

**Alles Introductory Biology: Illustrated Lecture Presentations**

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**Part Three: The Integration of Biological Knowledge**

**The Origin of Life on Earth**

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## **The Origin of Life on Earth**

- **When did life originate?**
- Where was it most likely to have originated?
- What is the current working hypothesis as to how it originated?

## **The Window of Opportunity**

**between 4200 m.y.a.**

**(toward the end of the impact frustration of the origin of life)**

**and 3500 m.y.a.**

**(the first fossil evidence of life)**

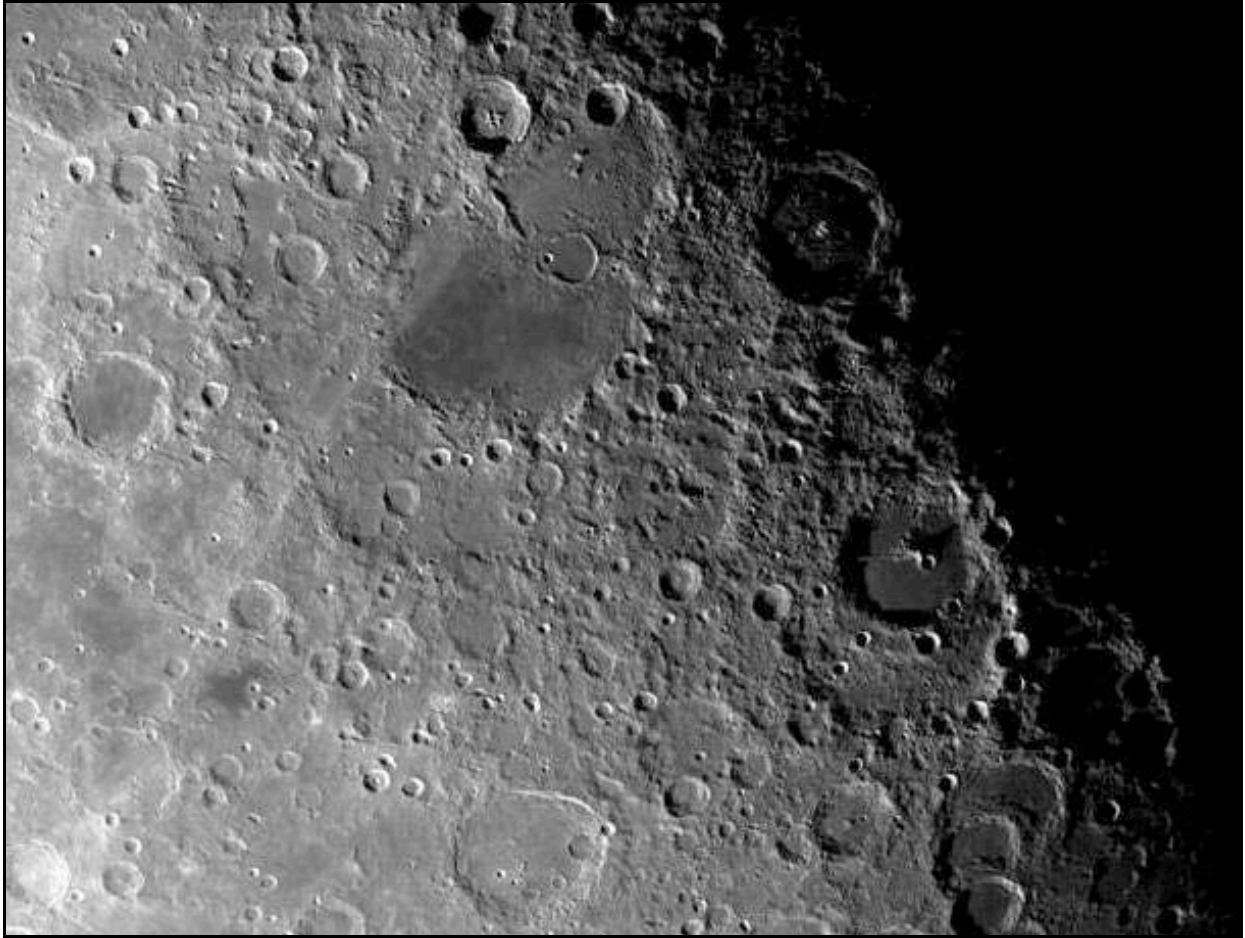
**Estimates**

**deep sea vent abiogenesis 4200 to 4000 m.y.a.**

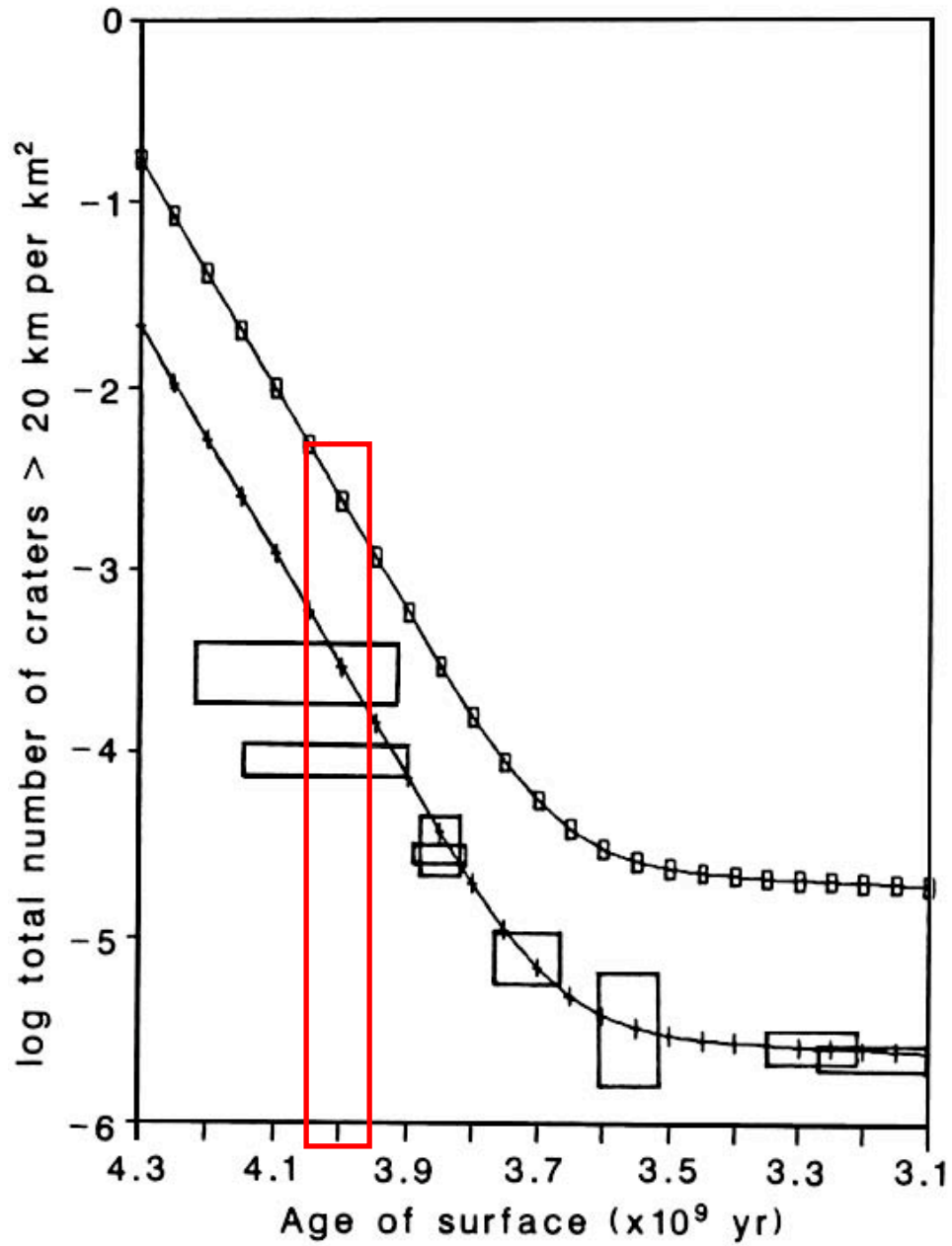
**surface abiogenesis 4000 to 3700 m.y.a.**

**(abiogenesis—the origin of life by chemical evolution)**

**(after Maher & Stevenson, 1988)**

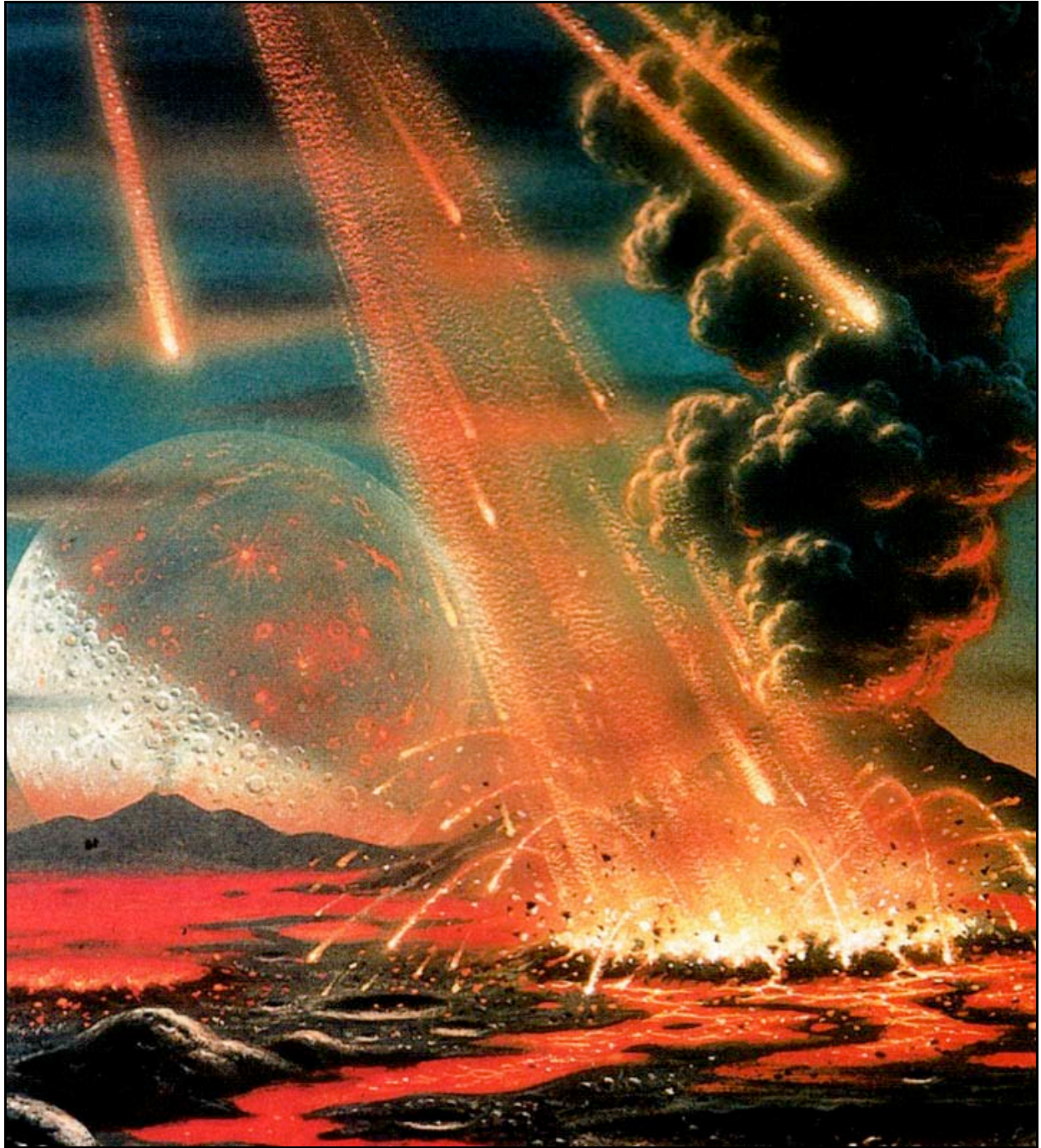


**Because the moon's surface does not erode, it preserves a record of meteorite impacts that have occurred since it's surface solidified.**

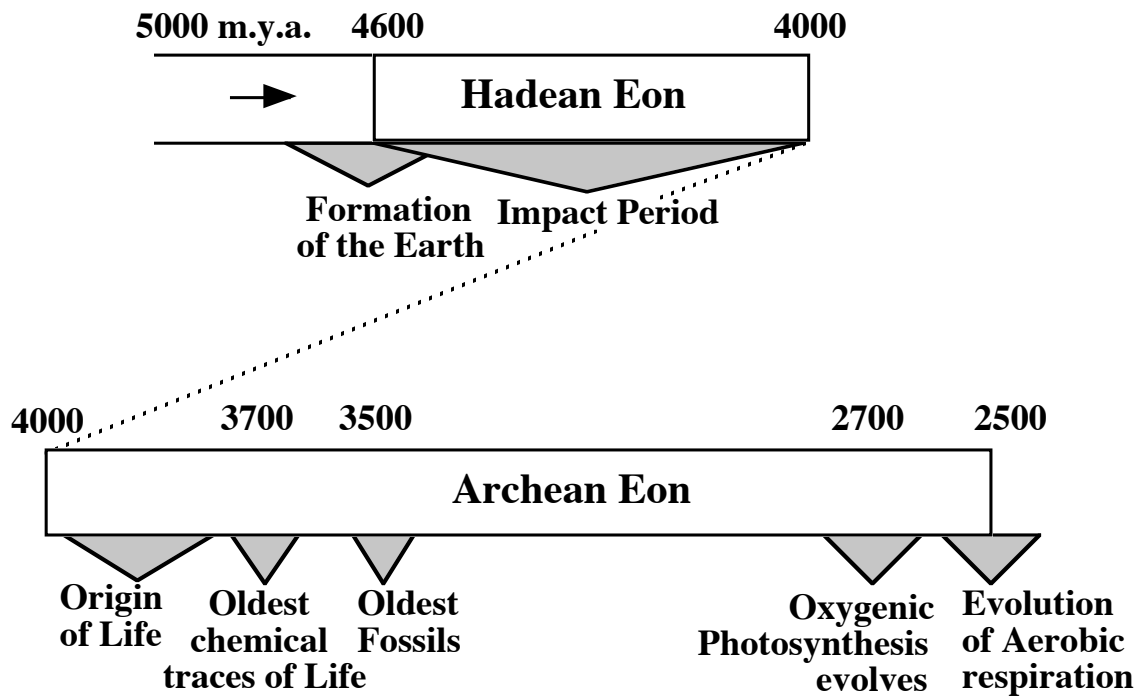


**Number of Meteorite Impacts during early Earth History**

(Maher & Stevenson, 1988)



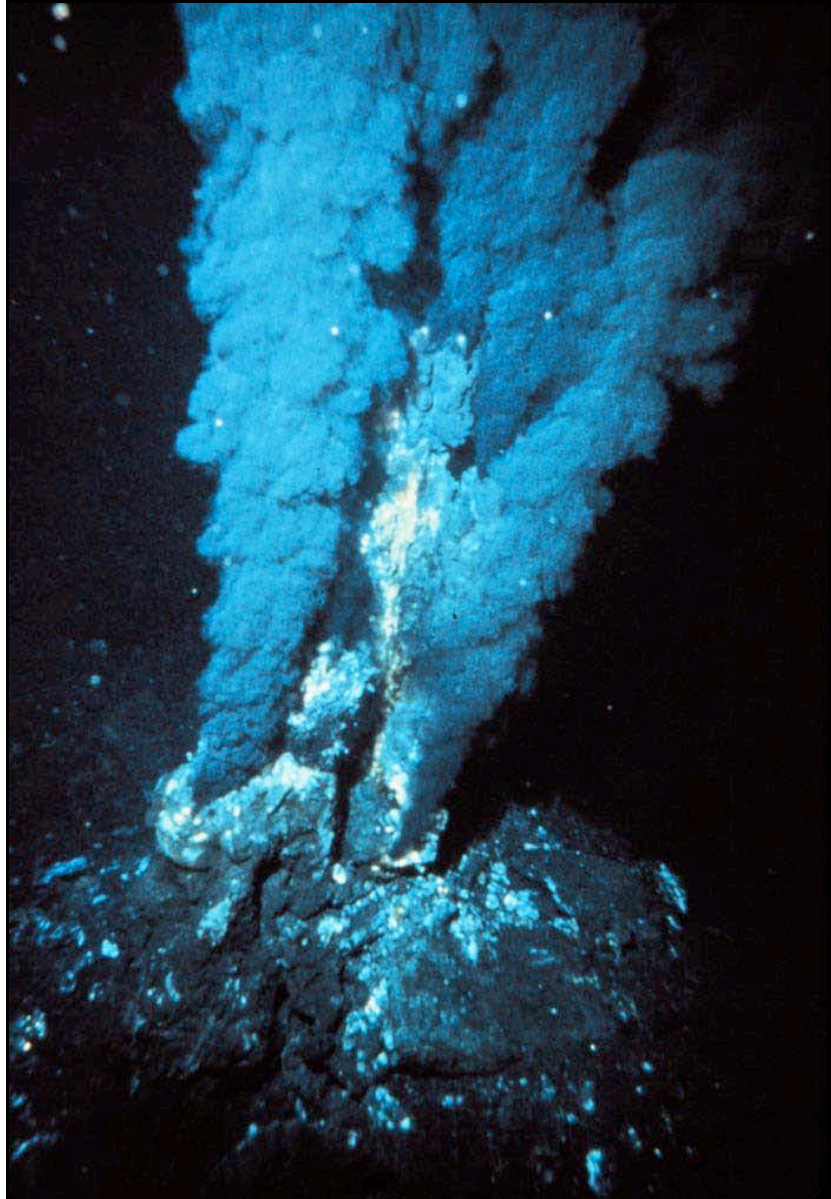
**Hadean Eon Impact Frustration of the Origin of Life**



## The Origin of Life on Earth

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## **The Hydrothermal Vent Hypothesis for the Origin of Life**

(Photograph of hydrothermal vent by P. Rona courtesy of NOAA)

Web Reference

<http://www.pmel.noaa.gov/vents/chemistry/fluid.html>

## **Essay—Resolving the Hadean/Archean Boundary**

### **Some Fixed Points**

1. It has been a standard in the past to use the oldest known rocks as the beginning of Earth geology and therefore the beginning of the Archean. There is now, however, good evidence for continental core rocks from the Acasta area of NW Canada that have been dated to 4055 m.y.a. (Zimmer, 1999).
2. Few people dispute the notion that between 4100 and 3800 m.y.a., our planet was heavily bombarded by debris from space, a period known as the Late Heavy Bombardment (LHB) (Bortman, 2000). The usual date given for the end of the impact period is 3900 m.y.a.. The question is: If life originated before the LHB, could it have survived the bombardment?
3. There is a consensus that the first biochemical traces of life on Earth date to 3700 m.y.a. (Simpson, 2003).
4. Sedimentary rocks from Greenland dated to 3850 m.y.a. are the oldest, conclusive evidence of liquid water on the Earth's surface.
5. There is new evidence, however, for liquid water on Earth dating back to 4400 m.y.a. (Wilde, et al, 2001). Liquid water is an absolute requirement for life. But if the oceans were boiled away during the LHB and reformed only ~ 3900 m.y.a., that leaves a very narrow window, between 3900 and 3700 m.y.a., for the origin of life.
6. There has been serious suggestions to establish the beginning of the Archean Eon at 4000 m.y.a. as the earliest possible point for the origin of life (Nisbet 1996).

### **Conclusion**

If there are continental core rocks that survived the LHB 4100 to 3800 m.y.a. without melting, and they are the oldest known Earth rocks, and if it seems that life existed by 3700 m.y.a., then perhaps it is reasonable to say that life, especially at deep sea hydrothermal vents, originated at or even before 4000 m.y.a. and survived the Late Heavy Bombardment. If so, placing the Hadean/ Archean time boundary at 4000 m.y.a. accounts for most of what we know about the early Earth.

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## Chemical Evolution

**“Given the physical-chemical conditions that prevailed on our planet 4000 m.y.a., a protometabolism leading to RNA-like molecules was bound to arise along well-defined, reproducible chemical lines.”**

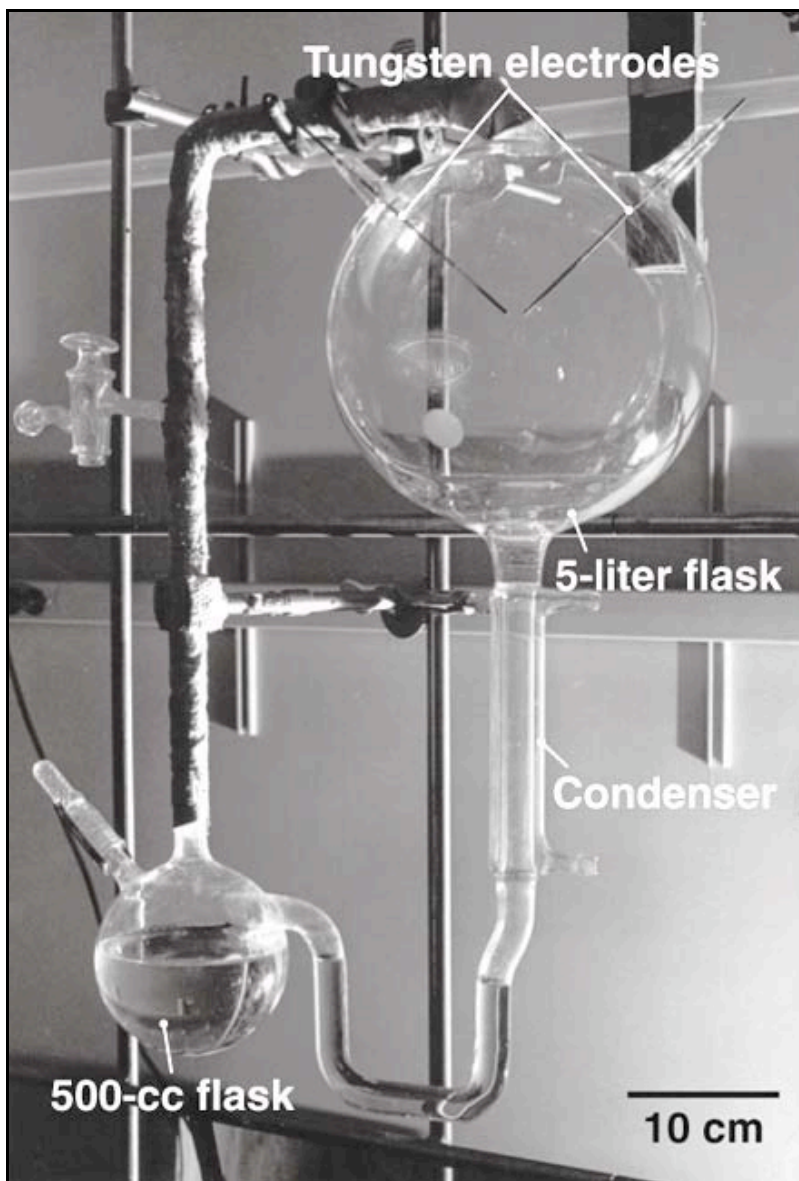
Christian de Duve from his book *Vital Dust* (1995)

## **Abiotic Molecular Building Blocks**

### **Amino acids, Stanley Miller and the 1953 experiment**

**“Life began when some compound or class of compounds developed the ability to copy itself in such a way that it occasionally made heritable ‘mistakes’. These mistakes sometimes produced generations of molecules that could replicate more efficiently than their predecessors.”**

Stanley Miller in Horgan (1991)



**The Miller Apparatus**

Web Reference

<http://www.accessexcellence.org/WN/NM/miller.html>

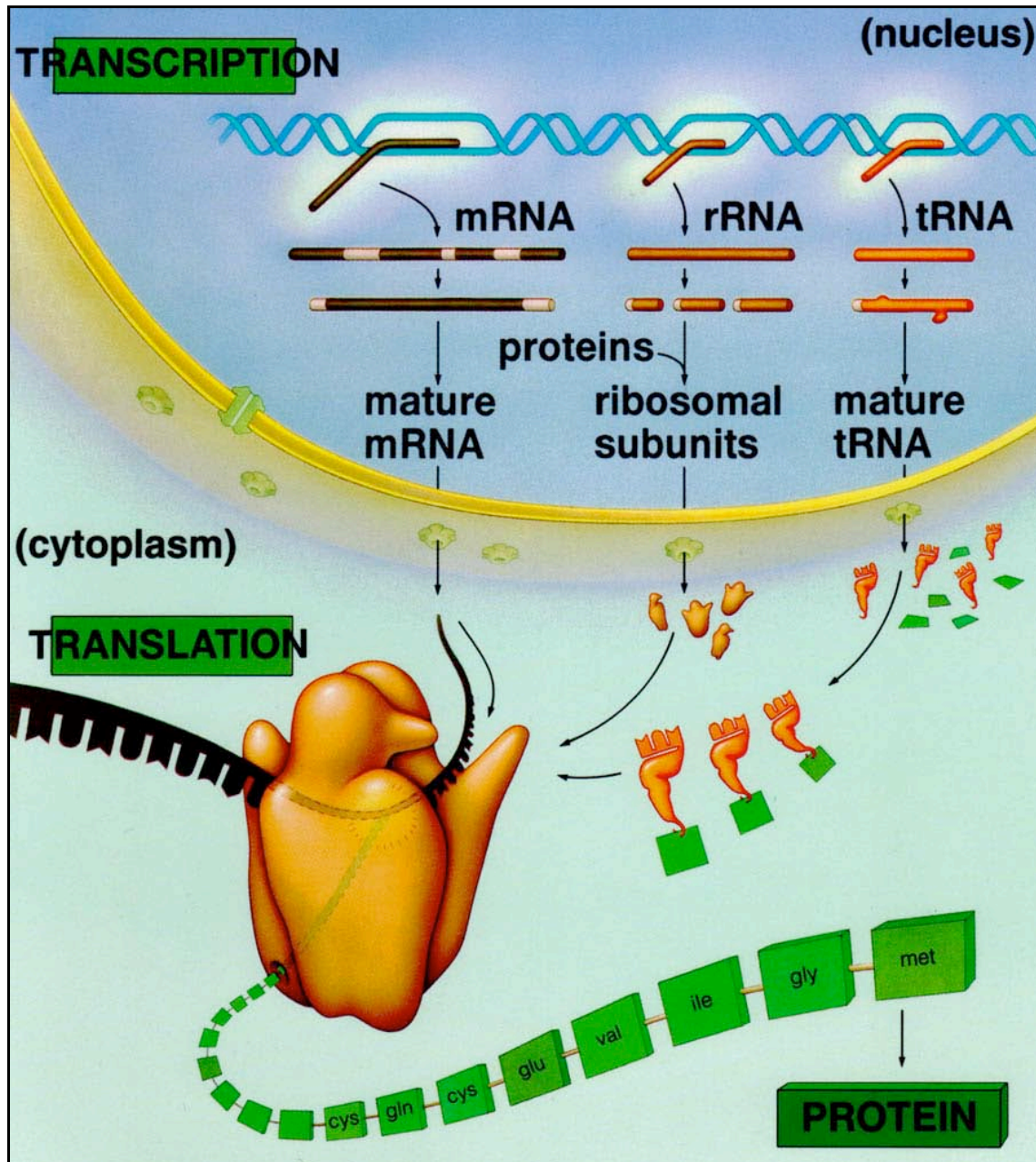
## **The “RNA World” Hypothesis for the Origin of Life**

How did protein synthesis evolve if it takes protein enzymes to mediate the process of transcription and translation? The answer came with the discovery that RNAs can act both as information molecule, a gene, and an enzyme—a ribozyme. Thomas Cech and Sidney Altman won the Nobel Prize in 1989, for discovering the ribozyme function of RNA.

Below is one possible “RNA World” scenario, showing the transition from the prebiotic RNA world to the biotic DNA world.

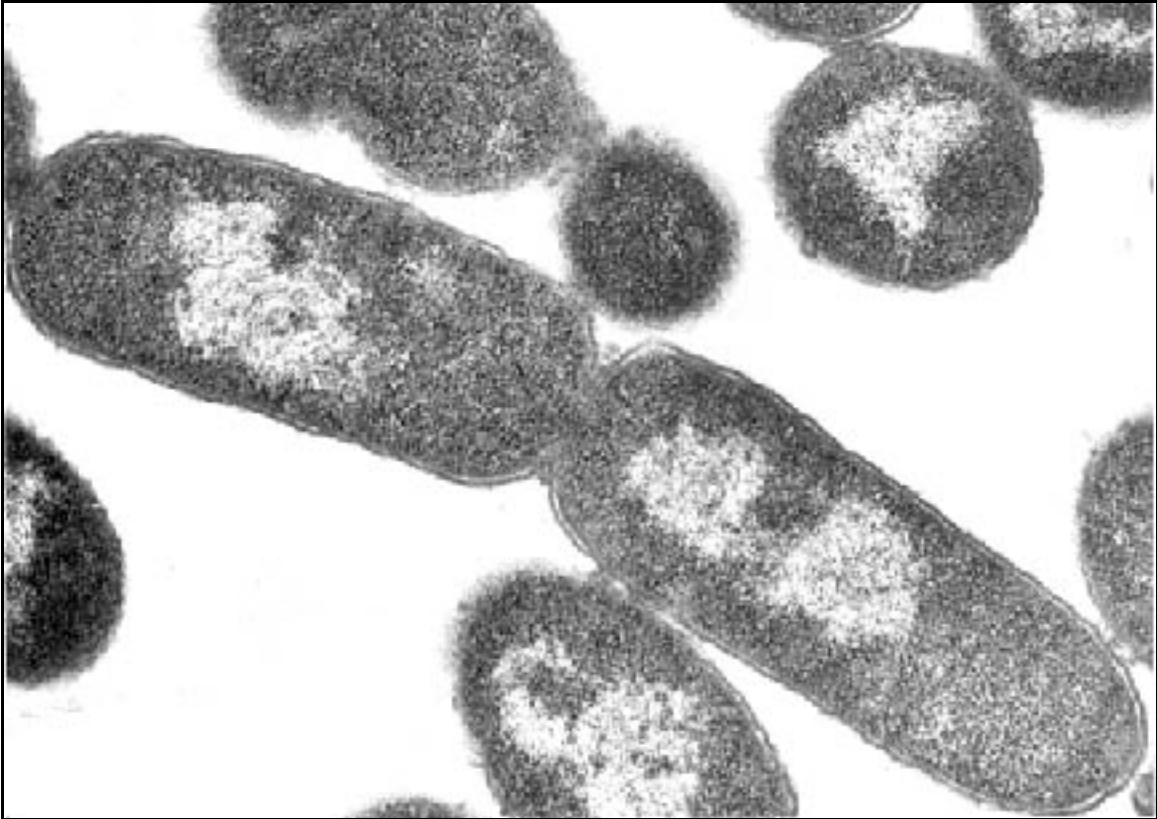
- 1. Creation of prebiotic soup, including nucleotides, from the Earth’s primitive atmosphere**
- 2. Production of short RNA molecules with random sequences**
- 3. Selective replication of self-duplication catalytic RNA segments**
- 4. Synthesis of specific peptides, catalyzed by RNA**
- 5. Increasing role of peptides in RNA replication; coevolution of RNA and protein**
- 6. Primitive translation system develops, with RNA genome and RNA-protein ribosomes**
- 7. Genomic RNA begins to be copied into DNA**
- 8. DNA genome, translated on RNA-protein ribosomes**



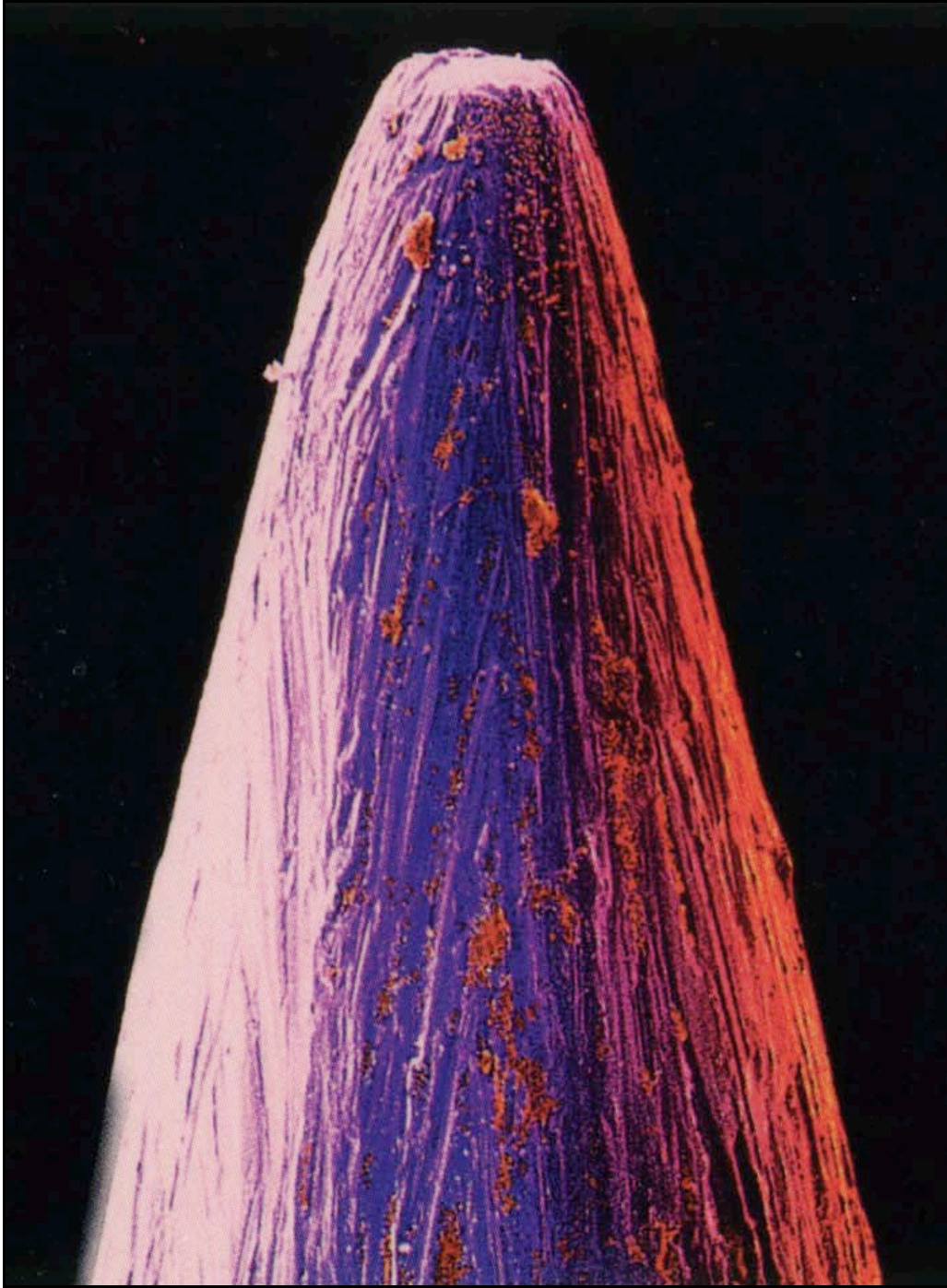


Recent discoveries have shown that RNA, and not protein enzymes, catalyses the formation of peptide chains in ribosomes (Cech, 2000). This discovery adds support to the “RNA World” hypothesis of the origin of life by showing that RNA acting as a ribozyme still plays a central role in the most basic of all cellular metabolic functions.





**The first forms of life on Earth were bacteria.**



**Above are bacteria on the tip of a pin magnified 140 times.**





**Magnified over 500 times**



**Bacillus bacteria magnified 14,000 times. Each one of these bacteria is 0.5 millionths of a meter across and 2 millionths of a meter long.**

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[http://nai.arc.nasa.gov/news\\_stories/news\\_detail.cfm?ID=231](http://nai.arc.nasa.gov/news_stories/news_detail.cfm?ID=231) (10/27/03)

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