BIOLOGY I

Chapter 1 – Introduction: THEMES IN THE STUDY OF LIFE

Evelyn I. Milian

Instructor

2012

Objectives for Today

1) Instructor introduction.
2) Students introduction.
3) Discussion of Course Syllabus.
4) Discussion of chapter 1.
5) Assignment for next class.

Instructor: **Evelyn I. Milian**

Office: Classroom or lab before and after class.
Office hours: 15 to 30 minutes before and after class; and by appointment.
E-mail: **evelyn@eveflyaway.com**

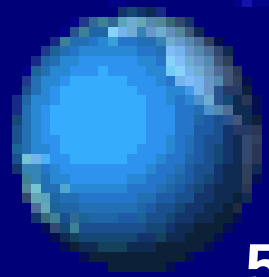
- Instructor of Biology & Microbiology.
- Graduate studies in Microbiology.
- Scientific research thesis: immunoallergy, with dust mites.
- Born in Puerto Rico.
- Moved to USA in 2005.
- Before being a biologist, I was an administrative secretary for 10 years. I also took many courses in accounting and humanities.
- Hobbies: reading, riding my bike, listening to music, playing guitar, watching TV shows about nature and wildlife, science, sports, outdoor recreation.

"Ice-Breaker" Activity

- The group of students will work in pairs.
- Each pair of students will interview each other, taking notes about your partner.
- Examples of information you can share ***if you want to***:
  - Name, occupation, where you live, kids, hobbies, any other piece of information or interesting fact about yourself that you feel like sharing with your partner and the class.
- Finally, you will introduce your partner to the rest of the students and your partner will introduce you.
- Tell the group what comes first to your mind when you hear the word **BIOLOGY**.

Discussion of Course Syllabus

- Students must read carefully the **Course Syllabus** and **use it as a guide throughout the course**.
  - *** All the details about the course are found in the Course Syllabus document.
- Make sure that you understand everything, write down questions as they arise and ask the instructor immediately.
- Feel free to contact the instructor before or after class, or by e-mail, as soon as you have any questions throughout the course.



Chapter 1 – Introduction: *Themes in the Study of Life*

- What is Biology?
  - **Biology** is the scientific study of **life**.
  - Biology is a quest, an ongoing inquiry about the nature of life.






How Do We Study Life?

- **Biology** is the scientific study of **life**. Biology consists of many areas of study, or subfields, because life has many aspects and perspectives.

Some Branches of Biology	
Anatomy	Study of the structure of an organism's body, and the relationships among body structures.
Physiology	Study of the functions and processes of the body of an organism; how the body parts work.
Botany	Study of plants.
Ecology	Study of the interactions of organisms with other organisms and with the physical and chemical environment.
Genetics	Study of heredity, gene function, and variation in organisms.
Microbiology	Study of microorganisms.
Zoology	Study of animals.

Why Study Biology?

- Biology influences all aspects of human life and helps us understand our world. This science allows us to:
  - Study and understand the structure and function of the human body.
  - Study and understand other organisms, with which we interact.
  - Obtain important information to make decisions about diverse aspects of human life, for example:
    - ✓ Effects of natural processes in human life.
    - ✓ Effects of chemical substances and other physical factors.
    - ✓ Study and understand our genetics, how we inherit characteristics.
    - ✓ Development and inheritance of illnesses.
    - ✓ Development of products, medicines, and treatments.
    - ✓ Effect of human activities in our planet and life in general.
- * Read article titled: ***"The Significance of Biology in Your Life"*** *(available in the Learning Web)*.

Why Study Biology?

- **"Biology is not a completed work but an exploration that has really just begun."**
- "We cannot urge you strongly enough, even if you are not contemplating a career in biology, to join in the journey of biological discoveries throughout your life. Don't think of biology as just another course to take, just another set of facts to memorize. Biology is a pathway to a new understanding of yourself and of the life on Earth around you."
  - *Teresa and Gerald Audesirk*; Biology: Life on Earth, Seventh Edition; 2005; Chapter 1 (Prentice Hall).

Three Basic Themes of Biology

1. **Evolution.** Scientific evidence shows that diverse life-forms on this planet are related and populations of organisms have *evolved*, that is, have changed over time, from earlier forms of life.
2. **Information transfer.** Information must be transmitted in an orderly way within organisms and among organisms to ensure the survival and function of every cell and every organism. Evolution depends on the transmission of genetic information from one generation to another.
3. **Energy for life.** Energy from the sun flows through living systems from producers to consumers. All life processes, including biochemical reactions, require energy.

What is Life?

Characteristics of Living Things (Properties of Life)

- Life is very diverse and cannot be defined in a straight-forward manner; it is best defined by several basic characteristics shared by all organisms.
- Those basic characteristics of life, taken together, distinguish living things from nonliving things.

Figure 1.1. Diversity of life.

Bacteria (prokaryotes)

Paramecium (a protist)

Morel (fungus)

Sunflower (plant)

Snow goose (animal)

Characteristics of Life: ***Living Things are Organized***

- Living things are ***structurally and functionally organized*** into levels, or a hierarchy: they have **order**. Structure and function are correlated at all levels of biological organization.
- **Levels of biological organization** go from the ***microscopic*** (too small to be seen by the unaided eye) to ***global***:
  - **atoms → molecules (chemical level) → organelles → cells → tissues → organs → organ systems → organisms → populations (a species) → communities → ecosystems → biosphere.**
- Each level of organization is ***more complex*** than the level preceding it and has properties beyond those of the former level: **emerging properties** that are due to the interactions among the parts making up the whole. The whole is more than the sum of its parts.

Organisms Are Organized

Levels of Biological Organization

- All life has a chemical basis, but the quality of life itself emerges on the ***cellular*** level.
- Interactions among the components of each level and the levels below it allow the development of the next-higher level of organization.
- **Subatomic particle → Atom → Molecule → Organelle → Cell → Tissue → Organ → Organ System → Organism → Population (a species) → Community → Ecosystem → Biosphere.**

Biosphere	That part of Earth inhabited by living organisms; includes both the living and nonliving components	Earth's surface
Ecosystem	A community together with its nonliving surroundings	snake, antelope, hawk, bushes, grass, rocks, stream
Community	Two or more populations of different species living and interacting in the same area	snake, antelope, hawk, bushes, grass
Population	Members of one species inhabiting the same area	herd of pronghorn antelope
Species	Very similar, potentially interbreeding organisms	
Multicellular Organism	An individual living thing composed of many cells	pronghorn antelope
Organ System	Two or more organs working together in the execution of a specific bodily function	the nervous system
Organ	A structure usually composed of several tissue types that form a functional unit	the brain
Tissue	A group of similar cells that perform a specific function	nervous tissue
Cell	The smallest unit of life	nerve cell
Organelle	A structure within a cell that performs a specific function	mitochondrion; chloroplast; nucleus
Molecule	A combination of atoms	water; glucose; DNA
Atom	The smallest particle of an element that retains the properties of that element	hydrogen; carbon; nitrogen; oxygen
Subatomic Particle	Particles that make up an atom	proton; neutron; electron

1. The biosphere

All the environments on Earth that are inhabited by life (all the ecosystems)

2. Ecosystems

All the living things in a particular area, along with all the nonliving components with which life interacts (soil, water, atmospheric gases, light, etc.)

3. Communities

The entire array of organisms inhabiting a particular ecosystem (all different species)

4. Populations

All the individual of a species living in a specified area.

A species is a group of organisms that have the potential to interbreed in nature and produce viable, fertile offspring.

5. Organisms

Individual living things

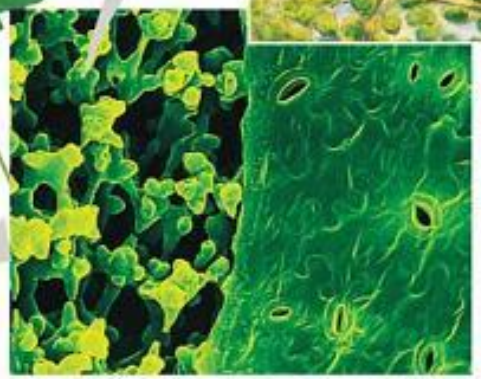
Figure 1.4. Levels of biological organization (part 1 of 2)

6. Organs and Organ Systems

An organ is a body part consisting of two or more tissues. Organ systems are teams of organs that cooperate in a specific function.

7. Tissues

Integrated groups of cells with a common function, structure, or both.

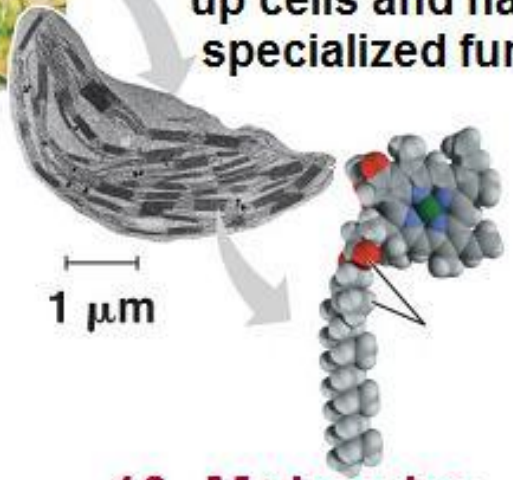


8. Cells - Life's fundamental units of structure and function.

Some organisms are single cells, other organisms are multicellular.

9. Organelles

Functional components or structures that make up cells and have specialized functions.



10. Molecules

Chemical structure consisting of two or more smaller chemical units called atoms.

Figure 1.4. Levels of biological organization (part 2 of 2)

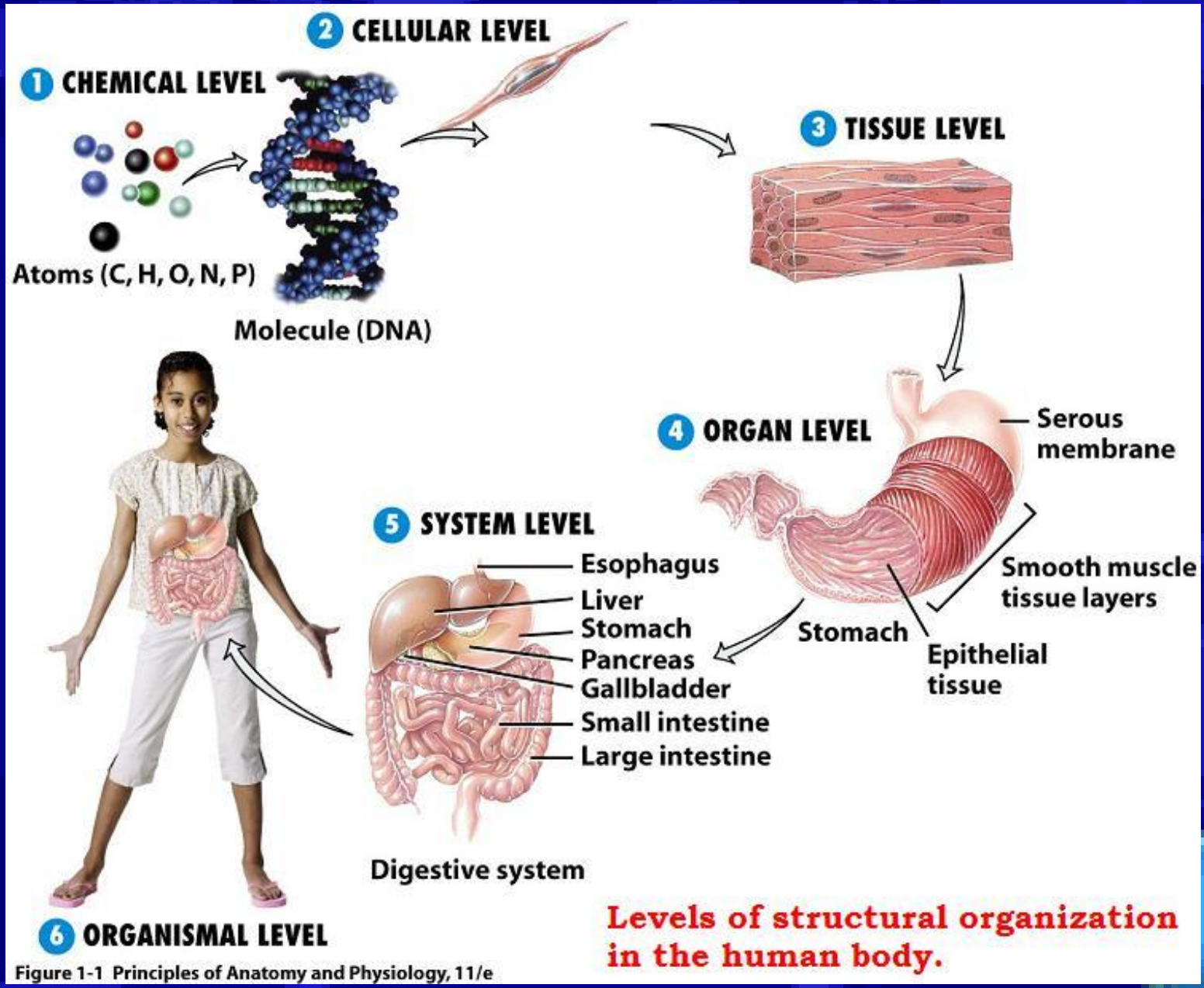


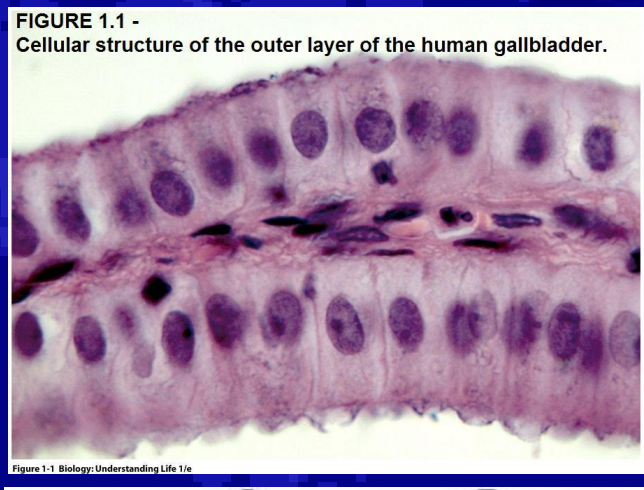
Figure 1-1 Principles of Anatomy and Physiology, 11/e

Levels of structural organization in the human body.

Organisms Are Organized:

A closer look into two of the levels of biological organization

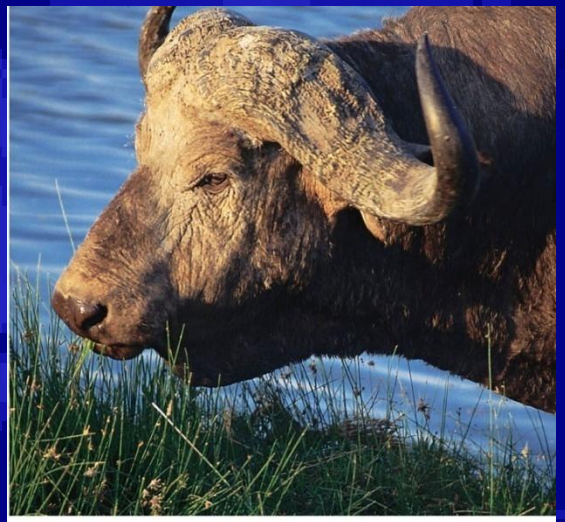
- **Cell:** ***The basic structural and functional unit of life;*** a cell is composed of several molecules (atoms held together by chemical bonds) functioning together.
  - Examples: a human gallbladder cell, or a bacterial cell.
  - **Cell theory:** The cell is the basic unit of life, of which all living things are composed, and all cells are derived from pre-existing cells.
- **Organism:** A complete living thing; an individual.
  - Organisms can be **unicellular** (composed of a single cell), such as a bacterium;
  - or **multicellular** (many cells), such as a plant or an animal.



Cells and Organisms:

Structure and Function are Correlated at All Levels of Organization

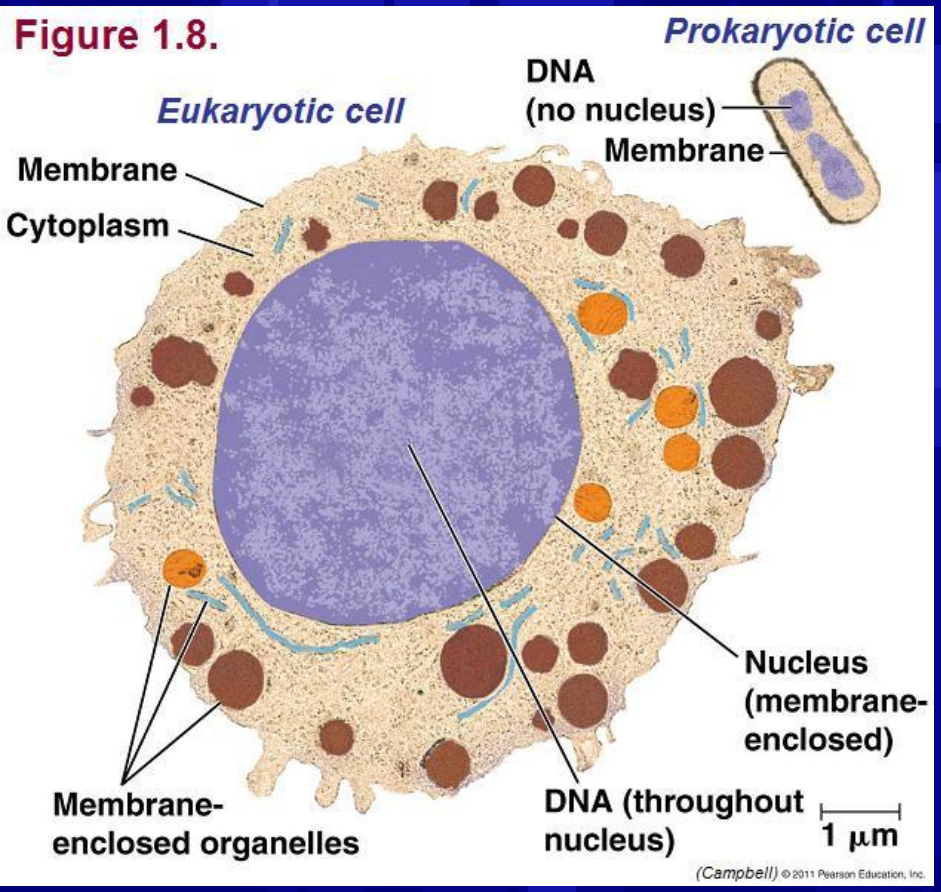
(a) Unicellular organisms consist of one intricate cell that performs all the functions essential to life. Ciliates, such as this *Paramecium*, move about by beating their hairlike cilia.



(b) Multicellular organisms, such as this African buffalo (*Syncerus caffer*) and the plants on which it grazes, may consist of billions of cells specialized to perform specific functions.

- **Unicellular organisms** consist of a single cell that performs all the functions essential to life. Ciliate protists, such as *Paramecium* (a microorganism), move about by beating their hairlike cilia.
- **Multicellular organisms**, such as this African buffalo (*Syncerus caffer*) and the plants on which it grazes, may consist of billions of cells specialized to perform specific functions.

Two Main Types of Cells



All cells are protected by a **cell membrane** that regulates the passage of materials between cell and environment.

Eukaryotic Cells

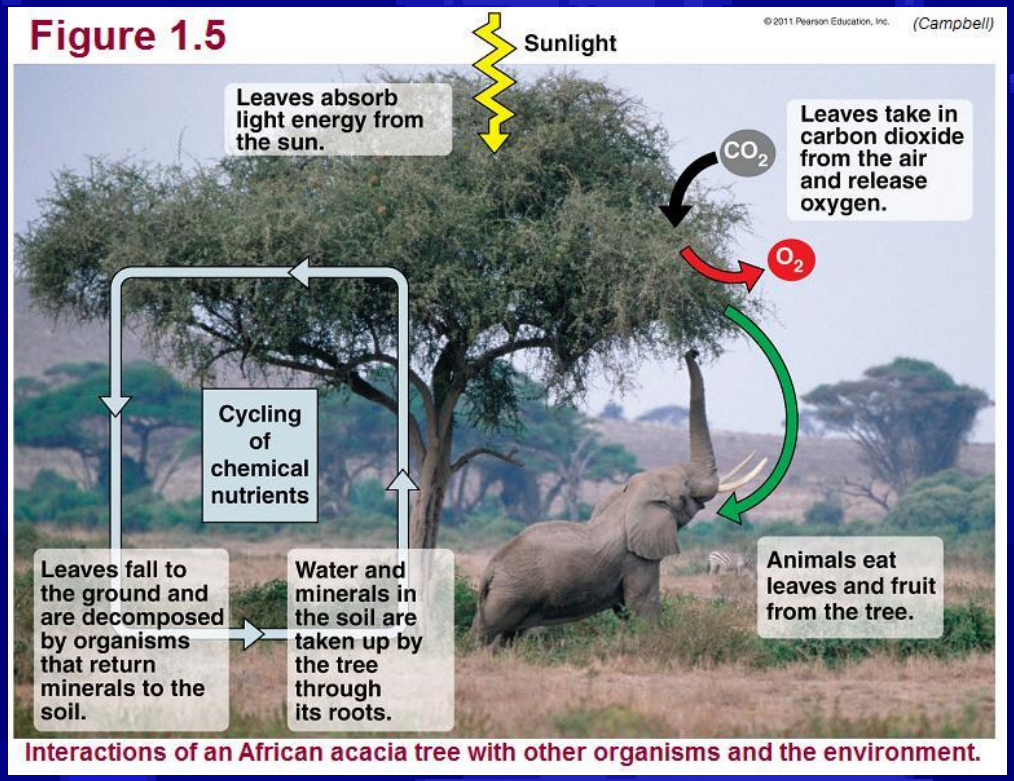
- Contain membrane-enclosed organelles (specialized structures), such as a **nucleus** (containing genetic material—DNA).
- More complex than prokaryotic cells.
- Eukaryotic organisms are: **protists, fungi, plants, animals**.

Prokaryotic Cells

- Do not contain membrane-bound internal organelles; **no true nucleus**.
- Simpler than eukaryotic cells.
- Prokaryotic organisms are: **bacteria** (microorganisms) and **archaea** (bacteria-like microorganisms)

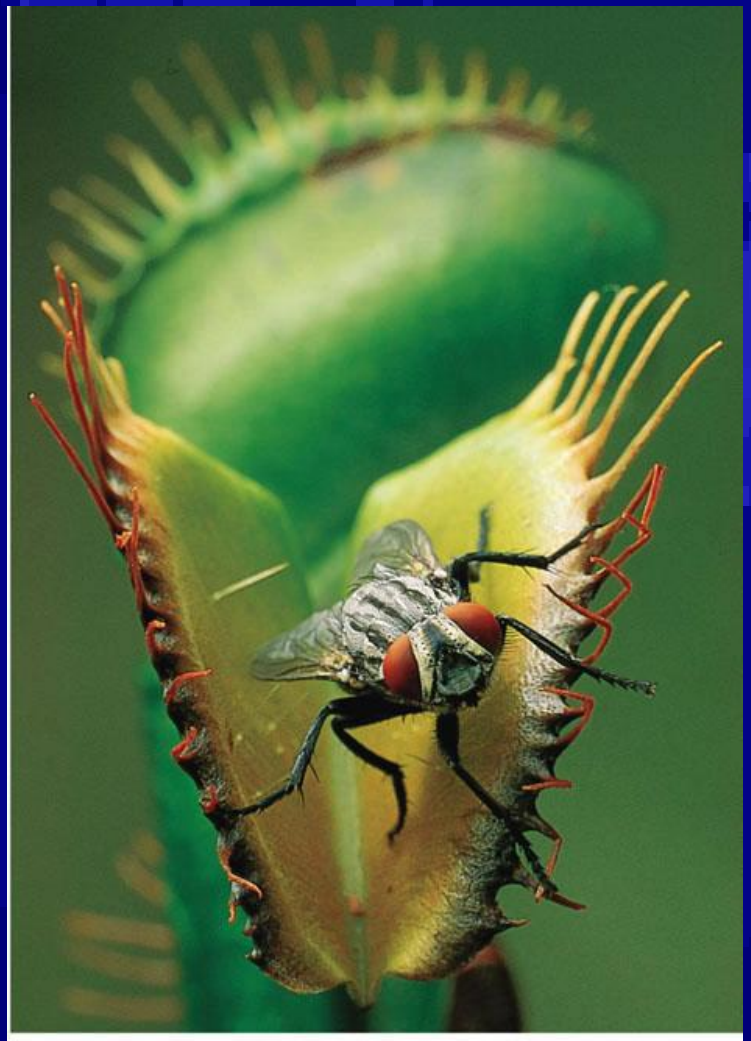
Organisms Interact with Other Organisms and the Physical Environment

- Organisms **perceive and respond to stimuli** from their internal and external environment. In other words, they **interact** with the environment as well as with other living things.
- Appropriate responses help **ensure survival** of the organism and allow it to carry on its daily activities.
  - Feeding, defense, communication, movements, other behaviors.
  - Animals have sensory organs, muscular and nervous systems.



Interactions of an African acacia tree with other organisms and the environment.

Organisms Interact with the Environment



(a) Hairs on the leaf surface of the Venus flytrap (*Dionaea muscipula*) detect the touch of an insect, and the leaf responds by folding.

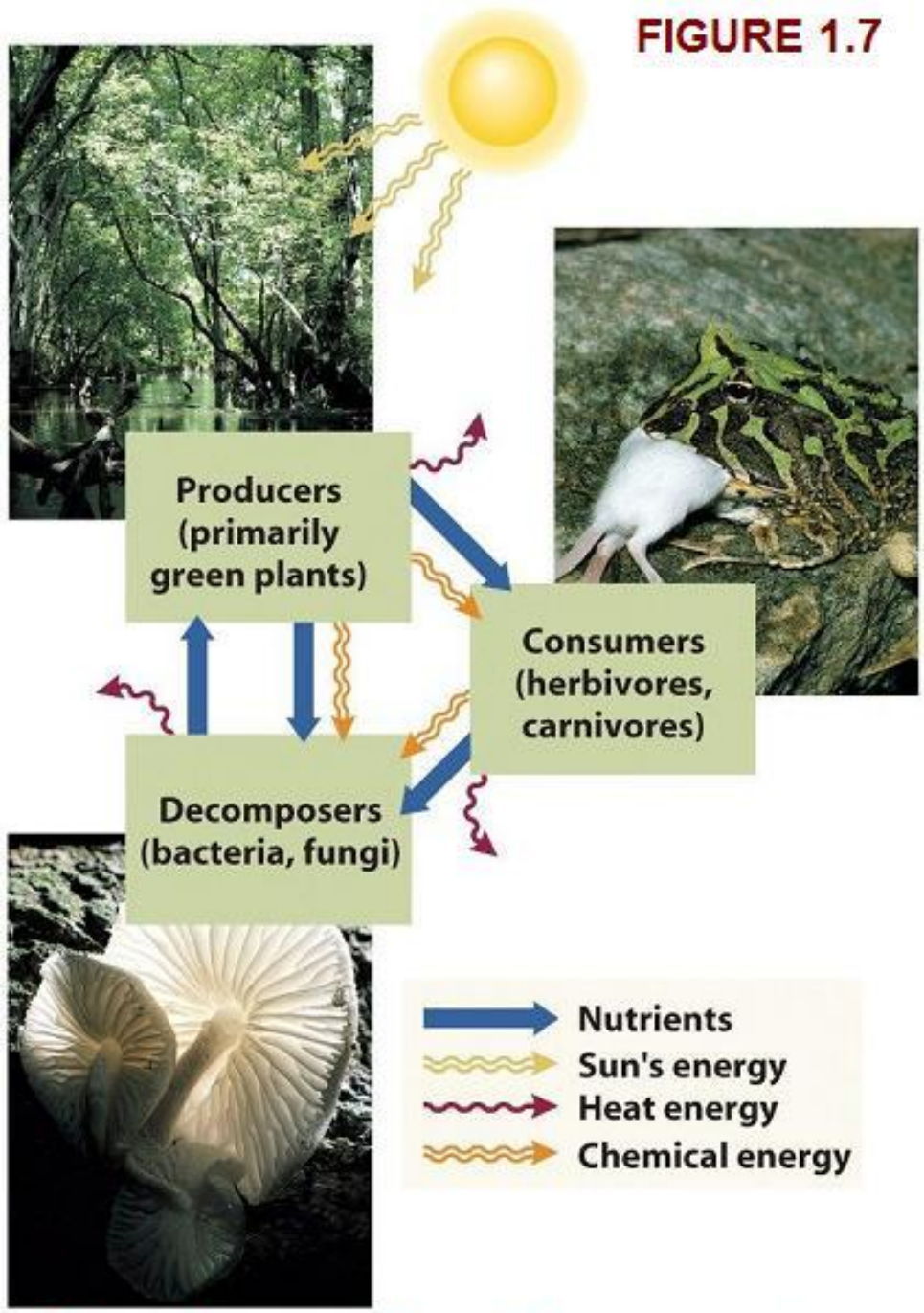
(b) The edges of the leaf come together and interlock, preventing the fly's escape. The leaf then secretes enzymes that kill and digest the insect.

Organisms Have Metabolism: *They Acquire and Process Energy and Nutrients*

- Organisms need **energy** and **nutrients** to maintain their high level of organization, to grow and to reproduce. They carry out **metabolism**, all the chemical reactions needed to sustain an organism's life.
- **Energy** is the capacity to do work (chemical reactions, growth, movement, reproduction, tissue repair, etc.).
  - Life requires energy transfer and transformation.
- **Nutrients** are molecules or substances that have an essential role in growth and survival.

Organisms Have Metabolism:
They Acquire and Process Energy and Nutrients

- ***How do organisms obtain energy and nutrients?***
  - **Producers or autotrophs** make their own nutrients by carrying out **photosynthesis** (capturing sunlight energy to incorporate it into molecules as chemical energy), or by using inorganic chemicals (without carbon).
    - ✓ Plants, algae, and some unicellular organisms
  - **Consumers or heterotrophs** acquire molecules from other organisms (producers and other consumers).
    - ✓ Animals, fungi, most bacteria
  - *The **sun** is the ultimate source of energy for nearly all life on Earth.* Organisms that cannot photosynthesize depend on photosynthetic life-forms for food, either directly or indirectly.



Flow of energy through an ecosystem.

Flow of Energy Through an Ecosystem

- **Producers** transform the sun's energy to chemical energy by means of photosynthesis. Nutrients are then transferred from producer to **consumers** (organisms, such as animals, that feed on producers and other consumers) and from consumer to consumer.
- **Decomposers** such as fungi break down the organic molecules of dead or decaying matter, making these nutrients available for reuse.
- Some energy is "lost" as heat, thereby becoming unavailable to the ecosystem to do work; therefore, organisms need a constant input of energy to perform the activities of life.

Organisms Have Metabolism: *They Acquire and Process Nutrients and Energy*

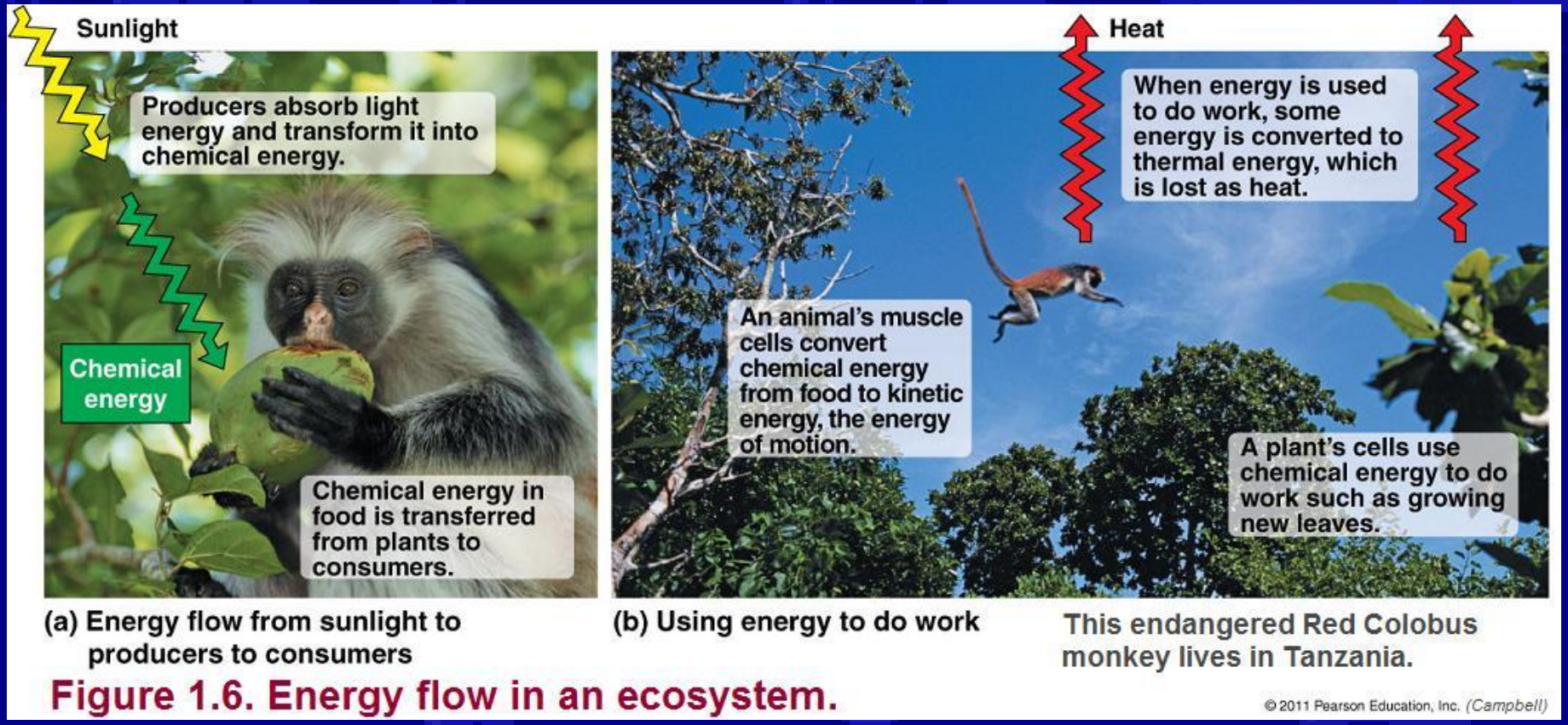


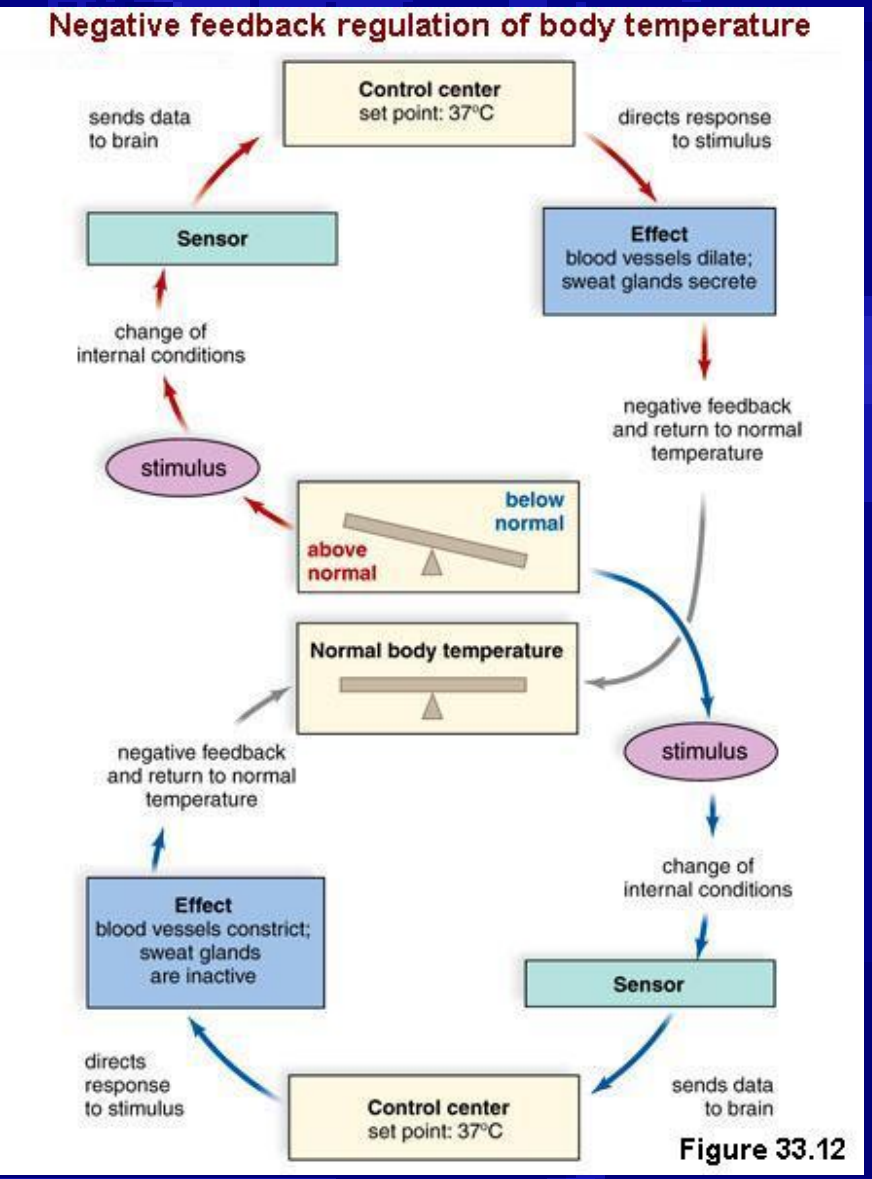
Figure 1.6. Energy flow in an ecosystem.

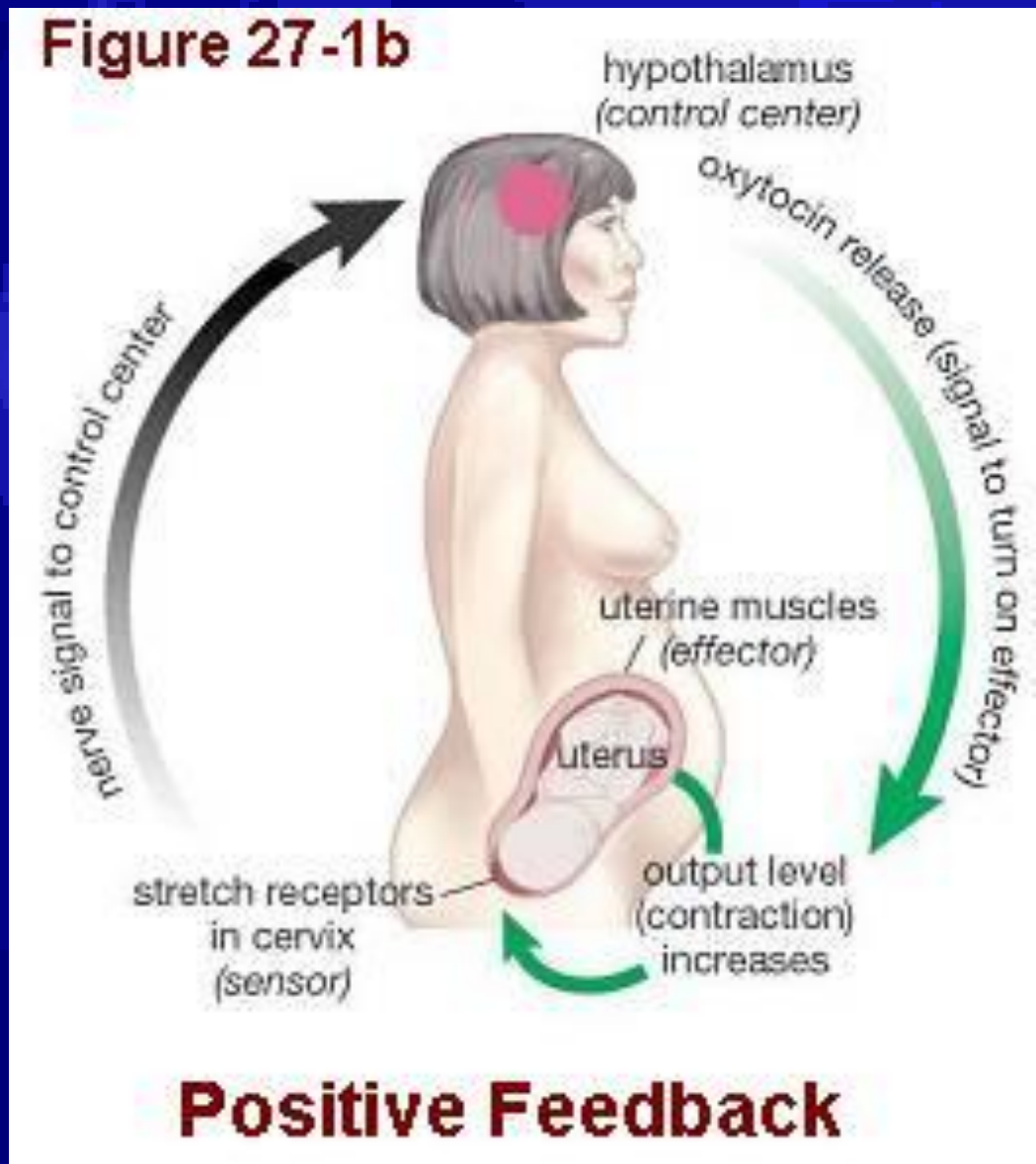
- A fundamental characteristic of living organisms is their use of energy to carry out life's activities. Moving, growing, reproducing, and the other activities of life are work, and work requires energy. Organisms transform one form of energy to another.

Organisms Maintain Homeostasis Through Regulation Mechanisms

- **Homeostasis ("steady state")** *(homeo* = unchanging + *stasis* = standing)*:* The condition of equilibrium, or maintenance of normal internal conditions in a cell or organism through **self-regulating mechanisms**; a state of biological balance.
- Homeostasis is maintained by mechanisms or **feedback systems** that monitor internal conditions and make routine and necessary adjustments.
  - Blood pressure, body fluid composition and volume, body temperature, and other physiological factors must remain within the tolerance range of the organism.
- **Negative feedback:** Mechanism of response that **reduces** ("damps") an initial stimulus or change, and restablishes the original state.
- **Positive feedback:** Mechanism of response that **amplifies** a stimulus or change (so it will end faster).

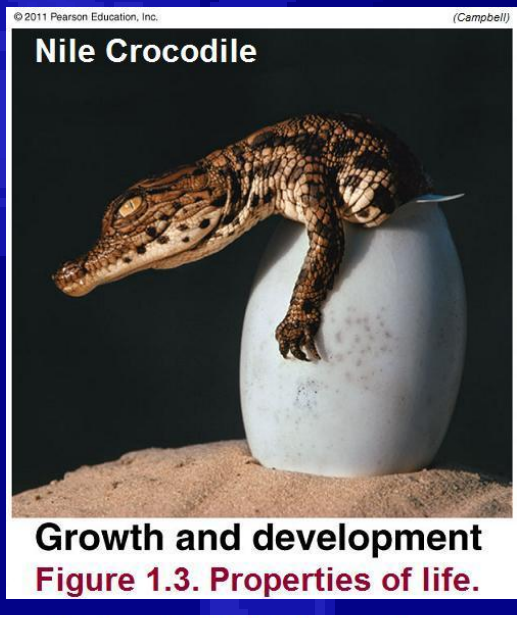
Organisms Maintain Homeostasis Through Regulation Mechanisms

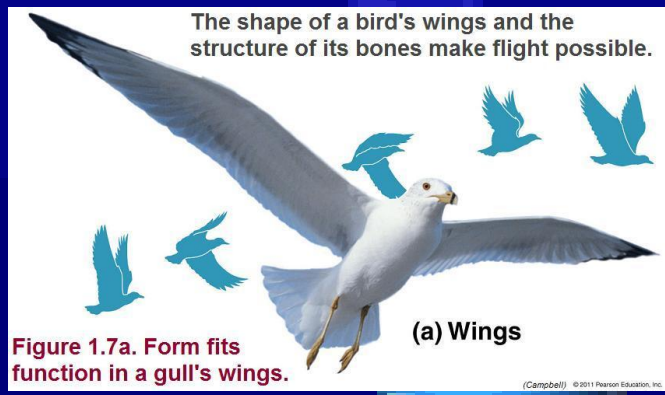




Organisms Grow and Develop

- **Growth** means increase in **size** of an organism, or increase in **number of cells**.
- In some organisms, growth is obvious (plants, animals); in others, such as bacteria, growth is not so obvious because they increase mainly in number.
- Growth involves the conversion of materials acquired from the environment into the specific molecules of the organism's body.
- Organisms have a **life cycle** with developmental stages. Inherited information carried by genes controls the pattern of growth and development of organisms.
- **Form fits function:** The way a component of an organism works is correlated with its structure.

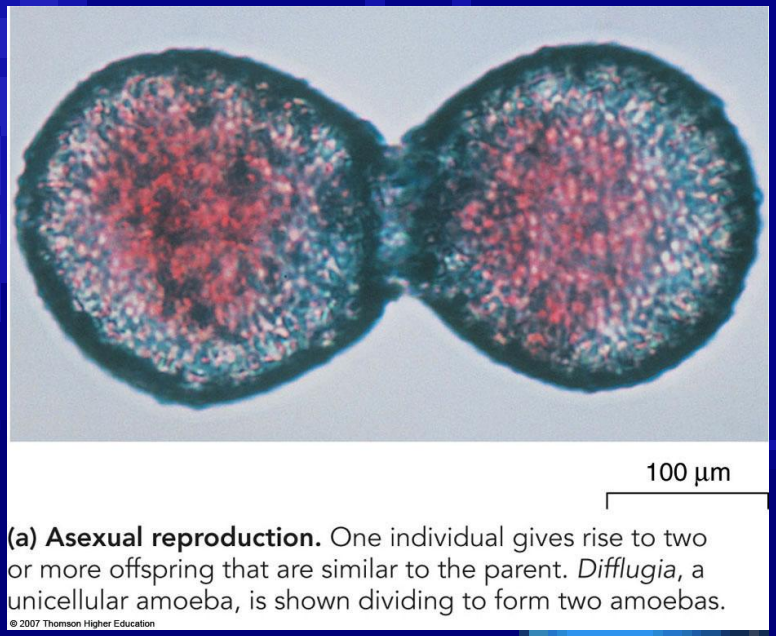




Organisms Reproduce Themselves: *The Continuity of Life*

- Organisms reproduce, giving rise to **offspring** (descendants) of the same type.
- Reproduction can occur ***sexually*** or ***asexually*** and results in:
  - ***Continuity*** of life.
  - ***Perpetuation*** of the parents' genetic material.
  - ***Diversity*** of life through recombination of genetic material.

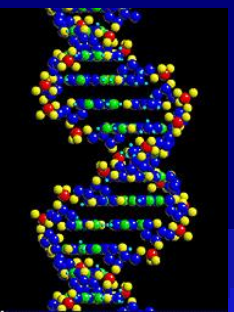
FIGURE 1.4 - Rockhopper penguins penguins with their offspring.



(a) Asexual reproduction. One individual gives rise to two or more offspring that are similar to the parent. *Difflugia*, a unicellular amoeba, is shown dividing to form two amoebas.

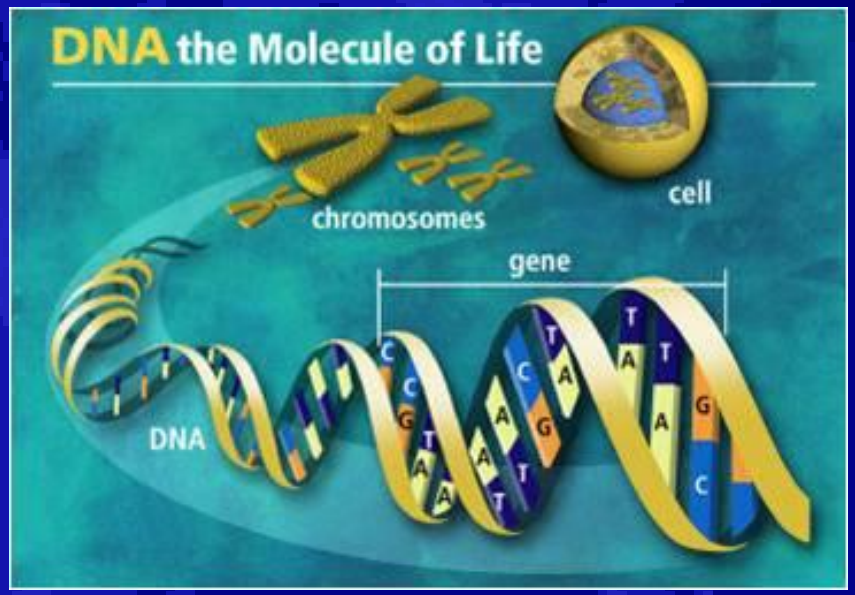
Organisms Reproduce Themselves: *Information Transfer – DNA, The Basis of Inheritance*

- Organisms transmit information chemically, electrically, and behaviorally.
  - **DNA** (deoxyribonucleic acid), which makes up the **genes**, is the **hereditary** material.
  - ***Information encoded in DNA is transmitted from one generation to the next.*** DNA contains the instructions for the development of an organism and for carrying out life processes.
  - DNA codes for **proteins**, large molecules that are important in determining the structure and function of cells and tissues.



Organisms Reproduce Themselves: *DNA, The Basis of Inheritance*

- All living things possess biological information that directs their structure and function. This biological information is the hereditary material: genes, or **DNA**.
- **Genes** are segments of **DNA (deoxyribonucleic acid)**, the molecule of heredity contained in the cellular structures called **chromosomes**.
- When an organism reproduces, it passes a copy of its DNA to its offspring. DNA is the hereditary blueprint for life.



- **DNA** is made up of molecules called nucleotides. There are 4 types of nucleotides named according to their *"nitrogenous bases":* adenine (A), thymine (T), cytosine (C), and guanine (G).

Organisms Reproduce Themselves: *DNA, The Basis of Inheritance*

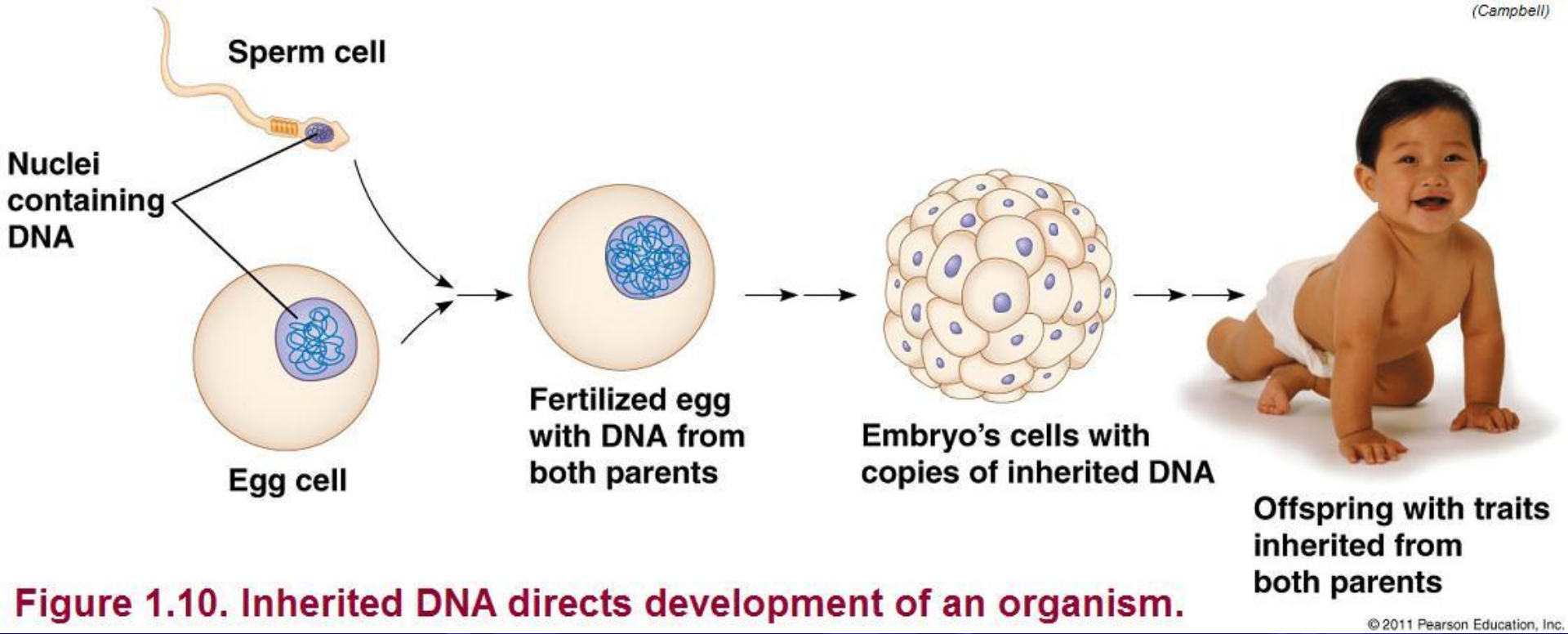


Figure 1.10. Inherited DNA directs development of an organism.

- Each of us began life as a single cell stocked with **DNA** inherited from our parents. Replication of that DNA transmitted those genes to our trillions of cells. In each cell, the genes along the length of DNA molecules encode the information for building the cell's other molecules. In this way, DNA directs the development and maintenance of the entire organism and, indirectly, everything it does. The DNA serves as a central database.

The Continuity of Life:
Information Transfer – DNA and Other Molecules

- **Cell signaling:** Cells use proteins and many other types of molecules to communicate with one another.
  - **Proteins** are large molecules important in determining the structure and function of cells and tissues. Proteins include **hormones**, chemical messengers that transmit messages from one part of an organism to another and are an important type of cell signaling.
- Many organisms have nervous systems that send **electrical signals (impulses)** to transmit information.
  - **Neurotransmitters** are chemical compounds sent by the nervous system to transmit information.

The Core Theme:
Evolution Accounts for the Unity and Diversity of Life

- **The Theory of Evolution:** The descent of organisms from common ancestors (preexisting life forms) with the development of **modifications** over time that make them more **suited (or adapted) to the environment**. Evolution is **"descent with modification"**.
  - This idea came into sharp focus with the work of **Charles Darwin** in the nineteenth century.
- Strictly speaking, the term evolution refers to ***genetic changes*** in organisms in a population that occur over the course of generations (over a long time).

The Basic Unifying Concept of Biology: *Evolution Accounts for the Unity and Diversity of Life*

- Charles Darwin (1809-82)
  - English naturalist who is credited with bringing the **theory of evolution by natural selection** into the mainstream of modern science.
  - Other scientists before Darwin had hypothesized that species could change over time, but Darwin saw hot the pieces of the puzze fit together.
  - Darwin went on a trip around the Southern Hemisphere aboard the ship **HMS *Beagle*** (1831-36). During the trip and later over the course of 20 years, he gathered enough evidence to support evolution.
  - 1859 – Darwin published ***On the Origin of Species by Means of Natural Selection***, explaining his hypotheses and evidence.

FIGURE 17.2 - Charles Darwin (1809-82)

Evolution Accounts for the Unity and Diversity of Life

- The main force in evolution is natural selection.
  - **Natural selection** is the process by which **organisms with favorable *adaptations* (modifications) survive and reproduce more successfully** than do others that lack those traits. Adaptive traits arising from genetic mutation are passed on to the next generation.
  - **Darwin** called the mechanism of evolutionary adaptation "***natural selection***" because the natural environment "selects" for the propagation of certain traits. In that way, certain characteristics become more common among a population of organisms.
    - ✓ Each species has its own unique, evolved solutions to life's challenges, such as how to acquire nutrients, find a mate, and reproduce.

Evolution Accounts for the Unity and Diversity of Life

- Organisms evolve and become ***adapted*** to the environment.
- **Adaptations** are modifications that make organisms suited to their way of life. Adaptations help an organism cope with the rigors of its environment; they improve the chances of survival and reproductive success of an organism in a given environment.
- Although the genetic makeup of a single organism remains essentially the same over its lifetime, the genetic composition of a species as a whole changes over many generations. Over time, mutations (genetic changes) and variable offspring create **diversity** in the genetic material of a species. In other words, the species ***evolve***.

Evolution Accounts for the Unity and Diversity of Life

- **"Descent with modification"** captures the duality of life's unity and diversity.
- Descent from a common ancestor (primitive cells on Earth) explains the **unity of life—**living things share a common chemistry and cellular structure because they are all descended from the same original source.
  - The structure and function of **DNA**, the genetic material, demonstrates the unity among all organisms.
- ***Adaptation*** to a particular environment explains the **diversity of life**.

Evolution Accounts for the Unity and Diversity of Life

FIGURE 1.19 - Unity and diversity in the orchid family.

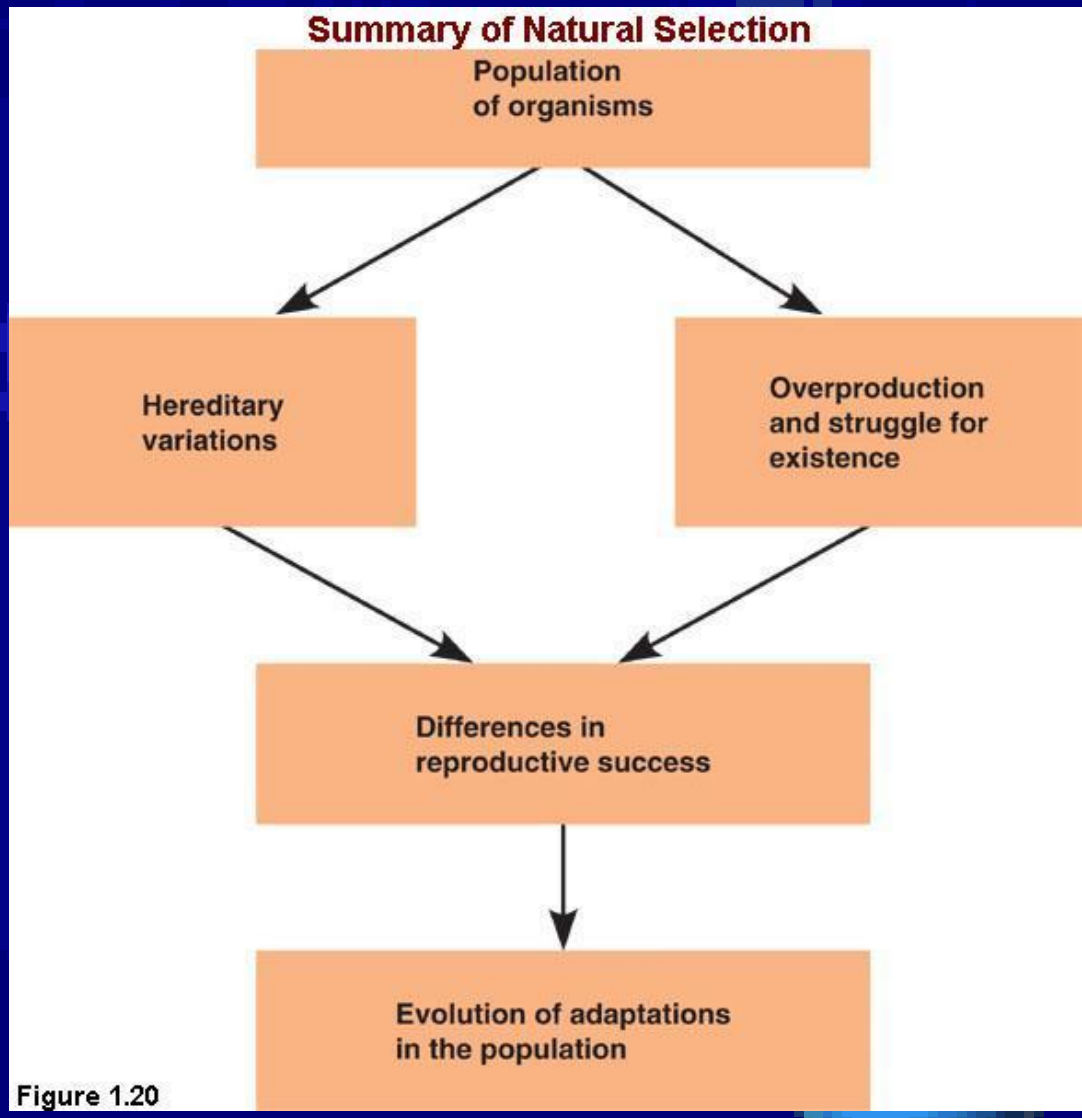
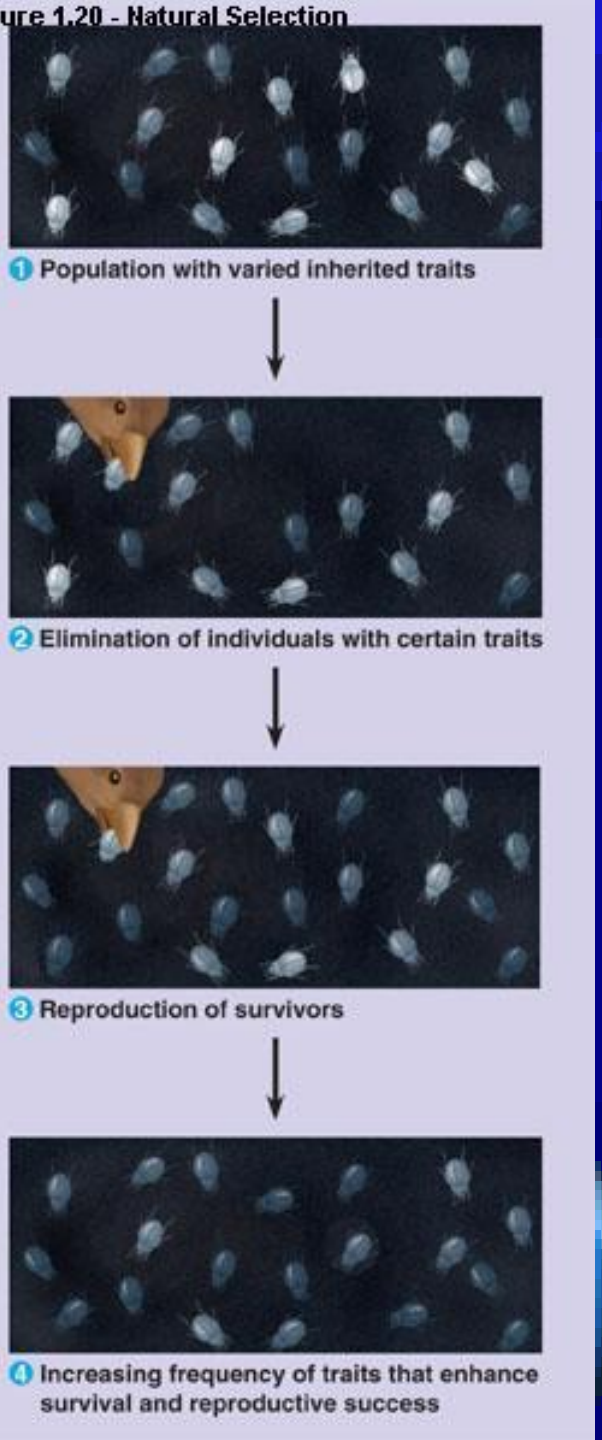


Figure 1.20

Evolution Accounts for the Unity and Diversity of Life

- Natural Selection
  - This imaginary beetle population has colonized a locale where the soil has been blackened by a recent brush fire. Initially, the population varies extensively in the inherited coloration of the individuals, from very light gray to charcoal. For hungry birds that pray on the beetles, it is easiest to spot the beetles that are lightest in color.
  - ***Individuals with certain traits will be eliminated; survivors will reproduce.*** **Traits that enhance survival and reproductive success will be increasingly frequent.**
  - It's **"survival of the fittest."**



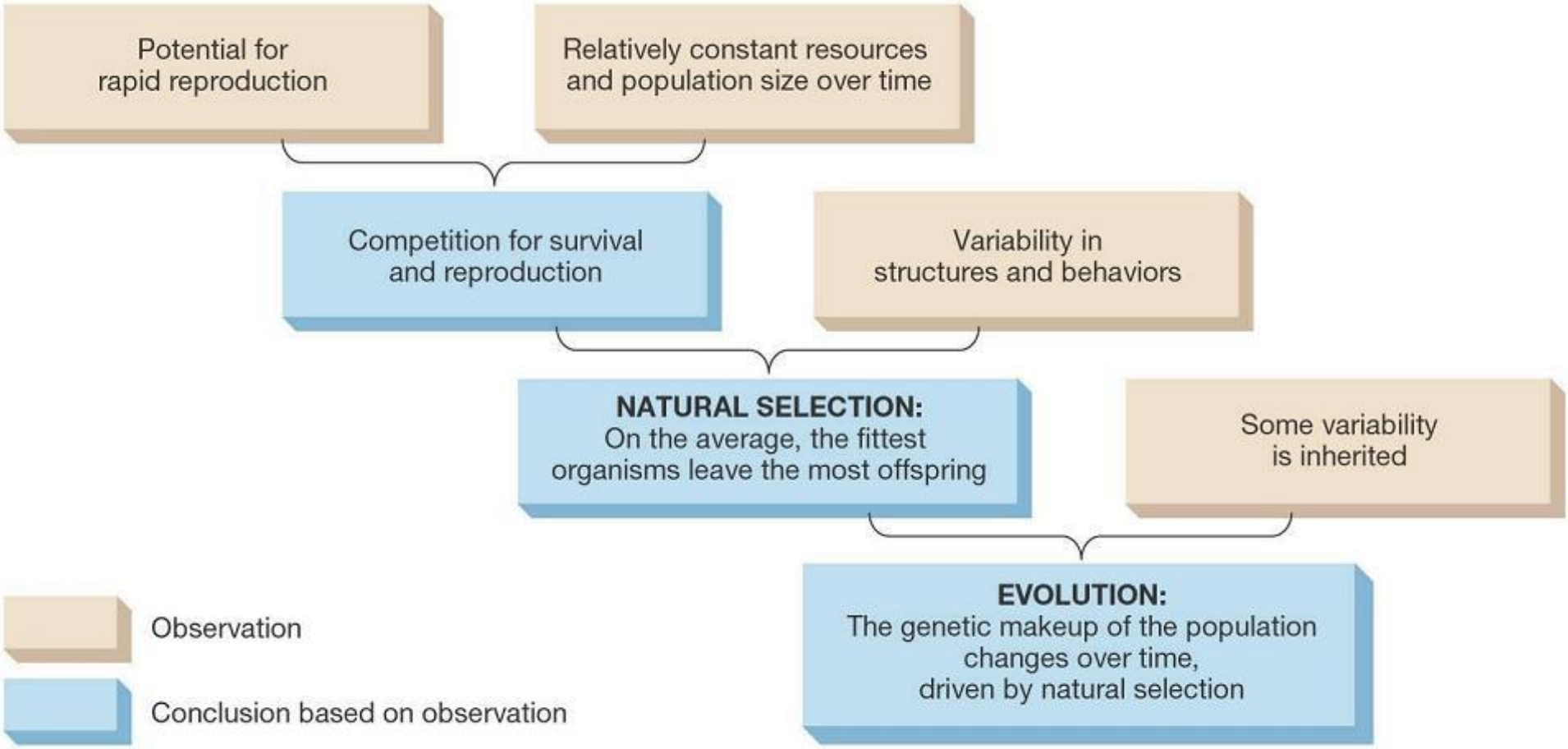


FIGURE 14-5. A flowchart of evolutionary reasoning.
This chart is based on the hypotheses of Darwin and Wallace but incorporates ideas from modern genetics.

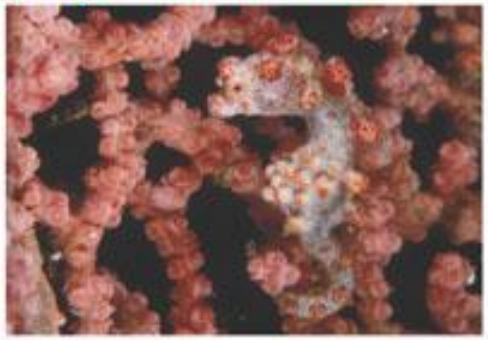
TABLE 1. SUMMARY OF CHARACTERISTICS OF LIFE

Organization (Order)	Living things are **structurally** and **functionally** organized (atoms → molecules → organelles → cells → tissues → organs → organ systems → organisms → populations → communities → ecosystems → biosphere).
Response to the Environment / Interaction	Living things **perceive** and **respond** to stimuli; they **interact** with one another and the environment, exchanging matter and energy.
Homeostasis / Regulation	Living things maintain a relatively stable internal environment (a state of biological balance) through regulatory mechanisms (**feedback mechanisms**).
Metabolism / Energy Processing	Living things acquire and process **nutrients** and **energy** for their metabolism (all the chemical reactions of the organism).
Growth and Development	Living things grow, they increase in **size or number of cells**, and they have a **life cycle** with developmental stages.
Reproduction	Living things reproduce themselves, passing **genetic material (DNA)** to their offspring. Reproduction results in the **continuity** and **diversity** of life.
Evolutionary Adaptation	Living things **evolve to adapt to their changing environment** and therefore be more successful.

Figure 1.3. Some properties of life.

(Campbell)

(a) **Order.** This close-up of a sunflower illustrates the highly ordered structure that characterizes life.



(b) **Evolutionary adaptation.** The appearance of this pygmy seahorse camouflages the animal in its environment. Such adaptations evolve over many generations by the reproductive success of those individuals with heritable traits that are best suited to their environments.

(c) **Response to the environment.** This Venus' flytrap closed its trap rapidly in response to the environmental stimulus of a dragonfly landing on the open trap.

(d) **Regulation.** The regulation of blood flow through the blood vessels of this jackrabbit's ears helps maintain a constant body temperature by adjusting heat exchange with the surrounding air.

(e) **Energy processing.** This hummingbird obtains fuel in the form of nectar from flowers. The hummingbird will use the chemical energy stored in its food to power flight and other work.

(g) **Reproduction.** Organisms (living things) reproduce their own kind. Here an emperor penguin protects its baby.

(f) **Growth and development.** Inherited information carried by genes controls the pattern of growth and development of organisms, such as this Nile crocodile.

CLASSIFICATION OF ORGANISMS
Basic Terms

Systematics	Scientific study of the diversity of organisms to **classify** them and determine their **evolutionary relationships**.
Phylogeny	**Evolutionary history** of a group of organisms (their evolutionary relationships). • Phylogeny is based on common ancestry inferred from shared characters, including structural, developmental, behavioral, and molecular similarities, as well as from fossil evidence.
Taxonomy	The science of identifying, describing, naming, and classifying organisms into categories. • **Nomenclature:** A system of names. • **Taxon** (plural: ***taxa***): A category used to classify organisms; e.g., domain, kingdom, phylum, etc.)

Why are phylogeny and taxonomy important?

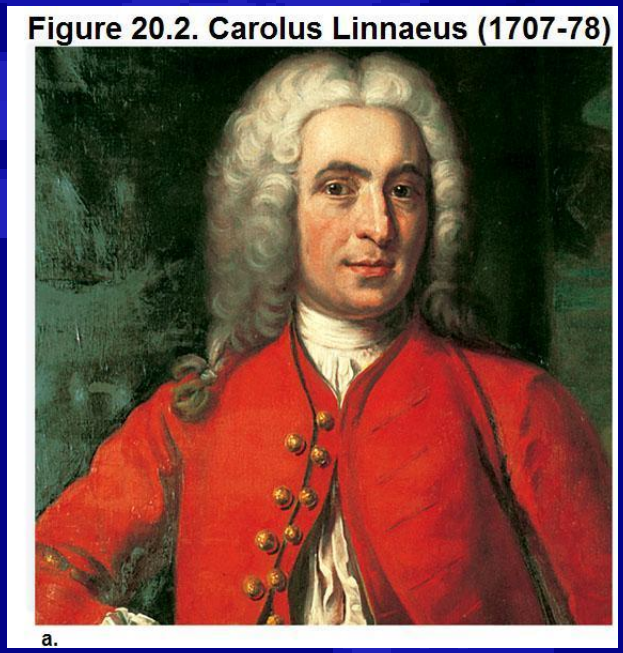
- Why do organisms need scientific names and classifications? Why study their evolutionary relationships?
  - Given the **great number and diversity of organisms**, taxonomy provides ***universal names*** for organisms: a **universal language** for effective communication between scientists. Scientific names are important because they allow biologists from different countries with different languages to communicate about organisms without confusion.
  - Classifications and phylogeny help biologists **organize and apply their knowledge**. Taxonomy provides a reference for identifying and placing organisms into categories or **taxa** (singular = *taxon*). Phylogeny provides much information about a species and its evolutionary history, hence, phylogenies are useful in a wide range of applications.

TAXONOMY: THE SCIENCE OF CLASSIFICATION

- **Taxonomy** uses the fundamental concepts of ***unity and diversity*** among living things.
  - **Unity:** Organisms classified in any particular group have certain common characteristics.
  - **Diversity:** Organisms within certain group also display variations in characteristics such as shape, size, abilities, and other.
- Taxonomy ***changes*** with evolutionary changes and new knowledge: the system must reflect our current knowledge.

Linnaeus, the Father of Taxonomy: **The Binomial Nomenclature System**

- **Carolus Linnaeus** (Carl von Linné; 1707-1778) founded the science of **taxonomy**—the ***classification of living beings***. He grouped organisms into a hierarchy of increasingly inclusive categories, or taxa (*singular*: taxon).
- He established the **binomial nomenclature system**, which gives organisms a scientific name of two parts (*binomial* = two names, *nomenclature* = naming).



Carolus Linnaeus is considered the father of taxonomy, the science of naming and classifying organisms.

TAXONOMY: CLASSIFICATION OF ORGANISMS

- **Binomial Nomenclature System** (Binomial Name or Scientific Nomenclature System):
  - Assigns a two-part scientific name for each organism.
    1) **Genus** (*plural* = genera): First part of the name; it is capitalized (first letter is uppercase).
    2) **Specific epithet,** or **species** (*plural*: species)**:** Second part of the name; it is not capitalized (all letters are lowercase).
  - **Scientific names:**
    - ✓ Are written in ***italics*** or underlined.
    - ✓ Are generally derived from **Latin** or **Greek** language roots and used worldwide.
    - ✓ May be **descriptive** of the organism, or honor a scientist, or identify the habitat of the organism.

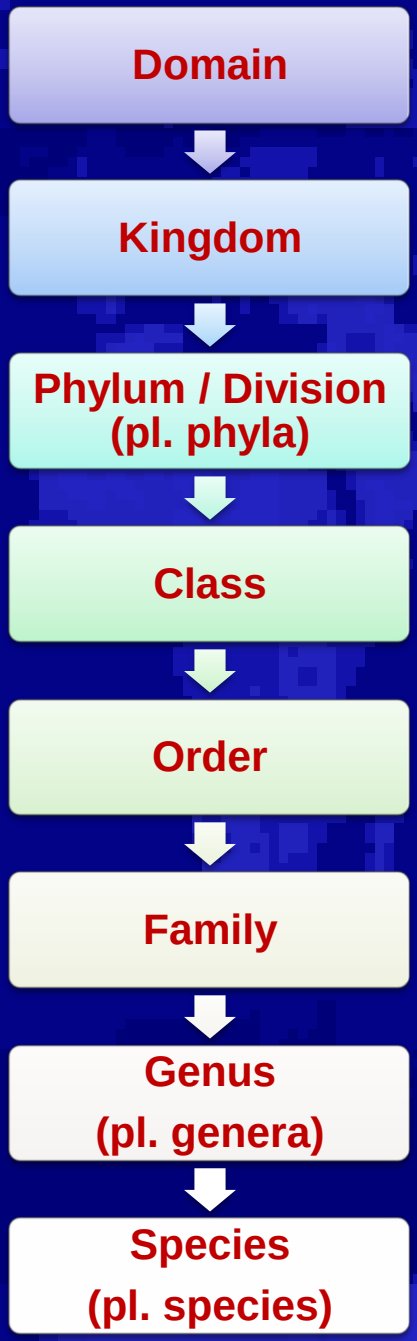
Binomial Nomenclature: *Examples of Scientific Names*

ORGANISM	GENUS (First letter is uppercase)	SPECIFIC EPITHET (SPECIES) (All in lowercase)
Homo sapiens (the human) 	***Homo*** = man	***sapiens*** = wise or knowledgeable
Rhizopus nigricans (a mold, a type of microscopic fungus) 	***Rhizo*** = root (describes the root-like structures of the fungus)	***nigricans*** = black (describes the color of the fungal spore sacs)

***** Both parts of the name are written in *italics* or <u>underlined</u> and arise from the Latin or Greek language.**

Classification of Organisms into Categories (Taxa): **The Linnaean System**

- Organisms are placed into categories, shown here from the **most inclusive** or comprehensive (containing more types of organisms) on top, to the **least inclusive** (with fewer organisms).
- **Each category includes all of the other categories below it.** For example, each domain contains a number of kingdoms, each kingdom contains a number of phyla, each phylum includes a number of classes, and so on.



- As we move **down** the hierarchy, groups are smaller and smaller; species is the narrowest.
- The organisms that fill a particular classification category are distinguishable from other organisms by **sharing a set of traits or characters**. Organisms in the same domain have general traits in common; those in the same species have quite specific traits in common.

Biological *species* concept: One or more populations whose members can **interbreed** in nature and produce fertile offspring, and do not interbreed with members of other species.

Classification of Organisms: Organizing the Diversity of Life

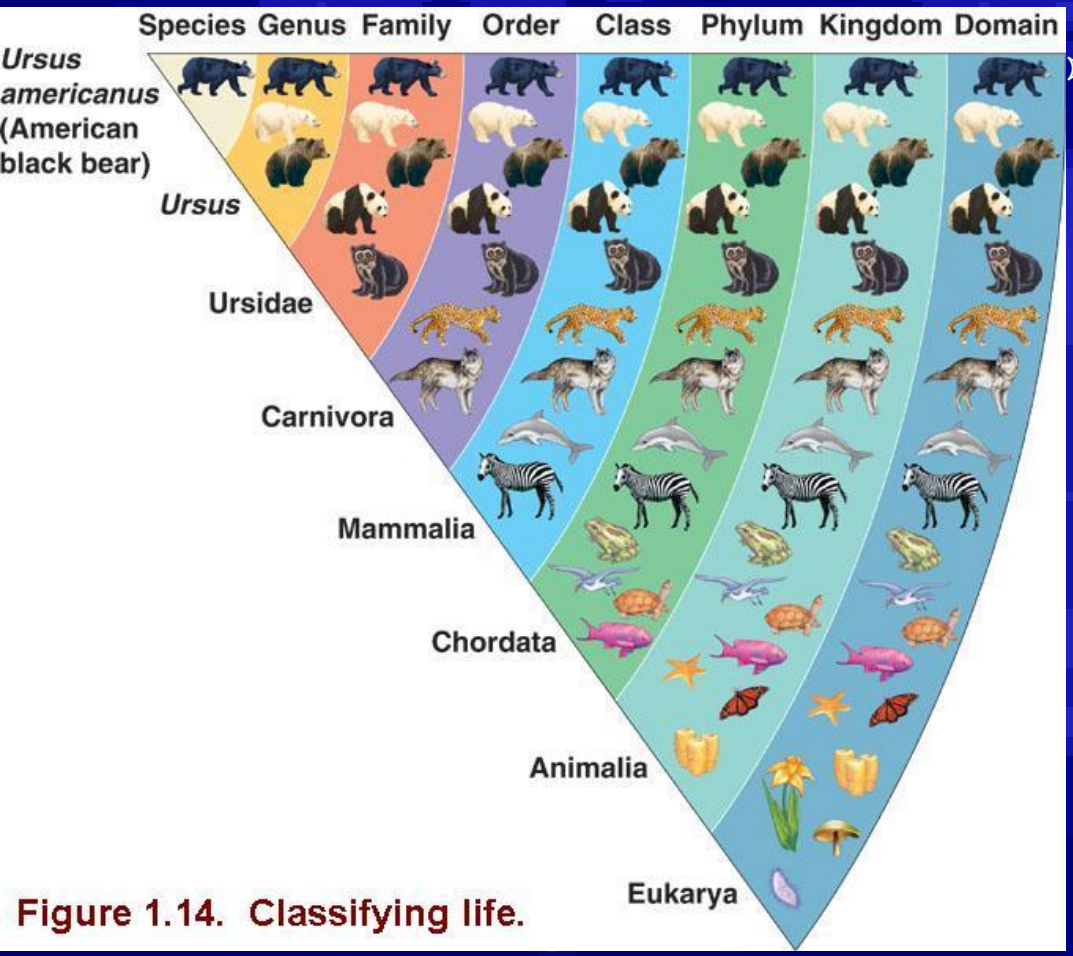


Figure 1.14. Classifying life.

- To help organize the diversity of life, biologists classify species into groups that are then combined into even broader groups. In the traditional **"Linnaean" system**, species that are very closely related such as polar bears and brown bears, are placed in the same genus; genera (plural) are grouped into families; and so on. This example classifies the species ***Ursus americanus***, the American black bear.

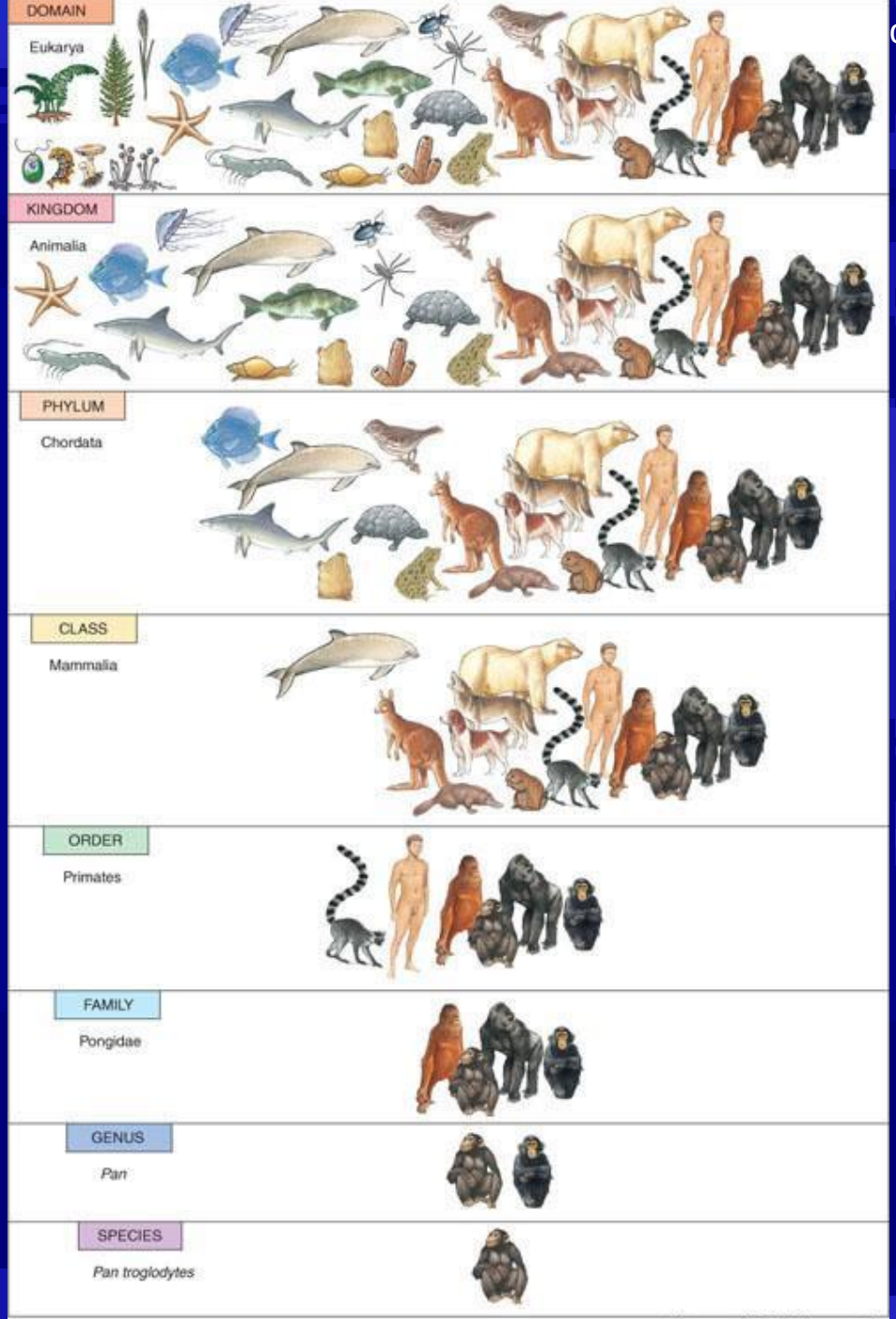
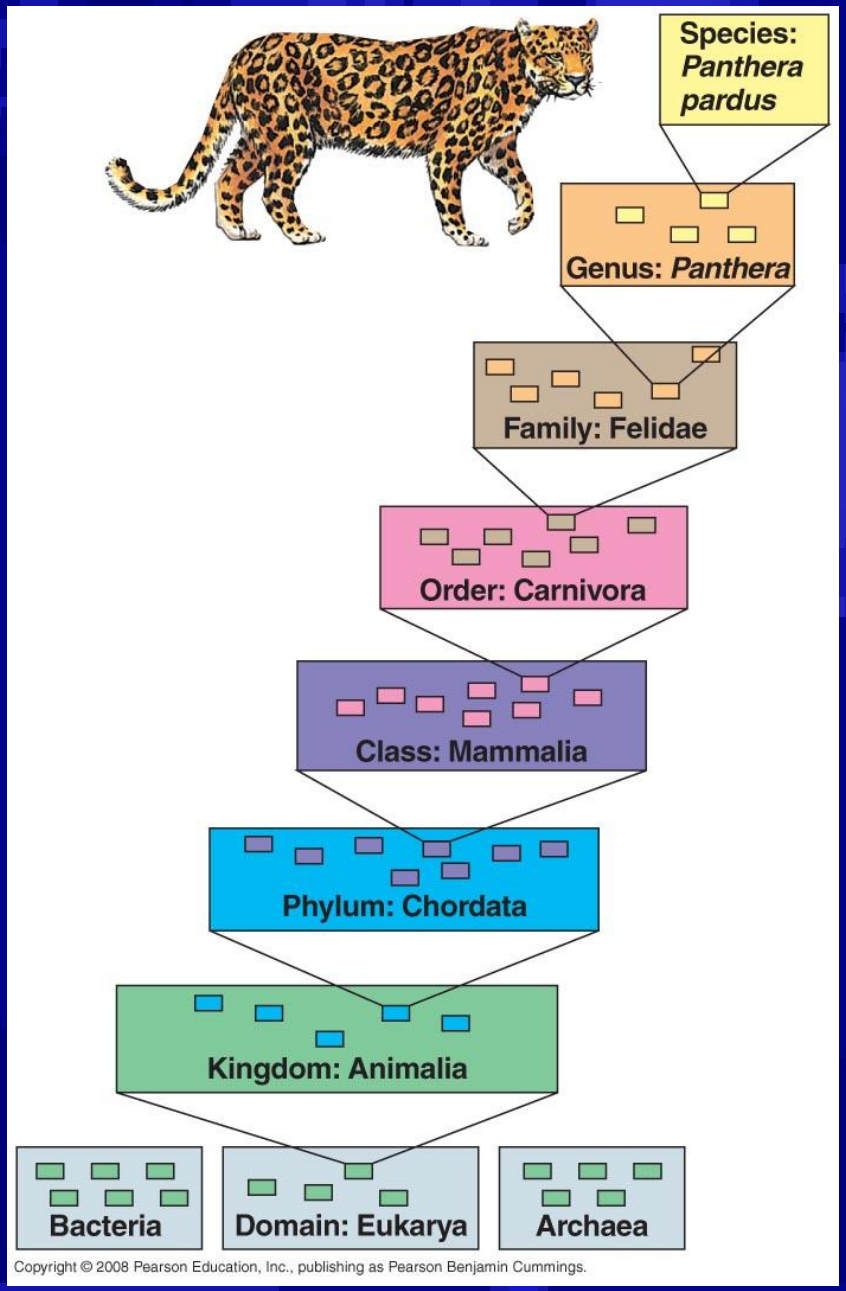


Figure 1.8 (Solomon)

Classification of Organisms

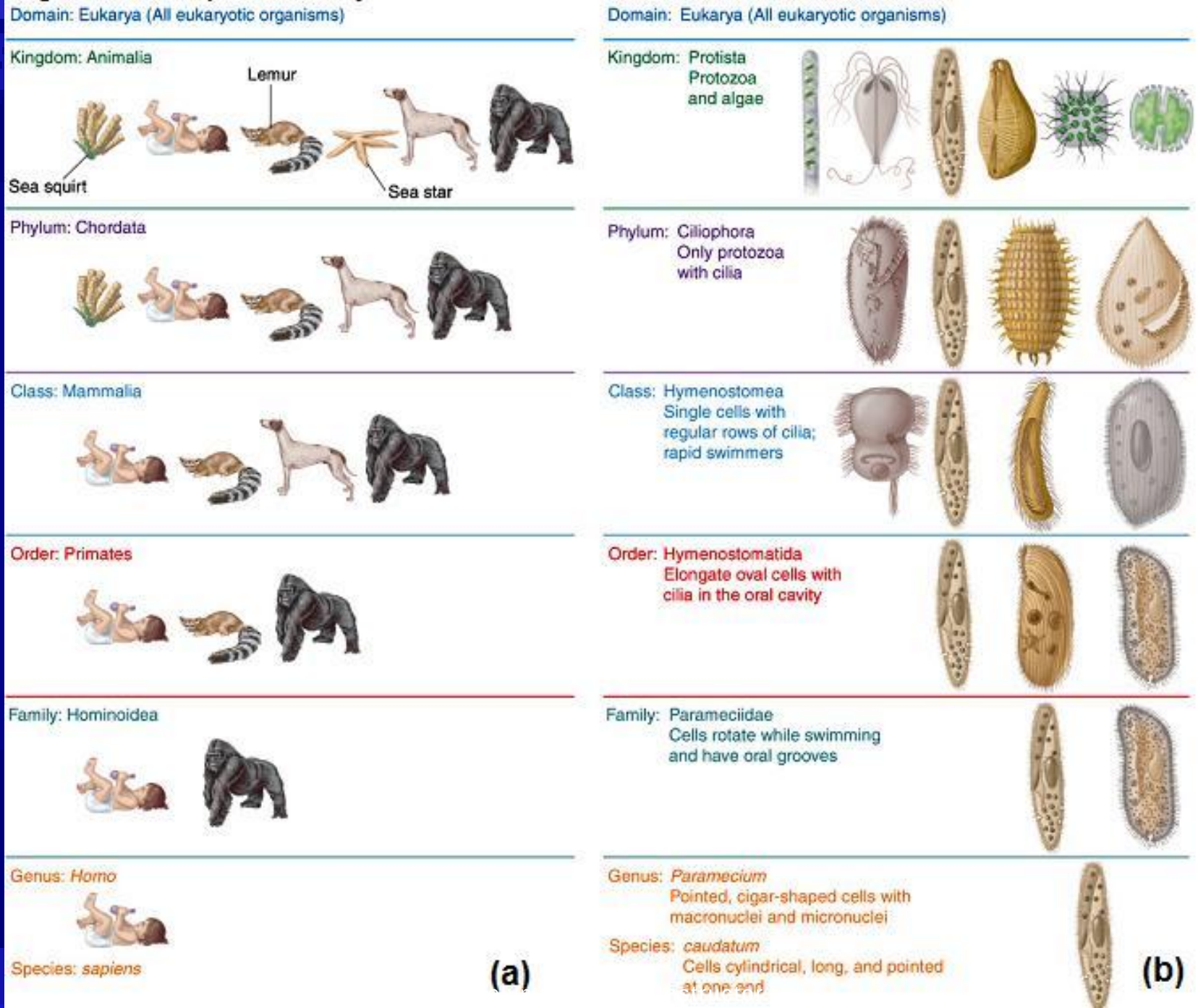
- Figure 1-8: **Classification of the chimpanzee** (scientific name: *Pan troglodytes*).
- Biologists use a hierarchical classification scheme with a series of taxonomic categories from species to domain.
- Each category is more general and more inclusive than the one below it.



TAXONOMY: Classification of Organisms

- At each level of the **Linnaean classification system**, species are placed into groups belonging to more comprehensive groups.
- Species that appear to be closely related are grouped into the same genus. For example, the leopard (*Panthera pardus*) belongs to a genus that also includes the African lion (*Panthera leo*), the tiger (*Panthera tigris*) and the jaguar (*Panthera onca*).

Figure 1.12. Sample Taxonomy.



TAXONOMY: **Classification of Organisms**

Table 18-1 Classification of Selected Organisms, Reflecting Their Degree of Relatedness

	Human	Chimpanzee	Wolf	Fruit Fly	Sequoia Tree	Sunflower
Domain	**Eukarya**	**Eukarya**	**Eukarya**	**Eukarya**	**Eukarya**	**Eukarya**
Kingdom	**Animalia**	**Animalia**	**Animalia**	**Animalia**	**Plantae**	**Plantae**
Phylum	**Chordata**	**Chordata**	**Chordata**	Arthropoda	Coniferophyta	Anthophyta
Class	**Mammalia**	**Mammalia**	**Mammalia**	Insecta	Coniferosida	Dicotyledoneae
Order	**Primates**	**Primates**	Carnivora	Diptera	Coniferales	Asterales
Family	Hominidae	Pongidae	Canidae	Drosophilidae	Taxodiaceae	Asteraceae
Genus	*Homo*	*Pan*	*Canis*	*Drosophila*	*Sequoiadendron*	*Helianthus*
Species	*sapiens*	*troglodytes*	*lupus*	*melanogaster*	*giganteum*	*annuus*

*Boldface categories are those that are shared by more than one of the organisms classified.
Genus and species names are always italicized or underlined.

Scientific Classification of The Human Being

TABLE 20.1

Hierarchy of the Taxa to Which Humans Are Assigned

Domain Eukarya	Organisms whose cells have a membrane-bounded nucleus
Kingdom Animalia	Usually motile, multicellular organisms, without cell walls or chlorophyll; usually, internal cavity for digestion of nutrients
Phylum Chordata	Organisms that at one time in their life history have a dorsal hollow nerve cord, a notochord, pharyngeal pouches, and a postanal tail
Class Mammalia	Warm-blooded vertebrates possessing mammary glands; body more or less covered with hair; well-developed brain
Order Primates	Good brain development, opposable thumb and sometimes big toe; lacking claws, scales, horns, and hoofs
Family Hominidae	Limb anatomy suitable for upright stance and bipedal locomotion
Genus *Homo*	Maximum brain development, especially in regard to particular portions; hand anatomy suitable to the making of tools
Species *Homo sapiens**	Body proportions of modern humans; speech centers of brain well developed

* *To specify an organism, you must use the full name, such as* Homo sapiens.

THE THREE-DOMAIN CLASSIFICATION SYSTEM

- Devised by **Dr. Carl Woese** during the 1970s, this system recognizes three groups or **domains** of organisms based primarily on ***type of cells*** and ***molecular*** characteristics.

1) Archaea (previously Archaeabacteria)

- Unicellular, microscopic, **prokaryotic** organisms (without a true nucleus) that are found even in extreme environments; they **do not** have a compound called *peptidoglycan* in their cell walls.

2) Bacteria (previously Eubacteria)

- ✓ Unicellular, microscopic, **prokaryotic** organisms; cell walls composed of **peptidoglycan**. They differ from archaea in biochemical and physiological characteristics.

3) Eukarya

- Unicellular and multicellular **eukaryotic** organisms (their cells have a true nucleus).
- **Animals, fungi, plants, protists.**

THE THREE-DOMAIN CLASSIFICATION SYSTEM

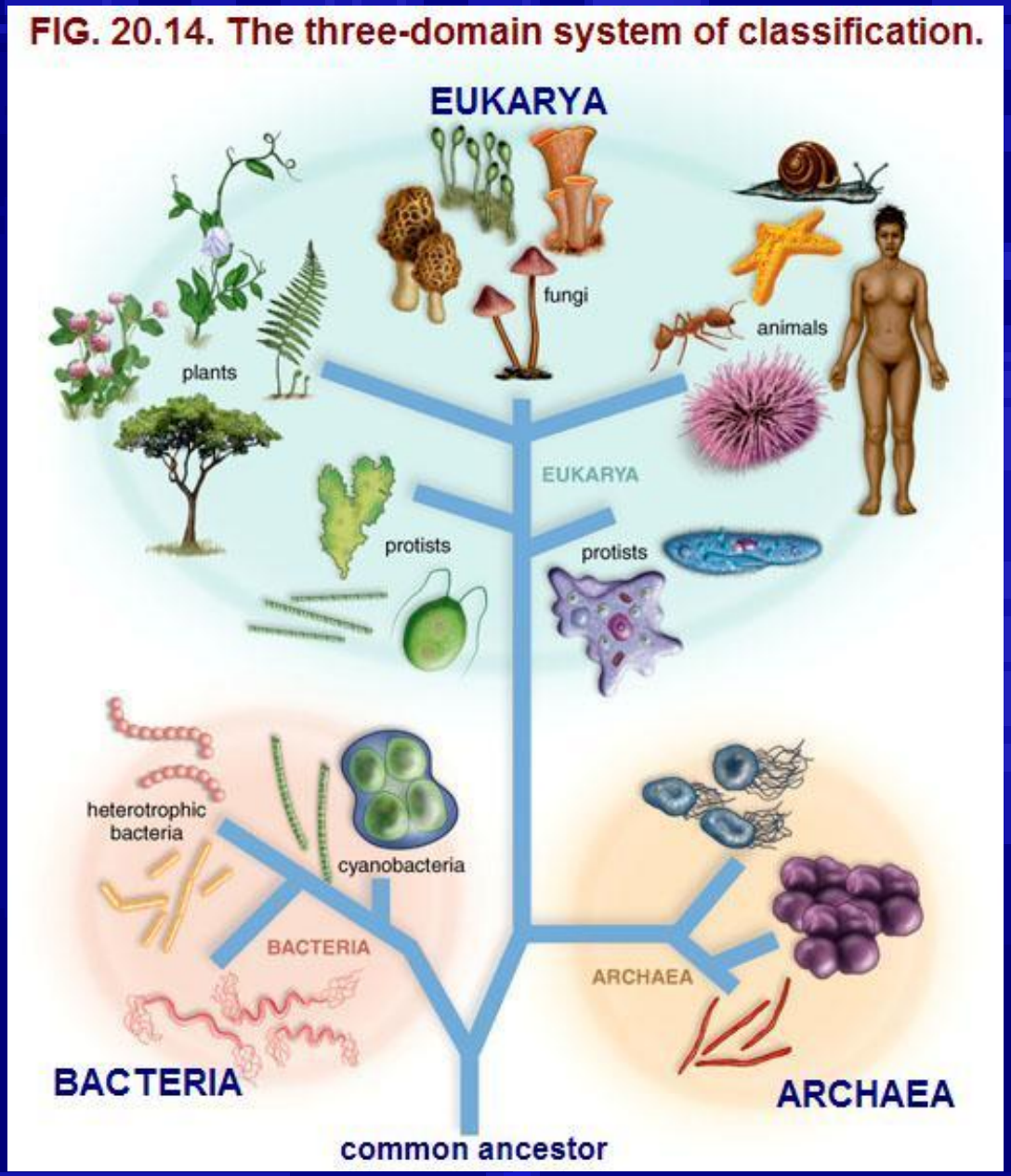
(Mader, 10th Ed.)

TABLE 19.2

Major Distinctions Among the Three Domains of Life

	Bacteria	*Archaea*	*Eukarya*
Unicellularity	Yes	Yes	Some, many multicellular
Membrane lipids	Phospholipids, unbranched	Varied branched lipids	Phospholipids, unbranched
Cell wall	Yes (contains peptidoglycan)	Yes (no peptidoglycan)	Some yes, some no
Nucleus	No	No	Yes
Membrane-bounded organelles	No	No	Yes
Ribosomes	Yes	Yes	Yes
Introns	No	Some	Yes

- **Lipids:** A group of biological molecules that mix poorly, if at all, with water.
- **Cell wall:** A protective layer external to the cell membrane in the cells of plants, prokaryotes (bacteria and archaea), fungi, and some protists.
- **Nucleus:** An organelle of an eukaryotic cell that contains the genetic material in the form of chromosomes.
- **Organelles:** Membrane-enclosed structures with specialized functions, suspended inside eukaryotic cells.
- **Ribosomes:** A structure that functions as the site of protein synthesis in cells.
- **Introns:** Noncoding, intervening sequences of genes (DNA segments) that are removed during RNA processing (after synthesis of RNA from DNA). (RNA = ribonucleic acid).



THE THREE-DOMAIN CLASSIFICATION SYSTEM

- Representatives of each domain are depicted in the ovals, and the phylogenetic tree shows that domain Archaea is more closely related to domain Eukarya than either is to domain Bacteria.

The Traditional 5 Kingdom Classification System

- Before 1970, all forms of life were classified into two kingdoms: **Animalia** and **Plantae**.
- As scientists learned more about fungi and microorganisms, however, it became apparent that the two-kingdom system oversimplified evolutionary history.
- To help rectify this problem, **Robert H. Whittaker** proposed a **five-kingdom** classification 1969 that was eventually adopted by most biologists.
- Organisms were placed in these kingdoms according to the **type of cell** (prokaryotic or eukaryotic), **complexity** (unicellular or multicellular), and **type of nutrition**.
- ***** Note:** *The kingdom-level of classification is in a state of transition as systematists try to incorporate the latest information*.

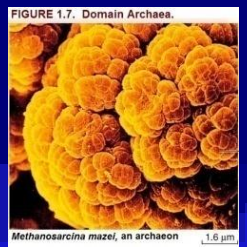
The Traditional 5 Kingdom Classification System

- The five kingdom system is based mainly on cell structure and the way that organisms derive nutrition from their environment (proposed by R. H. Whittaker in 1969).
- Originally, there were only two kingdoms: Animalia & Plantae.

1) **Monera or Prokaryotae =** Now **Domains Archaea & Bacteria**.
2) **Protista**
3) **Fungi**
4) **Plantae**
5) **Animalia**

Domain Eukarya

- ** Taxonomists are in the process of deciding how to categorize **archaea**, **bacteria**, and **protists** into more kingdoms*.



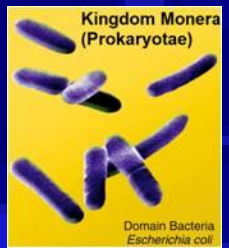
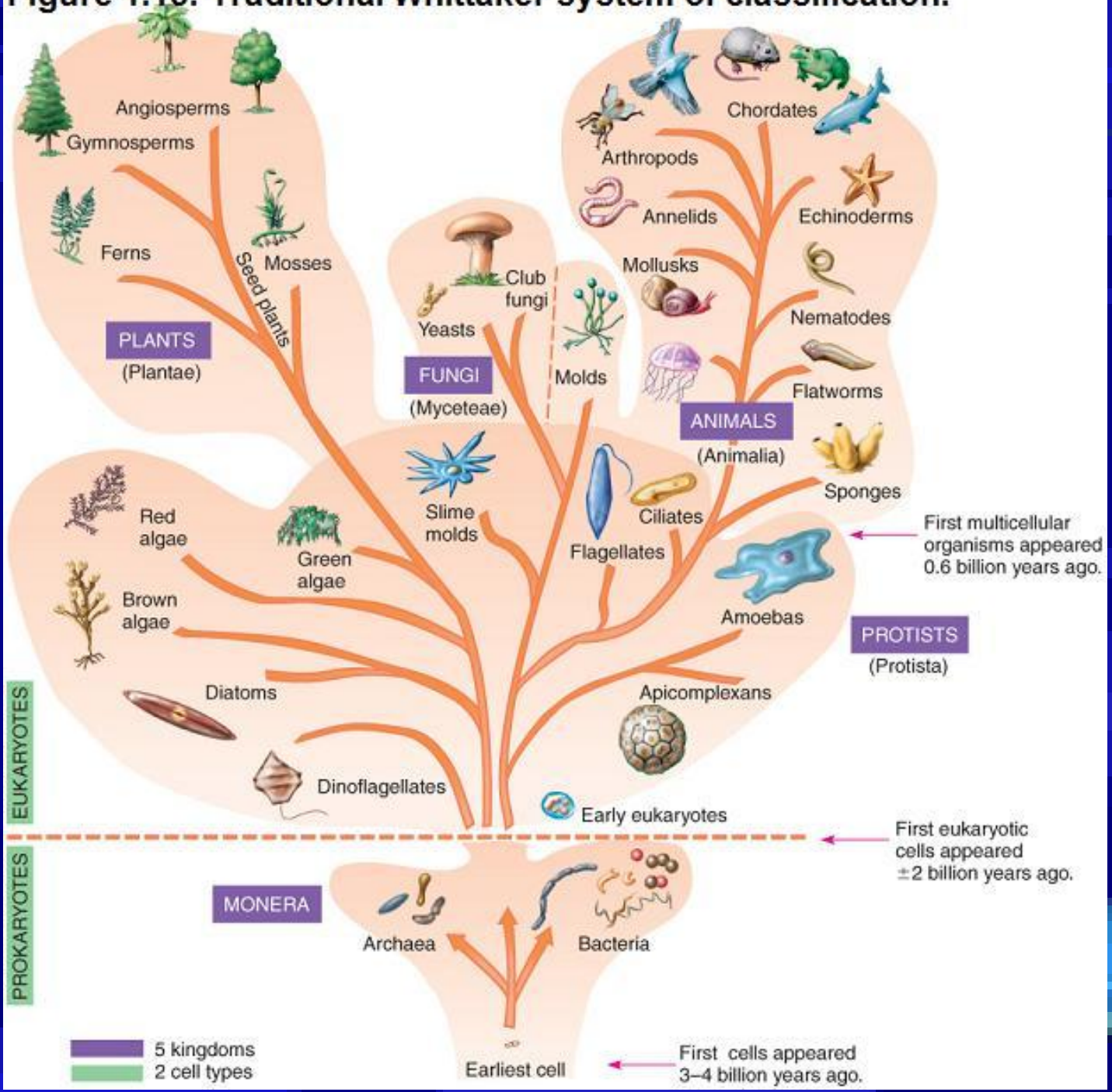
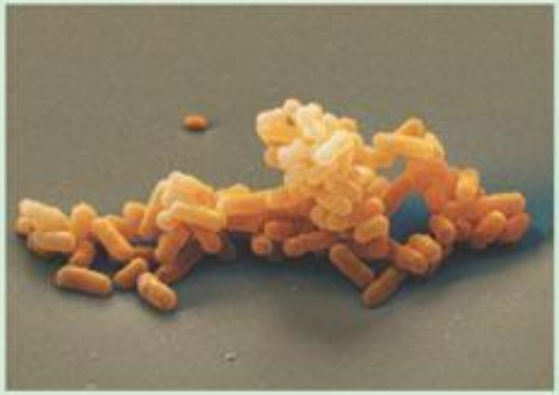


Figure 1.13. Traditional Whittaker system of classification.



DOMAIN BACTERIA

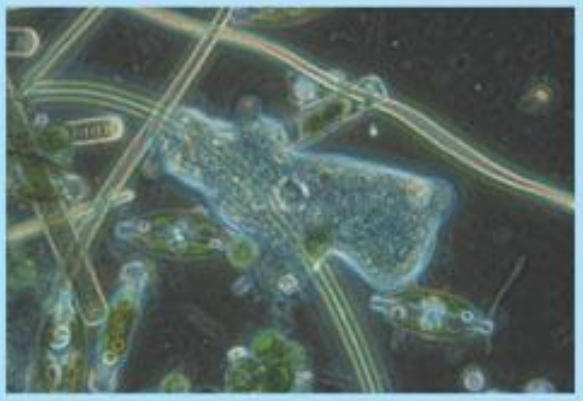


Bacteria are the most diverse and widespread prokaryotes and are now divided among multiple kingdoms. Each of the rod-shaped structures in this photo is a bacterial cell. 4 μm

DOMAIN ARCHAEA

Many of the prokaryotes known as **archaea** live in Earth's extreme environments, such as salty lakes and boiling hot springs. Domain Archaea includes multiple kingdoms. The photo shows a colony composed of many cells. 0.5 μm

DOMAIN EUKARYA



Protists (multiple kingdoms) are unicellular eukaryotes and their relatively simple multicellular relatives. Pictured here is an assortment of protists inhabiting pond water. Scientists are currently debating how to split the protists into several kingdoms that better represent evolution and diversity. 100 μm

Kingdom Plantae consists of multicellular eukaryotes that carry out photosynthesis, the conversion of light energy to food.

Kindom Fungi is defined in part by the nutritional mode of its members, such as this mushroom, which absorb nutrients after decomposing organic material.

Kindom Animalia consists of multicellular eukaryotes that ingest other organisms.

Figure 1.15. The three domains of life.

Classification of Organisms: **Domains and Kingdoms**

DOMAIN ARCHAEA

FIGURE 1.7. Domain Archaea.

Methanosarcina mazei, **an archaeon**

DOMAIN BACTERIA

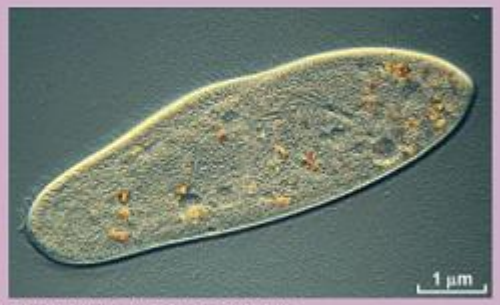
FIGURE 1.8. Domain Bacteria.

Escherichia coli, **a bacterium**

FIGURE 1.9. The four kingdoms in domain Eukarya.

DOMAIN EUKARYA

KINGDOM PROTISTA (protists)



Paramecium, a unicellular organism

- Algae, protozoans, slime molds, and water molds
- Complex single cell (sometimes filaments, colonies, or even multicellular)
- Absorb, photosynthesize, or ingest food

KINGDOM PLANTAE (plants)

Passiflora, passion flower, a flowering plant

- Mosses, ferns, conifers, and flowering plants (both woody and nonwoody)
- Multicellular with specialized tissues containing complex cells
- Photosynthesize food

KINGDOM FUNGI

Coprinus, a shaggy mane mushroom

- Molds, mushrooms, yeasts, and ringworms
- Mostly multicellular fillaments with specialized, complex cells
- Absorb food

KINGDOM ANIMALIA (animals)

Vulpes, a red fox

- Sponges, worms, insects, fishes, frogs, turtles, birds, and mammals
- Multicellular with specialized tissues containing complex cells
- Ingest food

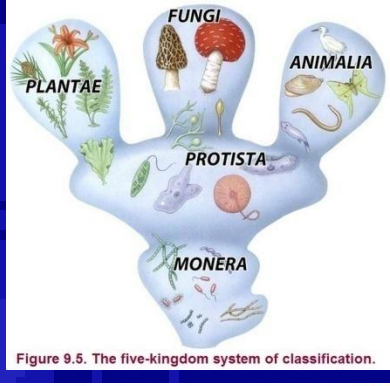


Figure 9.5. The five-kingdom system of classification.

CLASSIFICATION OF ORGANISMS:
Domains and Kingdoms

TABLE 20.4

Classification Criteria for the Three Domains

	Domains Bacteria and Archaea	*Domain Eukarya*			
		Kingdom Protista	***Kingdom Fungi***	***Kingdom Plantae***	***Kingdom Animalia***
Type of cell	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Complexity	Unicellular	Unicellular usual	Multicellular usual	Multicellular	Multicellular
Type of nutrition	Autotrophic or heterotrophic	Photosynthetic or heterotrophic by various means	Heterotrophic by absorption	Autotrophic by photosynthesis	Heterotrophic by ingestion
Motility	Sometimes by flagella	Sometimes by flagella (or cilia)	Nonmotile	Nonmotile	Motile by contractile fibers
Life cycle*	Asexual usual	Various life cycles	Haploid	Alternation of generations	Diploid
Internal protection of zygote	No	No	No	Yes	Yes

*See the Science Focus, Life Cycles Among the Algae, page 386

Classification of Organisms: **Kingdoms and Domains**

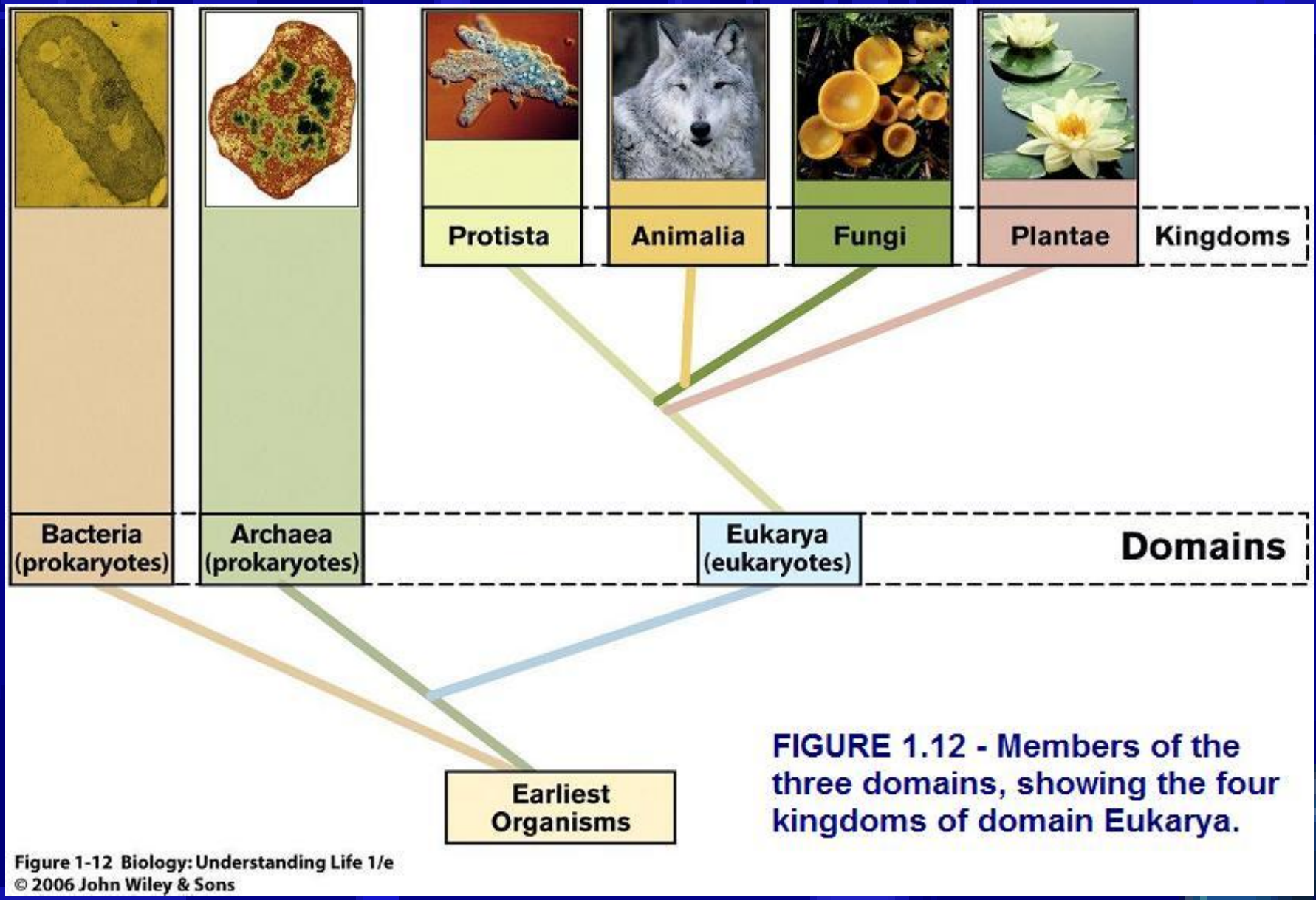


FIGURE 1.12 - Members of the three domains, showing the four kingdoms of domain Eukarya.

Figure 1-12 Biology: Understanding Life 1/e

Exploring life: How does one study biology?

- Reductionism and systems biology: we need both.
  - Biological systems are much more than the sum of their parts.
    - ✓ To understand how biological systems (cells, organisms, ecosystems) work, it is not enough to have a "parts list", even a complete one. The future of biology is in understanding the behavior of whole, integrated systems.
  - **Reductionism** involves *reducing complex systems to* ***simpler components*** that are more manageable to study. *To understand a whole organism, one must understand all its parts.*
  - **Systems biology:** A **system** is a combination of components that function together. **Systems biology** seeks to *create models of the dynamic behavior of whole biological systems based on a study of the interactions among the system's parts*. With such models, scientists will be able to predict how a change in one part of the system will affect the rest of the system.

Biology is a Science. Science is Inquiry.

- **Science** is derived from a Latin verb meaning **"to know"**. Science is the systematic study of the natural world.
- The heart of science is **inquiry**, a search for information and explanation, often focusing on specific questions.
- What elements does science include?
  - Challenge, adventure, luck, planning, reasoning, surprise, creativity, cooperation, competition, patience, persistence.
- We gather information by making observations using our senses. Recorded observations are called **data**.
  - **Qualitative data** are recorded descriptions.
  - **Quantitative data** are recorded measurements.

Discovery Science (Descriptive Science)

- **Discovery science** is the scientific inquiry that describes natural structures and processes as accurately as possible through careful observation and analysis of data.
- **Induction,** or **inductive reasoning,** is a type of logic used in discovery science.
  - We derive a **generalization** or **conclusion** based on specific observations; in other words, we go from **"specific to general".**
  - Example: ***"All organisms are made of cells."*** (the cell theory). This generalization was based on repeated observations for hundreds of years by many biologists.

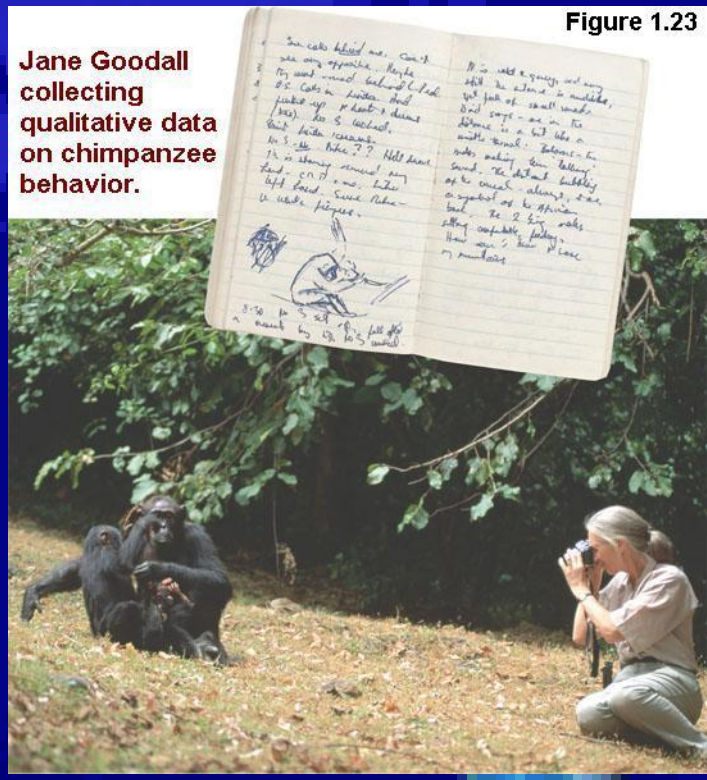


Figure 1.23
Jane Goodall collecting qualitative data on chimpanzee behavior.

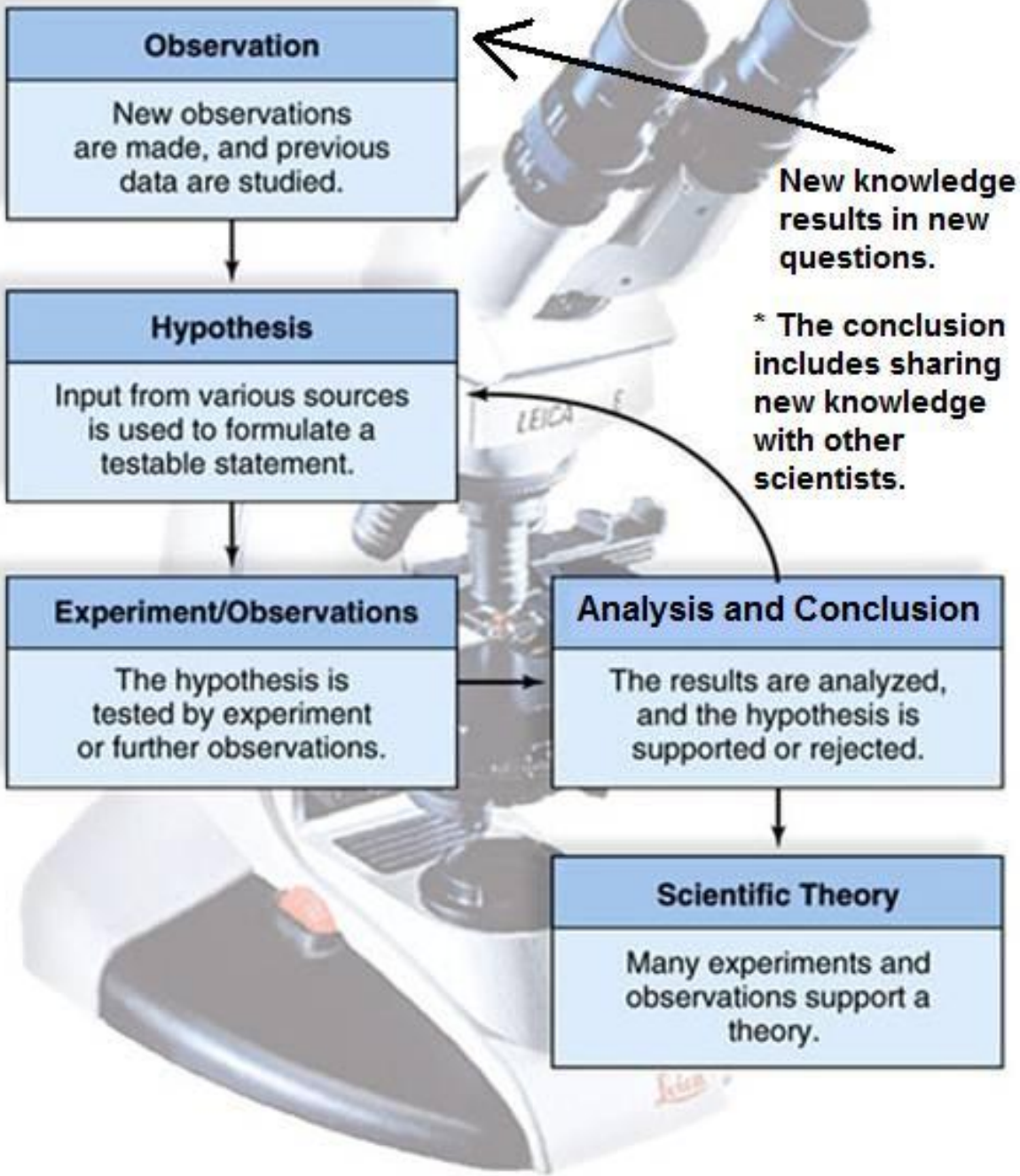
Hypothesis-Based Science

- **Hypothesis;** an **"educated guess"** or an **"explanation on trial":**
  - A **tentative explanation** to a well-framed question about an event, observation or phenomenon that guides scientific inquiry; it is based on available evidence, and should be **testable** and **falsifiable**, often by experimentation.
- **Inductive reasoning**—creating a ***generalization*** from our ***specific*** observations, helps us develop a hypothesis.
- **Deductive reasoning**—moving from the ***general*** hypothesis to a ***specific*** situation, helps us design the experiment to test the hypothesis. We can use the ***"if . . . then"*** logic in our statement.
  - Based on observations, we make **predictions**, deductive, logical consequences about what outcomes of experiments we should expect if a particular hypothesis (premise) is correct.
  - ***If*** situation **"A"** occurs, ***then*** result **"B"** will follow; for example:
  - ***If*** all organisms are made of cells (premise 1), and humans are organisms (premise 2), ***then*** humans are composed of cells (deductive prediction about a specific case).

Hypothesis-Based Science and The Scientific Method

- The **scientific method** is a rigorous procedure for making observations of specific phenomena and searching for the order underlying those phenomena. It consists of **four** basic operations:
  1) **Observations;** study of the specific event, organism, phenomenon or situation; asking questions; gathering information; previous data studied.
  2) **Hypothesis;** a supposition or prediction based on previous observations, offered as explanation of the event or phenomenon.
     - ✓ Remember the ***if . . . then logic*** (deductive reasoning). We make **predictions** based on the observations and hypothesis.
  3) **Experiments** or tests are carried out in order to test the hypothesis and the accuracy of predictions. More **observations** are made and data is recorded.
  4) **Analysis and Conclusion**; the experimental and observational results are analyzed and the scientists come to a conclusion as to whether the hypothesis is supported or not.
     - ✓ The conclusion can lead to the hypothesis for another experiment, or to a **scientific theory**, which is an explanation supported by a broad range of evidence (observations, experiments, and data).

FIGURE 1.10 - Flow diagram for the scientific method

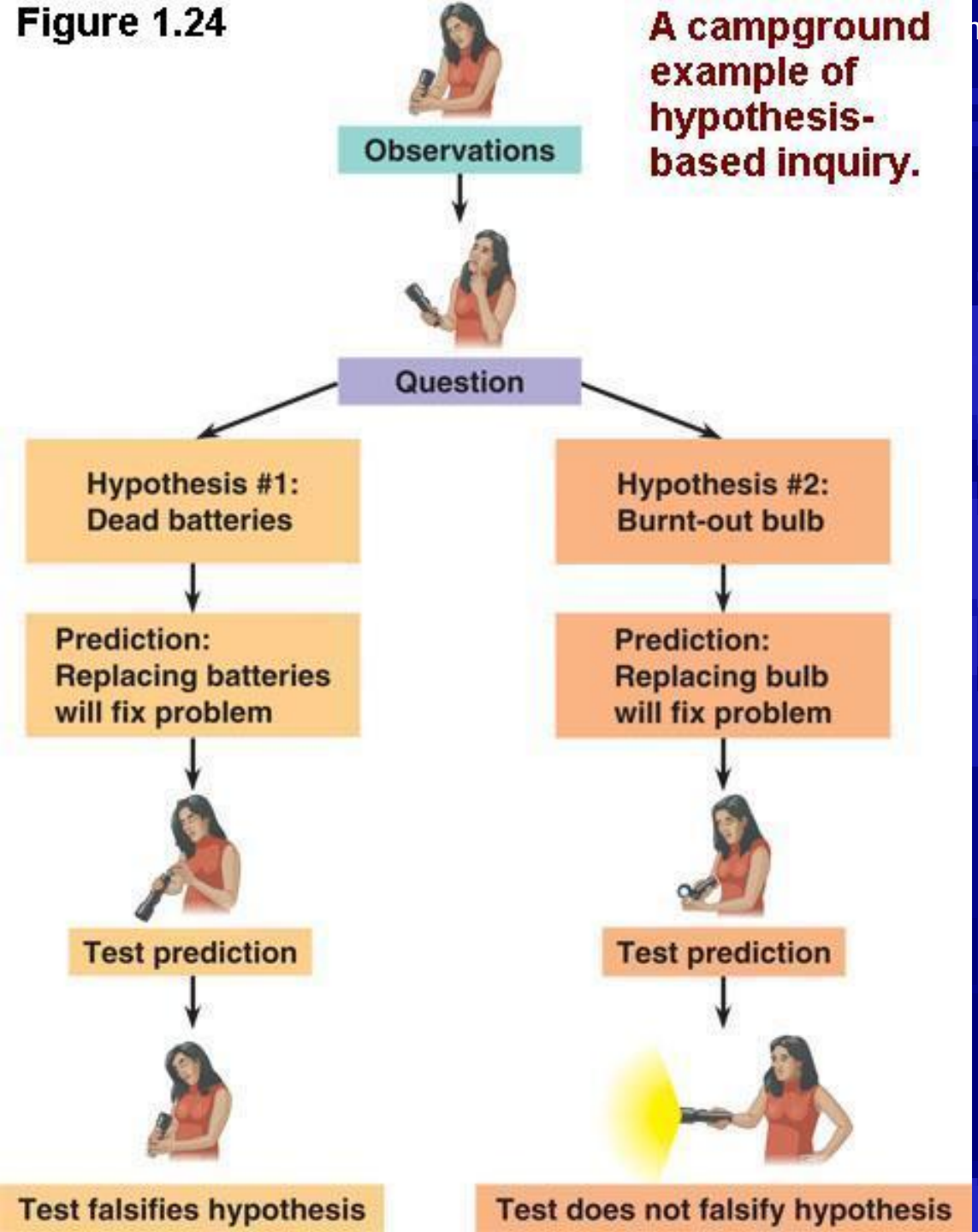


The Scientific Method

- The return arrow indicates that a scientist often chooses to retest the same **hypothesis** or to test a related hypothesis.
- Conclusions from many different but related experiments may lead to the development of a **scientific theory**, an explanation supported by a broad range of evidence (data, observations, and experiments). For example, studies pertaining to anatomy, development, and fossil remains all support the *theory of evolution*.

Figure 1.24

A campground example of hypothesis-based inquiry.



Deductive Reasoning and Hypothesis Testing

- **We all use hypothesis in solving everyday problems!**
- A scientific hypothesis **makes predictions that can be tested** by recording additional observations or by designing experiments.
- Example situation: A flashlight fails during a camp-out.
- ***"If… then"*** logic: If the dead-battery hypothesis is correct, and you replace the batteries with new ones, *then* the flashlight should work.

Questions that Can and Cannot Be Addressed by Science

- A hypothesis must be ***testable***; there must be some way to check the validity of the idea.
- A hypothesis must also be ***fasifiable***: there must be some observation or experiment that could reveal if such an idea is actually ***not*** true.
  - A hypothesis gains credibility by surviving multiple attempts to falsify it while alternative hypotheses are eliminated (falsified) by testing.
- Scientific experiments and results must be ***reproducible***; observations and experiments must be reported in such a way that anyone with the proper equipment can verify the results.
- Science is a ***continuous*** cycle; it has no end. **Science does not provide final answers, nor is it a search for ultimate truth.** Instead, it is a way of producing successively more detailed and exact descriptions that allow us to predict more of the behavior of the physical world with higher and higher levels of confidence.

Limitations of Science

- There are limitations to the kind of questions science can answer.
- Science cannot provide answers to **subjective** issues such as moral, philosophical, or religious questions.
- Science cannot address **supernatural phenomena** or anything that is beyond nature, because hypotheses must be **testable and falsifiable** and observations and experimental results must be **repeatable**.

The Flexibility of the Scientific Method

- Very few scientific inquiries adhere rigidly to the sequence of steps prescribed by the "textbook" scientific method.
  - For example, a scientist may start to design an experiment, but then backtrack upon realizing that more observations are necessary.
  - Scientists sometimes redirect their research when they realize they have been asking the wrong question.
  - Some scientists observe, describe, and report on some aspect of nature, then leave the hypothesizing to others.
- In addition, *discovery science* has contributed much to our understanding of nature without most of the steps of the so-called scientific method.
- It is important for us to avoid stereotyping science as a lock-step adherence to this method.

About the Word "Theory" in Science

- A ***scientific theory*** is much **broader** in scope than a hypothesis; a ***theory*** is a long-standing hypothesis or explanation of a broad range of related phenomena or observations that has been **supported by many tests**.
- Also, a theory is general enough to spin off many new, specific hypotheses that can be tested. A scientific theory is *still open to revisions*, but it differs from speculation because:
  - It has been **tested many times** and there is **a lot of evidence supporting it**; and researchers have yet to find evidence that disproves it.
  - For example, Darwin's theory of natural selection successfully explains diverse issues and after more than a century of many thousands of tests, it holds, with only minor modifications.

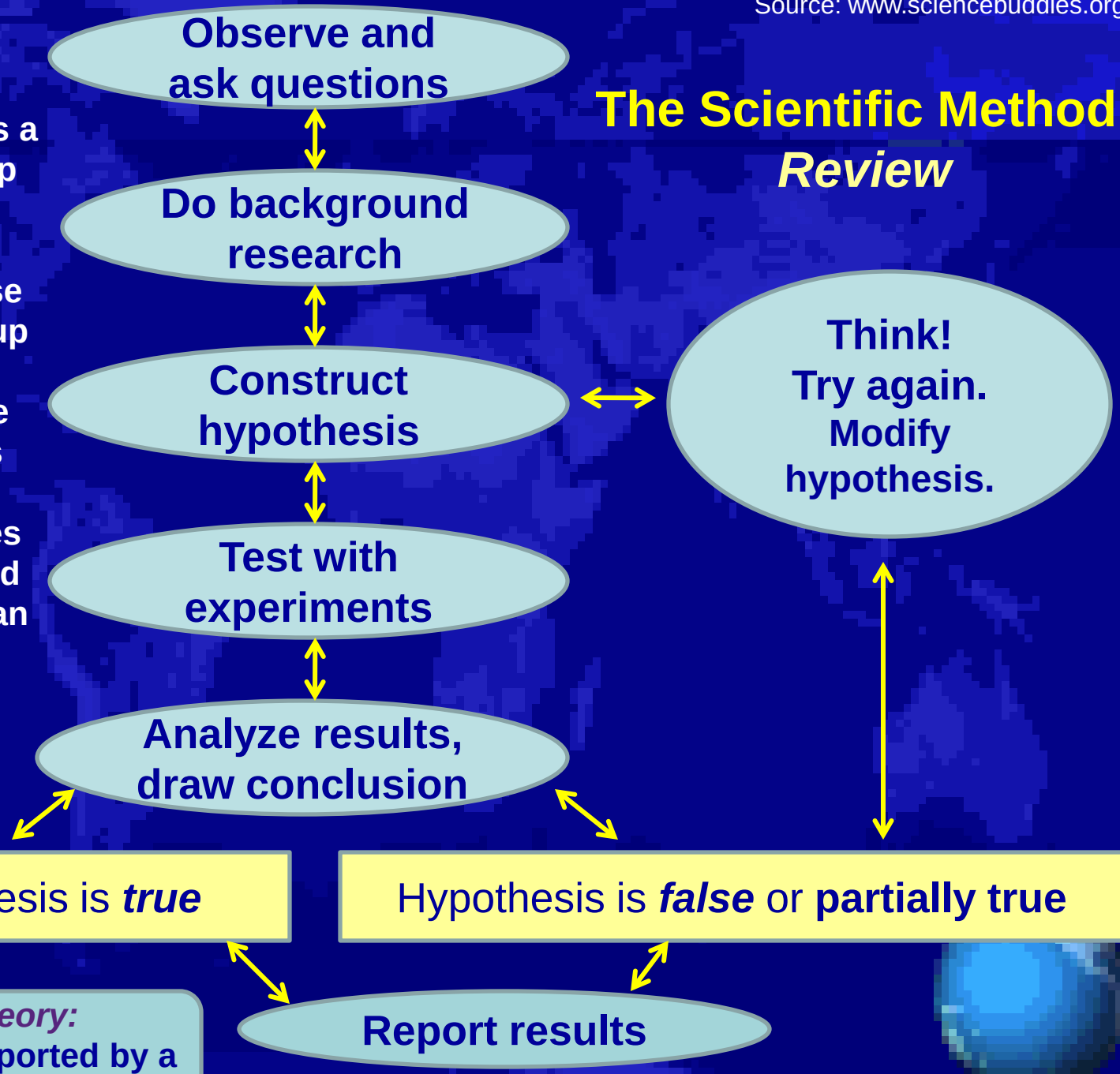
Table 1.4 Examples of Scientific Theories

Gravitational theory	Objects attract one another with a force that depends on their mass and how close together they are.
Cell theory	All organisms consist of one or more cells, the cell is the basic unit of life, and all cells arise from existing cells.
Germ theory	Germs cause infectious diseases.
Plate tectonics theory	Earth's crust is like a cracked eggshell, and its huge, fragmented slabs slowly collide and move apart.
Theory of evolution	Change can occur in lines of descent.
Theory of natural selection	Variation in heritable traits influences which individuals of a population reproduce in each generation.

Source: www.sciencebuddies.org

The Scientific Method: *Review*

Even though this diagram shows the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an *iterative process*.



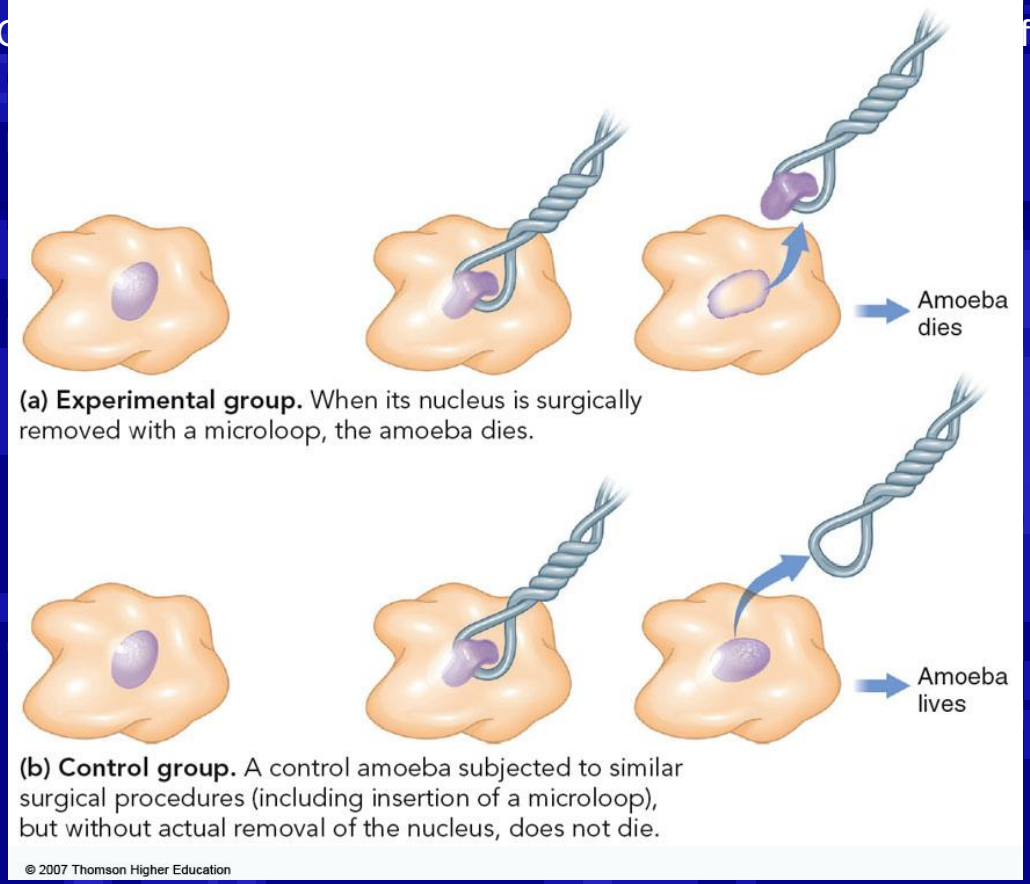
Designing Controlled Experiments

- **Experimental design** is the manner (methodology) in which a scientist intends to conduct an experiment.
- A **controlled experiment** compares an ***experimental group*** (being tested) with a ***control group***. We consider:
  - **Variables**, or factors that are subject to change (and thus may affect the outcome of the experiment).
    - ✓ **Experimental or independent variable** is the factor of the experiment being tested or manipulated.
    - ✓ **Dependent or responding variable** is the result or change that occurs due to the experimental variable.

Designing Controlled Experiments

- An **experimental group**, is the one in which only the variable being tested (***experimental variable***) is changed.
- A **control group** is the portion or sample that does not contain the variable being tested (is not exposed to it); in other words, the control group does not receive the substance, drug, treatment, etc. being tested.
  - The **control group** is a *standard* against which the results of an experiment are checked. All possible variables are held constant. The control group is included to insure that the results obtained are due to a difference in only one variable.
  - Ideally, the experimental and control groups differ only in the one factor the experiment is designed to test.

EXPERIMENTAL DESIGN



- *Observation:* The nucleus is the most prominent part of the cell.
- *Ask critical questions:* Why is the nucleus so large? What is its importance?
- *Develop hypothesis:* Cells will be adversely affected if they lose their nuclei.
- *Make a prediction* that can be tested: If the nucleus is removed from an amoeba, the amoeba will die.
- *Perform experiments* to test the prediction (as shown in the figure).
- Conduct *analysis and conclusions* about the experiments.

a Hypothesis
Olestra® causes intestinal cramps.

↓

b Prediction
People who eat potato chips made with Olestra will be more likely to get intestinal cramps than those who eat potato chips made without Olestra.

↓

c Experiment

Control Group	Experimental Group
Eats regular potato chips	Eats Olestra potato chips
↓	↓
d Results	
93 of 529 people get cramps later (17.6%)	89 of 563 people get cramps later (15.8%)

↓

e Conclusion
Percentages are about equal. People who eat potato chips made with Olestra are just as likely to get intestinal cramps as those who eat potato chips made without Olestra. These results do not support the hypothesis.

Figure 1.11

Typical Sequence of Steps Taken in a Scientific Experiment

- **Olestra** is a synthetic fat replacement made from sugar and vegetable oil. It was approved by FDA (Food & Drug Administration) in 1996. Olestra was first used in potato chips.
- Some people complained of severe gastrointestinal distress after eating the chips and investigation ensued.

Table 1.2 A Guide to Evidence-Based Thinking

Be able to state clearly your view on a subject.

Be aware of the evidence that led you to hold this view.

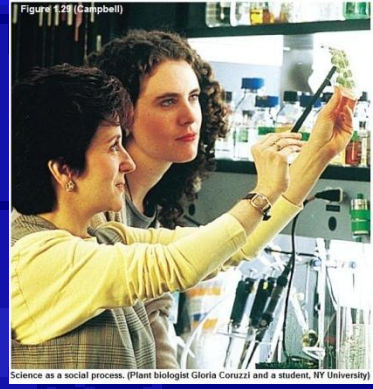
Ask yourself if there are alternative ways to interpret the evidence.

Think about the kind of information that might make you reconsider your view.

If you decide that nothing can ever persuade you to alter your view, recognize that you are not being objective about this subject.

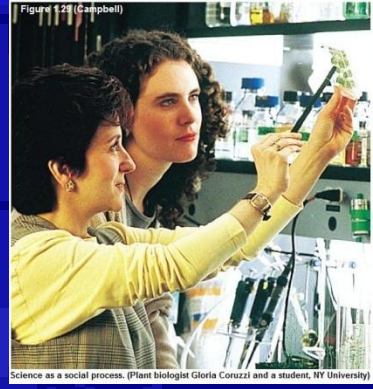
Table 1.3 Example of a Scientific Approach to a Question

1. Observation	People get cancer.
2. Question	Why do people get cancer?
3. Hypothesis	Smoking cigarettes causes cancer.
4. Prediction	If smoking causes cancer, then individuals who smoke will get cancer more often than those who do not.
5. Observational test	Conduct a survey of individuals who smoke and individuals who do not smoke. Determine which group has the highest incidence of cancers.
6. Experimental test	Establish identical groups of laboratory rats. Expose one group (the model system) to cigarette smoke and compare the incidence of new cancers (if any) with the incidence in the control group.
7. Report	Report the test results, quantitatively if possible, and the conclusions drawn from them.



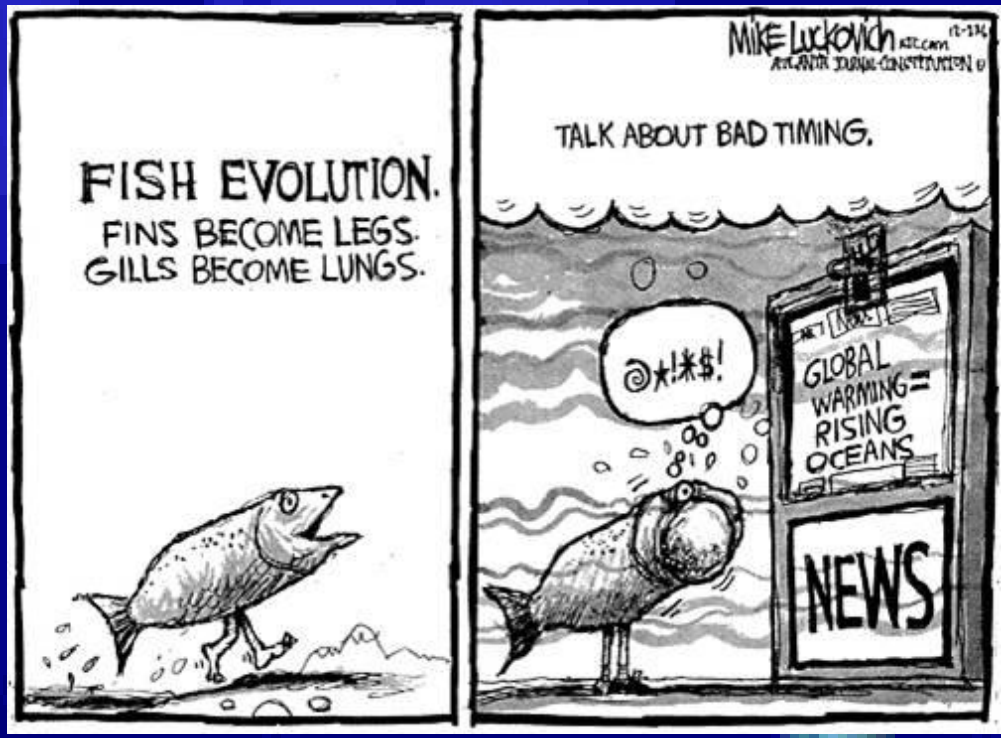
Biology is Exploration

- **REMEMBER:** Biology is challenging, but do not feel intimidated!
- **"Biology is not a completed work but an exploration that has really just begun."**
  - Teresa and Gerald Audesirk (Biology: Life on Earth, Seventh Edition; 2005; Chapter 1).
- The set of themes that we have seen today connects the concepts of biology, providing a framework for understanding this fascinating science.



Biology is Exploration

- **REMEMBER:** Biology is challenging, but do not feel intimidated!
- **"Biology is not a completed work but an exploration that has really just begun."**
  - Teresa and Gerald Audesirk (Biology: Life on Earth, Seventh Edition; 2005; Chapter 1).
- The set of themes that we have seen today connects the concepts of biology, providing a framework for understanding this fascinating science.



References

- **Audesirk, Teresa; Audesirk, Gerald & Byers, Bruce E.** (2005). ***Biology: Life on Earth*.** Seventh Edition. Pearson Education, Inc.-Prentice Hall. NJ, USA.
- **Belk, Colleen; Borden, Virginia.** (2007). ***Biology, Science for Life.*** Second Edition. Pearson Education, Inc-Prentice Hall. NJ, USA.
- **Campbell, Neil A.; Reece, Jane B., et al.** (2011). ***Campbell Biology.*** Ninth Edition. Pearson Education, Inc.-Pearson Benjamin Cummings. CA, USA.
- **Mader, Sylvia S.** (2010). ***Biology.*** Tenth Edition. The McGraw-Hill Companies, Inc. NY, USA.
- **Presson, Joelle & Jenner, Jan.** (2008). ***Biology, Dimensions of Life.*** The McGraw-Hill Companies, Inc. NY, USA.
- **Solomon, Eldra; Berg, Linda; Martin, Diana W.** (2008). ***Biology.*** Eighth Edition. Cengage Learning. OH, USA.
- **Starr, Cecie.** (2008). ***Biology: Concepts and Applications Volume I.*** Thompson Brooks/Cole. OH, USA.
- **Tortora, Gerard J.; Derrickson, Bryan.** (2006). ***Principles of Anatomy and Physiology.*** Eleventh Edition. John Wiley & Sons, Inc. NJ, USA. www.wiley.com/college/apcentral.
- **Tortora, Gerard J.; Funke, Berdell R.; Case, Christine L.** (2010). ***Microbiology An Introduction.*** Tenth Edition. Pearson Education, Inc.-Benjamin Cummings; CA, USA. www.microbiologyplace.com.
- **Trefil, James & Hazen, Robert M.** (2011). ***The Sciences An Integrated Approach*.** Sixth Edition. John Wiley & Sons, Inc. NJ, USA.