EVOLUTION—Descent with modification. Change through time. Can apply to the **phenotype** or the **genotype**. Does not imply a specific mechanism. The notion of evolution was around long before Charles Darwin. **Darwin** is famous for proposing a specific, plausible and well-supported mechanism for evolution—**natural selection**.

GENOTYPE—The total set of genes/genetic information held within an individual organism.

PHENOTYPE—The physical body of the organism and its functions. In total it consists of the anatomy, the functions and the behaviors of an organism.

NATURAL SELECTION—The mechanism responsible for most (but not all) evolution and especially, for **adaptation** (the 'match' or 'fit' between an organism's phenotype and the environment it inhabits). Proposed by Darwin and supported by his book, *The Origin of Species*, published in 1859. Natural selection simply proposes that any individual who possesses some heritable trait (a trait that can be passed on to the next generation) that gives that individual an advantage, however slight, in staying alive to reproduce will leave more offspring, on average, than individuals lacking the trait. As such, the number of individuals possessing the advantageous trait will usually increase in number in the population through time (across generations) and the new trait (an adaptation) will become a fixed characteristic of the species.

ARISTOTLE (384-322 BC)—was a great scientist, thinker, scholar and philosopher. He organized all life into a **vertical hierarchy** based on his perception of relative complexity. This hierarchy came to be called the 'scale of life' or **scale of nature** (*scala naturae*). Humans, or course, were at the top of this hierarchy.

RICHARD OWEN (1804-1892)—One of the greatest comparative anatomists of all time. He coined the terms **homology** and **analogy**. He was not an evolutionist (at least not publicly) and he argued that species did not transform into other species (i.e., he believed in **special creation**). However, he suggested that there was an **archetype** that represented an idealized, basic/generalized form of a group, such as the vertebrates, and that all vertebrate species were variations on the theme of this archetypal form.

CHARLES DARWIN (1809-1882)—The most famous evolutionist, Darwin wrote the *Origin of Species* (1859) in which he proposed his new theory of **natural selection**, which he supported with voluminous facts and observations. He also originated the **metaphor of a tree** to represent the branching pattern of life as it evolves through time, with one species giving rise to two daughter species, etc.

STEPHEN J. GOULD (1941-2002)—Along with Niles Eldridge, is responsible for the notion of **punctuated equilibrium**, among many other things.

HIERARCHICAL CLASSIFICATION—The type of classification proposed by **Aristotle**, in which species are fixed and ranked one above the other (hierarchically) from least complex to most complex. This type of classification of life was applied by Judeo-Christian theology and teaching for the next 2000 years!

TREE METAPHOR—Originated by Darwin, in which the evolutionary history or pattern of genealogical descent/continuity among species is represented by a branching pattern (**phylogeny**) showing the historical connectedness among species.

"PLANE OF EQUIVALENCY"—All species living at one time (e.g., the present) can be represented as dots arrayed across a flat surface (a plane) with their genealogical history (**branching pattern/phylogeny**) beneath them. This metaphor emphasizes that every living species has exactly the same amount of evolutionary history beneath them and that no one species is 'above' or 'below' another—there are no 'lower' or 'higher' organisms.

PROTOSTOMES vs. DEUTEROSTOMES—Together, the large groups Protostomata and Deuterostomata contain most of the animals we are familiar with (but not ALL animals). Protostomes include arthropods, nematodes, platyhelminths, rotifers, mollusks, annelids and some others; deuterostomes contain the **echinoderms** (starfish, sea urchins, etc.) and the **chordates** (incl. vertebrates) The two groups are distinguished on the basis of several differences in their early development. 'Protostome' = "first mouth" and refers to the fact that in the **gastrula**, the **blastopore** first forms a mouth, whereas in deuterostomes ("second

mouth", the blastopore eventually becomes the anus and the mouth forms later in development as a separate opening on the other side of the embryo (deuterostome = second mouth).

ECHINODERMS—A group containing starfish and sea urchins that together with the Hemichordata and the **Chordata** constitute the **deuterostomes**. This seems strange, at first, because echinoderm adults are all **radially symmetrical**—unlike **chordates**, which are all **bilaterally symmetrical**. However, it turns out the echinoderm larvae are bilaterally symmetrical and share a deuterostome method of gastrulation in the early embryo.

CHORDATA—The **monophyletic group** including the **Cephalochordata**, the **Urochordata**, and the **Vertebrata**. All chordates share certain characters, such as **pharyngeal pouches** (and sometimes **slits**), a **notochord**, a **dorsal, hollow nerve cord**, a **thyroid gland or endostyle** and a **post-anal tail** *at some point in their life*.

CEPHALOCHORDATA—The non-vertebrate, chordate group containing the amphioxus or lancelet, a small aquatic creature that lives in the sand, filter-feeding. It possesses a notochord, a dorsal hollow nerve chord and an extensive pharyngeal skeleton (fibrous) used to trap food particles, but it lacks any head structures anterior to the end of the notochord.

UROCHORDATA—Includes tunicates ('sea squirts). *The chordate group most closely related to* ***vertebrates***. Adult sea squirts don't look anything like vertebrates, but their larvae have a **tail**, **pharyngeal slits, an endostyle**, and a **notochord.**

VERTEBRATA—Contains the living jawless fishes (**Aganatha**), including **hagfish** and **lampreys** (**Cyclostomata**), **cartilaginous fishes**, several groups of **bony fishes** and all **tetrapods**. Characterized by a **notochord** (at some point in their lives), a **head skeleton** and **vertebrae**, as well as other chordate characters.

AGNATHA—Jawless fishes. Evolved before vertebrates with jaws (**gnathostomes)**. Once very numerous and diverse, all are now extinct except for **hagfish** and **lampreys** (**the cyclostomes**). All had or have **cartilaginous internal skeletons**, but some extinct species also had **bony armor** in their skin.

GNATHOSTOMATA—Jawed vertebrates. Living groups include the **cartilaginous fishes**, various **bony fish groups** and the **tetrapods**. Evolved from **jawless fishes** in which the **first visceral arch became modified into grasping jaws** as they evolved from passive filter-feeders to more active predators that grasped individual prey items.

CHONDRICHTHYES—The **cartilaginous fishes**, including sharks, rays and ratfish (chimaera). As in ancestral fishes and the early embryos of all vertebrates, their internal skeleton is made of cartilage, but unlike other vertebrate groups, it remains cartilage even as adults. It is presumed that they lost the dermal bone found in the skin of their agnathan ancestors (sharks still retain dermal spicules in their skin called '**denticles**' that make their skin rough). Chondrichthyans branched off from the vertebrate lineage after jaws evolved, but before a bony, internal skeleton evolved.

OSTEICHTHYES—This name means 'bony fishes', but in modern terms it is the group that includes all vertebrates that have bone in their skeletons (i.e., everything but agnathans and Chondrichthyans). As such, it includes terrestrial vertebrates (tetrapods), because they evolved from within one particular group of bony fishes. The major group of osteichthyan that is not a tetrapod is called the **'ray-finned fishes'** or **Actinopterygia**. These include more 'primitive' members, such as the bowfin (*Amia*), the gar and the bichir (*Polypterus*), as well as very derived fishes belonging to the **Teleostei (teleosts)**. We often use the informal term 'bony fishes' to refer only to the members of the Osteichthyes that are actually fish, i.e., the members of the group not including tetrapods. This would include the ray-fins, the **coelacanth** and the **lungfish (Dipnoi)**, as well as many extinct, fossil groups (the Dipnoi is the living fish group most closely related to tetrapods). The coelacanth and the lungfish (plus their fossil relatives), along with the tetrapods, are together called the **Sarcopterygia**, meaning 'fleshy-fins'. Tetrapods evolved from an extinct group of fleshy-finned fish in which the muscular fin lobes were transformed into terrestrial limbs with digits instead of fins.

ACTINOPTERYGIA—The largest group of vertebrates, the **ray-finned fishes**, including the most diverse and numerous group, the **teleosts**. Their fins have narrow bases and the fins are supported by a series of **fin rays.**

SARCOPTERYGIA—These are the so-called **fleshy-finned fishes** (or **lobe-finned fishes**), the Sarcopterygia includes the **tetrapods** (whose fleshy fins became limbs). Non-tetrapod fleshy-finned fishes include the **coelacanth** and the **lungfish**. The fin base is extends from the side of the body and contains bones and musculature that are homologous with those in the limbs of tetrapods. In the fishes, the fleshy fin base, or lobe, supports the fin structure.

TETRAPODA—The terrestrial vertebrates, including their aquatic and limbless descendants. The earliest tetrapods lived an essentially fish-like existence, but are distinguished from their fish ancestors by the presence of individual **digits** rather than fins.

REPTILIA—The **monophyletic group** including **turtles**, **tuatara**, **lizards**, **snakes**, **crocodilians** and **birds**. Usually defined as the common ancestor of all the living groups (listed here) and all of its descendants. Although the earliest (stem) reptiles had anapsid skulls, modern reptiles are derived from a diapsid ancestor.

SYNAPSIDA—The lineage of vertebrates that ultimately gave rise to the living **mammals**. The group is characterized by a synapsid skull in which there is a single temporal fenestra (largely obscured by brain enlargement in living mammals).

MAMMALIA—The common ancestor of all the living mammals (**monotremes**, **marsupials** and **eutherians**) and all of its descendants. Mammals are synapsids, but have evolved many novel features, such as a new jaw joint (**dentary-squamosal instead of articular-quadrate**) and **3 middle ear ossicles** (instead of 1).

PHYLOGENY—The evolutionary history of a group of organisms, represented by a **branching diagram** or **evolutionary/phylogenetic tree**.

ONTOGENY—The transition of a single organism, from a **zygote,** to an **embryo** or **larva**, to a **hatchling** or **newborn**, to a **juvenile**, to an **adult** (sexual maturity/reproductive), which then progresses through **senescence** to death. In other words, the complete life span of an individual organism. The first part of ontogeny, during which a zygote develops into a functional organism capable of living outside of an egg or the mother's body, is called **development** (usually restricted to the period from fertilization to birth/hatching)