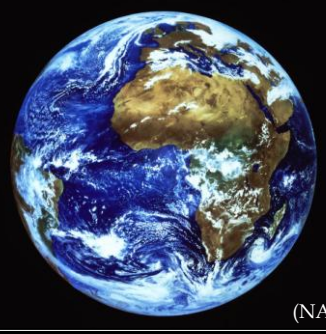
## Today in Astronomy 106: intelligence

- Information and brains.
- The evolution of neurons.
- The evolution of intelligence on Earth, aided by happenstance of geology.



(NASA)



## Information and intelligence

More information is generally stored in the DNA of more complex organisms, but not always, and it can mostly be junk: for example, only 2% of the human genome codes for proteins.

| Unit | Bits | Pages | Books |
|---|---|---|---|
| Base pair | 2 | | |
| Codon | 6 | | |
| Virus | $10^3$ | 1 | |
| (Eu-) bacterium | $10^6$ | 1000 | 1 |
| Single-cell eukaryote | $5\times10^8$ | | 500 |
| Human | $6.4\times10^9$ | | 6400 |
| Newt | $10^{11}$ | | 100,000 |

Only 128 non-junk



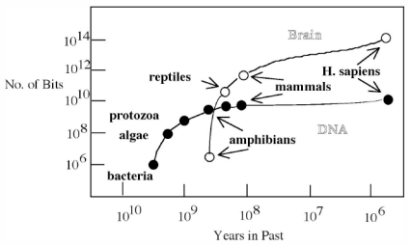
## Information and intelligence (continued)

So information stored in DNA, though it contains the instructions for building a new copy of the organism, and may even account for instinctive reactions to stimuli, cannot tell the whole story.

- To learn, a life form must have a non-genetic way to store information, thus to record the unique and random experiences of the individual.
- This of course is the function of the nervous system in higher animals, exemplified by our brain.
- The product is **intelligence**.
- **Intelligence can change the rules of evolution** when it reaches a certain stage, as there are aspects of intelligence that can be passed to progeny.



## Information and intelligence (continued)




Plot of information capacity of DNA in filled circles – including junk – and of nervous systems in open circles. From Evans 2002 (our textbook).



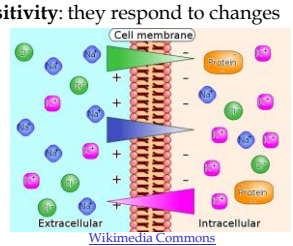
## Development of senses and neurons

The fifth part of our provisional definition of life is

- [living things] exhibit **sensitivity**: they respond to changes in their environment.

In sensation is the beginning of neural activity.

- Cell membranes are made of layers of lipids (fats) and proteins that are **polarized**: the negatively-charged ends of these zwitterions always lie toward the cell's interior, and the positive charges on the cell's exterior.

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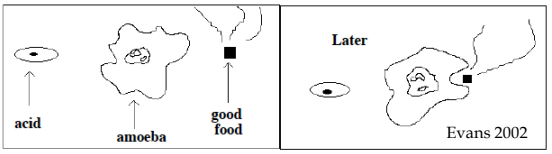
## Development of senses and neurons (continued)

- As a result there is an electric voltage across the membrane, albeit a small one.
- This is a result of natural selection: other arrangements of "containers" do not retain the proteins and nucleic acids, or allow the transmission of ions and monomers from the outside.
- But it has other uses too, as the polarization allows the membrane to be distorted or modified by other electrical impulses, for example
  - impulses specific to certain larger molecules, like nutrients that would save the cell the making of.
  - impulses passed on from cell to cell in a multicell organism.

## Development of senses and neurons (continued)

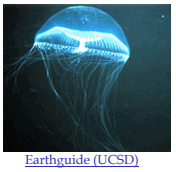
- If a certain cell-membrane configuration …
  - which, of course, is coded in the DNA!
- … is electrically conducive to beneficial electrical distortion that make it easier for organisms to survive or reproduce, the population of these organisms will increase dramatically. Natural selection strikes again.






## Development of senses and neurons (continued)

- Simple example: jellyfish, in which membrane-mediated electrical transmission among the cells around the edges synchronize the movement of these cells, help propel the organism through the water, and thereby make more food accessible.

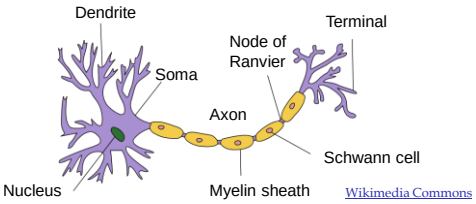

Earthguide (UCSD)

- No brain or memory in jellyfish: this simple nervous system is autonomous. Cut a jellyfish in half and the halves will still "swim" in the same fashion.
- However, this principle easily extrapolates to arrangements of cells that **store** electrical impulses, and can (thus) transmit that **memory** among the cells.



## Development of senses and neurons (continued)

- The result of this selection is the appearance of species with specialized cells that preserve previous sensations and can compare them (by adding or subtracting voltages) to current sensation: **neurons**.



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## Development of senses and neurons (continued)

- And so on. Once neurons exist, memory and commanding is possible, and would clearly give species a high propensity to reproduce, survive, and if necessary compete for scarce resources.
- As it is beneficial, the trait of having increasingly larger memory and commanding capacity will continue to be selected naturally, til the memory capacity of neurons far outstrips the storage capacity inherent in the nucleic acids.
- But the structure of the neurons is still encoded in the nucleic acids. The nucleic acids serve the same purpose as the boot ROM and BIOS in your computer; the neurons the same purpose as the RAM and hard disk.



## Mid-lecture Break

- Homework #3 is still open on WeBWorK; due tonight by midnight.
- **Exam #2** is tomorrow, 10 June 2011, in a 75-minute span of your choice between 10 AM and 6 PM.
- A Practice Exam is on WeBWorK.
- Pre-Exam office hours are today from 1-3 PM in B&L 477.



## Development of brains and intelligence

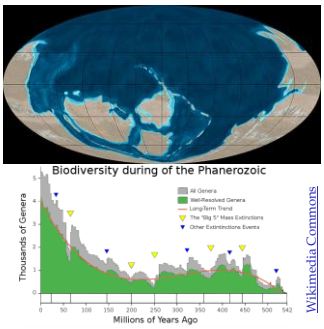
Recall, however, that a multi-cell organism can't modify its DNA in a prescribed fashion, in every cell reproducibly, in response to neural impulses.

- Thus these changes still have to be facilitated by mutation or sexual reproduction, the largest gene pool possible, and natural selection…
- …and will still therefore take a very long time to produce much in the way of capacity for thinking.
- Fortunately, billions of years were available.
- Furthermore, the resources from which intelligence could developed were arranged in a rather lucky fashion, due to an accident of plate tectonics.

## Development of brains and intelligence (continued)

Earth's surface for the last 600 Myr – that is, starting with the Cambrian Explosion -- and the increase in diversity at the same time.

Note that diversity really takes off at about 200 Myr, at which time the continents were all joined up in one big mass called **Pangaea**.

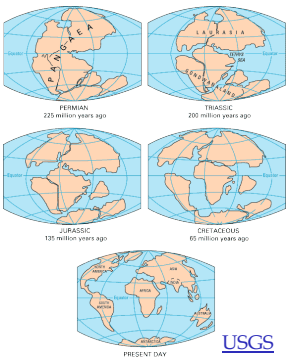





## Intelligence (continued)

This promoted more rapidly than it would otherwise the evolution of intelligence, as all the land was accessible to all the species, and therefore the entire gene pool was involved.

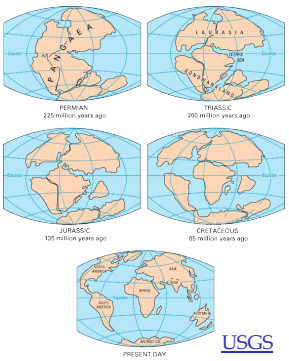
- Consider mammals, for instance. By about 175 Myr ago the most successful species were marsupials, which overspread Pangaea.






## Intelligence (continued)

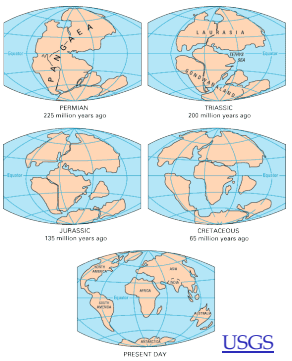
- The edges of Pangaea began to break off about 160 Myr ago.
- First to go was a plate containing Antarctica, Australia and India. The former two remain isolated and sparsely populated compared to the rest, and today marsupials remain the most advanced native animals.






## Intelligence (continued)

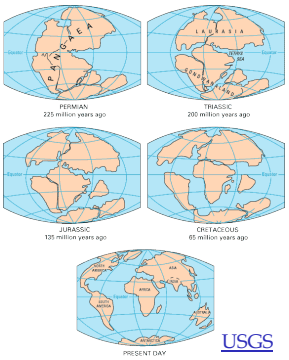
- Over the next 50 Myr, placental mammals evolved from the still-large gene pool in the forested areas of Pangaea. The most advanced beings at this time were the prosimians, led by the lemur.
- Madagascar broke off 110 Myr ago, taking lemurs along. Lemurs remain the most advanced there.






## Intelligence (continued)

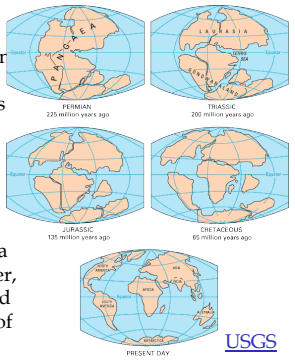
- Next to go was South America, about 90 Myr ago.
- By then true monkeys existed, which in South America have subsequently evolved into the new world monkeys, including marmosets and spider monkeys.
- But a far larger gene pool remained in Africa-Eurasia-North America.






## Intelligence (continued)

- By far the densest collection of animals of all sorts – the bulk of the gene pool – was the forested, low-latitude part of the remains of Pangaea, which in turn means Africa.
- By about 50 Myr ago the connections between Africa and the rest became flimsier, due to further cracking, and to periodic desertification of the northern part.



## Intelligence (continued)

- A few million years ago the next set of cracks began to develop, splitting Arabia from Africa.
- This crack, called the Great Rift, proceeds southward from the Red Sea into the continent.
- It splits around Lake Victoria; the cracks themselves are occupied by long, very deep lakes like Turkana, Tanganyika and Nyasa.



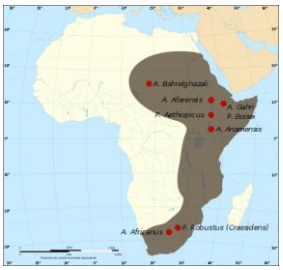

## Intelligence (continued)

- The rifting process also raised the land on either side of the crack (e.g. the Ruwenzori range).
- This had a decisive influence on the climate to the east of the rift. Weather comes from the west in this part of the world; the new mountains caused most of the rain to fall west of their crest, and left a rain shadow in the east.




## Intelligence (continued)

- By this time the most advanced mammals – large brains, fingered limbs, opposable thumbs – were the simian tree dwellers of the extensive forests.
- Climate change took place on a time scale faster than the usual migration times, leaving a population of tree-dwellers with very few trees.

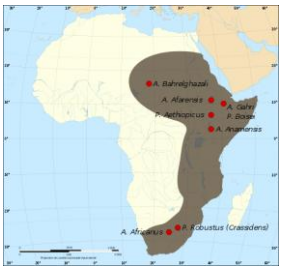



Hominid fossil finds (Wikimedia Commons)



## Intelligence (continued)

- To go from tree to tree it was necessary to cross grassland. The ones who survived were the ones who crossed fastest, walking on two feet.
- This left hands free. Having large brains, they soon developed other advanced uses for hands.
- This selection produced a new set of species, called of course **hominids**.




Hominid fossil finds (Wikimedia Commons)