




Scientific Principles

- Biology is a scientific discipline
- All scientific inquiry is based on a small set of assumptions or principles:
 - Natural causality
 - Uniformity in space and time
 - Similar perception



Natural Causality



- Historical approaches to studying life
 1. A belief that some events happen through supernatural forces (e.g. the actions of Greek gods).
 2. A belief that all events can be traced to natural causes that we can comprehend (**natural causality**).
 - Corollary: Evidence gathered from nature has not been deliberately distorted to fool us.

Natural Laws Apply Everywhere



- Natural laws are uniform in space and time (“uniformity”).
- This principle is key to understanding biological events (e.g. evolution) that occurred before humans recorded them.



Similar Perceptions



- Assumption that all human beings perceive natural events in fundamentally the same way.
- Common perception allows us to accept observations of other humans as reliable.



Similar Perceptions



- Common perception is usually not found in appreciation of art, poetry, and music, nor between cultures or religious beliefs.

- Value systems are subjective.
- Science requires objectively gathered data.



The Scientific Method



- Scientific inquiry is a rigorous method for making observations
- The Scientific Method for inquiry follows 4 steps...



The Scientific Method



- 1. Observation of a phenomenon**
 - Subsequent development of **questions**.
- 2. Formulation of a hypothesis**
 - A supposition that explains an observed phenomenon, leading to testable **predictions**.



The Scientific Method



3. Testing through experimentation

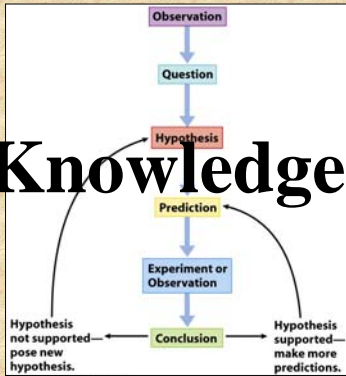
- Additional controlled observations.

4. Development of a conclusion

- Evaluation of hypothesis in light of experimental data.



Knowledge!



The Scientific Method



- Scientific experimentation tests the assertion that a *single variable* causes a particular observation.
- The experiment must rule out the influence of other possible variables on the recorded observations.



The Scientific Method



- **Controls** are incorporated into experiments.
- **Controls** keep untested variables constant.
- The method is illustrated by Francesco Redi's experiment.



The Scientific Method



Observation: Flies swarm around meat left in the open; maggots appear on meat.

The Scientific Method



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Question: Where do maggots on meat come from?

The Scientific Method



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Hypothesis: Flies produce the maggots.

The Scientific Method

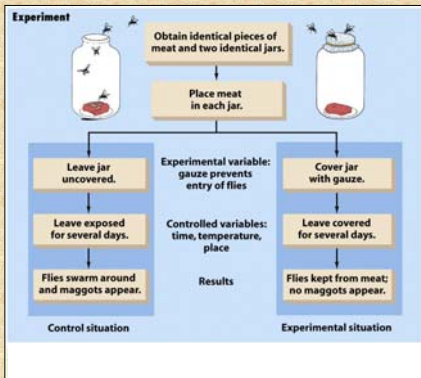


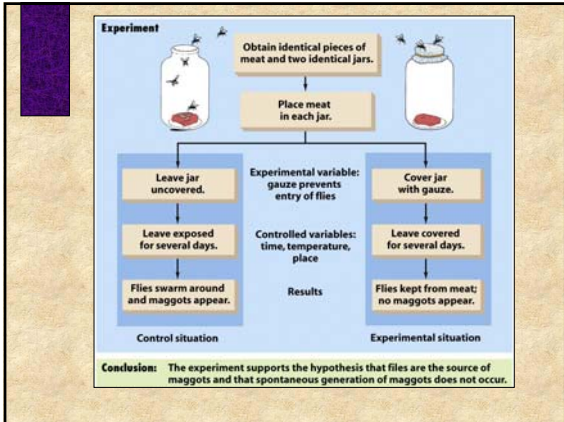
Observation: Flies swarm around meat left in the open; maggots appear on meat.

Question: Where do maggots on meat come from?

Hypothesis: Flies produce the maggots.

Prediction: IF the hypothesis is correct, THEN keeping the flies away from the meat will prevent the appearance of maggots.






Application to Everyday Problems

- Assume you are late for an appointment and hurriedly try to start your car.


1. **Observation:** The car won't start.



Observation Car won't start.


↓

Question Why won't the car start?



Application to Everyday Problems


2. **Hypothesis:** the battery is dead.



Question Why won't the car start?

↓

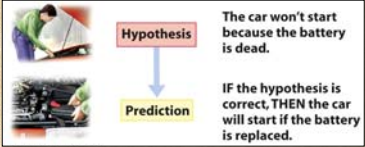
Hypothesis The car won't start because the battery is dead.



Application to Everyday Problems



3. Experimental design: Replace your battery with another and restart the car.



Application to Everyday Problems



4. Premature conclusion:

- The problem was a dead battery because the car starts when replaced with a different one.



Application to Everyday Problems



5. Recognition of inadequate controls

- Did you attempt to start the car more than once?
- Was the battery cable on my original battery loose?

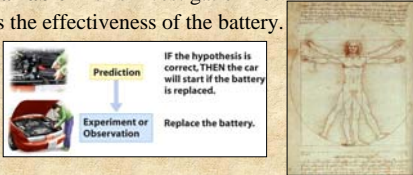


Application to Everyday Problems



6. Establishing a control

- Reinstall your old battery, check for tight cables, *now* try to start the car.
- If car *still* fails to start on old battery, the **only variable** in this investigation now is the effectiveness of the battery.

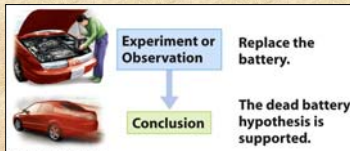


Application to Everyday Problems



7. Making a better conclusion, based on controlled experiments

- Your battery was probably dead.





Limitations of the Scientific Method



- Can never be sure *all* untested variables are controlled.
- Conclusions based on the experimental data must remain tentative.
- Must think in terms of probability.
- Can never “*prove*” because of random effects.



Limitations of the Scientific Method



- Results of experimentation must be communicated thoroughly and accurately to other scientists for repetition.
- Repetition by other scientists add verification that findings can be used as the basis for further studies.



Science Is a Human Endeavor



- Human personality traits are part of “*real science*”.
- Scientists, like other people may be driven by pride, ambition, or fear.
- Scientists sometimes make mistakes.
- Accidents, lucky guesses, intellectual powers, and controversies with others contribute strongly to scientific advances.

Science Is a Human Endeavor



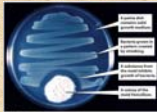
1. In the 1920s, bacteriologist Alexander Fleming grew bacteria in cultures.
2. One of the bacterial cultures became contaminated with a mold.
3. Fleming nearly destroyed the culture when he noticed the mold (*Penicillium*) inhibited bacterial growth in the culture.



Science is a Human Endeavor



4. Fleming hypothesized that the mold produced an antibacterial substance
5. Further tests using broth from pure *Penicillium* cultures lead to the discovery of the first antibiotic, penicillin.



Science is a Human Endeavor



6. Fleming continued beyond a lucky “*accident*” with further scientific investigation to a great discovery.
7. “*Chance favors the prepared mind*” (Louis Pasteur)



Scientific Theory



- A **scientific theory** differs in definition from that of everyday usage.
 - Many people use the word *theory* to mean *hypothesis*, and “educated guess”.



Scientific Theory



- A scientific theory is a general explanation for important natural phenomena.
 - It is extensively and reproducibly tested.
 - It is more like a principle or natural law (e.g. the atomic, gravitational, and cell theories).
 - If compelling evidence arises, a theory may be modified.



Science Is Based on Reasoning



- Inductive Reasoning
 - Used in the development of scientific theories.
 - A *generalization* is created from many observations.
 - e.g., the cell theory (all living things are made of one or more cells) arises from many observations that all indicate a cellular basis for life.

The Scientific Method



Question:

What are the steps in the scientific process?

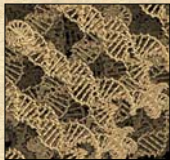


The Scientific Method



Question:

What is the definition of “Life”?



Defining Life



- Dictionary definition of *life* is:
 - “the quality that distinguishes a vital and functioning being from a dead body”.
- Living things are more than the sum of their parts; *life* is difficult to define.
- The complexity and ordered interactions of parts in living things gives rise to certain *emergent properties*.

Characteristics of Life

1.3 What Are the Characteristics of Living Things?

- Living Things Acquire and Use Materials and Energy
- Living Things Grow
- Living Things Reproduce Themselves
- Living Things as a Whole Have the Capacity to Evolve
- Living Things are Made of Cells
- Respond to Stimuli
- Must maintain relatively constant internal conditions (**homeostasis**)



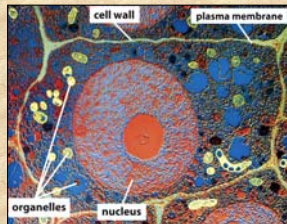
Living Things Are Composed of Cells

- Living things are complex **and** organized



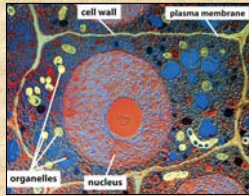
Living Things Are Composed of Cells

- The **cell theory** states that the cell is the basic unit of life.
- A single cell has an elaborate internal structure.



Living Things Are Composed of Cells

- Cells contain:
 - **Genes** that provide information to direct the cell.
 - **Organelles**, small specialized structures that perform specific functions.
 - A **plasma membrane** that encloses the fluid cytoplasm and organelles from the outside world



Homeostasis



- Organisms must maintain relatively constant internal conditions (**homeostasis**)
 - e.g. many organisms regulate body temperature



Homeostasis



- Homeostatic mechanisms include:
 - Sweating in hot weather or dousing oneself with cool water.
 - Metabolizing more food, basking in the sun, or turning up the thermostat in cold weather.
- Organisms still grow and change while maintaining homeostasis.

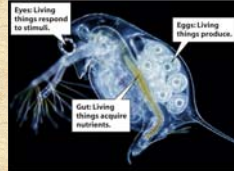


Living Things Respond to Stimuli

- Organisms sense and respond to internal and external environmental stimuli.
 - Sensory organs in animals can detect and respond to external stimuli like light, sound, chemicals, etc.
 - Internal stimuli in animals are perceived by stretch, temperature, pain, and chemical receptors.
 - Plants and bacteria respond to stimuli as well (e.g. plants to light, bacteria to available nutrients in the medium).

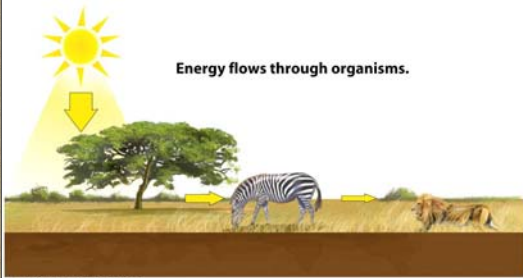
Living Things Acquire Materials

- Materials and energy required to maintain organization, to grow, and to reproduce.

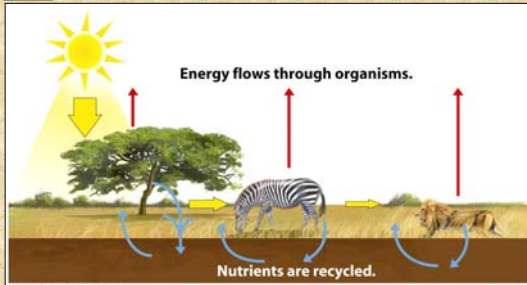


Living Things Acquire Materials

Energy flows through organisms.



Living Things Acquire Materials



Living Things Acquire Materials

- Nutrients are incorporated into the bodies of organisms.
- **Metabolism** is the sum total of all the chemical reactions needed to sustain an organism's life.

Question: What are nutrients?

Living Things Acquire Materials

- Organisms obtain energy in two ways:
 - Plants and some single-celled organisms capture sunlight in **photosynthesis**.
 - Other organisms consume energy-rich molecules in the bodies of other organisms
- All energy that sustains life comes directly or indirectly from the sun.



Living Things Grow



- Every organism becomes larger over time.
 - Plants, bird, and mammals grow by producing more cells to increase their mass.
 - Bacteria grow by enlarging their cells; they also divide to make more individuals
- Growth involves the conversion of acquired materials to molecules of the organism's body.



Living Things Reproduce Themselves

- Organisms give rise to offspring of the same type (**reproduction**).
- The parent's genetic material (DNA) is passed on to the offspring, creating *continuity of life*.
- *Diversity of life* occurs because offspring may be genetically different from their parents.



They Have the Capacity to Evolve (Change)

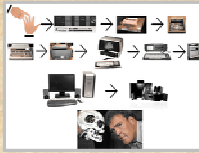
- The genetic composition of a whole species **changes** over many generations.
- Mutations and variable offspring allow a species to **evolve**.



The Capacity to Evolve

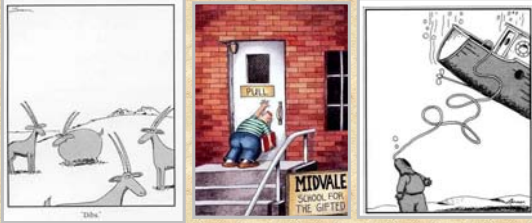


- Evolutionary theory states that modern organisms descended **with modification** from pre-existing life-forms.
- **Natural selection** is a process where organisms with certain adaptations survive and reproduce more successfully than others.



Science Is Part of Everyday Human Existence

- Scientific understanding and a sense of wonder about nature are not mutually exclusive.



Levels of Organization

- The living and nonliving world is organized at many levels



Levels of Organization

Community	Two or more populations of different species living and interacting in the same area	
Population	Members of one species inhabiting the same area	
Multicellular Organism	An individual living thing composed of many cells	
Organ System	Two or more organs working together to the execution of a specific bodily function	
Organ	A structure usually composed of several tissue types that form a functional unit	
Tissue	A group of similar cells that perform a specific function	
Cell	The smallest unit of life	
Molecule	A combination of atoms	
Atom	The smallest particle of an element that retains the properties of that element	

Order
and
Complexity

Levels of Organization

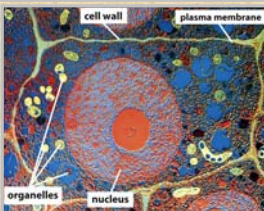
- All matter is formed of **elements**
- An **atom** is the smallest particle of an element retaining the properties of an element
- Atoms combine to form **molecules**
- **Molecules** provide the building blocks for **cells**, the smallest unit of life

Molecule	A combination of atoms	
Atom	The smallest particle of an element that retains the properties of that element	

Levels of Organization




- Some forms of life consist of single cells

Cell	The smallest unit of life	
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Levels of Organization

- In multicellular forms cells combine to form **tissues**
- Tissues combine to form **organs**, which can be united as **organ systems**

Organ System	Two or more organs working together in the execution of a specific bodily function	 the digestive system
Organ	A structure usually composed of several tissue types that form a functional unit	 the stomach
Tissue	A group of similar cells that perform a specific function	 epithelial tissue

Levels of Organization

- **Multicellular organisms** are composed of multiple organ systems

Multicellular Organism	An individual living thing composed of many cells	 pronghorn antelope
		

Levels of Organization

- Organisms of the same type that are capable of interbreeding are called a **species**.
- A group of organisms of the same species living in a given area is a **population**.
- Interacting populations make up a **community**.

Population	Members of one species inhabiting the same area	 herd of pronghorn antelope
Multicellular Organism	An individual living thing composed of many cells	 pronghorn antelope

Levels of Organization

- Interacting populations make up a **community**

Community	Two or more populations of different species living and interacting in the same area	 antelope, hawk, grass
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Levels of Organization

- A community and its nonliving environment is an **ecosystem**.
Larger areas with general patterns of life are **biomes**.



Levels of Organization

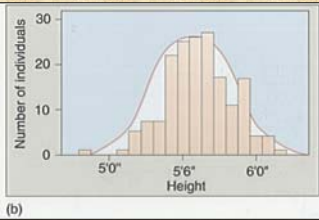
- The entire surface of the Earth, including living and nonliving components is the **biosphere**.



Why is there Variation among Species & Populations?



(a)



(b)
