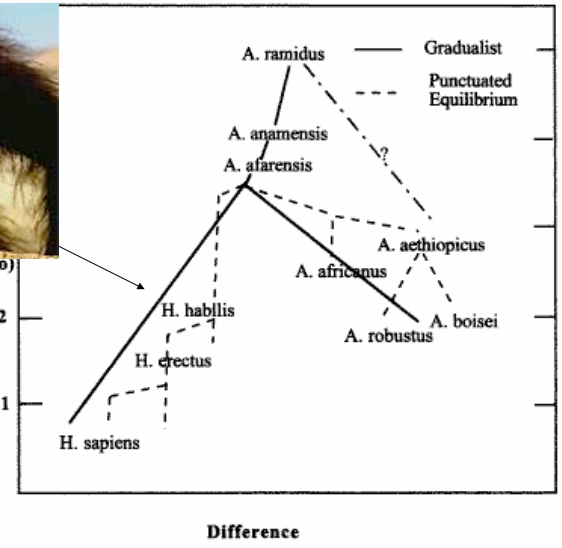

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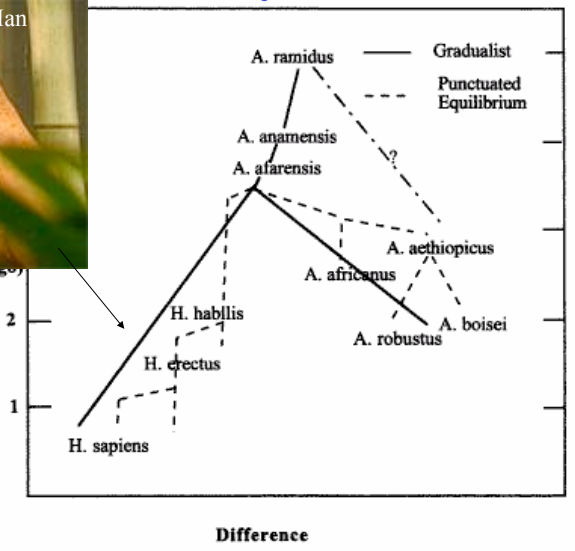
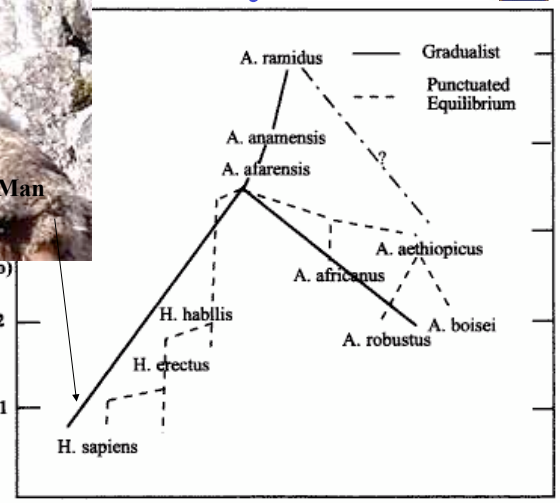


The Last 5 Myrs

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.



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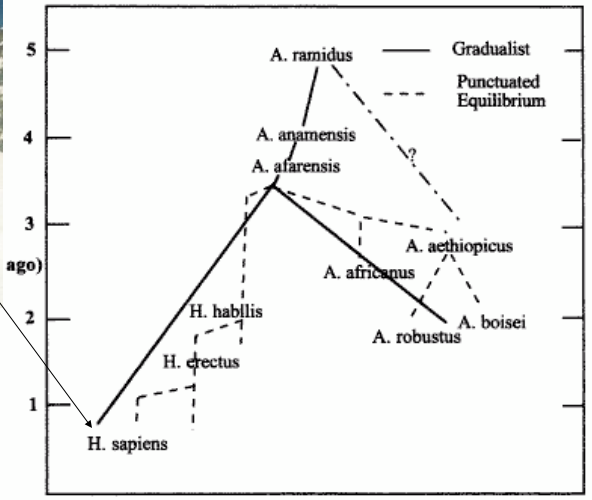
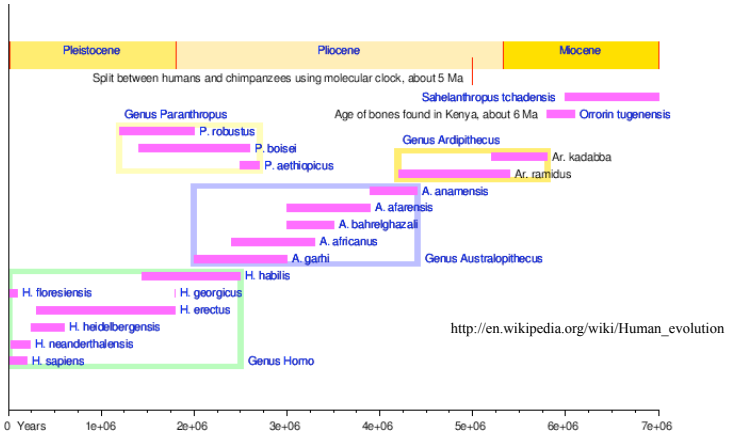


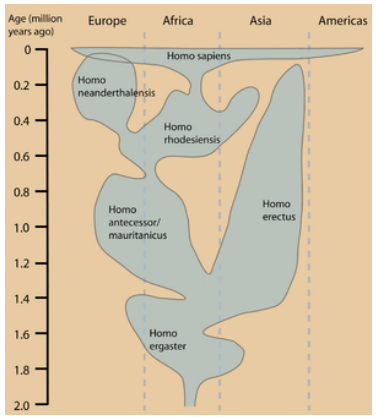
Ancestors

- 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

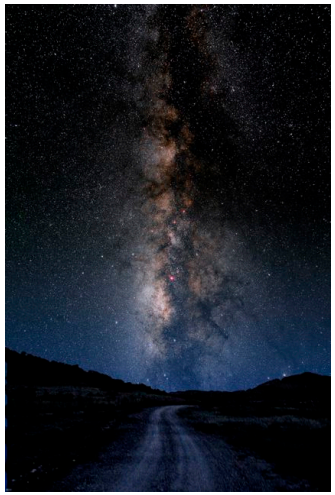
a) a smooth and direct path.
b) simple and inevitable, after the extinction of the dinosaurs
c) depended only upon the local environment in Africa.
d) an awkward path of evolution with many surprises.
e) likely orchestrated by aliens.

f_i 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_i 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.

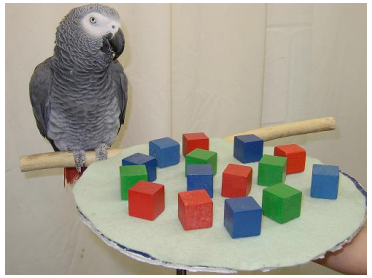


f_i Considerations

- 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.