

Kingdom Animalia

1. General Measures of Complexity
 - a. Embryonic development
 - i. The embryos of all animals go through the same stages during development so this can't be used as a measure of development *per se*. We include it here because the germ layers (See below) are established during this time.
 - ii. The zygote becomes an adult through **embryonic development**.
 - iii. The cells of the zygote divide to form a hollow ball of cells called a **blastula**. This ball folds inward to form a **gastrula** during **gastrulation**. The opening of the gastrula becomes either the mouth or anus.
 - b. Germ layers
 - i. All cells of the adult organism can be traced to one of the three **germ layers**. Some animals have only the inner and outer germ layers but more complex animals have mesoderm as well.
 - (1) The **ectoderm**, or outer layer, gives rise to the outer covering of the animal (skin, hair, nails, feathers, scales) and the nervous system.
 - (2) The **endoderm**, or inner layer gives rise to the digestive tract and associated organs.
 - (3) The **mesoderm**, or middle layer gives rise to muscles, skeleton, circulatory system, kidney, reproductive system
 - c. Body cavity
 - i. The evolution of a body cavity is important because:
 - (1) Circulation - fluids moving in the cavity function as a circulatory system
 - (2) Movement - fluid in the cavity makes the body rigid
 - (3) Organ function - organs can function without being deformed
 - (4) Food movement, digestion and waste removal - are not limited by movement of the animal
 - d. Symmetry
 - i. **Asymmetry** - The simplest animals have no symmetry.
 - ii. **Spherical** - No animals possess spherical symmetry.
 - iii. **Radial** - The axis of symmetry goes through the center of the animal from top to bottom. These animals are more complex than those with no symmetry. No one end leads.
 - iv. **Bilateral** - The axis of symmetry is through the middle of the animal from head to tail. Bilateral organisms exhibit right and left halves, mirror images to each other.
2. Evolutionary trends in Kingdom Animalia
 - a. Symmetry - from none to bilateral
 - b. Germ layers - from one to two to three
 - c. Cephalization - from none to highly cephalized
 - d. Digestive tract - from two-way to one-way
 - e. Reproduction - from hermaphrodites with external fertilization and little young care to separate sexes with internal fertilization and extensive young care
 - f. Circulatory system - from none to an open system to a closed system
 - g. Behaviour - from very simple to complex
 - h. Segmentation - from none to highly segmented

3. Phylum Porifera - sponges

a. General

- i. Sponges are the simplest of animals, having only one germ layer (some biologists say they have no true germ layers), and lacking symmetry and tissues.
- ii. The body is little more than a mass of specialized cells, not not organized into tissues.
- iii. Adults are **sessile** and remain anchored to the ocean floor or lake bottoms

b. Nutrition

- i. They gain nutrients by filtering particles out of the water.

c. Reproduction

- i. Asexual reproduction by budding is common.
- ii. Sponges are **hermaphrodites** but produce eggs and sperm at different times to avoid self-fertilization. This is called **sequential hermaphroditism**.

4. Phylum Cnidaria - jellyfish, sea anemones and corals

a. General

- i. Cnidarians have radial symmetry. Although starfish and sea urchins also display radial symmetry as adults, they are not in this phylum.
- ii. Have only two germ layers which give rise to true tissues in the adult body.
- iii. Have two body forms
 - (1) **Polyp**: cylindrical, generally attached to a substrate (*e.g.*, anemone)
 - (2) **Medusa**: umbrella-shaped, free floating, gelatinous (*e.g.*, jellyfish)

b. Nutrition

- i. Carnivores which capture food with tentacles surrounding the mouth. **Cnidocytes** (stinging cells) on the tentacles paralyze prey which is then brought into the mouth.
- ii. Food is digested in a gut (**gastrovascular cavity**) and the resulting particles are absorbed by cells. This allows the animal to digest something larger than its own cells. The **extracellular digestion** of food is an evolutionary development.
- iii. The single opening (mouth/anus) is a **two-way digestive system**.

c. Reproduction

- i. Separate sexes jellyfish but lower cnidarians like the hydra show asexual (budding) as well.

5. Phylum Platyhelminthes - flatworms

a. General

- i. Flatworms (*e.g.*, planaria) can be found in marine or aquatic environments, as well as damp terrestrial habitats.
- ii. Bilateral symmetry allows both the specialization of different body parts and **cephalization**. Cephalization allows animals to move through and experience their environment head first. Having sensory equipment at the anterior end is more efficient for seeking food and avoiding danger.
- iii. This phylum shows the first appearance of **organs** - a group of tissues that function as one unit.
- iv. These acoelomates have a thin body to allow diffusion of gases and nutrients

b. Nutrition

- i. The digestive system is branched with a single opening (two-way digestive system).

c. Nervous system

- i. Primitive eye spots allow planarians to distinguish light and dark.

- ii. Beginnings of cephalization.
 - d. Reproduction
 - i. Sexual hermaphrodites with the reproductive system only appearing during mating season.
 - ii. Asexual reproduction can result if the animal is split in two.
6. Phylum Nematoda
- a. Roundworms that live in soil and water. Most are harmless but some are parasitic.
 - b. As pseudocoelomates, they have a body cavity located between endoderm and mesoderm.
 - c. Nutrition:
 - i. Having a separate mouth and anus creates a **one-way digestive system**.
 - d. Reproduction:
 - i. Sexual reproduction with separate sexes.
7. Phylum Mollusca - clams, osyters, octopus, snails
- a. General
 - i. Second largest phylum of animals and second most successful land animals, next to insects. There are more terrestrial mollusks than terrestrial vertebrates.
 - ii. These coelomates have a body cavity (**coelom**) that is completely surrounded by mesoderm.
 - (1) The coelom allows space for more complex internal organs, a digestive tract that can be longer than the animal, and a larger reproductive system.
 - iii. All mollusks, except for the bivalves, show clear cephalization. The heavy shell makes these animals largely sessile so cephalization is not required.
 - b. Nutrition
 - i. The longer digestive tract with specialized organs allows better digestion and more diverse food.
 - ii. Gastropods scrape food from surfaces. Bivalves use the gills to filter food particles from the water. Cephalopods are predators with a hard beak for tearing and biting.
 - c. Circulation
 - i. A large body cavity requires the development of a circulatory system. A fluid (often blood) is circulated by the contraction of a muscular heart (or hearts). Blood carries nutrients and oxygen to cells and carries wastes and carbon dioxide away.
 - (1) In a **closed circulatory system**, a network of vessels carries blood to all parts of the body.
 - (2) In an **open circulatory system**, blood circulates freely in the body cavity. As blood is pumped into body spaces, the organs are constantly bathed in it
 - ii. Only cephalopods have a closed circulatory system with a heart and blood vessels. The other mollusks have an open circulatory system. The closed system has allowed cephalopods to be larger and more active.
 - d. Nervous system
 - i. The nervous system is highly developed in cephalopods because they are predators. They have a highly developed brain which allows them to learn and solve problems. Their image-forming eyes gives them quite good vision.
 - e. Reproduction
 - i. Most mollusks show sexual reproduction with separate sexes.
 - ii. Young care is highly developed in the octopus.

8. Phylum Annelida - earthworms, leeches, some marine worms
- a. General
 - i. Segmented worms (*e.g.*, earthworms) have a body built from a series of similar segments.
 - (1) The evolutionary advantage is that by changing one segment, it can create a new body part without affecting other parts.
 - (2) Although segmentation is continued through all other phyla (including humans) it is not always obvious. Examples of segmentation in humans is seen in muscles and in the spine.
 - b. Nutrition
 - i. One-way digestive system.
 - c. Circulation
 - i. Closed circulatory system. There is no real heart but the muscular sections of some blood vessels are the beginnings of a more advanced system.
 - d. Nervous system
 - i. Simple brain and single nerve cord with short branches into each segment.
 - e. Reproduction
 - i. Some annelids show separate sexes while some are hermaphrodites.
9. Phylum Arthropoda
- a. General
 - i. Arthropods are found in all habitats and are the most numerous and diverse of invertebrates.
 - ii. Jointed appendages are a major advancement because they can be specialized for different functions.
 - iii. The exoskeleton is rigid and made of chitin. It provides protection and limits water loss. The exoskeleton is strong but its weight limits the size of arthropods. To become larger, animals require a strong, flexible endoskeleton. The problem with the exoskeleton is that the animal must molt to grow.
 - b. Adaptations for success
 - i. Segments have specialized functions.
 - ii. Well defined head with excellent sensory apparatus.
 - iii. Jointed appendages. Some are sensory while some are for feeding, manipulating, and moving.
 - iv. Exoskeleton.
 - v. Waste from the blood is excreted as solid crystals.
 - c. Digestion
 - i. Arthropods show a wide variety of feeding strategies that are dependant on their feeding appendages
 - d. Circulation and gas exchange
 - i. Circulation is open.
 - ii. Arachnids exchange gases through a simple lung. Crustaceans have gills at the base of some legs. Insects are quite active and so need a more sophisticated system of gas exchange. They have a system of tubes which open to the outside through which gases can travel.
 - e. Nervous system
 - i. Well developed overall.
 - (1) Crustaceans are able to detect tiny vibrations in the water and have

compound eyes able to form crude images.

- (2) Insects have highly developed sensory gear and most can detect stimuli outside the human range of detection. Most have a few simple eyes and a pair of compound eyes which enable them to form images. They cannot focus well but are excellent for detecting movement. Some insects have tiny hairs which detect air vibrations.

f. Reproduction

- i. Separate sexes.
- ii. **Pheromones** are chemicals released by one individual to affect the behaviour of another individual. Sex pheromones are used to attract a mate.

g. Additional adaptations of insects

- i. Camouflage and coloration
 - (1) **Hiding** - blend into the environment to evade predators or hide from prey
 - (2) **Attracting attention** - bright colors are used to warn potential predators
 - (3) **Mimicry** - harmless insects mimic the coloration of a harmful one to avoid being eaten.
- ii. Social behaviour.
 - (1) Termites, bees, ants, and some wasps have complex social systems with specific division of labour, making the colony more efficient by having individuals who specialize in particular tasks.

10. Phylum Chordata

a. General

- i. Unlike the invertebrates, all chordates are in the same phylum.
- ii. Four characteristic features (not present in all adult chordates):
 - (1) Dorsal, hollow nerve cord. This becomes the spinal cord in most chordates.
 - (2) Flexible rod (notochord) along the back of the embryo. Muscles attach to the rod providing flexible locomotion and leads to the possibility of much large animals. This becomes the backbone in most Chordates.
 - (3) Pharyngeal (gill) slits located behind the mouth
 - (4) Post-anal tail

b. Subphylum Vertebrata

- i. Vertebrates possess a backbone. The notochord becomes surrounded and replaced by a bony vertebral column which protect the dorsal nerve cord. The vertebral column allows the body to flex and provides attachment sites for muscles as well as surrounding and protecting the nerve cord.
- ii. The endoskeleton is made of bone which is much stronger than chitin.
 - (1) All vertebrates have a similar skeletal plan.
 - (2) Fused bones form a skull to protect the brain.
 - (3) Vertebrae protect the spinal cord.
 - (4) Ribs extend from some vertebrae to protect internal organs.
 - (5) Most vertebrates have two pairs of limbs.
- iii. There is a specialized outer covering of the body made of either skin, feathers, hair, scales.
- iv. Vertebrates have a large coelom containing vital organs.
- v. Vertebrates have a closed circulatory system.
- vi. The sexes are separate.

c. Evolutionary trends in the vertebrates

- i. Vertebrates have evolved from being totally dependent on water to having a terrestrial lifestyle. This change required:
 - (1) a change from a cartilaginous to a bony skeleton and legs to support their weight and allow movement on land
 - (2) lungs rather than gills to obtain oxygen from the air
 - (3) a waterproof outer covering
 - (4) a change in reproduction to enable gametes to meet
 - ii. Increasingly complex heart. Vertebrate hearts contain muscular chambers called **atria** (singular, atrium) and **ventricles**. Contraction of a chamber forces blood out. The atrium functions to receive blood that is returning to the heart. When it contracts, blood is pumped into the ventricle. When a ventricle contracts, blood is pumped away from the heart to the body, lungs, or gills.
 - (1) Circulatory System of Fish
 - (a) Fish have a **two-chambered heart** with one atrium and one ventricle. The gills contain many capillaries for gas exchange, so the blood pressure is low after going through the gills. Low-pressure blood from the gills then goes directly to the body, which also has a large number of capillaries.
 - (b) The activity level of fish is limited due to the low rate of blood flow to the body.
 - (2) Circulatory System of Amphibians
 - (a) Amphibians have a **three-chambered heart** with two atria and one ventricle. Blood from the lungs (**pulmonary circuit**) goes to one atrium while blood from the body (**systemic circuit**) goes to the other atrium. Both atria empty into the ventricle where the blood is mixed.
 - (b) The advantage of this system is that there is higher pressure in vessels that lead to both the lungs and body.
 - (3) Circulatory System of Reptiles
 - (a) In most reptiles, the ventricle is partially divided. This reduces the mixing of oxygenated and deoxygenated blood in the ventricle.
 - (4) Circulatory System of Birds and Mammals
 - (a) Birds and mammals (also crocodilians) have a **four-chambered heart** which acts as two separate pumps. After passing through the body, blood is pumped under high pressure to the lungs. Upon returning from the lungs, it is pumped under high pressure to the body.
 - (b) The high rate of oxygen-rich blood flow through the body enables birds and mammals to maintain high activity levels. Also, the mixing of oxygenated and deoxygenated blood is prevented.
 - (c) The increased efficiency of the four-chambered heart permitted birds and mammals to become endotherms. The oxygen demand of providing the energy necessary to maintain a relatively high body temperature could not be met by an open circulatory system.
 - iii. Increased size and complexity of the cerebrum (for learning and complex behaviour).
- d. Class Agnatha - Lamprey eels.

- i. Have a minimal skeleton made of **cartilage** but lack jaws and paired fins.
 - ii. These animals take water in and out through the gills.
- e. Class Chondrichthyes - Sharks and rays
- i. General
 - (1) They have a superior, streamlined design for swimming. Immoveable, paired fins increase propulsion, stabilization and directional movement.
 - (2) The skeleton is made of cartilage.
 - ii. Digestion
 - (1) Development of the moveable jaw allowed these animals to eat larger prey and become top predators. Teeth are sharp and pointed backward.
 - iii. Nervous system
 - (1) Very keen sense of smell.
 - (2) The lateral line - a series of small pits along the animal's body - allow the animals to detect vibrations in the water. The sound receptors of terrestrial vertebrates may have evolved from these organs.
 - iv. Reproduction
 - (1) Fertilization is internal which is advanced for a fish. Eggs generally develop inside the female's body, and young are born alive.
- f. Class Osteichthyes - bony fishes
- i. General
 - (1) The bony fishes developed a heavy skeleton made completely of bone. A backbone surrounds the spinal cord and the brain is fully encased in a protective skull.
 - (2) Their swim bladder is a gas-filled sac that allows the animal to float at any depth in the water (sharks must move through the water to avoid sinking).
 - (3) Highly mobile, paired fins are more maneuverable.
 - (4) The body is covered with a layer of mucous to facilitate gliding through the water and to protect from parasites.
 - ii. Circulation
 - (1) Gills extract dissolved oxygen from the water around them. Water is brought in through the mouth and passes over filaments rich in blood vessels which provide a huge surface area. Water is then forced out slits in the side of the throat.
 - (2) Two chambered heart (See "Evolutionary trends in the vertebrates" above).
 - iii. Nervous system
 - (1) The lateral line is present.
 - (2) The nervous system is quite developed to allow for some complex behaviors and movement.
 - (3) Although their vision is not great, they have quite a good sense of smell.
 - iv. Reproduction
 - (1) Separate sexes with mostly external fertilization.
- g. Class Amphibia - frogs, toads and salamanders
- i. Amphibians were the first to invade the land. They are the first **tetrapods**. The juvenile phase of the life cycle is dependant on water and gas exchange is through gills. The adult phase is less dependant on water and gas exchange is through

- lungs.
 - ii. Adaptations to live on land
 - (1) Legs for movement and to support body weight.
 - (2) Lungs replaced gills because the thin filaments of the gills would clump together out of water.
 - (3) Improved heart to deliver more oxygen to walking muscles.
 - (4) Eggs are laid in water to prevent them drying out.
 - (5) Most species live close to water to prevent the skin from drying out.
 - iii. Circulation and gas exchange
 - (1) Amphibians have a three-chambered heart (See “Evolutionary trends in the vertebrates” above).
 - (2) Amphibians have small, inefficient lungs and most species also get some oxygen by diffusion through the skin. Because the skin is used in gas exchange it must remain moist, so amphibians can not venture far into very dry habitats.
 - iv. Reproduction
 - (1) External fertilization requires that sperm swim through water to the egg so the animals must stay in or near water for reproduction.
 - (2) The eggs do not have an outer covering or shell and therefore are not protected against drying out.

- h. Class Reptilia - turtles, crocodiles, alligators, lizards, and snakes.
 - i. Adaptations to a fully terrestrial lifestyle
 - (1) Limbs are directed downward, bent more under the body to raise it up off the ground. This improved support enables reptiles to move more easily and even to run.
 - (2) The lungs and heart are more efficient.
 - (3) The skin is waterproof and made from the protein **keratin** - the same protein in human hair and fingernails and in bird feathers.
 - (4) Fertilization is internal and the **amniotic egg** is encased in a water-tight, leathery shell covering.
 - (5) Reptiles are **ectotherms** (get their heat from outside their body) and regulate body temperature by behavior (*e.g.*, basking in the sun or hiding in shade).
 - ii. Circulation
 - (1) Partially separated ventricle (See “Evolutionary trends in the vertebrates” above).
 - (2) Reptiles have more efficient lungs than amphibians. Reptiles do not need to use their skin for gas exchange because the lungs are sufficient. They have a thick, scaly skin with keratin that makes it impermeable to water and gases.
 - iii. Nervous system
 - (1) Most have a good sense of smell but poor eyesight.
 - (2) Most do not have hearing as we think of it. They have membranes on the sides of the head to detect vibrations.
 - iv. Reproduction
 - (1) Internal fertilization is necessary because reproduction occurs on land. The sperm must be deposited inside the female. Internal fertilization allows animals to mate without having to be in water.
 - (2) The eggs are encased in leathery shells to protect them from drying out.

This eliminates the need for a swimming larval stage.

- (3) The eggs are encased in leathery shells to prevent drying out.
 - (a) The amniotic egg has several membranes which make it a valuable adaptation for a terrestrial lifestyle. The egg has structures to surround and protect the embryo, provide food, store wastes, and allow oxygen to enter, but retain water.
- (4) Most reptiles do not care for their young.

i. Aves (avis - wing) - birds

i. General

- (1) Scales on their legs and feet and claws on their toes are reptilian characteristics. These are made of keratin.
- (2) The beak and feet are adapted to suit the bird's lifestyle.
- (3) Their success is derived from the development of the feather which allows them to fly. Feathers contain the same protein as reptilian skin. They insulate against heat loss and allow birds to be **endotherms**, meaning they regulate their body temperature, allowing them to be active when the environmental temperature is low.
- (4) Birds have many specialized anatomical features related to flight.
 - (a) Forelimbs have developed into wings and feathers provide lift.
 - (b) The bony or cartilaginous tail has been replaced by feathers.
 - (c) The skeleton is made of hollow bones to reduce weight.
 - (d) The breastbone is enlarged for attachment of strong flight muscles.
 - (e) Females have only one ovary and birds have no teeth.
 - (f) Birds have efficient breathing that allows a one-way flow of air through their lungs. As a result, the lungs receive fresh air during inhalation and again during exhalation. During inhalation, the air sacs fill; during exhalation, they empty. Air passes through the lungs in only one direction but does so during inhalation and exhalation both.

ii. Digestion

- (1) Birds eat small amounts of food often and digestion is very fast to minimize the weight during flight. Birds must consume enough food to provide the energy needed for endothermy and flight.

iii. Circulation and gas exchange

- (1) Birds and mammals have a double circulatory system with 2 atria and 2 ventricles. The double circulatory system is required for the high activity levels seen in birds and mammals as well as being an endotherm.
- (2) Birds have a four chambered heart (See "Evolutionary trends in the vertebrates" above).

iv. Nervous system

- (1) Highly developed with excellent vision. This is required for flight.
- (2) Smell and taste are not as good although hearing is excellent.
- (3) The well-developed cerebrum allows for complex behaviour and learning. The cerebellum is also well-developed to allow the complex muscle movements required for flight.

v. Reproduction

- (1) Birds have internal fertilization and produce hard-shelled, amniotic eggs.

(2) Birds exhibit complex behavior including parental care.

j. Class Mammalia - mammals

i. General

- (1) All mammals have hair. Made of **keratin**, hair comes in many forms and has many functions.
 - (a) It insulates the body against heat loss. Being endothermic allows activity at any time of day or night in many climates.
 - (i) Note that marine mammals have blubber in addition to or instead of hair. The lack of hair minimizes drag in the water.
 - (b) It provides camouflage.
 - (c) Whiskers function as sensory structures.
 - (d) It may serve as defensive weapons as in porcupines.
- (2) All female mammals have mammary glands.
 - (a) They produce milk for the young. Young are born relatively helpless but are fed milk and cared for by one or both parents. Most young are born live.
 - (b) Milk is 95% water but is rich in fat, sugar, protein.
- (3) Mammals walk more efficiently than reptiles because their legs are positioned further under their body.
- (4) Almost all large land vertebrates are mammals, although the typical mammal is not large - 3200 of 4100 species are rodents, bats, shrews, or moles.

ii. Digestion

- (1) Mammals have a diversity of teeth for different kinds of foods. Fish, amphibians, and reptiles have teeth that are all similar.

iii. Circulation and gas exchange

- (1) Mammals have a four chambered heart (See “Evolutionary trends in the vertebrates” above).
- (2) More efficient breathing results from the **diaphragm** muscle.

iv. Nervous system

- (1) Mammals have well-developed sense organs and a large brain with a large cerebrum.

v. Reproduction

- (1) **Monotremes** are egg-laying mammals which include the duck-billed platypus and spiny anteater. Unlike other mammals, monotremes lay eggs which the female incubates. Milk is secreted to the surface of the skin so they lack nipples.
- (2) **Marsupials** are pouched-mammals which includes opossums, kangaroos, and koalas in addition to some mouse and wolf relatives in Australia. Marsupial young begin development in the female’s body. They are born very immature (in as few as eight days after fertilization) and crawl into the mother’s pouch. There they attach to nipples and continue to develop.
- (3) **Placental mammals** give birth to well-developed young. Nutrients, water, and oxygen pass from mother to fetus while wastes pass from fetus to mother. This exchange is possible because the blood of the fetus and of the mother are in close contact in the placenta. Placental mammals are born relatively mature because the well-developed placenta enables them to

- remain within the mother for an extended period of development.
- (4) The length of young care is related to the complexity of behaviour in adults.