Introduction: Themes in the Study of Life

Chapter 1
definitions

**Evolution**

process of change transformed life over 3.5 billion years

**Biology** study of living things

evidence based answers
Characteristics of life
1. Regulation

keep internal conditions relatively constant under changing environmental conditions

Ex. body temperature
2. Energy processing

- Capture
- Use
- Store

Heart rate max 1200 b/m
3. Growth and Development
4. Reproduction
Produce next generation

• Strategies

FYI
• Female birds, rabbits, reptiles can store sperm for months
• Tilapia (fish) brood eggs in the mouth
• Reef fish can switch sex in minutes
• Kangaroo raise young in a ventral pouch
• Leopard slug
5. Response to environment

stimulus $\rightarrow$ response
6. Evolutionary adaptation

- Evolve over many generations
- Hereditable traits

Cuttlefish – capture energy, regulation, reproduction, adaptation
7. Order

Arrangement of structures

Function

Find the properties of life in this video

Regulation, energy processing, growth and development, reproduction, response, adaptation, order
Life studied at different organizational levels
molecules → living planet

power of ten
Enhanced scale of universe
Biosphere - all environments on Earth that support life

What are these environments?
Ecosystem - living things in an area + nonliving

Ex. forest, ocean
Communities - all living species in an ecosystem
Population - all individuals of a species in a specific area
Organism - individual

Amoeba has properties of life
**Organ system** - organs that cooperate for specific function

**Organ** - multiple tissue types to function

Organ = leaf
Organ system = shoot system

Organ = heart
Organ system = ?
Tissues – group of cells that work together

Dermal tissue

Myocardial tissue
• **Cell** – basic unit of life
  – Organisms unicellular or multicellular

• **Organelles** – functional components of a cell
Molecules – consist of two or more atoms

Atom– smallest unit of matter that retains the properties of an element

\[ \text{H}_2\text{O} \quad \text{NaCl} \quad \text{C}_6\text{H}_{12}\text{O}_6 \]

Chlorophyll
\[ \text{C}_{55}\text{H}_{72}\text{O}_{5}\text{N}_4\text{Mg} \]
Theme: Emergent properties

• Arrangement and interaction of parts in complex organisms lead to complex properties

Example: A heart cell cannot perform all the functions of a heart, but collectively, they pump blood
Reductionism

• Study parts of system
Systems Biology
study of system
ex. a leaf, a brain

• Ex:
  – How does drug for blood pressure affect other organs?
  – How does increase in CO2 affect life on earth?
Interaction of proteins in a eukaryotic cell
Themes: Organisms interact with environments, exchanging matter, energy

Ex: tree

water from soil → roots help form soil
Ecosystem Dynamics

– Cycling of nutrients
  • materials used by plants/animals return to the soil via decomposition
  • Rabbit decomposition

– Flow of energy
  • sunlight $\rightarrow$ producers $\rightarrow$ consumers $\rightarrow$ decomposers
ECOSYSTEM DYNAMICS

Cycling of nutrients

and

Energy flow

Producers (plants and other photosynthetic organisms)

Chemical energy

Consumers (such as animals)
Energy Conversion

- Energy in different forms
  - light, chemical, kinetic, thermal

Light $\rightarrow$ sugar $\rightarrow$ ATP $\rightarrow$ motion $\rightarrow$ heat
•  http://session.masteringbiology.com/myct
•  Activity: Energy Flow and Chemical Cycling
• **Theme: Structure and function correlated**
  
  – leaf thin and flat, max capture of light
  – birds wings aerodynamic
Theme: Cells are basic unit of life

• Lowest level of organization that can perform all life activities

• Cells:
  – Cell membrane
  – DNA genetic information
  – Replicate
Two types of cells

Eukaryotic cell
- Membrane-enclosed organelles, and nucleus
- Plantae, Animalia, Fungi, Protista

Prokaryotic cell
- Simpler, smaller
- No nucleus or organelles
- Bacteria, Archaea
• Theme: The continuity of life is based on heritable information (DNA)

• Chromosomes
  – Strands of DNA (deoxyribonucleic acid)
  – Contain genes

• Genes
  – units of DNA that encode proteins
  – Proteins determine traits
• DNA double helix of nucleotide building blocks

• **Genome** = all the DNA in a cell (has all instructions)
DNA is inherited
Before a cell divides, DNA is copied
The human genome and others have been sequenced

<table>
<thead>
<tr>
<th>Species</th>
<th>Chromosomes</th>
<th>Genes</th>
<th>Base pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human (Homo sapiens)</td>
<td>46 (23 pairs)</td>
<td>28-35,000</td>
<td>3.1 billion</td>
</tr>
<tr>
<td>Mouse (Mus musculus)</td>
<td>40</td>
<td>22.5-30,000</td>
<td>2.7 billion</td>
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<tr>
<td>Puffer fish (Fugu rubripes)</td>
<td>44</td>
<td>31,000</td>
<td>365 million</td>
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<tr>
<td>Malaria mosquito (Anopheles gambiae)</td>
<td>6</td>
<td>14,000</td>
<td>289 million</td>
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<tr>
<td>Fruit fly (Drosophila melanogaster)</td>
<td>8</td>
<td>14,000</td>
<td>137 million</td>
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<tr>
<td>Roundworm (C. elegans)</td>
<td>12</td>
<td>19,000</td>
<td>97 million</td>
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<tr>
<td>Bacterium * (E. coli)</td>
<td>1</td>
<td>5,000</td>
<td>4.1 million</td>
</tr>
</tbody>
</table>

*Bacterial chromosomes are chromonemes, not true chromosomes

Theme: Feedback mechanisms

• Allow body to self-regulate

• Negative feedback
  – as more of product accumulates, the process that creates it slows and less product produced
Describe how the sweating response is negative feedback.
• **Positive feedback**
  
  – As more of product accumulates, the process that creates it *speeds up* and *more* product produced
Positive feedback: uterine contractions

1. Head of fetus pushes against cervix
2. Nerve impulses from cervix transmitted to brain
3. Brain stimulates pituitary gland to secrete oxytocin
4. Oxytocin carried in bloodstream to uterus
5. Oxytocin stimulates uterine contractions and pushes fetus toward cervix
Core Theme: Evolution

“Nothing in biology makes sense except in the light of evolution” — Theodosius Dobzhansky

All organisms living on Earth are descendants of common ancestors

– Shared features
  • Ex. Backbone in vertebrates, cells, DNA

– Divergent features
  • Ex. Number of toes in foot, cell wall
Diversity of Life

• Evolution unifies biology
• ~1.8 million extant species have been identified and named to date (could be >10 million)

6,300 bacteria
10,000 fungi
290,000 plants
52,000 vertebrates
1 million insects
Grouping Species

• Taxonomy
  – name and classify species into groups
Ursus americanus

Ursus

Ursidae

Carnivora

Mammalia

Chordata

Animalia

Eukarya

Species
Genus
Family
Order
Class
Phylum
Kingdom
Domain
Three Domains of Life

- Domain **Bacteria** and Domain **Archaea** - prokaryotic cells
- Domain **Eukarya** – Eukaryotic cells

Anthrax  
*T. aquaticus*  
Paramecium
Bacillus anthracis
Methanosarcinia rumen is anaerobic, produces methane, is found in rumen of cows.

Methanobrevibacter smithii lives in the human gut digests polysaccharides.

Staphylothermus is found in 98°C hot spring, thrives on sulfur.

Halococcus salphodinae lives in high salt.

http://www.microbiologyonline.org.uk
Eukarya includes kingdoms:
Plantae
Fungi
Animalia
Protista
Unity in Diversity

Examples:

DNA is the universal genetic material that connects diverse organisms

All living organisms consist of at least one cell
Cilia of Paramecium

Cross section of a cilium, as viewed with an electron microscope

Cilia of windpipe cells
September 15, 2009 Niger -- Scientists excavate the 43-foot-long (13-meter-long) skeleton of a new species of sauropod--or four-legged plant-eater. *Spinophorosaurus nigerensis*, had a tail studded with bony spikes that the animal likely swung at predators.
• Charles Darwin *On the Origin of Species by Means of Natural Selection* in 1859

• 2 main points:
  – **Descent with modification**
    • Species share a common ancestor
  – **Natural selection mechanism of evolution**
Attenborough video

Which orchids are the most successful?  
What traits are selected for?  
What is in the pollen?  
Where is the pollen delivered?  
Which orchids will send their genes to the next generation?  
Think: millions of years of evolution results in adaptive traits in species
• Darwin observed that:
  1. Traits vary randomly
"In October 1838, that is, fifteen months after I had begun my systematic inquiry, I happened to read for amusement Malthus on Population, and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The results of this would be the formation of a new species. Here, then I had at last got a theory by which to work".

Elephants start to breed at around age 30. They breed to 90 years old. In that time, one elephant has 6 offspring. Darwin calculated that after 750 years, there would be 19 million descendants from the original breeding pair IF all survived.
3. Competition
4. Reproductive fitness
5. Traits are heritable
• Darwin inferred that:
  – Because of natural selection, in time, more individuals in a population will have the advantageous traits
  – No acquired traits inherited
1. Population with varied inherited traits.
2. Elimination of individuals with certain traits.
4. Increasing frequency of traits that enhance survival and reproductive success.
• Natural selection results in adaptations

Ex. Bat wings
Examples of adaptations
Descent with modification leads to adaptation
Ex. Mammalian limb
• natural selection
  – ancestral species $\rightarrow$ descendent species
  – Ex. finch species of Galápagos Islands
Evolutionary tree shows ancestral relationships
• Fossils
• Fossils document the evolution of life on Earth over billions of years
THE SCIENTIFIC METHOD

• The word *Science* means “to know”

• **Inquiry**
  – search for information and explanation

• 2 types of scientific inquiry:
  – discovery
    • Describe nature
  – hypothesis-based
    • Design experiments to test a hypothesis
**Hypothesis** - tentative answer to well-framed question, an educated guess

- leads to predictions that can be **tested**
Hypotheses

• must be testable
• test one hypothesis at a time

• Must be falsifiable
• does not need to be correct
• **Independent (experimental) variable**
  • the one aspect that varies among test groups

• **Control group**
  – baseline group for comparison

• **Controlled variables**
  – Held constant, do not vary among groups

• **Dependent variable**
  – What is measured
• failure to falsify hypothesis does not prove hypothesis

The research team tested 3 preparations of the roots of a *Echinacea angustifolia*. They extracted the root using procedures that represent some of the different ways that Echinacea is used to treat colds.

Hypothesis:

Independent variable:

Control group:

What is a *placebo*?
437 healthy adult volunteers were assigned at random to receive one of the three root preparations or a placebo. The volunteers received Echinacea or a placebo in two phases: a preventive phase and a treatment phase. The preventive phase lasted 7 days. On the 7\textsuperscript{th} day, the volunteers were exposed to a nasal spray with a virus that induces a cold in ~ 2 days. Then, volunteers were isolated for 5 days while the research team observed and tested them as to the appearance and severity of cold signs and symptoms.

Dependent variable(s):
The researchers found that none of the 3 preparations of *Echinacea* at the 900 mg per day dose had effects on whether volunteers became infected with the cold virus. The 3 preparations did not affect the severity or duration of symptoms among those who developed colds.

Critics of this study believe the dose of *E. angustifolia* used was too low.
• Hypothesis
  – Zinc helps people recover from colds

Y axis???
Data

- **Qualitative** = descriptions
- **Quantitative** = measurements-organized into tables and graphs

http://thesituationist.files.wordpress.com/2008/02/jane-goodall.jpg
Limitations of Science

• Results must be repeatable
• Science must use natural processes!
Theories in Science

• **Theory**
  – Broader in scope than hypothesis
  – General and can lead to new testable hypotheses
  – Supported by large body of evidence

Theory of gravity
Theory of evolution
Theory of round earth
In a Univ. of Virginia study, 3 drugs, interferon, chlorpheniramine and ibuprofen were investigated for the effects on symptoms of the common cold.

- Chlorpheniramine – antihistamine that blocks cold symptoms
- Ibuprofen (Advil) – anti-inflammatory
- Interferon – antiviral drug

Hypothesis:

What is a double blind study?
The researchers tested the treatment in a **double blind, placebo-controlled** trial in 150 young male and female adults.

A Q-tip containing virus inserted was inserted into the nose. All developed colds.
Treatment with the three drugs or placebo started as soon as the cold developed. The drugs were given orally at 12 hour intervals.

For 5 days, the volunteers scored their symptoms of sneezing, runny nose, sore throat, cough, and headache. The virus concentration in nasal secretions was determined.

**Independent variable**

3 **controlled variables**

Control

**Dependent variable(s)**
results

the average total symptoms of volunteers receiving the actual drugs were reduced by 33 -73 % compared to those on non-active placebo treatment.

Conclusion:

The new treatment is licensed to Coldcure, Inc., in Richmond for development into commercial use.