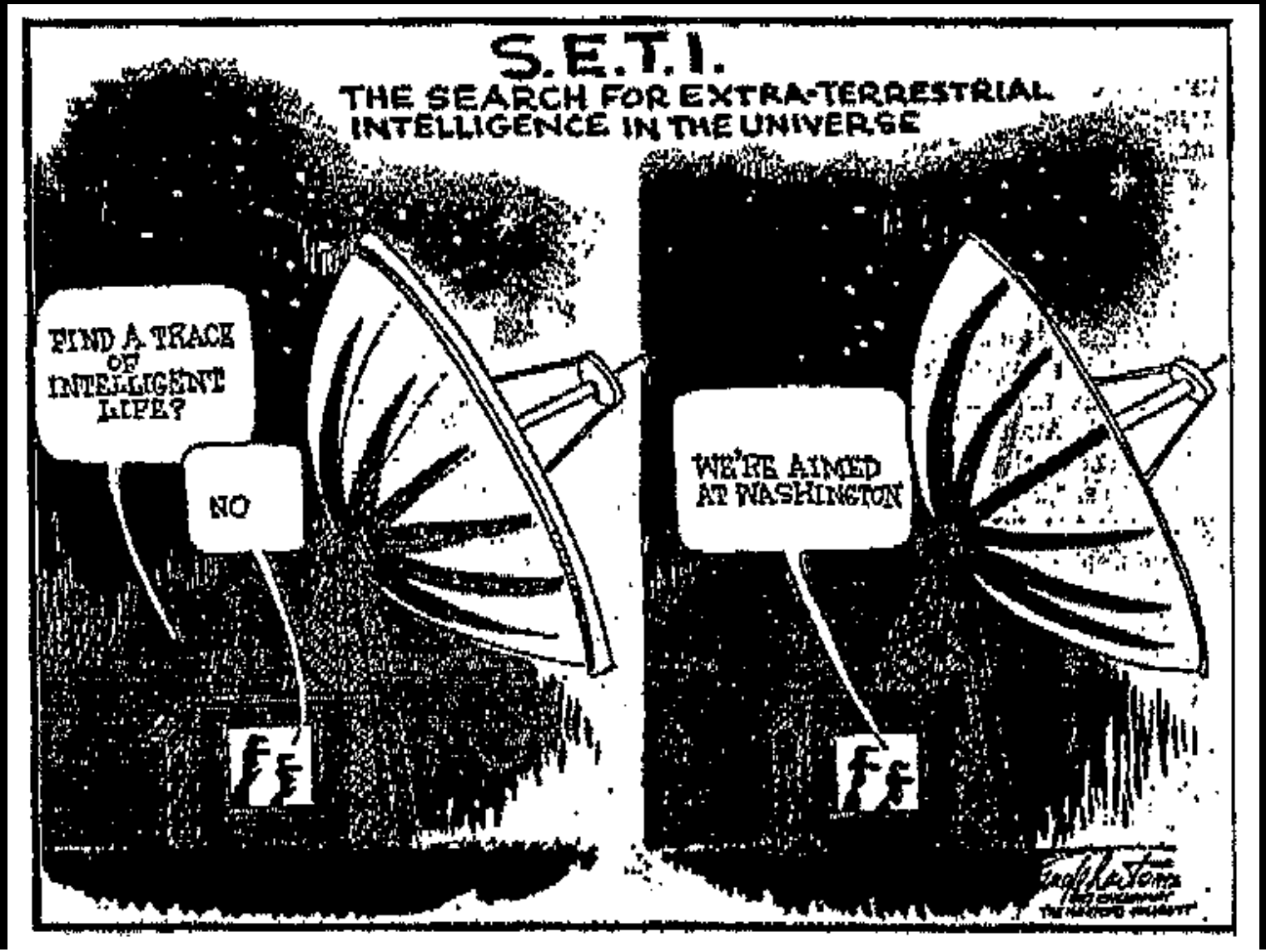
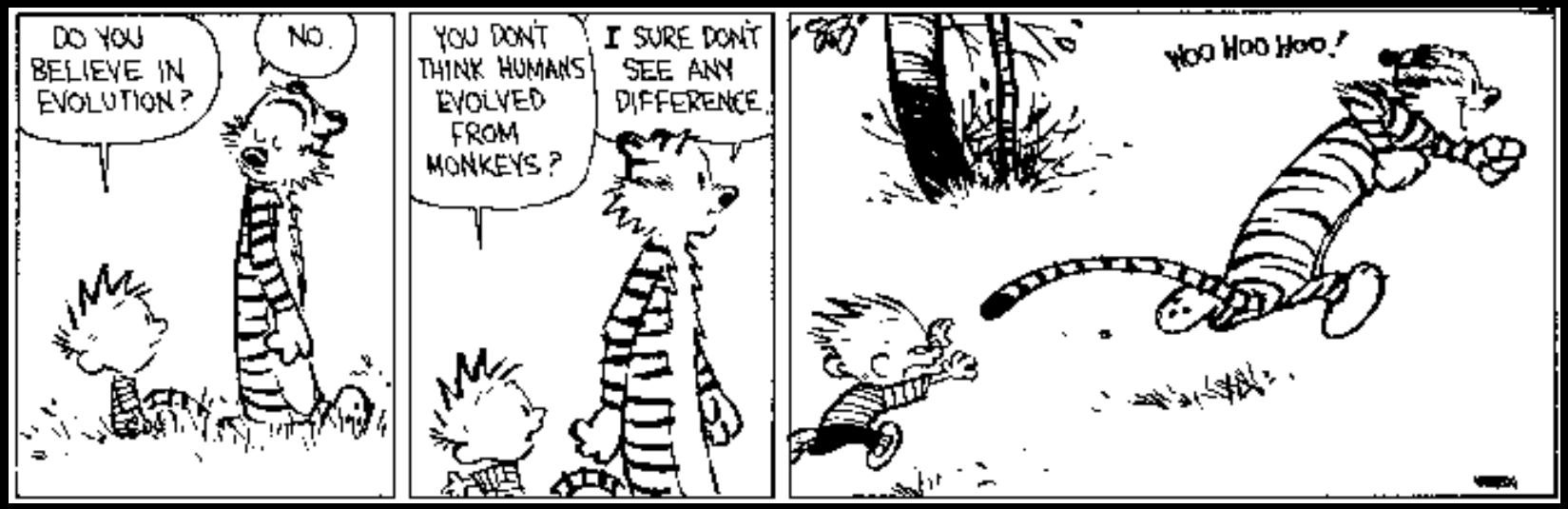
ASTR 380
Is Intelligence Common?



ASTR 380
Is Intelligence Common?

What is intelligence, and which species have it?
Biological prerequisites for intelligence
Development of intelligence in humans
The advantages and cost of intelligence on Earth
The competition of human evolution
What does this imply for the fraction of planets with life that develop intelligent life?



Bill Watterson

What is Intelligence?

- Clearly we would like to define it in terms of humans, but let's try to be objective
- Some components include:
  Adaptability to changes or new environment
  Capacity for knowledge, reason, abstractions
  Capacity for original thought
- What animals on Earth have this?

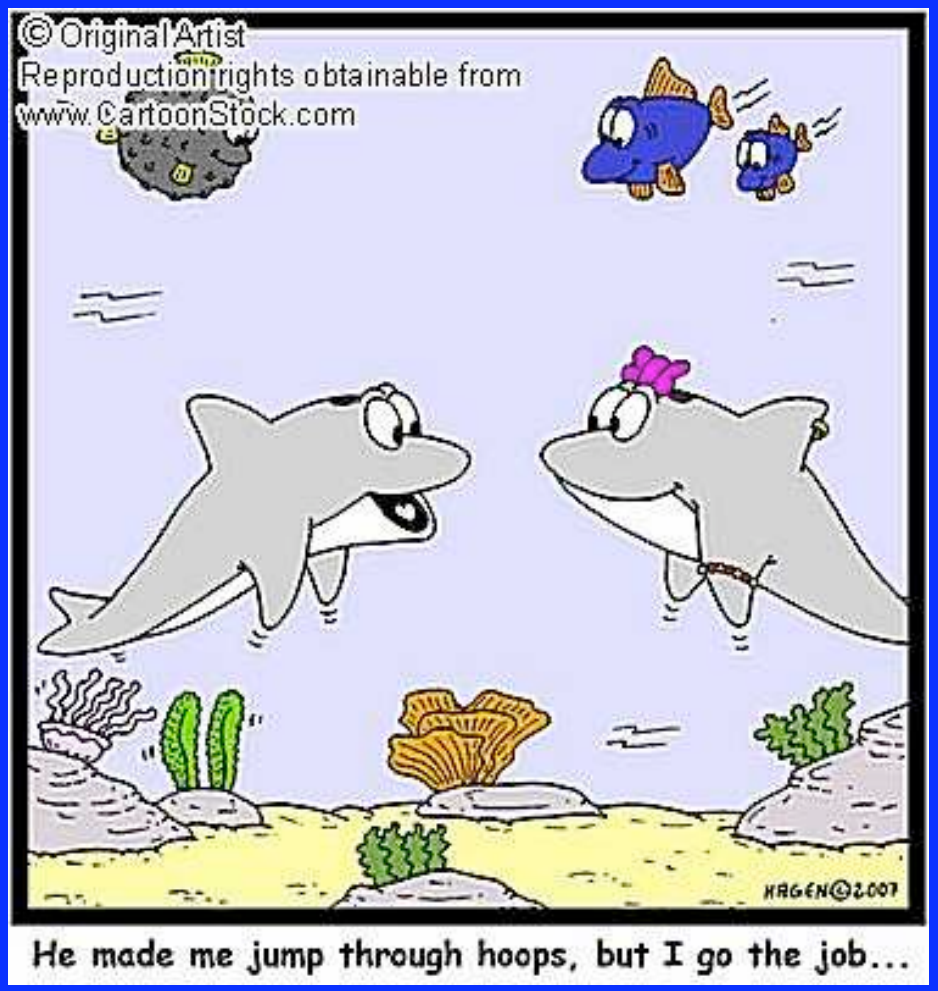
Are Crows Intelligent?

- Very smart birds!
- This one has bent a wire, then used it to pick a bucket of food out of a container
- Should it count as intelligent?

users.ox.ac.uk/~kgroup/ tools/crow_photos.shtml

Are Dolphins Intelligent?

- Large brain/body mass ratio
- Can solve complex puzzles
- Brain development through echolocation



Are Chimps or Bonobos Intelligent?

- Our closest relatives
- Complex social interactions, tool use, curiosity

http://scienceblogs.com/afarensis/2008/05/11/know_your_primate_pan_paniscus/

Collective Organisms

- Individual bees or termites aren't intelligent
- But their colonies have significant complexity
- Collectively, might they count as intelligent?

http://www.hiltonpond.org/images/TermiteColony01.jpg

It's Not Just Brains

- Our brains alone are insufficient for technology
- We are master tool makers and users
- Dolphins don't have this advantage, and most other animals don't either
- Lucky break for us?

http://techh2o.com/wp-content/uploads/2008/07/gamerhell.jpg

ASTR 380
Is Intelligence Common?

Biological prerequisites for intelligence:

From the fossil record of early life on Earth….

100 million years after the end of global sterilizing impact first life arose.

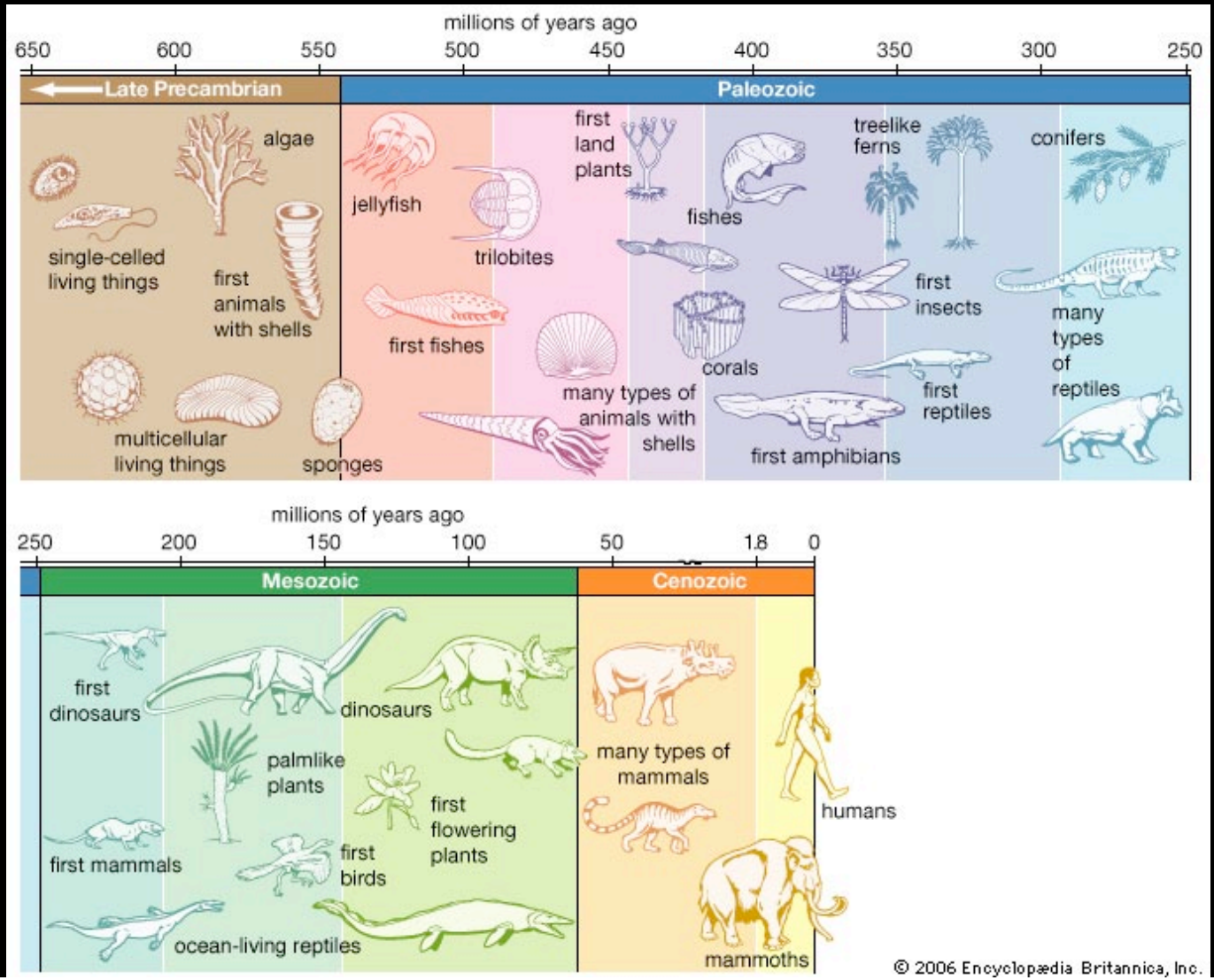
200-400 million years later cells capable of photosynthesis developed

2.5 billion years later the first multi-cellular life

It took the Earth roughly 3 billion years to develop multi-cellular organisms!

ASTR 380
Is Intelligence Common?

And another roughly 600 million years to get to us



ASTR 380
Is Intelligence Common?

Biological prerequisites for Intelligence:

Clearly the development of multi-cellular organisms was a major change and a required step toward intelligence.

From the genetic evolution and natural selection point of view, no single obvious step from a single self-sufficient cell to an organism with many specialized cooperating cells.

development from the cell within a cell model of
modern mitochondria or
the important development of stem cell biology?

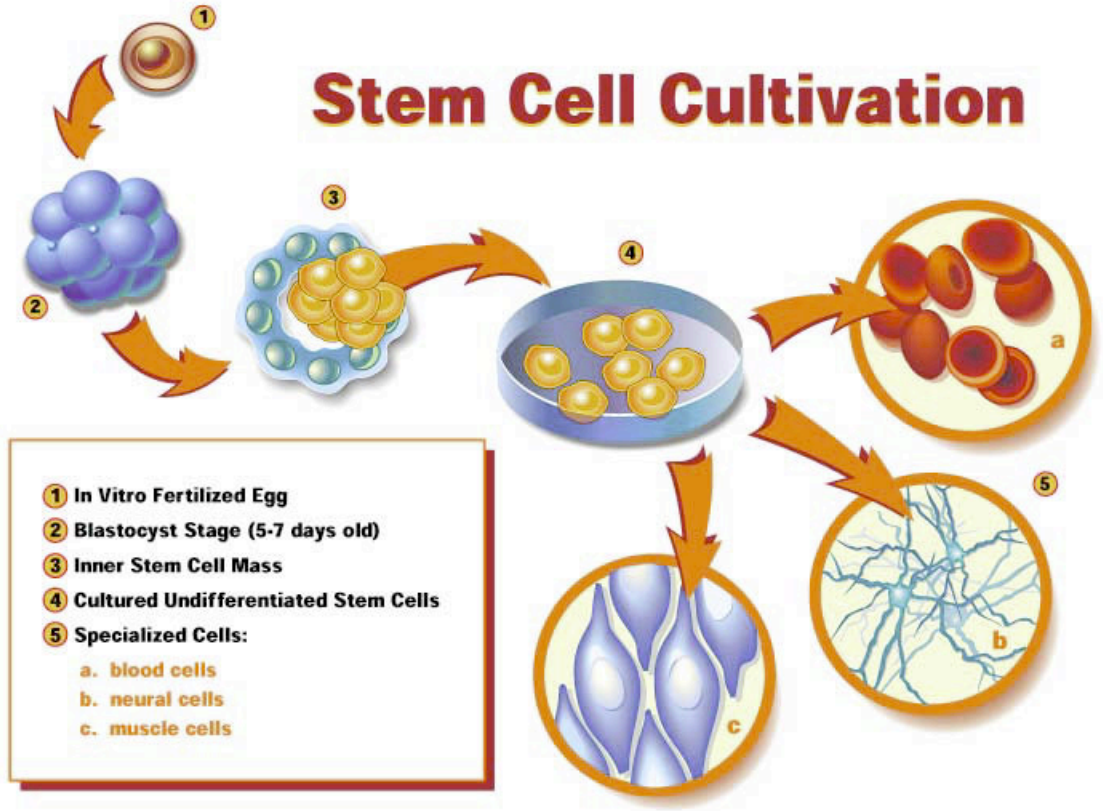
ASTR 380
Is Intelligence Common?

Biological prerequisites for intelligence:
All multi-cell organisms use stem cells as the mechanism to go from a single cell to many cells with different functionality.

The process appears to be controlled by chemical signals.

One genetic plan
Many types of cells

More than 200 types in us.



ASTR 380
Is Intelligence Common?

Biological prerequisites for intelligence:

Reproduction from a single “egg” cell – sexual reproduction -- is common in multi-cell organisms but asexual reproduction is also possible on some.

Some sponges (animals) can reproduce by budding – where a piece of the organism breaks off and becomes a new organism.

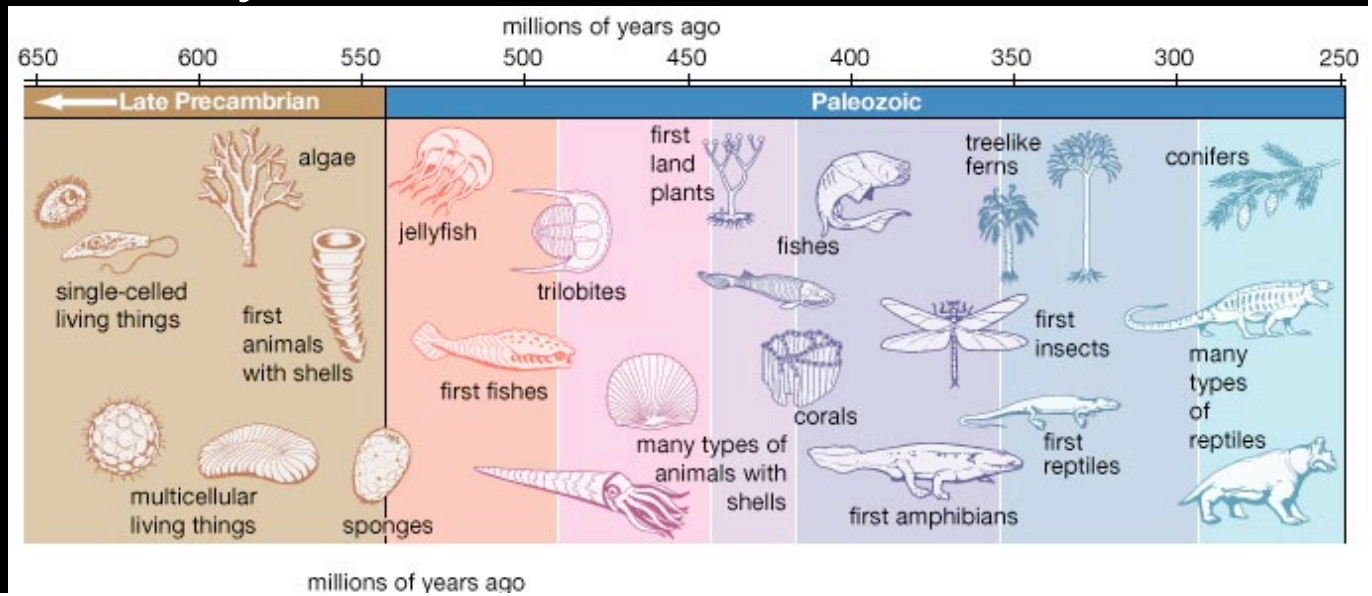
Some plants can be grown from leaf cuttings or produce baby plants on themselves.

ASTR 380
Is Intelligence Common?

Biological prerequisites for Intelligence:

The concept of a central nervous system and central control of the organism developed at some point.

It can be argued that this occurred by the time of the first fish – about 100 million years after the first multi-cell organism.



ASTR 380
Is Intelligence Common?

Biological prerequisites for Intelligence:

The most intelligent organisms on Earth are mammals – from whales to dolphins to monkeys and humans.

Why mammals?

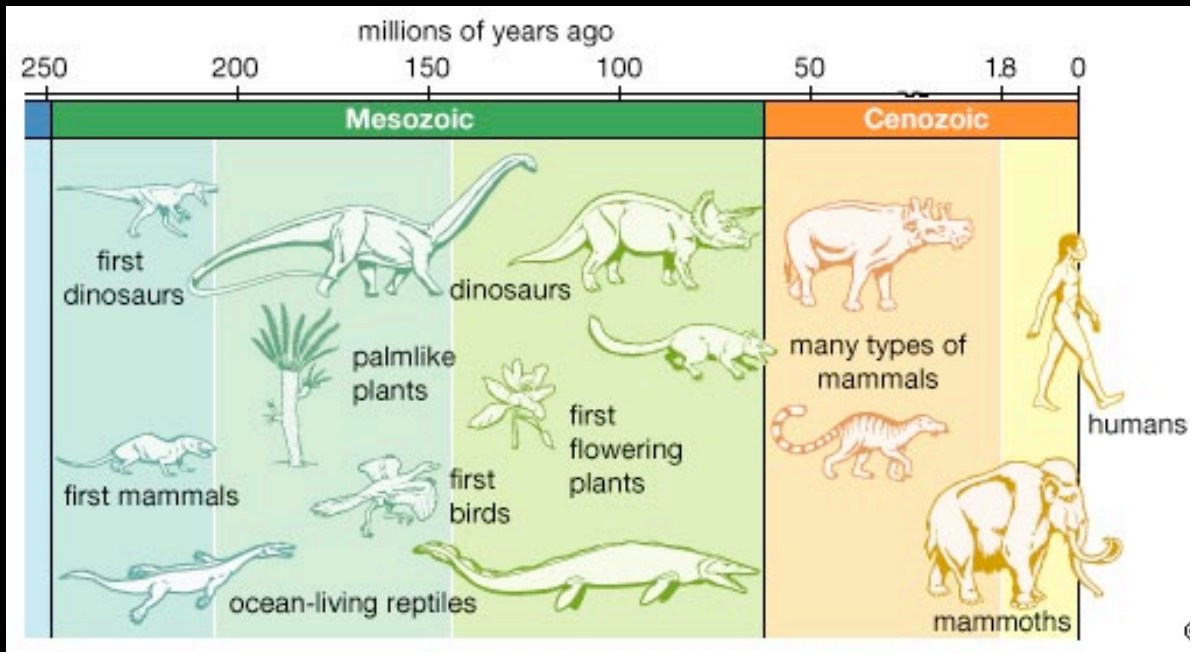
Why didn't reptiles develop intelligence?

The only apparent answer is evolutionary pressure. The brain became an essential weapon for being the "fittest" – like size, strength, and speed.

ASTR 380
Is Intelligence Common?

Mammals first emerged as tiny shrew-like creatures around 210 million years ago – when dinosaurs dominated.

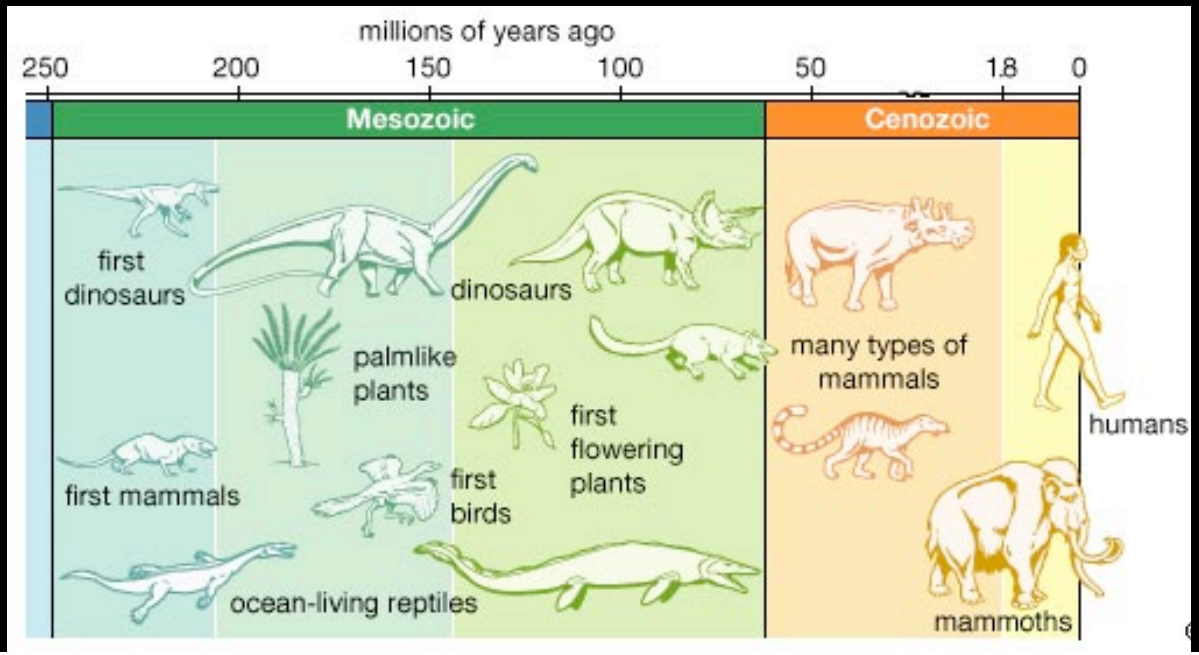
65 million years ago, mammals were a well established minor group and they rose to power when the non-avian dinosaurs died off.



ASTR 380
Is Intelligence Common?

The key to mammals ascending was the opening of a host of ecological niches for mammals to spread.

Ecological opportunities spur rapid evolution and competition to develop winning traits.



ASTR 380
Is Intelligence Common?

Biological prerequisites for intelligence:

multi-cellular structure with specialization
central nervous system and central control
evolutionary pressure to select for complex behavior
which makes intelligence a survival asset
evolutionary opportunities through mass extinctions

What more can you think of?

Again, we are working from an example of one Earth. Perhaps Earth life did not take the only possible path to intelligence.

ASTR 380
Is Intelligence Common?

Development of intelligence in humans:

It is commonly argued that human intelligence was driven by factors like need for social interaction, the development of speech, and the complexity of the human hand.

The fact is that the size of the brain evolved strongly in our ancestors.

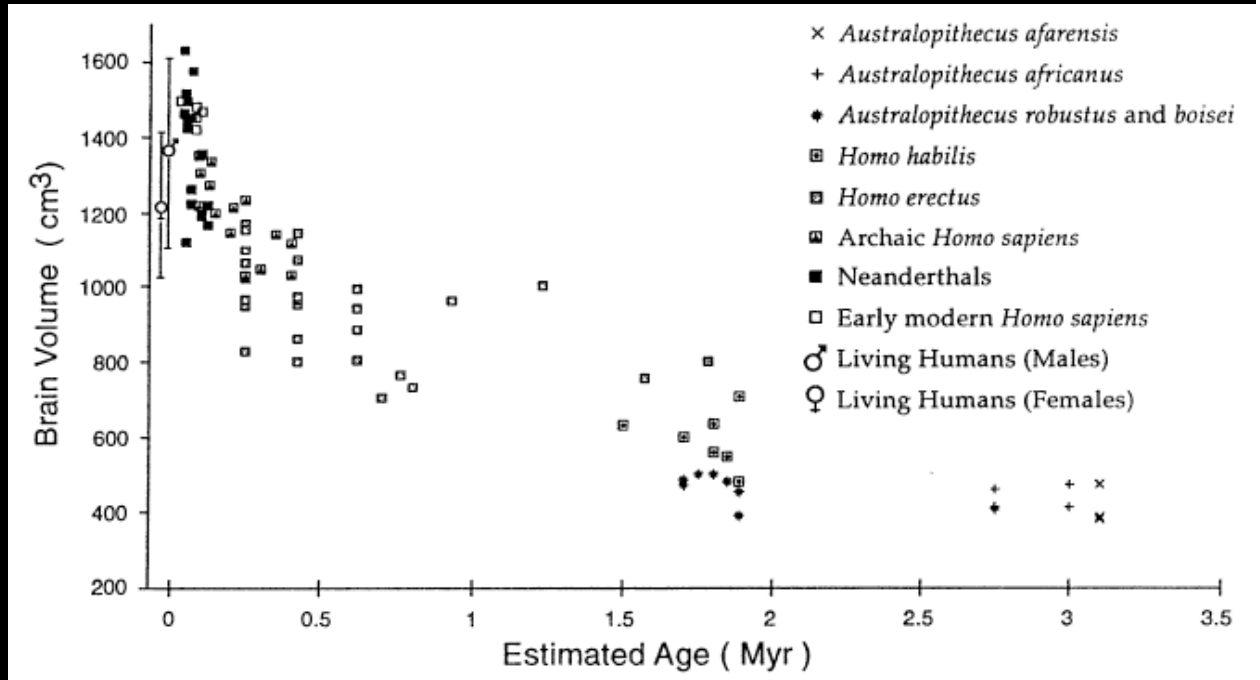


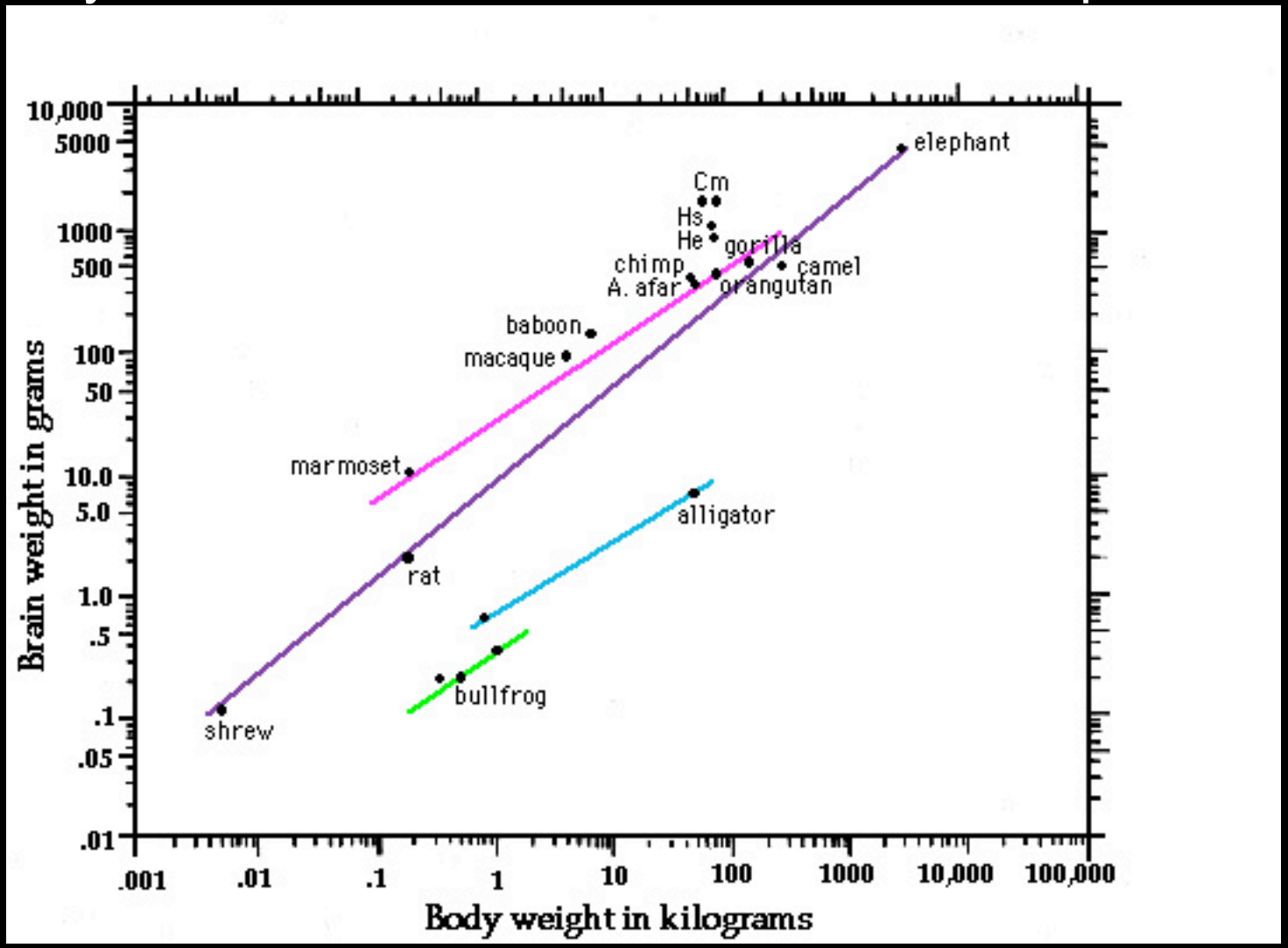
FIG. 4. Brain size (in cm^3) plotted against time (Myr) for specimens attributed to Hominidae.

It's Not Just Mass

- Intelligence does not just depend on brain mass!
  This was, of course, argued by male scientists, who overlooked that men are heavier than women on average
- Better measure might be brain/body mass ratio (in which case women win), but likely depends on many characteristics

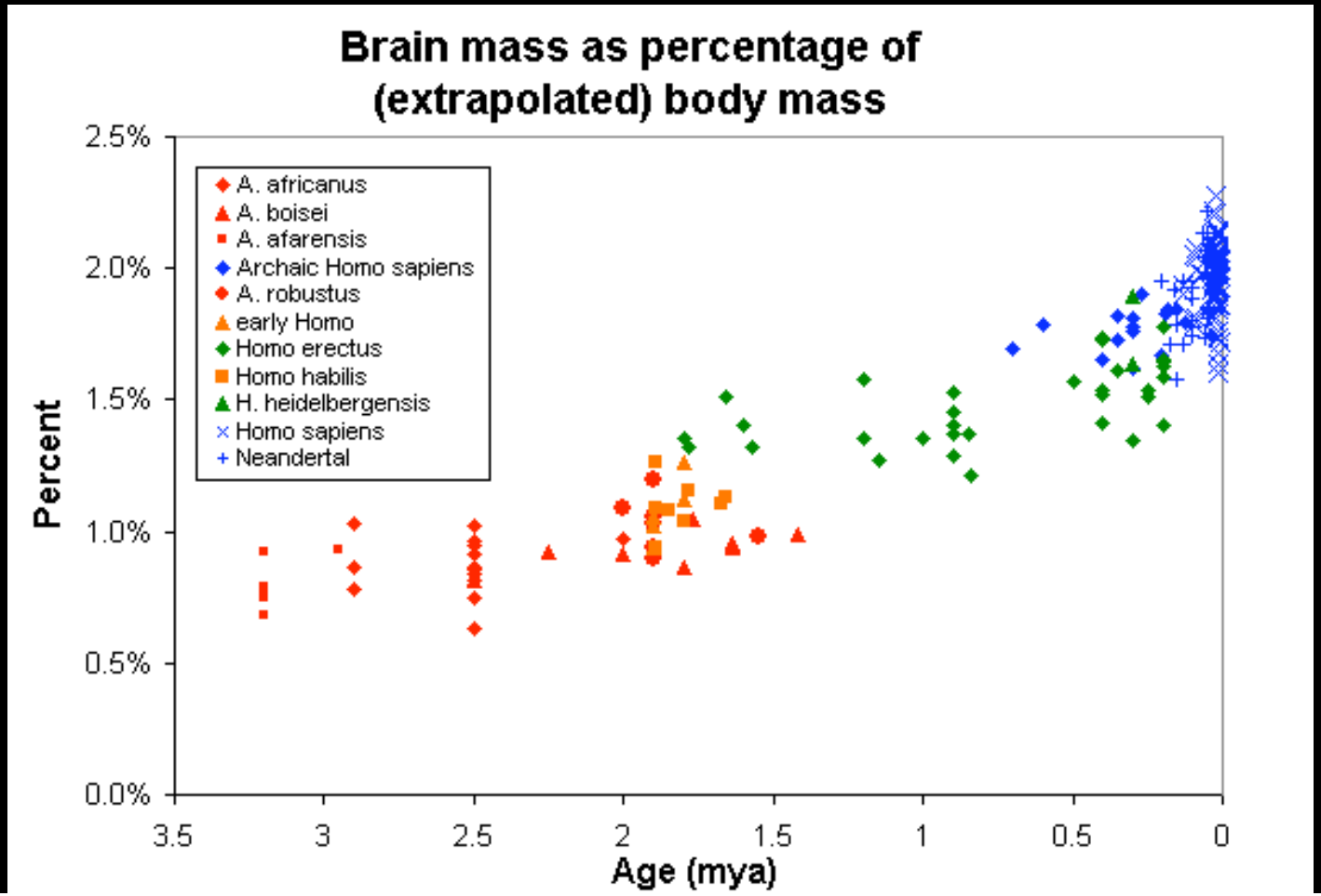
ASTR 380
Is Intelligence Common?

Our early ancestors had brains similar to other apes.



ASTR 380
Is Intelligence Common?

We have about triple the normal ratio of brain mass to body mass. Some animals beat us, though.

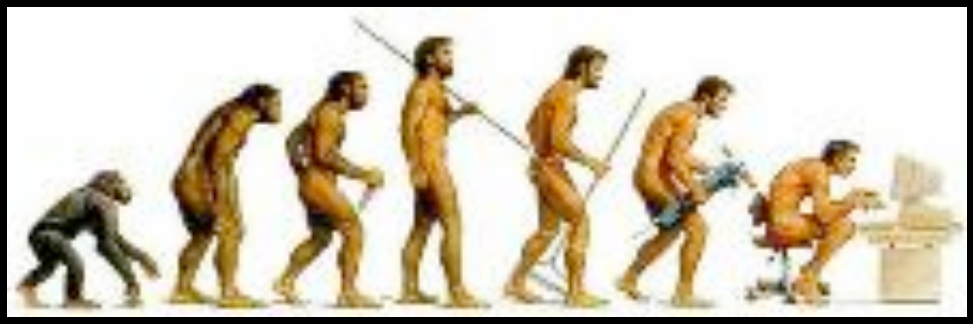


ASTR 380
Is Intelligence Common?

Clearly the brain must have given a survival advantage to early humans.

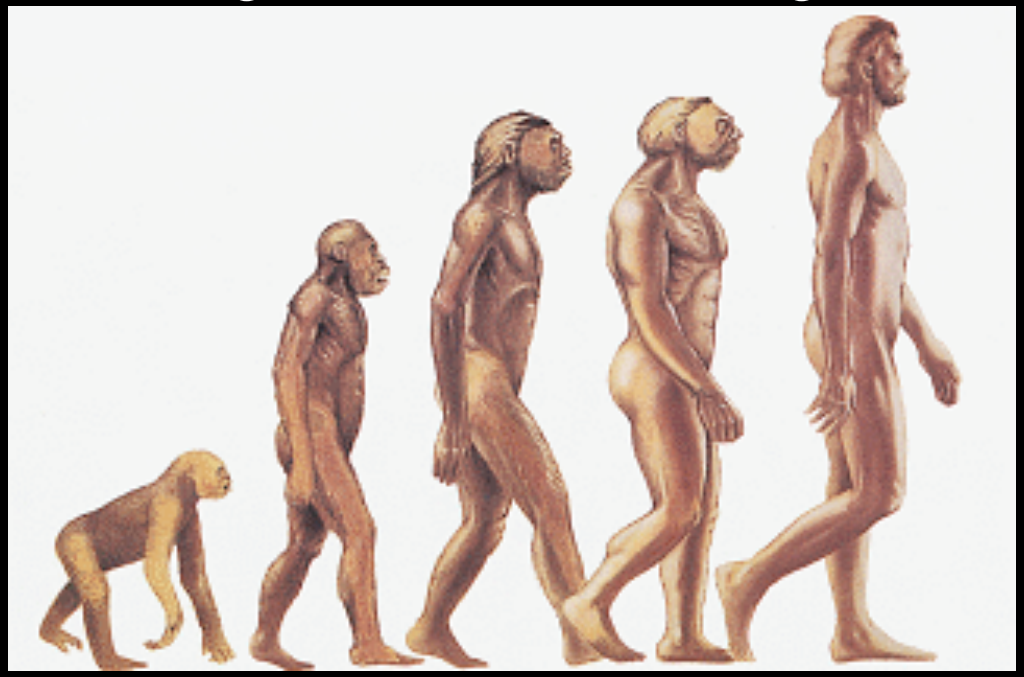
In modern humans about 20% of your daily calories are consumed by the brain – 2% of your body mass. This is a high price to pay biologically if there is not a strong advantage.

So… If intelligence is such a good thing, why aren't there more intelligent species on Earth?



ASTR 380
Is Intelligence Common?

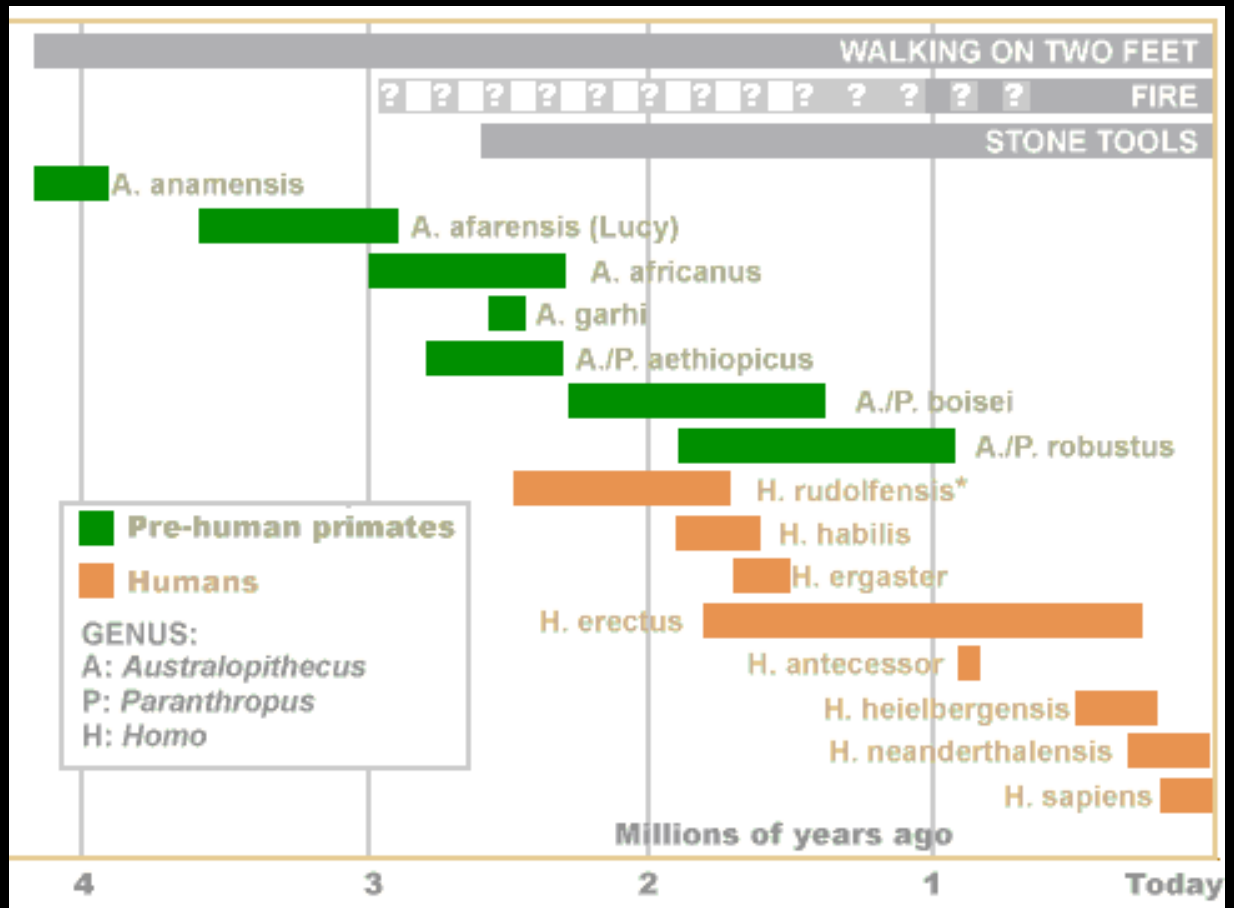
The old story of the linear evolution from ape to human is being shown to be wrong….



The family tree is being replaced with a family bush, Perhaps with a very sordid history…

ASTR 380
Is Intelligence Common?

Current fossil evidence argues for the co-existence of various human ancestors right up to 30,000 years ago.



Brains Aren't Everything, Pt. 2

- Neanderthals, humans lived at same time
- Neanderthals had larger brains!
- Not *necessarily* smarter, but it could be that we were more aggressive rather than brainier

ASTR 380
Is Intelligence Common?

Homo Sapiens (us) and Homo Neanderthalensis co-existed in time, and in some physical locations for a period of time.

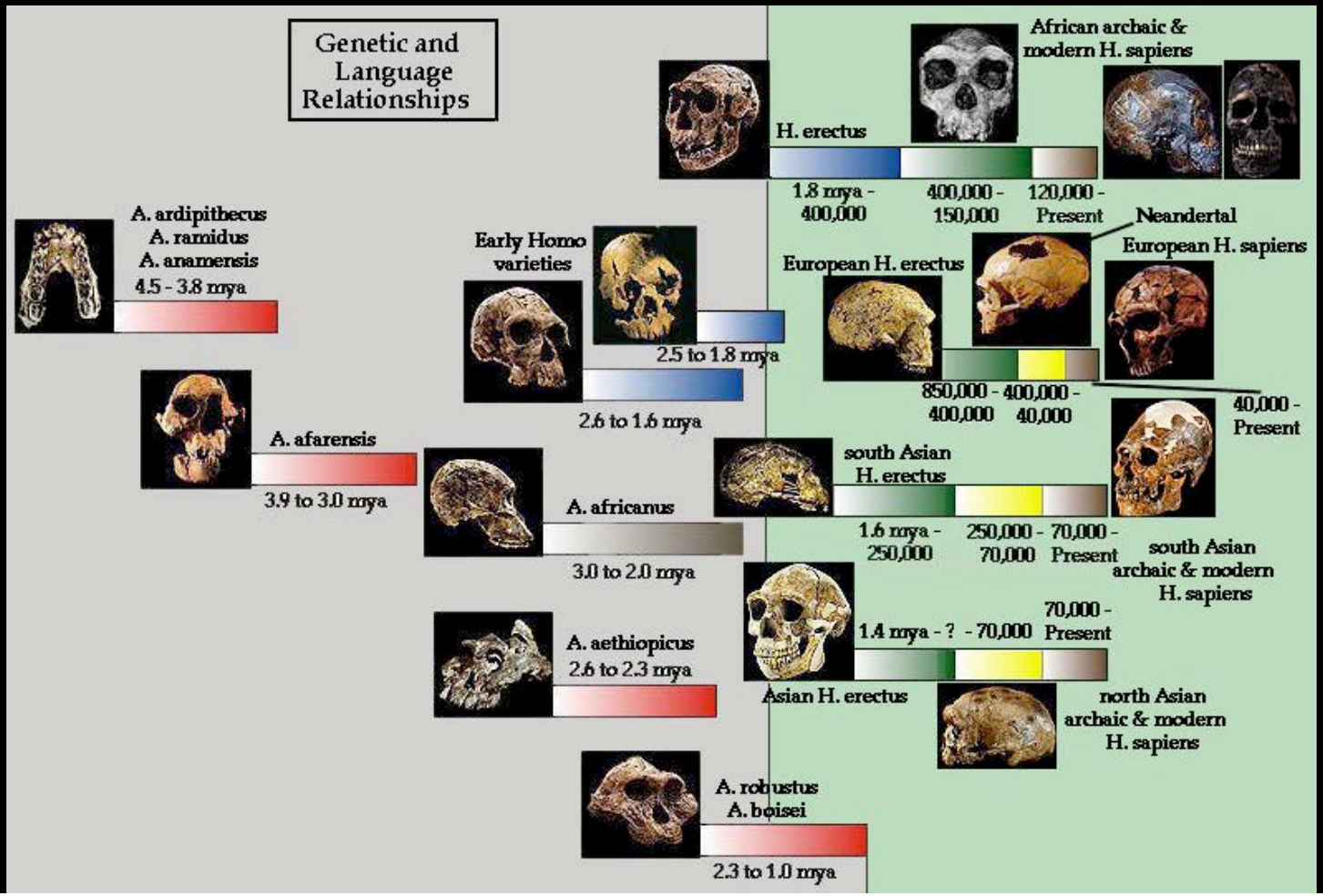
But it is argued based on genetic analysis that they are separate species which diverged from a common ancestor roughly 500,000 years ago.

Neanderthals used tools, had death rituals, and other hallmarks of intelligence.

Why did Neanderthals go extinct? We don't know but the fossil record suggests that there were "displaced" by the spread of Homo Sapiens.

ASTR 380
Is Intelligence Common?

A reasonable hypothesis is that we are the only highly intelligent species on Earth because we and our direct ancestors actively "displaced" the competition.

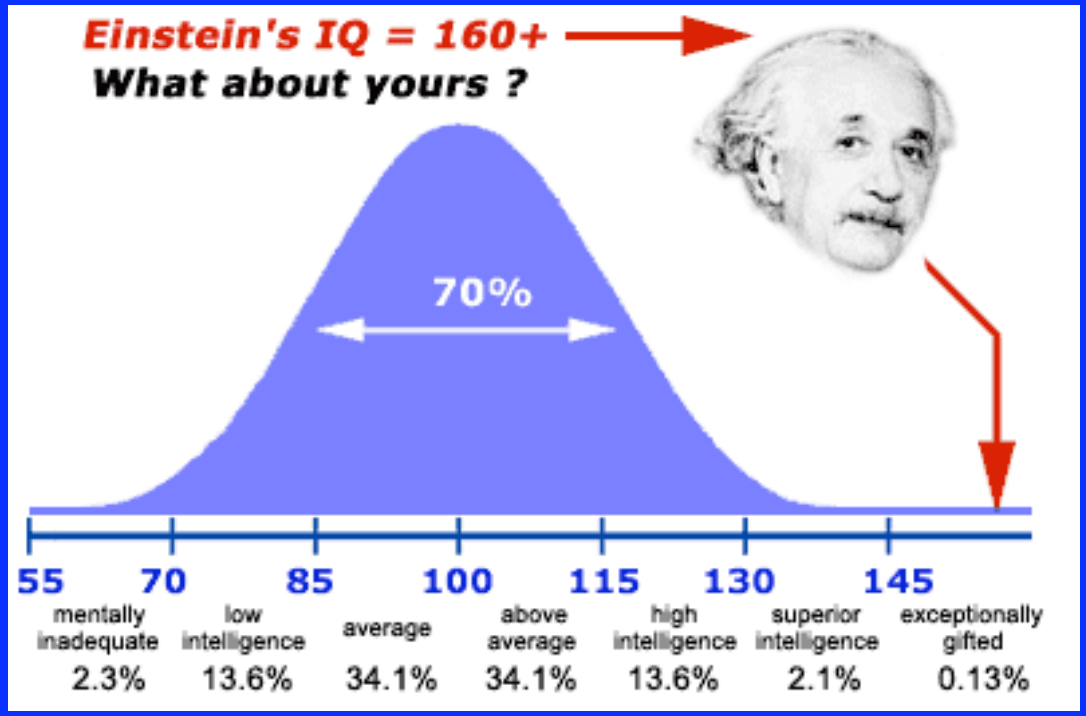


What Does "Displaced" Mean?

- Let's be explicit here!
- Most benign interpretation would be that we were better at getting to resources
- But, evidence exists that we underwent active warfare with Neanderthals
- Some persistent hypotheses that we might have interbred, but no positive evidence

Intelligence in Humans

- We like to simplify, but there is no single measure of "intelligence".
- Many components: "book smarts", mechanical aptitude, observational acuity, ...



http://img.usatests.com/iqtest/courbe-bell.gif

Microcosm of Evolution

- Remember, there is no such thing as an organism that is universally adapted; it depends on the environment
- For example, our tendency to find patterns, and even our adaptability, can be negatives
- Our intelligence, however, has proved remarkably useful in many circumstances

Intelligence in Humans, Pt. 2

- What is needed depends on environment
- Has changed over time; will continue
- For example, tech understanding likely to be more important in future

http://www.beyondtraining.com.au/images/ML%20EQhead.gif

Developmental Factors: Competition

- Drives evolution
- Has also driven human society and change
- Positive in that sense
- But with our current capabilities, is also placing us on the brink of problems!

http://weblogs.baltimoresun.com/sports/college/maryland_terps/blog/TERPS%2520%25232%5B1%5D.jpg

Developmental Factors: Cooperation

- Since the first mass hunts, has been critical advantage of humans
- Individual intelligence can't bring us to the stars

http://www.ci.huntington-beach.ca.us/images/users/fire/fire_rescue.jpg

Implications

- For us, both competition and cooperation have been essential
- Does this mean that herbivores could not develop substantial intelligence?
- Does this mean that solitary species could not put their intelligence to use?

ASTR 380
Is Intelligence Common?

What do you think would happen if humans were to suddenly disappear from the Earth? Would another intelligent species arise from the mammals?

What do you think would happen if a nearly sterilizing impact wiped out everything except selected insects and creatures living around volcanic ocean vents? Would intelligent species arise again?

ASTR 380
Is Intelligence Common?

It can be argued that:

size
strength
speed
armor
poison
weapons (claws, teeth, etc)
and intelligence

Are all potential characteristics that a species can try to maximize in the battle of natural selection.

The result of evolution at a given point in time is determined by which characteristics are developed to domination first.

ASTR 380
Is Intelligence Common?

What are the implications for the likelihood of intelligent life developing on other planets with Earth-like conditions?

The key questions – that we do not have the answers to are:

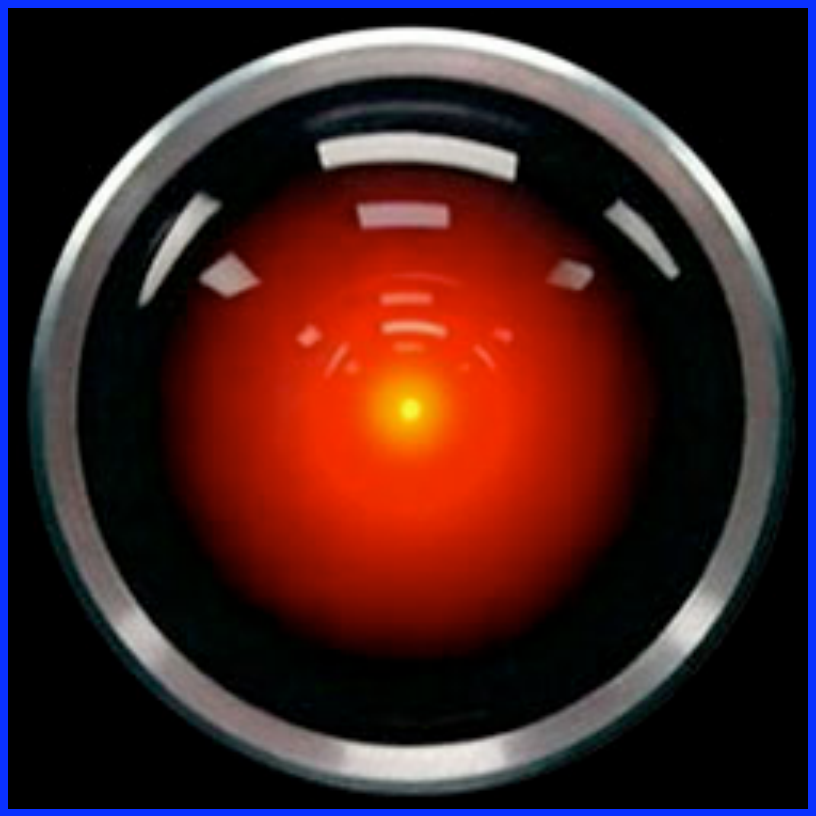
Is the development of multi-cell organisms a fluke or a guarantee given enough time?

In multi-cell organisms, is the development of central command and control a fluke or a guaranteed event?

Is intelligence the winning evolutionary strategy that some species will always find…. eventually?

Artificial Intelligence

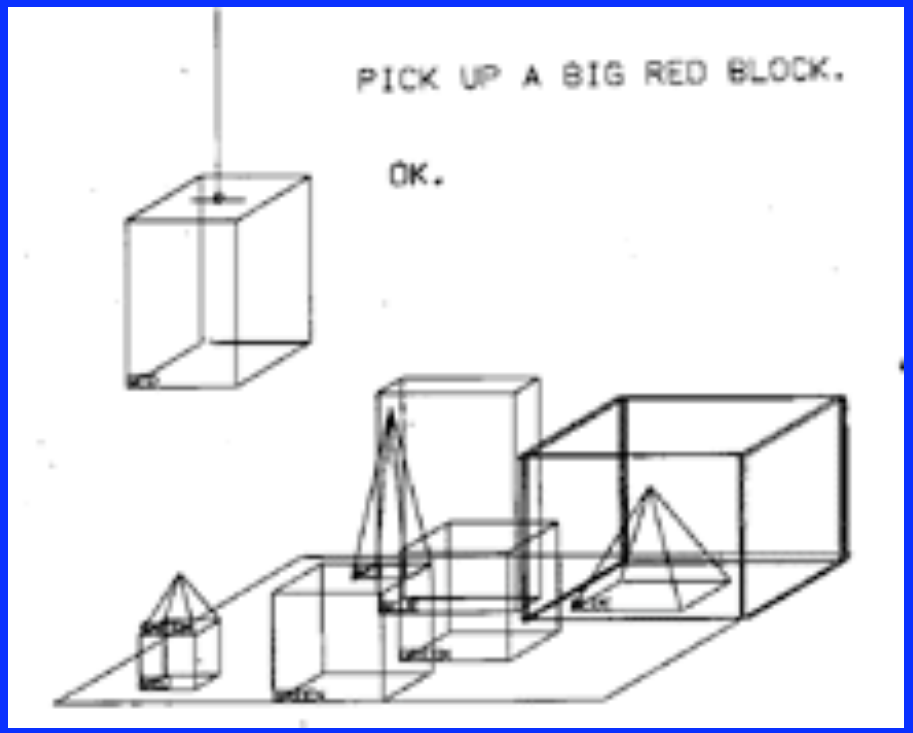
- Starting in the 1950s, people began to dream of making computers that could converse in natural language and otherwise be like us
- How successful has this been?



HAL 9000, from 2001

Artificial Intelligence

- Some early successes
- SHRDLU: natural language in block world
- But slower progress than expected
- For example, best human chessplayers crushed computers into 1990s



SHRDLU: Terry Winograd

Artificial Intelligence

- In 1997, Deep Blue beat Garry Kasparov in match
- Now computers are much better than humans at chess
- Current status?

http://archi-plans-4u.com/images/db.jpg

Artificial Intelligence

- Lesson seems to be that easy things for us (e.g., walking!) are tough for robots
- Even autonomous robots are no more intelligent than bacteria by this measure
- Can we get there? Would such life take over, or travel to stars?

http://cache.io9.com/assets/resources/2008/03/20040629-MarsroversSpirit.jpg

ASTR 380
Is Intelligence Common?

What are the implications for the likelihood of intelligent life developing on other planets with Earth-like conditions?

What advice do I have for you about f_i in the Drake Equation?

Think about the issues.
Decide on a strategy for arriving at a value
Be able to justify your value with facts and ideas

We do not know correct answer.

Perhaps future discoveries of life in our solar system can resolve at least the question about multi-cell organisms.

Summary

- Intelligence is a complicated quantity
- Its origin, and whether it is inevitable, are unclear
- In addition, other factors must enter; a species of hyperintelligent philosophers with no technology would not go anywhere!