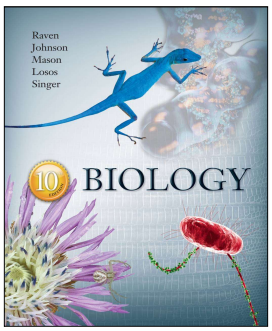


Chapter 01

Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.

The Science of Biology

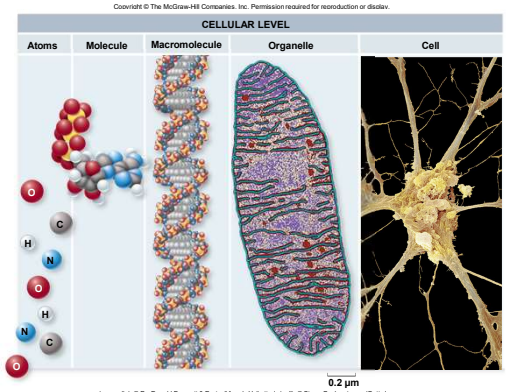
Chapter 1

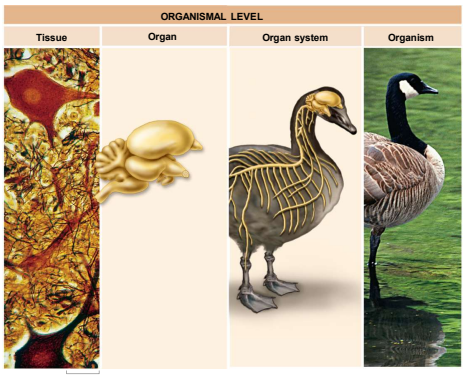
The Science of Life

- Biology unifies much of natural science
- Life defies simple definition
  - Living systems are the most complex chemical systems on Earth
  - Life is constrained by the properties of chemistry and physics
- Science is becoming more interdisciplinary
  - Combining multiple fields

- 7 characteristics of all living organisms
  1. Cellular organization
  2. Ordered complexity
  3. Sensitivity
  4. Growth, development, and reproduction
  5. Energy utilization
  6. Homeostasis
  7. Evolutionary adaptation

- Living systems show hierarchical organization
  - Cellular level
    - Atoms, molecules, organelles, cells
    - Cell is the basic unit of life
  - Organismal level
    - Tissues, organs, organ systems





(tissue): © Ed Reschke; (organism): © Russell Illig/Getty Images RF

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- Populational level
  - Population, community
- Ecosystem level
- Biosphere
  - Earth is an ecosystem we call the biosphere

- Each level has emergent properties
  - Result from interaction of components
  - Cannot be deduced by looking at parts themselves
  - "Life" is an emergent property

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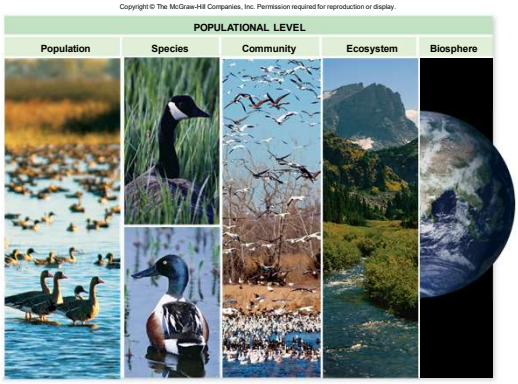

(population): © George Ostertag/agefotostock; (species): © PhotoDisc/Volume 44 RF; (community): © Ryan McGinnis/Alamy; (ecosystem): © Robert and Jean Pollock; (biosphere): NASA

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The Nature of Science

- Science aims to understand the natural world through observation and reasoning
- Science begins with observations, therefore, much of science is purely descriptive
  - Classification of all life on Earth
  - Human genome sequencing

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- Science uses both deductive and inductive reasoning
- Deductive reasoning uses general principles to make specific predictions
- Inductive reasoning uses specific observations to develop general conclusions

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- Scientists use a systematic approach to gain understanding of the natural world
  - Observation
  - Hypothesis formation
  - Prediction
  - Experimentation
  - Conclusion

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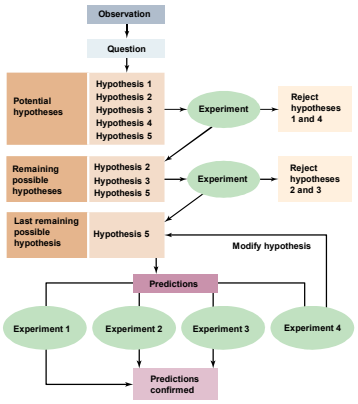
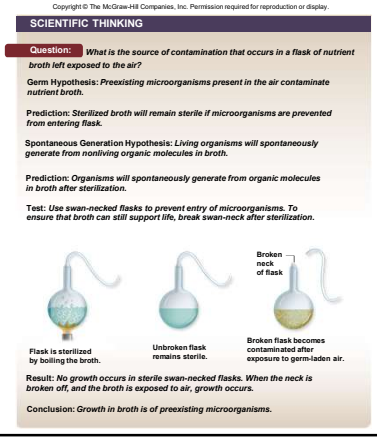


- A hypothesis is a possible explanation for an observation
- A hypothesis
  - Must be tested to determine its validity
  - Is often tested in many different ways
  - Allows for predictions to be made
- Iterative
  - Hypotheses can be changed and refined with new data

- Experiment
  - Tests the hypothesis
  - Must be carefully designed to test only one variable at a time
  - Consists of a test experiment and a control experiment

- Predictions
  - Hypotheses should make predictions
  - Predictions provide a way to test the validity of hypotheses
  - Hypothesis must be rejected if the experiment produces results inconsistent with the predictions
  - The more experimentally supported predictions a hypothesis makes, the more valid the hypothesis



- Philosophical approaches to science
  - Reductionism
    - To break a complex process down to its simpler parts
  - Systems biology
    - Focus on emergent properties that can't be understood by looking at simpler parts

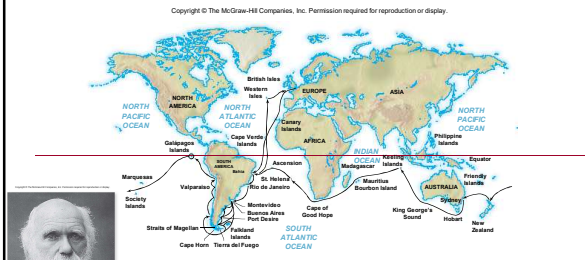
- Models in science
  - Way to organize thought
  - Parts provided by reductionist approach
  - Model shows how they fit together
  - Suggest experiments to test the model

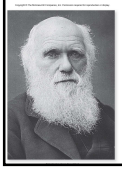
- Scientific theory
  - Is a body of interconnected concepts
  - Is supported by much experimental evidence and scientific reasoning
  - Expresses ideas of which we are most certain
- Compare to general meaning of theory
  - Implies a lack of knowledge or a guess

Darwin and Evolution

- Example of how a scientist develops a hypothesis and a theory gains acceptance
- Charles Darwin served as naturalist on mapping expedition around coastal South America
- 30 years of observation and study before publishing *On the Origin of Species by Means of Natural Selection*

Voyage of the *HMS Beagle*



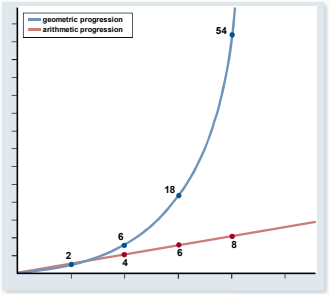


- Darwin was not the first to propose evolution
  - Living things have changed over time
- Darwin's contribution was a mechanism
  - Natural selection

- On the *Beagle*, Darwin saw that characteristics of similar species varied from place to place
- Galápagos Finches
  - 14 related species differ only slightly
  - "Descent with modification" or evolution

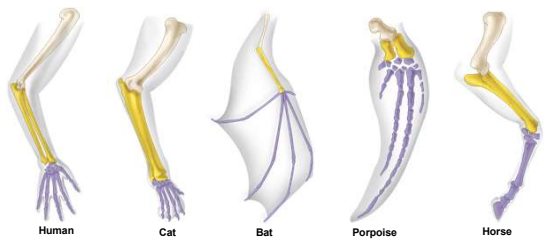
- Darwin studied Thomas Malthus's *An Essay on the Principle of Population*
  - Populations of plants and animals increase geometrically
  - Humans can only increase their food supply arithmetically
  - Populations of species remain constant because death limits population numbers

- Darwin saw that although every organism has the potential to produce more offspring, only a limited number do survive and reproduce themselves

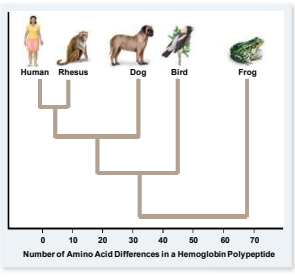


- Evidence supporting Darwin's theory has only grown
  - Fossil record
    - Transitional forms have been found at predicted positions in time
  - Earth's age
    - Physicists of Darwin's time were wrong
    - Earth is very old – 4.5 billion years old

  - Mechanism for heredity
    - Mendel's laws of inheritance were unknown to Darwin
  - Comparative anatomy
    - Vertebrate forelimbs all share the same basic array of bones
    - Homologous – same evolutionary origin but now differ in structure and function
    - Analogous – structures of different origin used for the same purpose (butterfly and bird wings)

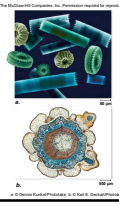


  - Molecular Evidence
    - Compare genomes or proteins of different organisms
    - Phylogenetic trees – based on tracing origin of particular nucleotide changes to reconstruct an evolutionary history



Unifying Themes in Biology

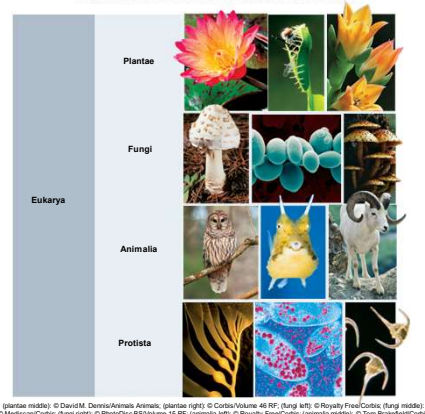
- Cell theory
  - All organisms composed of cells
  - Cells are life's basic units
  - All cells come from preexisting cells



- Molecular basis of inheritance
  - Deoxyribonucleic acid (DNA)
  - Sequence of 4 nucleotides encode cell's information
  - Gene – discrete unit of information
  - Genome – entire set of DNA instructions
  - Continuity of life depends on faithful copying of DNA into daughter cells

- Structure and function
  - Study structure to learn function
  - Know a function – look for that structure in other organisms
  - Example
    - Receptor on human cell for insulin known
    - Find similar molecule in a worm
    - Might conclude this molecule functions the same in the worm

- Diversity of life arises by evolution
  - Underlying unity of biochemistry and genetics argues for life from the same origin event
  - Diversity due to evolutionary change over time
  - 3 domains
    - Bacteria – single-celled prokaryote
    - Archaea – single-celled prokaryote
    - Eukarya – single-celled or multicellular eukaryote



- Evolutionary conservation
  - All organisms today descended from a simple creature 3.5 BYA
  - Some characteristics preserved – use of DNA
  - Conservation reflects that they have a fundamental role

- Cells are information-processing systems
  - Information in DNA used to direct synthesis of cellular components
    - Control of gene expression leads to different cells/ tissue types
  - Cells process environmental information
    - Glucose levels, presence of hormones
  - Cells in multicellular organisms must coordinate with each other

- Nonequilibrium state
  - Living systems are open systems
  - Constant supply of energy needed
  - Self-organizing properties at different levels
  - Emergent properties from collections of molecules, cells, and individuals