TwoOldGuys™ Study Guides
BI114 Biological Concepts for Teachers
Chapter 4. History of Life
4.1. Primordial soup, or peanut butter & jelly sandwich

Based on Indiana's Academic Standards, Science, as adopted by the Indiana State Board of Education, Nov 2000.
Numbers refer to the age-appropriate grade-level for the content.

Review

The patterns of inheritance and the apparent success of agricultural breeding in developing new varieties of plants and animals suggests to modern Biologists that natural selection ought to be able to account for the diversity of naturally occurring plants and animals, both living and extinct fossil forms. Natural selection is understood to favor those traits which are well adapted to the recent (several to many generations) environment. Mutation is the natural mechanism believed to provide the expressions of the traits on which natural selection works to drive this evolutionary process of preserving Life in spite of relatively major changes in the environment..

This entire chapter makes a number of major assumptions, which should not be interpreted as representing truth. Rather it merely establishes a theoretical (hypothetical) basis for explaining the changes in the species found in the World today compared to a sequence of fossil species.

We assume that dating of Geologic strata is valid, so the relative ages of fossils can be determined. This leads to the statement that fossil plants and animals form a sequence. We also assume that natural causes can explain what has happened during the span of Geologic Time.

Specifically, we assume that natural selection, micro-evolution and even macro-evolution occur.

primordial soup
primordial peanut butter & jelly

Consistent universe

I have always felt that any account of the Universe ought to provide for a consistent universe. To illustrate this, let me retrace for you the history of hypotheses concerning the planets in the Solar System. At one time, near the middle of the 20th Century, the only known object in the solar system with craters was the Earth's Moon [there is one crater out in Arizona, but that's an exception]. To explain this there needed to be a hypothesis: that the Moon was the closest to the asteroid belt, the source of the meteors that cause craters [Mars is closer, but we apparently were supposed to ignore that]. Then, we began sending robot cameras into space, where they photographed the planets. Then, the only known solid object in the Solar System without craters was the Earth [there is one crater out in Arizona, but that's an exception]. Again we needed a hypothesis: that the Moon functioned as a vacuum cleaner sweeping up those meteors which would have hit the Earth [in spite of the movie, *Space Balls*, this hypothesis which I read in a reputable journal made no sense to me]. Finally someone figured out that a camera capable of photographing Mars, could also be used to photograph Earth. We now know of over 100 craters on Earth with diameters of 8.5 kilometers or more. The Universe has become consistent relative to craters on planets.

Another issue in Consistent Universes concerns planetary atmospheres. Most planets in the Solar System with atmosphere; Venus, Jupiter, Saturn, Uranus, Neptune, Pluto – Charon; the atmosphere is composed of methane, ammonia, carbon dioxide, and water vapor. Yet,

there are two more planets with atmosphere; Earth, and Mars. These two planets have strange atmospheres with Nitrogen, Oxygen, Carbon dioxide and water.

The simplest hypothesis to explain this anomaly is to assume that at one time these two planets had 'normal' planetary atmosphere, then something happened to change it.

date B.P.	primitive atmosphere	
4.6 billion	water vapor	H_2O
	Nitrogen	N_2
	Carbon dioxide	CO_2
	Methane	CH_4
	Hydrogen	H_2
	Ammonia	NH_3

A Russian scientist, Oparin hypothesized that an atmosphere like the above would provide little filtering of UV light, which would drive complex chemical reactions in the atmosphere. After filtering by Ozone [and Oxygen], the UV energy striking Earth today (Ebert, et al., 525) is

wavelength	cal/cm^2-yr
< 250 nm	570
< 200 nm	85
< 150 nm	3.5

In addition, he reasoned, lightning would have a similar effect. Lightning produces an estimated 4 cal/cm^2-yr today. We now know that lightning on other planets is common. Robotic satellites orbiting Jupiter have detected the radio signature of lightning (the familiar interference with television pictures on broadcast channel 2) with synchronous visible light video images showing flashes of light. The evolution of complex chemicals Oparin envisioned is:

Chemical Evolution	
1	organic acids
	amino acids
	lipids
2	polypeptides
	nucleic acids

An American, Harold Urey independently came to a similar conclusion [but later than Oparin, so Oparin gets credit for the hypothesis]. He wanted to test the hypothesis, so had his graduate student, Stanley Miller set up an experiment. Miller created the hypothesized atmosphere in a sealed jar with electric sparks for lightning, with atmosphere circulating above warm (evaporating) water via glass tubing to a condenser causing rain to fall past the lightning. After some time, a sample of the water was withdrawn and tested. It contained organic

acids, amino acids, and lipids. In later experiments starting with the products of Miller's experiments in gently heated water, polypeptides and nucleic acids have spontaneously appeared. These experiments are taken to support Oparin's hypothesis.

Oparin continued from the production of the chemicals of life to suggest that the rain falling on the primitive Oceans of Earth would have contributed these organic molecules into the water, yielding a thin broth. As this broth was splashed into tide pools at high tide, then the water evaporated at low tide, the broth would be concentrated to a primordial soup. The lipids in this soup would froth when agitated by tide splashing in. When one of the froth bubbles (coacervate) included all of the chemicals of Life, it would have spontaneously become alive! When I read Oparin (in translation from the Russian), it seemed to me that this hypothesis did not meet the consistent universe rule, since it became necessary to "wave a magic wand" a minimum of seven times to arrive at Life. My consistent universe does not require a magic wand to continue functioning.

An intriguing alternative to the primordial soup hypothesis is the primordial peanut butter and jelly sandwich hypothesis (Gonick). This hypothesis suggests that the early organic molecules including lipids would have formed a slime on rocks. As more complex molecules formed they would dissolve in the lipid slime on the rocks. Eventually all of the chemicals of Life would be present in the slime. At this point, the processes of Life would spontaneously begin, producing gaseous byproducts. The gases released would cause the slime to froth. When coacervate bubbles broke loose from the slime covered rocks, they would include all the chemicals of the slime (all of the chemicals of Life). The resulting coacervates would be alive, resembling primitive Archeae (primitive bacteria). In Gonick's version, the rock is the bread of the [open-face] sandwich; the slime is the peanut butter; and the froth is the jelly. The primordial peanut butter & jelly sandwich hypothesis is better

than the primordial soup hypothesis, in that it largely avoids the magic wand treatment.

Coacervates	
soup	peanut butter & jelly
concentrate in tide pool	slime on rocks
froth under agitation	biochem of Life
enzymes of Life	Life processes (metabolism)
metabolism	gas byproducts
RNA, DNA	froth
LIFE	LIFE
chemical evolution	

Early Evolution

In either version [soup or peanut butter & jelly] the first living thing, which formed around 3 ½ billion years BP, would have been like a primitive bacterium. It's energy source would be the organic molecules in the broth and/or in the slime. The code for the manufacture of the chemicals necessary to extract the energy for the food source is physically stored in DNA molecules. Unfortunately, DNA is sensitive to damage [mutation] when exposed to UV light, and we previous established that the UV was not filtered by the atmosphere in the absence of Oxygen and Ozone. Occasionally, a mutation would have produced a new way for the bacterium to get energy. You need to understand that "occasionally" is not a problem when a bacterial

generation is a day or so, and the evolution has available as much as two billion years, or about 600 billion generations!

Among the unique methods for obtaining energy in the modern bacteria are chemosynthesis, for example converting rust (ferric oxide) to a water soluble form of iron (ferrous sulphate) which is how iron gets into well water. Another example of chemosynthesis is the conversion of sulphate to hydrogen sulfide (the smell of rotten eggs, frequently found around marshes). A relatively simple mutation in the enzyme that converts sulphate produces a purplish pigment that absorbs sunlight as a energy source. These bacteria do not require a food source, because they can manufacture sugar using solar energy.

Another relatively simple mutation can change the purplish photosynthetic chemical to a more efficient greenish purple chemical, called bacteriochlorophyll (*b*-chlorophyll), which still releases hydrogen sulfide as a waste product. With an even simpler mutation, the waste product of *b*-chlorophyll becomes molecular Oxygen. The final interesting mutation in this line changes the *b*-chlorophyll to chlorophyll *b* which is bluish green (rather than greenish purple) and works much more efficiently.

As a result of the more efficient Oxygen-producing photosynthesis, waste Oxygen would begin to accumulate in the ocean water, then to bubble into the air. Remember the air contained methane, also called natural gas or city gas, which burns in your gas cook stove. So we have a methane atmosphere with oxygen bubbling into it in the presence of lightning. The atmosphere could have caught fire and burned until it produced the nitrogen, oxygen, carbon dioxide, water atmosphere of modern Earth. This also caused the first mass extinction [of many of the oxygen-intolerant bacteria of the pre-Cambrian], about 1 ½ billion years ago!

The hypothesis states that the present atmosphere of Earth was produced by Life. This predicts that any planet, such as Mars, with a

similar atmosphere either has Life on it, or once had Life on it. This is exactly why we are spending so much effort (and tax dollars) attempting to find Life on Mars. It has nothing to do with little green men from Mars, but everything to do with little green ***bacteria*** from Mars.

Works Cited

Ebert, E. B., *et al. Biology.* New York: Holt, Rinehart and Winston, 1973.

Gonick, L. *Cartoon History of the Universe.* New York: Doubleday, 1990.