Astronomy 330

This class (Lecture 20):
Origin of Intelligence 2
~~*Adam Flanders*~~

Next Class:
Cultural Evolution
Clara Mount

HW #8 due today

Music: *E.T. – Katie Perry*

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
- What is f_i?
- Will a civilization develop that has the appropriate technology and worldview?

Drake Equation

That's 2.7 life systems/year

Frank Drake

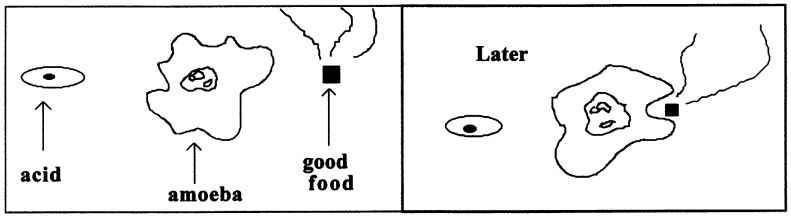
$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

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
	20 stars/ yr	0.8 systems/ star	2 x 0.11 = 0.22 planets/ system	0.775 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

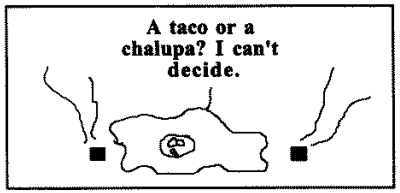
Evolution of Intelligence

- 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

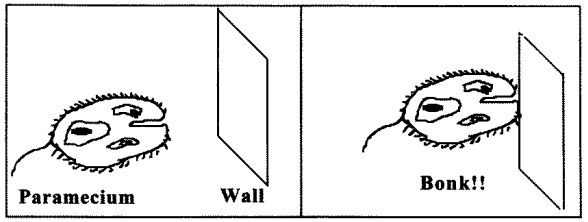


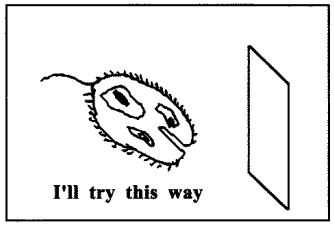
- Has a model of its environment.
- What if two pieces of food are placed nearby?



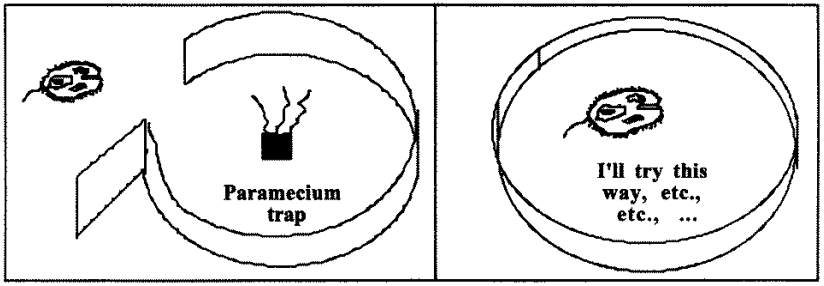
The Intelligent Paramecium?

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

Spottet Dolphins sounds
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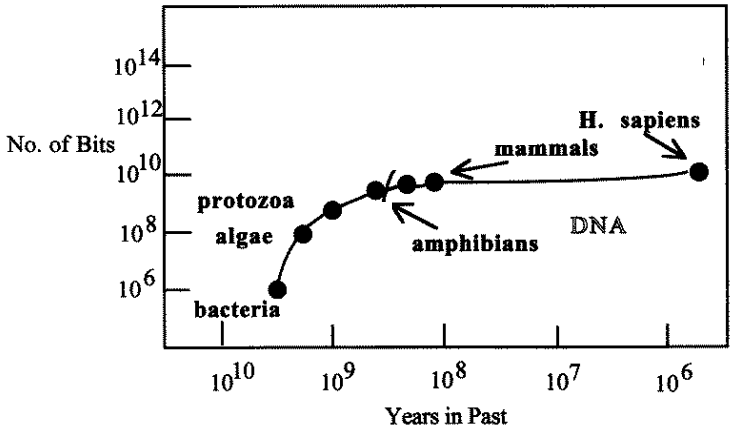
Development of Intelligence



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 1.2×10^8 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 (i.e. diversity locked in the DNA) with time led to **some** species with intelligence.
- A niche is found where intelligence is preferred..

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

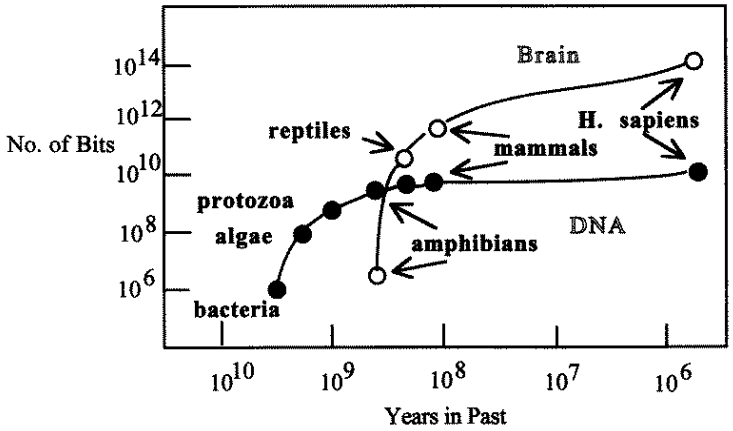
- What did life do?
- Evolution devised a new way (extra-genetic) to store information.
- Life developed a nervous system and brains. More bits of storage that are R/W. We can learn!

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 1000 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)

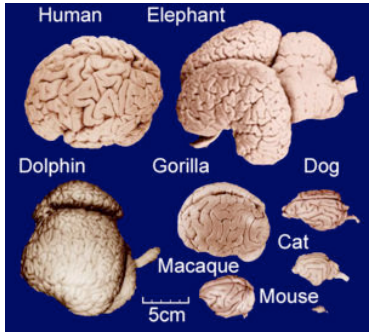
Development of Intelligence



Development of Intelligence

Who has the biggest brain?
Not Humans.

Largest is Sperm Whale at 17.5 lbs and human brain is 2.7 lbs, but we have the largest brain compared to our body size, sort of.



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

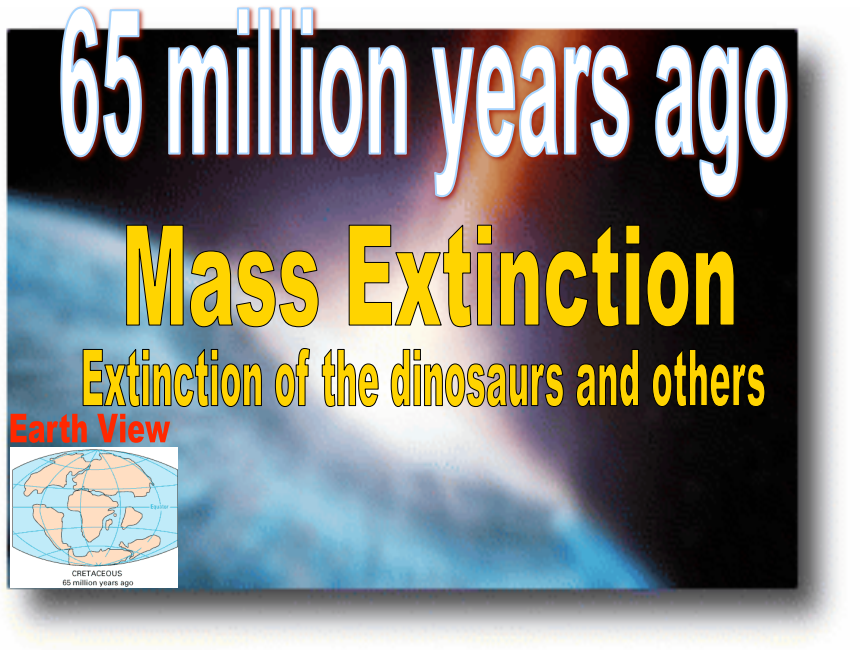
Intelligence

- 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

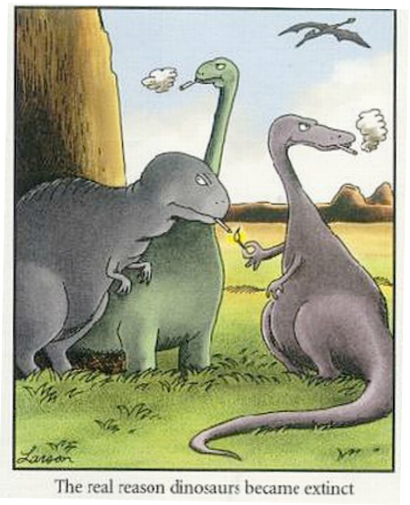
- Our species is the only one on Earth to have developed a technological civilization.
- How likely is that to happen on other planets?



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

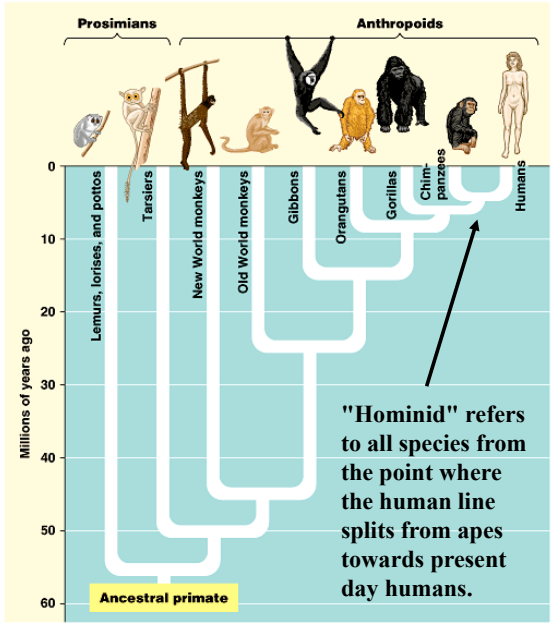
- Basically, with **one** large exception, primates have not been very successful.

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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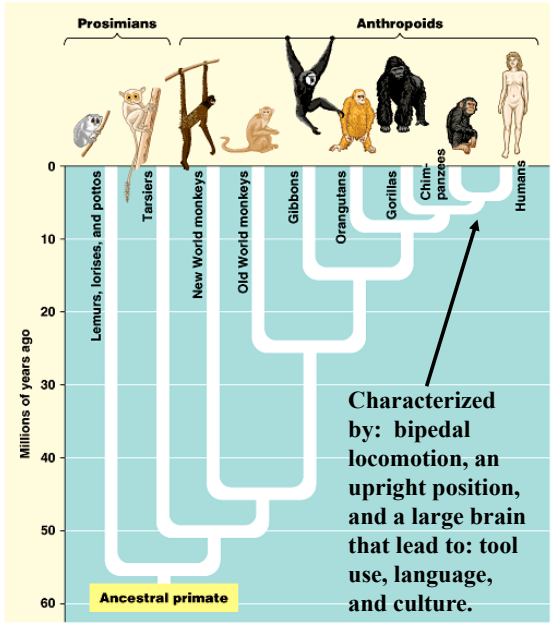
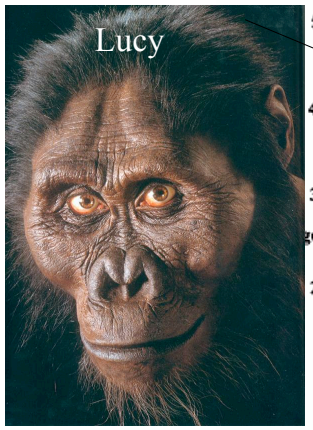
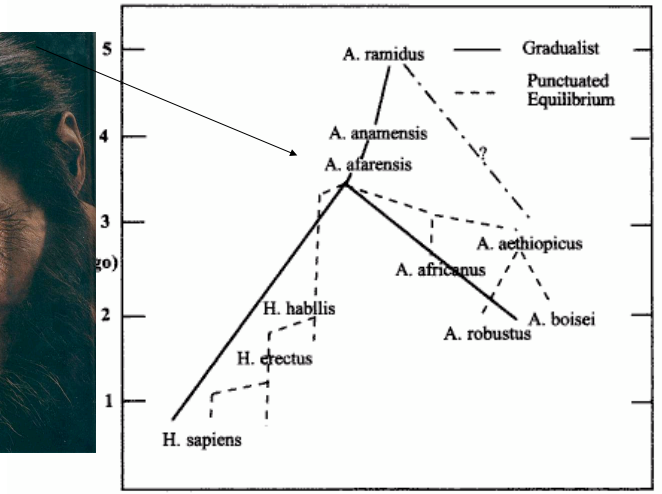


Path to Intelligence

- 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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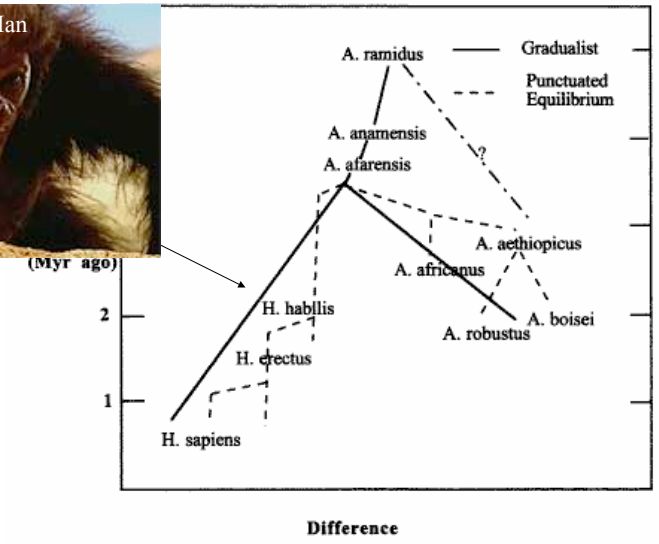

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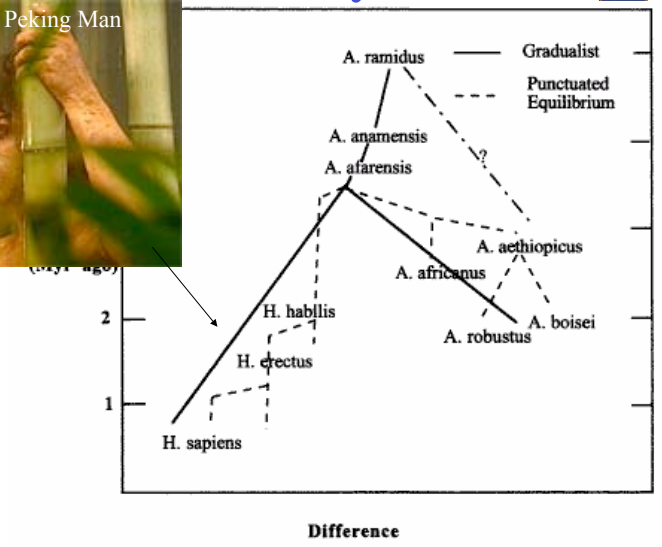
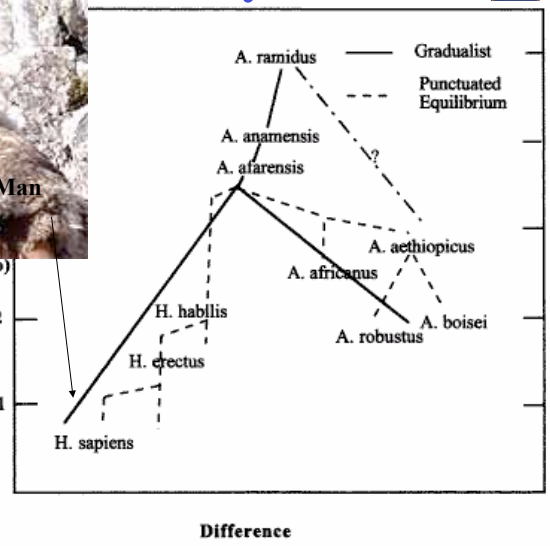


The Last 5 Myrs

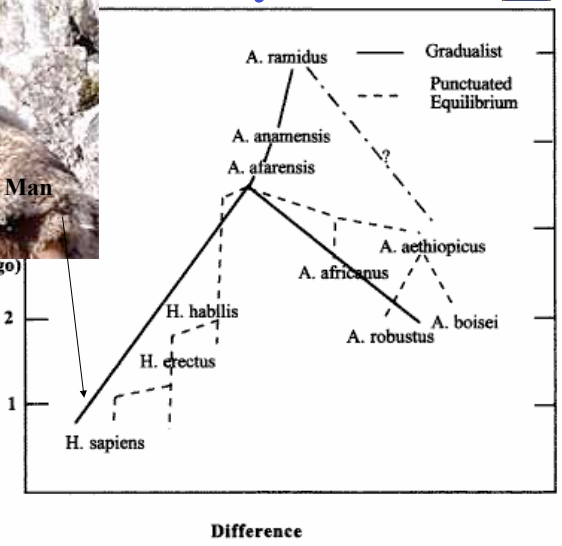
Was an earlier species that had larger brain volume and language.

Went extinct 28000 yrs ago.



The Last 5 Myrs

New DNA comparison suggests interbreeding with modern humans roughly 80,000 and 50,000 years ago; 1–4% of the genome of Eurasians from Neanderthals



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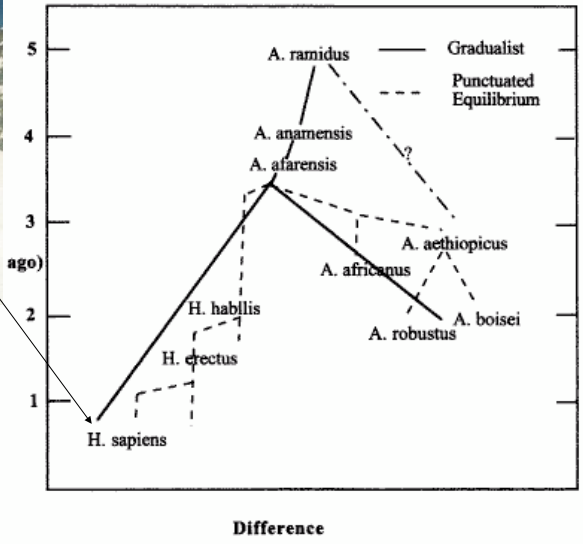
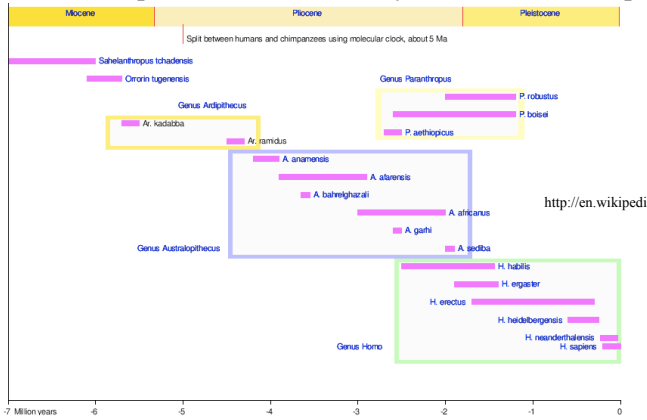


Ancestors

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



http://en.wikipedia.org/wiki/Human_evolution

Ancestors

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- At some points there were many distinct hominid species living.

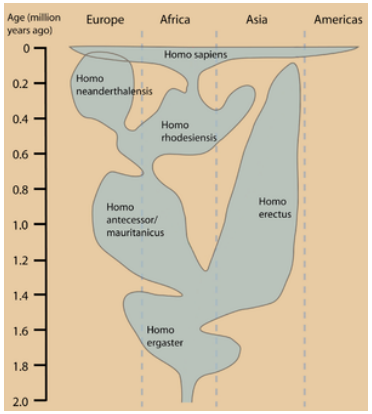
Comparative table of *Homo* species

view · talk · edit

Species	Lived when (Ma)	Lived where	Adult height	Adult mass	Cranial capacity (cm³)	Fossil record	Discovery / publication of name
Denisova hominin	0.04	Altai Krai				1 site	2010
H. antecessor	1.2 – 0.8	Spain	1.75 m (5.7 ft)	90 kg (200 lb)	1,000	2 sites	1997
H. cepranensis	0.5 – 0.35	Italy			1,000	1 skull cap	1994/2003
H. erectus	1.8 – 0.2	Africa, Eurasia (Java, China, India, Caucasus)	1.8 m (5.9 ft)	60 kg (130 lb)	850 (early) – 1,100 (late)	Many	1891/1892
H. ergaster	1.9 – 1.4	Eastern and Southern Africa	1.9 m (6.2 ft)		700–850	Many	1975
H. floresiensis	0.10 – 0.012	Indonesia	1.0 m (3.3 ft)	25 kg (55 lb)	400	7 individuals	2003/2004
H. gautengensis	>2 – 0.6	South Africa	1.0 m (3.3 ft)			1 individual	2010/2010
H. georgicus	1.8	Georgia			600	4 individuals	1999/2002
H. habilis	2.3 – 1.4	Africa	1.0–1.5 m (3.3–4.9 ft)	33–55 kg (73–120 lb)	510–660	Many	1960/1964
H. heidelbergensis	0.6 – 0.35	Europe, Africa, China	1.8 m (5.9 ft)	90 kg (200 lb)	1,100–1,400	Many	1908
H. neanderthalensis	0.35 – 0.03	Europe, Western Asia	1.6 m (5.2 ft)	55–70 kg (120–150 lb) (heavily built)	1,200–1,900	Many	(1829)/1864
H. rhodesiensis	0.3 – 0.12	Zambia			1,300	Very few	1921
H. rudolfensis	1.9	Kenya				1 skull	1972/1986
H. sapiens idaltu	0.16 – 0.15	Ethiopia			1,450	3 craniums	1997/2003
H. sapiens sapiens (modern humans)	0.2 – present	Worldwide	1.4–1.9 m (4.6–6.2 ft)	50–100 kg (110–220 lb)	1,000–1,850	Still living	–/1758

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

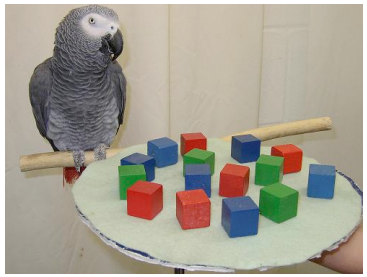
- Remember, human intelligence took 4.5 billion years.
- Systems very near the center of the galaxy are more likely to be hit with supernovae event in that time.
- 4.5 Byrs is about half the age of our Galaxy. Were we fast or slow? Fast: severely limits ETs. Slow: there can be multiple ETs.

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

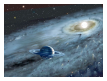
- What is the fraction of life that forms human or better intelligence in less than about 4.5 billion years?
- If you think that it always does, then $f_i = 100\%$
- If you think that it is a statistical fluke or required supernatural invention then you could use 1/billion or $10^{-7}\%$.
- Anywhere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

Drake Equation

Frank Drake

That's 1.38 intelligent systems/year





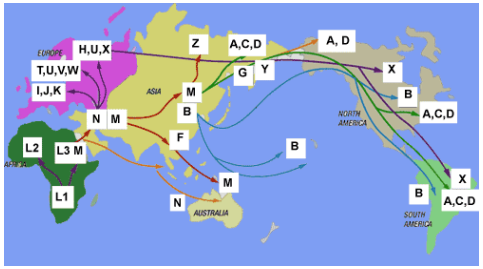



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# 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 commun-icate	Lifetime of advanced civilizations
	20 stars/ yr	0.8 systems/ star	2 x 0.11 = 0.22 planets/ system	0.775 life/ planet	0.505 intel./ life	comm./ intel.	yrs/ comm.

Backdrop of Civilization

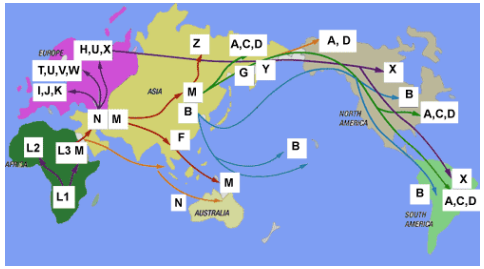
- Origin of modern H. sapiens is disputed, but the genetic and linguistic evidence points toward a spread of humans across Eurasia then the Americas.
- We share a common gene pool, but genetic drifts and selection for local environments created genetic differences among groups.



http://en.wikipedia.org/wiki/File:Migration_map4.png

Backdrop of Civilization

- These genetic differences have little to do with the concept of race, which has been showed by genetic studies to be a meaningless concept.
- The greatest genetic and linguistic variations are found in Africa, supporting the "out of Africa" idea.



http://en.wikipedia.org/wiki/File:Migration_map4.png

Cultural Evolution

- Once humans spread across the globe, the primary method for evolutionary change shifted from biological to cultural evolution.
- Anatomically modern H. sapiens evolved 100,000 yrs ago, but the first modern behavior did not appear until 40,000 yrs ago– e.g. cave painting.
- Regardless, there has not been any significant biological evolution for the last 40,000 yrs– e.g. brain increase.

http://www.codcottage.freeserve.co.uk/images/hand_castillo_spain.jpg

Cultural Evolution

- The rest is cultural– from hunter-gathers to cell-phone-users.
- Cultural evolution was fast.
- Is cultural evolution needed for ET? Why would a ET culture try to communicate with us?
  - Capability (suitable technology) and interest (worldview?).

Hunting and Gathering

- Until 10,000 years ago, H. Sapiens functioned completely as hunter-gathers.
- Small nomadic tribes with few possessions.
- Except for shortages, a fair and easy life
  - No midterms/finals
  - Only working about 4 hours a day
  - But, no way to create surpluses or free members for other roles.
  - When things go bad, they really go bad.

http://www.cnn.com/WORLD/9511/safrica_bushmen/

Agriculture

- Tribal societies– 100s of people into villages
- Due to agriculture, larger and larger communities and new societal organizations.
- Began about 10,000 yrs ago, around the dead sea.
  - Mixed hunting with harvesting of wild wheat and barley.
  - Storage, planting, and seed selection.
  - Mutant varieties took over and hunting decreased.
  - 1000 years later, animal domestication.

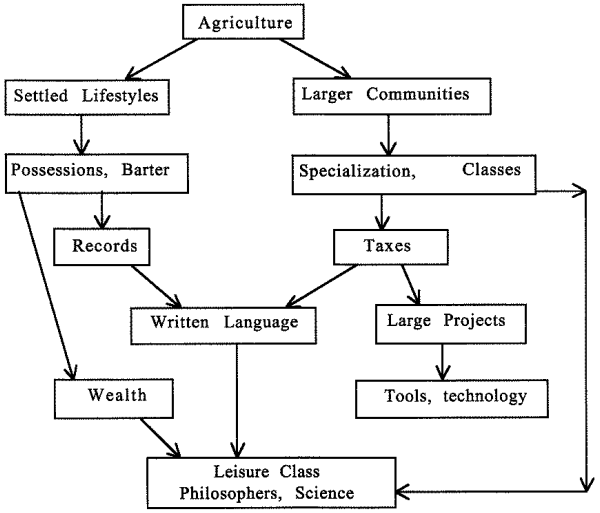
http://www.ffa.org/media/comm/index.html

Agriculture

- Provided long-term settlements for cultural evolution, information, tools, and energy sources.
- At first purely agriculture communities are hard:
  - A lot more work
  - Usually dietary deficiencies

http://www.ffa.org/media/comm/index.html

The Importance of Agriculture



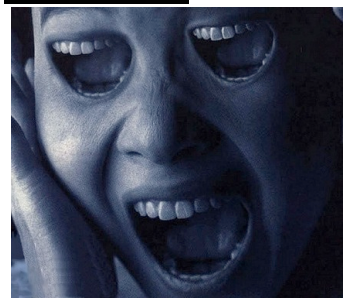
Question

What cultural break-through eventually allowed for professional scientist, like Astronomy professors?

a) Telescopes
b) Religion
c) The spoken word
d) Agriculture
e) Monkeys

Language and Information

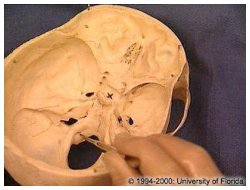
- Limited size for brain, due to birth canal size, so limited bits of info.
- Need to develop **extra-somatic** (outside the body) information storage techniques.
- First method to store information from another person was spoken language.
- Crucial development.



http://muslimhiphop.com/index.php?p=Popular_AIternative_Genres/Spoken_Word
http://beyondrace.com/articles/news/2228-henry-rollins-to-bring-spoken-word-tour-to-us
http://www.musiclikedirt.com/2008/12/05/the-art-of-the-spoken-word-compilation/

Language and Dis-Information

- But the origins of language are not well understood– no fossils.
- Probably in hunting parties for large prey.
- The control of the tongue is through the hypoglossal canal (hole) in the skull. In humans it is twice as large as chimps.
- First arose about 400,000 yrs ago in Australopithecines.

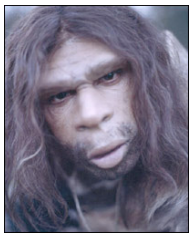


http://members.aol.com/paroleinfo/PRESSURE.HTM

http://imc.gsm.com/integrated/haonline/haonline/ha/imgs/00000/3000/600/3604.jpg

The Language Gene?

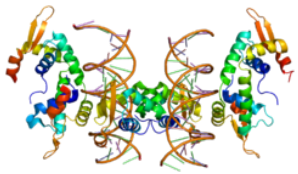
- FOXP2 was identified recently.
  - A severe speech and language disorder that affects almost half the members of a large family.
  - They are unable to produce the fine movements with the tongue and lips that are necessary to speak clearly.
- Human FOXP2 differs from chimp FOXP2 by only two amino acids, mouse by only 3, and zebra finch by only 7.
- Recent research shows that Neanderthal version is identical to ours. Maybe speech happened soon after chimp/hominid split?



http://news.bbc.co.uk/nolpda/ukfs_news/hi/newsid_6146000/6146908.stm

The Language Gene?

- FOXP2 also plays a role in songbirds
- In Zebra Finches a reduced FOXP2 results in incomplete and inaccurate song imitation.



Writing

- Oral language is clearly limited.
- Development of written language provided a powerful, new source of info storage.
- Earliest appearance was in Sumer– present day Iraq (8500 BCE).

MS 3008
Account of commodities. Sumer, ca. 3200 BC.
The earliest continuous writing known

http://www.nb.no/baser/schoyen/4/4.4/441.html

Writing:
The Beginning of History

- Probably started from economic need– barter or receipts.
- Common by 3000 BCE.
- Written records of taxes and a ruling class– the rise of civilization.
- Move from symbols to syllabic language developed by 1500 BCE.

MS 3008
Account of commodities. Sumer, ca. 3200 BC.
The earliest continuous writing known

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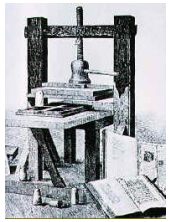
Question

Language and writing are examples of

a) culture.
b) the FOXP2 gene.
c) extra-somatic storage.
d) how daddy went to jail.
e) early government.

Extrasomatic Storage Leaps

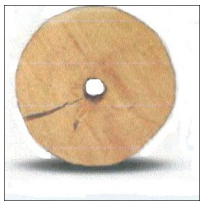
- Printing press (1456) – number of books jumped from 10,000 to 10 million in 50 yrs.
- Telegraph (1844)
- Radio (1895)
- Television (1936)
- Computers (1950s)
- Internet (1970s)
  - Huge extrasomatic storage: Well above brain storage



Does all of this increase the "intelligence" of our species?

From Rocks to Metal

- Stone tools (silicates) started with H. habilis about 2 Myrs ago.
- Agriculture developed at the end of the stone age.
- First pottery (still silicates) around 7000 BCE.
- First metal (copper) in 6500 BCE, mostly ornamentation.
- The wheel was invented in 6500 BCE.

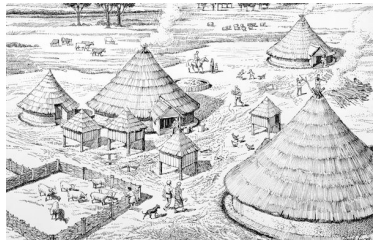


http://www.angelfire.com/country/veneti/images/OldestWheel.jpg

From Rocks to Metal

- Copper tools in 4000 BCE.
- Animal drawn vehicles & sailboats in 3300 BCE.
- Bronze (copper and tin) tools in 2800-1000 BCE (the Bronze age).
- Iron first showed up in 1500 BCE.

http://www.museumoflondon.org.uk/MOLsite/learning/who_are_you/teachers/images/citizenship/iron_age_settlement_no192.jpg



From Rocks, to Metal, to Rocks

- Next real step was developing energy sources.
- The industrial revolution.
- Modern technology based on electronics, crucial to our ability to communicate with ET.

http://www.learnhistory.org.uk/cpp/industrial-revolution-children-labor.jpg