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 SH₂, NH₃, and CH₄
  ▪ 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 their 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 CO₂
  ▪ 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 CO₂
  ▪ 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 H₂ gas to reduce CO₂ to CH₄
  - 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.