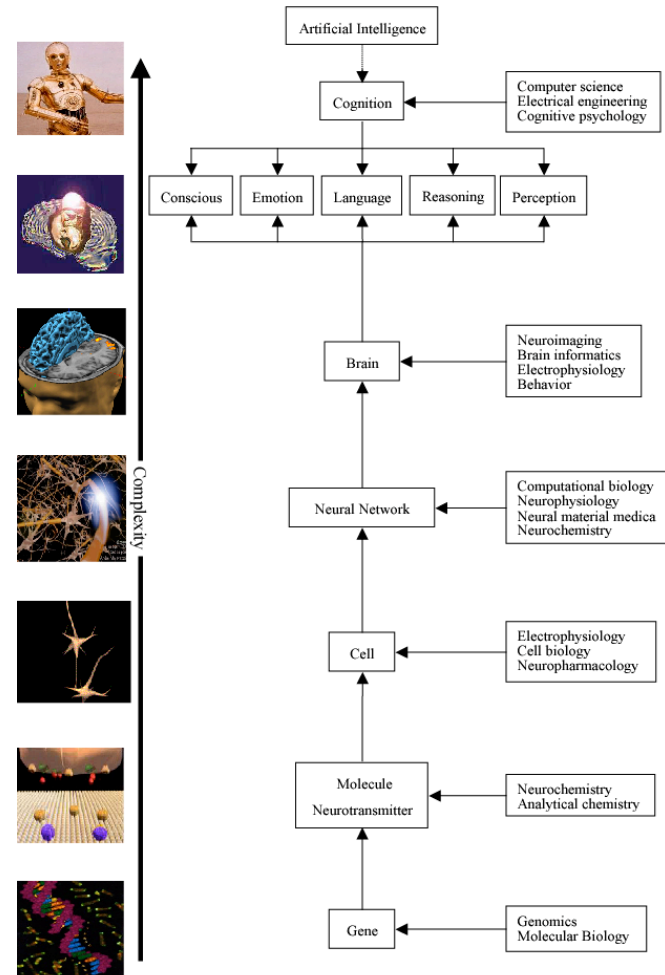


Lecture 29

Intelligent Life in the Universe

Outline of Lecture 29

- Basis of Human Intelligence:
 - Brain as the seat of consciousness.
 - Nerve impulses – “all or none.”
 - Chemical signals across synapses.
- Machine Intelligence:
 - Turing test.
 - Moore’s law.
 - Machine creativity?
 - Machine life?
- Search for Extraterrestrial Intelligence:
 - Inadvertent transmissions.
 - Drake’s law.
 - Radio searches for intelligent civilizations.
 - Where are they?
 - Colonization of other worlds



Consciousness: Last Bastion of Vitalism

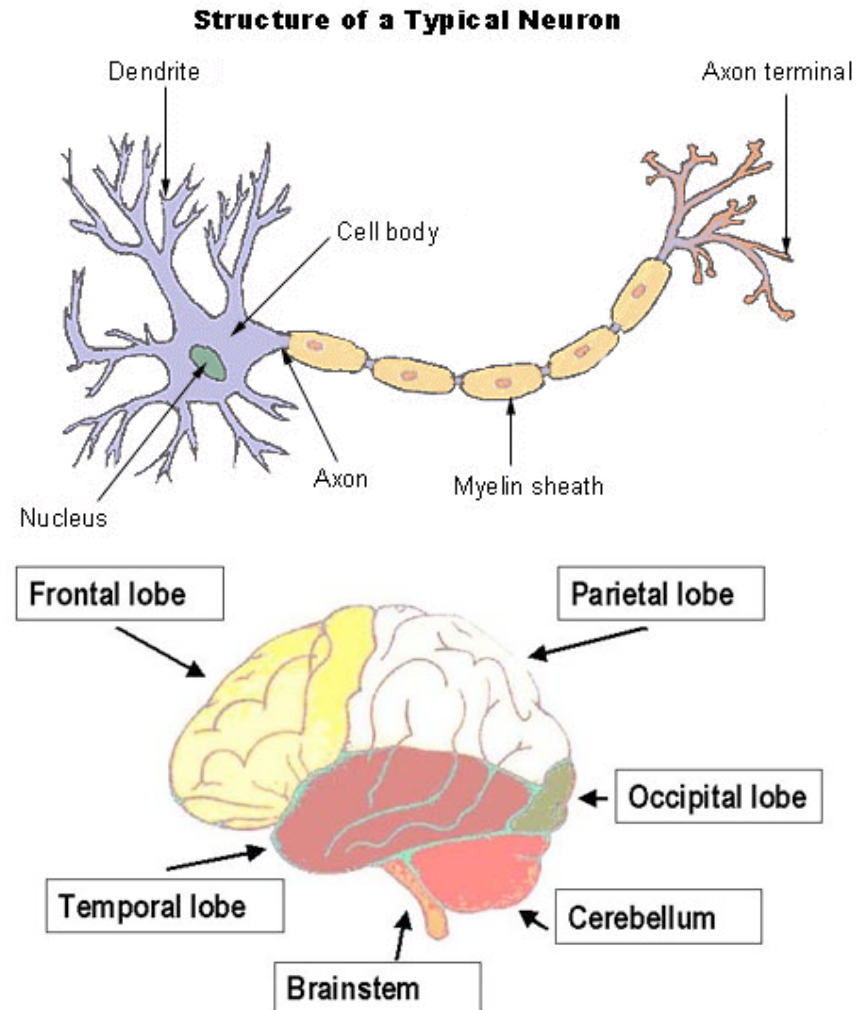
- Vitalism is not needed for consciousness.
 - Recognition of role of brain
 - Egyptians: Heart most important organ
 - Alcmaeon (ca 450 BC): eyes of dissected animals connected by optic nerve to brain
 - Ramon y Cajal (1852-1934) and Camillo Golgi (1843-1926): central nervous system consists of neural network
 - Mechanism of signaling among neurons by Charles Sherrington (1857-1952) and Edgar Adrian (1889-1977)
- Available evidence is that consciousness arises when there is sufficient complexity in the organization of the central nervous system.
 - Example of single fertilized egg becoming a conscious child.
 - Hardware vs software, nature vs nurture.



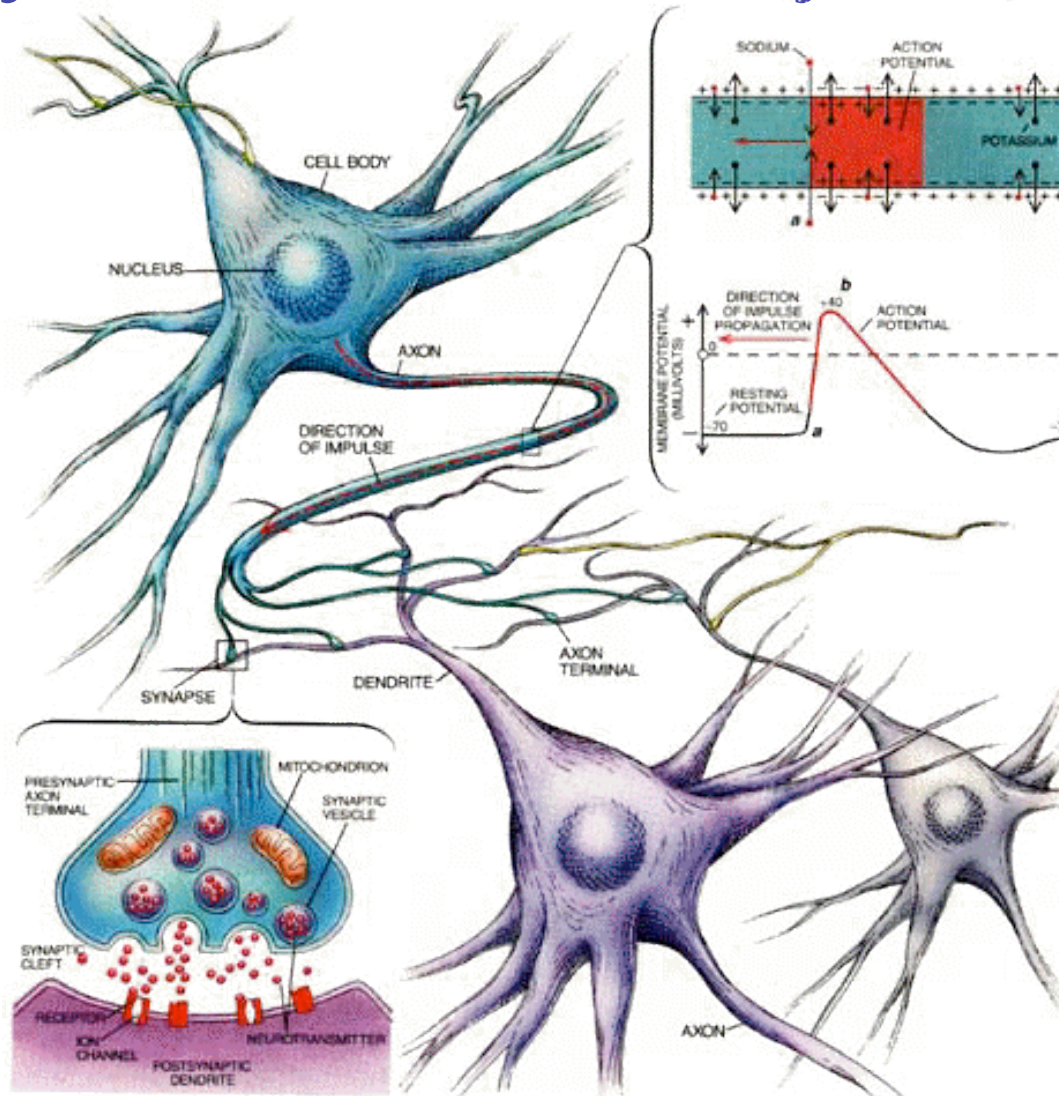
Rene Descartes (1596-1650)
Cogito ergo sum

Intelligence and Civilization

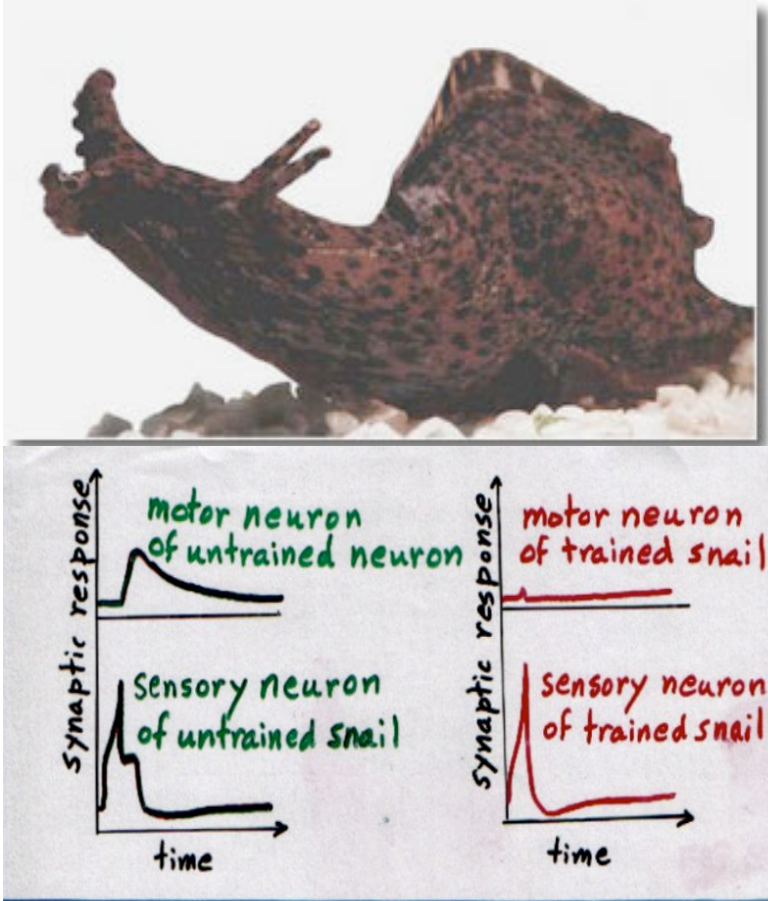
- Most remarkable among the specialized cells is the nerve cell, the neuron; and most remarkable among all organs is the brain, a hierarchical arrangement of 10^{11} neurons.
- The ascent of man is due in large measure to humanity's ability to pass down, not only inherited traits, but the accumulated knowledge and skills of society as a whole: civilization.
- How long has human culture been in existence? Only since the waning of the last ice age, 15,000 years ago.



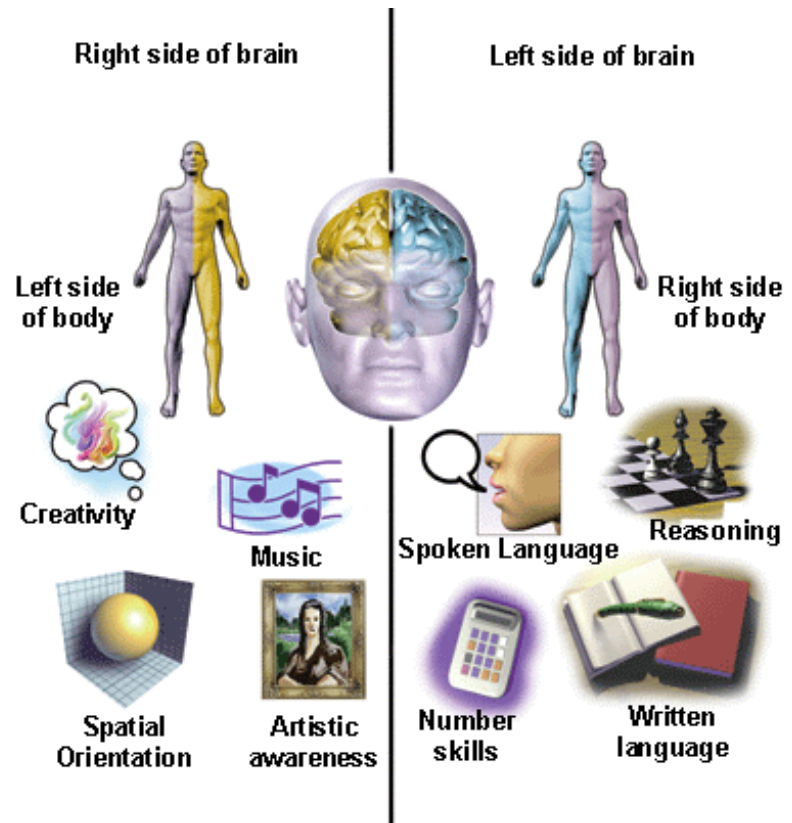
Transmission of Nerve Signals Partly Electrical, Partly Chemical



Training and Learning



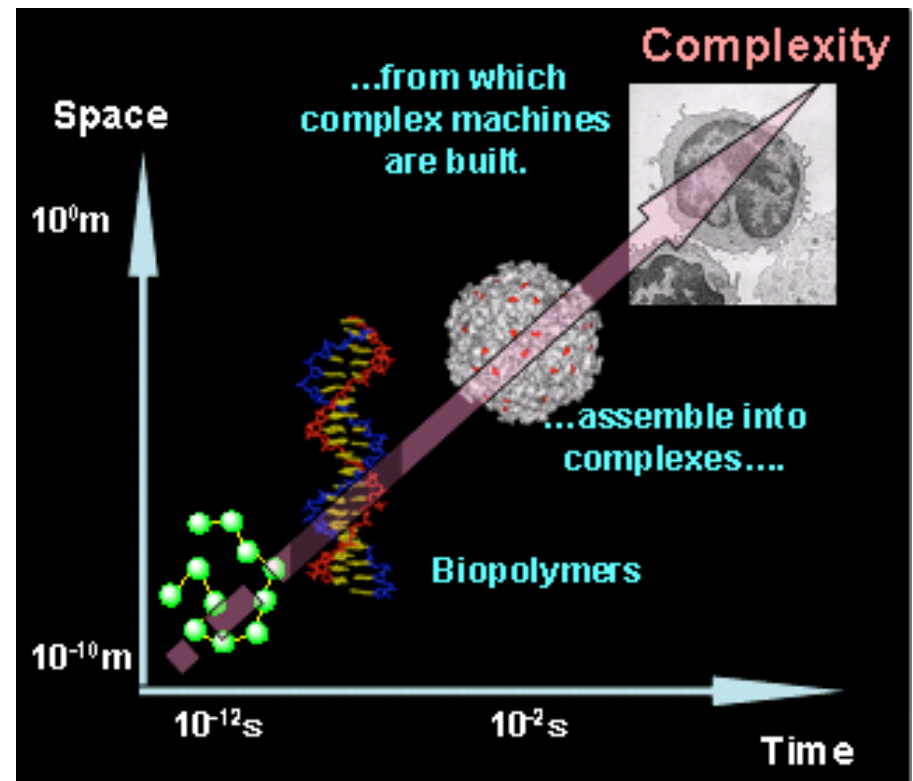
At its most elementary level, learning does not require vitalistic notions.



Cerebral cortex composed of large number of modules: each module is like a microprocessor. Human brain is organized in hierarchical structures, by far the most complex and elegant thing touched upon in this course.

Power of Hierarchical Structures

- **Literary World:**
 - Letters: a,b,c,...,x,y,z.
 - Words: beauty, truth.
 - Sentences: Truth is beauty; beauty, truth.
 - Paragraphs, chapters, books.
- Physical world: elementary particles, nuclei, atoms, and molecules; minerals and rocks; continents, oceans, and atmosphere; Earth.
- Biological world: elementary particles, nuclei, atoms, small molecules, macromolecules, cells, tissues, organ systems, organisms, societies, civilization.
- Business world: employee, organizational hierarchy, modules for mass production and mass marketing.



Number of Different Offsprings Possible in Human Reproduction

- Even without crossover events in meiotic division and fertilization, the number of different fertilized eggs and sperms potentially available to single pair of parents is

$$2^{23} \times 2^{23} = 2^{46} \approx 7 \times 10^{13}.$$

- With six billion people on Earth, the number of different possible pairings of father and mother are

$$(3 \times 10^9) \times (3 \times 10^9) = 9 \times 10^{18}.$$

- Thus, the number of potentially different descendants from the current pool of human beings on Earth without mutations or crossover events is

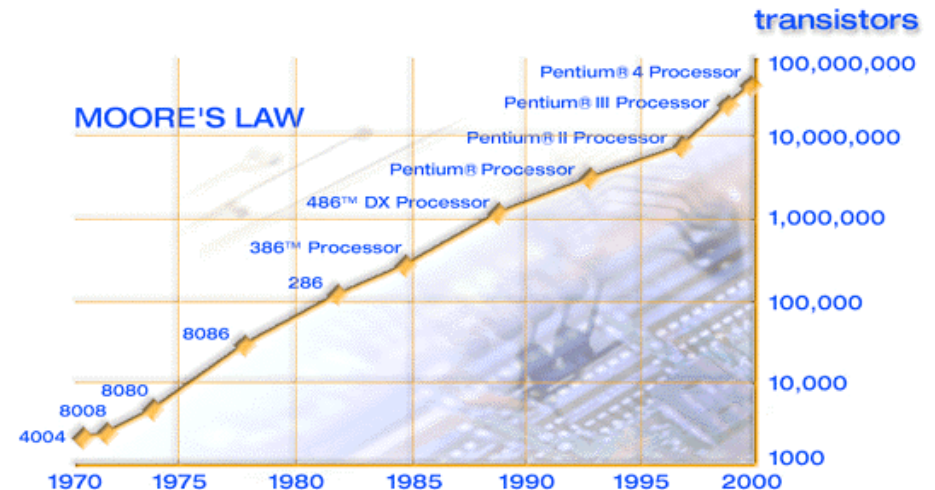
$$(7 \times 10^{13}) \times (9 \times 10^{18}) \approx 6 \times 10^{32},$$

enough to colonize every solar system in the observable universe with a population of humans comparable to the Earth!

- Whether this is desirable even if feasible is debatable. Nevertheless, reproductive success and diversity are the power behind life and a perhaps frightening hallmark of aggressive civilizations.

Machine Intelligence

- Turing Test.
- Biological vs electronic processes.
- Moore's law.
- Hardware vs software.
- Creativity.
- Emotions.
- Computers are not alive.



Intel

Machine Life on Earth

- Hallmark of life is *growth and reproduction*. Proteins and nucleic acids represent only one way to achieve growth and reproduction. There must be other ways.
- Present-day computer networks are not less auspicious for achieving life and intelligence than simple bacterium incapable of even fermenting.
- Serious moral problem: Why would we not pull the plug?
- Possible answer: humans and machines today have a *symbiotic relationship*. We supply them with energy and the materials for growth; they take over the job of heavy number-crunching for us. Thus, are we destined to become *mitochondria for supercomputers*?
- If symbiosis of organic lifeforms and machines is possible (indeed, already happening on Earth), has it already occurred elsewhere in the Galaxy or in the universe?
- Are the most intelligent beings in the universe not us, but cyborgs?
- Are there such intelligent beings trying to communicate with us?
- SETI = search for extraterrestrial intelligence.



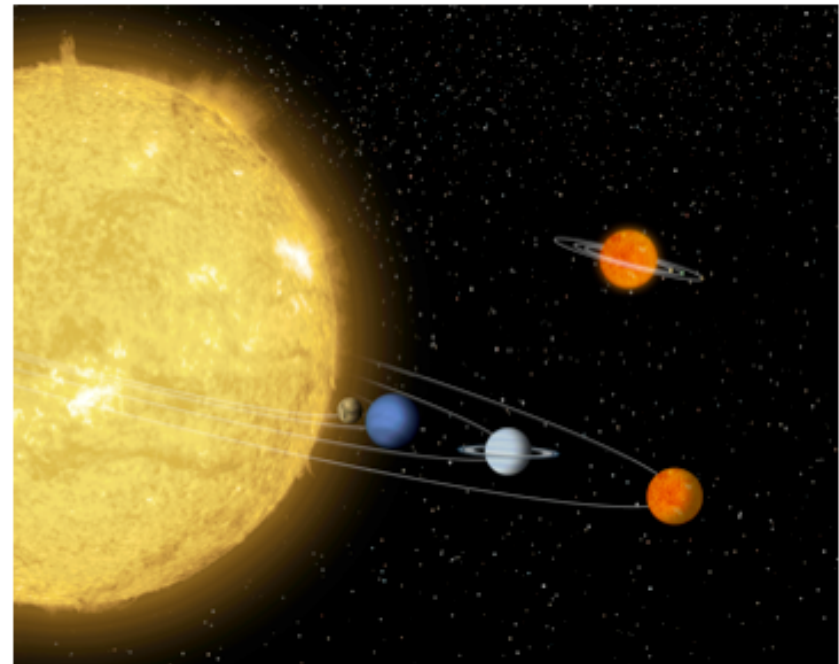
How Common is Intelligent Life in the Universe?

- There are 100 billion stars in our Galaxy, and 100 billion galaxies in the observable universe. Surely, our solar system cannot be the only one to harbor life?
- How about intelligence? How many lifeforms in the Galaxy possess the ability to communicate with other intelligences across the vast spans of interstellar space?
- Schematic estimate by Drake's equation:

$N = pN_*L/t_*$ where $N_* = 10^{11}$, $t_* = 10^{10}$ yr,
with $p = f_p n_e f_l f_i f_c$ and $L =$ technological lifetime.

$n_e =$ # of appropriate "Earthlike" planets per star may be much less than 1.

So may $f_i =$ fraction of planets that support life which also support intelligence.



www.science.psu.edu

55 Cancri is a sunlike star with a planetary system composed of 5 giant planets, one of which has half the mass of Saturn at about the same distance from its star as the Earth is from the Sun. If this planet has a decent sized moon, it could harbor Earthlike life.

Number N of Advanced Civilizations

Table of N and d = average separation (lt yr)

$p \backslash L$	10 yr	10^3 yr	10^5 yr	10^7 yr	10^9 yr
1	10^2 10,000	10^4 2,000	10^6 300	10^8 70	10^{10} 15
10^{-2}	1 -	10^2 10,000	10^4 2,000	10^6 300	10^8 70
10^{-4}	10^{-2} -	1 -	10^2 10,000	10^4 2,000	10^6 300
10^{-6}	10^{-4} -	10^{-2} -	1 -	10^2 10,000	10^4 2,000

Radio Searches for Extraterrestrial Intelligence

- Why would any extraterrestrial intelligences broadcast evidence for their existence?
 - Our own radio and television stations are already doing it inadvertently.
 - Best band to listen may be wavelengths around 21 cm.
- Since the pioneering Ozma experiment of Frank Drake in 1960, there have been dozens of SETI experiments. Much of received cosmic signals are analyzed by prototype of grid computing pioneered by astronomers at Berkeley: seti@home. So far, no confirmed success.



The Arecibo telescope in Puerto Rico could pick up the radio signals broadcast from another Arecibo anywhere in the Galaxy. Presently, astronomers are only receiving, not sending.

Supercivilizations in the Universe?

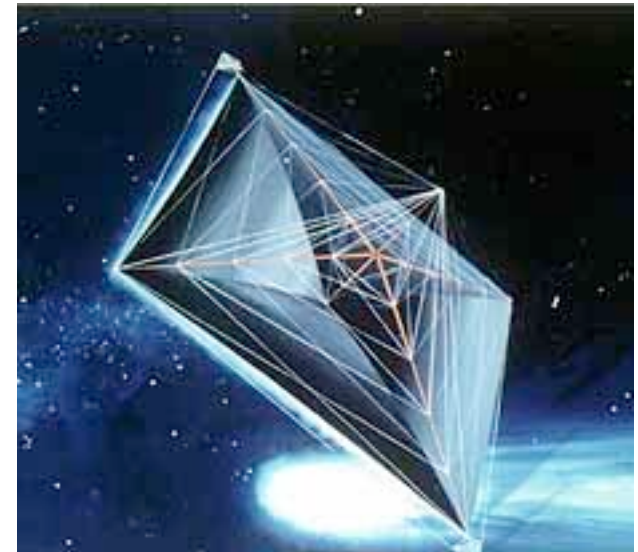
- Why have there been no observable evidence for vast engineering feats in the universe by supercivilizations?
- What are supercivilizations like?
 - Satisfied to observe, not to exert power?
 - No longer curious or ambitious?
- Why are they not here?
 - Is brief span of civilization on Earth a common experience?
 - Civilizations older by millions or billions of years than us are likely to have incomprehensibly superior technologies.
 - Colonization of the Galaxy requires just one supercivilization that wishes to explore and populate other worlds.
 - Life may be common in the Galaxy, but intelligence may be rare.
 - If we are alone (the first to develop spacefaring technology), are we or our descendants destined to inherit the Galaxy?



Starchild from Stanley Kubrick's 2001

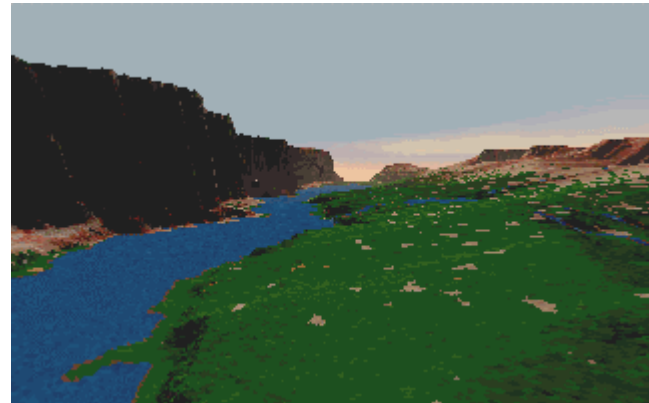
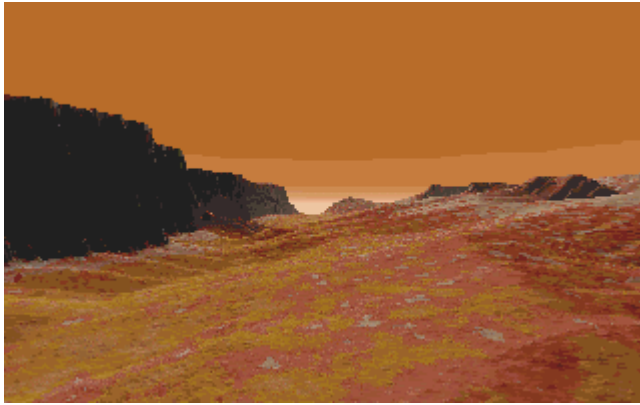
Interstellar Spaceflight

- To colonize the Galaxy, one can travel slowly, say, at $0.001 c \approx 300 \text{ km/s}$ (ten times faster than current rockets) to settle entire Galaxy in less than 100 million years.
 - Suppose each planetary system can support 10 billion beings before population pressure builds to colonize nearby planetary systems. The experience of human civilizations suggests that this will require less than 1,000 years per solar system.
 - After 1000 years, suppose each planetary system sends out two expeditions to settle nearby stars. Since $2^{37} \approx 10^{11}$, to populate all planetary systems in the Galaxy will require only 37,000 years of residence time on planets, negligible in comparison with the (cryogenic?) time to go across the Galaxy.
 - Since it takes less than 100 million years to go from any point in the Galaxy to any other point at $0.001 c$, the colonization of the entire Galaxy takes considerably less time than the age of the oldest sunlike stars (~ 10 billion years).
- Plenty of time for other advanced civilizations to have already done it. Even easier for cyborgs with much longer lifespans.

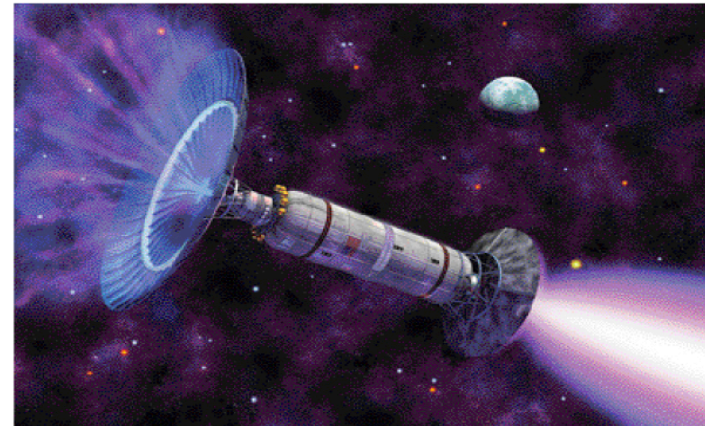
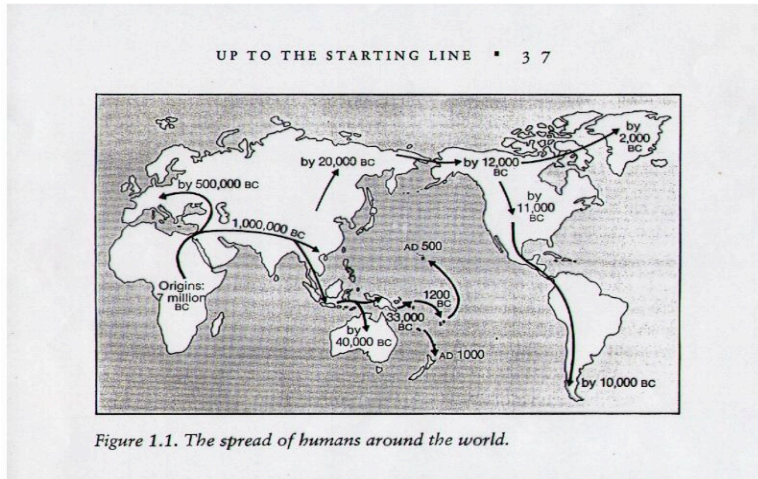


So why hasn't someone done it?
As Enrico Fermi (1901-1954) famously asked: **Where are they?**
A plausible possibility:
We are the first civilization in the Galaxy to achieve the capability for interstellar flight.
We or our (cyborg?) descendants are destined to inherit the Galaxy.

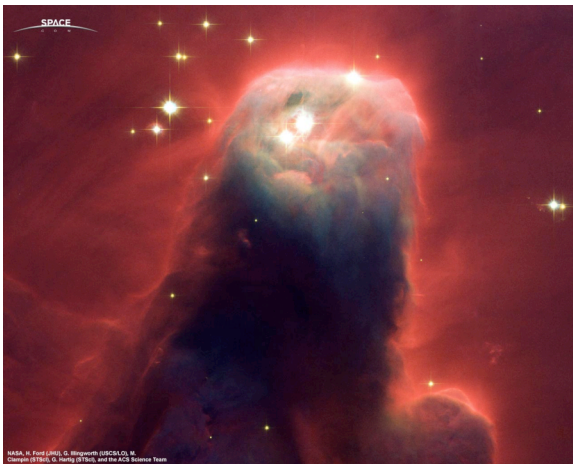
Perhaps Begin by Terraforming Mars



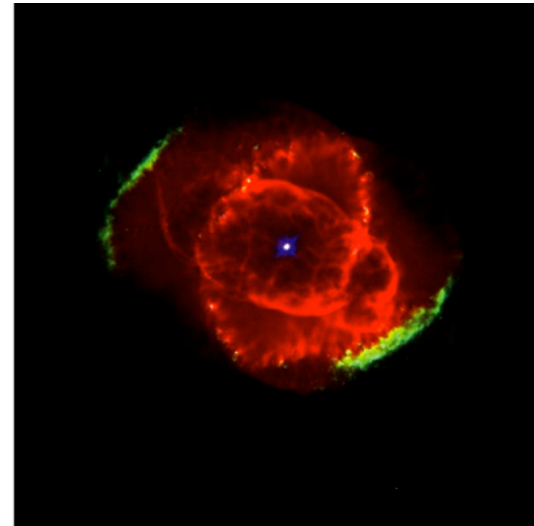
Continuing the Great Voyage of Expansion into the Universe



Copyright © Addison Wesley.



NASA, R. Ford (JPL), G. Wiegman (JPL/STL), M. Clayton (STFC), G. Islay (STFC), and the ACS Science Team

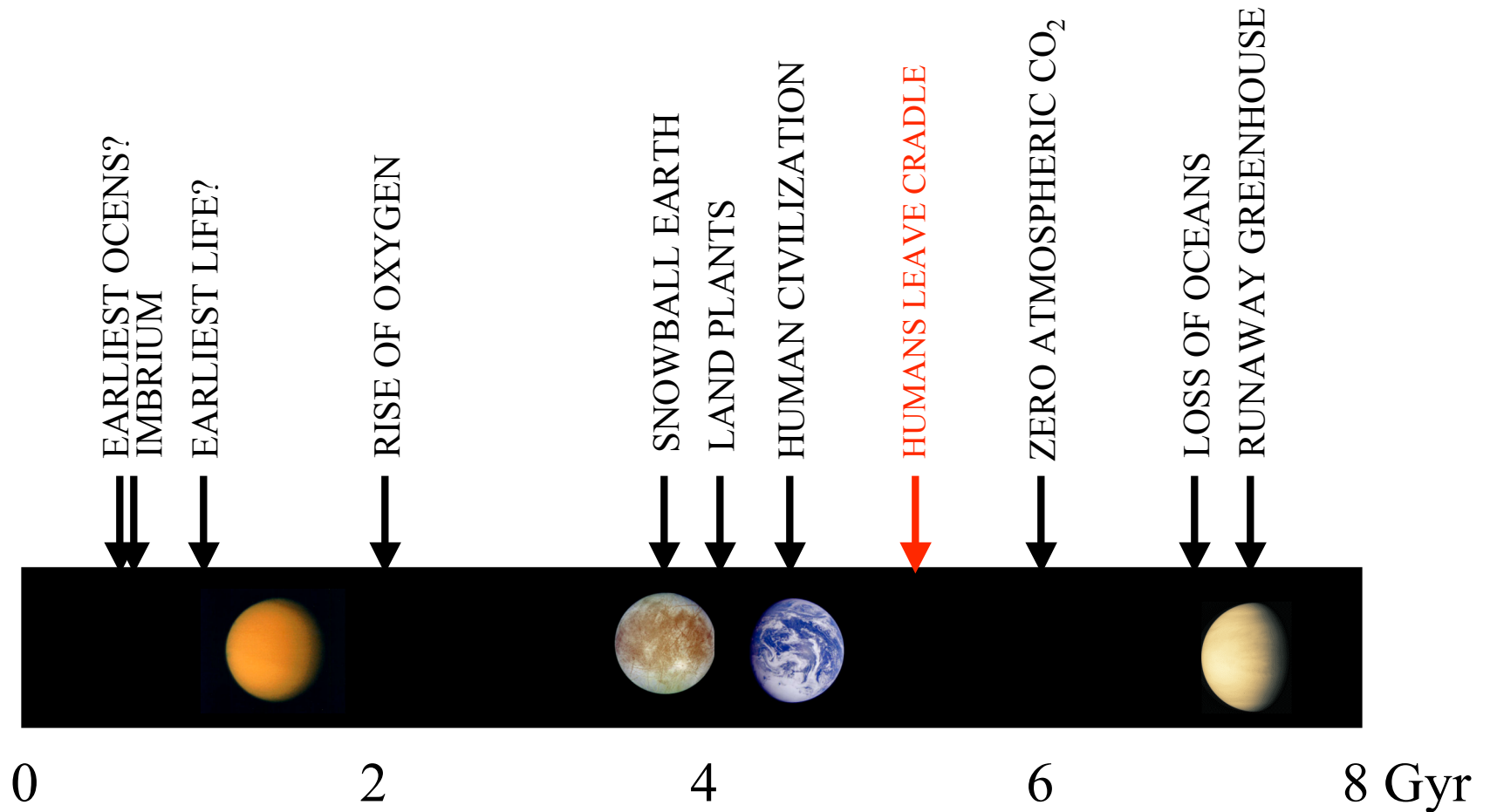


(b)

Copyright © Addison Wesley

Jared Diamond: Guns, Germs, and Steel

The Past and Future of the Earth



Appearance of Earth has changed (and will change) markedly over main-sequence lifetime of Sun

Earth may be on edge of climate stability/instability

Eric Gaidos

The Future of Humanity

- Although the ultimate fate of the Earth and the physical universe itself appears bleak, that future lies billions to trillions of years away.
- If we can solve and stabilize our situation on Earth, there exists plenty of time to explore and colonize the other planets and moons of the solar system. In a cosmic sense, we should do this because
 - Intelligent life in the universe may be rare.
 - It is important that we safeguard its survival in the one place where we know it has arisen.
 - The death of a single individual is sad, but the extinction of world civilization, of all the wondrous accomplishments of humanity, would be an unmitigated catastrophe.
- If human history is truly to be measured in the billions, or even trillions of years, rather than just in the thousands, what goal is sufficiently large to be worthy of our long-term efforts?
 - Surely, it cannot be ever more material comforts and wealth.
 - Surely, our inquisitive nature will not allow us to be bound permanently to our own solar system?
 - Surely, if this unimaginably large and rich universe has any purpose, it is meant to be explored, not only in the observations of aware and curious beings, but physically by its most courageous inhabitants.
- The only thing larger than the human imagination is the universe itself. This is the ultimate challenge of the story of astronomy.

Your Future

- Short-term problems of the Earth can be solved with an honest assessment of the predicament that we are in, coupled with appropriate action to combat global change.
- Make no mistake; sacrifices will be needed to get out of this predicament. But these sacrifices are not greater than those made by previous generations. However, the stakes have grown from the survival of the nation, to the survival of civilization, or even possibly of the human race.
- Yours is the generation that will have to meet this challenge. It is an awesome responsibility. It is also a wonderful opportunity to be part of something that really matters.
- If humans can survive the short term, the long term prospects are dazzling. Therefore,
 - Do not set your personal goals too low.
 - Do not let your country set its goals too low.
 - Try to make a difference with your life.
 - Do not lose hope.