SGCEP BIOL 1010K
Introduction to Biology I
Spring 2012 Sections
20585 & 20586

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What is: Science, Life, Biology and Evolution? And what these are not!

Biology is the science of life. Evolution is the framework of life. Let’s review what these concepts mean.
Science is . . .

The possession of knowledge, as opposed to ignorance or misunderstanding (Webster’s).

But what do we mean by science? I think it can be summed up by ideas concerning the systematic collection and testing of observable phenomenon in the world about us, and then the synthesis of overarching ideas that try to explain that phenomenon. Science can not be about phenomenon that is not observable (somehow) or testable (somehow) — it can not be religion or philosophy — these are neither observable nor testable, though they are certainly worthy pursuits of their own right.
The scientific method:

A general way of organizing an investigation, and a framework in which to consider ideas and evidence in a repeatable way. It consists of:

1. Observation;
2. Hypothesis;
3. Experimentation and Data Collection; and . . .
4. Analysis and Peer Review.

There is an interplay between all of these steps in a ‘feedback loop’ arrangement.
The scientific method

1. Ask a question
2. Formulate a hypothesis
3. Design a controlled experiment
4. Collect and interpret data
5. Draw conclusions
6. Make observations
7. Peer review
8. Publish
Observation . . .

May be a historical incident or perhaps a complete accident (Fleming’s penicillin).

It may be based on existing knowledge, and may include experimental results.

Scientists may make mental connections among previously unrelated observations.

A great example of this is Charles Darwin — based on his countless observations, he came up with the ideas of natural selection as a prime means of evolution.
What is Hypothesis?

* A hypothesis is a . . .
* Tentative explanation based on previous knowledge.
* It must be testable, and . . .
* Cannot be proven true with 100% certainty.
Experimentation and data collection

- Some investigations are discovery based.
- Some use experiments.
- Some are combinations of both.
- For example: Deciphering a DNA sequence is discovery based, but testing its function is experimental. That is . . .
- Demonstrating what a particular gene does requires experimentation.
Experimental Design

* Sample size (number of data points; more is better);
* Variables and Controls; and . . .
* Statistical Analysis.

<table>
<thead>
<tr>
<th>Table 1.2 Types of Variables in an Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Variable</strong></td>
</tr>
<tr>
<td>Independent variable</td>
</tr>
<tr>
<td>Dependent variable</td>
</tr>
<tr>
<td>Standardized variable</td>
</tr>
</tbody>
</table>
Controls...

* Provide a basis for comparison to the experimental group. For example...
* High, low, or no (control) fertilizer levels.
* Placebo — an inert substance resembling the treatment given to the experimental group. This tests for psychological factors.
* Double-blind design — neither researchers, nor participants, know who received the substance being evaluated until after the data is completely tabulated.
Here's a simple example.

<table>
<thead>
<tr>
<th>Treatments (independent variable)</th>
<th>Sample size = 3 plants per treatment</th>
<th>Average yield of tomatoes per plant (dependent variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1 high fertilizer</td>
<td>Plant 1</td>
<td>20</td>
</tr>
<tr>
<td>Treatment 2 low fertilizer</td>
<td>Plant 2</td>
<td>17</td>
</tr>
<tr>
<td>Treatment 3 no fertilizer (control)</td>
<td>Plant 3</td>
<td>15</td>
</tr>
</tbody>
</table>

All plants received the same amount of sunlight and water.
Statistical analysis

- An investigator must decide whether an independent variable (e.g. fertilizer) affected the dependent variable (e.g. yield) or not. Statistics help with this.

- Less variation in the data means it is more likely that the independent variable is really responsible for the difference.

- Statistical significance is based on sample size and variation — it measures the probability that results arose purely by chance.
Analysis and peer review

* After collecting and analyzing their data, investigators must reevaluate their hypotheses based on results.

* A “Feedback loop” encourages rethinking of the hypotheses.

* And then the scientist may write a journal research article. And in . . .

* Peer review other scientists evaluate the validity of the methods, data, and conclusions before publication.
Then what is a theory?

* The analysis of a set of facts in their relation to one another (Webster’s).

* A theory is an explanation of natural phenomenon that:

  * is broad in scope, encompassing multiple hypotheses;
  
  * is so widely accepted that it has become ‘truth,’ yet it must be “falsifiable;”
  
  * and it must have “predictive” power!
Limitations of scientific inquiry

* The scientific method is neither foolproof, nor all that easy to implement.

* Experimental evidence (results) may lead to multiple interpretations.

* Even the most carefully designed experiment can fail to provide a definitive answer. And . . .

* Researchers may misinterpret observations or experimental results.
Biology uses science to study life. But what is life?

- Obviously rocks aren’t alive, but why?
- The quality that distinguishes a vital and functional being from a dead body (Webster’s).
  
  Huh; that doesn’t help!
- Key features: organization, energy consumption, homeostasis, reproduction, evolution, death. These all make what we call an “organism.”
- So, what about viruses — are they alive?
**Life's Characteristics:**

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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization</td>
<td>Atoms make up molecules, which make up organelles, which occur inside cells, which make up tissues, and so on</td>
</tr>
<tr>
<td>Energy use</td>
<td>A kitten uses the energy from its mother’s milk to fuel its own growth</td>
</tr>
<tr>
<td>Maintenance of internal constancy</td>
<td>Your kidneys regulate your body’s water balance by increasing or decreasing the concentration of your urine. <strong>This is an example of homeostasis!</strong></td>
</tr>
<tr>
<td>Reproduction, growth, and development</td>
<td>An acorn germinates, develops into an oak seedling, and, at maturity, reproduces sexually to produce its own acorns</td>
</tr>
<tr>
<td>Evolution</td>
<td>Increasing numbers of bacteria survive treatment with antibiotic drugs</td>
</tr>
</tbody>
</table>

Wednesday, January 11, 2012
Organization

* The Cell — a membrane enclosed collection of organelles and DNA, plus lots of other biochemicals . . .

* But the cell is only part of a continuum of organization starting at the atom and extending to the entire living world, the Biosphere!
And that organization is . . .

Hierarchically arranged:

* Structures within structures . . .

* Make up an organism, which . . .

* Collectively make up the entire biosphere.
The "Levels of Biological Organization" to a critter

Levels of Organization

- Atom
- Molecule or Compound
- Organelle
- Cell
- Tissue
- Organ
- Organ System
- Organism
LEVEL 1 - Cells . . .

- Are the basic unit of structure and function in living things.
- They may serve a specific function within an organism.
- Examples — blood cells, nerve cells, bone cells, etc.

LEVEL 2 - Tissues . . .

- Are made up of cells that are similar in structure and function, and that work together to perform a specific activity.
- Examples — blood, nervous, bone, etc.
- Humans have four basic tissue types: connective, epithelial, muscle, and nerve.

LEVEL 3 - Organs . . .

- Are made up of tissues that work together to perform a specific activity.
- Examples — heart, brain, skin, kidney, etc.

LEVEL 4 - Organ Systems . . .

- Are groups of two or more organs working together to perform a specific overall function.
- Examples — circulatory system, nervous system, skeletal system, etc.
- The Human body has about a dozen — circulatory, digestive, endocrine, excretory, immune, integumentary, muscular, nervous, reproductive, respiratory, and skeletal.

LEVEL 5 - Organisms . . .

- Are entire living things that carry out all basic life processes, i.e. taking in nutrients, harnessing energy, releasing waste, growing, responding, reproducing, and evolving.
- Multicellular organisms are made up of organ systems, but an organism may be made up of only one cell, such as bacteria, archaeaons, and protists.
- Examples — E. coli, amoeba, mushroom, sunflower, human . . . . . .
Levels of Biological Organization...

On to the entire Biosphere!
Maybe this will help?

http://www.youtube.com/watch?v=Nmo5Ocivp&feature=related

And, for fun, check out the levels of organization at . . .

* http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

* Zooming in from “far, far away” all the way into the atoms of an oak tree!
And emergent properties —
the whole is greater than
the sum of the parts!

* Interacting components create
new, complex functions which
are . . .

* Not evident in the individual parts.

* This helps to explain structure/
function relationships.
The blood vessel does stuff the individual cells cannot do.
Life requires energy! A constant stream of energy is required to maintain organized life.
Energy consumption:

* All organisms must consume energy (of some form) to build, maintain, and repair structure, and to reproduce.

* Can categorize organisms by how they acquire this energy, i.e. their “trophic” level (think feed trough):
  
  Primary producers, i.e. “Autotrophs” (most plants and many microbes). These extract energy from non-living sources — the sun, or gases, or other elements of the earth’s environment.

* Consumers, i.e. “Heterotrophs” (all animals and many other microbes) eat other organisms, and “Decomposers” (fungi and still other microbes) eat wastes and dead organisms.
Trophic levels and the "Food Web"
Homeostasis:

* A state of internal constancy.
* Organisms must maintain a narrow range of parameters within their cells, tissues, organs, and bodies...
* For example — neither too wet, nor too dry; neither too hot, nor too cold; neither too salty, nor not salty enough.
You can relate . . .

* Your body must maintain an internal temperature of 37°C (98.6°F).

* So, if you go outside when it’s cold, your body shivers to generate heat and help keep warm. And . . .

* ‘Goosebumps’ form to stand fur on end to trap more air for better insulation (even though we no longer have fur). And . . .

* On a cold day, your lips and fingertips may turn blue as blood is diverted from the body surface, to keep your core organs warm.
Reproduction, including SEX, but also growth and development

- Asexual reproduction (‘natural’ cloning) — how boring, yet incredibly effective. The offspring are virtually identical to the parents. Not just single cell organisms, also lots of plants, e.g. Aspen in the Rocky Mt’s, and even some animals can do it this way.

- Sexual reproduction — now we’re talking! But even bacteria have sex. The common denominator is a mixing of DNA to come up with new combinations of traits, perhaps not even seen in the parents.
OK, what about Evolution?

* All of life evolves. What does that mean?
* Evolution is the change in genetic makeup of a population over time.
* All of life is actually related to one another by this process. It explains all of the diversity we see in the biosphere.
* Adaptations occur through “Natural Selection” and other processes.
* The process requires Variation!
Adaptation:

* An inherited characteristic or behavior that enables an organism to survive and reproduce successfully in a given environment.

* Two important facts are responsible:
  1. Populations produce more offspring than can possibly survive in a given space.
  2. Sexual reproduction results in genetic variability, and mutations (changes in DNA) occur with or without sex.
An example of an adaptation:

The lizard never saw anything until it was too late!

both: © Michael and Patricia Fogden/Animals Animals - Earth Scenes
Natural selection is . . .

- The enhanced reproductive success of certain individuals from a population based on inherited characteristics.
- Individuals with the better combinations of genes survive and reproduce.
- These individuals make up more and more of the population over time.
- When the environment changes, different combinations of traits may be better (or worse).
- Natural selection is but one mechanism of evolution.
Evolution is not:

* Progress! It is based on contingency.

* Try to dispel ideas concerning ‘higher’ versus ‘lower;’ ‘primitive’ versus ‘advanced;’ ‘simple’ versus ‘complex.’

* Evolution DOES ‘create’ organisms more “fit” to survive in their environment, than those organisms that they may compete with. This “fitness” is reflected in reproductive success. The “survival of the fittest!” But it can not predict what will or will not work in the future.
"The history of life is not necessarily progressive; it is certainly not predictable. The earth's creatures have evolved through a series of contingent and fortuitous events."
Natural selection at work:

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Staphylococcus aureus before mutation

Some bacteria mutate (red)

Antibiotic-resistant bacteria are most successful

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Life can be classified based on evolution!

- The Taxonomic hierarchy:
- domain, kingdom, phylum, class, order, family, genus, species...

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The three domains of life:

<table>
<thead>
<tr>
<th>Domain: Bacteria</th>
<th>Domain: Archaea</th>
<th>Domain: Eukarya</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Unicellular</em></td>
<td><em>Unicellular</em></td>
<td><em>Most unicellular</em></td>
</tr>
<tr>
<td><em>Cells lack nuclei and membrane-bounded organelles</em></td>
<td><em>Cells lack nuclei and membrane-bounded organelles</em></td>
<td><em>Cells with nuclei and membrane-bounded organelles</em></td>
</tr>
<tr>
<td><em>Cell walls different from Archaea and Eukarya</em></td>
<td><em>Cell walls and membranes different from Bacteria and Eukarya</em></td>
<td><em>Some have cell walls</em></td>
</tr>
<tr>
<td><em>Some autotrophs</em></td>
<td><em>Some autotrophs</em></td>
<td><em>Some autotrophs</em></td>
</tr>
<tr>
<td><em>Some heterotrophs</em></td>
<td><em>Some heterotrophs</em></td>
<td><em>Some heterotrophs</em></td>
</tr>
</tbody>
</table>

*Escherichia coli* | *Acidiphilum sp.* | *Chlamydomonas sp.* |

All have DNA housed in at least one nucleus.

**However, Protista is actually a ‘hodgepodge’ of directly and indirectly related critters — not truly a kingdom (IMHO).**
Whew! A lot of information.

* The next several weeks will investigate many of these levels of biological organization in much more depth. Perhaps more than you want!

* We’ll see how and where the components fit, in and out of cells, and in life in general.

* And we’ll see how they relate to energy use and production.

* Plus we’ll see how DNA runs the whole thing along with RNA.