Just a Whole Bunch of Science…
Origin of Life, Bacteria, Viruses

Origin of Life

- no one knows for sure where the first organisms came from
- there are three possibilities for the origin of life
  - **extraterrestrial origin**
  - **special creation**
  - **evolution**
- only the evolutionary origin provides a testable, scientific explanation
- the earth's environment when life originated 2.5 billion years ago was very different than today
  - there was little or no oxygen in the atmosphere
  - the atmosphere was full of hydrogen-rich gases, such as SH_2, NH_3, and CH_4
  - high energy electrons would have been freely created by added energy from photons or electrical energy in lightning

Origin of Life Experiment

- Stanley Miller and Harold Urey recreated an oxygen-free atmosphere similar to the early earth in a laboratory
  - when subjected to levels of lightning and UV radiation, many organic building blocks formed spontaneously
  - the researchers concluded that life may have evolved in a "primordial soup"
  - critics of this idea have pointed out that without an ozone layer (present only in an oxygen-rich atmosphere), UV radiation would have broken down the ammonia and methane in the atmosphere
    - these gases contain precursors needed to make amino acids
- the **bubble model** of Louis Lerman suggests that the problems with the primordial soup model disappear if the model is "stirred up"
  - the chemical processes generating the organic building blocks took place within bubbles on the ocean surface, not within the soup
  - bubbles produced by volcanic eruptions under the sea provide various gases and served as crucibles for these reactions
  - the bubble surface would protect the gases from breakdown by UV radiation
  - the sea foam of bubbles would serve as an interface between the atmosphere and the bubbles

A chemical process involving bubbles may have preceded the origin of life.

How Cells Arose

- RNA was probably the first macromolecule to form
  - when combined with high energy phosphate groups, RNA nucleotides form polynucleotide chains
  - when folded up, these RNA macromolecules could have been capable of catalyzing the formation of the first proteins

- the first cells probably formed spontaneously as aggregates of macromolecules

  - for example, shaking together oil and water produces tiny bubbles called **microspheres**

  - similar microspheres might have represented the first step in the evolution of cellular organization

  - those microspheres better able to incorporate molecules and energy would have tended to persist longer than others

- because RNA molecules can behave as enzymes, catalyzing there own assembling, perhaps they can act in heredity as well?

- the scientific vision of the origin of life is at best a hazy outline

A clock of biological time.

The Simplest Organisms

- prokaryotes have been plentiful on earth for over 2.5 billion years
- prokaryotes today are the simplest and most abundant form of life on earth
- prokaryotes occupy an important place in the web of life on earth
  - they play a key role in cycling minerals within the earth's ecosystems
  - photosynthetic bacteria were largely responsible for introducing oxygen into the earth's atmosphere
  - bacteria are responsible for some of the most deadly animal and plant diseases, including many human diseases

- prokaryotes are small and simply organized
  - they are single-celled and lack a nucleus
  - their single circle of DNA is not confined by a nuclear membrane
  - both bacteria and archaea are prokaryotes

- the plasma membrane of bacteria is encased within a cell wall of **peptidoglycan**
  - in some bacteria, the peptidoglycan layer is thin and covered over by an outer membrane of lipopolysaccharide

  - bacteria who have this outer layer of lipopolysaccharide are **gram-negative**
  - bacteria who lack this layer are **gram-positive**

The structures of bacterial cell walls.

- outside the cell wall and membrane, many bacteria have a gelatinous layer called a **capsule**
- many kinds of bacteria have long, threadlike outgrowths, called **flagella**, that are used in swimming
- some bacteria also possess shorter outgrowths, called **pili** (singular, **pilus**) that help the cell to attach to surfaces or other cells
- under harsh conditions, some bacteria form thick-walled **endospores** around their DNA and some cytoplasm
  - these endospores are highly resistant to environmental stress and can be dormant for centuries before germinating a new active bacterium
  - for example, *Clostridium botulinum* can persist in cans and bottles that have not been heated to high enough temperature to kill the spores
- prokaryotes reproduce by **binary fission**
  - the cell simply increases in size and divides in two

- some bacteria can exchange genetic information by passing plasmids from one cell to another
  - this process is called **conjugation**
  - a pilus acts as a conjugation bridge between a donor cell and a recipient cell

Bacterial conjugation.

Contact by a pilus.

Comparing Prokaryotes to Eukaryotes

- prokaryotes are far more metabolically diverse than eukaryotes

  - prokaryotes have evolved many more ways than eukaryotes to acquire the carbon atoms and energy necessary for growth and reproduction
  - many are **autotrophs**, organisms that obtain their carbon from inorganic CO_2
  - others are **heterotrophs**, organisms that obtain at least some of their carbon from organic molecules

- **photoautotrophs** use the energy of sunlight to build organic molecules from CO_2
  - cyanobacteria use chlorophyll *a* as a pigment
  - other bacteria use bacteriochlorophyll
- **chemoautotrophs** obtain their energy by oxidizing inorganic substances
  - different types of these prokaryotes use substances including ammonia, sulfur, hydrogen gas, and hydrogen sulfide

- **photoheterotrophs** use sunlight for energy but obtain carbon from organic molecules produced by other organisms
  - purple non-sulfur bacteria are an example
- **chemoheterotrophs** are the most common prokaryote and obtain both carbon atoms and energy from organic molecules
  - these types of prokaryotes include decomposers and most pathogens

Prokaryotes Compared to Eukaryotes

Importance of Prokaryotes

- prokaryotes affect our lives today in many important ways
  - prokaryotes and the environment
  - bacteria and genetic engineering
  - bacteria, disease, and bioterrorism

Using bacteria to clean up oil spills.

Prokaryotic Lifestyles

- many of the archaea that survive today are **methanogens**
  - they use H_2 gas to reduce CO_2 to CH_4
  - they are strict anaerobes and found in swamps and marshes where other microbes have consumed all of the oxygen

- other archaea are extremophiles, which live in unusually harsh environments
  - for example, **thermoacidophiles** favor hot, acidic springs

Thermoacidophiles live in hot springs.

Prokaryotic Lifestyles

- most prokaryotes are members of the Kingdom Bacteria

  - **cyanobacteria** are among the most prominent of the photosynthetic bacteria
    - nitrogen fixation occurs in almost all cyanobacteria within specialized cells called **heterocysts**
  - other forms of bacteria are non-photosynthetic
  - most bacteria are unicellular but some form layers on the surface of a substrate
    - this layer of cells is called a **biofilm**

The cyanobacterium *Anabaena*.

The Structure of Viruses

- viruses do not satisfy all of the criteria for being considered “alive” because they possess only a portion of the properties of living organisms
  - viruses are literally segments of DNA (or sometimes RNA) wrapped in a protein coat
  - they cannot reproduce on their own

- viruses are extremely small, with most detectable only through the use of an electron microscope
  - Wendell Stanley in 1935 discovered the structure of *tobacco mosaic virus* (TMV)
  - most viruses, like TMV, form a protein sheath, or **capsid**, around a nucleic acid core
    - many viruses form a membrane-like envelope around the capsid

The structure of bacterial, plant, and animal viruses.

How Bacteriophages Enter Prokaryotic Cells

- **bacteriophages** are viruses that infect bacteria
  - there is a large diversity among these viruses in terms of shapes and amounts of DNA and proteins
  - when the virus kills the infected host in which it is replicating, this is called a **lytic cycle**
  - at other times the virus integrates itself into the host genome but does not replicate
    - this is called the **lysogenic cycle**
    - while residing in the host in this fashion, the virus is called a **prophage**

A T4 bacteriophage.

- during the integrated portion of the lysogenic cycle, the viral genes are often expressed along with the host genes
  - the expression of the viral genes may have an important effect on the host cell
    - this process is called **lysogenic conversion**
    - the genetic alteration of a cell's genome by the introduction viral DNA is called **transformation**

Lytic and lysogenic cycles of a bacteriophage.

How Animal Viruses Enter Cells

- animal viruses typically enter their host cells by membrane fusion

- a diverse array of viruses occur among animals
  - a typical example of an animal virus is **human immunodeficiency virus (HIV)**
  - HIV infection leads to acquired immunodeficiency syndrome (AIDS)
    - there is a long latency period between HIV infection and developing AIDS

The AIDS virus.

- the HIV infects only certain cells within the human bloodstream
  - **macrophages** are attacked by HIV
    - the normal role of macrophages is to pick up cellular debris
  - HIV recognizes specifically the surface marker on macrophages, called **CD4**
    - protein spikes, called **gp120**, fit precisely to CD4 and allow HIV to attach to the macrophage

- certain cells of the immune system also possess CD4 markers

- these include T lymphocytes, or *T cells* but they are not infected right away
- once the T cells are infected and killed, AIDS commences
- researchers speculate that the presence of a second receptor found on macrophages but not on T cells might be responsible for the infection rate differences
  - this co-receptor protein is called **CCR5**

- once inside the macrophage, the HIV virus sheds its coat and exposes its viral RNA
- reverse transcriptase from the virus makes a viral DNA copy of the RNA
  - the copying is not 100% accurate so many mutations can be incorporated into the DNA copy during each reverse transcription
  - the viral DNA version can then be integrated into the host cell DNA
  - new versions of the virus will be produced and released but this does not harm the host cell

- during the long latency period of HIV infection, the HIV cycles through macrophages and multiplies powerfully
- eventually, by chance, HIV alters the gene for gp120 in a way that causes the protein to change its allegiance with its coreceptor
- the new version of gp120 prefers to bind to a different coreceptor, **CXCR4**, which occurs on the surface of T cells with a CD4 marker
  - when HIV takes over the machinery of these cells and makes new viruses, the T cell dies

- the destruction of T cells, which fight other infections in the body, blocks the body's immune response and leads to the onset of AIDS

How the HIV infection cycle works.

Disease Viruses

- **emerging viruses** are viruses that originate in one organism and pass to another organism
  - for example, influenza is fundamentally a bird virus and smallpox is thought to have passed from cows to humans
  - air travel and world trade in animals make emerging viruses a greater threat today than in the past

Important Human Viral Diseases

- the influenza virus is one of the most lethal viruses in human history
  - different strains of virus vary with respect to the composition of their protein spikes, which can be made of
    - hemagglutinin (H) or neuraminidase (N)
  - tremendous variability in these proteins makes it difficult to develop specific vaccines against a generation of virus
    - different flu vaccines are needed to protect against different subtypes of virus

- new strains of influenza usually originate in the Far East, where influenza hosts are common
  - the most common hosts are ducks, chickens, and pigs
  - these hosts live in close proximity to each other and to humans

How a new strain of bird flu might arise.