L23 Miller's 1950s experiment < monomers, amino acids, polymers, proteins >

Au commencement, Dieu créa LA MARTÉRE du ciel & de la terre. —Buffon.[1]

Nature has a surprising capacity to produce bizarre results within the confinesof physical laws.
—Stuart Ross Taylor, *Destiny or Chance*, 1998.[2]

Louis Pasteur (1822-1895) [3]

Prepped by Swammerdam's classification of insects by their developmental ways,[4] Francesco Redi in 1669 experimentally proved that maggots do not develop spontaneously in meat.[5] Did his generalization that macro-life can only arise from living prior-generations apply to micro-organisms? Could these bridge between the inanimate and the animate? For most, this question was already settled by Louis Pasteur's and John Tyndall's experimental proofs: "No,"[6] and the biological mantra that "life comes from life" had received a new lease of life. But, in modern reasoning, it again makes sense to posit spontaneous generation of life from the inanimate.

Could life have come into being from inorganic materials or even unliving organic materials? **Louis Pasteur** discovered for the French wine industry in 1856 that it could not. By boiling wine to destroy active yeast or by filtering out microorganisms, the souring of wine to vinegar by fermentation was stopped. This began his "swan-necked flask" experiments that demonstrated "pasteurization," which does not require boiling, but just enough heating to 55ºC for wine (65ºC for water, higher for dairy) to kill life. Pasteur was thus led to reject heterogenesis (the long held notion of the spontaneous generation of living things, without parents, from dead organic material). Understandable then his chagrin when in 1859 Felix Pouchet published *Hétérogénie ou Traité de la Génération Spontanée*.[7] Public attention to the ensuing Pasteur-Pouchet debate (which hinged on the initial sterility of Pouchet's lab preparations), was diverted when Clémence-Auguste Royer (1830–1902), no Pasteur ally and advocate of eugenic practices,[8] translated Darwin's *Origin of Species* into French: *De l'origine des espèces par sélection naturelle,* 1864.[9]

Now even to abiogenesis (spontaneous generation of life from inorganic matter) we must agree if Earth, like a volcanic island, began sterilized. Life is here.

Keith G. Davies summarizes: "In physics and chemistry, things tend to equilibrate: but for living cells equilibrium means death. Molecular biology was born with the recognition that the large molecular structures essential to living cells gave rise to autonomous feedback systems. They are based on chemical circuitry and yet, as François Jacob put it, they 'transcend chemistry.'[10] The living and the non-living do not differ in composition, but rather in their level of organization. All life can be seen as an interacting hierarchy of feedback systems, from cells to individuals, and from populations to communities and ecosystems"[11] (*recall* Gaia, Topic *a3*).

Models of the early inorganic-world have been investigated experimentally to see if the precursors of living organisms (simple organic molecules of C, H, N, and O, called *monomers*) can form spontaneously. They do: all 20 amino acids common in the proteins of living organisms have been synthesized (in the absence of free oxygen) in circumstances and conditions that would have occurred naturally at the surface of primordial Earth.

Stanley L. Miller's pioneering investigations in the 1950s [12] under the tutelage of Harold C. Urey and clues for success in the synthesis of organic compounds from others when exposed to ultraviolet light or an electrical field as, for example, glycine from wet formamide (significantly, for Miller, a compound unlikely to be present on the primitive Earth) by Walther Löb in 1913.[13] (In 1970, a surprise find by spectroscopy at radio frequencies, was the presence of glycine in interstellar space.)[14]

Miller used a particularly simple apparatus (***Figure L23.2***):[15] dry gases (approximating the composition of the original atmosphere) and water (representing the sea) were placed in a sealed glass flask (representing Earth). The whole was then sterilized (representing pre-life conditions). The water was then boiled (representing volcanism) and the steam was allowed to circulate through the gases to a cooling condenser which returned the water to be boiled again (representing the hydrological cycle). An electric spark (representing lightning) discharged through the water vapor gas mixture. The water in the apparatus changed over a week from colorless through yellow to an increasingly dark red. Analysis showed that this change was due to the accumulation of several amino acids that had been synthesized. However, some of the nucleotides which make up modern RNA, particularly pyrimidines, are exceedingly rare in such syntheses. Even so, an RNA world would not have been inhibited for long as RNA can, in fact, catalyze the synthesis of its own pyrimidine nucleotides.

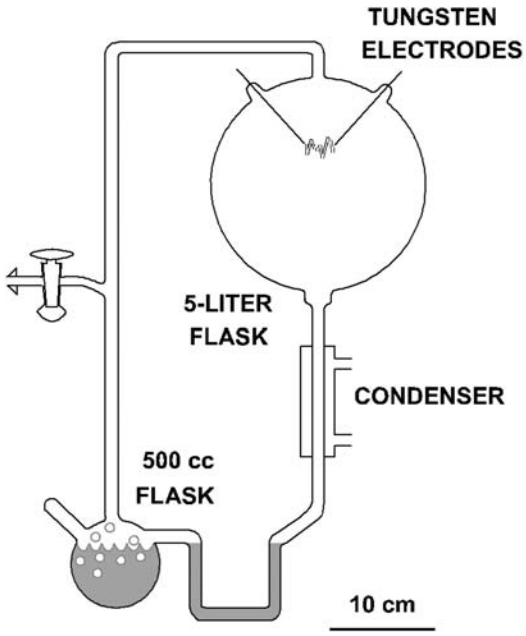

Figure L23.2[16] Miller's apparatus used for the electric-discharge synthesis of amino acids.

Also comets contain organic material, including the components of amino acids and in the water that they carry, an impact's energy could have driven some of the initial reactions that led to life. In simulated comet impact studies carried out by Jennifer Blank in 2001, several peptides were formed.[17]

Could RNA with its sugar (ribose) backbone survive in the hot world of the Early Hadean? If not, it could have been preceded by accumulations of heat tolerant PNA (peptide nucleic acid) with its peptide (a protein molecule called *AEG*) backbone. Peter E. Nielsen suggested this after, in the early 1990s, a DNA mimic, by combining nucleic acids with a protein backbone, had been demonstrated. Miller in 2000 reported that shooting electricity through a blend of methane, ammonia, nitrogen, and water creates AEG and other parts of PNA.[18]

A 1990s hypothesis by Günter Wächtershäuser is that life was set on its course by an environment in which acetic acid readily forms.[19] That is, life evolved and emerged from a succession of ever more complex organic molecules that involve acetic acid (*see* Topic *L24*).

Quite certainly life did appear, and, given the world, evolution is inevitable although we are not.

The reductionist view is that life is just another set of chemical compounds. And, in spite of the constraints of chemistry, when it comes to the genetic code, the millennia old view of Epicurus, that "The atoms come together in different order and position, like letters which though they are few, yet, by being placed together in different ways, produce innumerable words," is apt. Likely, throughout the universe there are multitudinous worlds, and past and future ones, that provision for the spontaneous emergence of life. No design is implied. When unveiled, Gordon Kane in his book *Supersymmetry*, 2000, concludes that the unsurprise of the ultimate laws of nature will be that "our universe has properties consistent with having humans, though ... a source of great sadness for some people ... it is indifferent to whether they are there and to whether they understand it." [20]

Distances quarantine.

Even so, from Earth, life should have spread as far as Mars and possibly beyond,[21] for, as Christopher P. McKay so graphically puts it: "We know that the planets throughout the solar system exchange material; they're swapping spit." [22] ❑