Biology

Concepts and Applications | 9e
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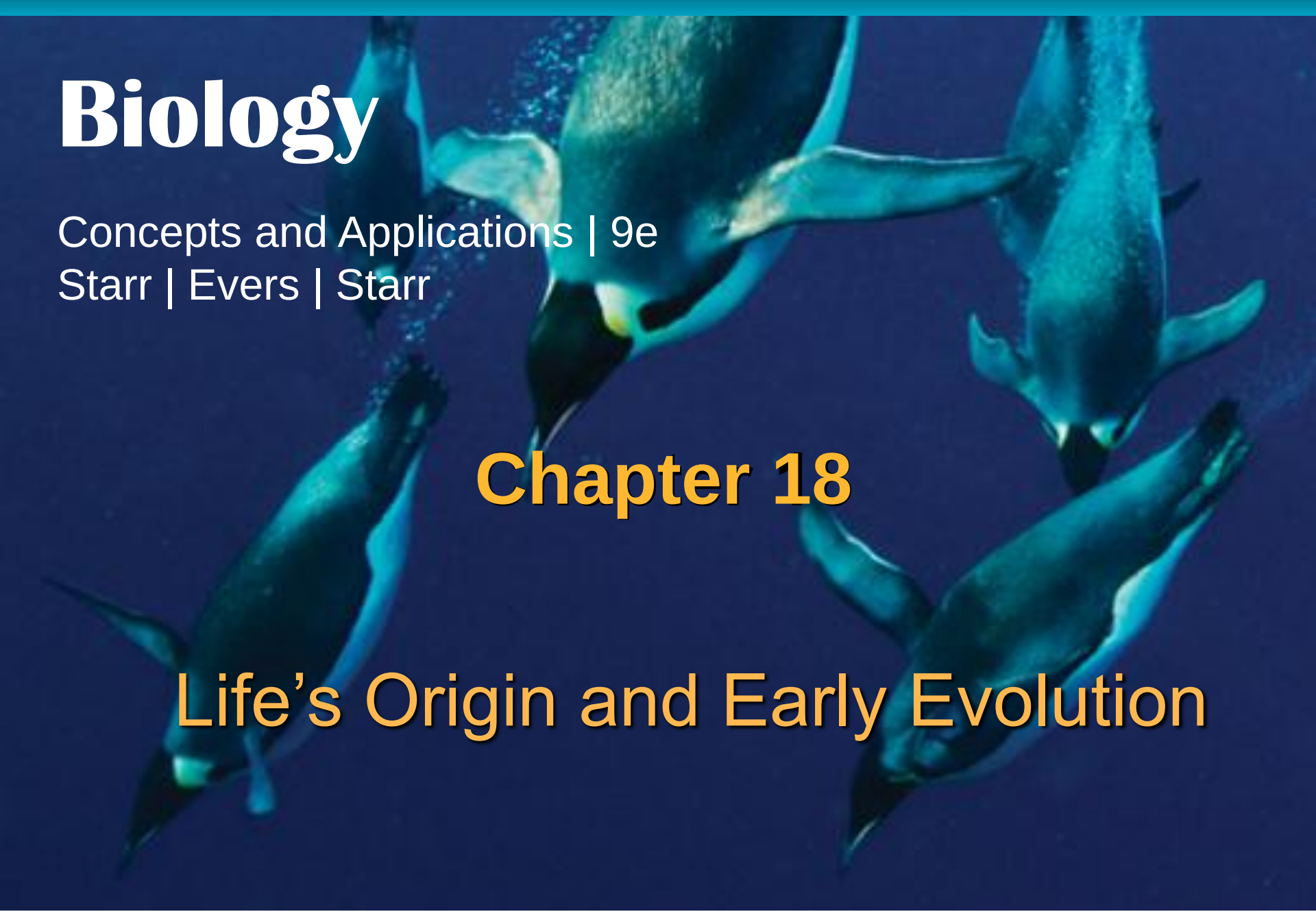

Chapter 18

Life's Origin and Early Evolution

18.1 What Was The Building Material For Earth's First Life?

- Conditions on early Earth
  - Earth formed about 4.6 billion years ago
  - Early atmosphere contained little or no oxygen
  - Presence of water
  - Volcanic eruptions were common
  - Constant hail of meteorites

What Was The Building Material For Earth's First Life? (cont'd.)

- Formation of simple organic compounds
  - All life consists of:
    - Amino acids
    - Fatty acids
    - Nucleotides
    - Simple sugars

What Was The Building Material For Earth's First Life? (cont'd.)

- Where did the subunits of the first life come from?
- There are several possibilities:
  - Lightning-fueled atmospheric reactions
  - Reactions at deep-sea hydrothermal vents
  - Meteorites from space

What Was The Building Material For Earth's First Life? (cont'd.)

- Miller-Urey experiment
  - 1953, Stanley Miller and Harold Urey showed that reactions in Earth's early atmosphere could have produced building blocks for the first life
  - Indirect evidence that organic compounds self-assemble spontaneously under conditions like those in Earth's early atmosphere

Animation: Miller's reaction chamber experiment

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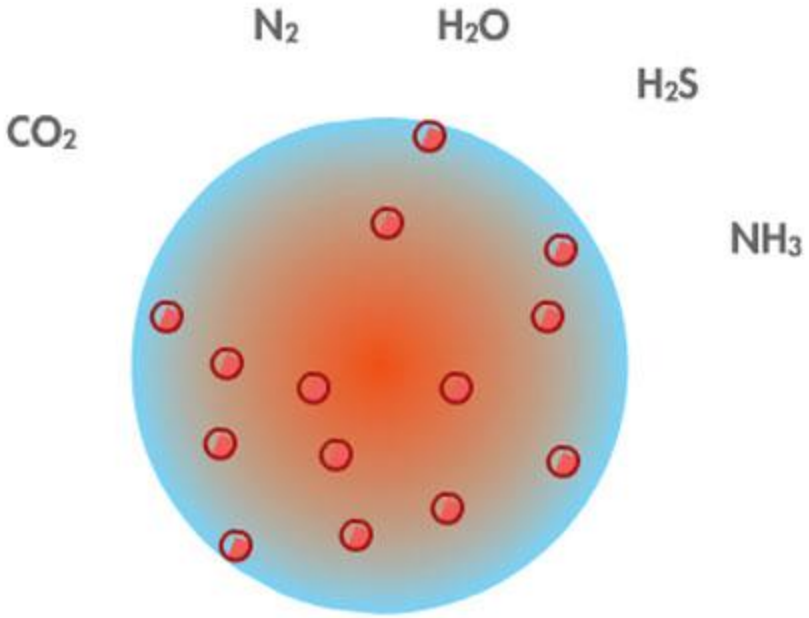
What Was The Building Material For Earth's First Life? (cont'd.)

- Hydrothermal vents
  - Deep underwater openings in ocean where mineral-rich water heated by geothermal energy streams out
    - Reactions in the hot, mineral-rich water near deep-sea hydrothermal vents also produce organic building blocks
    - Simulated experiments combining hot water with carbon monoxide (CO), potassium cyanide (KCN), and metal ions formed amino acids

18.2 What Steps Led to the Formation of the First Cells?

- Similarities in structure, metabolism, and replication among all life indicate descent from a common cellular ancestor
  - Experiments demonstrate how traits and processes seen in all living cells could have begun with physical and chemical reactions among non-living collections of molecules

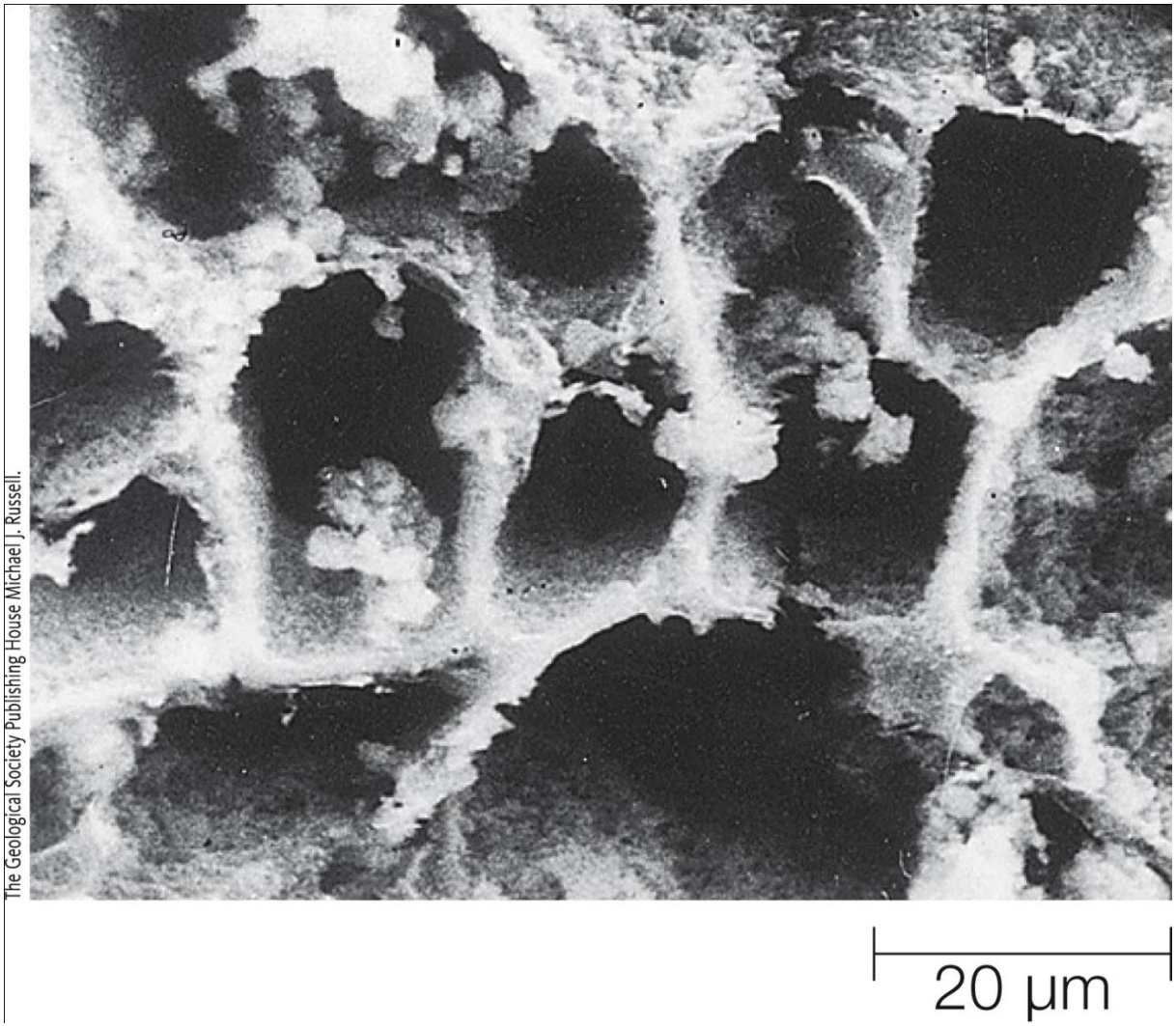
ANIMATION: Building blocks of life



What Steps Led to the Formation of the First Cells? (cont'd.)

- Origin of metabolism
  - Proteins that speed metabolic reactions might have first formed when amino acids stuck to clay, then bonded under the heat of the sun
  - Metabolism may have begun in rocks near deep-sea hydrothermal vents when iron sulfide in the rocks donated electrons to dissolved carbon monoxide

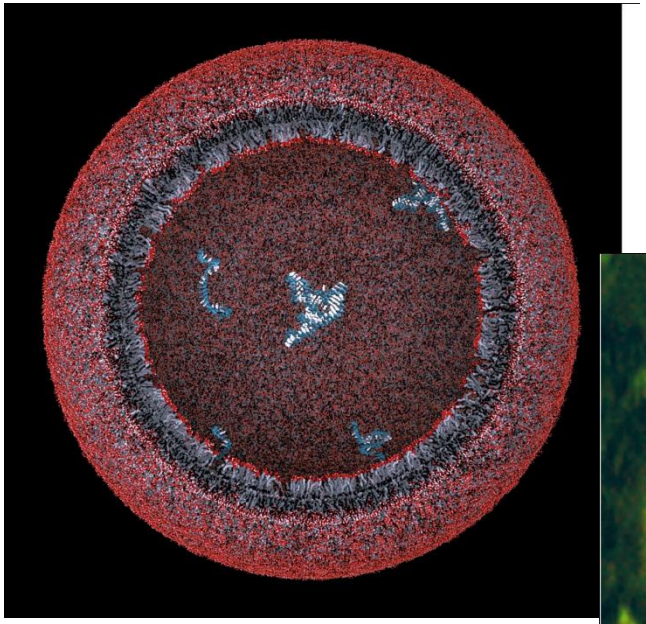
What Steps Led to the Formation of the First Cells? (cont'd.)



What Steps Led to the Formation of the First Cells? (cont'd.)

- Protocells
  - May have preceded cells
  - Membrane-like structures and vesicles form when proteins or lipids are mixed with water
  - Membranous sacs that contain interacting organic molecules; hypothesized to have formed prior to the earliest life forms
  - Origin of the cell membrane

What Steps Led to the Formation of the First Cells? (cont'd.)



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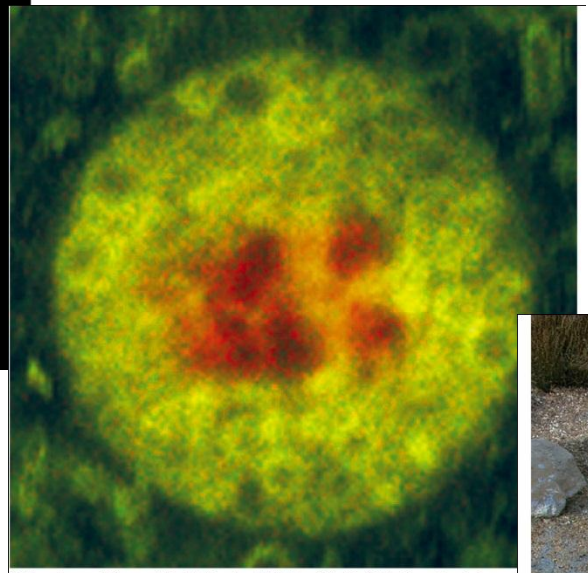

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(4B) From Hanczyc, Fujikawa, and Szostak, "Experimental Models of Primitive Cellular Compartments: Encapsul
and Division"; www.sciencemag.org, *Science* 24 October 2003; 302;529, Fig. 2, p. 619. Reprinted with permissior
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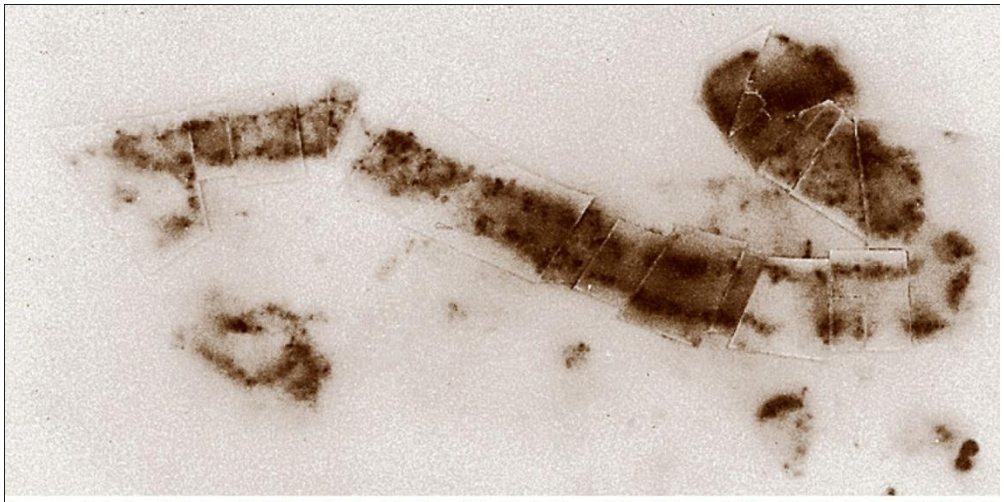
What Steps Led to the Formation of the First Cells? (cont'd.)

- Origin of the genome
  - All modern cells have a genome of DNA
  - Protein synthesis depends on DNA, which is built by proteins
  - How did this cycle begin?
    - An RNA world, a time in which RNA was the genetic material, may have preceded DNA-based systems
    - Ribozymes: RNA functions as an enzyme

18.3 What Do We Know About Early Cells?

- Early divergence separated bacteria from ancestors of archaeans and eukaryotes
  - An oxygen-releasing, noncyclic pathway of photosynthesis evolved in one bacterial lineage, cyanobacteria
  - 2.5 billion years ago, oxygen released by cyanobacteria began to accumulate in Earth's sea and air
  - Cyanobacteria changed Earth's atmosphere

What Do We Know About Early Cells? (cont'd.)



Courtesy of John Fuerst, University of Queensland, originally published in Archives of Microbiology vol 175, p 413–429 (Lindsay MR, Webb RI, Strous M, Jetten MS, Butler MK, Forde RS, Fuerst JA, Cell compartmentalisation in planctomycetes: novel types of structural organization for the bacteria cell, *Arch Microbiol*, 2001 Jun, 175(6): 413–29)

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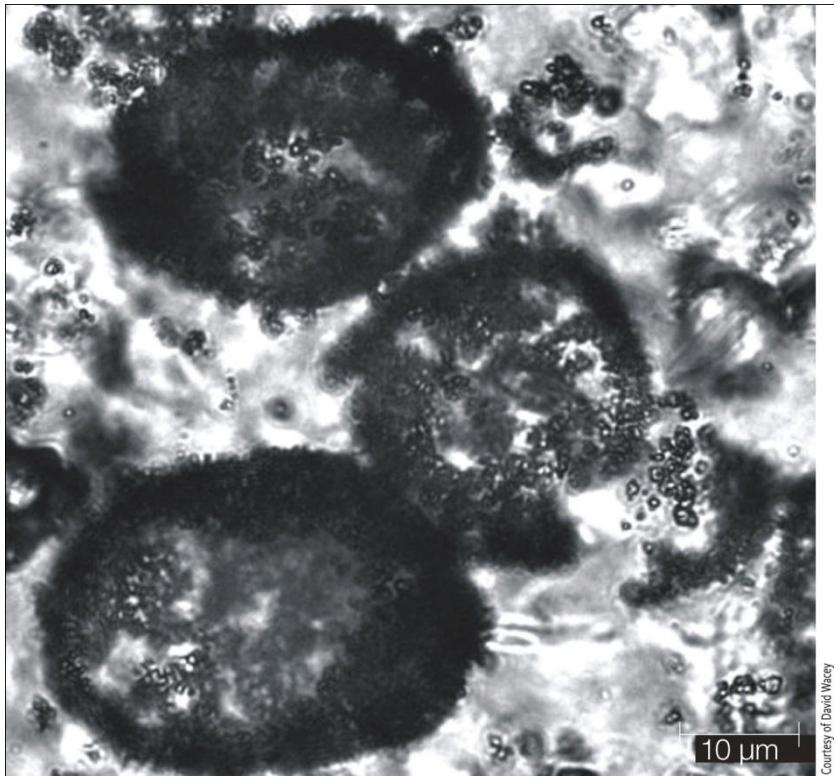

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What Do We Know About Early Cells? (cont'd.)

- Stromatolite
  - Dome-shaped structures composed of layers of bacterial cells and sediments
  - Each layer formed when a mat of living cells trapped sediments
  - Descendant cells grew over the sediment layer, then trapped more sediment, forming the next layer

What Do We Know About Early Cells? (cont'd.)

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18.4 How Did Increasing Oxygen Affect Early Life?

- Evidence of early eukaryotes
  - Biomarker
    - Molecule produced only by a specific type of cell
    - A molecular signature
  - Oldest widely accepted eukaryote microfossils date to about 1.8 billion years ago

How Did Increasing Oxygen Affect Early Life? (cont'd.)

- Effects of increasing oxygen
  - Interferes with self-assembly of complex organic compounds
  - Prevented evolution of new life from non-living molecules
  - Presence of oxygen gave organisms that thrived in aerobic conditions an advantage
  - Formation of an ozone layer in the upper atmosphere protected Earth's surface from high levels of solar ultraviolet (UV) radiation

18.5 How Did Eukaryotic Organelles Arise?

- Scientists study modern cells to test hypotheses about how organelles evolved in the past
  - By one hypothesis, internal membranes typical of eukaryotic cells may have evolved through infoldings of plasma membrane of prokaryotic ancestors
  - Existence of some bacteria with internal membranes supports this hypothesis

ANIMATION: Eukaryotic evolution

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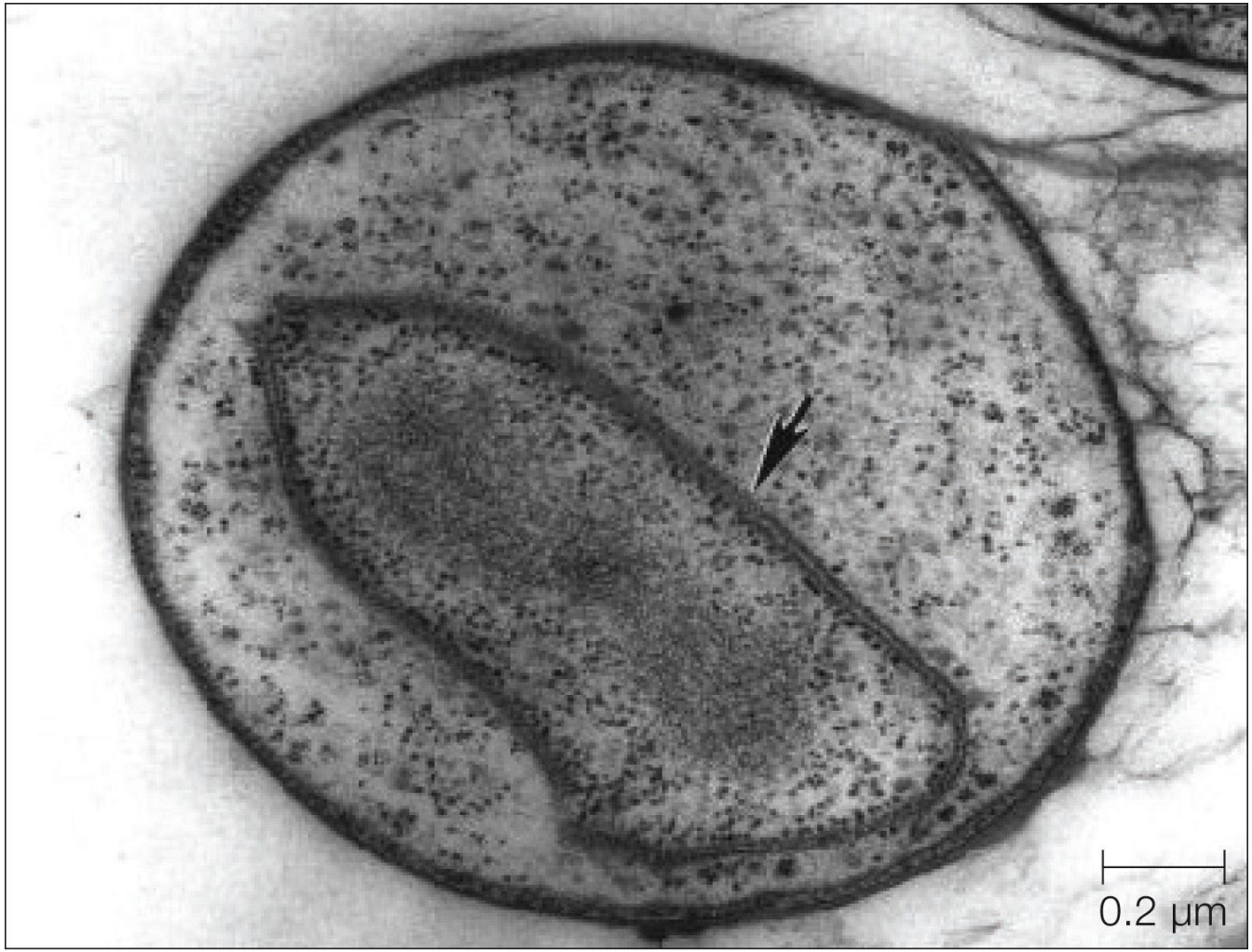
How Did Eukaryotic Organelles Arise? (cont'd.)

- Origin of the nucleus
  - Internal membranes can be advantageous
    - Can increase surface area
    - Hold more enzymes
    - Protect a genome from physical or biological threats

How Did Eukaryotic Organelles Arise? (cont'd.)



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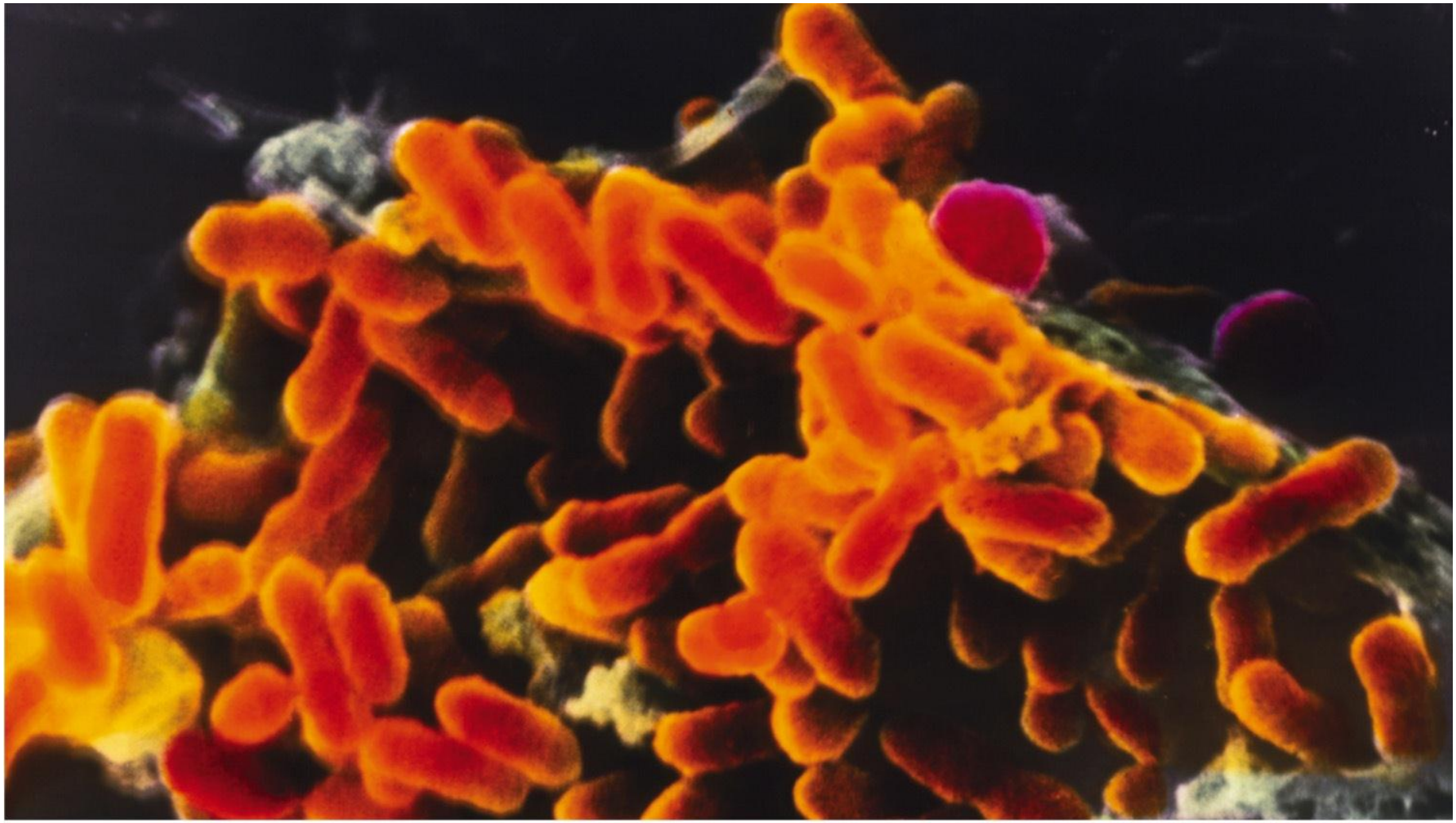
How Did Eukaryotic Organelles Arise? (cont'd.)

- Origin of mitochondria and chloroplasts
  - Endosymbiont hypothesis
    - Mitochondria and chloroplasts resemble bacteria
    - One species lives and reproduces inside another
    - Over generations, host and guest cells come to depend upon one another for essential metabolic processes

How Did Eukaryotic Organelles Arise? (cont'd.)



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How Did Eukaryotic Organelles Arise? (cont'd.)

- Evidence for endosymbiosis
  - *Rickettsia prowazekii*, an aerobic bacterium that infects human cells
    - Like mitochondria, these bacteria take up pyruvate from the cytoplasm and break it down by aerobic respiration
    - Microbiologist Kwang Jeon grew amoebas infected by a rod-shaped bacterium – eventually, the amoebas came to rely on the bacteria for some life-sustaining function

18.6 What Happened During the Precambrian?

- Precambrian
  - Encompasses almost all of Earth's history
  - From 4.6 billion years ago to Cambrian (542 mya)
  - Life arose and diversified
  - By the close of this period, bacteria, archaea, and eukaryotes lived in the sea

ANIMATION: Evolutionary tree of life

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18.7 Life in Extreme Habitats

- Astrobiologists study properties of the ancient Earth that allowed life to arise, survive, and diversify
  - Astrobiology
    - The scientific study of life's origin and distribution in the universe
- Presence of cells in deserts and deep below Earth's surface suggests life may exist in similar settings on other planets

Life in Extreme Habitats (cont'd.)

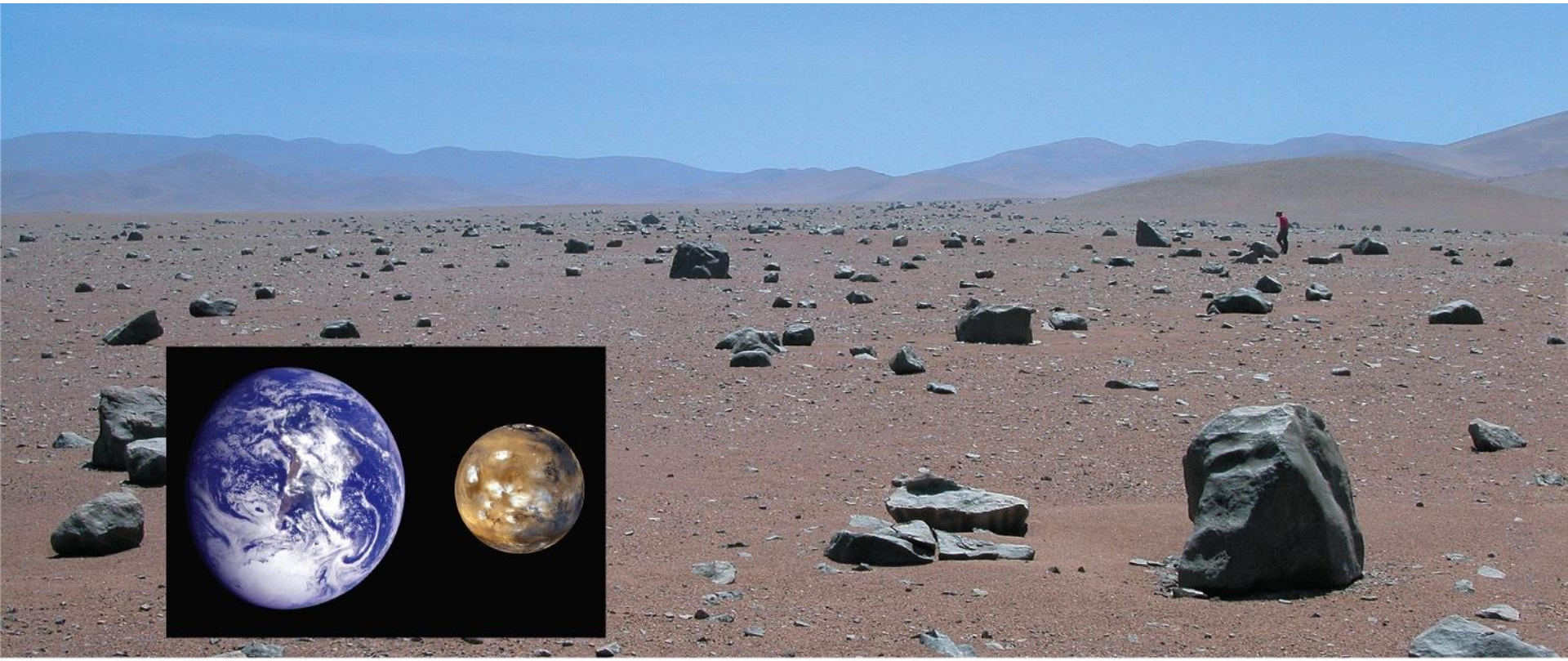

Photo by Julio Betancourt/ U.S. Geological Survey; (Inset) NASA/JPL.