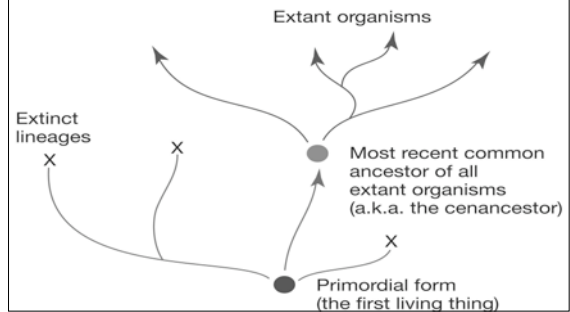


The Big Picture

- What was the first living thing?
- Where did it come from?
- What was the last common ancestor of today's organisms and when did it live?
- How did that organism's descendants evolve into today's organisms?
- What is the shape of the tree of life?

Tree of Life



What was the first living thing?

- Proteins can do all kinds of biological tasks but can't propagate themselves
- DNA can replicate but can't do much else

Life had to start with something that could do both.

RNA World?

- In the early 1980's, an enzyme was found which could break and reform the chemical bonds that link nucleic acids into chains
- It was the first enzyme found that was not a protein, instead it was RNA and was named **ribozyme**

So?

- Has a genotype: nucleic acid sequence
- Has a phenotype: it's shape determines what it can do (like protein enzymes)
- It could theoretically replicate itself AND it could do things like protein enzymes
- To exist it requires only a few organic molecules in solution

What is Life?

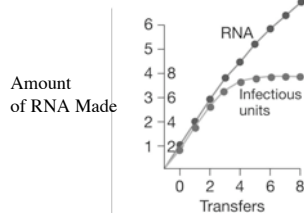
- Ability to evolve is key
- Living things can store and transmit information (genotype) and express it (phenotype) so they can record and make alterations in heritable information and distinguish good from bad
- If ribozymes can do this, they're alive?

RNA World Hypothesis

- The primordial life form was an RNA-based living system that evolved to life like we see it now where DNA stores the information and proteins make use of it (DNA is more stable, so this is better in the long run)

Evidence?

- The most conserved and universal component of the information processing machinery of a cell is the ribosome which suggests it was original equipment
 - It's built around RNA and RNA does the work
 - ATP and GTP, the basic energy currency of all cells are ribonucleoside triphosphates
- But can it evolve??



After just 4 "generations" the RNA lost its ability to infect (required addition of an enzyme and wasn't selection)

Can selection work on RNA?

- Researchers have found (by sequencing the nucleotides) that specific mutations can be selected for in incubating RNA
- They've "evolved" ribosomes that can catalyze proteins faster, form peptide and carbon bonds, and some other things that imply RNA could work as a living system

Darwin said that...

If individuals in a population show:

1. Variance
2. Inheritance
3. Excess reproduction
4. Variation in survival or reproductive success

The population will evolve.

Self-Replication

- This is the big stumbling block for RNA World
- So far, the addition of proteins has been required to copy RNA and if RNA came first, there would have been no proteins
- This is a big area of research right now

How do you get living things from an abiotic environment?

1. Information-containing biomolecules need to be made from simple inorganics
2. The necessary chemical reactions had to have an energy source
3. The building blocks had to self-assemble into polymers
4. Large biomolecules had to be protected from a harsh environment

The Panspermia Hypothesis

- Life originated somewhere else and traveled to earth
- The big questions are:
 - Did microbes exist on other planets in our solar system?
 - Could they have survived the trip?

Evidence?

- Viking spacecraft landers experiments
- “fossil” evidence of microbes and water from meteorites from Mars
- Europa, one of Jupiter’s moons looks to have liquid water and active volcanoes
- Surveyor 3 surviving *Bacillus*

The Murchison Meteorites

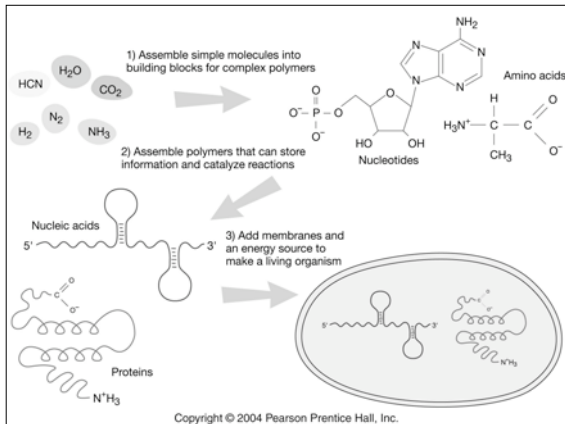
- Landed in 1969 in Australia
- Found to contain amino acids
- Evidence suggests that on early earth, synthesis of these type of molecules may not have been possible, at least not in high concentrations
- Is this how they got here?

The problem...

- Most meteorites burn up on entry or at least get so hot that any organics would be destroyed.....but obviously not all

Oparin-Haldane Model

- Originally it was thought that early earth could have provided a “pre-biotic soup”
- Stanley Miller’s 1953 experiments supported this
- Ideas about what it was like on early earth have changed, but this model is still sort of the null hypothesis against which everything else is tested



Problems....

- Nucleotides, amino acids, and aldehydes can all be synthesized fairly easily, but not the right stereoisomers
- Each building block would have to be chemically charged to incorporate it into a polymer so there has to be some reliable source of chemical energy (the cell wall concentrates this now)

More problems....putting the polymers together

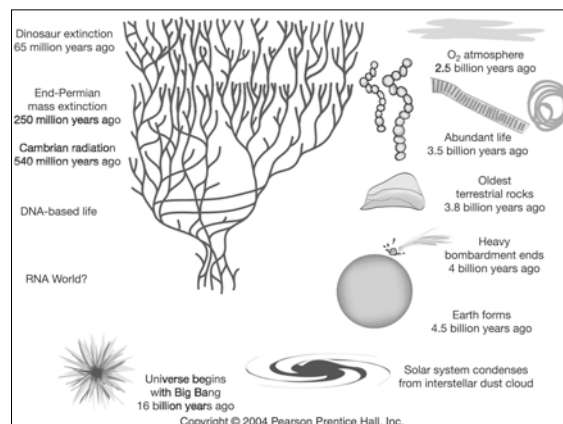
- If the organic building blocks were dissolved in water and the polymers were made in water, they'd break down by hydrolysis as fast as they were being built
- Turns out clay particles can act as a catalyst to hold chains together though, so maybe?

Protecting Life from the Environment

- The oldest evidence for life has been chemical fossils in rocks 3.6-3.8bya
- Nothing older than this is likely to be found because:
 - Erosion, plate tectonics, volcanic eruptions
 - Meteors--the last one big enough to vaporize the oceans occurred ~3.8-4bya

The last common ancestor

- Once self-replicating systems evolved, at least one adapted to the use of DNA to store heritable information and proteins to express it
- All organisms living today use the same 20 amino acids and the same structure in their genetic code
- Our ancestor must have used this too



The Cenancestor

- Since we all have cells too, our ancestor must have. Existed at least 2bya, maybe more. (possible fossils ~3.4by have been found) Cells offer advantages:
 - Compartmentalization--can concentrate necessary things on the inside
 - Genotypes and phenotypes can be linked

How do you get a cell?

- Mixtures of polyamino acids in water or salt solutions spontaneously organize themselves into microspheres similar to cells
- Precursors to cells were tiny compartments formed by inorganic mineral deposits formed at the mouths of deep sea vents

Phylogeny of Living Things

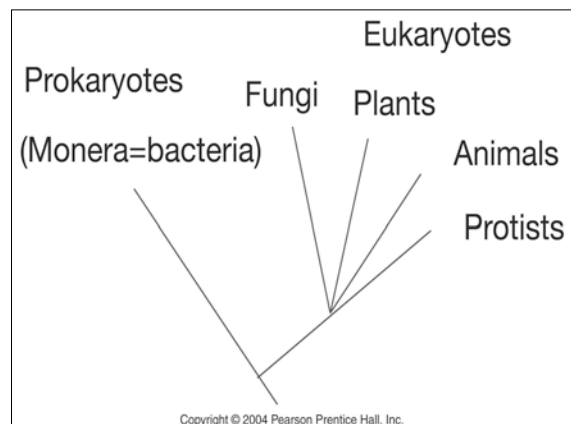
- There are no cell fossils obviously, but we can construct phylogenies through RNA/DNA sequencing
- The more similar the sequences, the more related the organisms
- However, to do this for all living things, you need a gene they all have

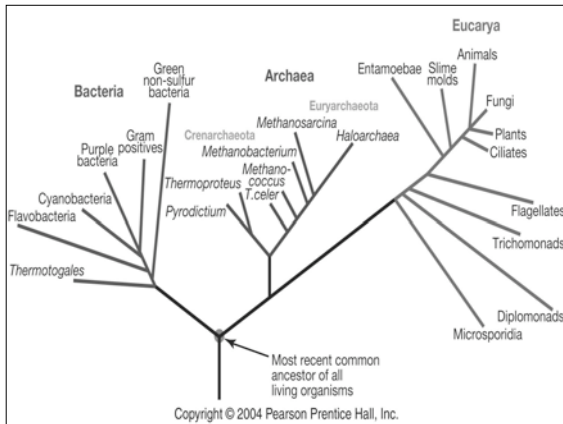
Requirements of that Gene

- Present in all organisms
- Code for a product whose function is essential and so subject to strong stabilizing selection to avoid drift
- The function must have stayed the same in all organisms

Is there a gene like that?

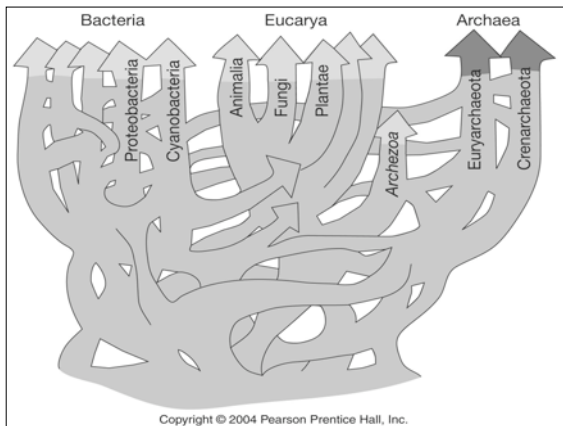
- Yes: the gene that codes for rRNA
- All organisms have ribosomes and all those ribosomes contain rRNA and protein
- All have similar structure and all are the machines for translation
- Translation is so important that even the sequence in *E. coli* and humans looks similar





What's surprising?

- If you try to do this with different genes, different relationships arise
- This is because of **horizontal gene transfer** turns out to be very common among early prokaryotes (they fused or exchanged genes routinely)
- So there might not be a single species ancestor....



Where did organelles come from?

- Eukaryotic genes involved in storage and use of genetic information tend to be similar to archean genes
- Eukaryotic genes involved in metabolic processes tend to be more similar to bacterial genes
- **Ring of Life Hypothesis:**

Figure 11-13 Evolutionary Analysis, 6/e
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The Chronocyte Hypothesis

The chronocyte lineage developed a cytoskeleton and the ability to eat other microbes. It ate an archaean that resisted digestion and became an endosymbiont. This eventually became the nucleus, incorporating the archaean-like use of genetic information.

Figure 17-33 Evolutionary Analysis, 6/e
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The 3-Viruses, 3-Domains Hypothesis

This says that viruses actually evolved first in RNA-world. Three different viruses infected the 3 different domains. In the process of overcoming the defenses of each type, the viral RNA was modified into DNA. Eventually the viral DNA "parasite" copied all the host RNA into DNA and in the process went from being parasitic to being a component of the host cell. Since DNA is more efficient than RNA, these 3 domains would then outcompete anything else that came along, so there remain only the 3.

Figure 11-13 Evolutionary Analysis, 6/e
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