TEACHER BACKGROUND INFORMATION
LIVING ORGANISMS

CHAPTER'S BIG IDEAS

- All living organisms have **common characteristics**:
    - Cellular organization
    - Response to environment
    - Reproduction and heredity
    - Growth and development
    - Energy utilization
    - Homeostasis (ability to maintain stable internal conditions)
    - Evolutionary adaptation
    - Interdependence

- All living organisms have **needs required for survival** and have developed a variety of adaptations (structural and reproductive) that allow them to meet these needs in their own environment. The basic needs for individual and population survival of a certain species are:
    - Water
    - Energy (food)
    - Shelter
    - Stable internal conditions
    - Reproduction (*for population survival only*)

- Living organisms are **classified** into eight categories based on their evolutionary relationships (from most inclusive to least inclusive). They are placed into domains and kingdoms based on their cell type, their ability to make food, and the number of cells in their bodies:
    - Domain
    - Kingdom
    - Phylum
    - Class
    - Order
    - Family
    - Genus
    - Species

CHARACTERISTICS OF LIVING ORGANISMS

How do we know if something is alive? While some may think it is easy to distinguish between living and non-living things, coming up with exact properties of life can be quite challenging and often arguable.

Biology is the study of life (bio = life; ology = study of). All living organisms share **common characteristics** (Table 1). They are generally made up of one or more cells, able to reproduce, and obtain and use energy (generally electromagnetic or chemical) to run the processes required for life. Living organisms also try to maintain a somewhat constant internal environment and pass on their inheritable traits to offspring (Note: not all traits are inheritable). Responding and adjusting to the environmental conditions as well as growing and developing, are other characteristics shared by all living organisms. Finally, all organisms are interdependent; they depend on other organisms for survival. Life is characterized by the presence of **all** of these properties at some stage in an organism's life.

CAUTION: There are living things that do not have all of these characteristics and often become the source of great debates! For example, take soldier ants in an ant colony, they do not reproduce yet they are living organisms. As another example, viruses are unable to reproduce, grow, metabolize and maintain homeostasis, yet they cause diseases in many living organisms. In general, viruses are considered to be non-living inert particles because they only function and replicate with the aid of a living host cell. It is important to remember that the common characteristics of living organisms are *general guidelines* and that nothing is set in stone!

Table 1 – Characteristic of living organisms

PROPERTIES OF LIFE	SOME EXAMPLES
Cellular Organization	Bacteria (unicellular)
Reproduction **Heredity**	Birds mate and lay eggs (sexual reproduction) and pass on their genes to their offspring
Metabolism (energy use)	Plants get energy from sunlight (Photosynthesis)
Homeostasis (response to surroundings)	Seals maintain warm temperature in cold waters
Response to environment	Plants grow towards sunlight
Growth and **Development**	Some plants start as single-celled seeds and grow into complex organisms
Evolutionary Adaptation	Giraffes have long necks as a result of natural selectic which allows them to reach food other animals cannot
Interdependence	Plants gets nutrients from decaying plants and animals

- **<u>Cellular Organization</u>**: Compared with nonliving matter of similar size, living organisms are *<u>highly complex</u>* and *<u>organized</u>*. For example, a crystal of table salt consists of just two chemical elements, sodium (Na) and chlorine (cl), arranged in a precise cubical arrangement: salt crystal is organized but simple (not complex). Oceans contain some atoms of all naturally occurring elements, but these atoms are randomly distributed: oceans are complex but not organized. In contrast, even a tiny water-flea (*Daphnia*) contains dozens of different elements linked together in thousands of specific combinations that are further organized into even larger and more complex assemblies to form structures such as eyes, legs, a digestive tract, and even a small brain.

Life on Earth consists of a hierarchy of structures with each level of the hierarchy based on the one below it and providing the foundation for the one above it. In other words, all life has a chemical (non-living) basis, but the quality of life itself emerges on the cellular level (Table 2). Interactions among the components of each level and the levels below it allow the development of the next-higher level of organization. For example, atoms join to form molecules and the latter combine to form complex structures such as organelles. Cells are made up of organelles and are grouped together to form tissues. Tissues give rise to organs, which are grouped together into systems that make up multicellular organisms. Organisms living in the same area form populations and together with Populations of other species form a community. A community with its nonliving surroundings forms an ecosystem. And finally, all ecosystems make up the biosphere.

HIERARCHY OF STRUCTURES	QUALITY OF LIFE
Biosphere	Living
Ecosystems	Living
Community	Living
Population	Living
Organism	Living
Organs	Non-Living
Tissue	Non-Living
Cells	Non-Living (except unicellular organisms)
Organelles	Non-Living
Molecules	Non-Living
Atoms	Non-Living

All living organisms are made up of building blocks called **cells**. Cells are highly complex and organized. They are also the smallest units capable of all life functions, just as atoms were the smallest units of elements that maintain the properties of an element. The basic structure of cells is the same in all organisms, although some may be more complex than others. In general cells are enclosed by a **membrane** that regulates the passage of material between the cell and its surroundings. And every cell, at some stage in its life, contains **DNA**, the heritable material that directs the cell's many activities. In most cells, the DNA is contained in a “packet” called the **nucleus**. There are some cells, such as blood cells, that do not have a nucleus at some stage in their life. They have a nucleus when they are formed in the bone marrow, but lose their nucleus when entering the blood stream to allow for more space to uptake gases.

There are two major kinds of cells – **prokaryotic** cells (pro = before; karyo = nucleus) and **eukaryotic** cells (eu = true/good; karyo = nucleus). These two kinds of cells can be distinguished by their structural organization including the presence of membrane-bound organelles (ell= small; small organs) and the packaging of their DNA. In prokaryotes there are no organelles and their DNA is found in the cytoplasm (fluid within cell) as strands (Fig. 1).

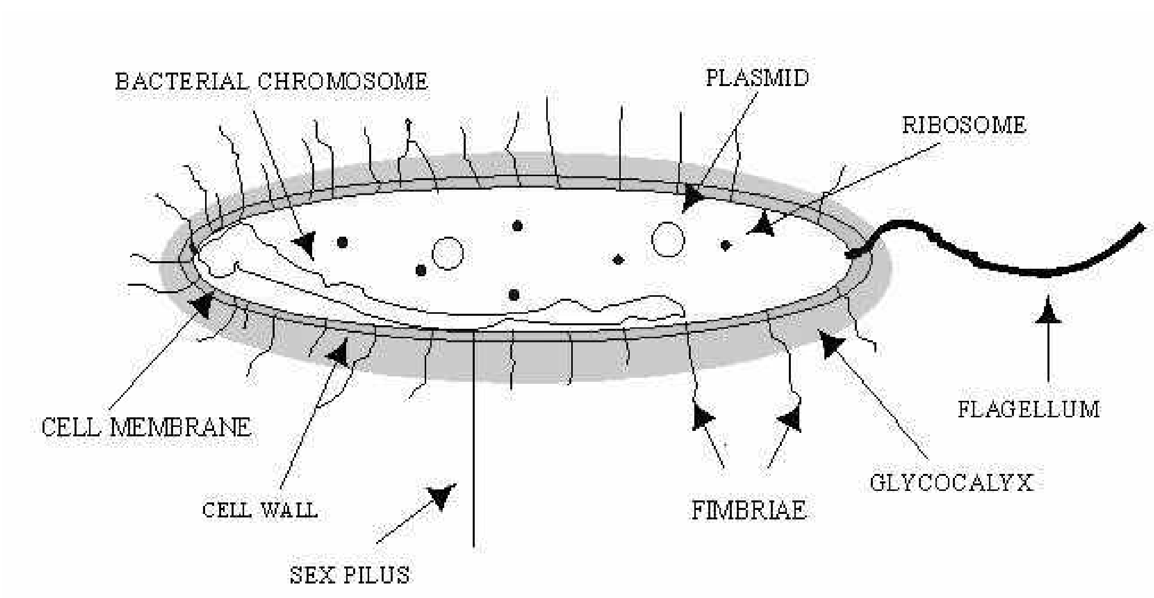

Figure 1 – Prokaryotic Cell Model. Notice chromosome is not enclosed in a nucleus and there are no membrane-bound organelles. (Diagram from http://www.ivytech.net)

The cells of organisms called bacteria and archae (archa = old) are prokaryotic. In eukaryotes, there are many organelles and their DNA is enclosed in a double-membrane (nuclear membrane) bound organelle known as a nucleus (Fig.2).

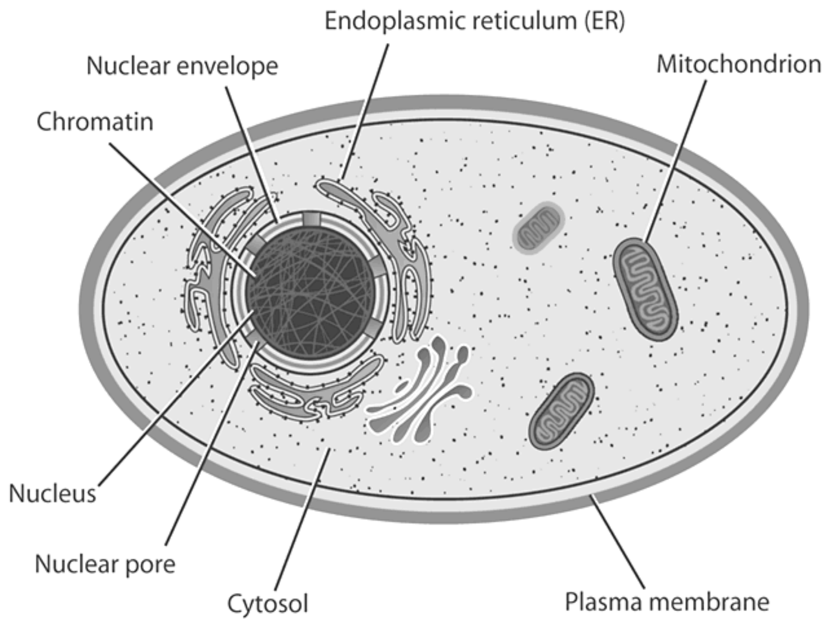

Figure 2 – Eukaryotic Cell Model. Notice the chromosomes (chromatin) are enclosed inside the nucleus and the presence of membrane-bound organelles. (Diagram from http://www.press.uillinois.edu)

Some organisms have only a single cell (**unicellular**), while others have multiple cells (**multicellular**). Cells vary widely and differ in size, shape, and function, but all are highly ordered structures that carry out complicated processes necessary for maintaining life. For example, in humans, nerve cells carry messages to and from the brain and blood cells carry oxygen to all other cells. Both types of cells are very different structurally and functionally, but both are essential for survival.

- **Reproduction and Heredity**: The continuity of life depends on the passing of biological information (heredity) in the form of DNA molecules from one generation to another by reproduction. All living things have the ability to reproduce. They are able to make more organisms of the same kind, known as offspring. Methods of reproduction vary among living things. Animals, plants, and fungi (eukaryotes) reproduce sexually and/or asexually, while bacteria and archae (prokaryotes) generally reproduce asexually.

Asexual reproduction is the creation of new individuals whose genes are identical to and all come from one parent. This occurs in many ways without the fusion of egg and sperm (fusion of egg and sperm is fertilization which occurs in organisms who undergo sexual reproduction). Many invertebrates and bacteria reproduce asexually by *fission*, separation of a parent into two or more individuals of approximately equal size (e.g. some sea anemones split into two genetically identical individuals). *Budding*, also common among invertebrates, involves new individuals splitting off from existing ones (e.g. new genetically identical individuals grow out from the body of a parent and will either detach, as with certain jellyfish, or remain joined to form a large colony, as happens with corals). Another type of asexual reproduction is *fragmentation*, the breaking of the body into several pieces, some or all of which develop into complete adults by regeneration (regrowth of lost body parts). Fragmentation is common in sponges, corals, polychaete Worms and tunicates. The other type of asexual reproduction is *parthenogenesis* (partheno = virgin; genesis = birth), a process in which an egg develops without being fertilized. Once again the eggs are clones of the parent (mother in this case). Parthenogenesis is common in invertebrates (e.g. bees, wasps, ants, water fleas), but is also used by vertebrates (e.g. some lizards, fish, amphibians). Plants and fungi are also able to reproduce asexually. Fungi produce spores, whereas some plants undergo fragmentation and others produce seeds without fertilization (e.g. dandelions).

Sexual reproduction is the creation of offspring by the fusion of an egg and sperm, known as **fertilization**, to form a zygote (fertilized egg). The offspring are NOT identical to the parents because half of their genes come from the father and the other half come from the mother. Sexual reproduction increases genetic variability among offspring by generating unique combinations of genes inherited from two parents. This genetic variability enhances reproductive success by ensuring that some of the offspring will survive even in a changing environment. For example, if all cats were genetically identical and suddenly a new disease appeared that they were not immune to, they would most likely all die. The fact is, cats are not genetically identical and some of them would be immune to the disease and survive to pass on their genes. Sexual reproduction can be problematic for sessile (attached/not-moving), burrowing or parasitic animals, which may have difficulty encountering a member of the opposite sex. One solution to this problem is ***hermaphroditism***, in which individuals have both male and female reproductive systems. Although some hermaphrodites fertilize themselves, most are hermaphroditic so that on the rare occasion they meet another individual of their species, they do not have to worry about its sex. In this case, each animal serves as male and female, donating and receiving sperm. Each individual encountered is a potential mate, resulting in twice as many offspring than if only one individual's eggs were fertilized. Examples of animals that are hermaphrodites include some earthworms, slugs, snails, and fish (including Nemo from "Finding Nemo"!!!). Actually some fish are *sequential hermaphrodites*, meaning they reverse their sex at some point in their life (they never are two sexes at once). Some reef fish may start off as male or female and for reasons that would take to long to explain, become the opposite sex.

Animals may reproduce sexually or asexually exclusively, or they may alternate between the two modes depending on environmental factors. For example, *Daphnia* (water flea) use different modes of reproduction according to the seasons. They reproduce asexually under favorable conditions and sexually during times of environmental stress.

- **<u>Metabolism</u>**: Organisms need materials (matter) and energy to maintain their high level of complexity and organization. Organisms acquire the atoms and molecules they need from air, water, or soil or from other living things. These materials, called **nutrients**, are extracted from the environment and incorporated into the molecules of the organisms' bodies (chemical change), as they are unable to synthesize these materials themselves. The sum total of all the chemical reactions needed to sustain life is called **metabolism**.

Organisms obtain energy - the ability to do work, including carrying out chemical reactions, growing leaves, or contracting muscle – in one of two basic ways:

(1) Plants, algae and some bacteria capture the electromagnetic energy of sunlight, convert it and store it in energy-rich sugar molecules (chemical energy), a process known as **photosynthesis** (Fig. 3). Once the complex molecules are made, the energy must be extracted from the molecules to run cell processes. To do this, inside each cell the glucose produced by photosynthesis and oxygen from the air we breathe are used to

undergo a reaction that releases chemical energy. This process of releasing energy from nutrients is known as **cellular respiration** (Fig.3) and occurs in most organisms including plants and animals. Cellular respiration is actually the "opposite" of photosynthesis. The energy released by respiration can then be converted into kinetic and thermal energy, which allows organisms to move and run cellular processes.

(2) In contrast, fungi, animals, and most bacteria can not photosynthesize; these organisms must consume the energy-rich molecules contained in the bodies of other organisms and extract the energy through cellular respiration.

In either case, the acquired energy is converted into a form that organisms can use or store for later use. The exchange of energy between organisms and their surroundings involves the **transformation of one form of energy to another**. For example, when a leaf produces sugar, it converts electromagnetic energy from the sun into chemical energy in the form of sugar molecules. When animal muscle cells use this sugar as fuel to power movements, they convert the chemical energy into kinetic energy, the energy of motion. Most of the work of cells involves the transformation of chemical energy (high quality energy) into heat (lower quality energy).

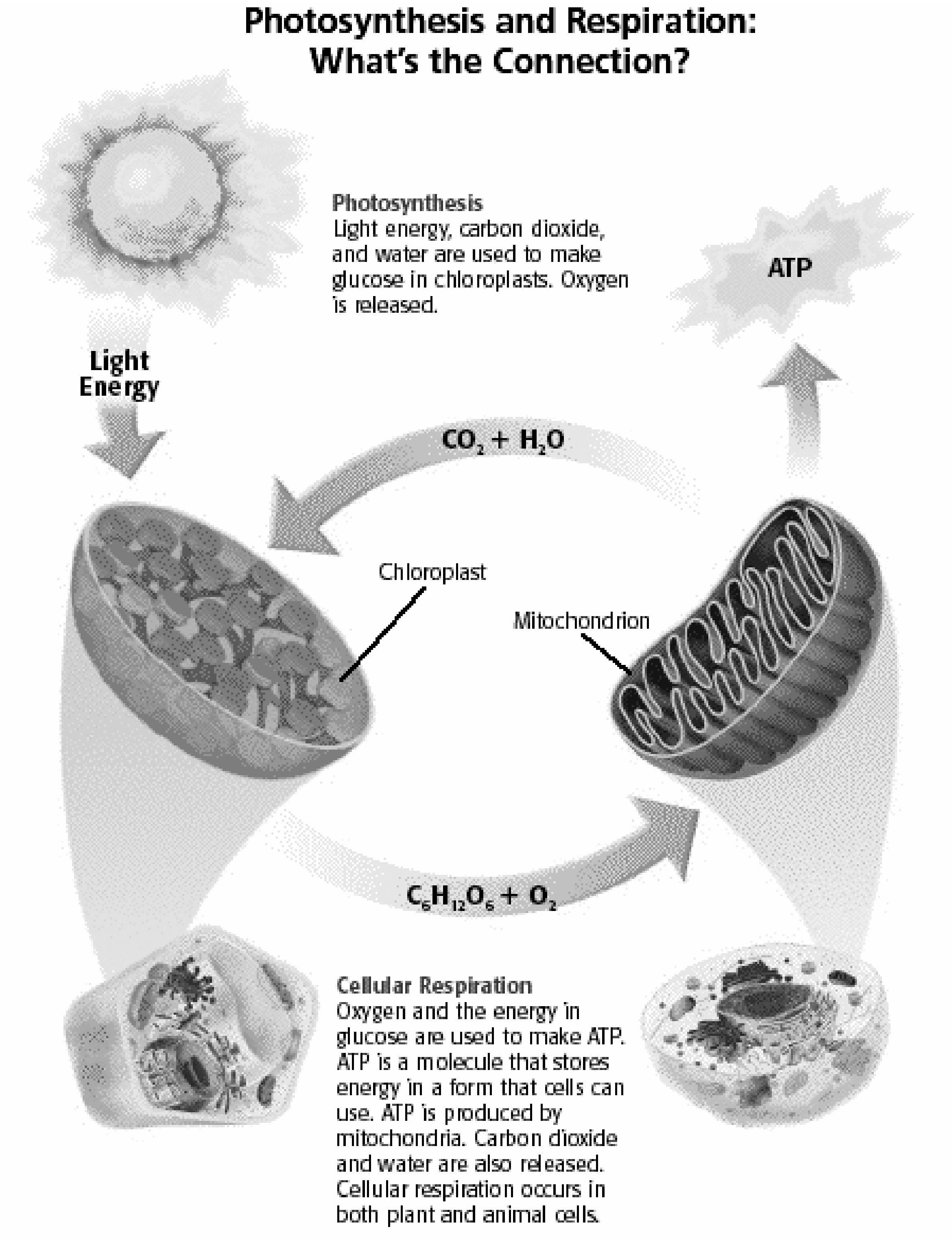

Figure 3 – Summary diagram of photosynthesis and respiration in plants.

(Diagram from http://marshallteachers.sandi.net)

- **<u>Homeostasis</u>**: All living organisms must maintain a stable internal environment in order to function properly. Organisms respond to changes in their surroundings and adjust their processes accordingly. The ability to maintain a stable internal environment in spite of changes in the external environment is called **homeostasis** (homeo = same; sta = unmoving; is = process of). For example, Arctic seals are able to maintain a constant body temperature despite their cold environment. Marine fish are able to keep most of the salt out of their bodies, despite their very salty surroundings. These are all examples of organisms maintaining stable internal environments in hostile external conditions.

A change in an organism's surroundings that causes the organism to react is called a *<u>stimulus</u>*. Stimuli include changes in temperature, light, sound, and other factors. An example of this is a plant bending towards light when put in the shade.

- **<u>Growth and Development</u>**: Another characteristic of living things is that they grow and develop. Growth is the process of becoming larger, while development is the process of change that occurs during an organism's life to produce a more complex organism (think of the development of our brains!). Organisms need energy in order to create and develop new cells.

- **Evolutionary Adaptations**: The great diversity of life on Earth is the result of a long history of change. Change in the inherited traits of species over time is called evolution. A **species** is a group a similar organisms that can produce fertile offspring. The individuals with genetic differences that better enable them to meet their environment's challenges are the ones that survive, reproduce and become more common. Charles Darwin called the process in which organisms with favorable genes are more likely to survive and reproduce **natural selection**. Adaptation plays a major role in natural selection. An **adaptation** is a characteristic or trait that helps an organism survive in its environment. For example, strong conical bills in finches are a physical adaptation of these birds that allows them to eat seeds that other birds are unable to crack open. An adaptation makes an organism better at surviving in its environment and allows it to pass on its genes to the next generation.

IMPORTANT: Organisms DO NOT CHOOSE a new adaptation. Finches did not suddenly decide to grow thicker bills. Adaptations of organisms to their environment are a product of natural selection. Genetic variation within a population is generally caused by mutations and the individuals with genes better suited to their environment survive and reproduce (natural selection).

Interdependence: Organisms in a biological community have evolved to live and interact with other organisms. A biological community is a group of interacting organisms and *ecology* is the science that studies these communities and how they interact with the non-living part of their environment. Organisms are dependent on one another and their environment – they are interdependent. Interdependence within biological communities is the result of a long history of evolutionary adjustments. For example, all animals depend directly or indirectly on plants for food, and all plants depend on the decay of plants and animals for essential minerals to make their own food. Most organisms depend on one another and the extinction of one species can disrupt the lives of many others.

NEEDS OF LIVING ORGANISMS

All living organisms have the same basic needs and fulfill these needs in a variety of ways. In order for a species to survive, individuals must satisfy their basic needs for food (energy), water, living space, stable internal conditions, and reproduction.

- **Food**: Organisms need food as a source of energy to live. Some organisms, such as plants, capture the sun's energy and convert it to chemical energy (Note: not all of the sun's energy will be converted into chemical energy; some will be lost as heat and some is reflected). This energy can be stored or used to run processes in the body. Organisms capable of making their own food, such as plants, algae, and some bacteria, are known as **autotrophs** (auto = self; troph = food; "self-feeding"). Organisms that are unable to make their own food are known as **heterotrophs** (hetero = other; "other-feeding" or "feeding on other"). Some heterotrophs eat autotrophs and use the energy stored in the autotroph's food (e.g. antelope eating grass). Some heterotrophs consume other heterotrophs that eat autotrophs (e.g. lion eating antelope that ate grass). The electromagnetic energy of the sun is therefore transformed into chemical energy by autotrophs which is then transferred to heterotrophs. Animals, mushrooms, and slime molds are all examples of heterotrophs.

- **Water**: All living things need water to obtain chemicals from their surroundings, break down food, grow, move substances within their bodies, and reproduce. One vital property of water is its ability to dissolve chemicals. Water is known as the universal solvent. In fact, water makes up about 90% of the liquid part of human blood. The food needed by cells dissolves in blood and is transported to all parts of the body. Waste from cells is also dissolved in blood and carried away. Cells are also made up of mostly water, providing a watery environment in which chemicals are dissolved.

- **Living space (shelter)**: All organisms need a place to live – a place to get food, water and be sheltered from their environment. Whether an organism lives in the freezing Arctic or the scorching desert, its surroundings must provide what it needs to survive. Due to the limited space and resources on Earth, organisms often compete for resources. For example, trees in a forest compete for sunlight above ground, but also compete for water and minerals underground. Organisms also need shelter from predators and develop an array of structures and strategies to avoid being eaten. For example, plants might have spines and toxins to deter herbivores. Some animals use camouflage as a predator avoidance strategy.
- **Stable internal conditions**: Organisms must be able to keep stable conditions inside their bodies, even when conditions in their surroundings change significantly. Remember, the maintenance of a stable internal condition is called homeostasis. Homeostasis keeps internal conditions just right for cells to function. For example, when water levels are low in the human body, chemicals send signals to the brain causing the individual to feel thirsty. Other organisms have different mechanisms for maintaining homeostasis. For example, adult barnacles are often exposed to air for long hours during low tide. Without a way to keep water from evaporating, the barnacles would soon die. Barnacles have adapted to these conditions by

having a hard outer plate that they can close up into and trap water inside. In this way, barnacles are able to remain moist until the next high tide.

- **Reproduction**: While all the needs just mentioned are vital for an individual's survival, if individuals do not reproduce the species as a whole would soon become extinct. The various methods of reproduction (sexual and asexual) were previously discussed. Organisms evolve various structures and strategies which enhance their reproductive success, such as brilliant plumage in peacocks to attract females.

CLASSIFYING ORGANISMS

Reconstructing evolutionary history is part of the science of **systematic**, the study of biological diversity, past and present. A key part of systematic is **taxonomy** (taxis = arrangement), the science of naming organisms and placing them into categories on the basis of their evolutionary relationships.

Biologists use classification to organize living things into categories so that organisms are easier to study. Biological classification was formally started by Carolus Linnaeus (1707-1778), a Swedish physician and botanist. The Linnaean system has two main characteristics: a two-part name for each species and a hierarchical classification of species into broader groups of organisms. Linnaeus's system assigns to each organism a two-part

Latinized name, or binomial (bi= two; nomial= name). The first part of a binomial is the **genus** (plural, genera) to which the species belong. The second part of the binomial refers to one species. This type of classification is based purely on physical similarities, not necessarily on genetic similarities.

In addition to defining and naming species, a major objective of systematic is to group species into broader taxonomic categories. For example, the leopard, *Panther a Pardus*, belongs to a genus that also includes the African lion (*Panther a Leo*) and the tiger (*Panthera tigris*). Beyond the grouping of species within genera, taxonomy extends to progressively broader categories of classification. Actually there are eight major categories starting with the most broad: (1) **domain**, (2) **kingdom**, (3) **phylum**, (4) **class**, (5) **order**, (6) **family**, (7) **genus**, and (8) **species**. These taxonomic categories form a nested hierarchy in which each level includes all of the other levels below it. Each domain contains many kingdoms, each kingdom contains many phyla, each phylum includes many classes, and so on. Each category is increasingly narrow and specifies a group whose common ancestor is increasingly recent (Table. 2).

NOTE: Classifying a species by domain, kingdom, phylum, and so on, is analogous to sorting mail, first by state, then by zip code, and then by street name , house number, and specific member of the household.

Table 2 – Classification of selected organisms, reflecting their degree of relatedness in bold-faced words. Note: genus and species are always italicized.

	Gray Wolf	Dog	Fruit Fly	Sunflower
Domain	**Eukarya**	**Eukarya**	**Eukarya**	**Eukarya**
Kingdom	**Animalia**	**Animalia**	**Animalia**	Plantae
Phylum	**Chordata**	**Chordata**	Arthropoda	Entophytic
Class	**Mammalia**	**Mammalia**	Insecta	Dicotyledoneae
Order	**Carnivora**	**Carnivora**	Diptera	Asterales
Family	**Canidae**	**Canidae**	Drosophilidae	Asteraceae
Genus	***Canis***	***Canis***	*Drosophila*	*Helianthus*
Species	*lupus*	*familiaris*	*melanogaster*	*annuus*

Organisms are placed into domains based on the presence or absence of a nucleus. Those without a nucleus are either Bacteria or Archae and those with a nucleus are Eukarya. The Eukarya are further divided into kingdoms based on the number of cells in their bodies and their ability or inability to make food (Table 3).

Table 3 – The three-domain and four kingdom classification system with distinguishing characteristics for each category.

Domain	**Bacteria**	**Archae**	**Eukarya**			
Kingdom	**Eubacteria**	**Archae-bacteria**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryote	Prokaryote	Eukaryote	Eukaryote	Eukaryote	Eukaryote
Body Type	Unicellular	Unicellular	Unicellular & Multicellular	Unicellular & Mulitcellular	Multicellular	Multicellular
Nutrition	Autotrophic & Heterotrophic	Autotrophic & Heterotrophic	Autotrophic & Heterotrophic	Heterotrophic	Autotrophic	Heterotrophic
Example	*E. Coli*	*Bacillus subtilis*	Amoeba	Mushroom	Pine tree	Elephant

- **Domain Bacteria**: Bacteria are found everywhere. Yogurt, skin, rocks, and your intestines are just some examples of their location. Bacteria are unicellular prokaryotes: they lack a nucleus. Some bacteria are autotrophs, while others are heterotrophs. Most bacteria are vital for the survival of organisms (interdependence), including humans. Some bacteria may be harmful, such as those that cause strep throat.

<u>Domain Archae:</u> Archae can be found in some of the most extreme environments on Earth, including hot springs, very salty water, swamps, and the intestine of cows! Like bacteria, archae are unicellular prokaryotes and some are autotrophs, while others are heterotrophs. Archae are classified in a separate domain because their cell structure and chemical makeup differ from that of bacteria.

- **<u>Domain Eukarya:</u>** Organisms in this domain are eukaryotes and are further divided into four kingdoms: protista, fungi, plantae and animalia.
  - **Protista**: Protists are so diverse that few characteristics other than *<u>eukaryotic</u>* can be cited. Most protists are *<u>unicellular</u>*, but some are colonial and *<u>multicellular</u>*. Each unicellular protist is NOT analogous to a single cell from a human, but is itself an organism as complete as any whole animal or plant. Protists are further divided by their lifestyle into protozoans (e.g. amoebas), slime molds, unicellular algae, and seaweeds.

  - **Fungi**: Fungi include mushrooms, yeasts, and molds. Most fungi are *<u>multicellular eukaryotes</u>*. A few, such as yeast used for baking, are unicellular eukaryotes. Fungi are found almost everywhere on land, but only few live in freshwater. All fungi are *heterotrophs* and feed by *absorbing* nutrients from dead or decaying organisms.

- **Plantae**: Plants are *multicellular eukaryotes* and most live on land. Plants are also *autotrophs* that make their own food and provide food for most of the heterotrophs on land. The plant kingdom includes a variety of organisms. Some produce flowers, while others do not. Some plants grow very tall, while others, such as mosses, never grow taller than a few centimeters.

- **Animalia**: All animals are *multicellular eukaryotes* and they are *heterotrophs*. Animals have different adaptations that allow them to locate food, capture it, eat it, and *digest* it. Members of the animal kingdom live in diverse habitats throughout Earth, including both water and land.