

ET: Astronomy 230



HW 7 due on Friday!

Presentations Monday Nov 7th

Nick Warren

Jeff Greenswag

Jennifer Brown

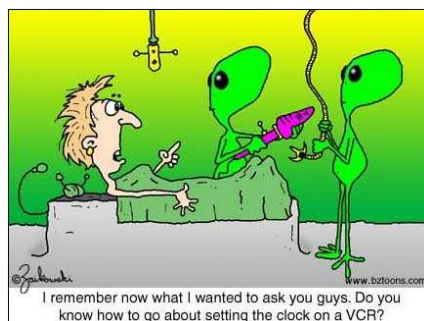
This Class (Lecture 29):

Origin of Intelligence

Next Class:

Cultural Evolution

Music: *Space Oddity* –
David Bowie



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Outline



- Early Life– making the atmosphere.
- Summary of life on Earth.
- What is intelligence?
- Development of intelligence.
- Brains. Brains.
- The rise of the primates!

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= 0.21

Life planets
/year

Drake Equation

Frank
Drake



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

# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commu- nicate	Lifetime of advanced civilizations
	10 stars/ yr	0.38 systems/ star	0.11 planets/ system	0.5 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

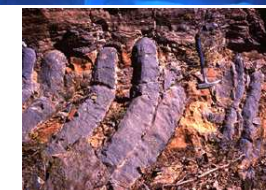
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Making Oxygen!

- The early prokaryotes played a crucial role for life on Earth by producing oxygen through photosynthesis.
- Cyanobacteria (was 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.



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Making Oxygen!

- 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).



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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.

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Evolution of Intelligence



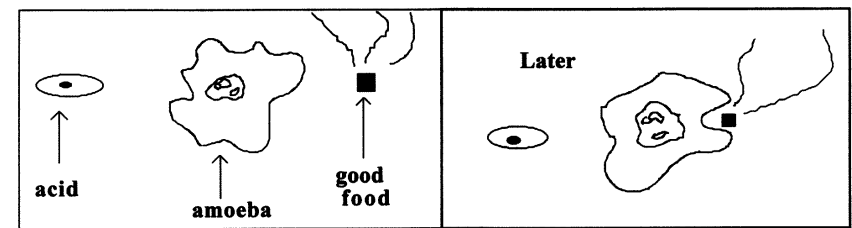
- Through diversity, evolution has resulted in an increase in the complexity of organisms on Earth.
- Can we associate complexity with intelligence?
- If intelligence is an advantageous trait, it is plausible that intelligence would increase over time.
- But, what is intelligence?

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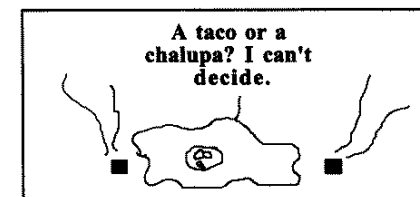
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An Amoeba Distinguishes



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



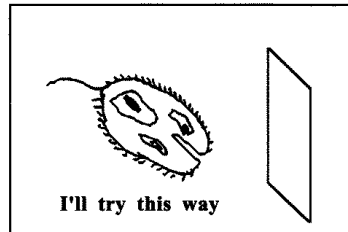
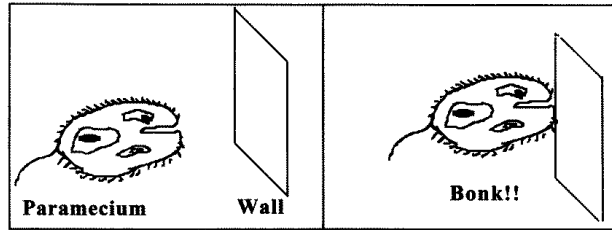
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The Intelligent Paramecium?



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

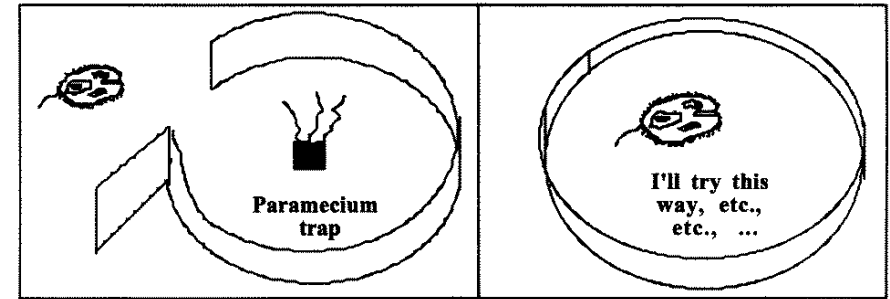


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Intelligence Breakdown



- 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.

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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?

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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>

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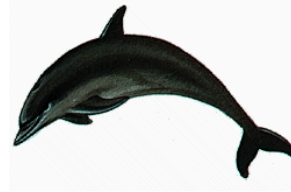
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DNA Storage



- 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, like 4000 books of 500 pages.



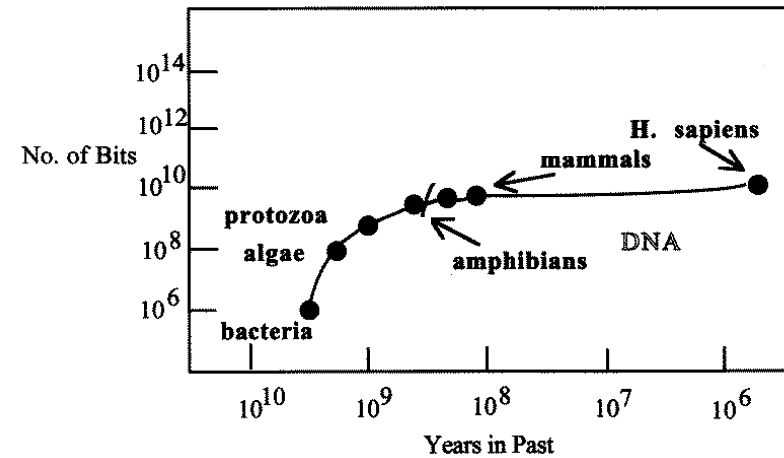
Spottet Dolphins sounds
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Development of Intelligence



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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 actually codes proteins, then humans have 1.2×10^8 bits, or 800 books
 - For some organism the junk DNA is significant: Newts and lilies would have more than 10^{11} bits.
- 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.ceingeorgia.org/cic/images/landfill.jpg>

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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.
- 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!



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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.



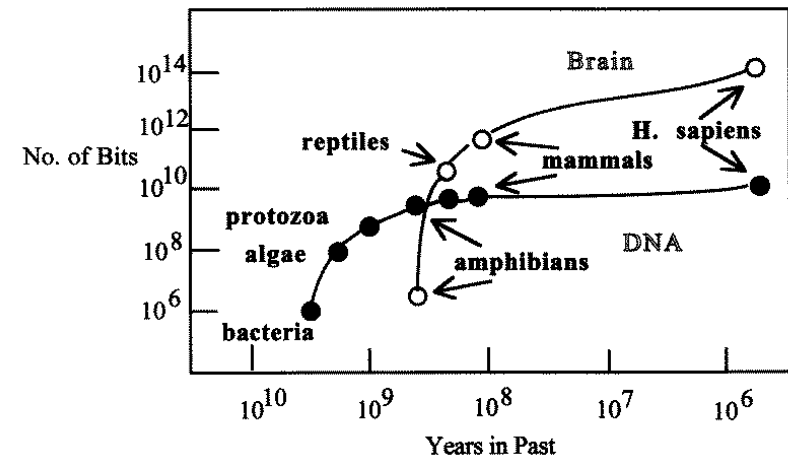
- An impulse triggers a chain of neurons to “fire” causing a reaction. So, really the information is stored in synapses. $10^{11} \times 10^3 = 10^{14}$ bits

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Development of Intelligence



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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 diversity is the key. With more organisms of all types, a more intelligent species is reasonable.
- 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>

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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?
- 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.

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65 million years ago

Mass Extinction

Extinction of the dinosaurs and others

Earth View



CRETACEOUS
65 million years ago

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



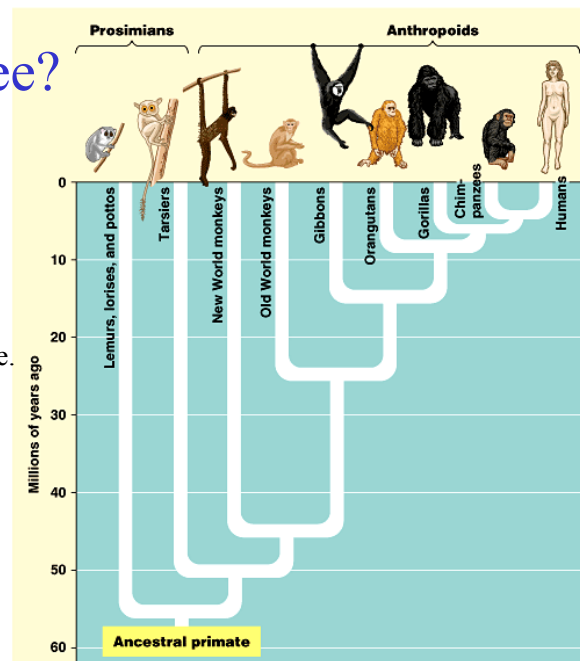
Not that one →

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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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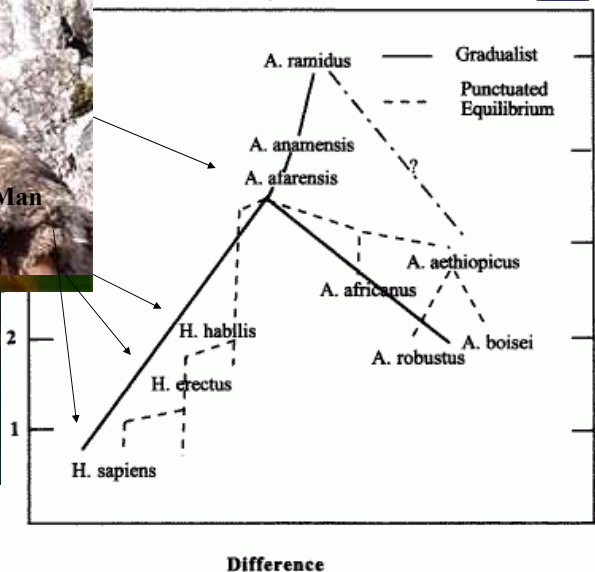
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The Last 5 Myrs



May or may not be 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 4-6 distinct hominid species living.
- 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.

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f_i Considerations



- Complexity leads to intelligence, but complexity seems to require a benign environment. Harsher environments have simpler organisms.
- Perhaps life may exist on harsh planets, but more intelligent life?
- Remember, human intelligence took 4.5 billion years.
- Systems too 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.

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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.

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f_i Considerations



- How unique is our intelligence?
- Teaching sign language to chimps and gorillas have shown they are more intelligent than we thought.
- Whales and dolphins are speculated to be of high intelligence.
- 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.

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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.