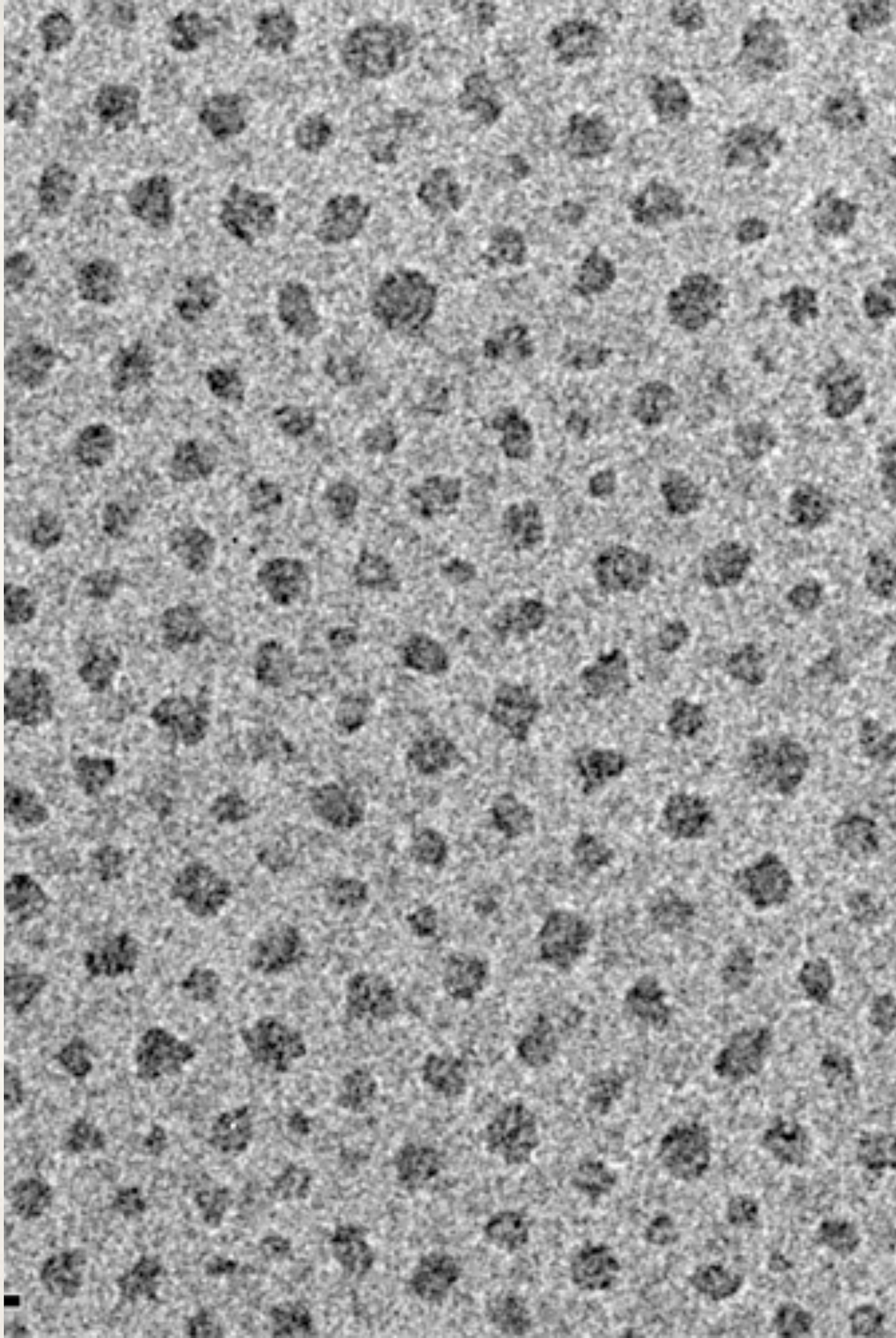
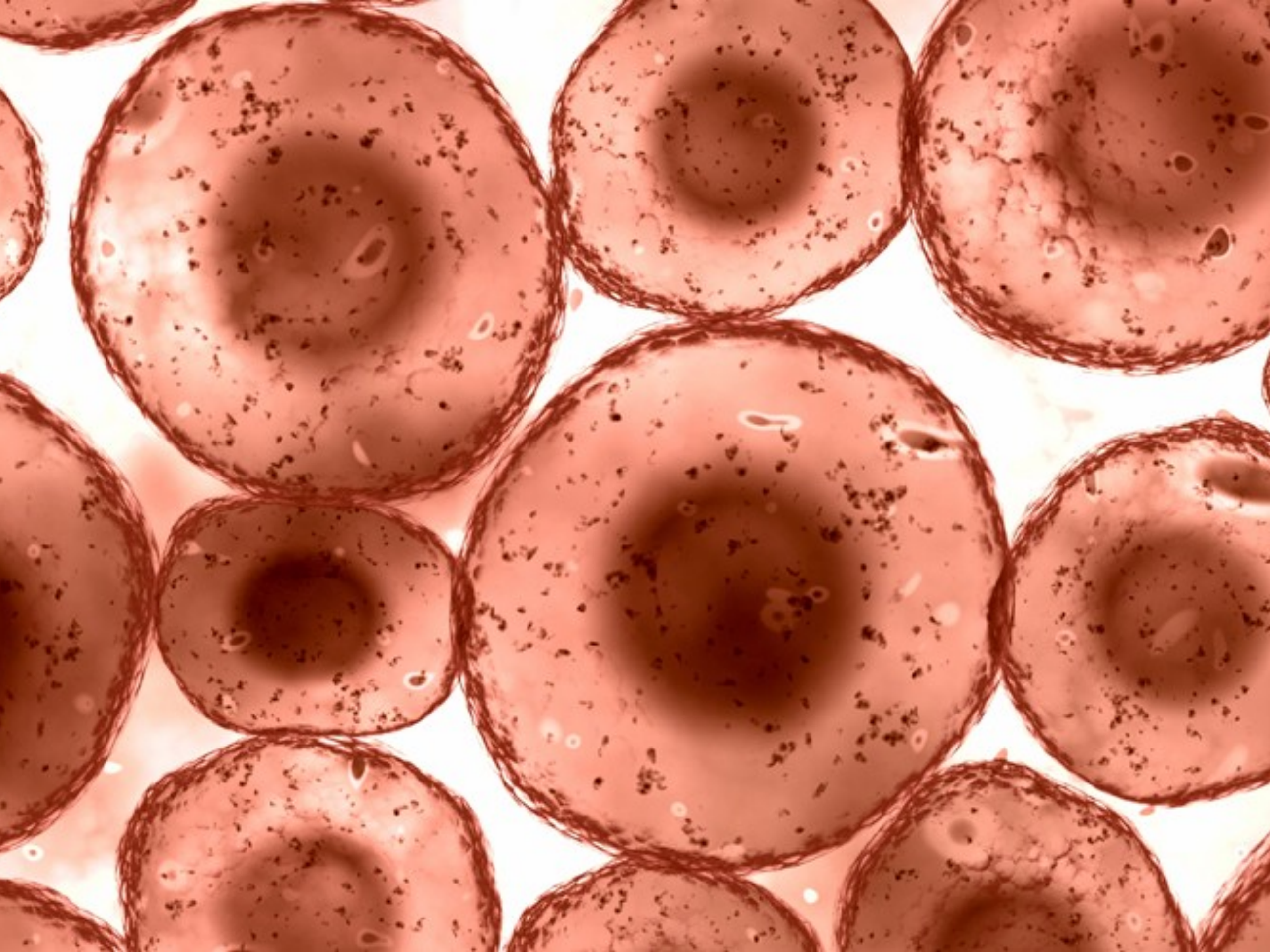
Origin of Life

Carolina Investigations for AP Biology



Satellites



Overview

In the guided activity, you will follow a procedure to create coacervates, phospholipid vesicles similar to those created in the laboratory by Alexander Oparin in the 1920s as he investigated the origin of life. In the inquiry activity, you will explore the life-like properties of coacervates through an experimental question of your own design.

Objectives

Students will

- learn about current scientific models to explain the origin of life.
- combine organic molecules under specific environmental conditions to create phospholipid vesicles.
- explore the life-like properties of coacervates.
- perform experiments with coacervates that model Oparin's experiments into the origin of life.

Big Idea #1
The process of evolution drives the diversity of life.

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

- Essential knowledge 1.D.2: Scientific evidence from many different disciplines supports models of the origin of life.

Background Knowledge

- organic molecules, including monomers and polymers
- cell membrane structure and selective permeability
- the defining characteristics of living organisms
- calculations for magnification and field of view
- calculations involving pH and concentration of ions
- the differences between evolution and the origin of life

Life on Earth

- Scientific research suggests that Earth is approximately 5 billion years old.

- Biological evidence supports that the first prokaryotes arose between 4 and 3.5 billion years ago as Earth's crust cooled.

- The earliest evidence of life, dating to 3.5 billion years ago, is fossilized bacterial colonies called stromatolites.

- Eukaryotic organisms do not appear in the fossil record until 1.5 billion years ago.

Origin of Life in the Laboratory

- Although some biologists claim to have achieved it, or at least to be close to achieving it, the origin of life has not yet been duplicated in the laboratory.

- Several models describe key steps in the formation of life.

- The most famous of the models derive from the experiments of Oparin and Haldane, Miller and Urey, and Sidney Fox.

The Oparin-Haldane Hypothesis

- Alexander Oparin and J.B.S. Haldane predicted that the first life forms originated in an acidic primordial sea.

- Oparin predicted that organic molecules became increasingly complex, eventually forming coacervates in an aquatic environment.

- Oparin created coacervates by mixing different solutions of organic molecules under specific conditions.

- We will mix a solution of gum arabic and gelatin to form coacervates.

- Gum arabic is made up of carbohydrate. Gelatin is made up of protein.

The Miller-Urey Model

- Stanley Miller and Harold Urey recreated the possible conditions of Earth's early atmosphere and primordial sea.
- Water simulated the primitive sea.
- The water was heated, evaporating into a chamber containing methane, ammonia, and hydrogen.
- The chamber was sparked, simulating lightning.
- The gas was condensed into a murky brown liquid, which was collected.
- This liquid contained organic molecules, including amino acids.
- Miller and Urey concluded that organic monomers were formed through the reactions between water and the gases in the atmosphere, returning to Earth as rain.

Sidney Fox and Proteinoids

- By dripping solutions of organic monomers onto hot mineral substrates, Sidney Fox was able to mimic the condensation of the Miller-Urey model.

- This provided a favorable environment for the formation of organic polymers from the monomers.

- These polymers could then aggregate to form proteinoids, another form of protobiont.

Characteristics of Life

- order and organization
- the ability to reproduce
- the ability to grow and develop
- the ability to uptake energy to utilize and do work
- the ability to respond to external stimuli from the environment
- the ability to regulate an internal environment and maintain homeostasis in a changing external environment
- the ability as a population to evolve through favorable adaptations to the environment
- Living organisms are composed of one or more cells.
- These are characteristics of living things AS WE KNOW THEM. For more information on living things as we don't know them, refer to "The Meaning of Life," by Carl Zimmer.

Guided Activity

Sample Data Table

	Run 1	Run 2	Run 3	Run 4	Run 5
Drops of 0.1 M HCl	0	1	2	3	4
pH	6	5	4	3.5	3
Concentration of hydrogen ions	0.000001 mol/L	0.00001 mol/L	0.001 mol/L	0.000316 mol/L	0.001 mol/L
Solution Observations	clear; very viscous	more cloudy	very cloudy	less cloudy	mostly clear; free-flowing solution
Number of coacervates	0	10	17	10	0

Sample Answers to Analysis Questions

1. magnification of eyepiece X magnification of objective = total magnification

2. Use a metric ruler and position it in the field of view so that a tick mark just touches the far left side of the field of view. Count the number of millimeters that appear across the field of view. Multiply this number by 1000 to convert to micrometers.

3. Coacervates are larger than most prokaryotes, but about the size of the average eukaryotic cell: 10 - 20 micrometers in diameter.

4. The independent variable is pH. The dependent variable is the number of coacervates.

Sample Answers to Analysis Questions

5. Calculating the amount of hydrogen for each pH value measured

pH = -log [H]

$[H] = 10^{-pH}$

At a pH of 6, $[H] = 10^{-6} = 0.000001$ mol/L

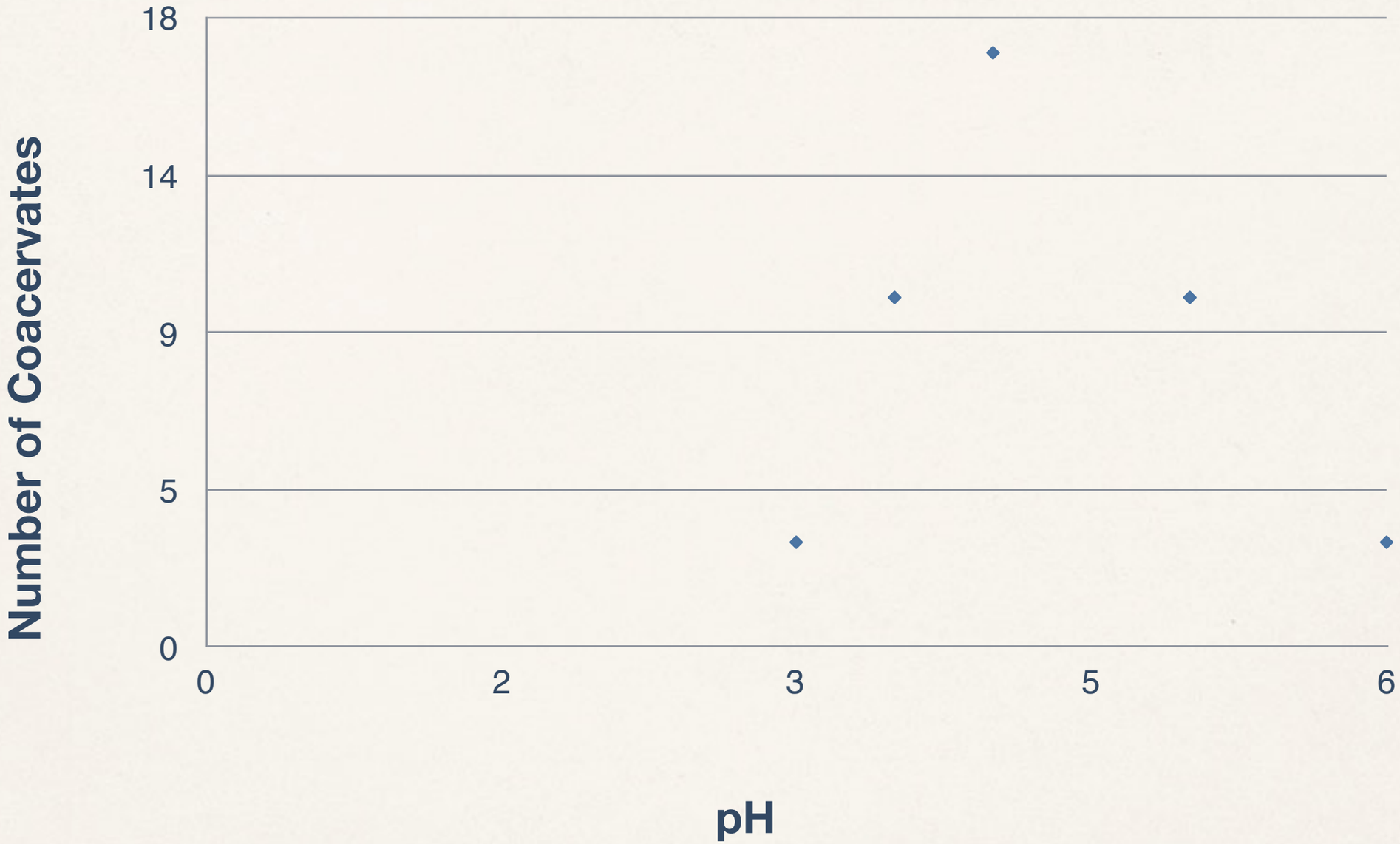
At a pH of 5, $[H] = 10^{-5} = 0.00001$ mol/L

At a pH of 4, $[H] = 10^{-4} = 0.0001$ mol/L

At a pH of 3.5, $[H] = 10^{-3.5} = 0.000316$ mol/L

At a pH of 3, $[H] = 10^{-3} = 0.001$ mol/L

The Number of Coacervates Observed at Varying pH



Laboratory Questions

1. At which pH were the coacervates most abundant?

2. Describe any shared characteristics you observed between coacervates and living organisms.

3. What kind of organic molecule is gelatin? Gum Arabic? What is the function of these types of molecules in unicellular organisms?

4. Why are cells considered a necessary precursor to life?

5. Based on the results of this experiment, why would pH have been important in the origin of life?

Laboratory Questions

1. The coacervates were most abundant in a solution with pH 4.

2. The coacervates have a membrane of organic macromolecules separating their external environment from the internal environment. They appear to move and absorb substances, such as stains.

3. Gelatin is a protein. Gum arabic is a carbohydrate. In cells, proteins are embedded in the cell membrane. These proteins facilitate the movement of molecules into and out of the cell. Proteins also provide structure and support to the cell membranes and cytoskeleton. Carbohydrates provide energy for living organisms, contribute to cell signaling, and are a component of ATP, RNA, and DNA.

4. Cells consist of a plasma membrane, which separates the interior of a living organism from the external environment, which is constantly changing. A cell membrane contains and protects all of the organelles that perform essential life processes, from replication, transcription, and production of proteins to digestion, photosynthesis, and cellular respiration. The unit of the cell (via the membrane) enables a living being to possess an internal environment with the specific conditions that allow thee processes to take place.

5. The results of this experiment suggest that a specific acidic pH is conducive to the aggregation of organic molecules to form primitive cell membranes.

Inquiry Possibilities

Can you create coacervates by adding a base, instead of an acid, to the gelatin and gum arabic solution?

Substitute 0.1M sodium hydroxide for hydrochloric acid.

What other solutions will yield coacervates?

Substitute mixtures -- e.g., alcohol or dilute sodium sulfate added to gelatin solution; gum arabic, sucrose, or alcohol added to egg albumin.

Are coacervates permeable to oil-soluble substances? Water-soluble substances?

Use stains such as Congo red stain or Sudan III stain and observe the stained solution under a microscope.

Is the formation of coacervates affected by temperature?

Cool or heat the coacervate solution, take temperature measurements, and count coacervates.

Is the formation of coacervates affected by salinity?

Add drops of a known concentration of saline solution to the coacervate solution and count coacervates.

Do variations in the concentration of "protein" (gelatin) and "carbohydrate" (gum arabic) affect the number and size of coacervates?

Count and measure coacervates.

Present Your Findings

- PowerPoint or Keynote Presentation
- Poster
- Scientific Report

Big Idea Assessment

1. It is assumed that the origin of living things can be explained by natural processes. Describe the conditions on Earth and the natural processes that are believed to have contributed to the origin of life.

2. There are causal models about the origin of life on Earth. Explain the term “scientific model” and then describe two models about the origin of life on Earth.