Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.D: The origin of living systems is explained by natural processes.

Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.

a. Scientific evidence supports the various models.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized due to the presence of available free energy and the absence of a significant quantity of oxygen.

Preface

- Origin of life happened once a long time ago.
- The question of Life's origin is difficult to answer but not impossible.
- Remember the rules of science predicate a "natural" explanation, this might not always seem the most reasonable or probable but slides that follow represent the best plausible natural explanation.
- Although some explanations are speculative they still lead to testable predictions in the lab.

Themes

- The theme to look for throughout this powerpoint is CHANGE.
- The earth has changed, it is changing today and will continue to change into the future.
  - This change includes both the abiotic and biotic.
  - Look for examples of abiotic factors effecting biotic change but also look for examples throughout earth's history where the biota effect the earth's abiotic characteristics.
- The changes in earth and its living organisms are episodic, significant events followed by stasis, repeated over and over again through time.

What did early earth look like?

- The easy answer...nothing like it does today!
- The early earth was a barren, inhospitable place devoid of any life.
  - There were no oceans, no oxygen.
  - Earth was under continual bombardment of rock and ice from the formation of the solar system.
  - Latest evidence suggests that the atmosphere was primarily nitrogen and carbon dioxide.
  - Volcanoes were large and numerous, the earth as hot.
  - UV radiation was great with no atmosphere to filter it
  - Lightning was widespread

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Evidence of student learning is a demonstrated understanding of each of the following:

2. In turn, these molecules served as monomers or building blocks for the formation of more complex molecules, including amino acids and nucleotides. [See also **4.A.1**]

3. The joining of these monomers produced polymers with the ability to replicate, store and transfer information.

4. These complex reaction sets could have occurred in solution (organic soup model) or as reactions on solid reactive surfaces. [See also **2.B.1**]

How did life begin? **Modern Abiogenesis**

- The current explanation involves 4 general steps.
  - 1. The synthesis of small organic molecules.
    - *monomers*
  - 2. The synthesis of large organic molecules.
    - *polymers*
  - 3. The synthesis of vesicles.
    - *protocells*
  - 4. The synthesis of self-replicating RNA
    - *ribozymes*

Synthesis of Small Organic Molecules

- As the earth formed and cooled there was an abundance of certain chemicals.
  - *nitrogen oxides, carbon dioxides, methane, ammonia, hydrogen, hydrogen sulfide, water vapor*
  - Recent evidence confirms that meteorites carry carbon compounds, 1-2% of their mass.
    - *meteorite fragments have been analyzed and found to contain, some amino acids, simple sugars, lipids and nitrogenous bases.*
- Under favorable conditions these compounds may have formed simple organic compounds, monomers.

Synthesis of Small Organic Molecules

- The favorable conditions are as follows:
  - Time *billions of years available*
  - Energy *earth was very hot and its slowly cooled*
  - Building Blocks *by-products of earth's formation*
  - A reducing (or even neutral) atmosphere
    - *the presence of oxygen would have would have created a degradative environment where the breakdown of compounds would have been favored over the synthesis of compounds*
  - In the 1920's two chemists Oparin and Haldane hypothesized that a reducing atmosphere would favor the production of organic molecules

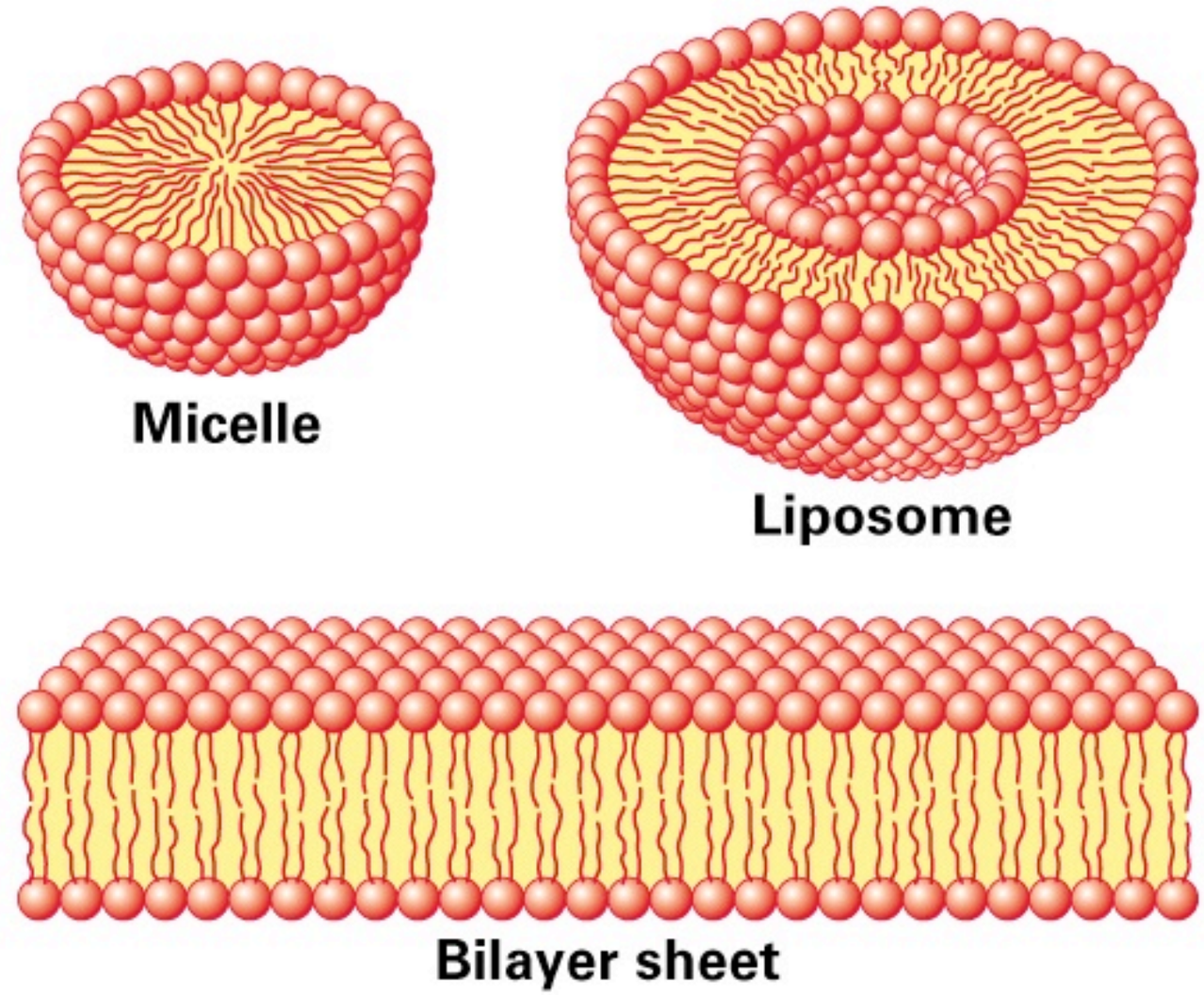
Synthesis of Large Organic Molecules

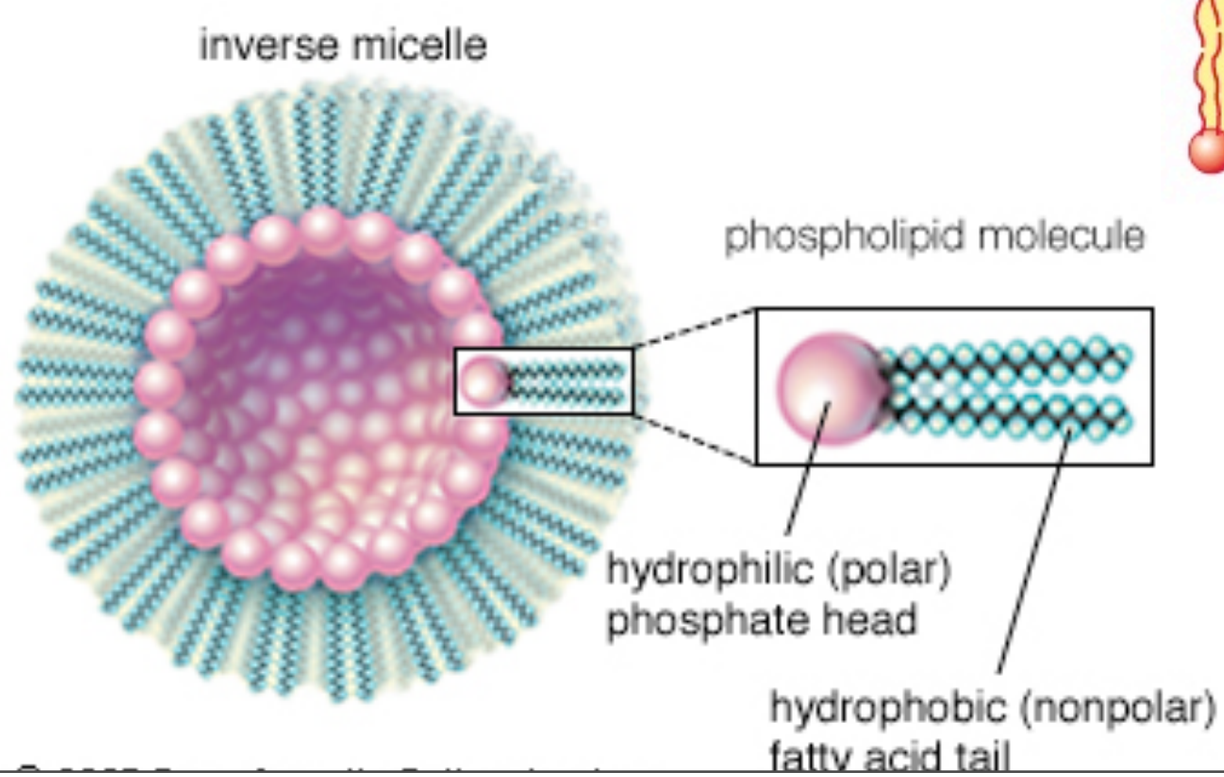
- All cells have a vast collection of large macromolecules.
  - Some research has shown that a solution of amino acids and nucleotides have formed spontaneously when dripped onto hot sand, clay or rock.
    - *the clay etc acts as a catalyst*
    - *the results are not overwhelming as the proteins that did form were are mix of linked and cross-linked amino acids unlike the our proteins*

The Synthesis of Vesicles

- The synthesis of vesicles.
  - *vesicles form spontaneously when lipids and other organics are added to water*
  - *soft mineral clays thought to be present on early earth have been shown to increase the rate of production of these vesicles*
  - *these vesicles could have trapped organics inside during their formation or small organics may have diffused through the membrane later*
  - *vesicles have been shown to grow and reproduce on their own*

The Synthesis of Vesicles





The Synthesis of Self-Replicating RNA

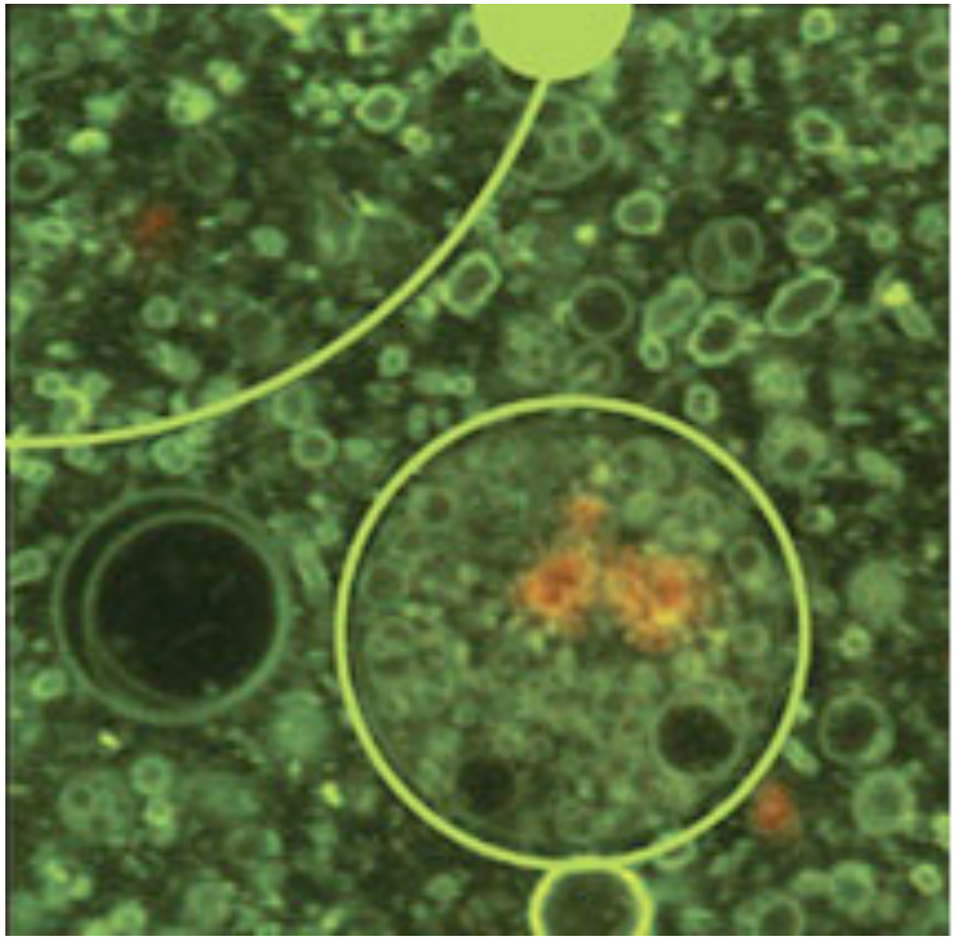
Until recently biology had a "chicken or the egg" problem. DNA synthesis requires proteins, protein synthesis requires DNA

- Then came the discovery of **ribozymes,** an RNA molecule that contains genetic instructions and has catalytic properties.
  - *Up to this discovery it was believed that proteins were the only organic molecule that had catalytic properties, now we realize that organic catalysts include certain proteins and certain nucleic acids.*
- Single stranded RNA is thought be the first genetic molecule.
- In fact because single stranded RNA could fold into different shapes (phenotype) and contained genetic instructions (genotype), natural selection could have driven its evolution.

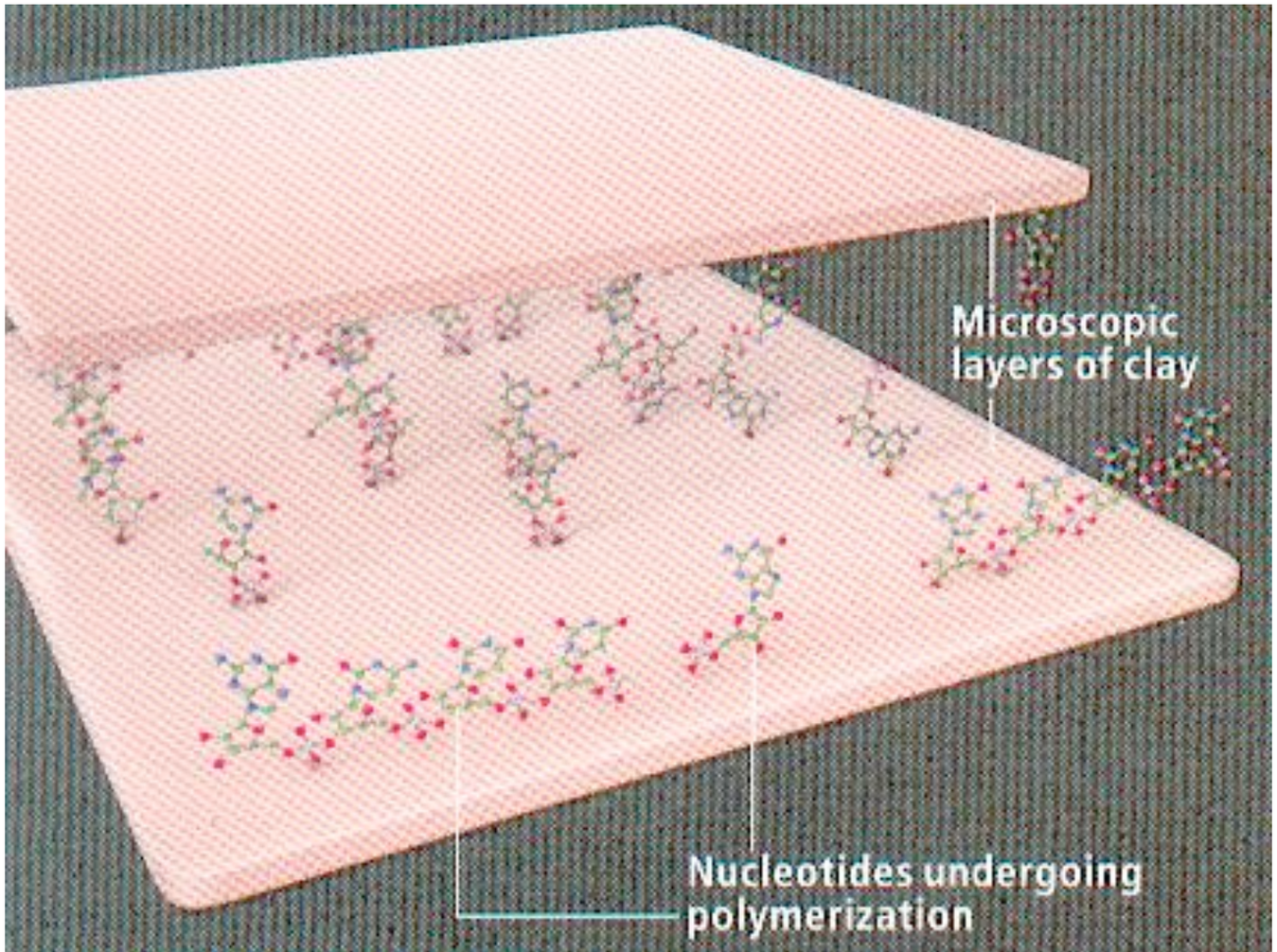
The Synthesis of Self-Replicating RNA

- RNA self replicates, vesicles grow and split (reproduce) passing on some the self replicating RNA
- Protocells would have limited amounts of genetic instructions, traits and metabolism.
- Those that best able to exploit resources would have been selected for
- RNA could serve as a template for DNA synthesis
- DNA may have been selected for because its double stranded structure is far more stable.

The Synthesis of Protocells



THE GLOWING, GROWING HORDES: RNA, with red fluorescent dye adsorbs to the surface of a montmorillonite clay particle encapsulated by a fatty acid vesicle labeled with green fluorescence. This structure forms through a process of self organization mediated by the clay, and illustrates a possible pathway by which the precursors of the first living cells could have formed.



RNA BREEDING GROUNDS

In the water solutions in which they formed, nucleotides would have had little chance of combining into long strands able to store genetic information. But under the right conditions—for example, if molecular adhesion forces brought them close together between microscopic layers of clay (*above*)—nucleotides might link up into single strands similar to modern RNA.

Essential knowledge 1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.

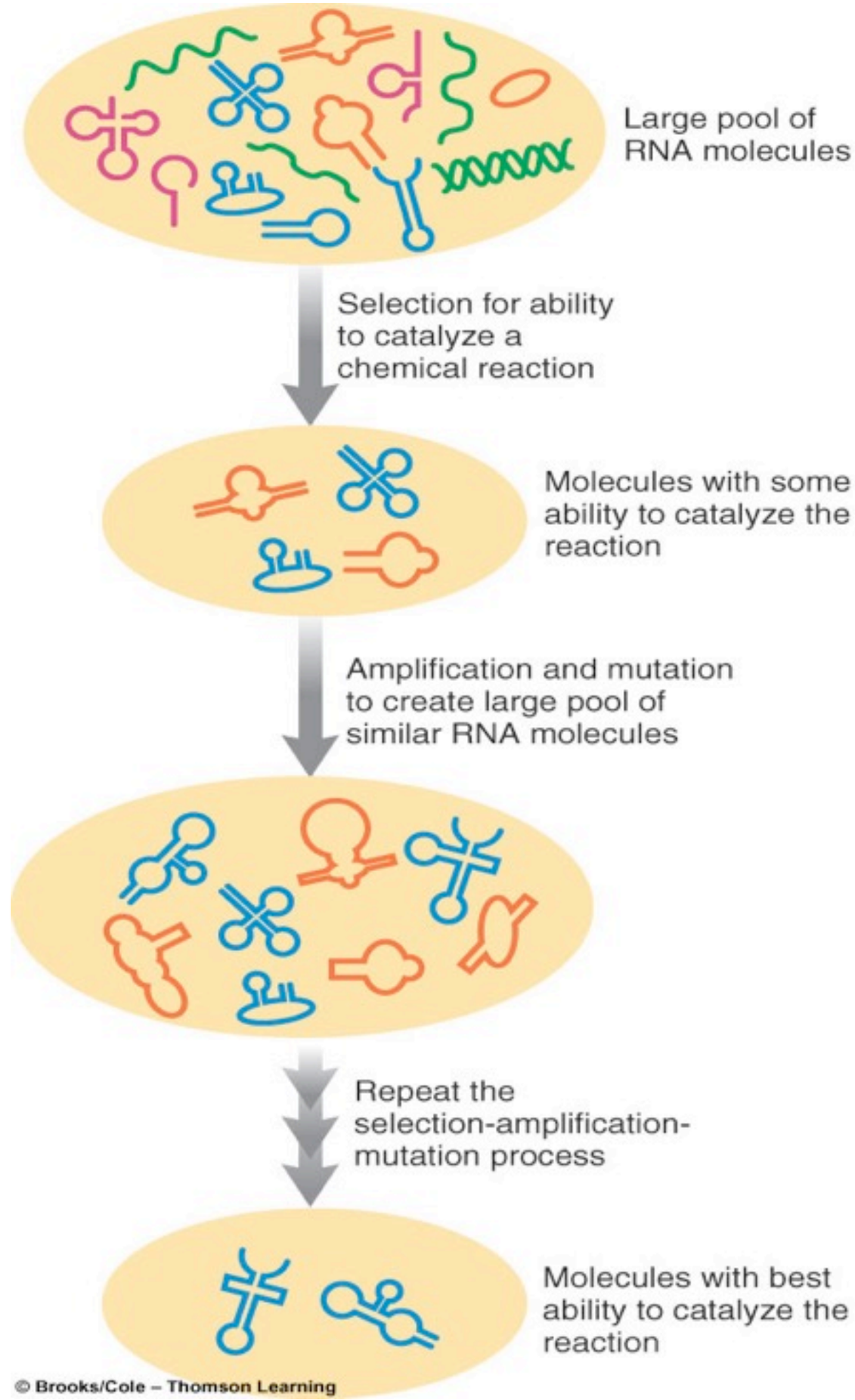
a. Scientific evidence supports the various models.

Evidence of student learning is a demonstrated understanding of each of the following:

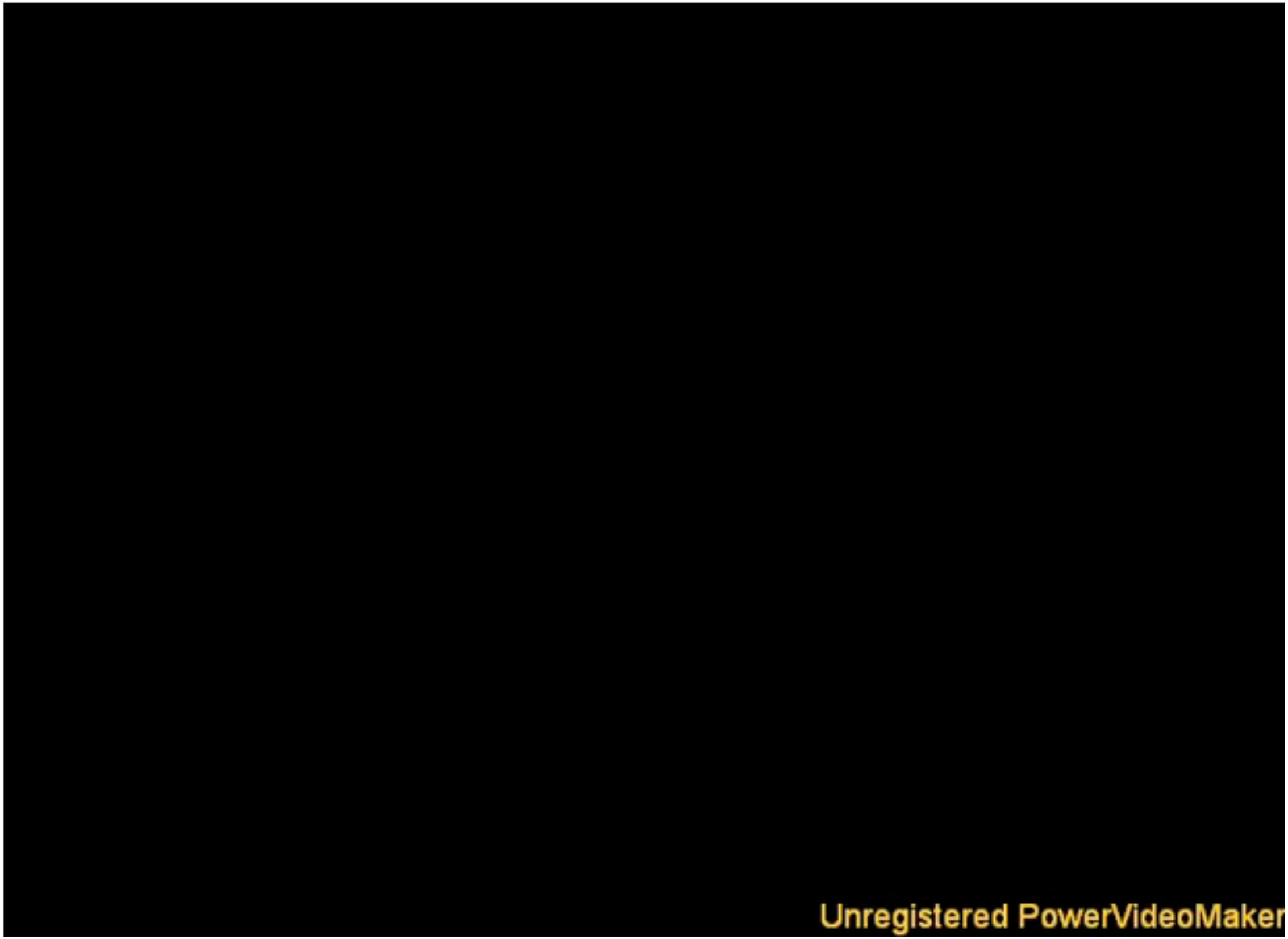
5. The RNA World hypothesis proposes that RNA could have been the earliest genetic material.

The Evolution of RNA Molecules

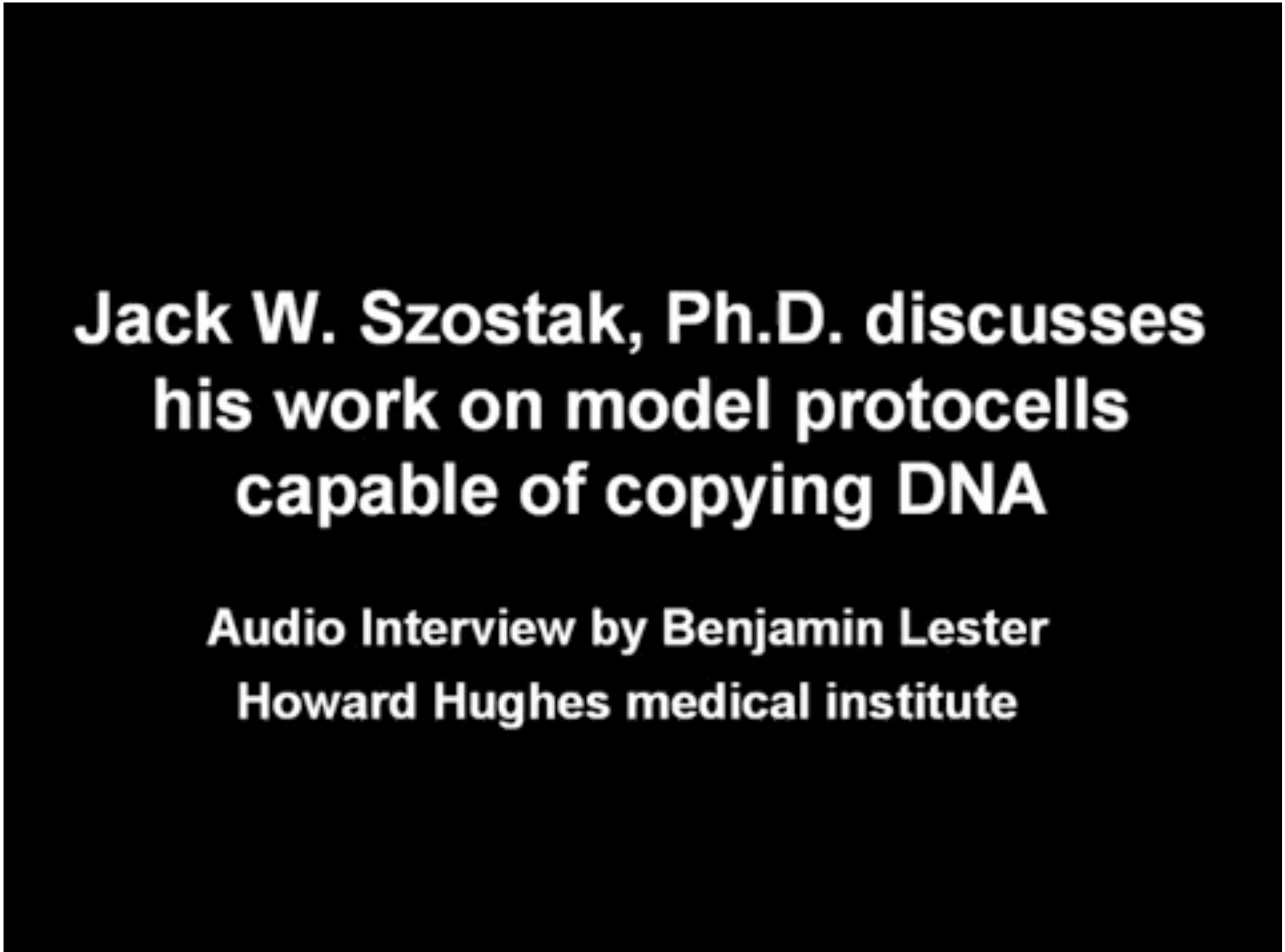
- *some RNA's would be more stable and replicate faster than others and would be therefore more fit*



Origin of Life Summary



Origin of Life Interview



Learning Objectives

LO 1.27 The student is able to describe a scientific hypothesis about the origin of life on Earth. [See **SP 1.2**]

LO 1.28 The student is able to evaluate scientific questions based on hypotheses about the origin of life on Earth. [See **SP 3.3**]

LO 1.29 The student is able to describe the reasons for revisions of scientific hypotheses of the origin of life on Earth. [See **SP 6.3**]

LO 1.30 The student is able to evaluate scientific hypotheses about the origin of life on Earth. [See **SP 6.5**]

LO 1.31 The student is able to evaluate the accuracy and legitimacy of data to answer scientific questions about the origin of life on Earth. [See **SP 4.4**]