

TEACHER BACKGROUND INFORMATION

ANIMALS

CHAPTER'S BIG IDEAS:

- Animals have **common characteristics**:
 - All are heterotrophic
 - All obtain nutrients by ingestion
 - All are eukaryotes
 - All are multicellular
 - Most are motile
 - Most exhibit body symmetry

- All animals 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 animal species are:
 - Water
 - Energy (food)
 - Oxygen
 - Stable internal conditions
 - Shelter
 - Reproduction (*for population survival only*)

- **Structure and function** are generally correlated at all levels of biological organization.
 - The ability of a part to function is dependent on its structure.
 - The success of the structure determines if that part will be found in future generations of a species (natural selection).

CHARACTERISTICS OF ANIMALS

Members of the animal kingdom (Domain Eukarya) share several characteristics:

- All are **heterotrophic** (Feed on others)
 - All obtain nutrients by **ingestion**
 - All are **eukaryotic** (true-nucleus)
 - All are **multicellular** (made up of more than one cell)
 - Most have **motility** (ability to move)
 - Most exhibit body **symmetry**
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- **Heterotrophic:** All animals are **heterotrophs** meaning they cannot make their own food but must obtain it by eating other organisms. In contrast, plants are autotrophs; they are able to make their own food. Most animals take food into a cavity inside their bodies and digest it by breaking the food down into substances they can absorb and use.

 - **Ingestion:** All animals carry on ingestion meaning they eat food. This mode of nutrition contrasts animals with fungi, which obtain nutrients by absorption after digesting food outside the body. Animals digest their food within their bodies. The ingested organisms may be dead or alive, whole, or by the piece.

- **Eukaryotic:** Animal cells are **eukaryotic** meaning they have a true nucleus surrounded by a nuclear membrane. But unlike plant cells that have both a cell membrane and a cell wall, animal cells are enclosed by a **cell membrane** only. Animal cells contain many other structures or organelles (mini-organs, see Fig. 1) that are scattered throughout the cell's cytoplasm (fluid inside the cell). The **nucleus** is an organelle that houses

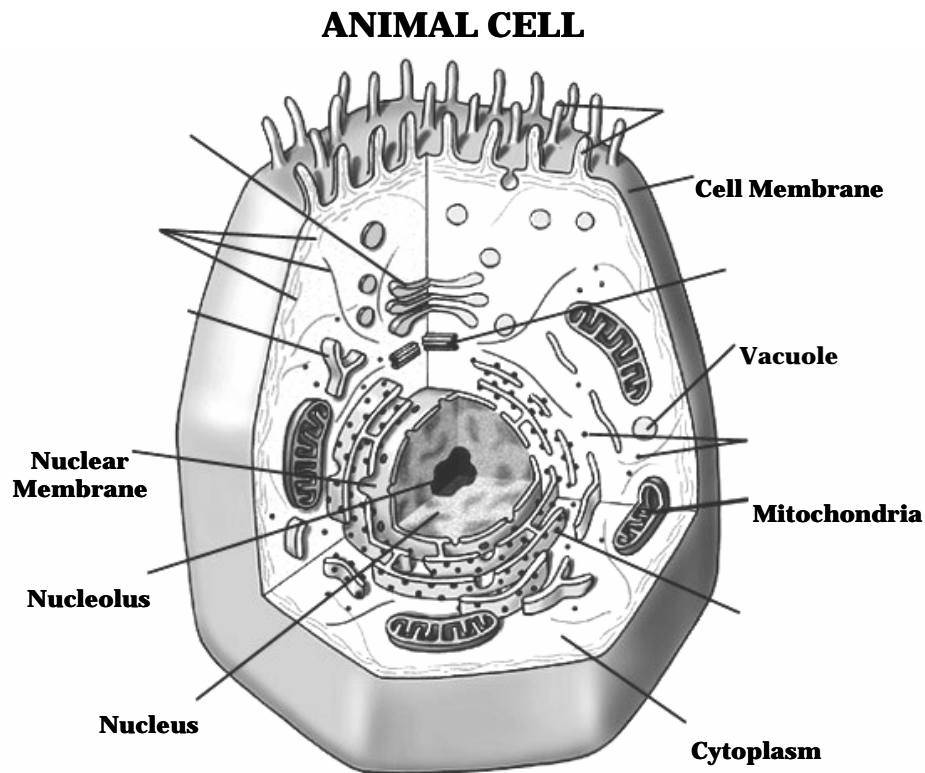


Figure 1 – Typical animal cell. (Diagram from <http://www.gadsdenstate.edu/sci>)

the cell's DNA (De-oxy Ribonucleic Acid). It is also known as the control center and determines almost all the activities that take place in a cell.

Other organelles include **mitochondria** which are known as the “power

houses” of cells, where glucose (stored chemical energy) is converted into ATP (Adenine-Tri-Phosphate - a usable form of energy).

Note: Animal cells differ from plant cells in that animal cells do not have a cell wall, do not have chloroplasts (chloroplasts contain chlorophyll and are the site of photosynthesis) and do not have a large central vacuole (stores substances and gives plants rigidity). Vacuoles are found in both plant and animals cells, but only plants contain a central vacuole.

- **Multicellularity**: All animals are **multicellular** meaning their bodies are composed of many cells. Eukaryotic organisms made up of one cell (unicellular) are known as protists (see Tab 3 – Living Organisms).

The cells of most animals are grouped together to form different kinds of **tissues** (except sponges). A tissue is a group of similar cells that perform a specific job. For example, muscle tissue allows animals to move, while nerve tissue carries messages from one part of the body to another. Tissues may combine to form an **organ**, which is a group of different tissues that work together to perform a specific job that is more complex than the functions of each tissue by itself. A human thigh bone, for example, is an organ that contains bone tissue, nerve tissue, and blood. In most animals, different organs combine to form an **organ system**, such as the digestive system, skeletal system, etc. Tissues, organs and organ systems will be

discussed in more detail later in the Human Body section (See Tab 6 of binder).

- **Motility:** Most animals are able to move on their own. **Movement** in animals is generally associated with obtaining food, reproducing, and avoiding predators. For example, barnacles wave their feathery appendages through the water to collect plankton. Some birds, such as ducks, fly thousands of miles each spring to the place where they mate and lay eggs. Hermit crabs are able to squeeze their bodies into their shells to escape hungry predators.

Some animals are **sessile**, meaning they cannot move from place to place, but these animals *do have motility at some stage in their life*. For example, oysters, sponges and corals all stick firmly to underwater rocks and other solid surfaces as adults. However, *in their larval stage* during the first few weeks of their lives, they swim around the ocean as plankton.

In order for animals to move, they must overcome two physical properties in the environment – **gravity** and **friction**. Animals encounter less friction in air than in water. However, they encounter less effect of gravity in water than in air due to buoyancy. Animals that fly have adaptations, such as wings, for overcoming gravity. They also tend to be less massive than animals that don't fly. Aquatic animals tend to be

streamlined, which reduces friction. When comparing the amount of energy used by animals while moving on land or through air or water, swimming requires the least energy for those animals that are adapted to an aquatic lifestyle. Furthermore, the amount of energy used is related to an animal's size. For example, larger animals expend less energy per unit of body mass than do smaller animals – elephants use less energy per unit mass than do dogs. Overall, however, elephants use much more energy than dogs because they are so much bigger.

- **Body Symmetry:** There are three basic kinds of symmetry in living things – **spherical**, **bilateral**, and **radial** (See Fig. 2). Spherical symmetry is when everything is the same in all directions (like on the surface of a sphere). An animal is bilaterally symmetrical if there is a single plane that divides it into two mirror images. And finally, an organism has radial symmetry if there are many planes that divide it into mirror images.

Animals that lack these basic symmetries, such as sponges, are said to be **asymmetrical**. Spherical symmetry is rare but may be observed in free-floating organisms, such as some protozoans (protists). Amoebas become spherical when they are at rest.

Some animals exhibit both radial and bilateral symmetry but at different stages in their life cycles. For example, echinoderms (e.g. sea stars) are

radially symmetrical as adults, but the larvae are bilaterally symmetrical.
The presence of bilateral symmetry in the larval stage is one characteristic that indicates the relatedness of echinoderms to chordates (organisms with a nerve chord).

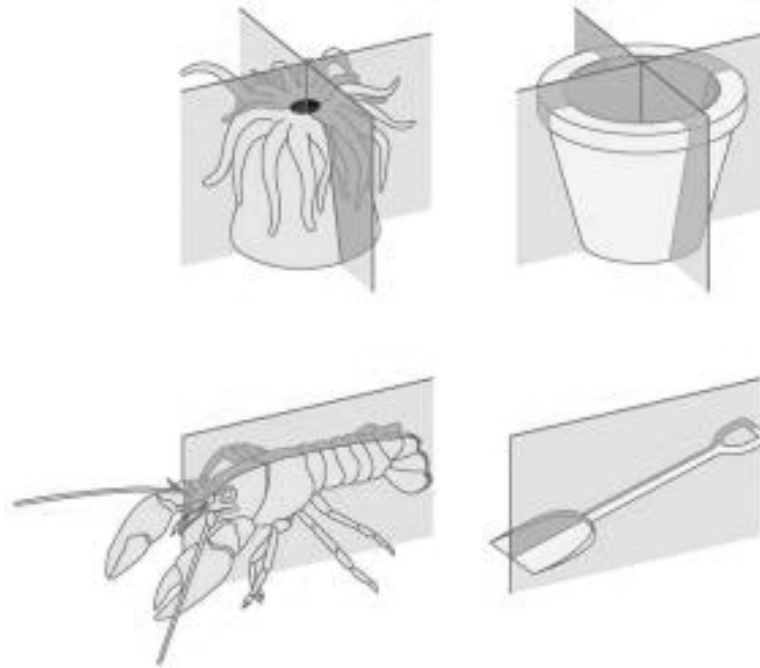


Figure 2 - On top, sea anemone and pot showing radial symmetry.
On bottom, lobster and shovel showing bilateral symmetry.
(Diagram from <http://www.uta.edu/biology>)

NEEDS OF ANIMALS:

Animals need to find and consume food containing energy and nutrients, while at the same time they need to avoid being consumed themselves. Animals require locomotion systems enabling them to find food and to escape from consumers (predators) and unfavorable surroundings. Animals also need to exchange respiratory gases with their environment and carry out metabolic processes. Because most animals differ in chemical composition from their environment, they need to regulate their internal composition, this includes removing metabolic waste products, monitoring how the internal and external environments are changing, and if appropriate, act on it.

Animals must adopt reproductive and life-cycle strategies that maximize their genetic contribution to future generations. Most importantly, the development and timing of all these different functional systems need coordination in order for the individual to act as a unified whole in its behavior and physiology.

What this basically means is that all animals 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 an animal species are:

- Water
- Energy (food)
- Oxygen
- Stable internal conditions
- Shelter
- Reproduction (*for population survival only*)

Animals vary not only in size but also in body structure, outward appearance, and the environment in which they live. Despite their diversity, however, all animals carry out the same **basic functions** (digestion, respiration, reproduction, excretion, etc...) to meet their need for water, food, oxygen, stable internal conditions, movement and reproduction. Structures and behaviors that allow animals to perform these basic functions in their environments are called **adaptations**.

- **Obtaining Water:** Like all living things, animals need water. Water is needed for the chemical reactions that keep animals alive, such as the breakdown of food and excretion of metabolic wastes. Animals obtain water from their environment, finding some of it in their food. Most animals need freshwater. Others have adapted to drinking saltwater and excreting the excess salt through specialized glands (e.g., seabirds and sea

turtles excreting the salt through crying). Some animals live in areas with very little water, such as desert kangaroo rats. These animals obtain water from their food and their specialized kidneys allow them to conserve most of that water and excrete very concentrated urine. Camels are also desert animals that rarely drink and they are able to conserve water by concentrating not only their urine, but their dung as well. In fact, the fresh dung is so dry that it can be burned for fuel!

- **Obtaining Energy (Food):** Animals are unable to make their own food and therefore obtain it by consuming other organisms. Animals may feed on plants, other animals, or a combination of plants and animals. They have adaptations that allow them to eat particular kinds of food. For example, tarantulas have an adaptation called fangs – structures that allow them to pierce other animals and suck in their juices.

Food provides animals with the raw materials for growth and with the energy needed for their bodies' activities, such as breathing and moving. Most animals take food into a cavity inside their bodies. Inside this cavity the food is digested, or broken down into substances that the animal's body can absorb and use.

Animals can be categorized according to what they eat:

- **Herbivores** are animals that eat only plants. These animals have adaptations such as teeth with broad flat surfaces that are good for grinding tough plants. Examples of small herbivores include grasshoppers, termites and garden snails; large herbivores include cows, elephants and manatees.
- **Carnivores** are animals that eat only other animals. Many carnivores are **predators** that hunt and kill other animals. Predators have adaptations that help them capture and kill the animals they feed upon, their **prey**. Tigers, for example, run down their prey. Their adaptations include sharp claws, keen hearing and eyesight. The teeth of most carnivores are sharp and pointed – they are adapted for cutting and stabbing. The distance between the canine teeth of a tiger is equal to the distance between its prey's (deer) vertebrae. This adaptation allows tigers to snap the deer's neck efficiently. Not all predators use teeth to kill their prey. Some, such as frogs and anteaters, have sticky tongues which help them capture and keep hold of insects.
- **Omnivores** are animals that eat both plants and animals. For example, black bears eat fruits and berries but will occasionally eat insects and small mammals. Humans are also considered

omnivorous. Omnivores have teeth that suit their diet, a combination of sharp teeth to tear flesh and flat teeth to grind plants.

- **Decomposers** are animals that consume dead organic material (detritus), which is mainly decaying plants and animals.

Decomposers recycle the carbon in decaying plants and animals by mechanically and chemically breaking it down. During decomposition, carbon is returned to the atmosphere to be reabsorbed by living plants. Without decomposers, soils and water bodies would be buried in organic debris and lose their fertility.

Examples of decomposers include insects and earthworms.

- **Obtaining Oxygen:** An animal's cells *need oxygen to release Stored chemical energy* from food. Some animals, like turtles, get oxygen from air. Others, like fish, get oxygen from water.

Remember both plants and animals need to break down food molecules to release energy. This process is known **cellular respiration** and is the opposite of photosynthesis. Cellular respiration takes place in the **mitochondria** of plant and animal cells. It is a metabolic process similar to burning fuel. While burning converts almost all of the energy in a fuel to heat, cellular respiration releases much of the energy in food to make **ATP**

(Adenine Tri-Phosphate). This ATP provides cells with the energy they need to carry out their vital activities.

The word *burn* is often used to describe how cells get energy from food. Although the overall processes are similar, the “burning” of food in living cells clearly differs from the burning of a log in a campfire. When a log burns, the energy stored in wood is released quickly as heat and light. But in cells, chemical energy stored in food molecules is released gradually in a series of enzyme-assisted chemical reactions. When cells break down food molecules, some of the energy is released as heat. Much of the remaining energy is stored temporarily in molecules of ATP. Like money, ATP is a portable and usable form of energy “currency” inside cells. ATP delivers energy wherever energy is needed in a cell. The energy released from ATP can be used to power other chemical reactions, such as those that build molecules. Cellular respiration requires sugar and oxygen and releases carbon dioxide, water and ATP (usable form of energy).



Animals require sugar as an immediate source of energy but it is not enough for their survival. The animal must eat foods rich in **carbohydrates** (e.g. starch) for energy, **proteins** for cellular processes

(e.g. enzymes and muscle building), **fats** for storage and **minerals** to make important chemicals such as DNA. The glucose molecule contains carbon (C), hydrogen (H) and oxygen (O), all of which are derived from water (H₂O) and carbon dioxide (CO₂). Proteins and nucleic acids (components of DNA) are also made up of C, H and O, but they also contain phosphorus (P) and nitrogen (N). In addition to providing fuel for ATP production, an animal's diet must also supply all the raw materials needed for biosynthesis (synthesis of organic compounds such as DNA, proteins, lipids, etc...).

An animal's diet must also include **essential nutrients**, which can be broken down into four classes: essential amino acids, essential fatty acids, vitamins, and minerals. Essential nutrients are the materials that must be obtained in a preassembled form because the animal's cells cannot make them from any raw material. Some of these materials are essential for all animals, but others are needed only by certain species. For instance, ascorbic acid (Vitamin C) is an essential nutrient for humans, primates, guinea pigs, and some birds and snakes, but not for most other animals. Lack of vitamin C, for animals that require it, results in a disorder known as scurvy. An animal whose diet is missing one or more essential nutrients is said to be **malnourished**.

- **Maintaining Stable Internal Conditions:** All living things must maintain a stable environment within their bodies. If this balance is lost, living things including animals cannot survive for long. This ability of animals to regulate their internal environment is called **homeostasis** (homeo = same). Many animals have evolved elaborate physiological mechanisms that allow them to maintain precise internal conditions despite a lifetime spent in harsh environments. For example, desert dwellers such as the kangaroo rat have kidneys that allow them to conserve water, while freshwater animals such as trout or frog secrete excess salt from their gills. Because the cells of animals cannot survive if the conditions of the internal environment deviate from a small range of acceptable states, cells devote a large portion of their energy to actions that serve to keep the cellular environment stable.

Homeostasis regulates internal body temperature, blood pH, concentration of salts and water, and the concentration of nutrients and waste products.

Finding Shelter: In order to survive animals need more than food, water and stable internal conditions, they need to avoid becoming food themselves and they need to find a safe place to sleep and rear their young. Animals have **structural and behavioral adaptations** that help them

avoid being eaten by predators. Structural adaptations include spiny skin in hedgehogs or hard shells in turtles to deter predators from biting into them. Many animals, and especially their young, are **camouflaged** which allows them to blend in with their environment and avoid being seen by predators. Other animals have developed **chemical defenses** and advertise their toxicity with bright colors, as seen in poison arrow frogs. Animals can protect themselves behaviorally too. For example opossums and some snakes play dead when they are attacked, so their predators lose interest.

- **Reproduction:** Because no individual animal lives forever, animals must reproduce for their species to survive. 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. Most animals reproduce sexually, but some can reproduce asexually as well as sexually.

Sexual reproduction is the creation of offspring by fertilization, the fusion of an egg and sperm to form a zygote (fertilized egg). In this process, 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. Thus, 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 fishes may start off as a male or female and subsequently become the opposite sex. It would take a long time to explain how this happens, but it is a natural process for many common reef fish.

Asexual reproduction is the process by which a single organism produces a new organism identical to itself. This is the creation of new individuals whose genes all come from one parent *without* the fusion of egg and sperm. 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 (re-growth 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) to regenerate lost tails, etc. Note: Vertebrates do not use it for reproduction, rather they grow back certain body structures when lost.

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).

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.

STRUCTURE AND FUNCTION:

Structure (also referred to as form) and function are generally correlated at all levels of biological organization, from molecular to organismal. Natural selection fits a structure to a function over many generations (utilizing available variability). Animals have a variety of structures with specific functions. For example, moths have a long tong-like proboscis to

access nectar in flowers. The long proboscis (structure) is a structural adaptation for feeding (function) that evolved via natural selection.

Animal tissues are a great example of the form-function principle.

Basically, animals are comprised of hierarchical levels of organization (cells – tissues – organs – organ systems) and tissues are basically groups of cells with a common function and structure. Furthermore, different tissues have different structures especially suited to their functions.

Not all structures have functions, however, and not all traits are adaptive. Some traits exist because they are remnants of structures that were present in ancestors or that appeared in the individual as an embryo. Further, all adaptations are constrained by genetic correlations with other traits, lack of genetic variation, historical constraints, and trade-offs. In reproduction, for example, females must make a trade-off between the number and quality (size) of eggs that they produce. Because trade-offs are inevitable, all adaptations are compromises.

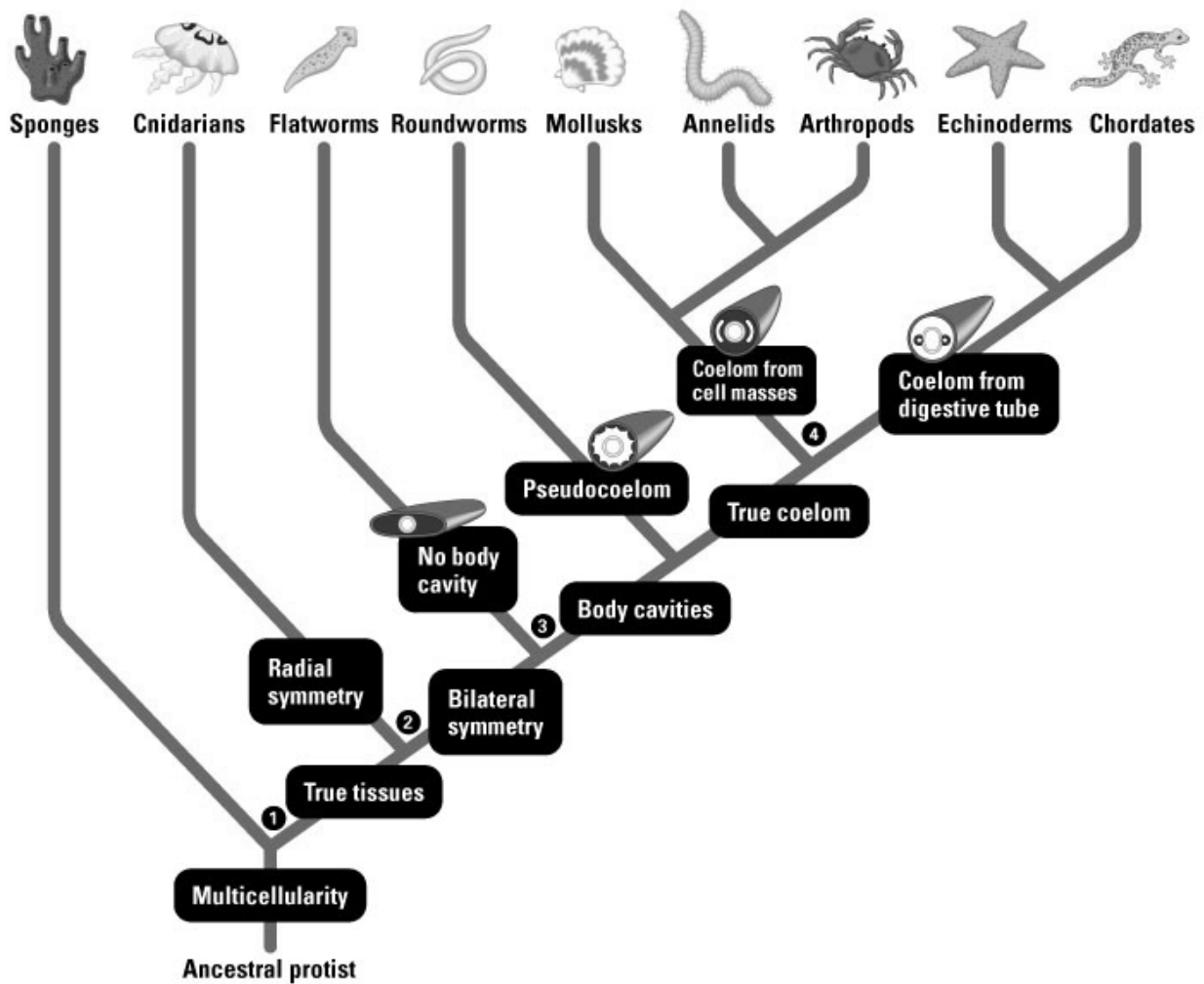
Note: **Anatomy** is the study of the structure of an organism and

Physiology is the study of the functions an organism performs. Both will be discussed in more detail later on (See Tab 6 of binder).

CLASSIFICATION OF ANIMALS:

Remember that animals belong to the domain Eukarya (presence of nucleus) and the Kingdom Animalia (multicellular heterotrophs), which contains about 35 phyla. To visually represent the relationships among various groups of animals, scientists often use a type of branching diagram called a **phylogenetic tree**.

This tree shows how the animal phyla are related through evolution (See Fig.3).



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Figure 3 – Phylogenetic tree of nine of the 30 animal phyla (kingdom Animalia). All these phyla are invertebrates except for chordates, they are vertebrates. (Diagram from www.campbellbiology.com)

The tree in figure 3 also shows the order in which biologists think animal life has evolved, or changed over time. This evolutionary process has resulted in all different phyla that exist today. Biologists hypothesize that all animals arose from unicellular ancestors (protists).

Animals are classified according to how they are related to other animals. These relationships are determined by an animal's body structure, the way the animal develops, and its DNA. All vertebrates are classified in a sub-phylum of the phylum chordata. All the other animal phyla contain invertebrates. Of all types of animals, about 97 percent are invertebrates.

- **Invertebrates:** The following information is purely in case kids ask questions, but do not spend any length of time on these organisms. Your goal is to get to vertebrates and study them in more detail.

Once again, invertebrates are animals without backbones and they include in evolutionary order: sponges, jellyfish, flatworms, roundworms, mollusks, annelids, arthropods and echinoderms. All these invertebrates have distinguishing characteristics that are summarized in Table 1.

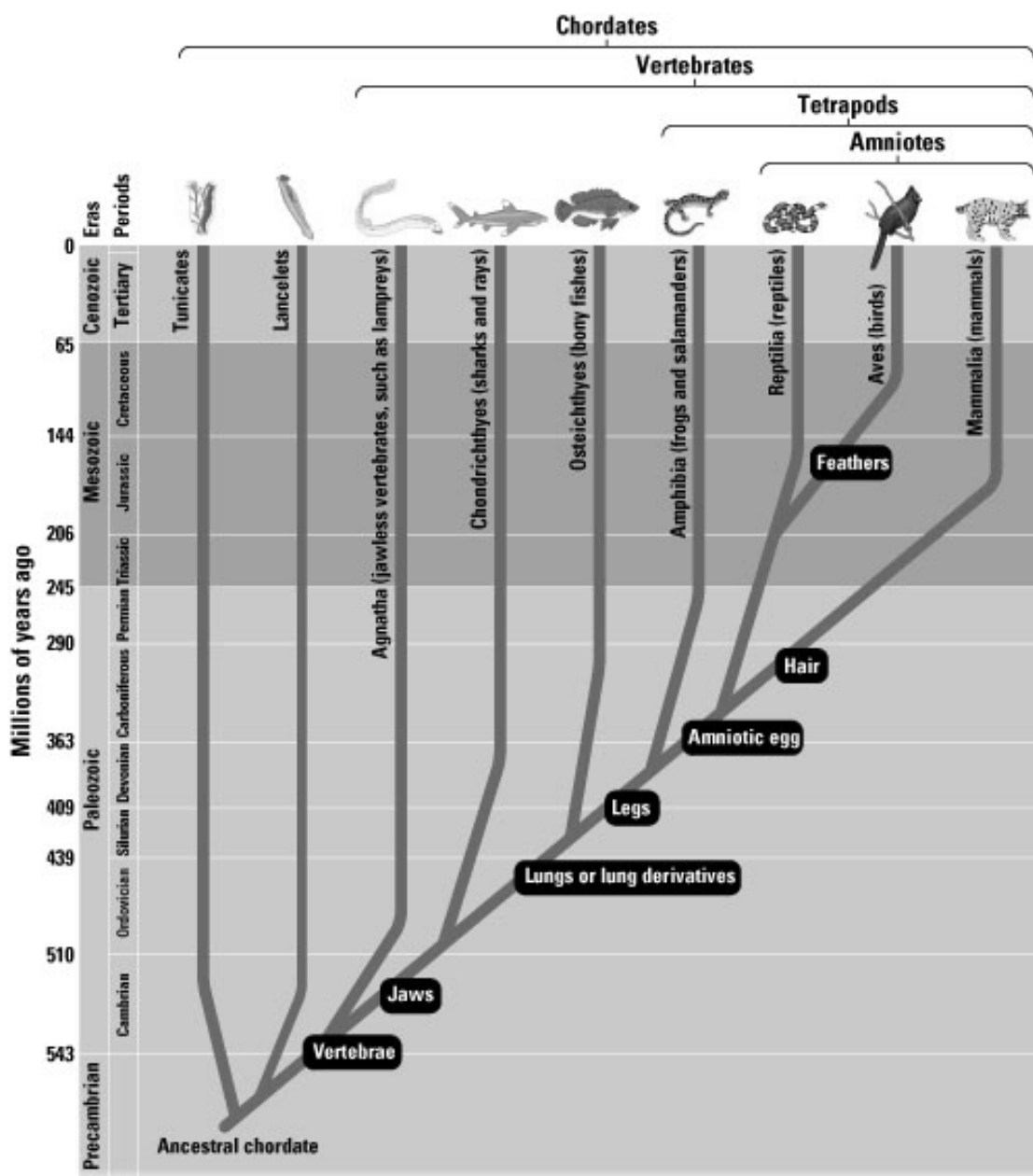
NOTE: It is important to remember that scientists are making constant discoveries about living things and these discoveries can sometimes lead to reclassification of these living organisms. Once again nothing is set in stone and there are always exceptions to every rule! Not all organisms can be classified according to key characteristics, but in general it is an easier way to study organisms.

TABLE 1 – Summary of the distinguishing characteristics of eight of the most common phyla of invertebrates.

Phylum	Examples	Characteristics
Sponges	Barrel sponge	<ul style="list-style-type: none"> • Assymetrical • Sessile • Body perforated with holes • Internal skeleton fibers
Jellyfish	Coral, man-o-war	<ul style="list-style-type: none"> • Radial symmetry • Possess tentacles with stinging cells • Basic body plan with one opening functioning both as a mouth and anus • No skeleton, although some build limestone covering around them (corals)
Flatworms	Tapeworms	<ul style="list-style-type: none"> • Bilateral symmetry • Flat bodies • Gases move by diffusion • No skeleton
Roundworms	Pinworms, hookworms	<ul style="list-style-type: none"> • Bilateral symmetry • Complete digestive tract with two openings: a mouth and an anus • No skeleton
Mollusks	Snails, clams, octopus	<ul style="list-style-type: none"> • Bilateral symmetry • Complete digestive tract • Soft-bodied but protected by hard shell (reduced or internal in squid, slugs and octopuses)
Annelids	Earthworms	<ul style="list-style-type: none"> • Bilateral symmetry • Segmented soft body • Complete digestive tract

Arthropods	Crustaceans, insects, arachnids, millipedes and centipedes	<ul style="list-style-type: none"> • Bilateral symmetry • Segmented bodies • Complete digestive tract • Exoskeleton • Molting
Echinoderms	Starfish, sea urchins, sea cucumbers	<ul style="list-style-type: none"> • Radial symmetry • Sessile or slow-moving • Complete digestive tract • Internal skeleton (hard plates under skin) • Bumpy or Spiny skin

- **Vertebrates:** These are animals that have a backbone. They are further sub-divided into classes, six of which in evolutionary order are: cartilaginous fishes and rays, bony fishes, amphibians, reptiles, birds



and mammals (See Fig. 4)

Figure 4 – The vertebrate phylogenetic tree. “Tetrapods” refer to the four legs of terrestrial vertebrates. “Amniotes” refers to the evolution of the amniotic egg, a shelled egg that made it possible for vertebrates to reproduce on land. (Diagram from <http://www.campbellbiology.com>)

Vertebrates share common characteristics, which are summarized in table 2, but there are always exceptions.

TABLE 2 –Distinguishing characteristics of the 5 most common vertebrate classes

Class	Examples	Characteristics
Cartilaginous Fishes	Sharks and Rays	<ul style="list-style-type: none"> • Skeleton made of cartilage • Most have teeth-like scales (denticles) • Breathe oxygen in water with gills • Lay eggs without shells or give birth to live young • Cold blooded
Bony Fishes	Salmon, tuna, goldfish	<ul style="list-style-type: none"> • Bony skeleton • Most scales • Breathe oxygen in water with gills • Lay eggs without shells or give birth to live young • Cold blooded
Amphibians	Salamanders, frogs	<ul style="list-style-type: none"> • Bony skeleton • Smooth, moist skin • Young breathe oxygen in water with gills; adults breathe with lungs and through skin • Lay jellylike eggs with no shells • Cold blooded
Reptiles	Snakes, turtles	<ul style="list-style-type: none"> • Bony skeleton • Have scales • Breathe air with lungs • Lay eggs with leathery shells or give birth to live young • Cold blooded
Birds	Penguins, owls	<ul style="list-style-type: none"> • Hollow bony skeleton • Have feathers • Breathe with lungs • Lay eggs with hard shells • Warm blooded
Mammals	Humans, dolphins, dogs	<ul style="list-style-type: none"> • Bony skeleton • Have hair or fur • Breathe with lungs • Mothers nurse young with milk • Almost all give birth to live young; a few lay eggs • Warm blooded