Chapter 48

BIOCHEMICAL ORIGIN OF TERRESTRIAL LIFE

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PRE-LECTURE ASSIGNMENT

1. Quickly review notes for the previous lecture.
2. Suggested readings:
   a. General genetics textbooks
      Altenburg: Chap. 27, pp. 487-488.
      Srb and Owen: Chap. 1, pp. 1-7.
   b. Additional references
      Lederberg, J. 1959. A view of genetics. Stanford Med. Bull., 17: 120-132. This Nobel Prize lecture is published also in "Science".
      Lederberg, J., and Cowie, D. B. 1958. Moondust. Science, 127: 1473-1475.
      Miller, S. L., and Urey, H. C. 1959. Organic compound synthesis on the primitive earth. Science, 130: 245-251.
      Oparin, A. I. 1957. The origin of life on the earth. 3rd Ed. New York: Academic Press.
      Sinton, W. M. 1959. Further evidence of vegetation on Mars. Science, 130: 1234-1237.

LECTURE NOTES

A. Terrestrial life and its origin
   1. The universe is about 10 billion years old.
   2. The earth is about five billion years old, and has a fossil record only for the past one billion years or so.
   3. The absence of fossils before this time requires a synthetic attempt to reconstruct
      a. the features of the earth when it originated.
      b. the most likely features from which organisms developed.

B. Common plan of present organisms
   1. Comparative biochemistry of present higher plants and animals, bacteria, and many viruses shows that
      a. the same amino acids are found universally.
      b. DNA is the carrier of genetic information.
   2. At a higher level of organization, the chromosome and the remarkably uniform process of mitosis are found both in plant and animal cells.
   3. It is concluded, then, life has had a common plan ever since plants and animals became separate nearly a billion years ago.
   4. Nucleic acid and protein are, perhaps, the most durable geochemical features of the earth.

C. Minimum requirements for the first organism
   1. It must be self-reproducing, and capable of mutation (heritable changes).
   2. The mutants must be subjected to a natural selection that retains the fitter forms.
   3. The free-living bacterium, too complex to have arisen spontaneously, must be the result of a previous evolution of complexity.
   4. The replication of DNA in vitro (Kornberg) would be one of the simplest systems subject to evolution. However, complex nucleoside triphosphates and other accessories are required for this synthesis.
   5. Accordingly, the primary living material may have been DNA synthesized by some mechanism even simpler than is presently known, or may have been even simpler than DNA.
   6. Attempts should be made, aided by the polymer industry, to construct linear polymers which show some degree of self-replication.

D. Organic synthesis prior to organisms
   1. Not very much is learned about the evolutionary steps leading to the first organism from our present habitat, for this is, in large measure, the result of the metabolism of living forms.

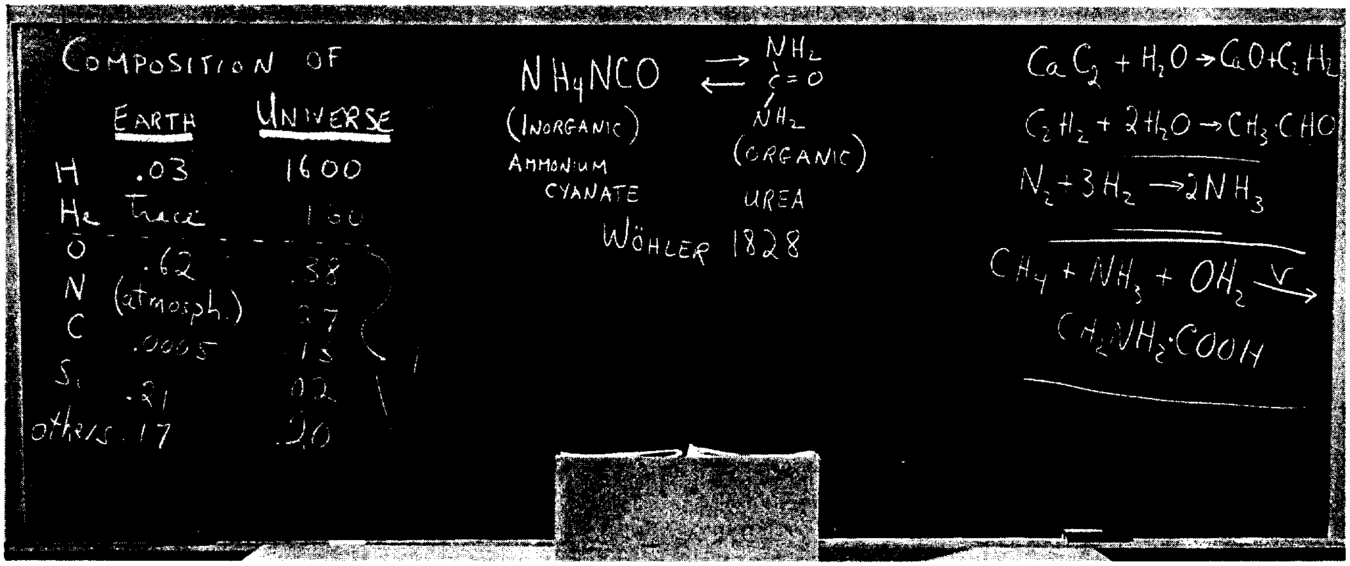

Figure 48-1

a. Living things have been responsible, for example, for large deposits of carbon in coal sediments and for the release of oxygen to the atmosphere consequent to photosynthesis.
b. Organisms tend to destroy large accumulations of organic compounds.
c. For these reasons the distribution of organic compounds might have been more complex before life started than it is now.

2. Organic compounds
   a. Such compounds of carbon are not made only by the metabolism of organisms.
   b. Wöhler synthesized the organic compound, urea, by heating the inorganic compound, ammonium cyanate (Fig. 48-1, center).
3. Oparin, about 1928, proposed that certain organic syntheses could occur naturally in the absence of life (Fig. 48-1, right top portion).
   a. Carbon or methane reacting with metals produces carbides (CaC_2), which upon hydrolysis yields acetylene (C_2H_2), which when hydrolyzed yields acetaldehyde ($CH_3 \cdot CHO$).
   b. Nitrogen can produce ammonia by reacting with hydrogen.
   c. Other reactions, between aldehydes and ammonia, would produce high molecular weight polymers of considerable interest for biological development.
4. Miller and Urey subjected mixtures of gases, predicated as being in the primitive earth atmosphere, to ultraviolet light and spark discharges. In this way, they have produced large amounts and large varieties of amino acids.
   a. The synthesis of glycine, indicated in Fig. 48-1 (right lower portion), is an example.
   b. The detailed chemical steps in these syntheses are unknown, but supposedly involve the production of highly-reactive free-radical intermediates.

E. Comparative chemistry of earth and universe (Fig. 48-1, left)
1. Most of the universe is hydrogen and helium.
2. If all the other atoms are totaled, the elements of unique importance in organic compounds (O, N, C)
   a. comprise 80% of this total in the case of the universe, while
   b. the earth has, relatively, only traces of carbon.
3. Whereas the universe is a good place, the earth is a very poor place for starting an organic chemistry which would be of biological interest.
4. Yet, despite the unlikelihood, life did develop on earth!
5. Comets have been shown to contain CH, CN, CC, and CO radicals. Such radicals are common in organic compounds.
6. The primitive earth could have accumulated large amounts of different complex organic

materials which remained undegraded until the advent of organisms.

a. As the first organisms used up these resources, there would be a selection in favor of mutants capable of synthesizing these organic materials from simpler or from inorganic components.

b. In this way organisms would acquire synthetic capabilities.

F. Search for organic compounds and life on other planets

1. Mars

a. Astronomers have reported variations in apparent color and texture of its surface.

b. Using the Palomar 200-inch telescope, Sinton found infra-red spectroscopic evidence for the presence there of organic molecules of an asymmetric type.

c. While there is, therefore, evidence for appreciable quantities of organic material on Mars, these may or may not be of organismic origin.

d. Missions to or near Mars will be necessary in order to determine definitely its organic contents, the presence of DNA, and the presence of life.

2. Accidental transplantation of terrestrial genotypes to other planets must be avoided.

a. If a single bacterium, like Escherichia coli, were placed on suitable medium it would occupy a volume the size of the earth in about 48 hours.

b. Such a premature transplantation would be disastrous for our study of

1) the indigenous forms of life, or,

2) in the absence of organisms, the pre-organismal evolution of organic compounds.

3. Venus

a. While estimates of its temperature vary widely, some are compatible with the existence of life.

b. Its surface is unknown, being hidden completely by an opaque highly-reflecting cloud layer.

c. It cannot be assumed biological activity is impossible there.

4. Moon

a. Having no atmosphere and probably no water, the presence there of earth-like life is out of the question.

b. It has been suggested that the moon might act as a gravitational trap for fossil spores which may have drifted between planets.

c. Although improbable, the very possibility of an interplanetary gene flow is too important to ignore in our plans to exploit and explore space.

G. The genetics of the minutest organisms and the replicative powers of DNA have cosmic importance.

POST-LECTURE ASSIGNMENT

1. Read the notes immediately after the lecture or as soon thereafter as possible, making additions to them as desired.
2. Review the reading assignment.
3. Be able to discuss or define orally or in writing the items underlined in the lecture notes.
4. Complete any additional assignment.

QUESTIONS FOR DISCUSSION

48. 1. Discuss the geochemical evolution of the earth from its origin to the time the first gene was formed.

48. 2. Discuss the gene as the basis of life.

48. 3. What properties would you predict for genes present on other planets?

48. 4. What evolutionary processes do you imagine took place on earth between the origin of the first gene and the occurrence of the first free-living organism?

48. 5. Do you suppose other planets have forms of life superior to ours? Explain your answer.

48. 6. What information might we obtain about life on other planets without leaving our own?

48. 7. What genetic predictions would you make for marriages between earth humans and planetary "humans"?

48. 8. What specific suggestions did Lederberg make with regard to future research on the origin of life?

48. 9. Do you believe planetobiological research should be supported regardless of cost? Explain.

48.10. Would superhumans on some other planet be likely to beam radio signals specifically to the earth? Why?

48.11. Are our present human genotypes adapted for living on Mars? Explain.

48.12. What would you predict about an organism which drifted to the moon from another planet?

48.13. Is RNA likely to be a basic component of the first organism on our own or on other planets? Explain.

48.14. In what respects do the earth's minutest organisms and DNA have cosmic importance?