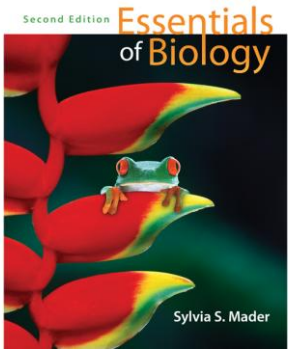


Essentials of Biology

Sylvia S. Mader

Chapter 1
Lecture Outline

Biology 100 Sections A & B: Instructor: Ken Marr
Lecture for Sec A & B: MW: 8:00 – 9:30; F: 8 – 9
Lab: Sec A: Tu 8 – 10; Sec B: Th 8 – 10

Announcements

1. Pick up handouts from wall files by the door
2. Labs meet in SC-255 → Prelab Assignment due at start of lab
3. Pick up at GRCC Bookstore A.S.A.P.
   - *Essentials of Biology* 2nd ed. by Mader
   - Do *not* purchase the Biology 100 Lab Packet!
4. Reading
   - Course Outline/Syllabus
   - Chapter 1
5. *By tomorrow*: Register for the *Connect* website
6. *Due Wed*: ALE #1: Activities 1 – 7 (pp. 1 – 7)
7. *Due Monday*: Chapter 1 LearnSmart (Connect Website)

Today's Agenda

1. Brief Introduction to…
   - Course & Syllabus
   - Class Website
   - Textbook's websites
2. Work in teams on ALE #1 (*Biology as a Science*)
   - Finish Activities 1 – 7 on pages 1 -7 for HW
     - Activity 5: select the number that corresponds to your group number
     - Activity 6:
       - ✓ Section A do #14
       - ✓ Section B do #16

Topics Covered in this Course
(on page 1 of Syllabus)

- This is a one-quarter introductory biology course intended for non-science students, or returning students needing a refresher course. Topics discussed include….
  - ✓ The process of science & Natural Selection
  - ✓ How cells work (cell structure & function)
  - ✓ How cells obtain energy: Cellular respiration and photosynthesis
  - ✓ How genes are passed on from parent to offspring and the role of natural selection
  - ✓ Cancer
  - ✓ The molecular basis of heredity—How DNA controls cells and a person's phenotype
  - ✓ Biotechnology and gene therapy
  - ✓ Biology of Aging: Processes responsible of aging and methods to slow the aging process

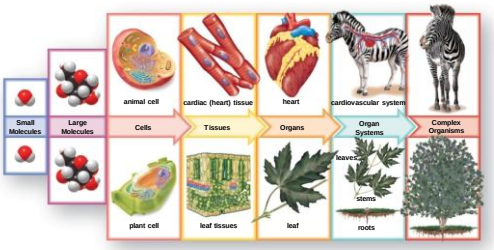
Major Emphasis in this Course

1. Show relevance: how does science affects your lives
2. Understand how science works
3. Help you to learn on your own once you leave this class
4. Issues in Human Genetics and Cellular Biology

1.1 The Characteristics of Life

1. Living things are organized.
   - Cell – smallest, most basic unit of life
     - Organisms may be unicellular or multicellular.
   - Tissues – made up of similar cells
   - Organ – made up of tissues
   - Organ systems – organs working together

Figure 1.1 Levels of biological organization



2. Living things acquire materials and energy.

- Life cannot be maintained without them.
- Food – building blocks and energy source
  - Energy – capacity to do work
  - Metabolism – all chemical reactions occurring in the cell
- Ultimate source of energy for Earth is the sun.
  - Photosynthesis transforms solar energy into chemical energy of food.
- Remaining homeostatic
  - Homeostasis – maintenance of internal conditions within certain boundaries
  - May be behavior – moving to a warmer area
  - May not require conscious activity – liver releases stored sugar

Figure 1.2 Acquiring nutrient material and energy

a: © age fotostock/SuperStock; b: © Ed Young/Corbis

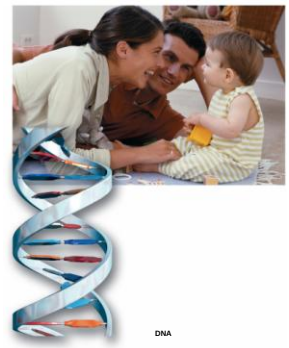
3. Living things respond.

- Find energy and/or nutrients by interacting with the environment.
- Ability to respond often results in movement.

4. Living things reproduce and develop.

- Every living thing can make another organism like itself or reproduce.
  - Bacteria simply split in two.
  - Union of egg and sperm produces embryo.
- Embryo grows according to genes inherited from parents.
- In all organisms, genes are made of DNA.
  - DNA is the blueprint.

Figure 1.3 A Human Family



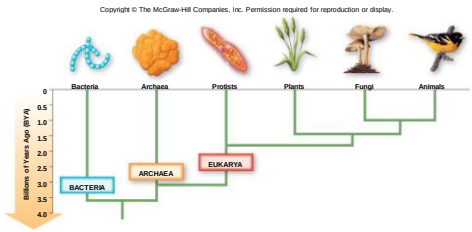
(family): © Vol. 113/Getty RF; (helix): © David Mack/SPL/Photo Researchers, Inc.

5. **Living things have adaptations.**
   - Modifications that make organisms suited to their way of life
   - Some hawks catch fish, others are better catching rabbits.
     - Adaptations for flight and catching prey
   - Penguins have adaptations for swimming and surviving in very cold temperatures.

1.2 Evolution: The Core Concept of Biology

- Evolution – process by which species have changed and diversified since life arose
  - Explains the unity and diversity of life
- Evolutionary tree illustrates the lineages of the major groups of living things.
  - Summarizes the 3.5 billion years of the history of life on Earth

Figure 1.4 Evolutionary tree



- Taxonomy – discipline of naming and classifying organisms according to certain rules
  - According to presumed evolutionary relationship
  - Categories of classification
    - Domain
    - Kingdom
    - Phylum
    - Class
    - Order
    - Family
    - Genus
    - Species

Most inclusive

Least inclusive

- Binomial name for each organism
  - ***Pisum sativum***, the garden pea (**P. *sativum***)
  - First word is **genus**
  - Second word: ***species***
  - Universally used by scientists to avoid confusion of common names

- **3 Domains of Life**
  - Domain **Archaea**
    - **Prokaryote – simple unicellular cells**, small, lacks membrane-bound nucleus
    - Live in extreme conditions (e.g. hot springs, thermal vents)
    - First cells on Earth found in the fossil record
  - Domain **Bacteria**
    - **Prokaryote – unicellular**, lacks membrane-bound nucleus
  - Domain **Eukarya**
    - **Eukaryote**
    - **Unicellular or multicellular**
    - **Membrane-bound nucleus**
    - **Larger and more complex cells (many organelles)**

1.2 Evolution: The Core Concept of Biology

- Evolution – process by which species have changed and diversified since life arose
  - Explains the unity and diversity of life
- Evolutionary tree illustrates the lineages of the major groups of living things.
  - Summarizes the 3.5 billion years of the history of life on Earth

Life in Its Diverse Forms

- Diversity is the hallmark of life
- The diversity of known life includes 1.7 million species
- Estimates of the total diversity range from 5 million to over 30 million species
- Classification of organisms → allows us to make sense of life's diversity

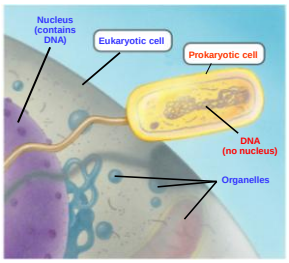
Prokaryotic vs. Eukaryotic Cells

Prokaryotic cells

– simple and other than ribosomes, they contain no organelles

Eukaryotic cells

– more complex
– contain organelles
– The **nucleus** is the largest organelle in most **eukaryotic cells**
– **Evolved after prokaryotes**



The Three Domains of Life

1. **Bacteria**
   - Prokaryotic cells
   - Live in mild conditions
2. **Archaea**
   - Prokaryotic cells
   - Extremophiles—live in extreme conditions
3. **Eukarya**
   - Eukaryotic cells
   - consists of four kingdoms

The Unity and Diversity of Life

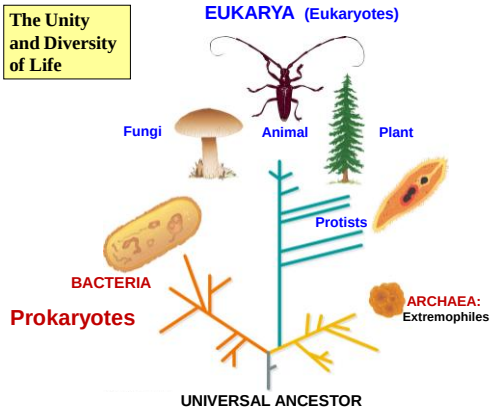
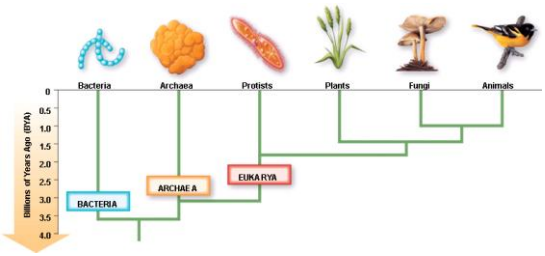


Figure 1.4 Evolutionary tree



The Four Kingdoms of Eukarya

1. **Protista**
   - **Unicellular Eukaryotes**
   - **Examples:**

Multicellular Eukaryotes:

2. **Plantae**
   - **Autotrophs—make own food from CO_2 & H_2O via photosynthesis**
   - **Examples:**
3. **Animalia**
   - **Heterotrophs—ingests food**
   - **Examples:**
4. **Fungi**
   - **Heterotroph—absorbs food**
   - **Examples:**

Unity in the Diversity of Life

- Underlying the diversity of life is a striking unity, especially at the lower levels of structure
  - Example: the universal genetic language of DNA
- Evolution accounts for this combination of unity and diversity

EVOLUTION: BIOLOGY'S UNIFYING THEME

- The history of life is a saga of a restless Earth billions of years old
  - **Fossils document this history**

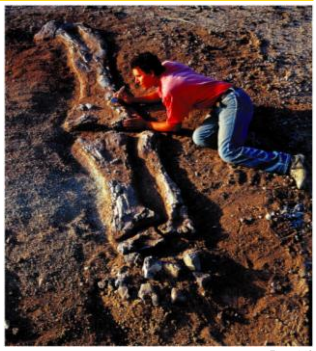


Figure 1.10

- **Natural selection**
  - **Charles Darwin** and **Alfred Russell Wallace**
    - independently concluded that evolution occurs by natural selection.
  - **Charles Darwin** wrote *On the* ***Origin of Species*** presenting substantiating data.
  - **Evolution is a core concept** in biology, medicine, anthropology, environmental science, conservation biology, agriculture, forestry, etc.
    - explains so many different types of observations in every many different fields of study

Natural selection

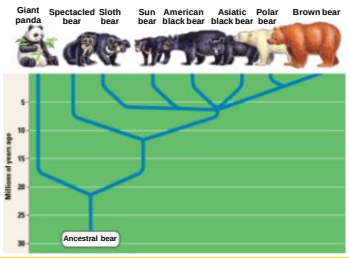
- **The process where steps 1-3 result in a population adapted to the environment.**

1. The members of a population have ***heritable variations.***
2. ***Over-reproduction***: More offspring are produced than can be supported.
3. ***Competition*** for resources results in the survival of better adapted members.

Result:

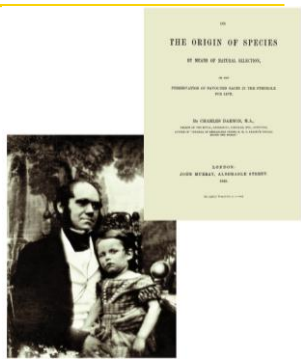
Across generations, a larger proportion of the population becomes adapted to the environment.

- **Life evolves**
  - Each species is one twig of a branching tree of life extending back in time



The Darwinian View of Life

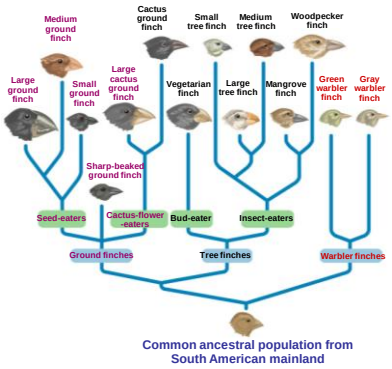
- The evolutionary view of life came into focus in 1859 when **Charles Darwin** published ***The Origin of Species***
- **Darwin's book developed two main points**
  - **Descent with modification**
  - **Natural selection**



Natural Selection

- Darwin was struck by the diversity of animals on the **Galápagos Islands**
- He thought of adaptation to the environment and the origin of new species as closely related processes
  - **As populations separated by a geographic barrier adapted to local environments, they became separate species**

- **14 species of Galápagos finches** have beak shapes adapted to suit their environments
- **Natural selection is the mechanism of evolution**



Darwin's Inescapable Conclusion

- Darwin synthesized the concept of natural selection from two observations that were neither profound nor original
  - Others had the pieces of the puzzle, but Darwin could see how they fit together

The Theory of Natural Selection

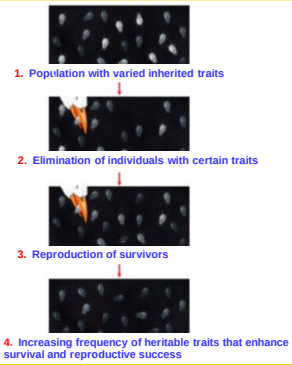
- **Observation 1:** Overproduction and struggle for existence
- **Observation 2:** Individual variation
- **Darwin's Hypothesis: Unequal reproductive success**
  - Some individuals are better suited to the environment than others and will therefore reproduce in larger numbers
- **It is this unequal reproductive success that Darwin called natural selection:**
  - **Those organisms with *heritable* traits that are best suited for the environment will survive and pass those traits on to future generations**
  - **What does the selecting in natural selection?**

The Theory of Natural Selection

- **Natural selection is the mechanism of evolution**
- **What are the two major causes of variation within a species?**

1.) Mutations

2.) Sexual Reproduction



Observing Natural Selection

Examples of natural selection in action

1. **The development of antibiotic-resistant bacteria**
2. **Pima Indians**
3. **Arctic Hare**
4. **Long Distance Runners from East Africa**
5. **Cockroaches in Florida**
6. **Alcohol Metabolism in Asians vs. Europeans**
7. **Human Skin Color**

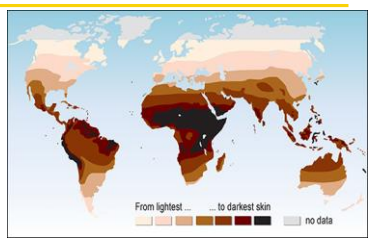
Tuberculosis

Observing Natural Selection: Human Skin Color

- **What role does Natural Selection Play in Determining Skin Color?**

Key Concepts…

- High doses of U.V. Light damages skin cells and DNA
- Our body needs some UV light to help us produce **Vitamin D**
- **Melanin** regulates how much UV light our skin lets in.



- *"Your Family May Once Have Been A Different Color" (NPR's Morning Edition 2-2-09): http://www.npr.org/templates/story/story.php?storyId=100057939*

Observing Artificial Selection

***Artificial selection*—**

- Selective breeding of domesticated plants and animal by humans

Prokaryotic vs. Eukaryotic Cells

Prokaryotic cells

- simple and other than ribosomes, they contain no organelles

Eukaryotic cells

- more complex
- contain organelles
- The **nucleus** is the largest organelle in most **eukaryotic cells**
- **Evolved after prokaryotes**

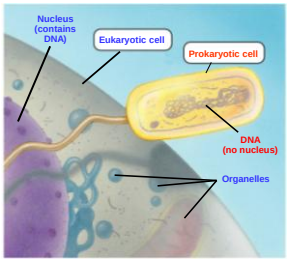
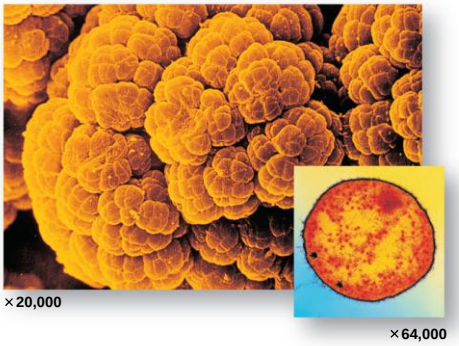


Figure 1.5 Domain Archaea (extremophiles!)



(main): © Ralph Robinson/Visuals Unlimited; (inset): © M. Rhode/GBF/SPL/Photo Researchers, Inc.

Figure 1.6 Domain Bacteria (prokayotes, live in mild conditions)

(main): © A.B. Dowsett/SPL/Photo Researchers, Inc.; (inset): © Biophoto Associates/Photo Researchers, Inc.

- Domain Eukarya is divided into four kingdoms
  - Kingdom Protista
  - Kingdom Fungi
  - Kingdom Plantae
  - Kingdom Animalia

Figure 1.7 Domain Eukarya, Kingdom Protista

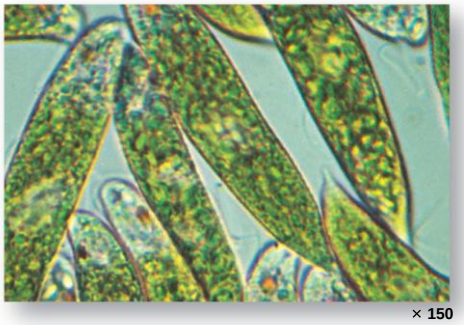


Figure 1.8 Domain Eukarya, Kingdom Fungi

Figure 1.9 Domain Eukarya, Kingdom Plantae

Figure 1.10 Domain Eukarya, Kingdom Animalia

- **Natural selection**
  - **Charles Darwin** and **Alfred Russell Wallace**
    - independently concluded that evolution occurs by natural selection.
  - **Charles Darwin** wrote *On the **Origin of Species*** presenting substantiating data.
  - **Evolution is a core concept** in biology, medicine, anthropology, environmental science, conservation biology, agriculture, forestry, etc.
    - explains so many different types of observations in every many different fields of study

Natural selection

- **The process where steps 1-3 result in a population adapted to the environment.**

1. The members of a population have ***heritable variations.***
2. ***Over-reproduction***: More offspring are produced than can be supported.
3. ***Competition*** for resources results in the survival of better adapted members.

Result:

Across generations, a larger proportion of the population becomes adapted to the environment.

- Darwin said evolution is descent with modification.
- Hawaiian honeycreepers
  - All evolved from one species of finch
  - Assortment of bill types adapted to different types of food
  - Still share certain characteristics from common finch ancestor – body shape, nesting behavior, etc.

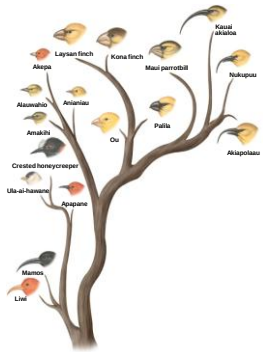


Figure 1.11 Evolution of Hawaiian honeycreepers

1.3 How the Biosphere Is Organized

- Biosphere – zone of air, land, and water at the surface of the Earth where living organisms are found
- Population – all members of a species in a particular area
- Community – populations interact among themselves
- Ecosystem – community and the physical environment (soil, atmosphere, etc.)

- North American grassland ecosystem
- Ecosystems characterized by
  - Chemical cycling – chemicals move through food chain
  - Energy flow – from sun to plants to members of the food chain
- Energy does not cycle – ecosystems could not stay in existence without solar energy or photosynthesizers.

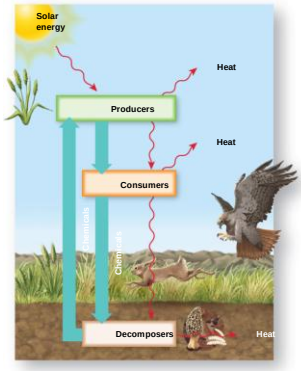


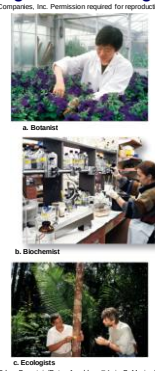
Figure 1.12 A grassland, a terrestrial ecosystem

- Biosphere
  - Climate largely determines where different ecosystems are found in the biosphere.
    - Desert in areas of minimal rain
    - Forests require more rain.
  - Two most biologically diverse ecosystems occur where solar energy is most abundant.
    - Tropical rain forests
    - Coral reefs

1.4 Science: A Way of Knowing

- Biology is the scientific study of life.

Figure 1.13 Biologists



a. Botanist

b. Biochemist

c. Ecologists

- Scientific method begins with **observations**.
  - May take advantage of knowledge and experiences of other scientists
- Scientist uses **inductive reasoning** – uses creative thinking to combine isolated facts into a cohesive whole.
  - **Hypothesis** – possible explanation for an event
    - **Consider only those that can be tested**.

Figure 1.14 Flow diagram for the scientific method

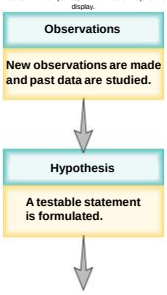
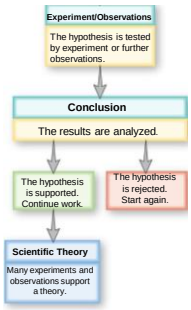


Figure 1.14 continued

- **Experiments** further observations and test hypothesis.
  - Good experimental design, all conditions constant except **experimental variable (Independent Variable)**
    - Experimental group vs. control group
  - Data may suggest correlation.
    - Does not necessarily mean causation
    - Scientists are skeptics
- **Conclusion** – is the hypothesis supported or not?
  - Experiments and observations must be repeatable.



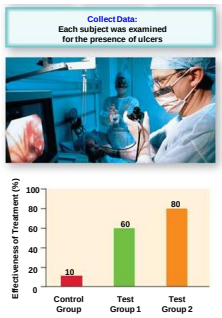
- **Scientific theory**
  - Ultimate goal of science is to understand the natural world in accepted explanations for how the world works.
  - Cell theory, gene theory
  - Theory of evolution is considered a unifying concept in biology.
  - Some biologists refer to the principle or law of evolution due to over 100 years of support by so many observations and experiments.

Controlled study

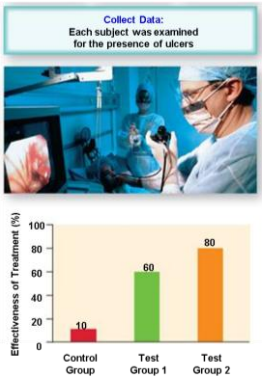
- Hypothesis : Antibiotic B is better than Antibiotic A in current use for the treatment of ulcers.
- 3 experimental groups
  - Reduce possible variances by randomly dividing large group.
  - Control group receives placebo.

Figure 1.15 A controlled laboratory experiment to test the effectiveness of a medication in humans

Figure 1.15 continued



- **Results determined by endoscopy**
  - **Double-blind study** – Technician doesn't know which group patient is in.
- **Conclusion** – ??????
- **Scientific studies published in a scientific journal**
  - Review process
  - General public usually relies on secondary sources which may be inaccurate.
  - Be especially careful of information on the Internet.



- **Results determined by endoscopy**
  - Double-blind study – Technician doesn't know which group patient is in.
- **Conclusion** – ??????
- **Scientific studies published in a scientific journal**
  - Review process
  - General public usually relies on secondary sources which may be inaccurate.
  - Be especially careful of information on the Internet.

- **Results determined by endoscopy**
  - Double-blind study – Technician doesn't know which group patient is in.
- **Conclusion** – investigators conclude their hypothesis is supported.
- **Scientific studies published in a scientific journal**
  - Review process
  - General public usually relies on secondary sources which may be inaccurate.
  - Be especially careful of information on the Internet.

The Process of Science in Action

Good News for Nightlights –(Morning Edition, 3/10/00)

NPR's Vicky Que reports that according to a new study in *Nature* magazine leaving a nightlight in a toddlers room does not appear to lead to myopia later in life. This latest report contradicts an earlier finding that found a link between myopia and nighttime lighting in children younger than 2 years old. (3:25)

http://www.npr.org/templates/story/story.php?storyId=1071349
http://www.npr.org/ramfiles/me/20000309.me.04.ram

The Process of Science: "The Scientific Method"

1. **Observe natural phenomena**
2. **Ask a question based on one's observations**
3. **Construct a hypothesis to answer the question**
4. **Test the hypothesis with experiments or pertinent observations**
5. **Drawing conclusions about the hypothesis based on the data resulting from the experiments or pertinent observation**
6. **Publishing results (hopefully in a scientific journal!)**

What's a Scientific Question?

Scientific Questions are….

1. *Definable*
2. *Testable*
3. *Measurable*
4. *Controllable*

What's a Hypothesis?

- Tentative, but untested explanations
- Make predictions that can be tested
- Written as "If……, then……" statements
- **Theories vs. Scientific Theories vs. Hypotheses**
  - **what's the difference?**

How do you test a Hypothesis?

Via controlled experiments or pertinent observations

- **All variables must be controlled**

Kinds of variables

1. **Independent variable**
2. **Dependent variable**
3. **Controlled Variables (nuisance variables)**

How do you test a Hypothesis?

Via controlled experiments or pertinent observations

- **All variables must be controlled**

Kinds of variables

1. **Independent variable**
   - **the thing (variable) studied, manipulated or tested**
2. **Dependent variable**
   - **the thing(s) affected by the independent variable**
3. **Controlled Variables (nuisance variables)**
   - **All other things (variables) that you try to hold constant**

Experiments of *classical* design

Individuals studied divided into two groups

1. *Experimental group*
   - exposed to the independent variable
2. *Control group*
   - exposed to the identical conditions as the experimental group, but not be exposed to the independent variable

The Process of Science in Action

- **Estrogen and Cardiac Health** (NPR's All Things Considered, 4/5/00)
  Women who've reached menopause face a big decision ... whether to take replacement hormones touted as being able to reduce the risk of heart disease and osteoporosis. But several recent studies have suggested that hormones may slightly increase the risk of heart disease. And now federal researchers are sending letters to women in a large trial saying that there does seem to be an initial increase in heart attacks and strokes. But the final word isn't in ... early data suggested that after two years, the extra risk may go away. (4:00)
  http://www.npr.org/ramfiles/atc/20000405.atc.08.rmm

Why is Science self-correcting?

1. Popular news reporting of current findings in science.....
   - **"In tomorrow's edition of the *New England Journal of Medicine*....."**
   - How much credibility should we give to recent findings?
2. Why do different researchers (or the same researcher!) get different and conflicting results while conducting what "same" experiment?

What is proof?

1. When does a hypothesis become a theory?
2. Can theories be proven true?
3. What's a scientific law?
4. Scientific Laws vs. Scientific Theories—what's the difference?
5. "Knowledge is what's left after you have demonstrated what cannot be true."

Self-test/Review Questions

Use these questions as a self test and then discuss your responses with your study group/classmates—your responses will *not* be collected.

1. What are the defining characteristics of life?
2. Trace the organization of life from atoms to a complete organism:
   atoms→_____→ _____ → _____ →
   → _____ → _____ → _____→ **Organism**
3. Differentiate between prokaryotic and eukaryotic cells giving examples of each.
4. Differentiate between organelles and organs—are they the same thing? Give examples of each.
5. What are genes? What are genes made of? Why are genes important? Do genes evolve/change over time?

Self-test/Review Questions (cont.)

6. What are the 3 domains of life? What are the distinguishing characteristics between the 3 domains of life?
7. Name the 4 kingdoms of eukarya. What are the distinguishing characteristics between the 4 kingdoms of eukarya?
8. What is the universal genetic language of life. Why is this significant?
9. Where can evidence be found that life evolved over time from simple organisms (e.g. unicellular prokaryotic organisms) to more complex organisms (e.g. multicellular eukaryotes)?
10. In your own words, state Darwin's theory of natural selection.
11. What does the selecting in natural selection?

Self-test/Review Questions (cont.)

12. Explain how each of the following are examples of natural selection.
    a. The development of antibiotic-resistant bacteria
    b. Pima Indians
    c. Arctic Hare
    d. Long Distance Runners from East Africa
    e. Cockroaches in Florida
    f. Alcohol Metabolism in Asians vs. Europeans
    g. Human Skin Color
13. What is the most important characteristic of an organism that leads to evolutionary change, and what role, if any, does the environment play?

Self-test/Review Questions (cont.)

14. Match the description with the appropriate term.

Terms: (a.) Protista (b.) Fungi (c.) Plantae (d.) Animalia
(e.) All of these (e.) None of the these

i. A kingdom that includes mushrooms and yeast
ii. Composed of eukaryotic cells
iii. Multicellular
iv. A kingdom that includes mostly single-celled prokaryotes
v. A kingdom that includes mostly single-celled eukaryotes

Self-test/Review Questions (cont.)

15. Match the description with the appropriate term.

Terms: (a.) Adaptation (b.) Evolution (c.) Mutation

(d.) Natural selection (e.) Kingdom (f.) None of the above

i. A category of classification of living things

ii. A change in the structure of a gene

iii. A structure or behavior in an organism that increases its ability to survive and reproduce

iv. The gradual accumulation of mutations that leads to changes in the kinds of organisms living on earth

v. The primary mechanism of evolution

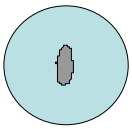
Estimating the Size of an Object Viewed with a Microscope

- Calculate the length and width of the following microscopic object in both millimeters and micrometers. **1 mm = 1000 µm**
- Base your calculations on the following field sizes:

Low power (40x): 4.5 mm

Medium power (100x): 1.8 mm

High power (400x): 0.45 mm



Object viewed at medium power (100x)

Remember: Field size decreases by the same factor as the magnification increases!

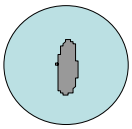
Estimating the Size of an Object Viewed with a Microscope

- Calculate the length and width of the following microscopic object in both millimeters and micrometers. **1 mm = 1000 µm**
- Base your calculations on the following *hypothetical* field sizes:

Low power (30x): 4.0 mm = ___µm

Medium power (180x): ___mm = ___µm

High power (300x): ___mm = ___µm



Object viewed at high power (300x)

Remember: Field size decreases by the same factor as the magnification increases!