

# Astronomy 330



This class (Lecture 17):

Biological Evolution

**Jennifer Christie**

**Jennifer Wojcicki**

Next Class:

Origin of Intelligence

**Michael Murphy**

**David Mayer**

**HW 7**

Music: *The Space Race is Over* – Billy Bragg

Oct 23, 2007

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# HW #3



- **Rogelio Cruz:**

<http://ufoevidence.conforums.com/index.cgi>

- **Josh Seiter :**

<http://www.alienmania.org/alien-abduction.html>

- **Steve Wyatt:**

<http://www.aliensandchildren.org>

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# Presentations



- **Jennifer Christie :**

[Human Colonization of Planets/Asteroids](#)

- **Jennifer Wojcicki :**

[Interplanetary and Interstellar Travel](#)

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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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## Increase of Complexity

<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
	Triassic	225	Mammals	Continental drift
	Permian	280	Reptiles	Pangaea breaks up
Paleozoic	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

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- Last table showed only the last 800 Myrs.
- More complex and intelligent organisms appeared later on.
- 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.

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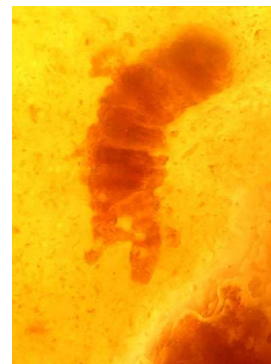
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<i>Myr Ago</i>	<i>Era</i>	<i>Event</i>
Now	Cenozoic	
	Mesozoic	
	Paleozoic	Macroscopic life/Snowball Earth
	Precambrian	
1000		Worm tracks
		Multicellular algae
		Eukaryotes certain
		Sexual reproduction
2000		Eukaryotes possible
	Protozoic	Oxygen-rich 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– 1/6<sup>th</sup> of the history of life on Earth.



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

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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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## Summary



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

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## Evolution of Intelligence

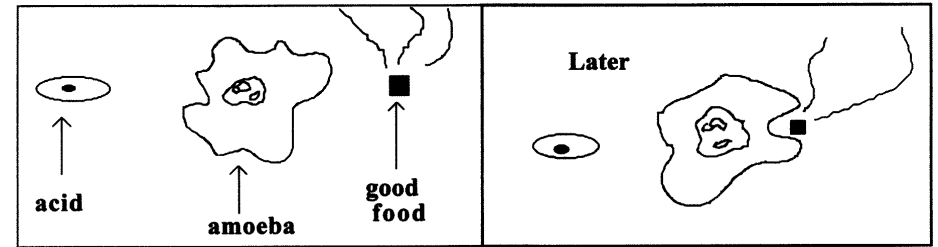


- Through diversity, evolution has resulted in an increase in the complexity of organisms on Earth.
- Can we associate complexity with intelligence?
- If intelligence is an advantageous trait, it is plausible that intelligence would increase over time.
- But, what is intelligence?

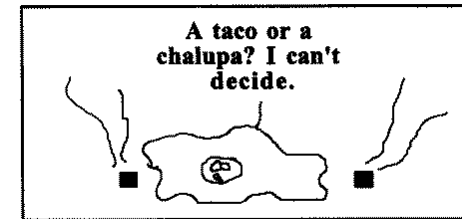
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## An Amoeba Distinguishes



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

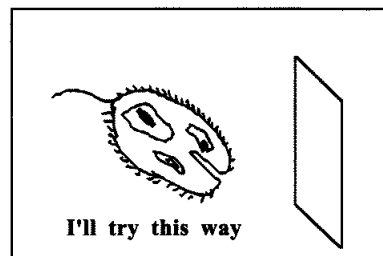
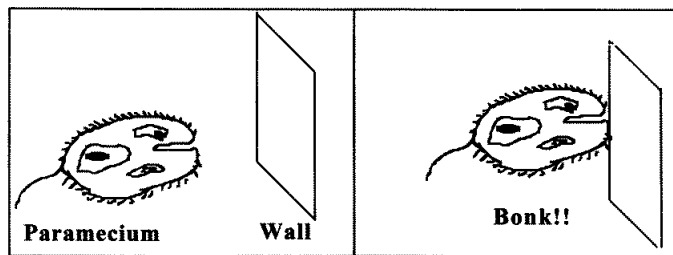


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## The Intelligent Paramecium?



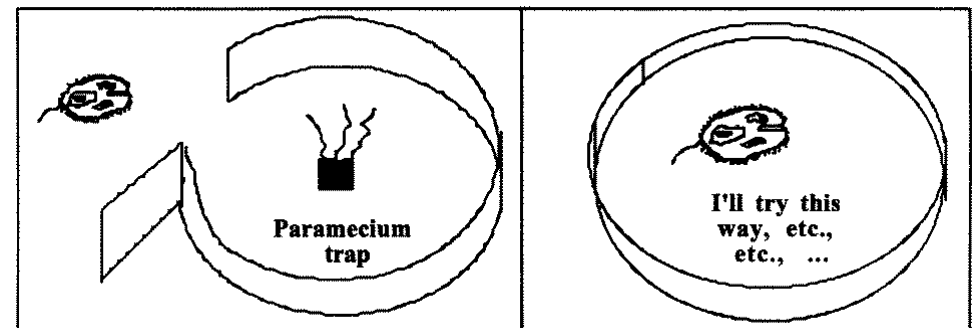
- Still one celled, but more complex.
- Has a kind of primitive memory.



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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>

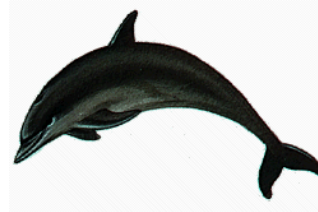
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## DNA Storage



- 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.

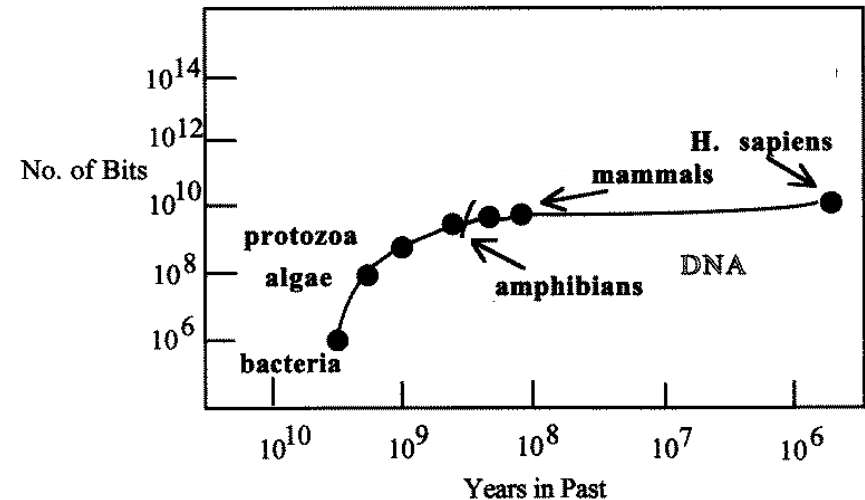


Spottet Dolphins sounds  
<http://neptune.atlantis-intl.com/dolphins/sounds.html>

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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  $1.2 \times 10^8$  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).
- 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.eetgeorgia.org/eic/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.

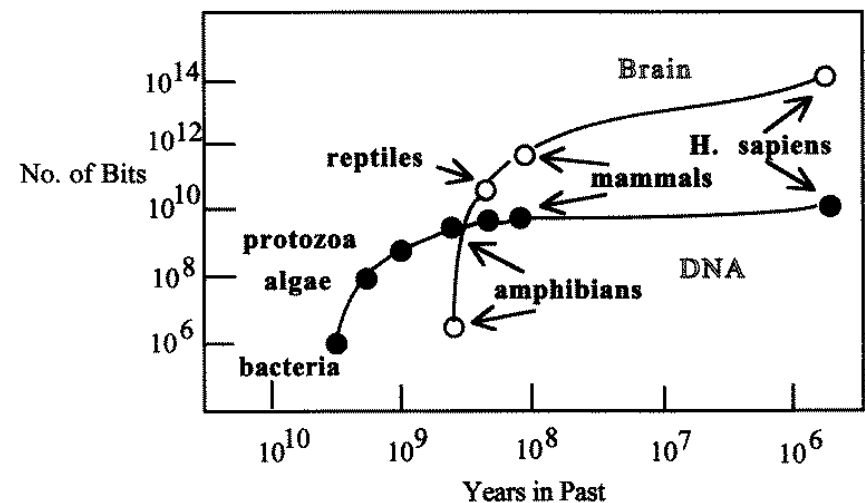


- An impulse triggers a chain of neurons to “fire” causing a reaction. So, really the information is stored in synapses.  $10^{11} \times 10^3 = 10^{14}$  bits (12.5 Terabytes)

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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



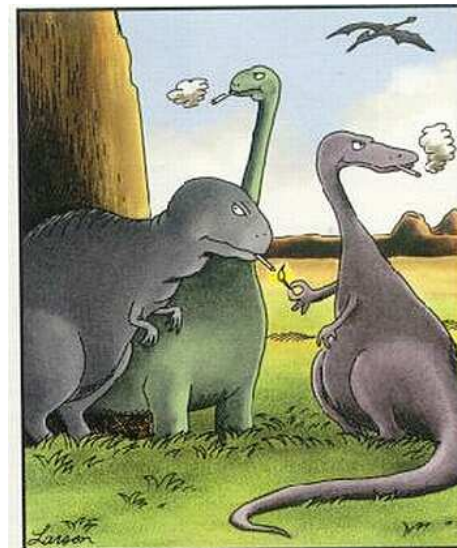
- Our species is the only one on Earth to have developed a technological civilization.
- How likely is that to happen on other planets?
- Actually the development of humans is still controversial, even among anthropologists. New fossils are appearing that change our understanding.
- Mammals first appeared on the fossil stage about 200 Myrs ago, but were minor players until about 65 Myrs ago.

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# Less Credible Theories



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

The real reason dinosaurs became extinct

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# 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.



← That one

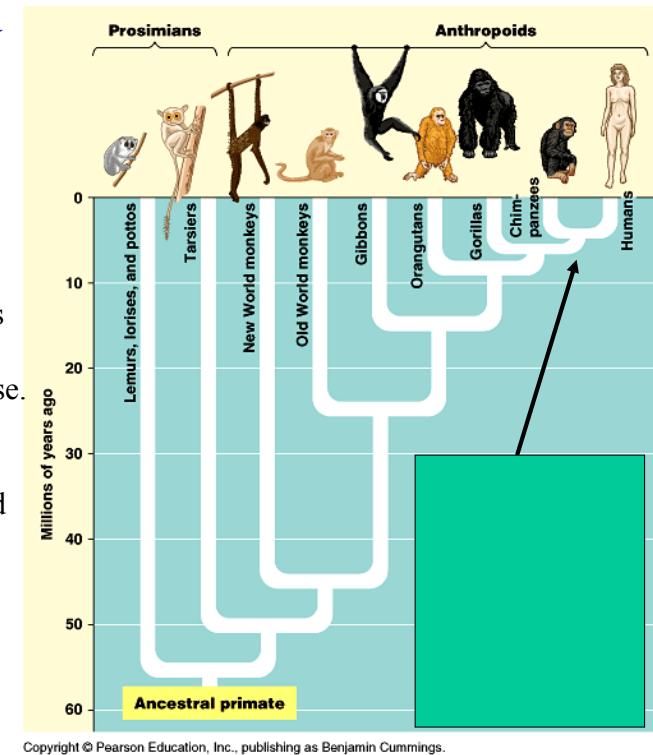
Not that one →



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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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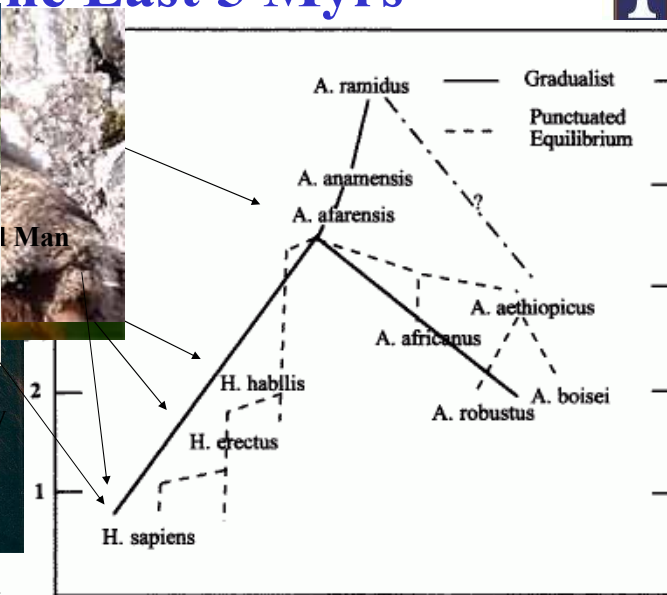
# The Last 5 Myrs



Sapiens that had larger brain volume and probably language.

Went extinct 28000 yrs ago.

May or may not be related to us.



Difference

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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<sub>i</sub> 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?
- 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.

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## f<sub>i</sub> 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<sub>i</sub> 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!"

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## f<sub>i</sub> Considerations



- 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.