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SCHOOL OF BIO & CHEMICAL ENGINEERING

DEPARTMENT OF BIOTECHNOLOGY

SBC1201: ZOOLOGY

UNIT – I - INVERTEBRATE AND CHORDATA – SBC1201

1. INVERTEBRATE

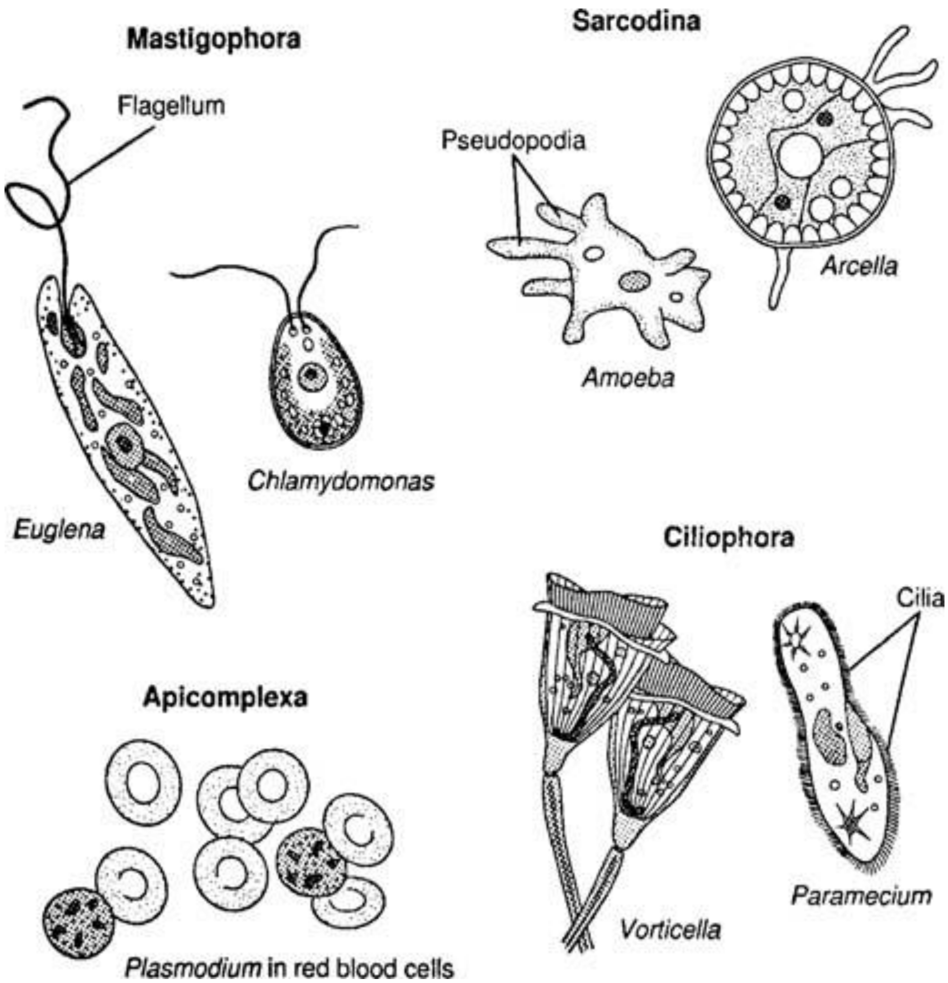
Invertebrate, any animal that lacks a vertebral column, or backbone, in contrast to the cartilaginous or bony vertebrates. More than 90 percent of all living animal species are invertebrates. Worldwide in distribution, they include animals as diverse as sea stars, sea urchins, earthworms, sponges, jellyfish, lobsters, crabs, insects, spiders, snails, clams, and squid. Invertebrates are especially important as agricultural pests, parasites, or agents for the transmission of parasitic infections to humans and other vertebrates.

Invertebrates serve as food for humans; are key elements in food chains that support birds, fish, and many other vertebrate species; and play important roles in plant pollination. Despite providing important environmental services, invertebrates are often ancillary in wildlife research and conservation, with priority given instead to studies that focus on large vertebrates. In addition, several invertebrate groups (including many types of insects and worms) are viewed solely as pests, and by the early 21st century the heavy use of pesticides worldwide had caused substantial population declines among bees, wasps, and other terrestrial insects.

Apart from the absence of a vertebral column, invertebrates have little in common. Indeed, they are distributed into more than 30 phyla. In contrast, all vertebrates are contained within a single phylum, the Chordata. (Phylum Chordata also includes the sea squirts and some other invertebrate groups.) Invertebrates are generally soft-bodied animals that lack a rigid internal skeleton for the attachment of muscles but often possess a hard outer skeleton (as in most mollusks, crustaceans, and insects) that serves, as well, for body protection.

Classification of Protozoa

All protozoal species are assigned to the kingdom **Protista** in the Whittaker classification. The protozoa are then placed into various groups primarily on the basis of how they move. The groups are called phyla (singular, phylum) by some microbiologists, and classes by others. Members of the four major groups are illustrated in Fig.



General Characteristics of Protozoa

Protozoa are eukaryotic microorganisms. Although they are often studied in zoology courses, they are considered part of the microbial world because they are unicellular and microscopic.

Protozoa are notable for their ability to move independently, a characteristic found in the majority of species. They usually lack the capability for photosynthesis, although the genus *Euglena* is renowned for motility as well as photosynthesis (and is therefore considered both an alga and a protozoan). Although most protozoa reproduce by asexual methods, sexual reproduction has been observed in several species. Most protozoal species are aerobic, but some anaerobic species have been found in the human intestine and animal rumen.

Protozoa are located in most moist habitats. Free-living species inhabit freshwater and marine environments, and terrestrial species inhabit decaying organic matter. Some species are parasites of plants and animals.

Protozoa play an important role as **zooplankton**, the free-floating aquatic organisms of the oceans. Here, they are found at the bases of many food chains, and they participate in many food webs.

Size and shape. Protozoa vary substantially in size and shape. Smaller species may be the size of fungal cells; larger species may be visible to the unaided eye. Protozoal cells have no cell walls and therefore can assume an infinite variety of shapes. Some genera have cells surrounded by hard shells, while the cells of other genera are enclosed only in a cell membrane.

Many protozoa alternate between a free-living vegetative form known as a**trophozoite** and a resting form called a **cyst.** The protozoal cyst is somewhat analogous to the bacterial spore, since it resists harsh conditions in the environment. Many protozoal parasites are taken into the body in the cyst form.

Most protozoa have a single nucleus, but some have both a macronucleus and one or more micronuclei. Contractile vacuoles may be present in protozoa to remove excess water, and food vacuoles are often observed.

Nutrition and locomotion. Protozoa are **heterotrophic** microorganisms, and most species obtain large food particles by **phagocytosis.** The food particle is ingested into a food vacuole. Lysosomal enzymes then digest the nutrients in the particle, and the products of digestion are distributed throughout the cell. Some species have specialized structures called **cytostomes**, through which particles pass in phagocytosis.

Many protozoal species move independently by one of three types of locomotor organelles: flagella, cilia, and pseudopodia. **Flagella** and **cilia** are structurally similar, having a “9-plus-2” system of microtubules, the same type of structure found in the tail of animal sperm cells and certain cells of unicellular algae. How a protozoan moves is an important consideration in assigning it to a group.

2. Phylum Porifera- Characteristics, classification, examples

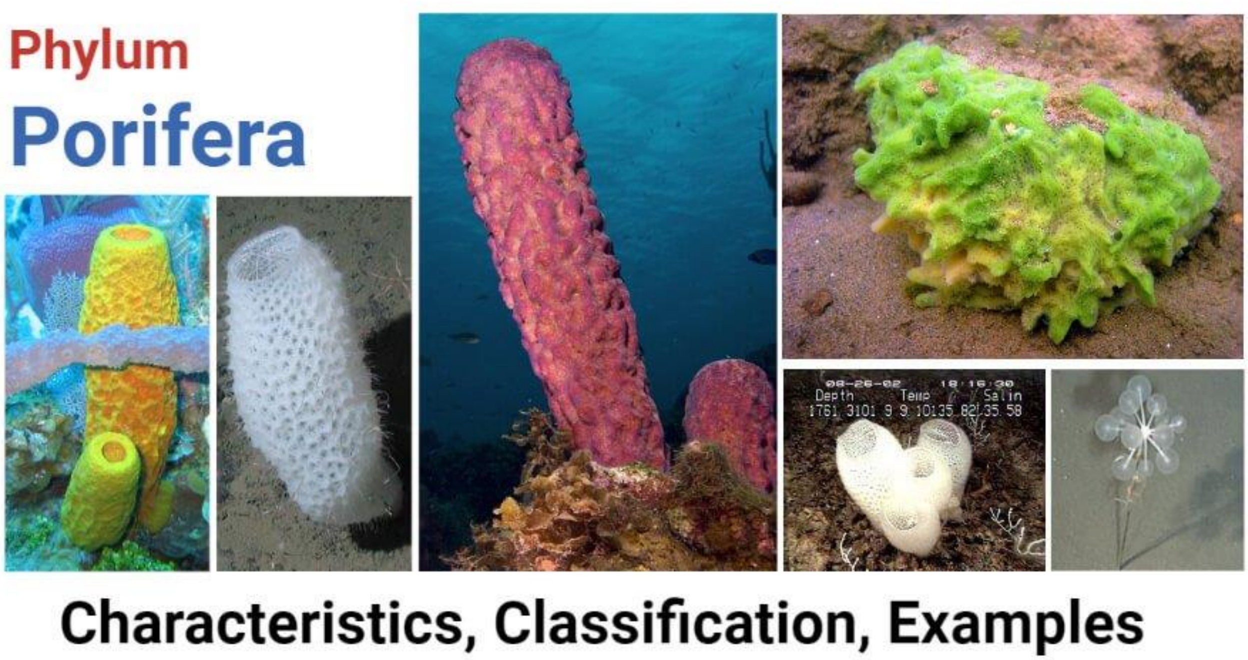
Porifera Definition

The Porifera may be defined as an asymmetrical or radially symmetrical multicellular organism with a cellular grade of an organization without well- definite tissues and organs; exclusively aquatic; mostly marine, sedentary, solitary or conical animals with body perforated by pores, canals, and cambers through which water flows; with one or more internal cavities lined with choanocytes; and with a characteristic skeleton made of calcareous spicules, siliceous spicules or horny fibers of spongin.

Phylum Porifera Characteristics

1. Porifera are all aquatic, mostly marine except one family Spongillidae which lives in freshwater.
2. They are sessile and sedentary and grow like plants.
3. The body shape is vase or cylinder-like, asymmetrical, or radially symmetrical.
4. The body surface is perforated by numerous pores, the Ostia through which water enters the body and one or more large openings, the oscula by which the water exists.
5. The multicellular organism with the cellular level of body organization. No distinct tissues or organs.
6. They consist of outer ectoderm and inner endoderm with an intermediate layer of mesenchyme, therefore, diploblastic
7. The interior space of the body is either hollow or permeated by numerous canals lined with choanocytes. The interior space of the sponge body is called spongocoel.
8. Characteristic skeleton consisting of either fine flexible spongin fibers, siliceous spicules, or calcareous spicules.
9. Mouth absent, digestion intracellular.
10. Excretory and respiratory organs are absent.
11. Contractile vacuoles are present in some freshwater forms.
12. The nervous and sensory cells are probably not differentiated.

13. The primitive nervous system of neurons arranged in a definite network of bipolar or multipolar cells in some, but is of doubtful status.
14. The sponges are monoecious.
15. Reproduction occurs by both sexual and asexual methods.
16. Asexual reproduction occurs by buds and gemmules.
17. The sponge possesses a high power of regeneration.
18. Sexual reproduction occurs via ova and sperms.
19. All sponges are hermaphrodite.
20. Fertilization is internal but cross-fertilization can occur.
21. Cleavage holoblastic.
22. Development is indirect through a free-swimming ciliated larva called amphiblastula or parenchymula.
23. The organization of sponges are grouped into three types which are ascon type, sycon type, and leuconoid type, due to simple and complex forms.
24. **Examples:** *Clathrina, Sycon, Grantia, Euplectella, Hyalonema, Oscarella, Plakina, Thenea, Cliona, Halichondria, Cladorhiza, Spongilla, Euspondia*, etc.



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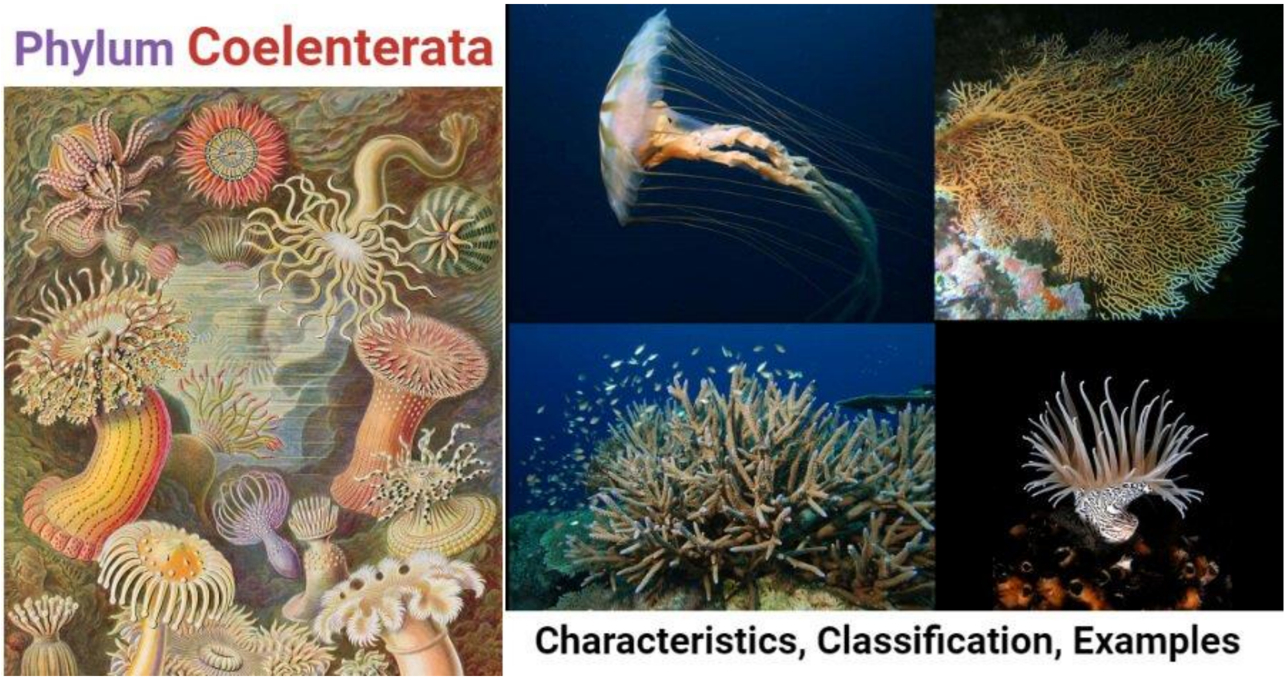
3. Phylum Coelenterata (Cnidaria)- Characteristics, classification, examples

Phylum Coelenterata (Cnidaria) Characteristics

1. They are aquatic, mostly marine except few freshwater forms like the *hydra*.
2. They are multicellular with tissue grade of organization.
3. They are solitary or conical. Sedentary or free-swimming.
4. Individuals are radially or biradially symmetrical about a longitudinal oral-aboral axis.
5. Body organization of cell-tissue grade. Cells mostly scattered and specialized for different functions. Some cells form tissues like nerve nets or nervous tissues.
6. Exoskeleton chitinous (perisarc) or calcareous(corals).
7. They are diploblastic animals with 2 cellular layers-outer an epidermis and an inner gastrodermis- with a gelatinous acellular mesoglea in between.
8. Acoelomate animals because they do not pose a second body cavity, the coelom.
9. Short and slender tentacles encircle the mouth in one or two whorls.
10. The tentacles are provided with nematocysts; tentacles serve for food capture, its ingestion, serve for adhesion, and for defense.
11. Two types of individuals occur, attached sessile and asexual zooid (polyps) and free swimming and sexual zooid (medusae). Some species are notable for polymorphism or variety of forms.
12. They are usually carnivorous; digestion is extracellular as well as intracellular.
13. No anus.
14. Coelom and respiratory, circulatory, and excretory system wanting.

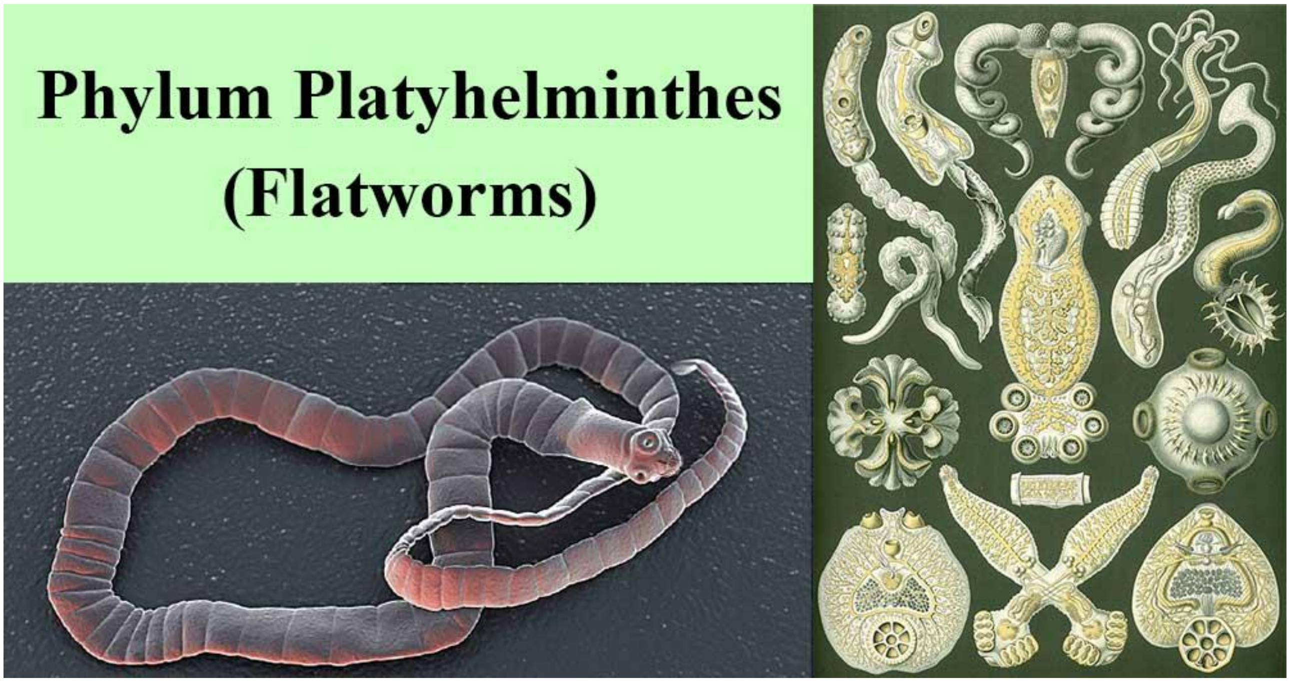
15. Nervous system primitive, consisting of a diffuse nerve net. Central nervous system absent.
16. The muscular system includes longitudinal and circular fibers formed by epithelia-muscle and endothelial-muscle cells.
17. A single cavity, lined with gastrodermis, called gastrovascular cavity or coelenteron, into which mouth opens.
18. Sensory organs form ocelli and statocysts.
19. Reproduction is both by asexual and sexual methods.
20. Asexual reproduction occurs by budding and sexual reproduction by the formation of gametes.
21. The development includes a free-swimming ciliated planula larva.
22. Life history exhibits the phenomena of alternation of generation or metagenesis in which the asexual polypoid, sessile generation alternates with sexual medusoid, free-swimming generation.



4. Phylum Platyhelminthes- characteristics, classification, examples

Platyhelminthes (flatworms) definition

Platyhelminthes are triploblastic, bilaterally symmetrical, dorsoventrally flattened, acoelomate flatworms with organ grade of construction without a definite anus, circulatory, skeletal or respiratory system but with Protonephridial excretory system and mesenchyme filling the space between the various organ of the body.



Phylum Platyhelminthes (flatworms) characteristics

- They are free-living, commensal or parasitic.
- They are bilaterally symmetrical and dorsoventrally flattened, triploblastic worm.
- Bilaterally symmetrical with the definite polarity of head and tail ends.
- Triploblastic i.e. body derived from three embryonic germ layers; ectoderm, mesoderm, and endoderm.
- Dorsoventrally fattened i.e. well-developed ventral surface with mouth and gonopore.
- Their body generally shapes as a worm but varies from moderately elongated flattened to long ribbon-like and leaf-like.
- They are small to moderate in size varying from microscopic to extremely elongated form measuring up to 10-15 meters.

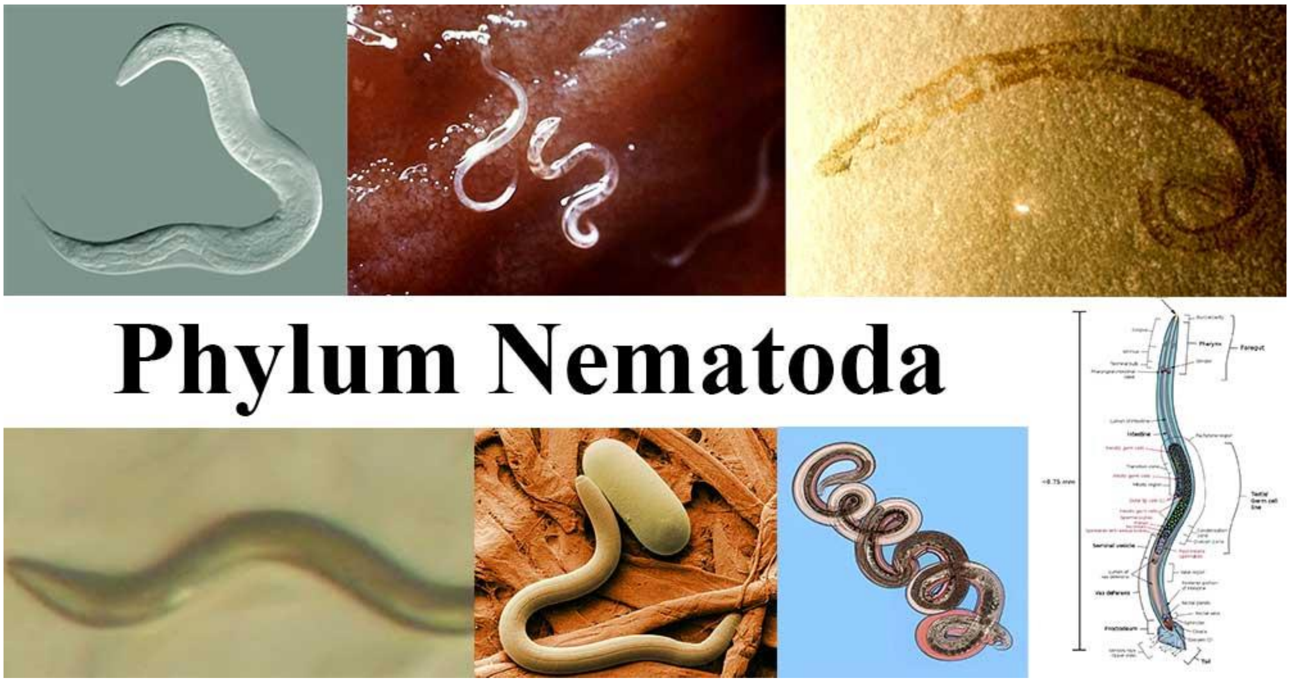
- Their body is unsegmented except in class Cestoda.
- The majority of them are white, colorless and some derive color from ingested food while free-living form are grey, brown-black or brilliantly colored.
- Their anterior end of the body is differentiated into the head.
- Mouth and genital pores on the ventral surface are well marked in turbellarians but less marked in cestodes and trematodes.
- Their parasitic form has adhesive structures like hooks, spines and suckers, and adhesive secretions.
- The body is covered with cellular or syncytial, frequently ciliated epidermis; while trematodes cestodes, lacks epidermis and their body covered with cuticle.
- Exo- and endoskeleton are completely absent, hence the body is generally soft. The hard part consists of cuticle, spines, thorns, hooks, teeth.
- They are acoelomate i.e. without any body cavity.
- Space between various organs filled with special mesodermal tissues, the mesenchyme, and parenchyma.
- Their digestive system is branched and incomplete without an anus and totally absent in acoela and cestode.
- They lack skeletal, respiratory and circulatory systems.
- The excretory system includes a lateral canal and a single or pair of protonephridia with flame cells or bulbs. Absent in some primitive form.
- Their nervous system is primitive, ladder-like. The main nervous system consists of a pair of ganglia or brain and one or three pairs of longitudinal nerve cords connected by transverse nerves.
- Their sense organs are simple. A common occurrence in tubellaria but greatly reduced in parasitic form. Chemo- and tangoreceptors commonly in the form of ciliated pits and grooves.
- They are mostly monoecious (hermaphrodite).
- Their reproductive system is highly evolved or complex in most of the forms.
- Asexual reproduction occurs by fission in many freshwater turbellaria.
- In the majority of form, eggs are devoid of yolk. They are produced separately in the yolk or vitelline glands.
- Fertilization is internal but cross-fertilization in trematodes and self-fertilization in cestodes.

- Their life cycle is complicated involves one or more hosts.
- Parthenogenesis and polyembryony commonly occur trematodes and tapeworms.
- Some tapeworm propagates by endogenous or exogenous budding.
- The flatworm is either free-living or ecto-or endocommensals or parasitic.

5. Phylum Nematoda- characteristics

Nematoda Definition

Nematodes (Gr., nema thread+ eidos, form) are commonly referred to as non-segmented roundworm, threadworm or pinworm, as distinct from flatworm and higher segmented annelids.



Phylum Nematoda Characteristics

- They are widely distributed, aquatic or terrestrial, parasitic or free-living.
- Their body is elongated, cylindrical, unsegmented, worm-like, bilaterally symmetrical and tapering at both ends.
- They are triploblastic animals with perivisceral cavity more extensive than that of **platyhelminths.**
- The body is of organ -system grade organization.
- The body is generally covered with thick, flexible multi-layered collagenous cuticle and often bears cuticle setae (hairs), spines or annulations.
- Cuticle moulted periodically.
- They have cellular or syncytial epidermis I.e. the nuclei are not separated from each other by cell membranes.

- They consist of only longitudinal muscle fibers with four bands.
- They lack true coelom. The body cavity is pseudocoel or blastocoel not lined by mesoderm and filled with parenchyma in most cases.
- They lack cilia.
- circulatory and respiratory systems are absent. i.e. respiration occurs through general body surface and aerobic in free-living form and anaerobic in parasitic form.
- Internal cephalization is present but externally there is little differentiation between the anterior and posterior region. i.e. distinct head is lacking. However, the mouth is present in the anterior region.
- The digestive system is complete with a distinct mouth and anus. Muscular pharynx and the inner surface of the gut usually not lined by cilia.
- Extracellular digestion occurs in them.
- The mouth is surrounded by six lips.
- Excretory without flame cell and nephridia. In the class Adenophorea glandular renette cells with the duct.
- The nervous system is not much developed. i.e. consists of circucumpharyngeal ring and longitudinal nerve cord.
- Sense organ are poorly developed in the form of papillae, which are well defined as amphid (in mouth) and plasmid (anus).
- Sexes are separate (gonochoristic). the male is smaller than females.
- Tubular gonad is present in them. Male genital duct leads into the cloaca. Female genital ducts with a separate opening.
- Amoeboid sperm cells.
- No asexual reproduction.
- Fertilization is internal or maybe cross or self.
- Development may be direct, with or without an intermediate host or indirect.
- Various lateral lines and pores are present on the surface of the body.

6. Phylum Annelida- characteristics

Annelida definition

Annelids are defined as triploblastic, bilaterally symmetrical, metamerically segmented, a coelomate worm with a thin flexible cuticle around the body.

Phylum Annelida Characteristics

- They are mostly aquatic; marine or freshwater some terrestrial, burrowing or tubicolous, sedentary or free-living, some commensal and parasitic.
- The body is elongated, triploblastic, bilaterally symmetrical, truly coelomate and vermiform.
- The body is metamerically segmented; externally by transverse grooves and internally by septa into a number of divisions; each division is called a segment, metamere or somite.
- Body organization is of organ grade system.
- The epidermis is of a single layer of columnar epithelial cells, covered by thin cuticle not made of chitin.
- The body wall is contractile or dermo-muscular consisting of outer muscle fiber circular and inner longitudinal.
- Appendages are jointed when present.

- Locomotory organs are segmentally repeated chitinous bristles called setae or chaetae, embedded in the skin. It may be bored by lateral fleshy appendages or parapodia.
- The presence of true schizocoelous coelom usually divided into compartments by transverse septa. Mostly well-developed in leeches. Coelomic fluid with cells or corpuscles.
- The alimentary canal is straight tube-like, complete, extending from mouth to anus. Digestion is entirely extracellular.
- Respiration occurs through moist skin or gills of parapodia and head.
- The blood vascular system is a closed type. Blood is red due to the presence of hemoglobin or erythromycin dissolved in plasma.
- Excretion is by metamerically disposed coiled tubes; nephridia which communicate the coelom to the exterior.
- The nervous system consists of a pair of cerebral ganglia; brain and double ventral nerve cord having segmentally arranged ganglia and lateral nerves in each segment.
- Receptor organs include tactile organs, taste buds, statocysts, photoreceptor cells and sometimes eyes with lenses in some.
- They are monoecious i.e. hermaphroditic or sexes separate cleavage spiral and determinate; dioecious or unisexual form also present.
- Their development is direct in monoecious form but indirect in dioecious form.
- Larva, when present is a trochophore is characteristics in case of indirect development, while in others this stage is passed through development.
- Regeneration is common.
- Asexual reproduction occurs in some.

7. Phylum Arthropoda- Characteristics

Arthropoda (Arthropods) Definition

Arthropods are bilaterally symmetrical, triploblastic, metamerically segmented animals with coelom which is reduced and modified. Their body is covered externally in a chitinous exoskeleton which molts periodically and their appendages are joined.

Phylum Arthropoda Characteristics

- They are bilaterally symmetrical, triploblastic, metamerically segmented animals.
- Body organization is of an organ-system level.
- The body is covered with a thick chitinous cuticle forming an exoskeleton.
- Body segments usually bear lateral and jointed appendages with varied functions as jaws, gills, legs, etc.
- Body divisible into head, thorax, and abdomen. Head and thorax often fused to form a cephalothorax.
- The musculature is not continuous but comprises separate striped muscles capable of rapid contraction.
- The body cavity is hemocoel. The true coelom is reduced to the spaces of the genital and excretory organs.
- The complete digestive system with mouth and anus. Mouthparts adapted for various modes of feeding.
- Open circulatory system with dorsal heart and arteries but without capillaries.
- Respiration by general body surface, gills in aquatic forms, trachea, or book-lungs in terrestrial forms.
- No true nephridia. Excretion organs are green glands or Malpighian tubules or coxal glands.
- The nervous system is typically annelidan, with a dorsal brain connected with a nerve ring to a double ventral nerve cord.
- Cilia are entirely absent from all parts of the body.
- Sensory organs comprise eyes (simple and compound), chemo- and tactile receptors, balancing and auditory organs.

- Sexes usually separate (dioecious). Reproduction organs and ducts paired.
- Internal fertilization. Oviparous or ovoviviparous.
- Development is usually indirect through larval stages. Parthenogenesis in some.
- Parental care is often well marked in many arthropods.
- Most diversified groups inhabiting the land, water, and air.

8. Phylum Mollusca- characteristics

Mollusca (Mollusks) Definition

Molluscs (also know as mollusks) are soft-bodied, bilaterally symmetrical, segmented, coelomate animals; usually shelled having a mantle, ventral foot, anterior head, and a dorsal visceral mass.

Phylum Mollusca (Mollusks) Characteristics

- They are essentially aquatic mostly marine, few freshwater and some terrestrial form.
- They may be found as hidden parasites in the interior of other animals.
- They vary in size from giant squids and clams to little snails, a millimeter long.
- They have at least two characters radula and mantle not found elsewhere.
- The body is soft, unsegmented (except in Monoplacophora), bilaterally symmetrical, coelomate, triploblastic.
- They have tissue-system grade of body organization
- The body consists of head, foot, mantle, and the visceral mass.
- The body is clothed with one-layered often ciliated epidermis.
- The body is commonly protected by an exoskeleton calcareous shell of one or more piece secreted by the mantle.
- Head is distinct, bearing mouth, eyes, tentacles and other sense organs except in pelecypoda and scaphodoa.
- The ventral body is modified into a muscular plough-like surface, the foot which is variously modified for creeping, burrowing and swimming.
- Mantle or pallium is a fold of a body wall that leaves between itself the main body, mantle cavity.
- The visceral mass contains the vital organs of the body in the compact form taking the form of dorsal humps or dome.
- The body cavity is hemocoel. The coelom is reduced and represented mainly by the pericardial cavity, gonadial cavity, and nephridia.
- The digestive tract is simple with anterior mouth and posterior anus but in gastropods, scaphodos, and cephalopods the intestine becomes U-shaped bringing anus to anterior part.

- Rasping organs, radula usually present, except in pelecypoda.
- The circulatory system is open type except in cephalopods.
- Respiratory organs contain numerous gills or ctenidia usually provided with osphradiuma at the base. The lung is developed in terrestrial forms.
- Respiration is direct or by gills or lungs or both.
- Haemocyanin is their respiratory pigments.
- Excretion is by paired metanephridia (kidney).
- The nervous system consists of paired cerebral, pleural, pedal and visceral ganglia joined by longitudinal and transverse connections and nerves. Ganglia usually form a circumenteric ring.
- Sense organs consist of eyes, statocysts, and receptors for touch, smell, and taste.
- Sexes are usually separate (dioecious) but some are monoecious (hermaphroditic).
- Fertilization is external or internal.
- Development is direct or with metamorphosis through the trochophore stage called veliger larva.

Image Source: Wikipedia

9. Phylum Echinodermata- Characteristics

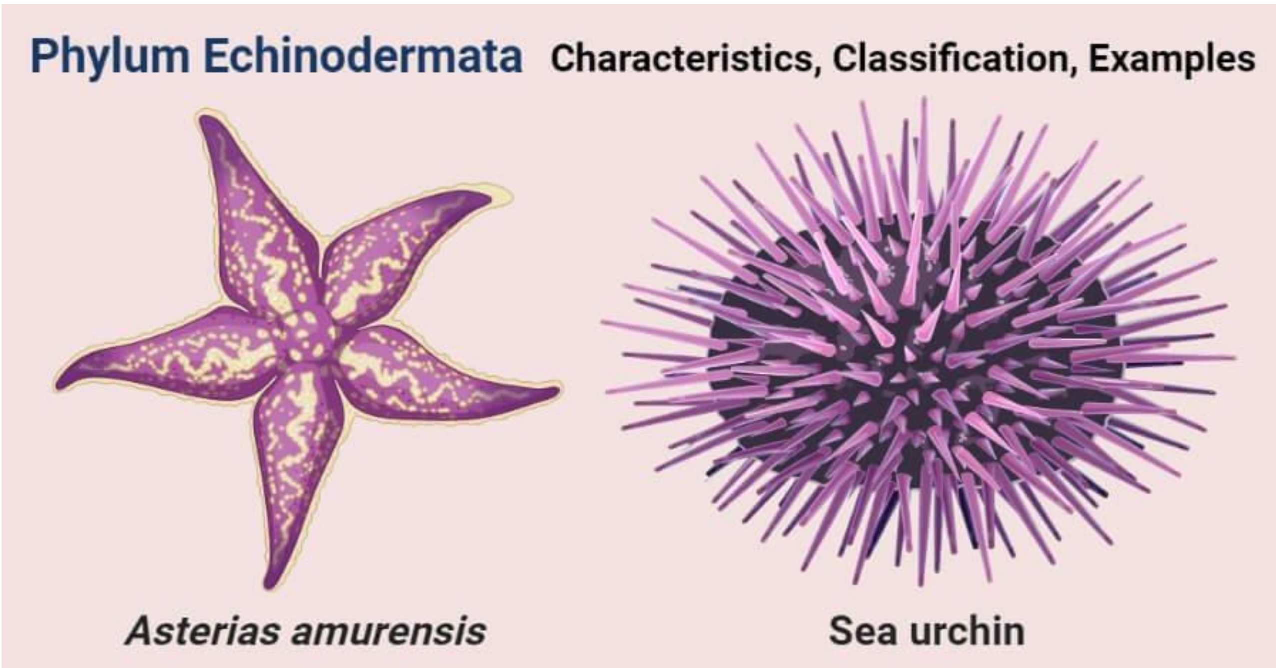
Echinodermata (Echinoderms) Definition

Echinoderms are enterocoelous coelomates with pentamerous radial symmetry, without distinct head or brain having a calcareous endoskeleton of separate plates or pieces and a peculiar water vascular system of coelomic origin with podia or tube-feet projecting out of the body.

Phylum Echinodermata Characteristics

1. They are exclusively marine and are among the most common and widely distributed marine animals.
2. They occur in all seas from the intertidal zones to great depths.
3. They have an organ grade system of body organization.
4. Symmetry usually radial, nearly always pentamerous.
5. The body is triploblastic, coelomate with distinct oral and aboral surfaces, and without definite head and segmentation.
6. They are moderate to considerable size but none are microscopic.
7. Body shape globular, star-like, spherical, discoidal, or elongated.
8. The surface of the body is rarely smooth, typically covered by 5 symmetrically radiating grooves called ambulacra with 5 alternating inter-radii or inter-ambulacra.
9. The body wall consists of an outer epidermis, a middle dermis, and an inner lining of the peritoneum.
10. Endoskeleton consists of closely fitted, plates forming a shell usually called theca or test or may be composed of separate small ossicles.
11. The coelom is spacious lined by peritoneum, occupied mainly by the digestive and reproductive system, and develops from embryonic archenteron i.e. enterocoel.
12. Coelom of enterocoelous type constitutes the perivascular cavity of water vascular system; coelom fluid with coelomocytes.
13. Water -vascular system of coelomic origin, including podia or tube feet for locomotion and usually with a madreporite.
14. The alimentary canal is usually a coiled tube extending from the mouth located on the oral surface to the anus on the aboral or oral surface.

15. Vascular and haemal or blood lacunar system, enclosed in coelomic peripheral channels.
16. Respiratory organs include branchiae, tube-feet, respiratory tree, and bursae.
17. A nervous system without a brain and with a circumoral ring and radial nerve.
18. The excretory system is wanting.
19. Poorly developed sense organs include tactile organs, chemoreceptors, terminal tentacles, photoreceptors, and statocysts.
20. Sexes are usually dioecious with few exceptions.
21. Gonads large and single or multiple; fertilization external, while few echinoderms are viviparous.
22. Development is intermediate including characteristic larvae which undergo metamorphosis into the radially symmetrical adults.
23. Regeneration of lost parts, a peculiarity.



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Phylum Chordata

The phylum Chordata contains all animals that have a dorsal notochord at some stage of development; in most cases, this is the backbone.

Key Points

- The phylum chordata is named for the notochord, a longitudinal, flexible rod between the digestive tube and the nerve cord; in vertebrates, this is the spinal column.
- The chordates are also characterized by a dorsal nerve cord, which splits into the brain and spinal cord.
- Chordata contains two clades of invertebrates: Urochordata (tunicates) and Cephalochordata (lancelets), both of which are suspension feeders.
- The phylum chordata includes all animals that share four characteristics, although they might each possess some of them at different stages of their development: a notochord, a dorsal nerve cord, pharyngeal slits, and a postanal tail.
- Chordata contains five classes of animals: fish, amphibians, reptiles, birds, and mammals; these classes are separated by whether or not they can regulate their body temperature, the manner by which they consume oxygen, and their method of reproduction.

Key Terms

- **dorsal nerve cord**: a hollow cord dorsal to the notochord, formed from a part of the ectoderm that rolls, forming a hollow tube.
- **notochord**: a flexible rodlike structure that forms the main support of the body in the lowest chordates; a primitive spine
- **pharyngeal slit**: filter-feeding organs found in non-vertebrate chordates (lancelets and tunicates) and hemichordates living in aquatic environments

Phylum Chordata

Animals in the phylum Chordata share four key features that appear at some stage of their development:

- A notochord, or a longitudinal, flexible rod between the digestive tube and the nerve cord. In most vertebrates, it is replaced developmentally by the vertebral column. This is the structure for which the phylum is named.
- A dorsal nerve cord which develops from a plate of ectoderm that rolls into a tube located dorsal to the notochord. Other animal phyla have solid nerve cords ventrally located. A chordate nerve cord splits into the central nervous system: the brain and spinal cord.
- Pharyngeal slits, which allow water that enters through the mouth to exit without continuing through the entire digestive tract. In many of the invertebrate chordates, these function as suspension feeding devices; in vertebrates, they have been modified for gas exchange, jaw support, hearing, and other functions.
- A muscular, postanal tail which extends posterior to the anus. The digestive tract of most nonchordates extends the length of the body. In chordates, the tail has skeletal elements and musculature, and can provide most of the propulsion in aquatic species.

In some groups, some of these traits are present only during embryonic development. In addition to containing vertebrate classes, the phylum Chordata contains two clades of invertebrates: Urochordata (tunicates) and Cephalochordata (lancelets). However, even though they are invertebrates, they share characteristics with other chordates that places them in this phylum. For example, tunicate larvae have both a notochord and a nerve cord which are lost in adulthood. Most tunicates live on the ocean floor and are suspension feeders. Cephalochordates, or lancelets, have a notochord and a nerve cord (but no brain or specialist sensory organs) and a very simple circulatory system. Lancelets are suspension feeders that feed on phytoplankton and other microorganisms.

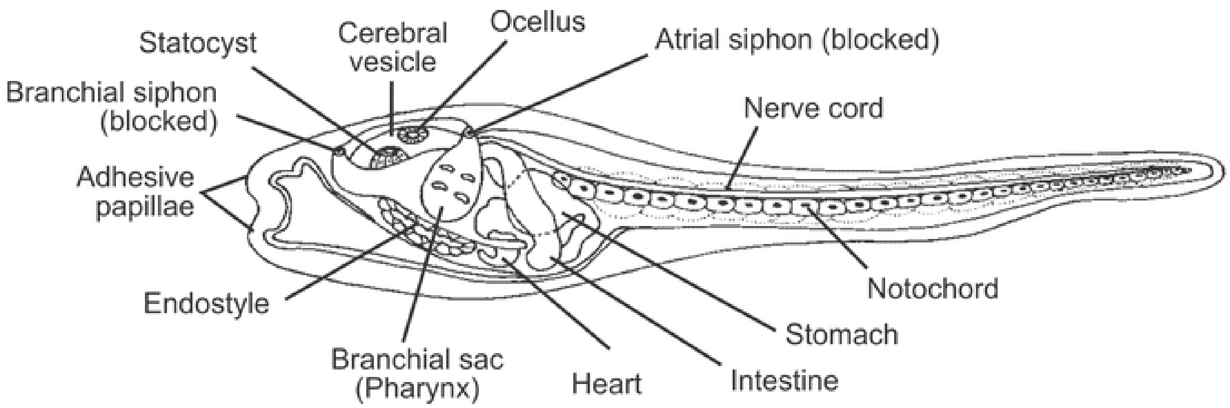


Figure 28.5C.128.5C.1: **Structures present in a tunicate larva**: While tunicates are invertebrates and may seem very different from the more familiar members of Chordata, the tunicate larva possesses both a notochord and a dorsal nerve cord, although both are lost in adulthood.

The phylum Chordata contains all of the animals that have a rod-like structure used to give them support. In most cases this is the spine or backbone. Within Chordata there are five classes of animals: fish, amphibians, reptiles, birds, and mammals. Three dividing factors separate these classes:

- Regulation of body temperature: animals are either homeothermic (can regulate their internal temperature so that it is kept at an optimum level) or poikilothermic (cannot regulate their internal temperature, the environment affects how hot or cold they are)
- Oxygen Absorption: the way in which oxygen is taken in from the air, which can be through gills, the skin (amphibians), or lungs
- Reproduction: this factor is particularly varied. Animals can be oviparous (lay eggs) or viviparous (birth live young). Fertilization can occur externally or internally. In mammals, the mother produces milk for the young.

Protochordate

Protochordate, any member of either of two invertebrate subphyla of the phylum Chordata: the Tunicata (sea squirts, salps, etc.) and the Cephalochordata (amphioxus). Like the remaining subphylum of the chordates, the Vertebrata, the protochordates have a hollow dorsal nerve cord, gill slits, and a stiff supporting rod, the notochord, the forerunner of the backbone. The protochordates differ chiefly from the vertebrates in not having a backbone. Recent protochordates are thought to have evolved from the same ancestral stock as that which gave rise to the vertebrates. Two main theories have gained general acceptance as to how the vertebrates may have evolved. One theory proposes that the ancestral form was sessile (attached), perhaps like a pterobranch but with an unspecialized larva. This larva adapted to an independent pelagic life and became sexually mature. Subsequently, the sessile stage was lost, and the vertebrates evolved from this free-swimming animal. The other, more recent theory postulates that the chordates evolved from a small fossil group called the mitrates.

Group ACRANIA (=PROTOCHORDATA)

(Primitive chordates without head and vertebral column)

Subphylum **HEMICHORDATA,** *Balanoglossus,Cephalodiscus, Rhabdopleura,* primitive and doubtful chordates, now classified under non-chordates after echinoderms.

Subphylum **UROCHORDATA,** *Herdmania, Salpa, Doliolum, Pyrosoma, Oikopleura* sedentary or planktonic tunicates in which chordate characters manifest in the larval stage.

Subphylum **CEPHALOCHORDATA,** *Amphioxus, Asymmetron,* typical chordates having chordate characters in the larval as well as adult stage.

Group **CRANIATA (=EUCHORDATA)**

(Chordates with skull, with 54,000 species of true chordates)

Subphylum **VERTEBRATA,** chordates with head, brain and vertebral column.

Superclass **AGNATHA**, 90 species of paraphyletic group of jawless fishes, which were also the first vertebrates. Living forms are elongated, scaleless, slimy parasites and scavengers that include lampreys and hagfishes. They have no paired fins.

Class **OSTRACODERMI,** extinct shelled jawless fishes of Ordovician period. *Cephalaspsis.*

Class **CYCLOSTOMATA,** jawless fishes of today, without scales and paired fins.

Order **Myxinoidea**: the hagfishes, 40 species. *Myxine*, *Bdellostoma*, *Eptatretus.*

Order **Petromyzontia**: lampreys, 41 species, parasitic on other fishes. *Petromyzon.*

Superclass **GNATHOSTOMATA,** vertebrates with jaws that are modified gill arches and paired appendages. They include cartilaginous fishes, bony fishes and tetrapods.

Characteristics of Protochordata

1. They are generally found in marine water.
2. Their body is bilaterally symmetrical, triploblastic, and coelomated.
3. At a certain stage of their lives, their body develops a long, rod-like structure for support called the notochord.
4. They exhibit organ system level of organization.

E.g., Herdmania, Amphioxus.

Classifications of Protochordata

Hemichordata

- They are found in marine water.
- Some live solitarily, and some stay in colonies.
- The body is cylindrical, unsegmented, and stout.
- The body is divided into proboscis, collar, and trunk.
- The collar bears arms and tentacles.
- They have a complete digestive system.
- They respire through gills or general body surface.
- The circulatory system comprises a heart with two longitudinal vessels.
- The blood has no colour and corpuscles.

- The proboscis gland or glomerulus make up the excretory system.
- Sexes may be separate or united and fertilization is either internal or external.

E.g., Cephalodiscus, Rhabdopeura.

Explore more: Excretory system.

Urochordata or Tunicata

- They are found in the marine environment.
- They are sessile and filter-feeders.
- They are also known as tunicates because their body is surrounded by a leathery sheath composed of tunicin (cellulose).
- The notochord appears in the larval stage in the tail of the larva and disappears in the adult. This is known as retrogressive metamorphosis.
- The neural tube in the larva is replaced by a dorsal ganglion in the adults.
- Respiration occurs through gills.
- They have an open circulatory system.
- The excretory organs are absent.
- They reproduce asexually by budding.

E.g., Herdmania, Selpa

Cephalochordata

- They are marine and filter-feeders.
- The notochords remain throughout life and extend up to the head region.
- The nerve cord and the tail also remain throughout life.
- Solenocyts are the excretory organs.
- They respire through gills which open in the atrium.
- The body wall comprises myotomes.

E.g., Amphioxus

FISHES

The Superclass Pisces (L. Piscis = fish) are the truly jawed vertebrates. They have organs of respiration and locomotion related to a permanently aquatic life. The respiratory organs are the gills and the organs of locomotion are paired and impaired fins. All are poikilothermous.

General Characters:

1. Aquatic, either freshwater or marine, herbivorous or carnivorous, cold blooded, oviparous or ovoviviparous vertebrates.

2. Body usually streamlined, spindle-shaped, some are elongated snake-like and a few are dorsoventrally compressed, and differentiated into head, trunk and tail.

3. Locomotion by paired pectoral and pelvic fins along with median dorsal and caudal fins, supported by true dermal fin-rays. Muscular tail used in propulsion.

4. Exoskeleton of dermal scales, denticles or bony plates (in Placodermi) covering body surface. Placoid in Chondrichthyes and ganoid, cycloid or ctenoid in Osteichthyes.

5. Endoskeleton is cartilaginous or bony. The notochord in usually replaced by vertebrae, either bone or cartilage. Presence of well-developed skull and a system of visceral arches, of which the first pair forms the upper and lower jaws, the latter movably articulated with the skull.

6. Muscles arranged into segments called myotomes, with separate dorsal and ventral parts.

7. Alimentary canal with definite stomach and pancreas and terminates into cloaca or anus.

8. Organs of respiration are gills. Gill-slits 5 to 7 pairs, naked or covered by an operculum.

9. Heart is venous and two chambered, i.e., one auricle and one ventricle. Sinus venosus and renal and portal systems present. Erythrocytes nucleated. Poikilothermous.

10. Kidneys mesonephros. Excretions ureotelic.

11. Brain with usual five parts. Cranial nerves ten pairs.

12. Nostrils are paired but do not open into pharynx except Dipnoi. Nasal capsules are partly separate in Chondrichthyes and completely separate in Osteichthyes.

13. Tympanic cavity and ear ossicles are absent.

14. Internal ear with three semicircular canals.

15. Lateral line system is well developed.

16. Sexes separate. Gonads typically paired. Gonoducts open into cloaca or independently.

17. Fertilisation internal or external. Females of Chondrichthyes are oviparous or ovoviviparous and of Osteichthyes are mostly oviparous and rarely ovoviviparous or viviparous. Eggs with large amount of yolk. Cleavage meroblastic.

18. Extra-embryonic membranes are absent.

19. Development usually direct without or with little metamorphosis.

Classification:

About 40,000 species of fishes are known. Various workers have proposed different schemes of classification of fishes. However, no classification has been universally accepted because of confusion due to large number of fishes and great diversity in their shape, size, habits and habitat.

J. Muller (1844) gave first classification of the lower vertebrates and divided Pisces into six subclasses:

1. Dipnoi

2. Teleostei,

3. Ganoidei,

4. Elasmobranchii,

5. Marsipobranchii (Cyclostomi) and

6. Leptocardii (Amphioxini).

Class **PLACODERMI,** extinct group of spiny sharks. *Climatius.*

Class **CHONDRICHTHYES** – cartilaginous fishes that have cartilaginous skeleton, ventral mouth, placoid scales, heterocercal tail fin and 5 pairs of gill slits.

Subclass **Elasmobranchii**— 850 species of sharks, rays and skates.

Subclass **Holocephali**— 30 species of ratfish *(Chimaeras)*.

Class **OSTEICHTHYES** – 20,000 species, bony fishes. Skeleton contains bone, four pairs of gills, covered with operculum. Possess swim bladder or lung.

Subclass **Actinopterygii**, ray-finned fishes.

Superorder **Chondrostei**, 25 species of sturgeons, bichirs and paddlefish.

Superorder **Holostei**, which includes *Lepistosteus* 7 species and *Amia* 1 species.

Superorder **Teleostei**, includes 20,000 species of bony fishes, such as tarpon, herring, perch, etc.

Subclass **Crossopterygii**, includes 2 species of coelacanth *(Latimeria).*

Class **CHOANICHTHYS (=DIPNOI)**, has 6 species of lungfishes under three genera, namely, *Protopterus, Lepidosiren* and *Neoceratodus.*

TETRAPODS

Class **AMPHIBIA**

Habit and Habitat of Amphibians:

Amphibians are cold blooded vertebrates having a smooth or rough, naked skin, rich in glands, which keep it moist, if scales are present, it is hidden in the skin. They are quite numerous and successful in the ecological niches that they occupy and make an important element in many food-chains. There are nearly 2,000 species identified so far, and placed in 250 genera.

Although amphibians are well adapted for certain situations, it is remarkable that they do not succeed in maintaining themselves in many different types of habitat. There are desert toads, e.g., Chiroleptes of Australia, but these survive by burrowing and by special abilities, such as the power to hold large amounts of water, associated with loss of the glomeruli of the kidneys.

The fossils of amphibian ancestors and early amphibians have been discovered in sediments of the middle and late Devonian period in Greenland and Australia. Therefore, it is assumed that the first amphibians originated during Devonian period. The classifications of amphibians are made by various authors in different ways.

Origin of Amphibians:

During the later part of the Devonian period a population of osteolepid fishes started crawling from pool to pool and spending more time on the land. They gave rise to a terrestrial population that we distinguish as Amphibia. This is the common idea of amphibian origin. But some herpetologists argued in different ways — these are as follows.

1. Polyphyletic view of amphibian origin:

Carroll and Currie (1975), Jarvik (1980) hypothesized that the three living orders, e.g., Anura, Urodela and Apoda have evolved separately. Jarvik also pointed out that the amphibians originated independently from more than one group of rhipidistian fishes. But this view is readily rejected by all scientists.

2. Di-phyletic view of amphibian origin:

Romer (1945), Romer and Watson (1962) opined that both salamanders and caecilians share a common ancestor and anurans were developed separately. By emphasizing on the vertebral column similarities in the different groups, it is considered that anurans have evolved from labyrinthodonts and urodeles and apodans from lepospondyls.

3. Monophyletic view of amphibian origin:

According to this view all living amphibians have evolved from the earliest amphibians the Ichthyostega and this group is also derived from Osteolepid fish. The proponents of this view are Noble (1931), Bolt (1979), McFarland (1985), Duellman and Trueb (1986).

General Characters of class Amphibians:

1. The body of amphibians comprises of a distinct head with elongated trunk. Neck and tail may be present or absent.

2. Highly glandular, moist skin is naked. In some apodans, dermal scales are present.

3. The body of amphibians is provided with two pairs of pentadactylous limbs.

4. Forelimbs are with four and hind limbs are with five clawless digits.

5. The body is ectothermic (poikilothermous or cold blooded or adjusters).

6. Eyes are often with eyelids. A tympanum is present.

7. Gut ends into a cloaca.

8. Three chambered heart. R.B.C. nucleated.

9. In adults respiration is performed by lungs, skin and buccopharyngeal cavity.

10. In adult salamanders, kidney is mesonephric type, while in caecillans it is opisthonephric type.

11. Central nervous system possess ten pairs of cranial nerves.

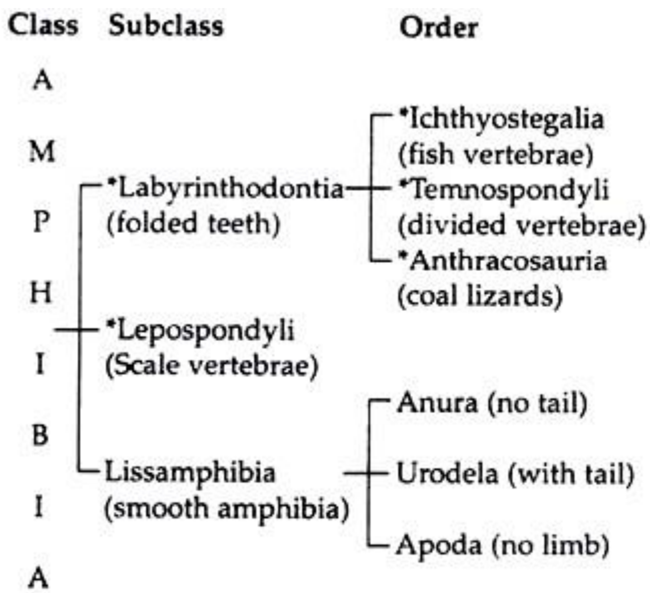
12. Procoelous vertebrae lacks ribs.

13. The skull possesses two occipital condyles. Post temporal fossa and ectopterygoid are absent.

14. Eggs are large, yolky and mesolecithal type.

15. Generally an aquatic tadpole larval stage is present in the life history.

Classification Scheme of Amphibians:



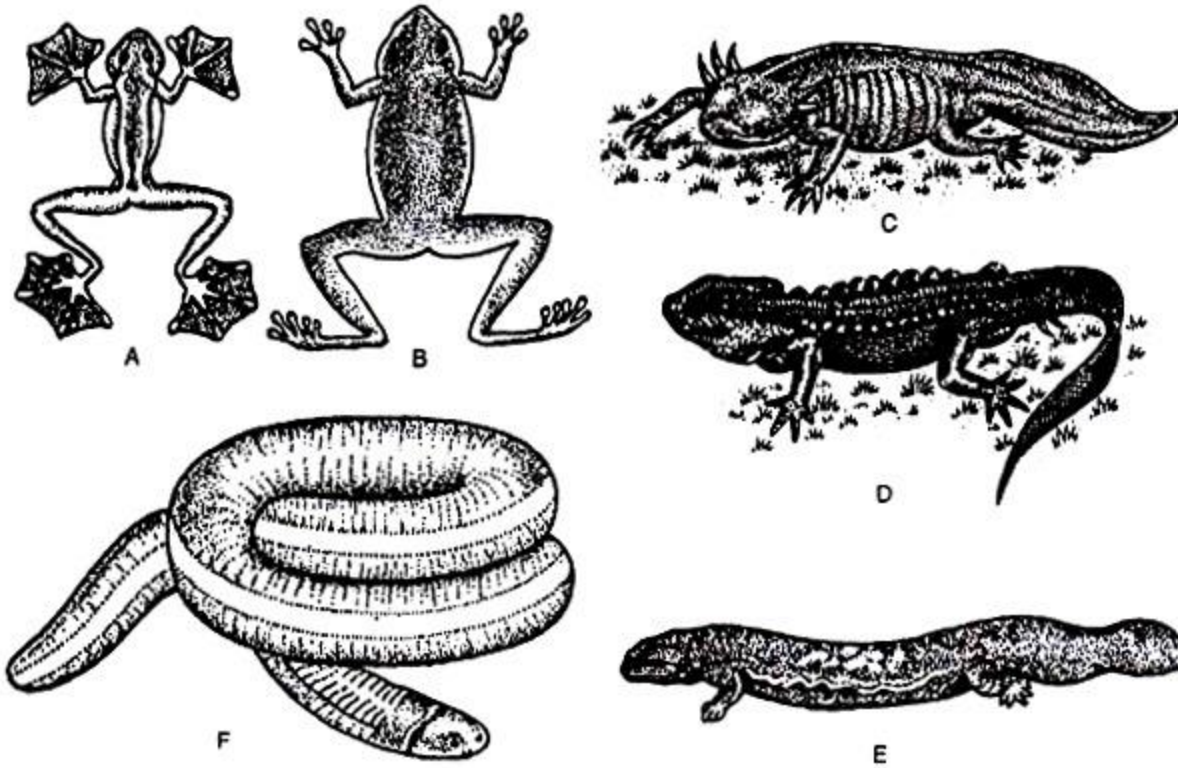


Fig. 1.60 : Some important amphibians : A. *Rhacophorus* sp., B. *Hyla* sp., C. Axolotl larva, D. *Tylototriton* sp., E. *Cryptobranchus* sp., F. *Ichthyophis* sp.

Class **REPTILIA**,

7800 species, turtles, crocodiles, lizards, snakes, etc.

They have internal fertilization and produce large cleioid eggs with leathery shells and are ectotherms. Body covered with epidermal scales, vertebrae procoelous.

Reptiles are cold-blooded vertebrates, breath by lungs and having the body covered by scales or scutes. A basioccipital bone is present in the skull which articulates with the vertebral column by a single condyle. In 1895, herpetologists separated reptiles from Amphibia as a different class.

They classified reptiles especially on the basis of skeletal characters. The major characteristic feature is the fossa of the temporal region, i.e., behind the orbit, of the skull.

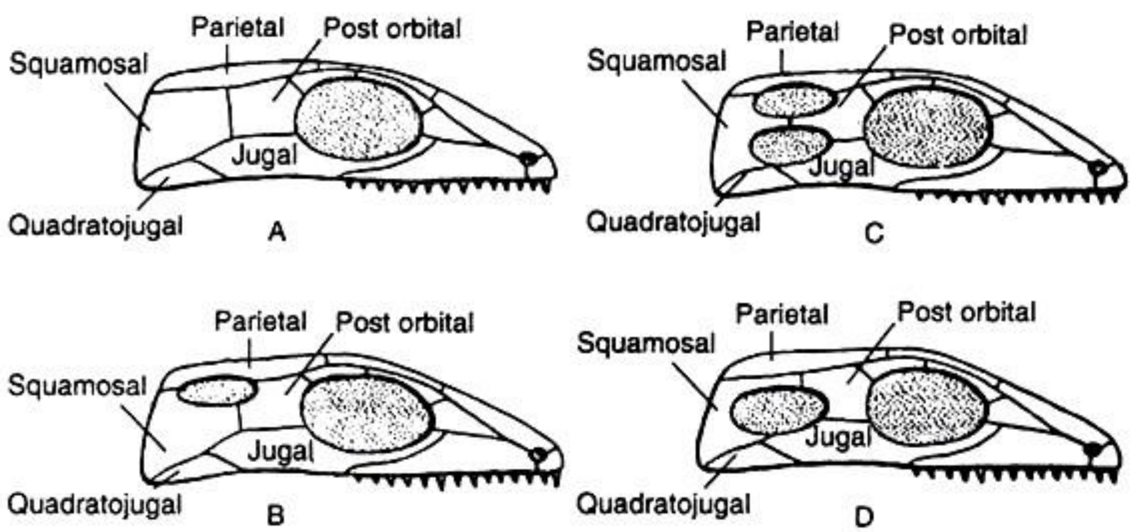


Fig. 1.81 : Different types of skull of reptiles : A. Anapsida, B. Parapsida, C. Diapsida, D. Synapsida

1. Anapsida — without any opening in the temporal region.

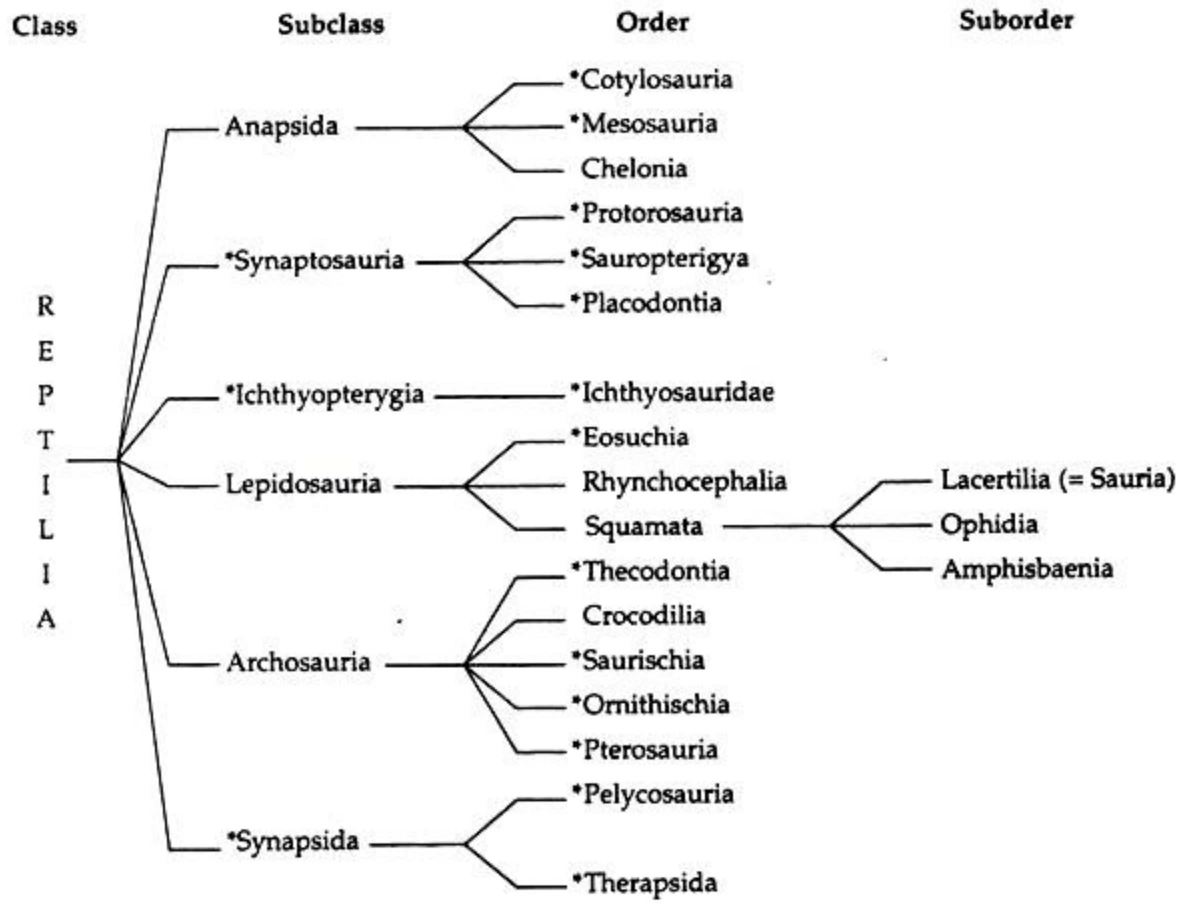
2. Parapsida — The skull possesses an upper opening in which the post-orbital and squamosal meet below.

ADVERTISEMENTS:

3. Diapsida — In this case there are two openings on each side, separated by pos- torbital and squamosal bones.

4. Synapsida — In this group a single opening is present with postorbital and squamosal meeting above.

Classification scheme of Reptilia



Since the separations of reptiles from amphibians at the last part of nineteenth century, different herpetologists came forward to classify them. Therefore, several schemes of classification exist. Here the classificatory scheme proposed in ‘The life of vertebrates’ by J. Z. Young (1981) is followed. The detail discussion on general characteristics is made only for extant orders.

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Class — Reptilia:

General characters:

1. They are inhabitants of terrestrial and aquatic (both marine and freshwaters) environments.

2. Their skin is dry, cornified and usually covered by epidermal scales or scutes. There are a few integumentary scent glands secreting pheromones during breeding seasons.

3. Single external nasal opening is present on the snout. Ear drums are slightly depressed.

4. Two pairs of pentadactyle limbs are present. The limbs end in clawed digits.

5. The cloacal opening is either transverse or longitudinal.

6. A post-anal tail is present.

7. The heart is composed of two auricles and a partially divided ventricle. There are right and left systemic arches.

8. The kidney is metanephric type.

9. Mullerian duct persists as oviduct in female and Wolffian duct is retained as vas deference in male. Males possess copulatory organs.

10. Twelve pairs of cranial nerves are present.

11. Vomero-nasal organ (Organ of Jacobson) is well-developed.

12. Single occipital condyle in the skull is present for the attachment with atlas.

13. Mandible consists usually six pieces of bones.

14. Vertebrae are procoelous. Sternum is greatly developed with ribs.

15. Cleidoic eggs are large. The calcareous shell serves for protection against desiccation and external injury. The shell is porous for gaseous exchange.

16. Fertilisation is internal.

17. Embryos are provided with extra-embryonic membranes, like amnion, chorion and allantois.

18. These are ectothermic or heliothermic (Gk. helios = sun) animals.

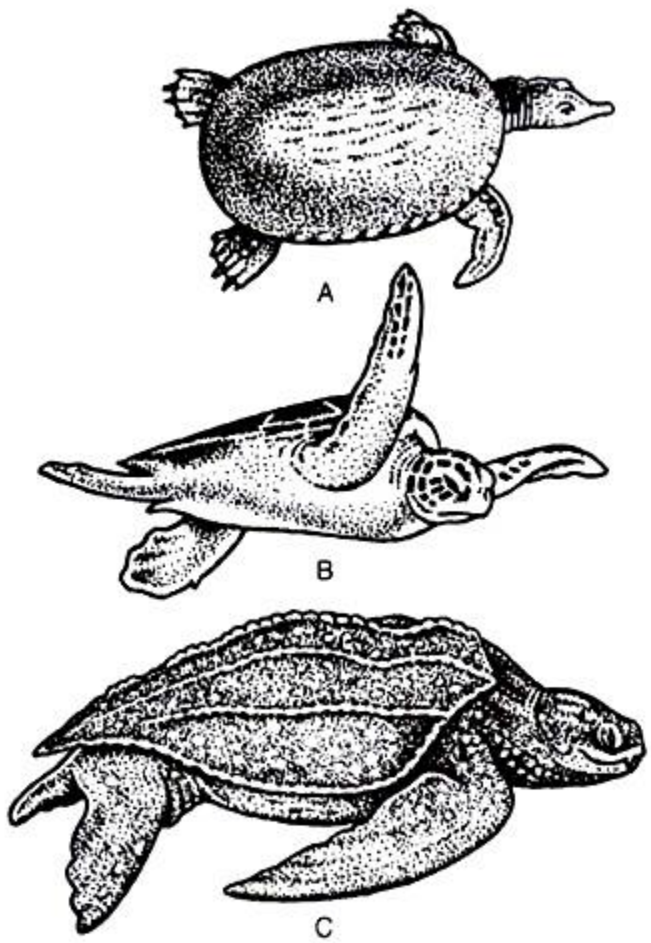


Fig. 1.82 : A. *Tryonix*, B. *Chelone*, C. *Dermochelys*

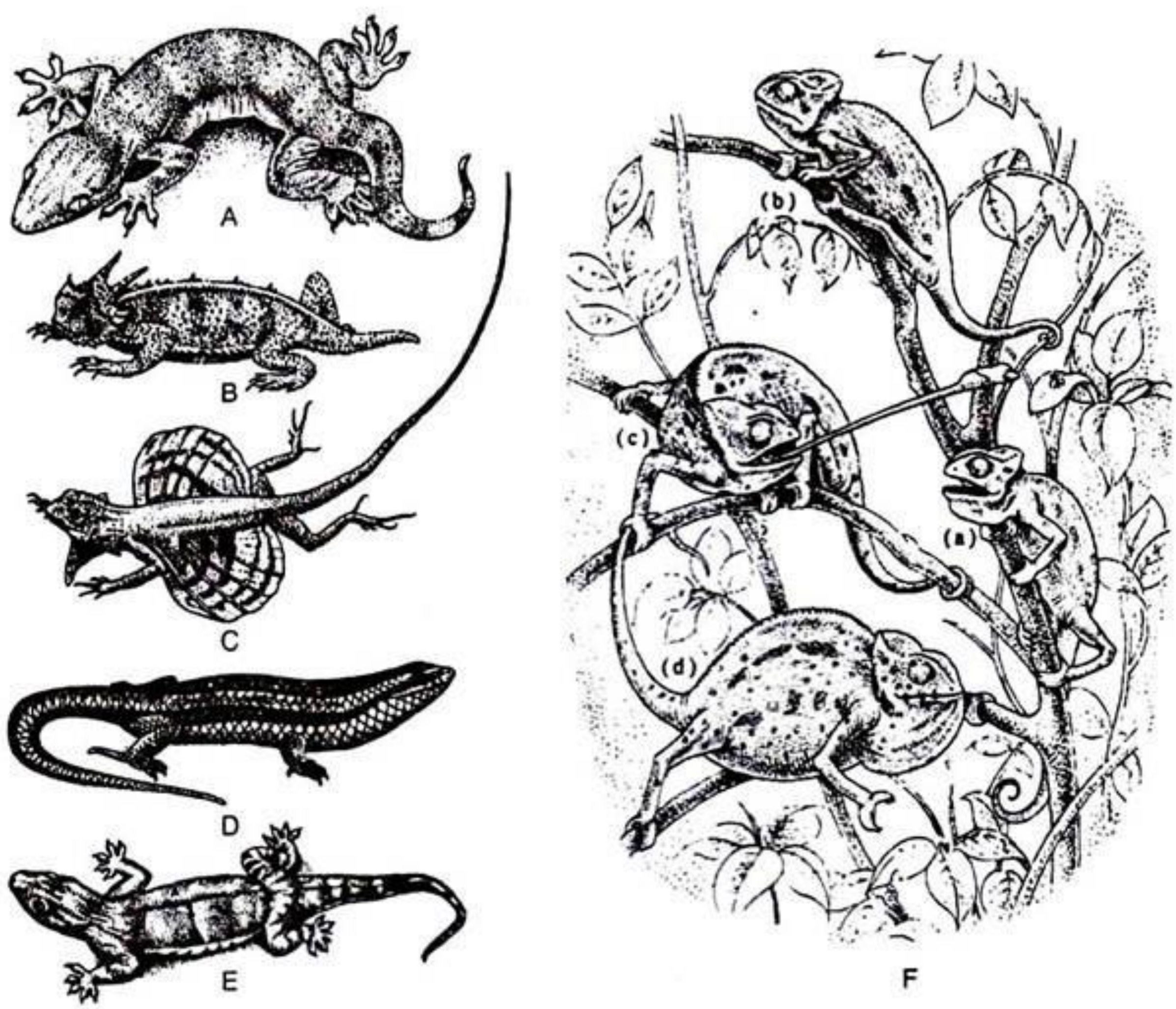


Fig. 1.83 : A. *Gekko*, B. *Pharynosoma*, C. *Draco*, D. *Mabuya*, E. *Hemidactylus*, F. *Chamaeleo* (= *Chamaeleon*)

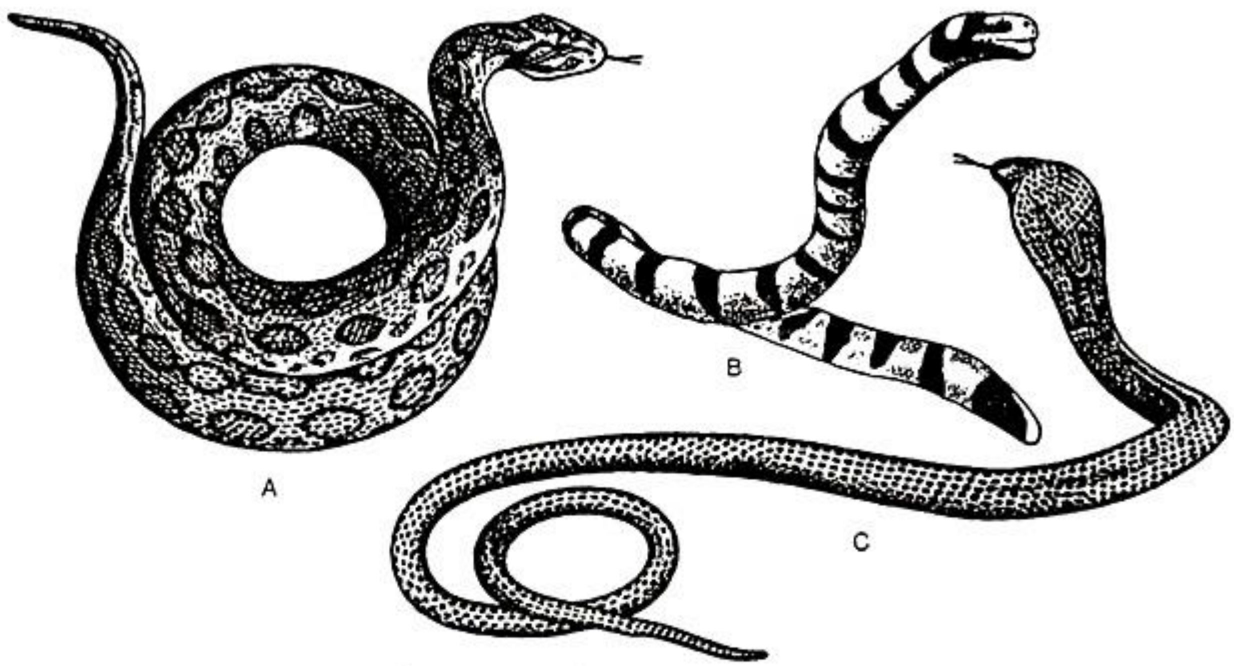


Fig. 1.84 : A. *Python*, B. *Hydrophis*, C. *Naja*

Class **AVES,** 9100 species.

Birds being feathered bipeds have internal fertilization and lay hard-shelled eggs and are endotherms. Nearly every anatomical feature is related to ability to fly. They are the only animals with feathers that are modified from reptilian scales.

General Characters of Birds:

1. Birds have spindle-shaped body is highly aero dynamically suitable and covered by feathers. Birds are homoieothermal animals.

2. Small head is placed on a fairly long movable neck.

3. Mouth is provided with a specialised exoskeletal derivative called beak. Teeth are absent in Birds.

4. Fore limbs are modified as wings, which is powered by strong flight muscles.

5. Hind limbs of birds possess four clawed digits.

6. Eyes of birds possess pecten.

7. Bones become pneumatic to reduce body weight.

8. Alimentary canal contains gizzard for crushing the food due to absence of teeth.

9. Specialised respiratory system performs double respiration. Air sacs are present in association with lungs.

10. Syrinx is the sound producing organ.

11. Heart of birds is four-chambered. Only right aortic arch is present.

12. Kidney is metanephric type. Urine is semisolid. Urinary bladder is absent.

13. Only left ovary is present, right ovary absent in birds.

14. These are oviparous animals having telolecithal eggs. Cleavage is meroblastic.

15. During embryonic development four types of extra-embryonic membranes appear. These are chorion, amnion, allantois and yolk sac.

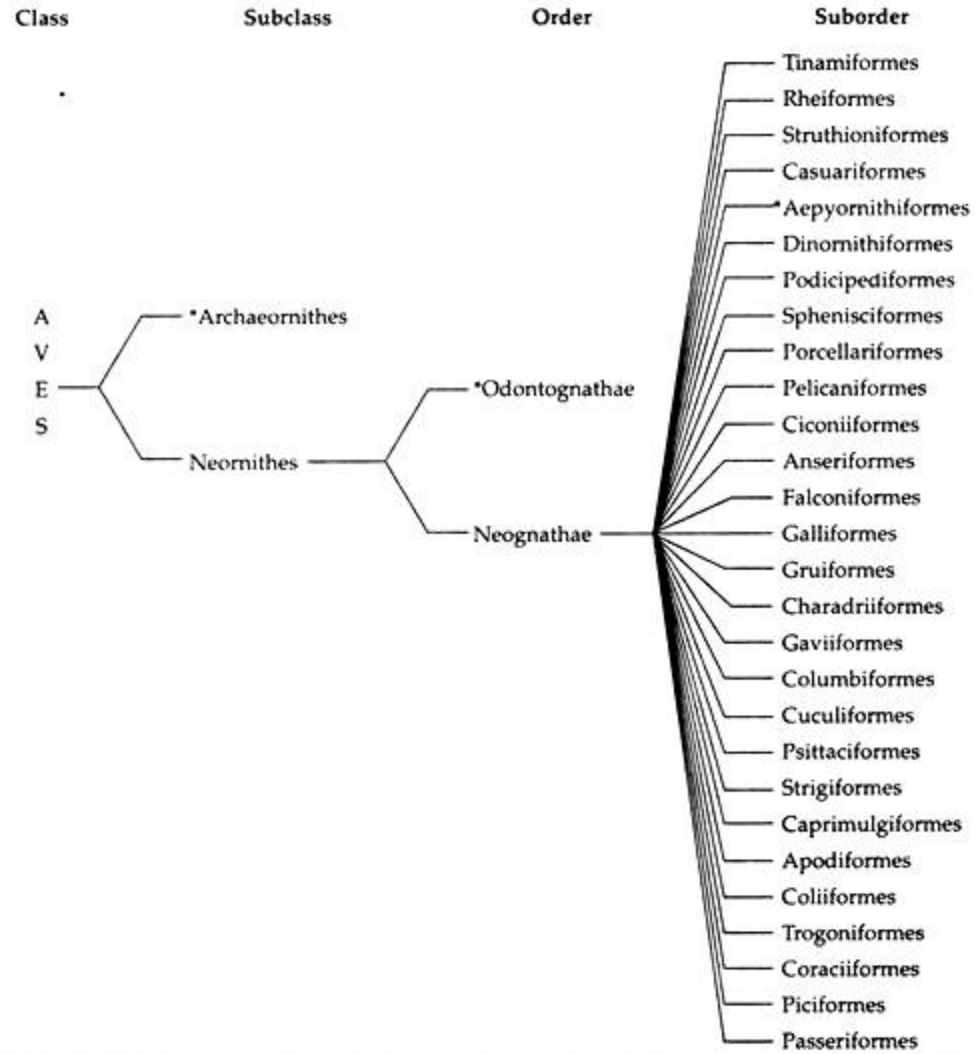
16. Cloaca is divided into three chambers — coprodeum, urodeum and proctodeum.

17. Highly developed nervous system includes brain and sense organs.

Classification of Birds:

As in other chordates, Class Aves is also classified in various ways by various authors. The scheme of classification adopted here is based on Young (1981) edn.

Outline classification



Class **MAMMALIA,** 4,500 species.

Mammals evolved in the late Triassic, the time dinosaurs first appeared and diversified greatly following the extinction of dinosaurs during the Coenozoic. Characteristics include hairs for protection and from heat loss; mammary glands; heterodont teeth; endothermy; 4 chambered heart etc.

Definition of Mammals:

Among vertebrates, mammals became most fully suited for life on land. There are many species of mammals in which the process of life are carried on under conditions far remote from those in which life first arose.

The information in their DNA provides them with numerous special adaptive devices. The success of the mammals in maintaining life in strange environments is largely due to the remarkable powers they possess of keeping their own composition constant.

Besides the regulation of temperature, there is also regulation of nearly all components of the blood, which are kept constant within narrow limits. Therefore, the most characteristic features of the modern mammals are seen to be largely in their behaviour and soft structures.

Mammals can be defined as ‘highly percipient and mobile animals, with large brains, spiral cochlea, warm blood, left aortic arch, and water-proof, usually hairy skin, whose young are born alive, and are nourished by milk.

General Characters of Mammals:

1. Body of mammals is covered by epidermal hair.

2. Integumentary glands are — sweat (sudoriferous), sebaceous (oil), scent (odoriferous) glands.

3. Mammary glands are present to supply milk for the nourishment of suckling young.

4. External fleshy pinna is present in mammals.

5. Eyes with upper and lower eyelids and often with eyelashes.

6. Nictitating membrane is translucent and hairless; it is vestigial in higher mammals.

7. A muscular diaphragm is present in between the thoracic and abdominal cavities.

8. Endo-thermal homoeotherm animals.

9. RBCs are non-nucleated, biconcave and usually circular in form.

10. The four-chambered heart is highly powerful.

11. Only left aortic arch is present in the arterial system.

12. Cerebral hemispheres are very large and highly convoluted.

13. Cerebellum is large, complex and solid in mammals.

14. There is a single urinary bladder in mammals.

15. Testes remain in scrotal sacs.

16. Small eggs are devoid of yolk. Fertilisation is internal.

17. Mammals are viviparous animals.

18. The skull has double occipital condyles. Quadrate absent.

19. A bony palate is formed by the union of premaxillae, maxillae and palatines that separates the nasal passage from the buccal cavity.

20. The lower jaw is composed of a pair of bones — the dentaries.

21. Vertebrae are acoelous type.

22. Ribs are double-headed — capitulum and tuberculum.

23. The teeth are heterodont, thecodont and diphyodont type.

24. Molars are tribosphenic (three-cusped).

25. Paired forelimbs and hind limbs are present in mammals.

26. The digits of the limbs are provided with either claw or nail or hoof.

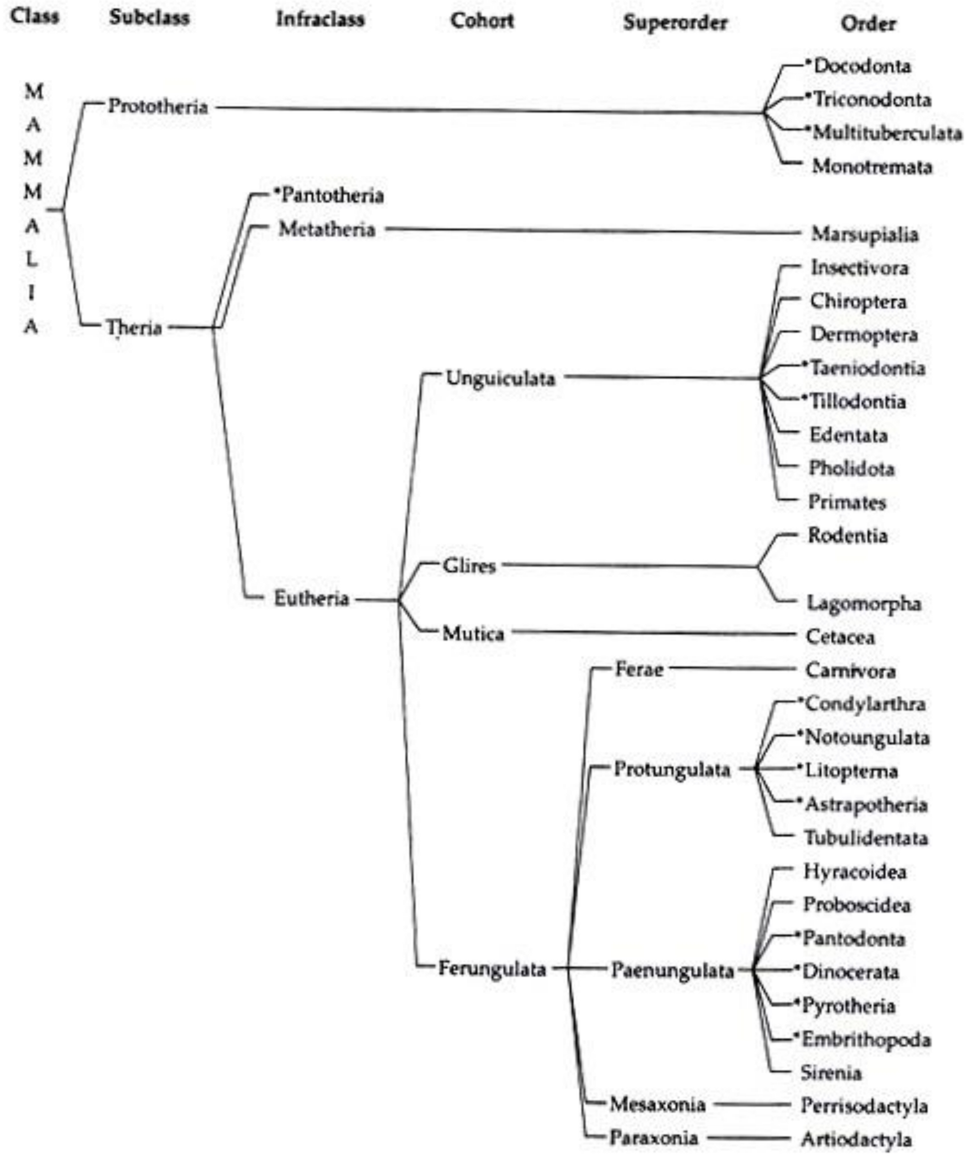
27. Cranial nerves twelve pairs.

28. Kidneys are metanephric type.

Scheme of Classification of Mammals:

Like other chordates, the classification of mammals is a very controversial and complex matter. There are several schemes of classification that exists in different literatures. But none of the existing classifications is beyond criticism.

However, in the present text, classificatory scheme of mammals as proposed by J. Z. Young (1981) is followed. In the scheme all the groups up to order are mentioned. But, for description, only living groups are considered. The extinct groups are marked with asterisks (*):


Class
Subclass
Infraclass
Cohort
Superorder
Order
MAMMALIA
Prototheria
*Docodonta
*Triconodonta
*Multituberculata
Monotremata
Theria
*Pantotheria
Metatheria
Marsupialia
Eutheria
Unguiculata
Insectivora
Chiroptera
Dermoptera
*Taeniodontia
*Tillodontia
Edentata
Pholidota
Primates
Glires
Rodentia
Lagomorpha
Mutica
Cetacea
Ferungulata
Ferae
Carnivora
Protungulata
*Condylarthra
*Notoungulata
*Litopterna
*Astrapotheria
Tubulidentata
Paenungulata
Hyracoidea
Proboscidea
*Pantodonta
*Dinocerata
*Pyrotheria
*Embrithopoda
Sirenia
Mesaxonia
Perrisodactyla
Paraxonia
Artiodactyla

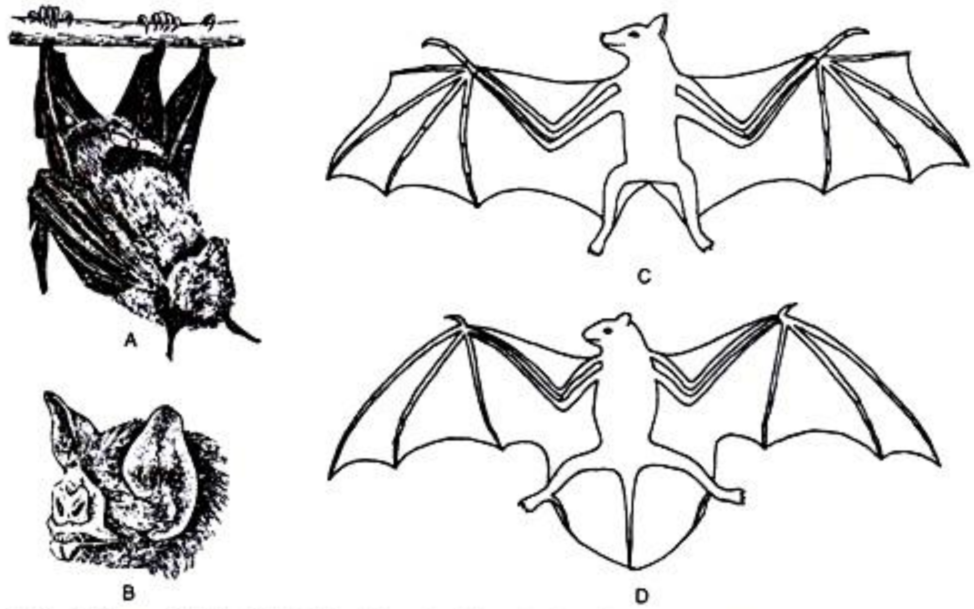


Fig. 1.129 : A. *Pteropus* (Fruit bat), B. Head of *Desmodus* (Vampire bat). C. & D. Diagrammatic figure of *Pteropus* and *Vespertilio*, respectivey. Note the patagium between the hind limbs in two groups of bats and the presence of tail in the latter

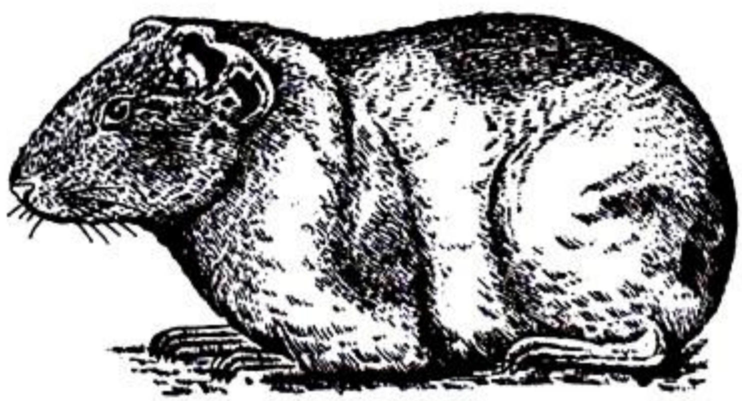


Fig. 1.130 : *Cavia* (Guineapig)

References:

https://www.notesonzoology.com/

UNIT – I

PART-A

Q.NO	QUESTIONS	CO (LEVEL)
1	Discuss the characteristic features of Protozoa.	1 (1)
2	Briefly explain about the general phylum Annelida	1 (2)
3	DefineArthropoda.	1 (1)
4	DefineMollusca	1 (1)
5	Classify Echinodermata with examples.	1 (2)
6	Explainthe characteristic features of Sharks and Rays	1 (2)
7	List the general characters of Fishes	1 (2)
8	Classify Amphibians	1 (2)
9	Summarize the general features of Avifauna	1 (2)
10	Highlight the importance of Mammalia	1 (1)

PART-B

Q.NO	QUESTIONS	CO (LEVEL)
1	Classify the phylum Protozoa with suitable diagrams.	1 (2)
2	Discuss in detail the classification of Porifera and Coelenterata	1 (1)
3	Summarize the general characters of phylum Platyhelminthes and Nematoda	1 (2)
4	Illustrate the phylumAnnelida	1 (2)
5	Discuss the characteristic features of Insects with suitable examples	1 (1)
6	Explain the general characters of Mollusca with suitable figures	1 (2)
7	Classify the fishes with suitable examples	1 (2)
8	Explain the characteristic features of Amphibians with suitable figures	1 (2)
9	Explain the general characters of the phylum Reptiles	1 (2)
10	Describe the following characters of the following phyla a) Aves b) Mammals	1 (1)

SCHOOL OF BIO & CHEMICAL ENGINEERING

DEPARTMENT OF BIOTECHNOLOGY

SBC1201: ZOOLOGY

UNIT – II - ANATOMY AND PHYSIOLOGY– SBC1201

1. Human Organs and Organ Systems

Human Organs

An organ is a collection of tissues joined in a structural unit to serve a common function. Organs exist in most multicellular organisms, including humans, other animals, and plants. In single-celled organisms (such as bacteria), the functional equivalent of an organ is an organelle.

Tissues in Organs

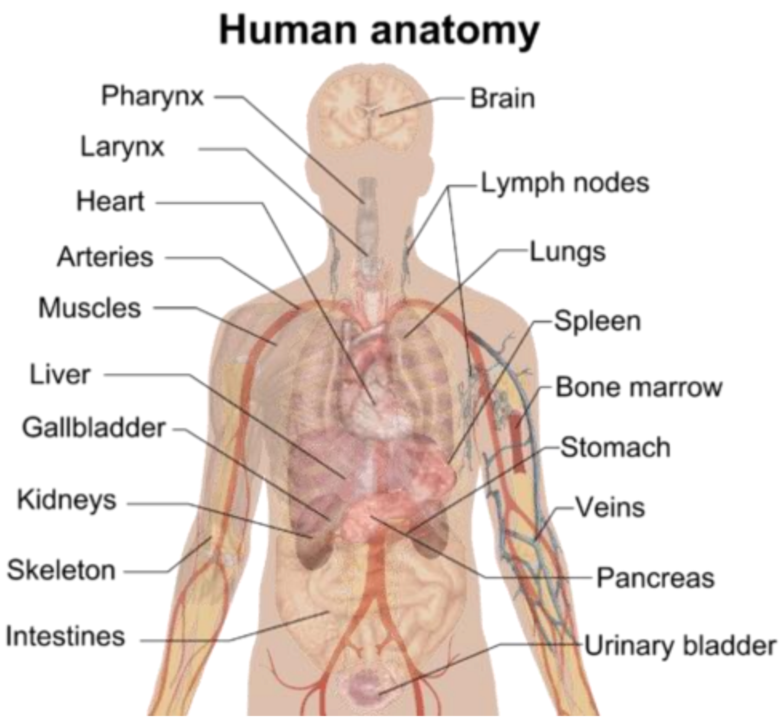
Although organs consist of multiple tissue types, many organs are composed of a main tissue that is associated with the organ's major function, along with other tissues that play supporting roles. The main tissue may be unique to that specific organ. For example, the main tissue of the heart is cardiac muscle, which performs the heart's major function of pumping blood and is found only in the heart. The heart also includes nervous and connective tissues that are required for it to perform its major function. For example, nervous tissues control the beating of the heart, and connective tissues make up heart valves that keep blood flowing in just one direction through the heart.

Vital Organs

The human body contains five organs that are considered vital for survival: the heart, brain, kidneys, liver, and lungs. The locations of these five organs — and several other internal organs — are shown in the figure below. If any of the five vital organs stops functioning and medical intervention is not readily available, the organism's death will be imminent.

1. The **heart** is located in the center of the chest, and its function is to keep blood flowing through the body. Blood carries substances to the cells they need. It also carries wastes away from cells.
2. The **brain** is located in the head and functions as the body's control center. It is the seat of all thoughts, memories, perceptions, and feelings.
3. The two **kidneys** are located in the back of the abdomen on either side of the body. Their function is to filter blood and form urine, which is excreted from the body.

4. The **liver** is located on the right side of the abdomen. Its functions include filtering blood, secreting bile that is needed for digestion, and producing proteins necessary for blood clotting.
5. The two **lungs** are located on either side of the upper chest. Their main function is exchanging oxygen and carbon dioxide with the blood.

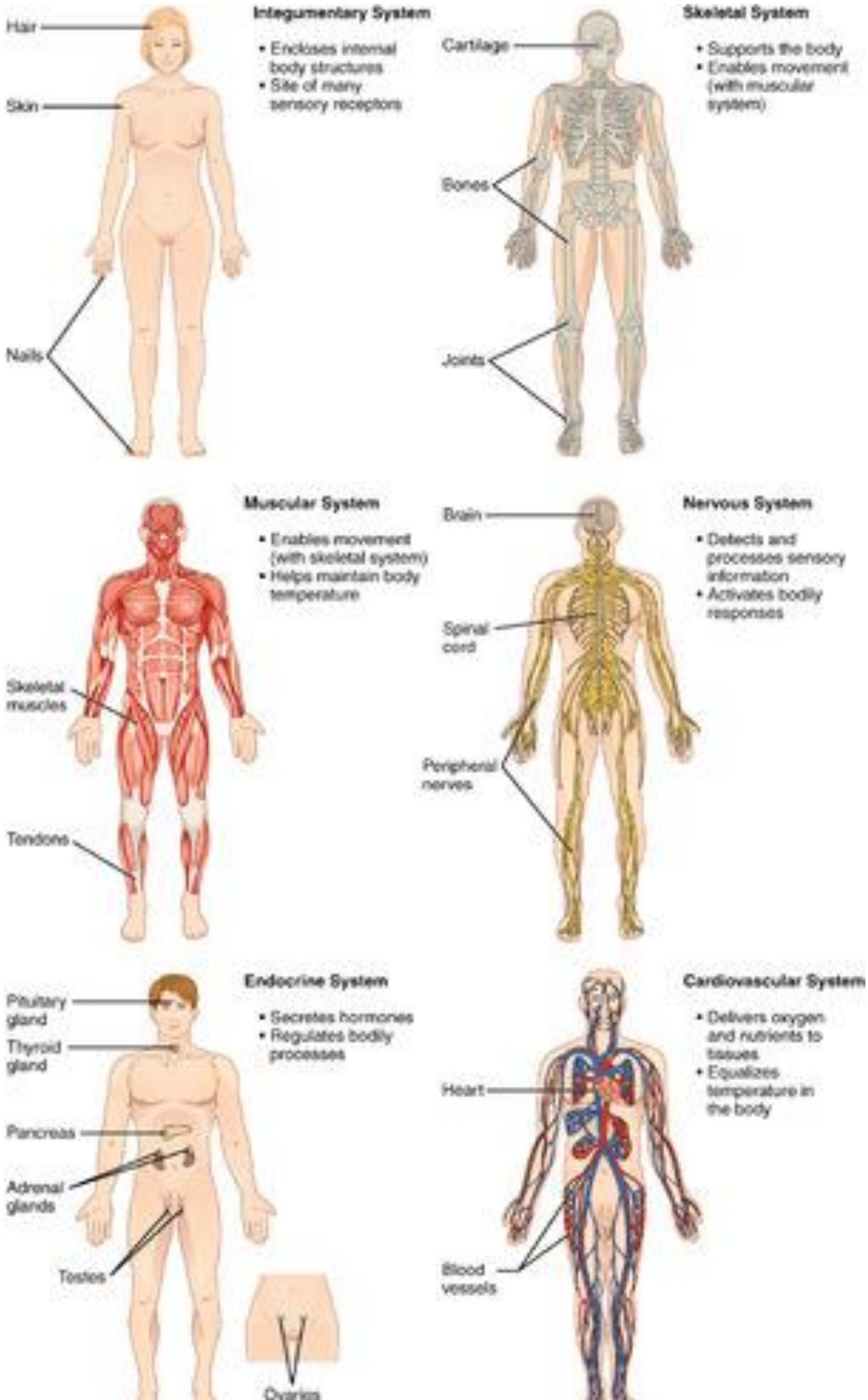


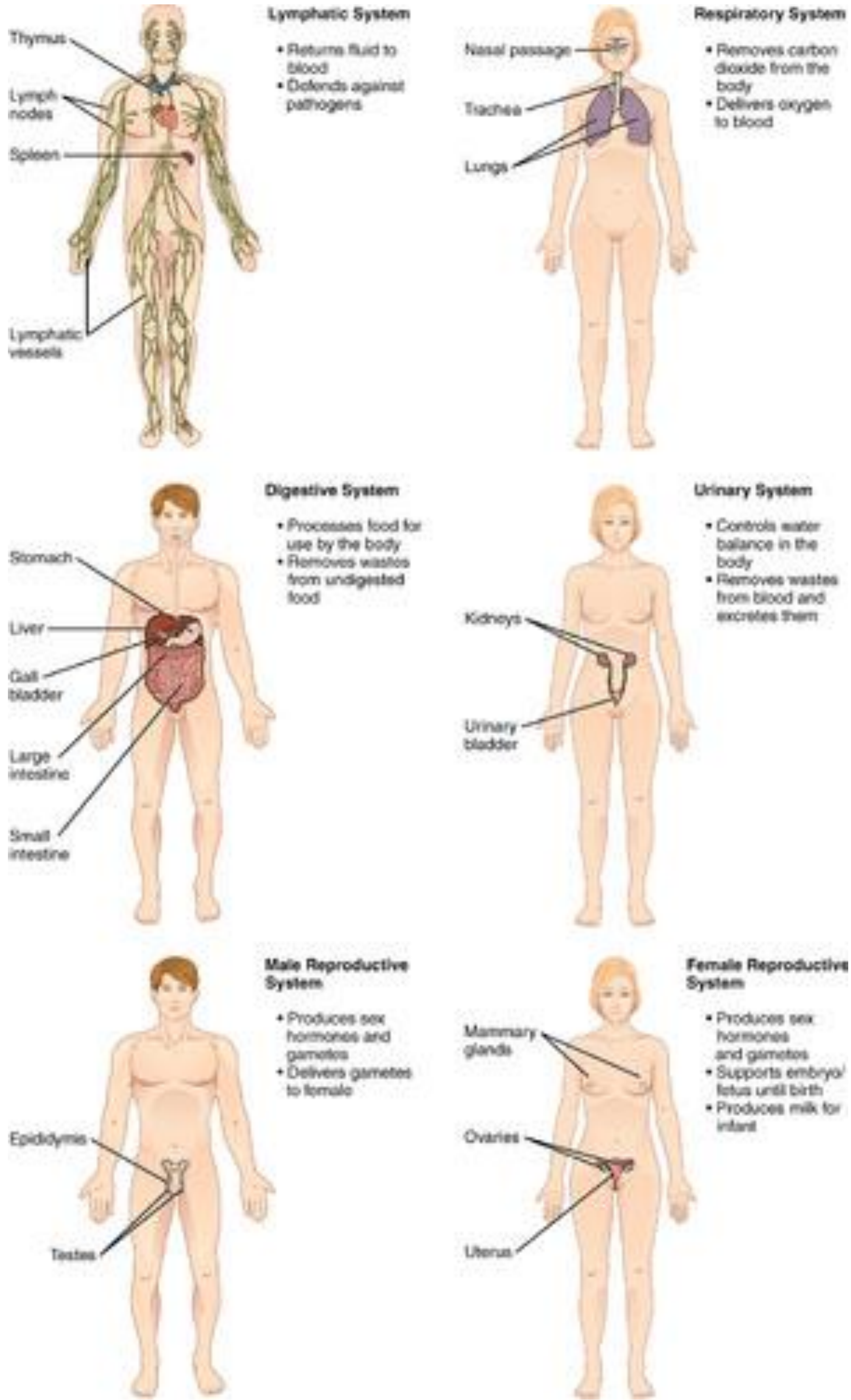
[Figure 2]

Use this shadow diagram of human anatomy to locate the five organs described above: heart, brain, kidneys, liver, and lungs. Do you know the functions of any of the other organs in the diagram?

Human Organ Systems

Functionally related organs often cooperate to form whole organ systems. The 12 diagrams in the figures below show 11 human organ systems, including separate diagrams for the male and female reproductive systems. Some of the organs and functions of the organ systems are identified in the figure. Each system is also described in more detail in the text that follows. Most of these human organ systems are also the subject of separate chapters in this book.


Hair
Skin
Nails
Integumentary System
• Encloses internal body structures
• Site of many sensory receptors
Cartilage
Bones
Joints
Skeletal System
• Supports the body
• Enables movement (with muscular system)
Skeletal muscles
Tendons
Muscular System
• Enables movement (with skeletal system)
• Helps maintain body temperature
Brain
Spinal cord
Peripheral nerves
Nervous System
• Detects and processes sensory information
• Activates bodily responses
Pituitary gland
Thyroid gland
Pancreas
Adrenal glands
Testes
Ovaries
Endocrine System
• Secretes hormones
• Regulates bodily processes
Heart
Blood vessels
Cardiovascular System
• Delivers oxygen and nutrients to tissues
• Equalizes temperature in the body


Lymphatic System
• Returns fluid to blood
• Defends against pathogens
Thymus
Lymph nodes
Spleen
Lymphatic vessels
Respiratory System
• Removes carbon dioxide from the body
• Delivers oxygen to blood
Nasal passage
Trachea
Lungs
Digestive System
• Processes food for use by the body
• Removes wastes from undigested food
Stomach
Liver
Gall bladder
Large intestine
Small intestine
Urinary System
• Controls water balance in the body
• Removes wastes from blood and excretes them
Kidneys
Urinary bladder
Male Reproductive System
• Produces sex hormones and gametes
• Delivers gametes to female
Epididymis
Testes
Female Reproductive System
• Produces sex hormones and gametes
• Supports embryo/fetus until birth
• Produces milk for infant
Mammary glands
Ovaries
Uterus

Integumentary System

Organs of the integumentary system include the skin, hair, and nails. The skin is the largest organ in the body. It encloses and protects the body and is the site of many sensory receptors. The skin is the body's first defense against pathogens, and it also helps regulate body temperature and eliminate wastes in sweat.

Skeletal System

The skeletal system consists of bones, joints, teeth. The bones of the skeletal system are connected by tendons, ligaments, and cartilage. Functions of the skeletal system include supporting the body and giving it shape. Along with the muscular system, the skeletal system enables the body to move. The bones of the skeletal system also protect internal organs, store calcium, and produce red and white blood cells.

Muscular System

The muscular system consists of three different types of muscles, including skeletal muscles, which are attached to bones by tendons and allow for voluntary movements of the body. Smooth muscle tissues control the involuntary movements of internal organs, such as the organs of the digestive system, allowing food to move through the system. Smooth muscles in blood vessels allow vasoconstriction and vasodilation, thereby helping to regulate body temperature. Cardiac muscle tissues control the involuntary beating of the heart, allowing it to pump blood through the blood vessels of the cardiovascular system.

Nervous System

The nervous system includes the brain and spinal cord — which make up the central nervous system — and nerves that run throughout the rest of the body, making up the peripheral nervous system. The nervous system controls both voluntary and involuntary responses of the human organism, and also detects and processes sensory information.

Endocrine System

The endocrine system is made up of glands that secrete hormones into the blood, which then carries hormones throughout the body. Endocrine hormones are chemical messengers that control many body functions, including metabolism, growth, and sexual development. The master gland of the endocrine system is the pituitary gland, which produces hormones that control other endocrine glands. Some of the other endocrine glands include the pancreas, thyroid gland, and adrenal glands.

Cardiovascular System

The cardiovascular system (also called circulatory system) includes the heart, blood, and three types of blood vessels: arteries, veins, and capillaries. The heart pumps blood, which travels through the blood vessels. The main function of the cardiovascular system is transport. Oxygen from the lungs and nutrients from the digestive system are transported to cells throughout the body. Carbon dioxide and other waste materials are picked up from the cells and transported to organs (such as the lungs and kidneys) for elimination from the body. The cardiovascular system also equalizes body temperature and transports endocrine hormones to cells in the body where they are needed.

Lymphatic System

The lymphatic system is sometimes considered part of the immune system. It consists of a network of lymph vessels and ducts that collect excess fluid (called lymph) from extracellular spaces in tissues and transport the fluid to the bloodstream. The lymphatic system also includes many small collections of tissue, (called lymph nodes) and an organ called the spleen, both of which remove pathogens and cellular debris from the lymph or blood. In addition, the thymus gland in the lymphatic system produces some types of white blood cells (lymphocytes) that fight infections.

Respiratory System

Organs and other structures of the respiratory system include the nasal passages, lungs, and a long tube called the trachea, which carries air between the nasal passages and lungs. The main function of the respiratory system is to deliver oxygen to the blood and remove carbon dioxide from the body. Gases are exchanged between the lungs and blood across the walls of capillaries lining tiny air sacs (alveoli) in the lungs.

Digestive System

The digestive system consists of several main organs — including the mouth, esophagus, stomach, and small and large intestines — that form a long tube called the gastrointestinal (GI) tract. Food moves through this tract, where it is digested. Its nutrients are then absorbed, and its waste products are excreted. The digestive system also includes accessory organs (such as the pancreas and liver) that produce enzymes and other substances needed for digestion, but through which food does not actually pass.

Urinary System

The urinary system is part of the excretory system, which removes wastes from the body. The urinary system includes the pair of kidneys, which filter excess water and a waste product (called urea) from the blood and form urine. Two tubes called ureters carry the urine from the kidneys to the urinary bladder, which stores the urine until it is excreted from the body through another tube called the urethra. The kidneys also produce an enzyme called renin and a variety of hormones. These substances help regulate blood pressure, the production of red blood cells, and the balance of calcium and phosphorus in the body.

Male and Female Reproductive Systems

The reproductive system is the only body system that differs substantially between males and females. Both male and female reproductive systems produce sex-specific sex hormones (testosterone in males, estrogen in females) and gametes (sperm in males, eggs in females). However, the organs involved in these processes are different. The male reproductive system includes the epididymis, testes, and penis. The female reproductive system includes the uterus, ovaries, and mammary glands. The male and female systems also have different additional roles. For example, the male system has the role of delivering gametes to the female reproductive tract, whereas the female system has the roles of supporting an embryo and fetus until birth and also producing milk for the infant after birth.

Summary

- An organ is a collection of tissues joined in a structural unit to serve a common function. Many organs are composed of a major tissue that performs the organ's main function, as well as other tissues that play supporting roles.
- The human body contains five organs that are considered vital for survival. They are the heart, brain, kidneys, liver, and lungs. If any of these five organs stops functioning, death of the organism is imminent without medical intervention.
- Functionally related organs often cooperate to form whole organ systems. There are 11 major organ systems in the human organism. They are the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems. Only the reproductive system varies significantly between males and females.

Organ System	**Functions**	**Organs**
Integumentary	• Barrier to invading organisms and chemicals • Temperature control	• Skin • Hair • Subcutaneous tissue
Skeletal	• Supports and moves body • Protects internal organs • Mineral storage • Blood formation	• Bones • Cartilage • Ligaments • Bone marrow
Muscular	• Locomotion • Heat production	• Muscles • Tendons
Nervous	• Coordinates activities of other organ systems	• Brain • Spinal cord

	• Responds to sensations	• Nerves • Eyes • Ears
Endocrine	• Regulates body functions by chemicals *(hormones)*	• Pituitary gland • Parathyroid gland • Thyroid gland • Adrenal gland • Thymus • Pancreas • Gonads
Cardiovascular	• Transports oxygen and nutrients to tissues • Removes waste products	• Heart • Blood • Blood vessels
Lymphatic	• Returns tissue fluid to blood • Defends against foreign organisms	• Spleen • Lymph nodes • Thymus • Lymphatic vessels
Respiratory	• Oxygen/carbon dioxide exchange	• Lungs • Trachea • Larynx • Nasal cavities • Pharynx
Digestive	• Processes foods	• Stomach • Intestinal tract

	• Absorption of nutrients into body	• Liver • Pancreas • Esophagus • Salivary glands
Urinary	• Elimination of wastes • Regulates pH and volume of blood	• Kidneys • Urinary bladder • Urethra
Reproductive	• Produces germ cells *(eggs and sperm)* • Environment for growth of fetus *(female)*	• Ovaries • Uterus • Mammary glands • Testes • Prostate gland • External genitalia

UNIT – II

PART-A

Q.NO	QUESTIONS	CO (LEVEL)
1	Summarize the digestion system of carnivore animals	2 (2)
2	Define circulation system and relate with vertebrates	2 (1)
3	Relate the respiratory system of aquatic species	2 (1)
4	Explainthe skeleton system with an illustration.	2 (2)
5	Explain the nervous system	2 (2)
6	List out the sensory organs and its functions	2 (1)
7	Define animal behaviour and compare with plants	2 (1)
8	Discuss the animal behaviour based on their feeding habit	2 (1)
9	Define animal reproduction in general	2 (1)
10	Summarize how invertebrate reproduce	2 (2)

PART-B

Q.NO	QUESTIONS	CO (LEVEL)
1	Explain the general pattern of digestive system of vertebrates	2 (2)
2	Prepare an elaborate account on circulatory system	2 (3)
3	Investigate how the respiratory system works in aquatic and terrestrial animals.	2 (5)
4	Assess the skeletal system of vertebrates	2 (5)
5	Review the functions of neurons and brain	2 (5)
6	Discuss in detail the sensory organs and their functions	2 (1)
7	Describe in detail aboutanimal behaviour	2 (1)
8	Investigate the different reproductive system of animal kingdom	2 (5)
9	Explain how the vertebrates reproduce	2 (2)
10	Illustrate the different mode of reproduction by invertebrates	2 (1)

SCHOOL OF BIO & CHEMICAL ENGINEERING

DEPARTMENT OF BIOTECHNOLOGY

SBC1201: ZOOLOGY

UNIT – III - DEVELOPMENTAL BIOLOGY– SBC1201

1. Developmental Biology

Developmental biology is the science that investigates how a variety of interacting processes generate an organism's heterogeneous shapes, size, and structural features that arise on the trajectory from embryo to adult, or more generally throughout a life cycle. It represents an exemplary area of contemporary experimental biology that focuses on phenomena that have puzzled natural philosophers and scientists for more than two millennia. Philosophers of biology have shown interest in developmental biology due to the potential relevance of development for understanding evolution, the theme of reductionism in genetic explanations, and via increased attention to the details of particular research programs, such as stem cell biology. Developmental biology displays a rich array of material and conceptual practices that can be analyzed to better understand the scientific reasoning exhibited in experimental life science. This entry briefly reviews some central phenomena of ontogeny and then explores four domains that represent some of the import and promise of conceptual reflection on the epistemology of developmental biology.

Animals and all other organized substances have no beginning … their apparent generation is only a development, a kind of augmentation … a transformation like any other, for instance like that of a caterpillar into a butterfly. (Smith 2011: 186–187)

A major theme that crystallized in this history of investigation is the distinction between epigenesis and preformation (see the entry on epigenesis and preformationism). Proponents of epigenesis claimed that heterogeneous, complex features of form emerge from homogeneous, less complex embryonic structures through interactive processes. Thus, an explanation of the ontogeny of these form features requires accounting for how the interactions occur. Proponents of preformation claimed that complex form preexists in the embryo and "unfolds" via ordinary growth processes. An adequate explanation involves detailing how growth occurs. Although preformation has a lighter explanatory burden in accounting for how form emerges during ontogeny (on the assumption that growth is easier to explain than process interactions), it also must address how the starting point of the next generation is formed with the requisite heterogeneous complex features. This was sometimes accomplished by embedding smaller and smaller miniatures *ad infinitum* inside the organism (Figure 1). Epigenetic perspectives were often dependent on forms of teleological reasoning (see the entry on teleological notions in biology) to account for why interactions among homogeneous components eventually result in a complex, integrated whole organism. Though nothing prevents mixing features of these two outlooks in explaining different aspects of development, polarization into dichotomous positions has occurred frequently (Rose 1981; Smith 2006).

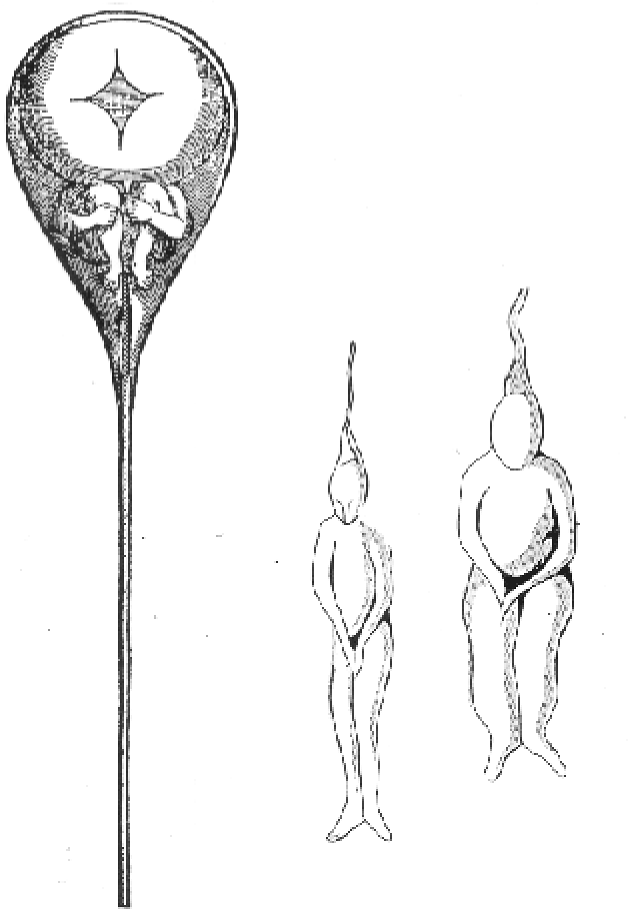


FIGURE 1: An early modern depiction of a tiny person inside of a sperm exemplifying preformationist views.

In the late 19th and early 20th century, the topic of development was salient in controversies surrounding vitalism, such as the disagreement between Wilhelm Roux and Hans Driesch over how to explain ontogeny (Maienschein 1991). Roux thought that a fertilized egg contains inherited elements that represent different organismal characteristics. During the process of cellular division, these elements become unequally distributed among daughter cells leading to distinct cell fates. Driesch, in contrast, held that each cell retained its full potential through division even though differentiation occurred. Although this issue is often understood in terms of the metaphysics of life (vitalism *versus* materialism), Driesch's interpretation of development and the autonomy of an organism had epistemological dimensions (Maienschein 2000). The explanatory disagreement involved different experimental approaches and divergent views on the nature of differentiation in early ontogeny (e.g., to what degree cells are pre-specified). A familiar philosophical theme running through these discussions, both epistemological and metaphysical, is the status of reductionism in biology. Through the middle of the 20th century, embryology—the scientific discipline studying development—slowly transformed into developmental biology with a variety of reworked and recalcitrant elements (Berrill 1961). In conjunction with the issue of reductionism, a key aspect of this history is the molecularization of experimental (as opposed to comparative) embryology (Fraser and Harland 2000), with a concomitant emphasis on the explanatory power of genes (see the entry on gene and Section 3.1). This complex and fascinating history, including interrelations with medicine and reproductive technology, has been detailed elsewhere (see, e.g., Oppenheimer 1967; Horder et al. 1986; Hamburger 1988; Hopwood 2019; Maienschein 2014; Maienschein et al. 2005; Gilbert 1991; Embryo Project in Other Internet Resources).

Developmental biology has increasingly become an area of exploration for philosophy of biology due to the potential relevance of development for understanding evolution (Love 2015; Section 5), the theme of reductionism in biology and explanations from molecular genetics (Robert 2004; Rosenberg 2006; Section 3), and via increased attention to the details of particular research programs, such as stem cell biology (Fagan 2013; Laplane 2016). However, it should not be forgotten that ontogeny was on the radar of philosophical scholars in the 20th century, as seen in Ernest Nagel's treatment of hierarchical organization and reduction in the development of living systems (Nagel 1961: 432ff). For contemporary philosophy of science, developmental biology displays a rich array of material and conceptual practices that can be analyzed to better understand the scientific reasoning exhibited in experimental life science (see the entry on experiment in biology). After a brief review of some central phenomena of ontogeny, this entry explores four domains that represent some of the import and promise of conceptual reflection on the epistemology of developmental biology.

Developmental Phenomena

Developmental biology is the science that seeks to explain how the structure of organisms changes with time. Structure, which may also be called morphology or anatomy, encompasses the arrangement of parts, the number of parts, and the different types of parts. (Slack 2006: 6)

Most of the properties that developmental biologists attempt to explain are structural rather than functional. For example, a developmental biologist concentrates more on how tissue layers fold or how shape is generated than on what the folded tissue layers do or how the shape functions. The ontogeny of function, at all levels of organization, is an element of developmental biology, but it is often bracketed because of the predominance (both past and present) of questions surrounding the ontogeny of form or structure (Love 2008).

Textbooks (e.g., Gilbert 2010; Slack 2013; Wolpert et al. 2010) typically describe a canonical set of events surrounding the changing structures displayed during animal development.[1] The first of these is *fertilization* (in sexually reproducing species), where an already semi-organized egg merges with a sperm cell, followed by the fusion of their nuclei to achieve the appropriate complement of genetic material. Second, the fertilized egg undergoes several rounds of *cleavage*, which are mitotic divisions without cell growth that subdivide the zygote into many distinct cells (Figure 2). After many rounds of cleavage, this spherical conglomerate of cells (now called a *blastula*) begins to exhibit some specification of *germ layers* (endoderm, mesoderm, and ectoderm) and then proceeds to invaginate at one end, a complex process referred to as *gastrulation* that eventually yields a through-gut. All three germ layers, from which specific types of cells are derived (e.g., neural cells from ectoderm), become established during gastrulation or shortly after it completes.[2] *Organogenesis* refers to the production of tissues and organs through the interaction and rearrangement of cell groups. Events confined to distinct taxonomic groups include *neurulation* in chordates, whereas other events correlate with mode of development (*metamorphosis* from a larval to adult stage) or individual trauma (*regeneration* of a limb).

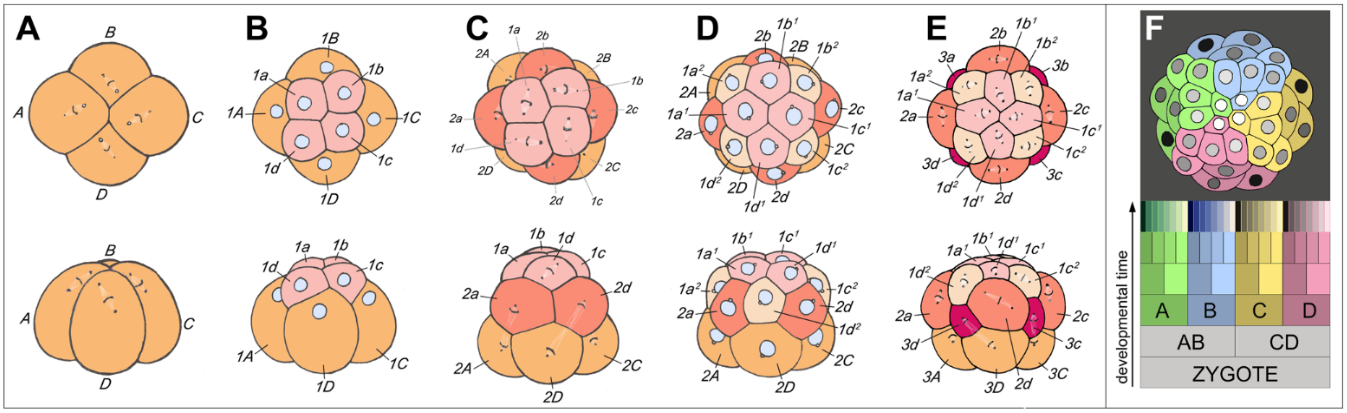


FIGURE 2: An example of embryonic cleavage in marine snail embryos showing the fate of different cell lineages through developmental time.

Several key processes underlie these distinct developmental events and the resulting features of form that emerge (e.g., the through-gut formed subsequent to gastrulation or the heart formed during organogenesis). These are critical to the ontogeny of form and link directly to major research questions in developmental biology (Section 2). First, cellular properties, such as shape, change during ontogeny. This is a function of *differentiation* whereby cells adopt specific fates that include shape transformations (Figure 3). Second, regions of cells in the embryo are designated through arrangement and composition alterations that correspond to different axes in different parts of the embryo (e.g., dorsal-ventral, anterior-posterior, left-right, and proximal-distal). The successive establishment of these regions is referred to as *pattern formation*. Third, cells translocate and aggregate into layers (e.g., endoderm and ectoderm, followed by the mesoderm in many lineages) and later tissues (aggregations of differentiated cell types). Fourth, cells and tissues migrate and interact to produce new arrangements and shapes composed of multiple tissue layers with novel functions (i.e., organs). These last two sets of processes are usually termed *morphogenesis* (Davies 2005) and occur via many distinct mechanisms (Section 1.3). Fifth, there is *growth* in the size of different form features in the individual, remarkably obvious when comparing zygote to adult, although proportional change between different features (*allometry*) is also striking.

FIGURE 3: A simple illustration of the kinds of differentiation related to the cellular components found in blood.

None of these processes occur in isolation and explanations of particular form features usually draw on several of them simultaneously, presuming other features that originated earlier in ontogeny by different instantiations and combinations of the processes. This sets a broad agenda for investigation: how do various iterations and combinations of these processes generate form features during ontogeny? Consider the concrete example of vertebrate cardiogenesis. How does the vertebrate heart, with its internal and external shape and structure originate during ontogeny (Harvey 2002)? How does the heart come to exhibit left/right asymmetry in the body cavity? What causes cells to adopt a muscle cell fate or certain tissues to interact in the prospective region of the heart? How do muscle cells migrate to, aggregate in, and differentiate at the correct location? How does the interior of the heart adopt a particular tubular structure with various chambers (that differs among vertebrate species)? How does the heart grow at a particular rate and achieve a specific size? Solutions relevant to explaining the ontogeny of form characterize causal factors that account for how different processes occur and yield various outcomes (Section 3).

Reference:

https://plato.stanford.edu/entries/biology-developmental/

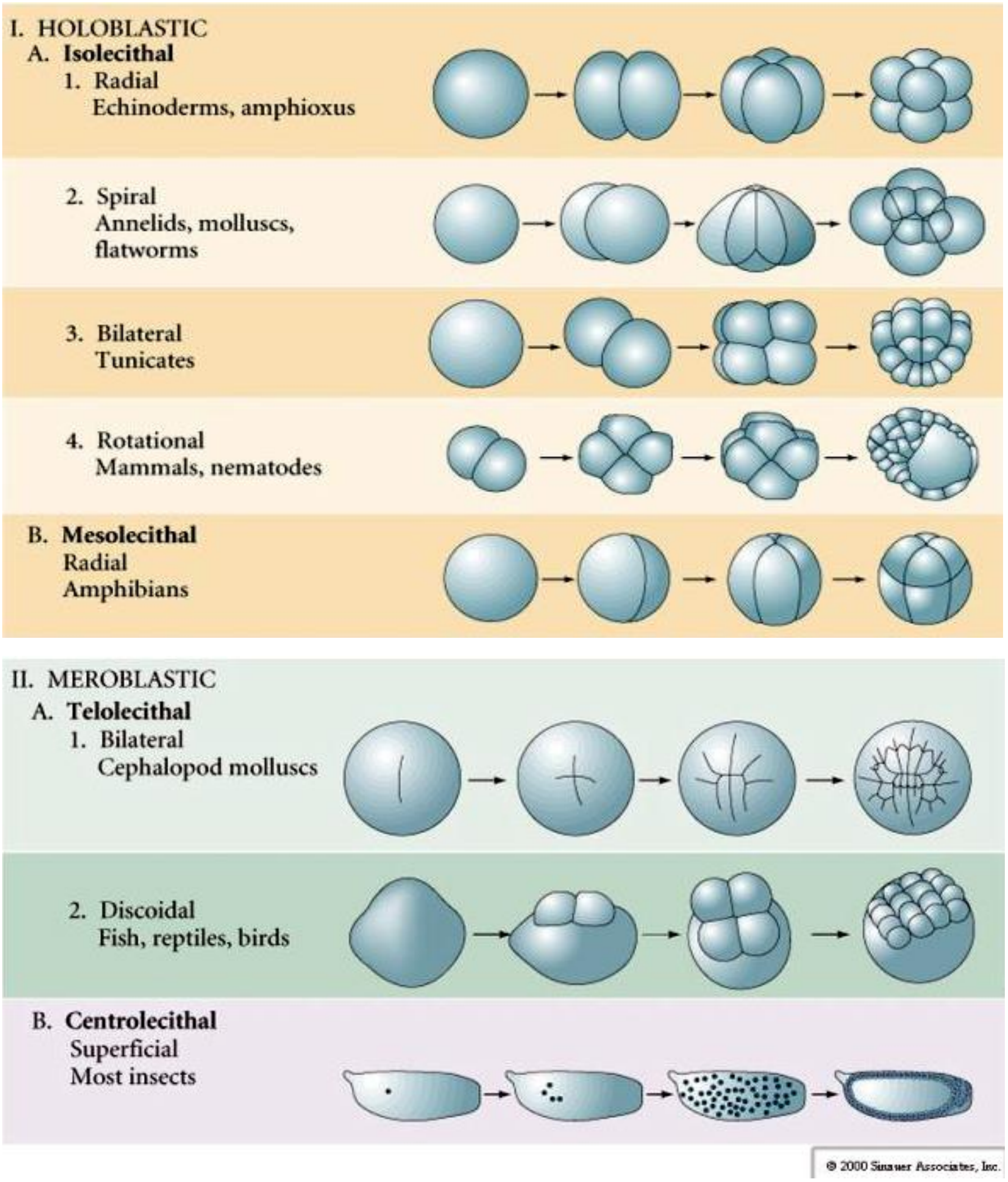
2. PATTERNS OF EMBRYONIC CLEAVAGE

Pattern of embryonic cleavage is determined both by the position of the mitotic spindles and by the amount and distribution of yolk. Yolk tends to inhibit cleavage. It slows it down or actually prevents complete cleavage. Yolk is an adaptation of those animals that go through more or less of embryogenesis isolated from any food supply. Some animals, like sea urchin, have relatively little yolk because they rapidly develop into a free swimming larval form that acquires nutrients from their environment. Other animals such as marsupials are born prematurely, but are provided nourishment in a parental pouch. Placental mammals develop a specialized organ through which the embryo is nourished throughout development and so also have little yolk.

The types of eggs based on yolk characteristics are described as:
Isolecithal: sparse evenly distributed yolk, eg., sea urchin, mouse
Mesolecthal: moderate amount of yolk, often unevenly distributed, eg., frog
Telolecithal: dense yolk concentrated at one end, eg., bird, reptile
Centrolecithal: yolk concentrated at the middle of the egg, eg. Fly

Many eggs are polarized with a yolk rich pole, termed the **vegetal pole** and a yolk poor pole termed the **animal pole,** eg., frog. The zygotic nucleus is generally displaced towards the animal pole. Zygotes with relatively little yolk (isolecithal and mesolecithal) cleave **HOLOBLASTICALLY**. The cleavage furrow extends all the way through the egg. While telolecithal and centrolecithal zygotes undergo **MEROBLASTIC** cleavage where the cleavage plane extends only to the accumulated yolk. In centrolecithal eggs (many insect eggs) cleavage is meroblastic and **superficial**, while in telolecithal eggs (birds and fish) cleavage is **discoidal**

There are several types of cleavage symmetry seen in nature: radial(echinoderms, amphibians), spiral (mollusks, annelids), Bilateral (ascidians,tunicates), Rotational (mammals). The two figures below show examples of holoblastic and meroblastic cleavage symmetries.


I. HOLOBLASTIC
A. Isolecithal
1. Radial
Echinoderms, amphioxus
2. Spiral
Annelids, molluscs, flatworms
3. Bilateral
Tunicates
4. Rotational
Mammals, nematodes
B. Mesolecithal
Radial
Amphibians
II. MEROBLASTIC
A. Telolecithal
1. Bilateral
Cephalopod molluscs
2. Discoidal
Fish, reptiles, birds
B. Centrolecithal
Superficial
Most insects
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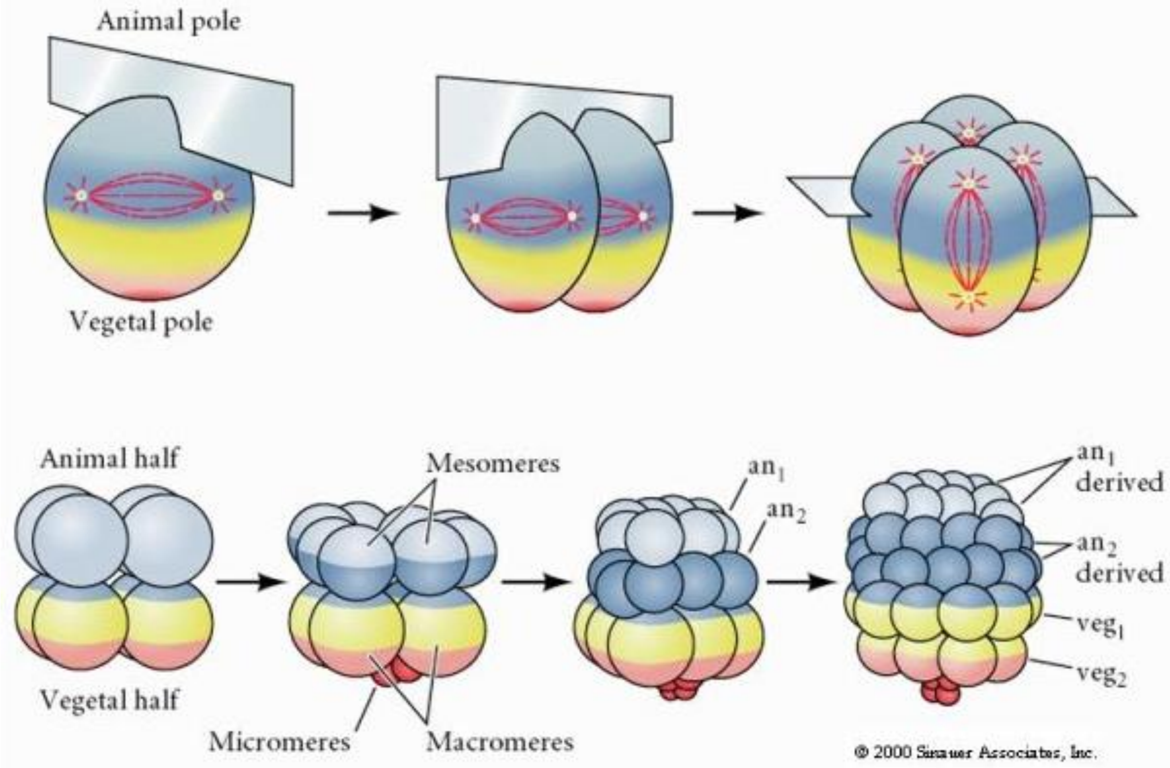
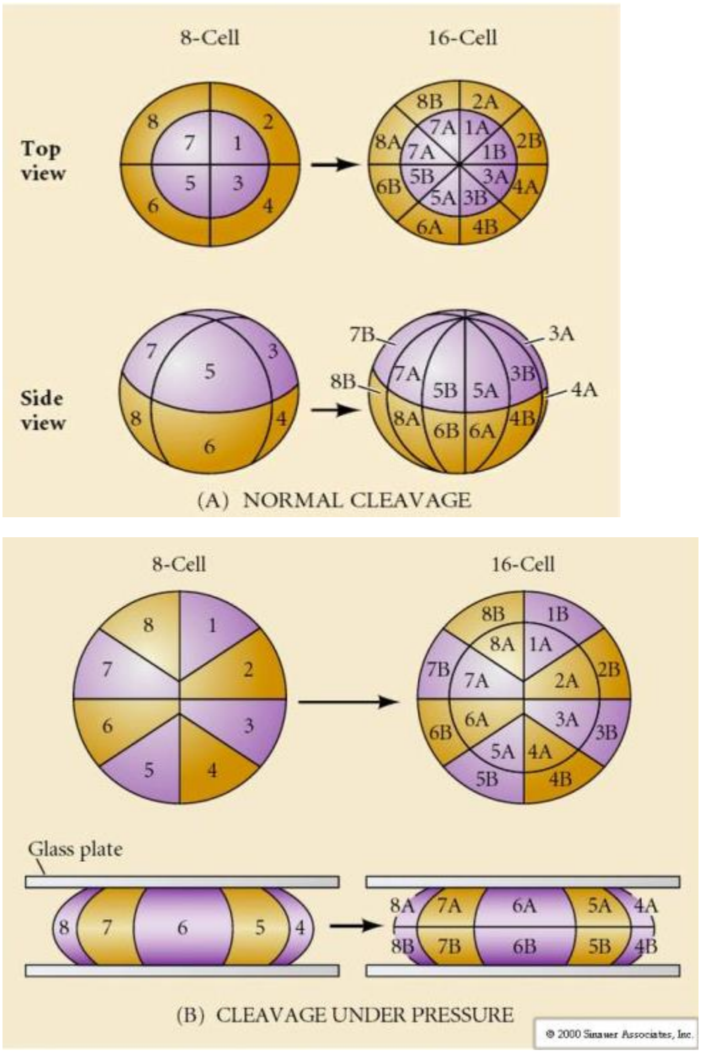
RADIAL HOLOBLASTIC CLEAVAGE



Excellent movie of sea urchin cleavage from Rachel Fink's "A Dozen Eggs".

Sea urchins also have radial holoblastic cleavage, but with some interesting differences. First cleavage is meridional.Second cleavage is meridional. Third cleavage is equatorial Fourth cleavage is meridional, but while the four animal pole cells split equally to give rise to eight equal sized animal blastomeres termed **MESOMERES**, the vegetal cells divide asymmetrically along the equatorial plane to give 4 large **MACROMERES** and 4 much smaller **MICROMERES** at the vegetal pole. Fifth division the MESOMERES divide equatorially to give two tiers of eight MESOMERES **an1** and **an2** , the MACROMERES divide meridionally forming a tier of eight cells below an2, the MICROMERES divide to give a cluster of cells below the **veg1** layer. The sixth divisions are all equatorial, giving a **veg2** layer. The seventh divisions are all meridional giving a 128 cell blastula.

What determines these cleavage patterns? Are they dependent on the previous cleavage and played out like a tape or are they determined by some intrinsic clock? In 1939 Horstadius inhibited one or two of the first three cleavages and found the appearance of the micromeres occurred at the right time regardless of the history of cleavages



The conclusion from these experiments is that there is some factor in the vegetal pole of the egg that determines the formation of the micromeres and further that there must be a "molecular clock" that starts at egg activation. The clock is independent of the actual cleavage event.

The 128 cell blastula is a rather loose ball of cells surrounding a hollow blastocoel. The ball is one cell layer thick with all cells in contact with the external hyaline layer and the internal fluid of the blastocoel. At this stage in development the cells begin to form the tight junctions characteristic of an epithelium. The central blastocoel is now isolated from the external environment. The blastomeres continue to divide with their axis parallel to the hyaline layer, remaining a epithelium one cell thick. The blastocoel continues to enlarge.

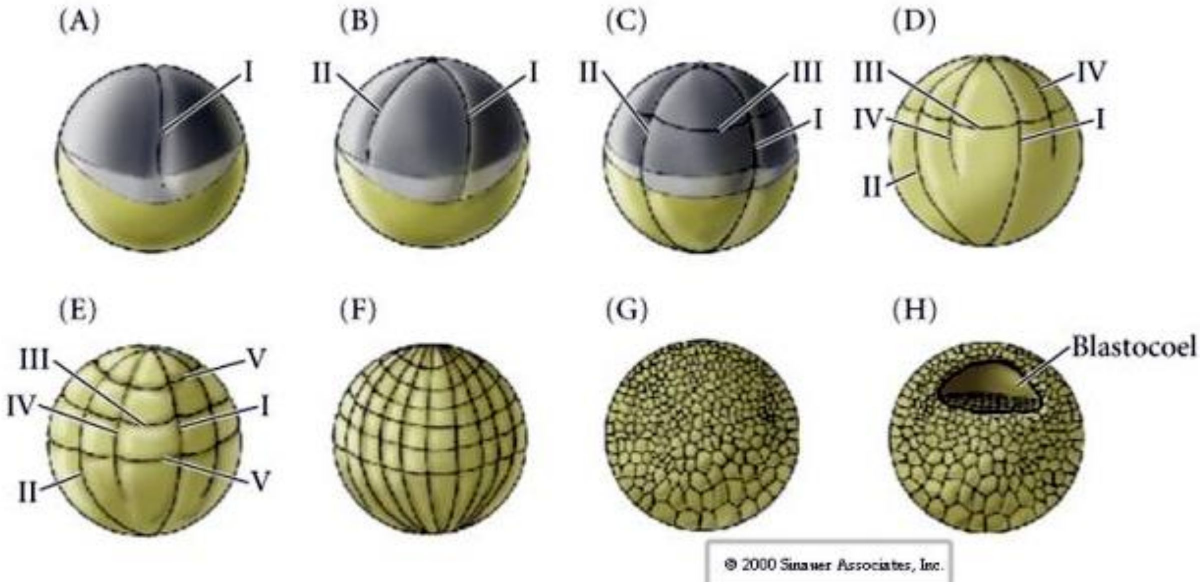
Two theories attempt to account for the pattern of enlargement of the blastocyst
1. The osmotic theory suggests that ions and proteins are secreted into the blastocoel by the blastomeres and this results in a pressure buildup due to the osmotic flow of water. This pressure would then be responsible for aligning the axis mitosis of the blastomeres and the enlargement of the blastocoel.

2. The alternate theory by Wolpert and his colleagues suggests that it is really the adhesive interactions among the blastomeres and between the blastomeres and the hyaline layer that aligns the mitotic axis's. That is the adhesion to the hyaline is greatest, the adhesion to other blastomeres is next, and finally the interaction with the blastocoel wall is least. The dominant adhesion with the hyaline layer forces the expansion of the blastocyst and blastocoel.

The cells of the blastula grow cilia on their outer surface, secrete a “hatching enzyme” (hyalinase) and become free swimming.

AMPHIBIAN CLEAVAGE

Cleavage in many amphibians is holoblastic with radial symmetry, however the large volume of yolk (its mesolecithal) interferes with cleavage. At the animal pole first cleavage proceeds at about 1mm/min, while through the vegetal pole is proceeds 50-100 times slower (.02mm/min). While the first cleavage is still incomplete in the yolky vegetal region of the egg the second meridional cleavage begins to take place.



The third cleavage is equatorial, but because the nuclei and asters are displaced “animal-ward” the cleavage plane although perpendicular to the animal vegetal axis is also displaced towards the animal pole and does not equally divide the blastomeres. The result is four smaller animal blastomeres (termed **MICROMERES**) and four large vegetal pole blastomeres (termed **MACROMERES**). This unequal holoblastic cleavage gives rise to a more rapidly dividing animal pole made up of smaller micromeres and a slower dividing vegetal pole made up of macromeres. The animal pole soon is composed of many small micromeres and the vegetal pole a few yolk filled large macromeres. Although the formation of the blastocoel begins with the first cleavage, it does not become obvious until the 128 cell stage.

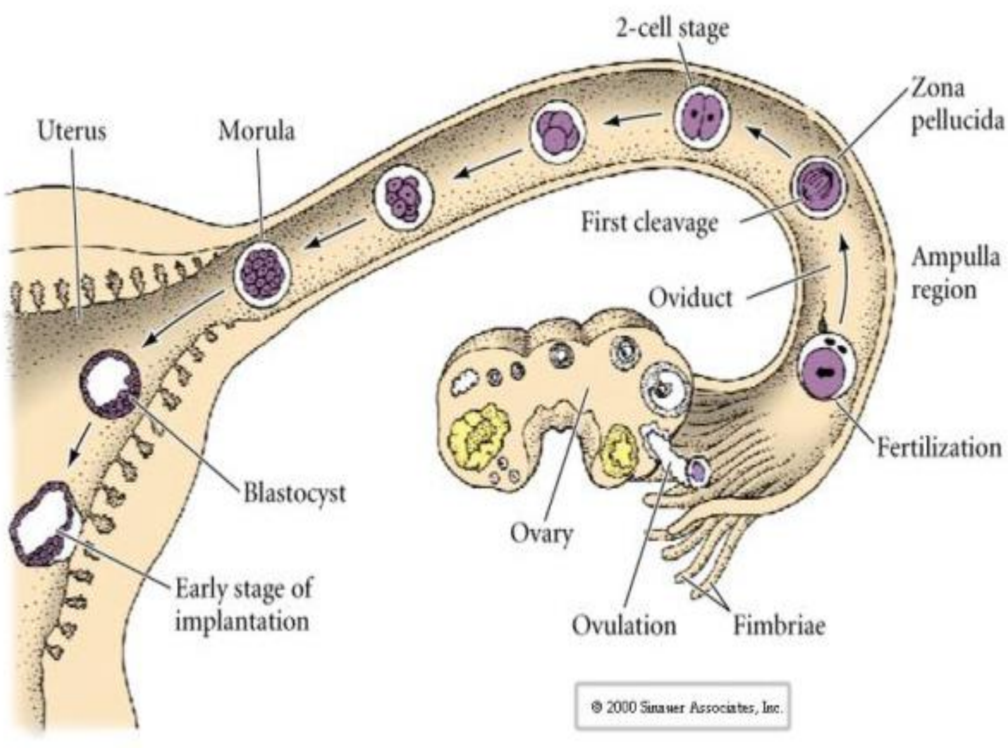
WHAT FUNCTION DOES THE BLASTOCOEL SERVE?

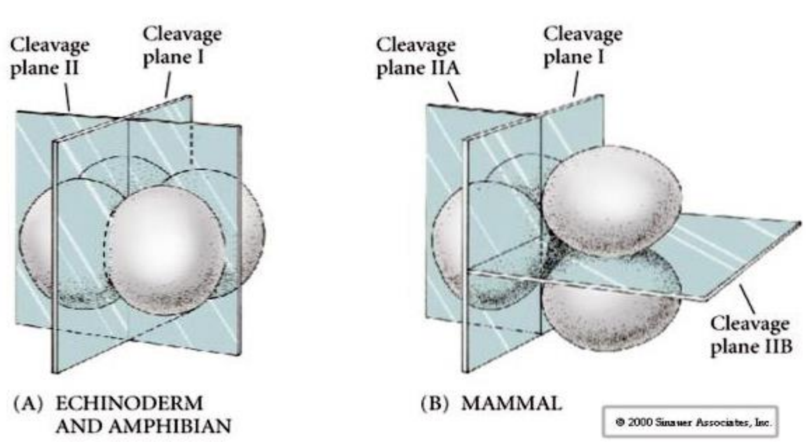
The blastocel spatially separates cells so they do not touch one another. Cells at the roof of the blastocoel normally become ectoderm. If you transplant cells from the roof of the blastocoel next to the yolky cells at the base of the blastocoel they will differentiate as mesoderm. Mesodermal derivatives are normally produced from cells adjacent to the endodermal precursors. One possibility that we will thoroughly explore is that the vegetal cells “induce” via cell-cell interactions the adjacent cells to become mesodermal. Thus the formation of the blastocoel may be necessary to prevent inappropriate "inductive" interactions among early cells of the blastocyst.

The second obvious need for the blastocoel may be during the subsequent stage of development, **GASTRULATION**, where cells migrate into the interior of the blastocoel.

MAMMALIAN CLEAVAGE

The mammalian egg is released from the ovary into the oviduct where it is fertilized. First cleavage begins about a day after fertilization within the oviduct. In sharp contrast to most animals, cleavage in mammals can be very slow---1/day.





Additionally, the cleavage planes are somewhat different from other animals. First cleavage is meridional just like sea urchin and frog. However, the second cleavage division sees one of the blastomeres dividing meridionally and the other equatorially! This type of cleavage is called **ROTATIONAL HOLOBLASTIC CLEAVAGE**.

Another unique feature of mammalian cleavage is that the blastomere cleavages are asynchronous. (compared with the synchrony of sea urchin and frog up till the midblastula transition). Cleavage of the mammalian embryo is regulated by the zyotic nucleus from the very start.

Through the third cleavage the blastomeres form a ball of loosely associated cells just like the other animals we've studied. Before the fourth cleavage the cells of the blastula dramatically change their behavior towards one another. They rapidly try to maximize their contacts with the other blastomeres and in doing cause the blastula to compact.

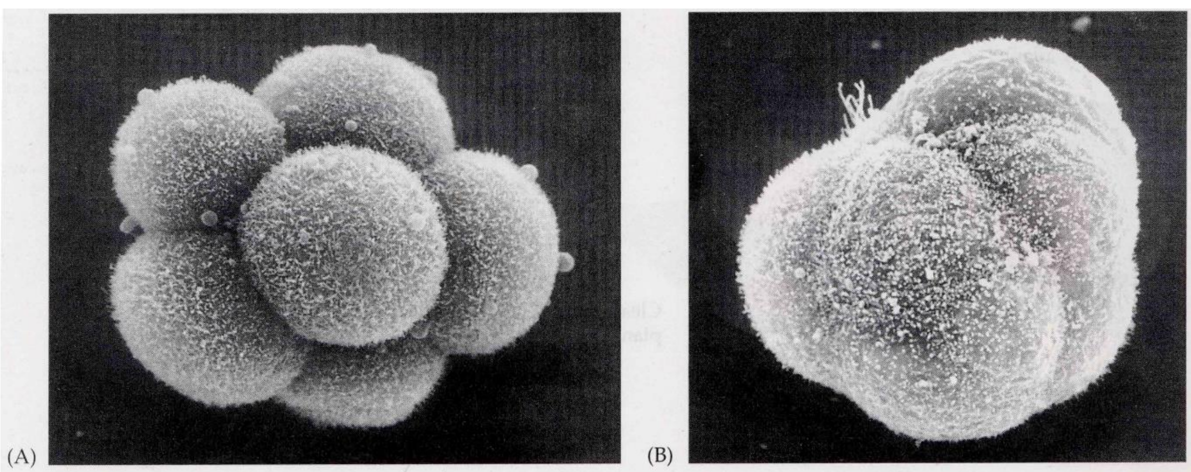


Figure 5.21
Scanning electron micrograph of (A) uncompacted and (B) compacted 8-cell mouse embryos. (Courtesy of C. Ziomek.)

Reference:

https://bastiani.biology.utah.edu/courses/3230/db%20lecture/lectures/a6cleav.html

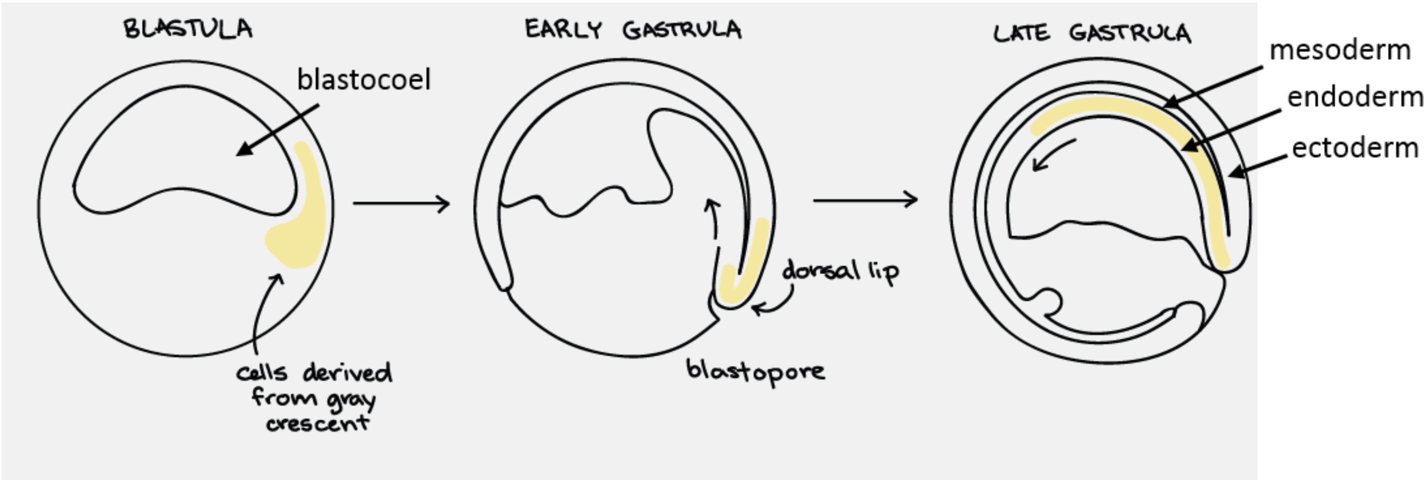
3. Gastrulation

At the end of cleavage, the typical blastula is a ball of cells with a hollow cavity in the middle (the blastocoel). The next stage in embryonic development is **gastrulation**, in which the cells in the blastula rearrange themselves to form three layers of cells and form the body plan. The embryo during this stage is called a **gastrula**. Gastrulation results in three important outcomes:

1. The formation of the embryonic tissues, called **germ layers**. The germ layers include the **endoderm, ectoderm,** and **mesoderm.** Each germ layer will later differentiate into different tissues and organ systems.
2. The formation of the embryonic gut, the **archenteron**.
3. The *appearance* of the major **body axes**. Recall that in some species, the *information specifying* the body axes was already present during cleavage as a result of cytoplasmic determinants and/or yolk polarity, but the axes actually become *visible* as a result of gastrulation.

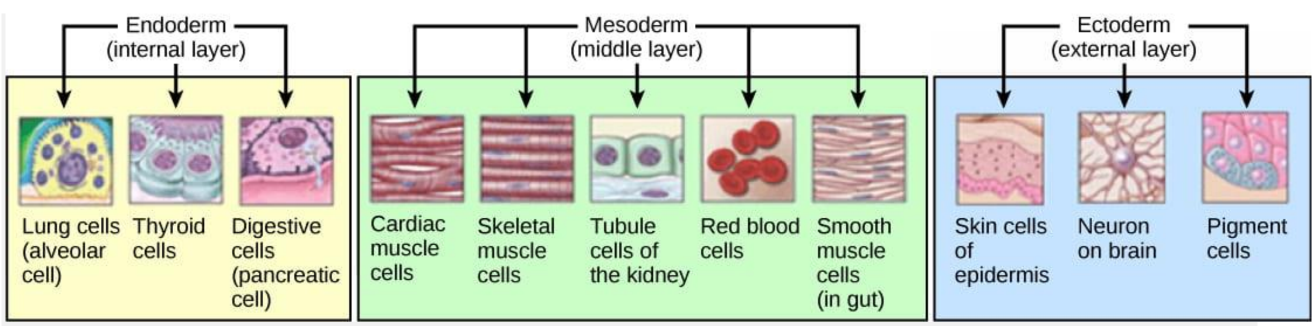
The specific details of gastrulation are different in different animal species, but the general process includes dramatic movement of cells across and inside the embryo. In triploblasts (animals with three embryonic germ layers), one group of cells moves into the blastocoel, the interior of the embryo, through an invagination called the **blastopore**. These interior cells form the **endoderm**. Another group of cells move to completely surround the embryo, forming the **ectoderm**, and a third group of cells move into the locations in between the outer and inner layers of cells, to form the **mesoderm.** The endodermal cells continue through the interior of the embryo until they reach the other side, creating a continuous tract through the embryo; this tract is the **archenteron**, or embryonic gut. In protostomes, the blastopore becomes the embryo's mouth; in deuterostomes, the blastopore becomes the embryo's anus.

Diploplasts (animals with only two germ layers) do not have mesodermal cells. These animals, which include jellyfish and comb jellies, have radial rather than bilateral symmetry and have far fewer tissue types than triploplasts due the lack of a mesoderm.



During gastrulation, the cells of the embryo move dramatically. The outer layer of cells moves toward the blastopore, the location on the embryo where these cells invaginate to form the three embryonic layers, the ectoderm, the mesoderm, and the endoderm. The gray crescent is a specific region in *Xenopus* frog embryos that directs movement of cells during gastrulation. The invagination will continue until it reaches the other side of the embryo, creating a both an anus and a mouth. Whether blastospore develops into a mouth or an anus determines whether the organism is a protostome or a dueterostome. Image credit: Modified from Khan Academy https://www.khanacademy.org/science/biology/ap-biology/developmental-biology/signaling-and-transcription-factors-in-development/a/frog-development-examples

The three germs layers, shown below, are the endoderm, the ectoderm, and the mesoderm. The ectoderm gives rise to the nervous system and the epidermis. The mesoderm gives rise to the muscle cells and connective tissue in the body. The endoderm gives rise to columnar cells found in the digestive system and many internal organs.



The three germ layers give rise to different cell types in the animal body. (credit: modification of work by NIH, NCBI)

This video provides an engaging overview of animal development, with a focus on gastrulation (and the fact that we're all, like, *tubes*). Focus on the first 7:40 minutes:

And this video describes the different tissues and organs that arise from the different germ layers during human development:

Tissues in Adult Animals

The information below adapted from Khan Academy "Principles of Physiology". All Khan Academy content is available for free at www.khanacademy.org

The cells in complex multicellular organisms are organized into **tissues**, groups of similar cells that work together on a specific task. **Organs** are structures made up of two or more tissues organized to carry out a particular function, and groups of organs with related functions make up the different **organ systems**.

The result of gastrulation is the formation of the three embryonic tissue layers, or **germ layers**. Over the course of development, these cells will proliferate, migrate, and differentiate into the four primary adult tissues: **epithelial tissue, connective tissue, muscle tissue, and nervous tissue**. Every organ is made up of two or more of these tissues.

Epithelial tissue consists of tightly packed sheets of cells that cover surfaces (such as the outside of the body) and line body cavities. For instance, the outer layer of your skin is an epithelial tissue, and so is the lining of your small intestine. The tight packing of epithelial cells lets them act as barriers to the movement of fluids and potentially harmful microbes. Epithelial cells are also polarized, meaning that they have a top and a bottom side. The apical, top, side of an epithelial cell faces the inside of a cavity or the outside of a structure and is usually exposed to fluid or air. The basal, bottom, side faces the underlying cells. For instance, the apical sides of intestinal cells have finger-like structures that increase surface area for absorbing nutrients.

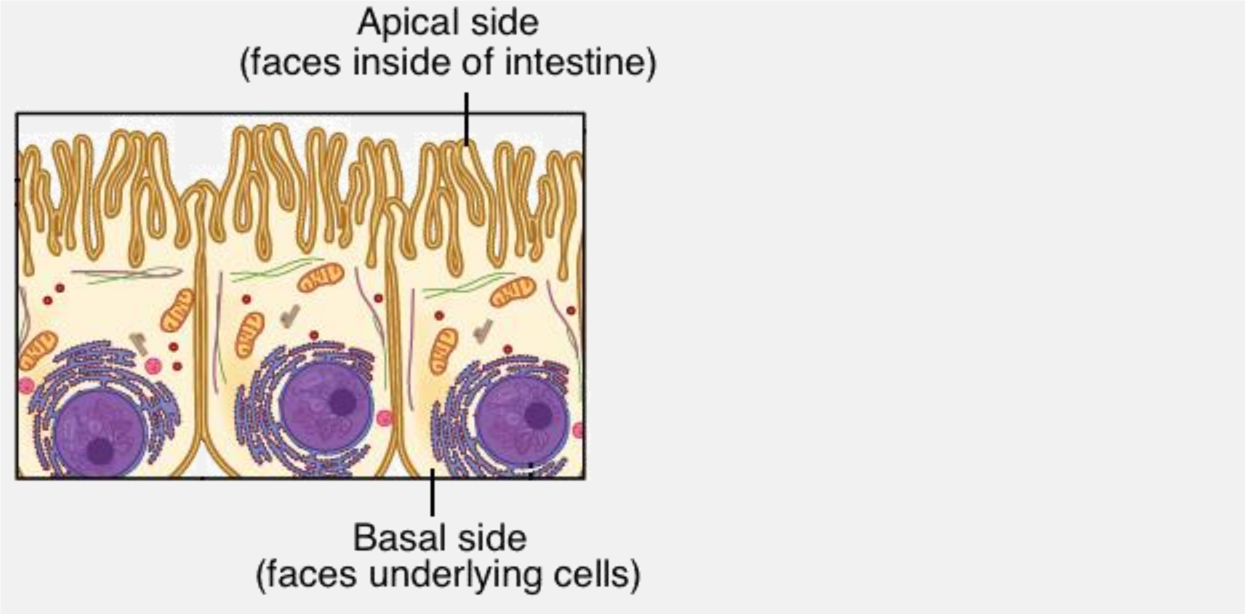
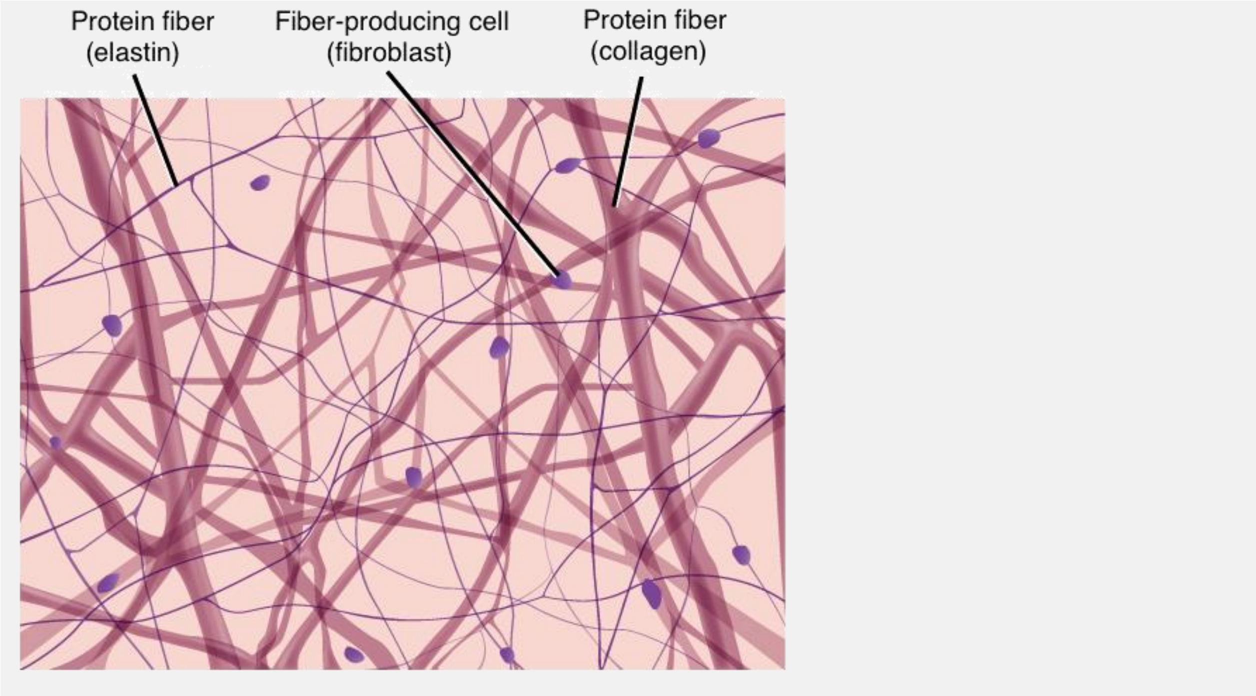


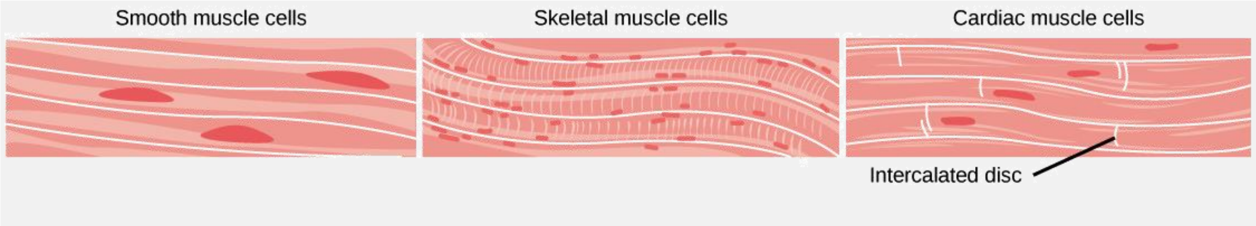
Image showing three cells lining the small intestine. Each cell contains a nucleus and is surrounded by a plasma membrane. The tops of the cells have microvilli that face the cavity from which substances will be absorbed. Image credit: Eukaryotic cells: Figure 3 by OpenStax College, Biology, CC BY 3.0

Connective tissue consists of cells suspended in an extracellular matrix. In most cases, the matrix is made up of protein fibers like collagen and fibrin in a solid, liquid, or jellylike ground substance. *Connective* tissue supports and *connects* other tissues. Loose connective tissue, show below, is the most common type of connective tissue. It's found throughout your body, and it supports organs and blood vessels and links epithelial tissues to the muscles underneath. Dense, or fibrous, connective tissue is found in tendons and ligaments, which connect muscles to bones and bones to each other, respectively. Specialized forms of connective tissue include adipose tissue (body fat), bone, cartilage, and blood, in which the extracellular matrix is a liquid called plasma.



Loose connective tissue is composed of loosely woven collagen and elastic fibers. The fibers and other components of the connective tissue matrix are secreted by fibroblasts. Image credit: Animal primary tissues: Figure 6 by OpenStax College, Biology, CC BY 4.0

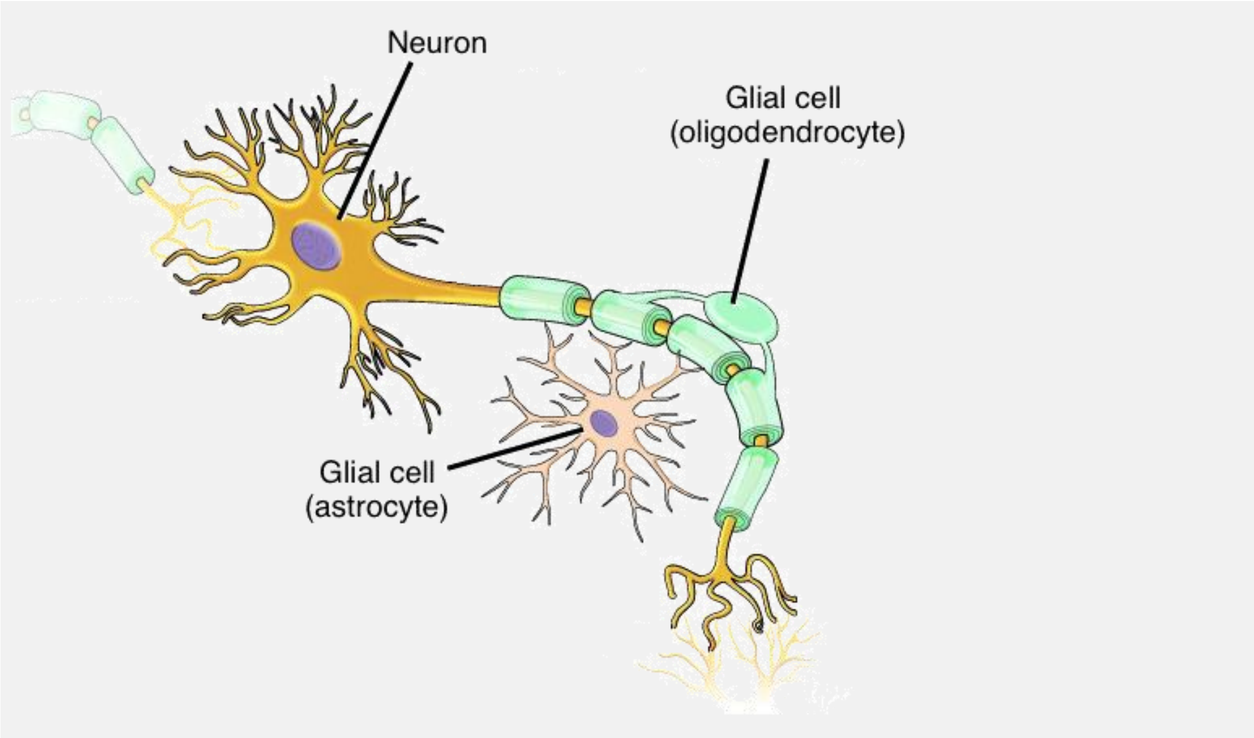
Muscle tissue is essential for keeping the body upright, allowing it to move, and even pumping blood and pushing food through the digestive tract. Muscle cells, also called muscle fibers, contain the proteins actin and myosin, which allow them to contract. There are three main types of muscle: skeletal muscle, cardiac muscle, and smooth muscle.



From left to right. Smooth muscle cells, skeletal muscle cells, and cardiac muscle cells. Smooth muscle cells do not have striations, while skeletal muscle cells do. Cardiac muscle cells have striations, but, unlike the multinucleate skeletal cells, they have only one nucleus. Cardiac muscle tissue also has intercalated discs, specialized regions running along the plasma membrane that join adjacent cardiac muscle cells and assist in passing an electrical impulse from cell to cell. Image credit: Animal primary tissues: Figure 12 by OpenStax College, Biology, CC BY 4.0

- Skeletal muscle is what we refer to as muscle in everyday life. Skeletal muscle is attached to bones by tendons, and it allows you to consciously control your movements.
- Cardiac muscle is found only in the walls of the heart. It's not under voluntary control, so (thankfully!) you don't need to think about making your heart beat.
- Smooth muscle is found in the walls of blood vessels, as well as in the walls of the digestive tract, the uterus, the urinary bladder, and various other internal structures. Smooth muscle is involuntary, not under conscious control. That means you don't have to think about moving food through your digestive tract.

Nervous tissue is involved in sensing stimuli (external or internal cues) and processing and transmitting information. It consists of two main types of cells: neurons and glia. The neurons are the basic functional unit of the nervous system: they generate electrical signals called action potentials that allow the neurons to convey information very rapidly across long distances. The glia mainly act to support neuronal function.



Picture of neuron. The neuron has projections called dendrites that receive signals and projections called axons that send signals. Also shown are two types of glial cells: astrocytes regulate the chemical environment of the nerve cell, and oligodendrocytes insulate the axon so the electrical nerve impulse is transferred more efficiently. Image credit: Animal primary tissues: Figure 13 by OpenStax College, Biology, CC BY 4.0

The Four Extra-Embryonic Tissues in Amniotes

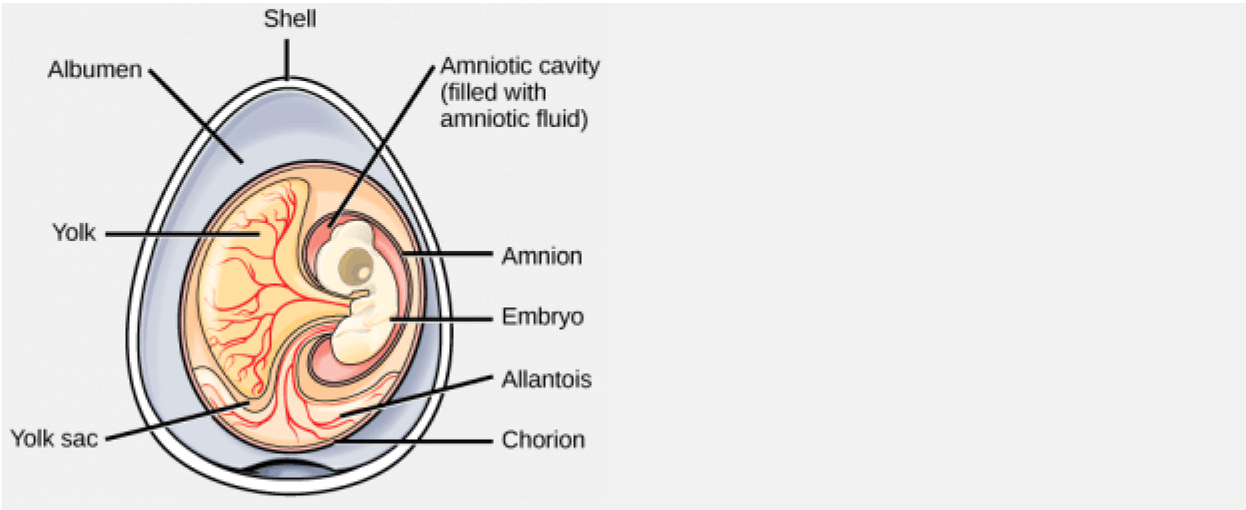
The information below was adapted from OpenStax Biology 29.4

The terrestrially-adapted amniotic egg is the defining characteristic of amniotes (reptiles, birds, and mammals). The evolution of amniotic membranes meant that the embryos of amniotes had their own aquatic environment built into their eggs, which led to less dependence on water for development and thus allowed the amniotes to branch out into drier environments. This was a significant development that distinguished them from amphibians, which were restricted to moist environments due their shell-less eggs.

In amniotes that lay eggs (birds and most reptiles), the shell of the egg provides protection for the developing embryo while being permeable enough to allow for the exchange of carbon dioxide and oxygen. The albumin, or egg white, provides the embryo with water and protein, whereas the fattier egg yolk is the energy supply for the embryo (as is the case with the eggs of many other animals, such as amphibians). The eggs of amniotes also contain four additional **extra-embryonic tissues**: the **chorion**, **amnion**, **allantois**, and **yolk sac**, shown below. Extra-embryonic membranes are membranes present in amniotic eggs that are derived from the embryo, but are not actually part of the body of the developing embryo (thus "extra"-embryonic). What do these extra-embryonic tissues do?

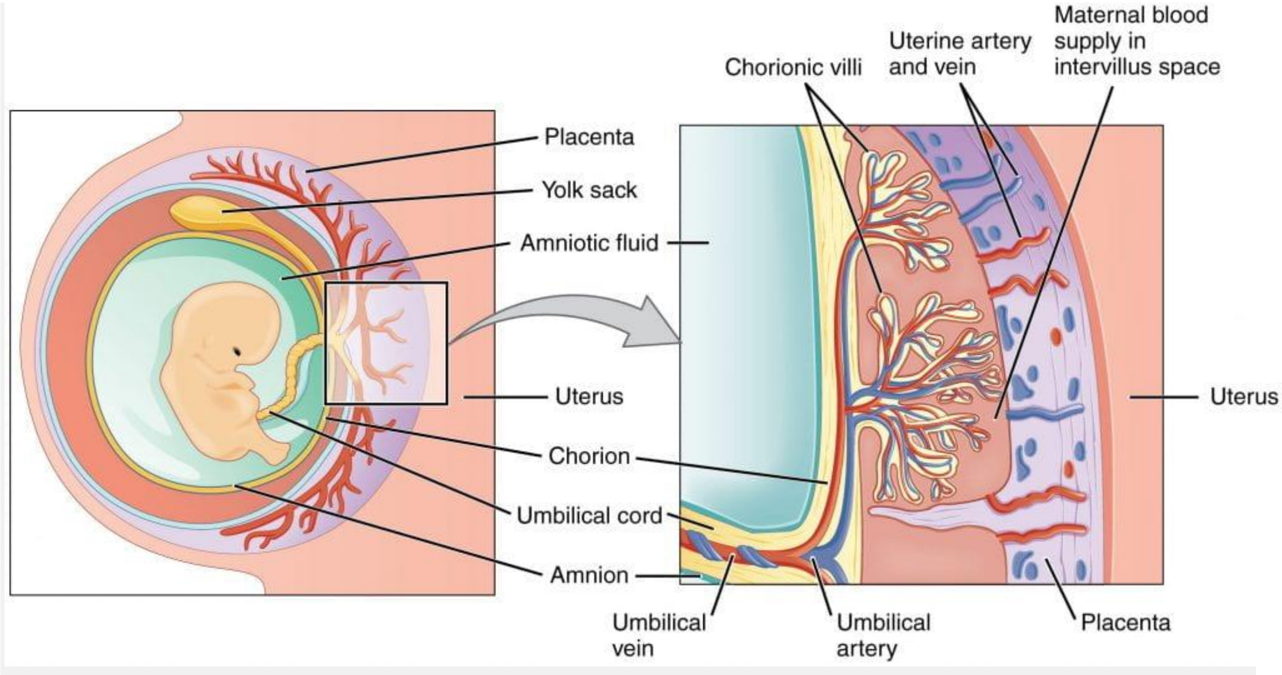
- The **amnion**, or inner amniotic membrane, surrounds the embryo itself, enclosing the aqueous environment that the embryo develops in to protect the embryo from mechanical shock and support hydration
- The **chorion.** which surrounds the embryo and yolk sac, facilitates exchange of oxygen and carbon dioxide between the embryo and the egg's external environment.
- The **allantois** stores nitrogenous wastes produced by the embryo and also facilitates respiration in combination with the chorion**.**

- The **yolk sac** encloses the nutrient-rich yolk and transports nutrients from the yolk to the embryo (note the yolk sac is not the yolk itself, but is the membrane that surrounds the yolk)



The key features of an amniotic egg are shown, including the four extra embryonic membranes. Image credit: OpenStax Biology

Most mammals do not lay eggs (though some do!), but they still have amniotic tissues that function as part of the placenta and umbilical cord, as shown below. In essence, pregnancy in placental mammals is the result of internalization and incorporation of the amniotic egg into the uterus, resulting in direct nourishment embryo inside of the amniotic egg rather than laying it outside of the body with a predefined amount of yolk.



In the placenta, maternal and fetal blood components are conducted through the surface of the chorionic villi, but maternal and fetal bloodstreams never mix directly. Image credit: OpenStax Anatomy & Physiology

As you can see above, the chorion separates the fetal and maternal sides of the placenta, and the aminon surrounds the developing fetus. Just as in the amniotic egg:

- the **chorion** regulates gas exchange
- the **amnion** encloses the fluid-filled cavity to provide an aqueous environment for the developing fetus
- together, the **yolk sac**, consisting of blood vessels that transport nutrients to the embryo, and
- the **allantois**, which functions in waste disposal, both function as part of the mammalian umbilical cord (not labeled above)

Reference:

https://organismalbio.biosci.gatech.edu/growth-and-reproduction/animal-development-ii/

4. Organogenesis

Organs form from the germ layers through the process of differentiation. During differentiation, the embryonic stem cells express specific sets of genes which will determine their ultimate cell type. For example, some cells in the ectoderm will express the genes specific to skin cells. As a result, these cells will differentiate into epidermal cells. The process of differentiation is regulated by cellular signaling cascades.

Scientists study organogenesis extensively in the lab in fruit flies (*Drosophila*) and the nematode *Caenorhabditis elegans*. *Drosophila* have segments along their bodies, and the patterning associated with the segment formation has allowed scientists to study which genes play important roles in organogenesis along the length of the embryo at different time points. The nematode *C.elegans* has roughly 1000 somatic cells and scientists have studied the fate of each of these cells during their development in the nematode life cycle. There is little variation in patterns of cell lineage between individuals, unlike in mammals where cell development from the embryo is dependent on cellular cues.

In vertebrates, one of the primary steps during organogenesis is the formation of the neural system. The ectoderm forms epithelial cells and tissues, and neuronal tissues. During the formation of the neural system, special signaling molecules called growth factors signal some cells at the edge of the ectoderm to become epidermis cells. The remaining cells in the center form the neural plate. If the signaling by growth factors were disrupted, then the entire ectoderm would differentiate into neural tissue.

The neural plate undergoes a series of cell movements where it rolls up and forms a tube called the **neural tube**, as illustrated in Figure 43.28. In further development, the neural tube will give rise to the brain and the spinal cord.

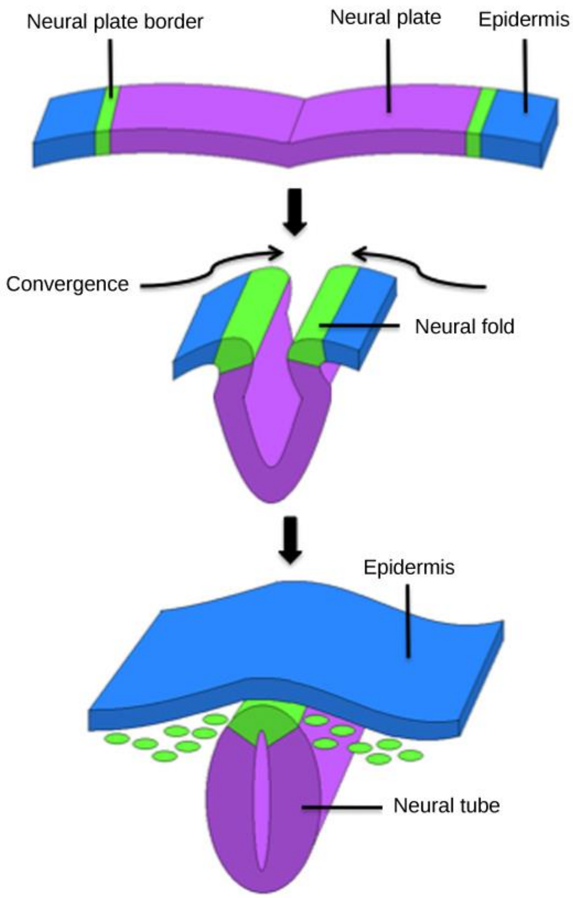


Figure 43.28 The central region of the ectoderm forms the neural tube, which gives rise to the brain and the spinal cord.

The mesoderm that lies on either side of the vertebrate neural tube will develop into the various connective tissues of the animal body. A spatial pattern of gene expression reorganizes the mesoderm into groups of cells called **somites** with spaces between them. The somites, illustrated in Figure 43.29 will further develop into the ribs, lungs, and segmental (spine) muscle. The mesoderm also forms a structure called the notochord, which is rod-shaped and forms the central axis of the animal body.

Figure 43.29 In this five-week old human embryo, somites are segments along the length of the body. (credit: modification of work by Ed Uthman)

Vertebrate Axis Formation

Even as the germ layers form, the ball of cells still retains its spherical shape. However, animal bodies have lateral-medial (left-right), dorsal-ventral (back-belly), and anterior-posterior (head-feet) axes, illustrated in Figure 43.30.

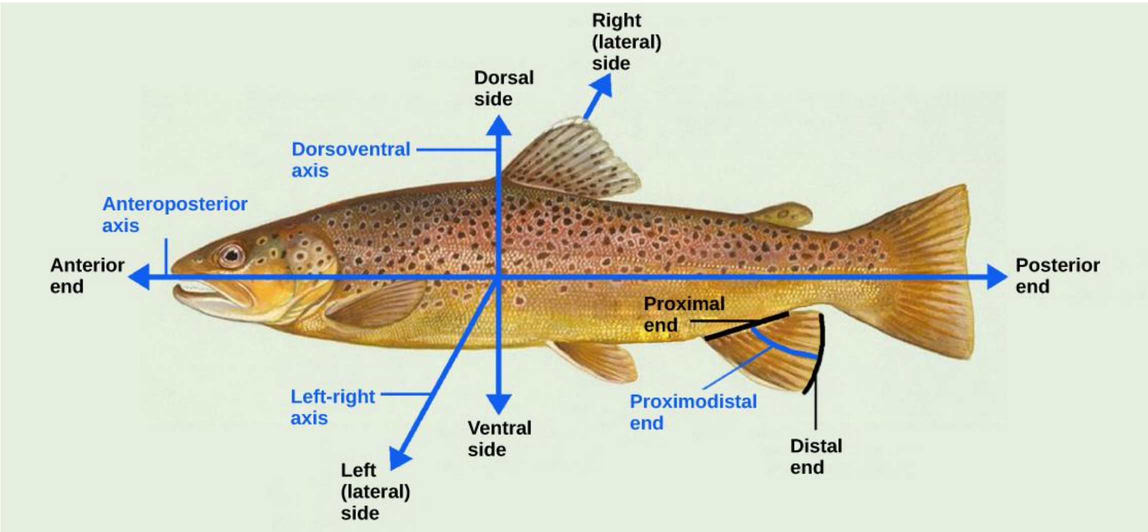


Figure 43.30 Animal bodies have three axes for symmetry. (credit: modification of work by NOAA)

How are these established? In one of the most seminal experiments ever to be carried out in developmental biology, Spemann and Mangold took dorsal cells from one embryo and transplanted them into the belly region of another embryo. They found that the transplanted embryo now had two notochords: one at the dorsal site from the original cells and another at the transplanted site. This suggested that the dorsal cells were genetically programmed to form the notochord and define the axis. Since then, researchers have identified many genes that are responsible for axis formation. Mutations in these genes leads to the loss of symmetry required for organism development.

Animal bodies have externally visible symmetry. However, the internal organs are not symmetric. For example, the heart is on the left side and the liver on the right. The formation of the central left-right axis is an important process during development. This internal asymmetry is established very early during development and involves many genes. Research is still ongoing to fully understand the developmental implications of these genes.

Reference:

https://openstax.org/books/biology/pages/43-7-organogenesis-and-vertebrate-formation

5. **Placental Structure and Classification**

The placentas of all eutherian (placental) mammals provide common structural and functional features, but there are striking differences among species in gross and microscopic structure of the placenta. Two characteristics are particularly divergent and form bases for classification of placental types:

1. The gross shape of the placenta and the distribution of contact sites between fetal membranes and endometrium.
2. The number of layers of tissue between maternal and fetal vascular systems.

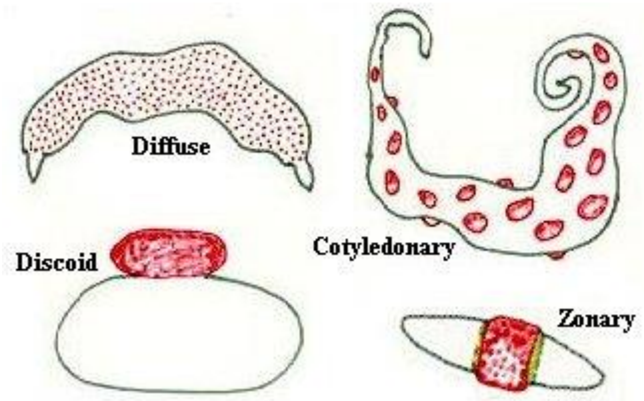
Differences in these two properties allow classification of placentas into several fundamental types.

Classification Based on Placental Shape and Contact Points

Examination of placentae from different species reveals striking differences in their shape and the area of contact between fetal and maternal tissue:

- **Diffuse**: Almost the entire surface of the allantochorion is involved in formation of the placenta. Seen in horses and pigs.
- **Cotyledonary**: Multiple, discrete areas of attachment called cotyledons are formed by interaction of patches of allantochorion with endometrium. The fetal portions of this type of placenta are called cotyledons, the maternal contact sites (caruncles), and the cotyledon-caruncle complex a placentome. This type of placentation is observed in ruminants.
- **Zonary**: The placenta takes the form of a complete or incomplete band of tissue surrounding the fetus. Seen in carnivores like dogs and cats, seals, bears, and elephants.

- **Discoid**: A single placenta is formed and is discoid in shape. Seen in primates and rodents.



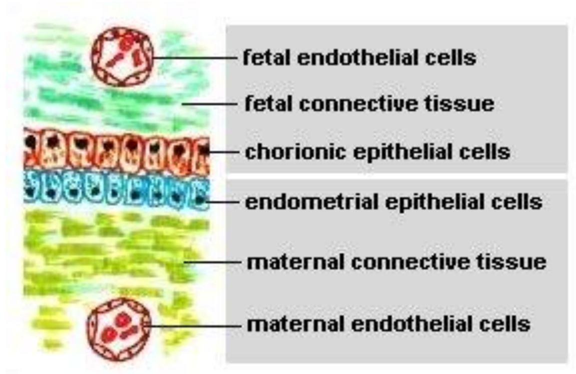
Classification Based on Layers Between Fetal and Maternal Blood

Just prior to formation of the placenta, there are a total of six layers of tissue separating maternal and fetal blood. There are three layers of fetal extraembryonic membranes in the chorioallantoic placenta of all mammals, all of which are components of the mature placenta:

1. Endothelium lining allantoic capillaries
2. Connective tissue in the form of chorioallantoic mesoderm
3. Chorionic epithelium, the outermost layer of fetal membranes derived from trophoblast

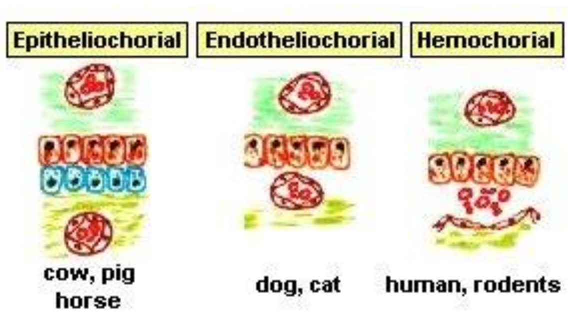
There are also three layers on the maternal side, but the number of these layers which are retained - that is, not destroyed in the process of placentation - varies greatly among species. The three potential maternal layers in a placenta are:

1. Endothelium lining endometrial blood vessels
2. Connective tissue of the endometrium
3. Endometrial epithelial cells



One classification scheme for placentas is based on which maternal layers are retained in the placenta, which of course is the same as stating which maternal tissue is in contact with chorionic epithelium of the fetus. Each of the possibilities is observed in some group of mammals.

Type of Placenta	**Maternal Layers Retained**			**Examples**
	Endometrial Epithelium	**Connective Tissue**	**Uterine Endothelium**	
Epitheliochorial	+	+	+	Horses, swine, ruminants
Endotheliochorial	-	-	+	Dogs, cats
Hemochorial	-	-	-	Humans, rodents



In humans, fetal chorionic epithelium is bathed in maternal blood because chorionic villi have eroded through maternal endothelium. In contrast, the chorionic epithelium of horse and pig fetuses remains separated from maternal blood by 3 layers of tissue. One might thus be tempted to consider that exchange across the equine placenta is much less efficient that across the human placenta. In a sense this is true, but other features of placental structure make up for the extra layers in the diffusion barrier; it has been well stated that "*The newborn foal provides a strong testimonial to the efficiency of the epitheliochorial placenta.*"

Summary of Species Differences in Placental Architecture

The placental mammals have evolved a variety of placental types which can be broadly classified using the nomenclature described above. Not all combinations of those classification schemes are seen or are likely to ever be seen - for instance, no mammal is known to have a diffuse, endotheliochorial, or a hemoendothelial placenta. Placental types for "familiar" mammals are summarized below, with supplemental information provided for a variety of "non-familiar" species.

Type of Placenta	**Common Examples**
Diffuse, epitheliochorial	Horses and pigs
Cotyledonary, epitheliochorial	Ruminants (cattle, sheep, goats, deer)
Zonary, endotheliochorial	Carnivores (dog, cat, ferret)
Discoid, hemochorial	Humans, apes, monkeys and rodents

Resources

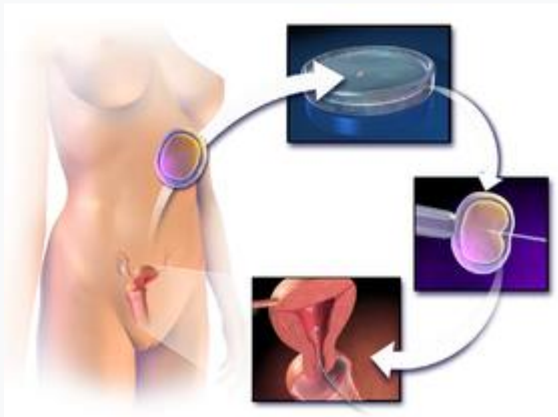
http://www.vivo.colostate.edu/hbooks/pathphys/reprod/placenta/structure.html

Comparative Placentation is an excellent and comprehensive site for obtaining information on placental structure for a large number of domestic and wild animals

6. In vitro fertilisation

From Wikipedia, the free encyclopedia

In vitro fertilisation



Illustrated schematic of IVF with single-sperm injection (ICSI)

Other names	IVF
ICD-10-PCS	8E0ZXY1
MeSH	D005307

[edit on Wikidata]

In vitro fertilisation (**IVF**) is a process of fertilisation where an egg is combined with sperm outside the body, in vitro ("in glass"). The process involves monitoring and stimulating a woman's ovulatory process, removing an ovum or ova (egg or eggs) from the woman's ovaries and letting sperm fertilise them in a culture medium in a laboratory. After the fertilised egg (zygote) undergoes embryo culture for 2–6 days, it is implanted in the same or another woman's uterus, with the intention of establishing a successful pregnancy.

IVF is a type of assisted reproductive technology used for infertility treatment and gestational surrogacy. A fertilised egg may be implanted into a surrogate's uterus, and the resulting child is genetically unrelated to the surrogate. Some countries have banned or otherwise regulate the availability of IVF treatment, giving rise to fertility tourism. Restrictions on the availability of IVF include costs and age, in order for a woman to carry a healthy pregnancy to term. IVF is generally not used until less invasive or expensive options have failed or been determined unlikely to work.

In July 1978, Louise Brown was the first child successfully born after her mother received IVF treatment. Brown was born as a result of natural-cycle IVF, where no stimulation was made. The procedure took place at Dr Kershaw's Cottage Hospital (now Dr Kershaw's Hospice) in Royton, Oldham, England. Robert G. Edwards was awarded the Nobel Prize in Physiology or Medicine in 2010. The physiologist co-developed the treatment together with Patrick Steptoe and embryologist Jean Purdy but the latter two were not eligible for consideration as they had died and the Nobel Prize is not awarded posthumously.[1][2]

With egg donation and IVF, women who are past their reproductive years, have infertile male partners, have idiopathic female-fertility issues, or have reached menopause can still become pregnant. After the IVF treatment, some couples get pregnant without any fertility treatments.[3] In 2018, it was estimated that eight million children had been born worldwide using IVF and other assisted reproduction techniques.[4] However, a recent study that explores 10 adjuncts with IVF (screening hysteroscopy, DHEA, testosterone, GH, aspirin, heparin, antioxidants in males and females, seminal plasma, and PRP) suggests that until more evidence is done to show that these adjuncts are safe and effective, they should be avoided.[5]

Reference:

https://en.wikipedia.org/wiki/In_vitro_fertilisation

7. Test-Tube Baby

By: *Stephen C. Ruffenach*

Published: *2009-01-13*

Keywords: Fertilization, Reproduction

A test-tube baby is the product of a successful human reproduction that results from methods beyond sexual intercourse between a man and a woman and instead utilizes medical intervention that manipulates both the egg and sperm cells for successful fertilization. The term was originally used to refer to the babies born from the earliest applications of artificial insemination and has now been expanded to refer to children born through the use of *in vitro* fertilization, the practice of fertilizing an egg outside of a woman's body. The use of the term in both media and scientific publications in the twentieth century has been accompanied by discussion as well as controversy regarding the ethics of reproduction technologies such as artificial insemination and *in vitro* fertilization. The evolution of these terms over time mirrors the perception of our ability to manipulate the human embryo, as seen by the general public as well as the scientific community.

The term "test-tube baby," prior to the development of *in vitro* fertilization technologies in the twentieth century, was used to refer to babies born as a result of artificial insemination. William Pancoast, a physician from Philadelphia, performed the first artificial insemination that led to a successful birth in 1884, marking the birth of the first test-tube baby. Despite the fact that this was the earliest instance of any sort of physician-assisted reproduction, the grandeur of the event was not recognized by the public or media in any notable way.

As reproduction technology continued to develop and *in vitro* fertilization research advanced in the mid twentieth century, the media began to pay more attention to the idea of test-tube babies and the impact their existence would have on the world. Publications began to publish articles in the early twentieth century that discussed the ethics behind the creation of children through means other than human sexual intercourse. Such publications as *The New York Times*, *Scientific American*, and *Newsweek*, among others, published articles discussing test-tube babies and the technologies used to create them, focusing on what their existence meant for the development of the public's understanding of reproduction as well as the ethics involved with such an advanced understanding. The articles refrained from being overtly outraged in response to the experiments but recognized the controversy involved with these new scientific developments and included this in their coverage.

By the middle of the twentieth century, *in vitro* fertilization had been thoroughly researched and reported on, though no successful human reproduction had occurred from its practice. However, the successful fertilization and reproduction of various species of animal besides humans through *in vitro* fertilization was common practice by 1960. It was also around this time that the discussion of a child born from *in vitro* fertilization began to show up in numerous publications. Look magazine published an article in 1971 entitled "The Test Tube Baby is Coming," which reported on the work of Landrum Brewer Shettles, an American biologist who would eventually attempt the first human *in vitro* fertilization in America, which was not successful.

It was not until 25 July 1978 with the work of two British medical researchers, Patrick Steptoe and Robert Edwards, that the revised definition of test-tube baby became a reality. With their work, the first child born from a zygote fertilized outside of a human body was created. The first baby born via *in vitro* fertilization was Louise Brown. It was also this breakthrough that really caught the attention of the world, made clear in the media's reaction to Louise Brown's birth. Newspapers reported the story as a significant scientific and medical breakthrough while tabloids and other similar publications treated the birth more like the arrival of a new celebrity into the world. The mixed media response to the birth of Louise Brown was also very foretelling of the diverse public reactions that would follow. Shortly after the birth, discussion of both legal and ethical implications regarding the existence of test-tube babies began in the international media as well as in scientific journals. These debates continue to this day as the ongoing research of embryos and reproduction leads to the development of new medical practices.

After the birth of Louise Brown, scientists in other countries around the world began pursuing the birth of their first child from *in vitro* fertilization. This goal was also accompanied by the development of numerous fertility clinics in various countries. The first fertility clinic in the United States opened at the Eastern Virginia Medical School in Norfolk, Virginia on 1 March 1980. It was also here that Jordan Elizabeth Carr, the first child who was a product of *in vitro* fertilization in America, was born on 28 December 1981. By this time, the practice of *in vitro* fertilization was much more publicly accepted, as it was observed that children born under such circumstances developed normally. This was not to say that there were no opponents to the practice at this time, but rather that Carr's birth was received with excitement from the general public and the media captured this response when covering the event. More fertility clinics were established all over the world and the number of successful test-tube baby births continued to grow as *in vitro* fertilization became both a more refined and more accepted practice.

Through the work of various scientists, the idea of traditional fertilization and human reproduction through sexual intercourse was no longer seen as the only means of fertilizing an egg in order to create a human life. This concept was represented by the existence of test-tube babies, the physical manifestation of a more advanced control over human reproduction. Through the work of such scientists as Pancoast, Steptoe, and Edwards, the definition of test-tube baby has changed over time but continues to refer to any child born from an embryo created by means of medical intervention that directly manipulates the sperm and egg cells.

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8. Metamorphosis

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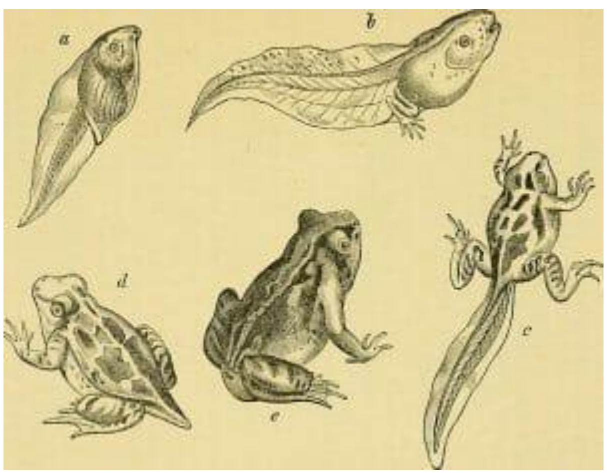
Metamorphosis Definition

Metamorphosis is a process by which animals undergo extreme, rapid physical changes some time after birth. The result of metamorphosis may be change to the organism's entire body plan, such as a change in the animal's number of legs, its means of eating, or its means of breathing.

In species that use metamorphosis, metamorphosis is also typically required for sexual maturity. Pre-metamorphic members of these species are typically unable to mate or reproduce.

Commonly known examples of metamorphosis include the process undergone by most insects, and the transformation of tadpoles into frogs. The diagram below shows the stages of this change, wherein the small fish-like tadpoles transform into what seems a completely different animal:



Animals that you may not know undergo metamorphosis include fish, mollusks, and many other types of sea creatures which are related to insects, mollusks, or fish. Lobsters, for example, which are closely related to insects, do undergo metamorphosis as part of their life cycle.

Metamorphosis is a remarkable process. The speed and extent of cell growth and differentiation is astonishing. In most species, such rapid growth and such sweeping changes to cell type only happen during embryonic development. Indeed, some scientists believe that the process of metamorphosis involves a sort of re-activating of genes that allow animal cells to change from one cell type to another.

The changes leading to metamorphosis are triggered by hormones, which the animal's body releases as the right conditions for metamorphosis approach. In some animals a hormone cascade follows, with the trigger hormone causing the release of several other hormones that act on different parts of the animal's body.

The hormones cause drastic changes to the functioning of cells, and even behavioral changes such as the caterpillar spinning its cocoon.

The effects of hormones on metamorphosis can be studied by artificially administering these hormones to pre-metamorphic animals. Tadpoles, for example, can be triggered to begin losing their tails and growing limbs early by the addition of thyroid hormones to their water supply. Unfortunately this has a detrimental effect on the animal's health.

Function of Metamorphosis

Scientists remain uncertain why metamorphosis evolved. For the animals of today, its purpose is obvious: if metamorphosis did not occur, tadpoles could not become frogs and larvae could not become full-grown adults capable of reproduction. Without reproductively mature members, these species would quickly die off.

But why would these species evolve to need this extra step in the first place? Why not just hatch full-grown butterflies or frogs from eggs?

At least some metamorphosing species did not start out that way: the earliest insects basically did hatch as full-grown adults. But a few hundred million years ago, some species stumbled upon the trick of metamorphosis. It was apparently wildly successful; it is thought that almost two-thirds of species alive today use metamorphosis to accomplish large changes between their adult and juvenile forms.

The benefit of metamorphosis may lie in its ability to reduce competition. Pre-metamorphic animals typically consume completely different resources from their adult forms. Tadpoles live in water, eating algae and plants. Frogs live on land, breathing air and eating insects. Caterpillars eat leaves; butterflies live off of nectar. Etc..

This effectively prevents older members of the species from competing with younger members. This may lead more members of the species to successfully reach sexual maturity, without the risk of being out-competed by older members of their species.

Types of Metamorphosis

Complete Metamorphosis

In complete metamorphosis, a larva completely changes its body plan to become an adult. The most famous example is that of the butterfly, which starts out as a worm-like, leaf-eating caterpillar and transforms into a flying, nectar-drinking creature with an exoskeleton.

Organisms that undergo complete metamorphosis are called “holometabolous,” from the Greek words “holo” for “complete” or “whole,” “meta” for “change,” and the noun “bole” for “to throw.” “Holometabolous,” then, means “completely changing,” or “wholly changing.”

This transformation is so swift and complete that the caterpillar must spin a cocoon and lie dormant for weeks while its body undergoes these radical changes.

Other animals which transform from a worm-like larval stage into an animal that looks completely different include beetles, flies, moths, ants, and bees.

Some scientists believe that the larval stage of complete metamorphosis may have evolved from insects which hatched from their eggs without developing properly. Some of these embryos may have survived long enough to find food in the outside world; and this may have ended up giving them an advantage, as they would be able to feed longer and gain more strength than their peers before metamorphosing into the adult stage.

Incomplete Metamorphosis

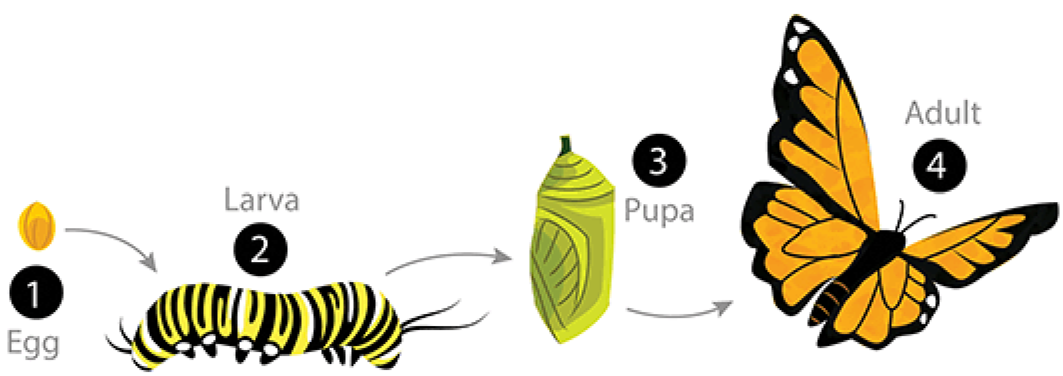
In incomplete metamorphosis, only some parts of the animal's body change during metamorphosis. Animals that only partially change their bodies as they mature are called "hemimetabolous," from the Greek words "hemi" for "half," "meta," for "change," and the verb "bole" for "to throw."

"Hemimetabolous," then, is a word meaning "half-changing."

Cockroaches, grasshoppers, and dragonflies, for example, hatch from eggs looking a lot like their adult selves. They do acquire wings and functioning reproductive organs as they grow, but they do not completely remake their bodies like their completely metamorphosing cousins do.

Examples of Metamorphosis

Butterflies



Many of us may have witnessed the process of metamorphosis first hand, by raising caterpillars into butterflies in school. The idea of a worm-like caterpillar wrapping itself in a cocoon for weeks and then emerging as a beautiful butterfly is certainly strange. But the obvious changes of appearance, such as the growth of wings, don't do justice to just how strange this process is.

In the cocoon, caterpillars don't simply gain legs, wings, and an exoskeleton. They also grow new eyes, lose their leaf-eating mouth parts and replace them with nectar-sucking proboscises, and gain mature reproductive organs.

To accomplish this drastic change, a metamorphosing caterpillar basically digests itself.

A great deal of energy and raw materials are required to turn a caterpillar into a butterfly. So to make it possible, caterpillars release enzymes that dissolve most of their bodies! Indeed, the hard shell of the cocoon is required not just to protect the metamorphosing insect from attack: it is required to keep its liquefying body bound together, lest it ooze away!

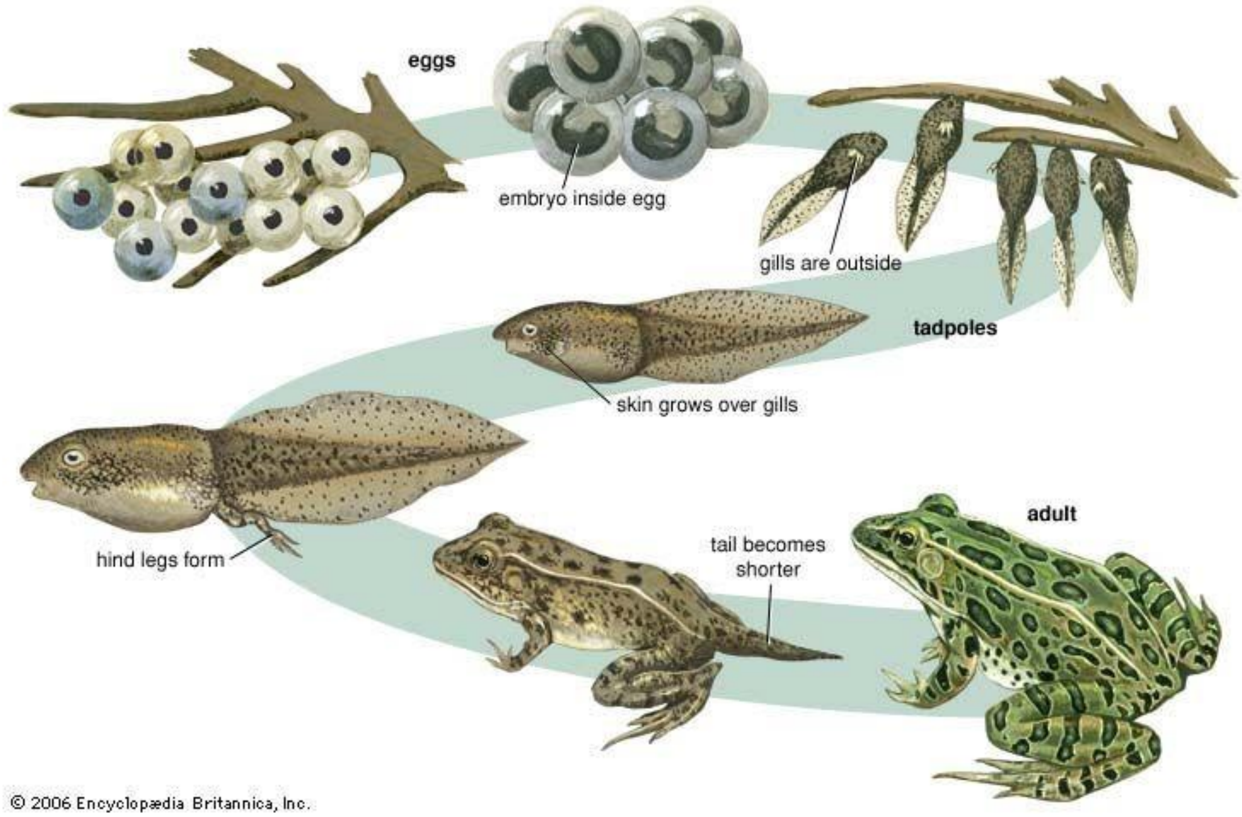
Not all of the caterpillar’s cells are dissolved by these enzymes. Special tissues called imaginal discs survive – and they use the soup that used to be the rest of the caterpillar’s body for nutrition. By consuming the proteins, vitamins, and minerals – everything you need to build a butterfly – these imaginal discs are able to grow incredibly quickly, developing into the butterfly’s mature body parts.

The new body has almost nothing in common with the old body. It has new legs, new sensory organs, a new exoskeleton, a new reproductive system. Even its digestive system does not work the same way, since it must now digest nectar instead of leaves. That’s all in addition to the beautiful wings.

This radical change allows butterflies to complete their life cycle very efficiently, with no competition between adult butterflies and caterpillars for food.

Many other insects pass through a similar process. They hatch as worm-like larva, eventually encase themselves in hard pupas, and emerge as adults with legs, exoskeletons, and other features that have little in common with the larva they once were. Bees, beetles, ants, and flies all use this strategy.

Frogs



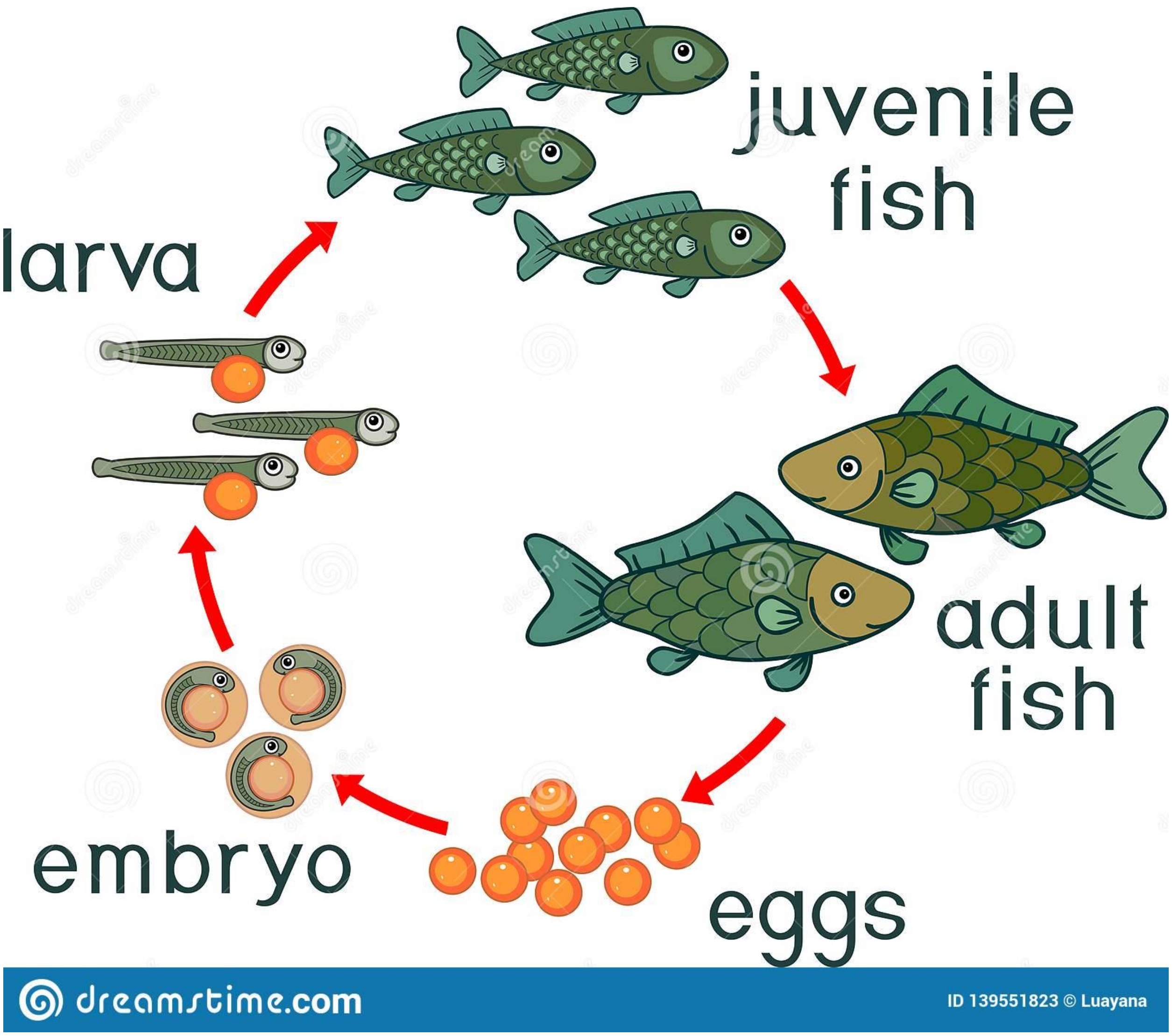
The metamorphosis of a tadpole into a frog is a little less violent than that of a caterpillar into a butterfly, but the processes share some important common features.

Tadpoles do not dissolve their bodies into mush; but they do "digest" them in a less spectacular way. Using the process of apoptosis – or "programmed cell death" – the tadpoles "order" the cells they don't need anymore to shred their DNA and die. The dead cells are then cannibalized for energy and raw materials to make other cells.

The cells of their tails are broken down and used to make their developing legs; a similar process happens with the gills, which disappear as the tadpole begins to develop air-breathing lungs.

One interesting thing to note is that tadpole metamorphosis and insect metamorphosis likely developed separately; the common ancestor of insects and amphibians diverged long ago, and the ancestors of modern insects are not thought to have used metamorphosis. When the same phenomenon evolves twice in radically different organisms, that's a sure sign that it is a useful adaptation!

Fish



Some species of fish undergo metamorphoses similar to those of the tadpole. Though those changes are not so dramatic, they can result in changes in the fish's food source, its body plan, and where it's able to live. Just like the more drastic forms of evolution, this may function to prevent adults from competing with juveniles for food.

The salmon, for example, is a freshwater fish in its juvenile form. After undergoing a partial metamorphosis, it becomes a saltwater fish.

When thinking about this process it is important to keep in mind that all organisms must regulate their salt/water balance. This is why humans can't drink seawater without dying: the salt would overwhelm our cellular chemistry, and our cells would not function properly. In just the same way, freshwater fish typically cannot live in saltwater. To become saltwater fish, then, salmon must develop new organs and cellular mechanisms to cope with the salt water.

That's why salmon must perform their annual migration upstream; adult salmon live in the ocean, but their eggs must hatch in fresh water in order for the juveniles to survive. That means that adult salmon must leave their homes in the ocean for freshwater rivers, and swim as far upstream as possible before laying their eggs!

Flounders, bizarrely, undergo a metamorphosis in which one of their eyes and nostrils move from one side of the head to the other. As juveniles, flounder look much like most fish: they swim vertical relative to the current, with one eye and one nostril on each side of their bladelike body. This body type allows them to swim fast like most other species of fish.

But in adulthood, flounder are flat fish which camouflage themselves by swimming on their bellies, pressed against the sea bed. To accomplish this lifestyle change, juvenile flounder essentially flip over on their sides and make one side of their body into their belly. Through cellular changes, the eye and nostril from the belly side actually migrate to join the other eye and nostril on what is now the "top" side of the fish.

Evolution sure has some creative ways of doing things!

Reference:

https://biologydictionary.net/metamorphosis/

9. Animals Reproduction

Some animals produce offspring through asexual reproduction while other animals produce offspring through sexual reproduction. Both methods have advantages and disadvantages. Asexual reproduction produces offspring that are genetically identical to the parent because the offspring are all clones of the original parent. A single individual can produce offspring asexually and large numbers of offspring can be produced quickly; these are two advantages that asexually reproducing organisms have over sexually reproducing organisms. In a stable or predictable environment, asexual reproduction is an effective means of reproduction because all the offspring will be adapted to that environment. In an unstable or unpredictable environment, species that reproduce asexually may be at a disadvantage because all the offspring are genetically identical and may not be adapted to different conditions.

During sexual reproduction, the genetic material of two individuals is combined to produce genetically diverse offspring that differ from their parents. The genetic diversity of sexually produced offspring is thought to give sexually reproducing individuals greater fitness because more of their offspring may survive and reproduce in an unpredictable or changing environment. Species that reproduce sexually (and have separate sexes) must maintain two different types of individuals, males and females. Only half the population (females) can produce the offspring, so fewer offspring will be produced when compared to asexual reproduction. This is a disadvantage of sexual reproduction compared to asexual reproduction.

Asexual Reproduction

Asexual reproduction occurs in prokaryotic microorganisms (bacteria and archaea) and in many eukaryotic, single-celled and multi-celled organisms. There are several ways that animals reproduce asexually, the details of which vary among individual species.

Fission

Fission, also called binary fission, occurs in some invertebrate, multi-celled organisms. It is in some ways analogous to the process of binary fission of single-celled prokaryotic organisms. The term fission is applied to instances in which an organism appears to split itself into two parts and, if necessary, regenerate the missing parts of each new organism. For example, species of turbellarian flatworms commonly called the planarians, such as *Dugesia dorotocephala*, are able to separate their bodies into head and tail regions and then regenerate the missing half in each of the two new organisms. Sea anemones (Cnidaria), such as species of the genus *Anthopleura* (Figure 13.2), will divide along the oral-aboral axis, and sea cucumbers (Echinodermata) of the genus *Holothuria*, will divide into two halves across the oral-aboral axis and regenerate the other half in each of the resulting individuals.

Figure 13.2 The Anthopleura artemisia sea anemone can reproduce through fission.

Budding

Budding is a form of asexual reproduction that results from the outgrowth of a part of the body leading to a separation of the "bud" from the original organism and the formation of two individuals, one smaller than the other. Budding occurs commonly in some invertebrate animals such as hydras and corals. In hydras, a bud forms that develops into an adult and breaks away from the main body (Figure 13.3).

Figure 13.3 (a) Hydra reproduce asexually through budding: a bud forms on the tubular body of an adult hydra, develops a mouth and tentacles, and then detaches from its parent. The new hydra is fully developed and will find its own location for attachment. (b) Some coral, such as the Lophelia pertusa shown here, can reproduce through budding. (credit b: modification of work by Ed Bowlby, NOAA/Olympic Coast NMS; NOAA/OAR/Office of Ocean Exploration) Part a: This shows a hydra, which has a stalk-like body with tentacles growing out the top. A smaller hydra is budding from the side of the stalk. Part b: This photo shows branching white coral polyps.

Concept in Action

View this video to see a hydra budding.

Fragmentation

Fragmentation is the breaking of an individual into parts followed by regeneration. If the animal is capable of fragmentation, and the parts are big enough, a separate individual will regrow from each part. Fragmentation may occur through accidental damage, damage from predators, or as a natural form of reproduction. Reproduction through fragmentation is observed in sponges, some cnidarians, turbellarians, echinoderms, and annelids. In some sea stars, a new individual can be regenerated from a broken arm and a piece of the central disc. This sea star (Figure 13.4) is in the process of growing a complete sea star from an arm that has been cut off. Fisheries workers have been known to try to kill the sea stars eating their clam or oyster beds by cutting them in half and throwing them back into the ocean. Unfortunately for the workers, the two parts can each regenerate a new half, resulting in twice as many sea stars to prey upon the oysters and clams.

Figure 13.4 (a) Linckia multifora is a species of sea star that can reproduce asexually via fragmentation. In this process, (b) an arm that has been shed grows into a new sea star. (credit a: modifiction of work by Dwayne Meadows, NOAA/NMFS/OPR)

Parthenogenesis

Parthenogenesis is a form of asexual reproduction in which an egg develops into an individual without being fertilized. The resulting offspring can be either haploid or diploid, depending on the process in the species. Parthenogenesis occurs in invertebrates such as water fleas, rotifers, aphids, stick insects, and ants, wasps, and bees. Ants, bees, and wasps use parthenogenesis to produce haploid males (drones). The diploid females (workers and queens) are the result of a fertilized egg.

Some vertebrate animals—such as certain reptiles, amphibians, and fish—also reproduce through parthenogenesis. Parthenogenesis has been observed in species in which the sexes were separated in terrestrial or marine zoos. Two female Komodo dragons, a hammerhead shark, and a blacktop shark have produced parthenogenic young when the females have been isolated from males. It is possible that the asexual reproduction observed occurred in response to unusual circumstances and would normally not occur.

Sexual Reproduction

Sexual reproduction is the combination of reproductive cells from two individuals to form genetically unique offspring. The nature of the individuals that produce the two kinds of gametes can vary, having for example separate sexes or both sexes in each individual. Sex determination, the mechanism that determines which sex an individual develops into, also can vary.

Hermaphroditism

Hermaphroditism occurs in animals in which one individual has both male and female reproductive systems. Invertebrates such as earthworms, slugs, tapeworms, and snails (Figure 13.5) are often hermaphroditic. Hermaphrodites may self-fertilize, but typically they will mate with another of their species, fertilizing each other and both producing offspring. Self-fertilization is more common in animals that have limited mobility or are not motile, such as barnacles and clams. Many species have specific mechanisms in place to prevent self-fertilization, because it is an extreme form of inbreeding and usually produces less fit offspring.

Figure 13.5 Many (a) snails are hermaphrodites. When two individuals (b) mate, they can produce up to 100 eggs each. (credit a: modification of work by Assaf Shtilman; credit b: modification of work by “Schristia”/Flickr)

Sex Determination

Mammalian sex is determined genetically by the combination of X and Y chromosomes. Individuals homozygous for X (XX) are female and heterozygous individuals (XY) are male. In mammals, the presence of a Y chromosome causes the development of male characteristics and its absence results in female characteristics. The XY system is also found in some insects and plants.

Bird sex determination is dependent on the combination of Z and W chromosomes. Homozygous for Z (ZZ) results in a male and heterozygous (ZW) results in a female. Notice that this system is the opposite of the mammalian system because in birds the female is the sex with the different sex chromosomes. The W appears to be essential in determining the sex of the individual, similar to the Y chromosome in mammals. Some fish, crustaceans, insects (such as butterflies and moths), and reptiles use the ZW system.

More complicated chromosomal sex determining systems also exist. For example, some swordtail fish have three sex chromosomes in a population.

The sex of some other species is not determined by chromosomes, but by some aspect of the environment. Sex determination in alligators, some turtles, and tuataras, for example, is dependent on the temperature during the middle third of egg development. This is referred to as environmental sex determination, or more specifically, as temperature-dependent sex determination. In many turtles, cooler temperatures during egg incubation produce males and warm temperatures produce females, while in many other species of turtles, the reverse is true. In some crocodiles and some turtles, moderate temperatures produce males and both warm and cool temperatures produce females.

Individuals of some species change their sex during their lives, switching from one to the other. If the individual is female first, it is termed protogyny or "first female," if it is male first, it is termed protandry or "first male." Oysters are born male, grow in size, and become female and lay eggs. The wrasses, a family of reef fishes, are all sequential hermaphrodites. Some of these species live in closely coordinated schools with a dominant male and a large number of smaller females. If the male dies, a female increases in size, changes sex, and becomes the new dominant male.

Fertilization

The fusion of a sperm and an egg is a process called fertilization. This can occur either inside (internal fertilization) or outside (external fertilization) the body of the female. Humans provide an example of the former, whereas frog reproduction is an example of the latter.

External Fertilization

External fertilization usually occurs in aquatic environments where both eggs and sperm are released into the water. After the sperm reaches the egg, fertilization takes place. Most external fertilization happens during the process of spawning where one or several females release their eggs and the male(s) release sperm in the same area, at the same time. The spawning may be triggered by environmental signals, such as water temperature or the length of daylight. Nearly all fish spawn, as do crustaceans (such as crabs and shrimp), mollusks (such as oysters), squid, and echinoderms (such as sea urchins and sea cucumbers). Frogs, corals, mayflies, and mosquitoes also spawn (Figure 13.6).


Figure 13.6 During sexual reproduction in toads, the male grasps the female from behind and externally fertilizes the eggs as they are deposited. (credit: Bernie Kohl)

Internal Fertilization

Internal fertilization occurs most often in terrestrial animals, although some aquatic animals also use this method. Internal fertilization may occur by the male directly depositing sperm in the female during mating. It may also occur by the male depositing sperm in the environment, usually in a protective structure, which a female picks up to deposit the sperm in her reproductive tract. There are three ways that offspring are produced following internal fertilization. In oviparity, fertilized eggs are laid outside the female's body and develop there, receiving nourishment from the yolk that is a part of the egg (Figure 13.7 **a**). This occurs in some bony fish, some reptiles, a few cartilaginous fish, some amphibians, a few mammals, and all birds. Most non-avian reptiles and insects produce leathery eggs, while birds and some turtles produce eggs with high concentrations of calcium carbonate in the shell, making them hard. Chicken eggs are an example of a hard shell. The eggs of the egg-laying mammals such as the platypus and echidna are leathery.

In ovoviparity, fertilized eggs are retained in the female, and the embryo obtains its nourishment from the egg's yolk. The eggs are retained in the female's body until they hatch inside of her, or she lays the eggs right before they hatch. This process helps protect the eggs until hatching. This occurs in some bony fish (like the platyfish *Xiphophorus maculatus*, Figure 13.7 **b**), some sharks, lizards, some snakes (garter snake *Thamnophis sirtalis*), some vipers, and some invertebrate animals (Madagascar hissing cockroach *Gromphadorhina portentosa*).

In viviparity the young are born alive. They obtain their nourishment from the female and are born in varying states of maturity. This occurs in most mammals (Figure 13.7 **c**), some cartilaginous fish, and a few reptiles.

(a) (b) (c)

Figure 13.7

In (a) oviparity, young develop in eggs outside the female body, as with these Harmonia axydridis beetles hatching. Some aquatic animals, like this (b) pregnant Xiphophorus maculatus are ovoviparous, with the egg developing inside the female and nutrition supplied primarily from the yolk. In mammals, nutrition is supported by the placenta, as was the case with this (c) newborn squirrel. (credit b: modification of work by Gourami Watcher; credit c: modification of work by “audreyjm529″/Flickr)

Reference:

https://opentextbc.ca/biology/chapter/13-1-how-animals-reproduce/#:~:text=Reproduction%20may%20be%20asexual%20when,budding%2C%20fragmentation%2C%20and%20parthenogenesis.

UNIT – III

PART-A

Q.NO	QUESTIONS	CO (LEVEL)
1	Describe about cleavage	3 (1)
2	Show how patterns of cleavage	3 (3)
3	Define asexual reproduction	3 (1)
4	Summarize chick embryo development	3 (2)
5	Execute the developmental biologyof mammals	3 (3)
6	Examine how the gastrulation process occurs in amphibia	3 (4)
7	Investigate why parthenogenesismode of reproduction occurs in some animals	3 (5)
8	Illustrate organogenesis of mammals	3 (2)
9	Explain about *in vitro* fertilization	3 (2)
10	Highlight the process of test tube baby	3 (1)

PART-B

Q.NO	QUESTIONS	CO (LEVEL)
1	Compare and contrast between cleavage and organogenesis	3 (4)
2	Analyse how the patterns of cleavage occur of amphibian, chick and mammal	3 (4)
3	Explain the developmental process of amphibian, chick and mammal	3 (2)
4	Investigate how the organogenesis occur in mammals	3 (4)
5	Examine the pathways of developmental of heart	3 (4)
6	Explain the metamorphosis of insects with a neat sketch	3 (2)
7	Formulate the development of urogenital system	3 (6)
8	Explain how asexual reproduction occurs in invertebrates	3 (2)
9	Discuss in detail the *in vitro* fertilization	3 (1)
10	Discuss in detail the metamorphosis of amphibians	3 (1)

SCHOOL OF BIO & CHEMICAL ENGINEERING

DEPARTMENT OF BIOTECHNOLOGY

SBC1201: ZOOLOGY

UNIT – IV - EVOLUTION, ADAPTIVE RADIATION AND FOSSILS– SBC1201

1. EVOLUTION

Evolution by natural selection describes a mechanism for how species change over time. That species change had been suggested and debated well before Darwin began to explore this idea. The view that species were static and unchanging was grounded in the writings of Plato, yet there were also ancient Greeks who expressed evolutionary ideas. In the eighteenth century, ideas about the evolution of animals were reintroduced by the naturalist Georges-Louis Leclerc Comte de Buffon who observed that various geographic regions have different plant and animal populations, even when the environments are similar. It was also accepted that there were extinct species.

During this time, James Hutton, a Scottish naturalist, proposed that geological change occurred gradually by the accumulation of small changes from processes operating like they are today over long periods of time. This contrasted with the predominant view that the geology of the planet was a consequence of catastrophic events occurring during a relatively brief past. Hutton's view was popularized in the nineteenth century by the geologist Charles Lyell who became a friend to Darwin. Lyell's ideas were influential on Darwin's thinking: Lyell's notion of the greater age of Earth gave more time for gradual change in species, and the process of change provided an analogy for gradual change in species. In the early nineteenth century, Jean-Baptiste Lamarck published a book that detailed a mechanism for evolutionary change. This mechanism is now referred to as an inheritance of acquired characteristics by which modifications in an individual are caused by its environment, or the use or disuse of a structure during its lifetime, could be inherited by its offspring and thus bring about change in a species. While this mechanism for evolutionary change was discredited, Lamarck's ideas were an important influence on evolutionary thought.

Charles Darwin and Natural Selection

In the mid-nineteenth century, the actual mechanism for evolution was independently conceived of and described by two naturalists: Charles Darwin and Alfred Russel Wallace. Importantly, each naturalist spent time exploring the natural world on expeditions to the tropics. From 1831 to 1836, Darwin traveled around the world on *H.M.S. Beagle*, including stops in South America, Australia, and the southern tip of Africa. Wallace traveled to Brazil to collect insects in the Amazon rainforest from 1848 to 1852 and to the Malay Archipelago from 1854 to 1862. Darwin's journey, like Wallace's later journeys to the Malay Archipelago, included stops at several island chains, the last being the Galápagos Islands west of Ecuador. On these islands, Darwin observed species of organisms on different islands that were clearly similar, yet had distinct differences. For example, the ground finches inhabiting the Galápagos Islands comprised several species with a unique beak shape (Figure 18.2). The species on the islands had a graded series of beak sizes and shapes with very small differences between the most similar. He observed that these finches closely resembled another finch species on the mainland of South America. Darwin imagined that the island species might be species modified from one of the original mainland species. Upon further study, he realized that the varied beaks of each finch helped the birds acquire a specific type of food. For example, seed-eating finches had stronger, thicker beaks for breaking seeds, and insect-eating finches had spear-like beaks for stabbing their prey.

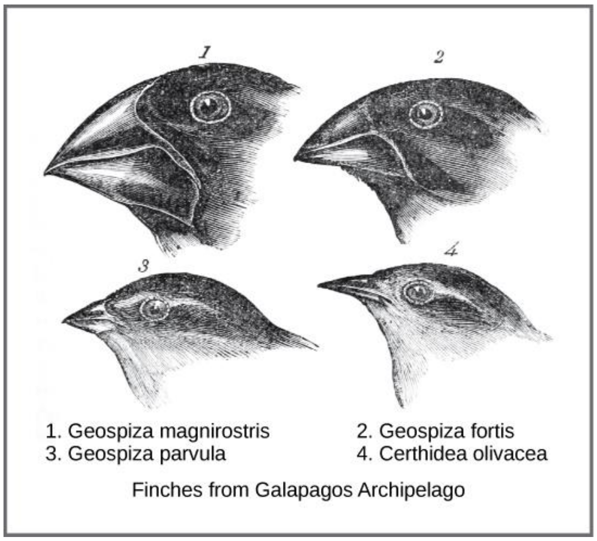


Figure 18.2 Darwin observed that beak shape varies among finch species. He postulated that the beak of an ancestral species had adapted over time to equip the finches to acquire different food sources.

Wallace and Darwin both observed similar patterns in other organisms and they independently developed the same explanation for how and why such changes could take place. Darwin called this mechanism natural selection. **Natural selection**, also known as “survival of the fittest,” is the more prolific reproduction of individuals with favorable traits that survive environmental change because of those traits; this leads to evolutionary change.

For example, a population of giant tortoises found in the Galapagos Archipelago was observed by Darwin to have longer necks than those that lived on other islands with dry lowlands. These tortoises were "selected" because they could reach more leaves and access more food than those with short necks. In times of drought when fewer leaves would be available, those that could reach more leaves had a better chance to eat and survive than those that couldn't reach the food source. Consequently, long-necked tortoises would be more likely to be reproductively successful and pass the long-necked trait to their offspring. Over time, only long-necked tortoises would be present in the population.

Natural selection, Darwin argued, was an inevitable outcome of three principles that operated in nature. First, most characteristics of organisms are inherited, or passed from parent to offspring. Although no one, including Darwin and Wallace, knew how this happened at the time, it was a common understanding. Second, more offspring are produced than are able to survive, so resources for survival and reproduction are limited. The capacity for reproduction in all organisms outstrips the availability of resources to support their numbers. Thus, there is competition for those resources in each generation. Both Darwin and Wallace's understanding of this principle came from reading an essay by the economist Thomas Malthus who discussed this principle in relation to human populations. Third, offspring vary among each other in regard to their characteristics and those variations are inherited. Darwin and Wallace reasoned that offspring with inherited characteristics which allow them to best compete for limited resources will survive and have more offspring than those individuals with variations that are less able to compete. Because characteristics are inherited, these traits will be better represented in the next generation. This will lead to change in populations over generations in a process that Darwin called descent with modification. Ultimately, natural selection leads to greater adaptation of the population to its local environment; it is the only mechanism known for adaptive evolution.

Papers by Darwin and Wallace (Figure 18.3) presenting the idea of natural selection were read together in 1858 before the Linnean Society in London. The following year Darwin's book, *On the Origin of Species*, was published. His book outlined in considerable detail his arguments for evolution by natural selection.

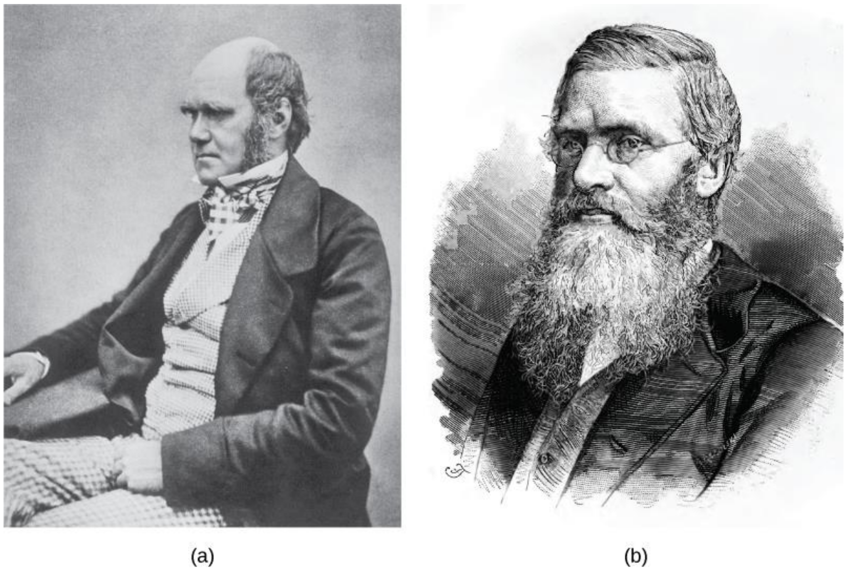


Figure 18.3 Both (a) Charles Darwin and (b) Alfred Wallace wrote scientific papers on natural selection that were presented together before the Linnean Society in 1858.

Demonstrations of evolution by natural selection are time consuming and difficult to obtain. One of the best examples has been demonstrated in the very birds that helped to inspire Darwin's theory: the Galápagos finches. Peter and Rosemary Grant and their colleagues have studied Galápagos finch populations every year since 1976 and have provided important demonstrations of natural selection. The Grants found changes from one generation to the next in the distribution of beak shapes with the medium ground finch on the Galápagos island of Daphne Major. The birds have inherited variation in the bill shape with some birds having wide deep bills and others having thinner bills. During a period in which rainfall was higher than normal because of an El Niño, the large hard seeds that large-billed birds ate were reduced in number; however, there was an abundance of the small soft seeds which the small-billed birds ate. Therefore, survival and reproduction were much better in the following years for the small-billed birds. In the years following this El Niño, the Grants measured beak sizes in the population and found that the average bill size was smaller. Since bill size is an inherited trait, parents with smaller bills had more offspring and the size of bills had evolved to be smaller. As conditions improved in 1987 and larger seeds became more available, the trend toward smaller average bill size ceased.

CAREER CONNECTION

Field Biologist

Many people hike, explore caves, scuba dive, or climb mountains for recreation. People often participate in these activities hoping to see wildlife. Experiencing the outdoors can be incredibly enjoyable and invigorating. What if your job was to be outside in the wilderness? Field biologists by definition work outdoors in the "field." The term field in this case refers to any location outdoors, even under water. A field biologist typically focuses research on a certain species, group of organisms, or a single habitat (Figure 18.4).

Figure 18.4 A field biologist tranquilizes a polar bear for study. (credit: Karen Rhode)

One objective of many field biologists includes discovering new species that have never been recorded. Not only do such findings expand our understanding of the natural world, but they also lead to important innovations in fields such as medicine and agriculture. Plant and microbial species, in particular, can reveal new medicinal and nutritive knowledge. Other organisms can play key roles in ecosystems or be considered rare and in need of protection. When discovered, these important species can be used as evidence for environmental regulations and laws.

Processes and Patterns of Evolution

Natural selection can only take place if there is **variation**, or differences, among individuals in a population. Importantly, these differences must have some genetic basis; otherwise, the selection will not lead to change in the next generation. This is critical because variation among individuals can be caused by non-genetic reasons such as an individual being taller because of better nutrition rather than different genes.

Genetic diversity in a population comes from two main mechanisms: mutation and sexual reproduction. Mutation, a change in DNA, is the ultimate source of new alleles, or new genetic variation in any population. The genetic changes caused by mutation can have one of three outcomes on the phenotype. A mutation affects the phenotype of the organism in a way that gives it reduced fitness—lower likelihood of survival or fewer offspring. A mutation may produce a phenotype with a beneficial effect on fitness. And, many mutations will also have no effect on the fitness of the phenotype; these are called neutral mutations. Mutations may also have a whole range of effect sizes on the fitness of the organism that expresses them in their phenotype, from a small effect to a great effect. Sexual reproduction also leads to genetic diversity: when two parents reproduce, unique combinations of alleles assemble to produce the unique genotypes and thus phenotypes in each of the offspring.

A heritable trait that helps the survival and reproduction of an organism in its present environment is called an **adaptation**. Scientists describe groups of organisms becoming adapted to their environment when a change in the range of genetic variation occurs over time that increases or maintains the "fit" of the population to its environment. The webbed feet of platypuses are an adaptation for swimming. The snow leopards' thick fur is an adaptation for living in the cold. The cheetahs' fast speed is an adaptation for catching prey.

Whether or not a trait is favorable depends on the environmental conditions at the time. The same traits are not always selected because environmental conditions can change. For example, consider a species of plant that grew in a moist climate and did not need to conserve water. Large leaves were selected because they allowed the plant to obtain more energy from the sun. Large leaves require more water to maintain than small leaves, and the moist environment provided favorable conditions to support large leaves. After thousands of years, the climate changed, and the area no longer had excess water. The direction of natural selection shifted so that plants with small leaves were selected because those populations were able to conserve water to survive the new environmental conditions.

The evolution of species has resulted in enormous variation in form and function. Sometimes, evolution gives rise to groups of organisms that become tremendously different from each other. When two species evolve in diverse directions from a common point, it is called **divergent evolution**. Such divergent evolution can be seen in the forms of the reproductive organs of flowering plants which share the same basic anatomies; however, they can look very different as a result of selection in different physical environments and adaptation to different kinds of pollinators (Figure 18.5).

(a) (b)

Figure 18.5 Flowering plants evolved from a common ancestor. Notice that the (a) dense blazing star (*Liatrus spicata*) and the (b) purple coneflower (*Echinacea purpurea*) vary in appearance, yet both share a similar basic morphology. (credit a: modification of work by Drew Avery; credit b: modification of work by Cory Zanker)

In other cases, similar phenotypes evolve independently in distantly related species. For example, flight has evolved in both bats and insects, and they both have structures we refer to as wings, which are adaptations to flight. However, the wings of bats and insects have evolved from very different original structures. This phenomenon is called **convergent evolution** , where similar traits evolve independently in species that do not share a common ancestry. The two species came to the same function, flying, but did so separately from each other.

These physical changes occur over enormous spans of time and help explain how evolution occurs. Natural selection acts on individual organisms, which in turn can shape an entire species. Although natural selection may work in a single generation on an individual, it can take thousands or even millions of years for the genotype of an entire species to evolve. It is over these large time spans that life on earth has changed and continues to change.

Evidence of Evolution

The evidence for evolution is compelling and extensive. Looking at every level of organization in living systems, biologists see the signature of past and present evolution. Darwin dedicated a large portion of his book, *On the Origin of Species*, to identifying patterns in nature that were consistent with evolution, and since Darwin, our understanding has become clearer and broader.

Fossils

Fossils provide solid evidence that organisms from the past are not the same as those found today, and fossils show a progression of evolution. Scientists determine the age of fossils and categorize them from all over the world to determine when the organisms lived relative to each other. The resulting fossil record tells the story of the past and shows the evolution of form over millions of years (Figure 18.6). For example, scientists have recovered highly detailed records showing the evolution of humans and horses (Figure 18.6). The whale flipper shares a similar morphology to appendages of birds and mammals (Figure 18.7) indicating that these species share a common ancestor.

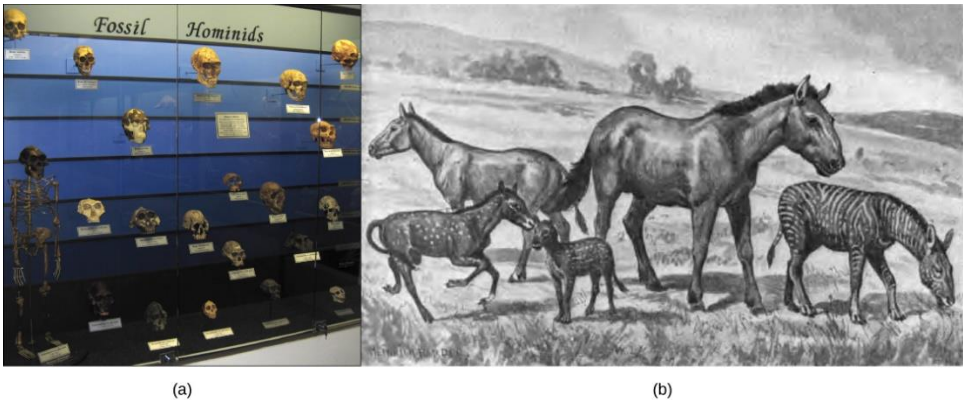


Figure 18.6 In this (a) display, fossil hominids are arranged from oldest (bottom) to newest (top). As hominids evolved, the shape of the skull changed. An artist's rendition of (b) extinct species of the genus *Equus* reveals that these ancient species resembled the modern horse (*Equus ferus*) but varied in size.

Anatomy and Embryology

Another type of evidence for evolution is the presence of structures in organisms that share the same basic form. For example, the bones in the appendages of a human, dog, bird, and whale all share the same overall construction (Figure 18.7) resulting from their origin in the appendages of a common ancestor. Over time, evolution led to changes in the shapes and sizes of these bones in different species, but they have maintained the same overall layout. Scientists call these synonymous parts **homologous structures**.

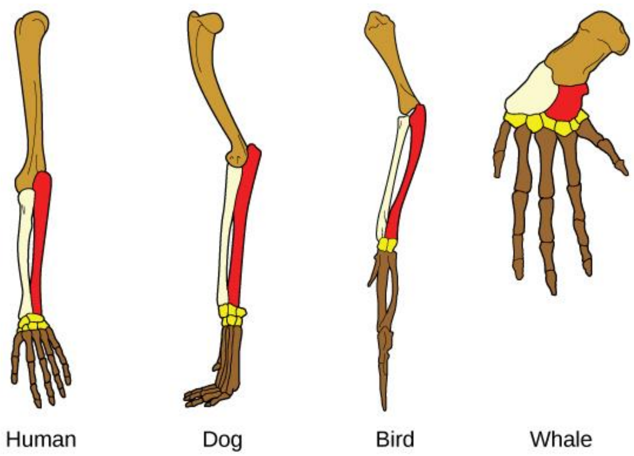


Figure 18.7 The similar construction of these appendages indicates that these organisms share a common ancestor.

Some structures exist in organisms that have no apparent function at all, and appear to be residual parts from a past common ancestor. These unused structures without function are called **vestigial structures**. Other examples of vestigial structures are wings on flightless birds, leaves on some cacti, and hind leg bones in whales.

LINK TO LEARNING

Visit this interactive site to guess which bones structures are homologous and which are analogous, and see examples of evolutionary adaptations to illustrate these concepts.

Another evidence of evolution is the convergence of form in organisms that share similar environments. For example, species of unrelated animals, such as the arctic fox and ptarmigan, living in the arctic region have been selected for seasonal white phenotypes during winter to blend with the snow and ice (Figure 18.8**ab**). These similarities occur not because of common ancestry, but because of similar selection pressures—the benefits of not being seen by predators.

(a) (b)

Figure 18.8 The white winter coat of the (a) arctic fox and the (b) ptarmigan's plumage are adaptations to their environments. (credit a: modification of work by Keith Morehouse)

Embryology, the study of the development of the anatomy of an organism to its adult form, also provides evidence of relatedness between now widely divergent groups of organisms. Mutational tweaking in the embryo can have such magnified consequences in the adult that embryo formation tends to be conserved. As a result, structures that are absent in some groups often appear in their embryonic forms and disappear by the time the adult or juvenile form is reached. For example, all vertebrate embryos, including humans, exhibit gill slits and tails at some point in their early development. These disappear in the adults of terrestrial groups but are maintained in adult forms of aquatic groups such as fish and some amphibians. Great ape embryos, including humans, have a tail structure during their development that is lost by the time of birth.

Biogeography

The geographic distribution of organisms on the planet follows patterns that are best explained by evolution in conjunction with the movement of tectonic plates over geological time. Broad groups that evolved before the breakup of the supercontinent Pangaea (about 200 million years ago) are distributed worldwide. Groups that evolved since the breakup appear uniquely in regions of the planet, such as the unique flora and fauna of northern continents that formed from the supercontinent Laurasia and of the southern continents that formed from the supercontinent Gondwana. The presence of members of the plant family Proteaceae in Australia, southern Africa, and South America is best by their presence prior to the southern supercontinent Gondwana breaking up.

The great diversification of marsupials in Australia and the absence of other mammals reflect Australia’s long isolation. Australia has an abundance of endemic species—species found nowhere else—which is typical of islands whose isolation by expanses of water prevents species to migrate. Over time, these species diverge evolutionarily into new species that look very different from their ancestors that may exist on the mainland. The marsupials of Australia, the finches on the Galápagos, and many species on the Hawaiian Islands are all unique to their one point of origin, yet they display distant relationships to ancestral species on mainlands.

Molecular Biology

Like anatomical structures, the structures of the molecules of life reflect descent with modification. Evidence of a common ancestor for all of life is reflected in the universality of DNA as the genetic material and in the near universality of the genetic code and the machinery of DNA replication and expression. Fundamental divisions in life between the three domains are reflected in major structural differences in otherwise conservative structures such as the components of ribosomes and the structures of membranes. In general, the relatedness of groups of organisms is reflected in the similarity of their DNA sequences—exactly the pattern that would be expected from descent and diversification from a common ancestor.

DNA sequences have also shed light on some of the mechanisms of evolution. For example, it is clear that the evolution of new functions for proteins commonly occurs after gene duplication events that allow the free modification of one copy by mutation, selection, or drift (changes in a population's gene pool resulting from chance), while the second copy continues to produce a functional protein.

Misconceptions of Evolution

Although the theory of evolution generated some controversy when it was first proposed, it was almost universally accepted by biologists, particularly younger biologists, within 20 years after publication of *On the Origin of Species*. Nevertheless, the theory of evolution is a difficult concept and misconceptions about how it works abound.

LINK TO LEARNING

This site addresses some of the main misconceptions associated with the theory of evolution.

Evolution Is Just a Theory

Critics of the theory of evolution dismiss its importance by purposefully confounding the everyday usage of the word "theory" with the way scientists use the word. In science, a "theory" is understood to be a body of thoroughly tested and verified explanations for a set of observations of the natural world. Scientists have a theory of the atom, a theory of gravity, and the theory of relativity, each of which describes understood facts about the world. In the same way, the theory of evolution describes facts about the living world. As such, a theory in science has survived significant efforts to discredit it by scientists. In contrast, a “theory” in common vernacular is a word meaning a guess or suggested explanation; this meaning is more akin to the scientific concept of “hypothesis.” When critics of evolution say evolution is “just a theory,” they are implying that there is little evidence supporting it and that it is still in the process of being rigorously tested. This is a mischaracterization.

Individuals Evolve

Evolution is the change in genetic composition of a population over time, specifically over generations, resulting from differential reproduction of individuals with certain alleles. Individuals do change over their lifetime, obviously, but this is called development and involves changes programmed by the set of genes the individual acquired at birth in coordination with the individual’s environment. When thinking about the evolution of a characteristic, it is probably best to think about the change of the average value of the characteristic in the population over time. For example, when natural selection leads to bill-size change in medium-ground finches in the Galápagos, this does not mean that individual bills on the finches are changing. If one measures the average bill size among all individuals in the population at one time and then measures the average bill size in the population several years later, this average value will be different as a result of evolution. Although some individuals may survive from the first time to the second, they will still have the same bill size; however, there will be many new individuals that contribute to the shift in average bill size.

Evolution Explains the Origin of Life

It is a common misunderstanding that evolution includes an explanation of life’s origins. Conversely, some of the theory’s critics believe that it cannot explain the origin of life. The theory does not try to explain the origin of life. The theory of evolution explains how populations change over time and how life diversifies the origin of species. It does not shed light on the beginnings of life including the origins of the first cells, which is how life is defined. The mechanisms of the origin of life on Earth are a particularly difficult problem because it occurred a very long time ago, and presumably it just occurred once. Importantly, biologists believe that the presence of life on

Earth precludes the possibility that the events that led to life on Earth can be repeated because the intermediate stages would immediately become food for existing living things.

However, once a mechanism of inheritance was in place in the form of a molecule like DNA either within a cell or pre-cell, these entities would be subject to the principle of natural selection. More effective reproducers would increase in frequency at the expense of inefficient reproducers. So while evolution does not explain the origin of life, it may have something to say about some of the processes operating once pre-living entities acquired certain properties.

Organisms Evolve on Purpose

Statements such as “organisms evolve in response to a change in an environment” are quite common, but such statements can lead to two types of misunderstandings. First, the statement must not be understood to mean that individual organisms evolve. The statement is shorthand for “a population evolves in response to a changing environment.” However, a second misunderstanding may arise by interpreting the statement to mean that the evolution is somehow intentional. A changed environment results in some individuals in the population, those with particular phenotypes, benefiting and therefore producing proportionately more offspring than other phenotypes. This results in change in the population if the characteristics are genetically determined.

It is also important to understand that the variation that natural selection works on is already in a population and does not arise in response to an environmental change. For example, applying antibiotics to a population of bacteria will, over time, select a population of bacteria that are resistant to antibiotics. The resistance, which is caused by a gene, did not arise by mutation because of the application of the antibiotic. The gene for resistance was already present in the gene pool of the bacteria, likely at a low frequency. The antibiotic, which kills the bacterial cells without the resistance gene, strongly selects individuals that are resistant, since these would be the only ones that survived and divided. Experiments have demonstrated that mutations for antibiotic resistance do not arise as a result of antibiotic.

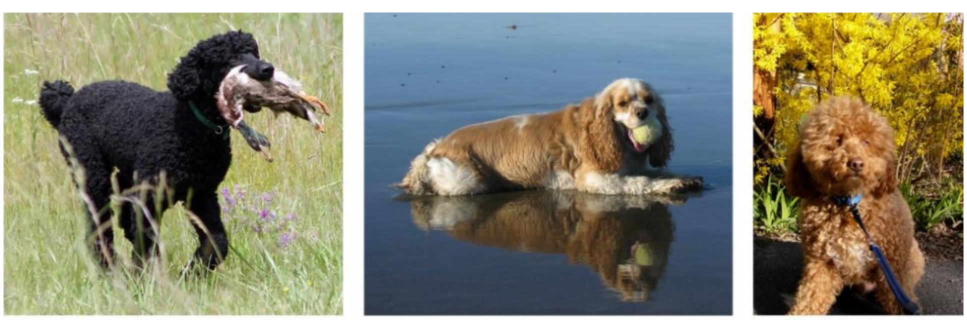
In a larger sense, evolution is not goal directed. Species do not become “better” over time; they simply track their changing environment with adaptations that maximize their reproduction in a particular environment at a particular time. Evolution has no goal of making faster, bigger, more complex, or even smarter species, despite the commonness of this kind of language in popular discourse. What characteristics evolve in a species are a function of the variation present and the environment, both of which are constantly changing in a non-directional way. What trait is fit in one environment at one time may well be fatal at some point in the future. This holds equally well for a species of insect as it does the human species.

Species and the Ability to Reproduce

A **species** is a group of individual organisms that interbreed and produce fertile, viable offspring. According to this definition, one species is distinguished from another when, in nature, it is not possible for matings between individuals from each species to produce fertile offspring.

Members of the same species share both external and internal characteristics, which develop from their DNA. The closer relationship two organisms share, the more DNA they have in common, just like people and their families. People's DNA is likely to be more like their father or mother's DNA than their cousin or grandparent's DNA. Organisms of the same species have the highest level of DNA alignment and therefore share characteristics and behaviors that lead to successful reproduction.

Species' appearance can be misleading in suggesting an ability or inability to mate. For example, even though domestic dogs (*Canis lupus familiaris*) display phenotypic differences, such as size, build, and coat, most dogs can interbreed and produce viable puppies that can mature and sexually reproduce (Figure 18.9).



(a) (b) (c)

Figure 18.9 The (a) poodle and (b) cocker spaniel can reproduce to produce a breed known as (c) the cockapoo. (credit a: modification of work by Sally Eller, Tom Reese; credit b: modification of work by Jeremy McWilliams; credit c: modification of work by Kathleen Conklin)

In other cases, individuals may appear similar although they are not members of the same species. For example, even though bald eagles (*Haliaeetus leucocephalus*) and African fish eagles (*Haliaeetus vocifer*) are both birds and eagles, each belongs to a separate species group (Figure 18.10). If humans were to artificially intervene and fertilize the egg of a bald eagle with the sperm of an African fish eagle and a chick did hatch, that offspring, called a **hybrid** (a cross between two species), would probably be infertile—unable to successfully reproduce after it reached maturity. Different species may have different genes that are active in development; therefore, it may not be possible to develop a viable offspring with two different sets of directions. Thus, even though hybridization may take place, the two species still remain separate.

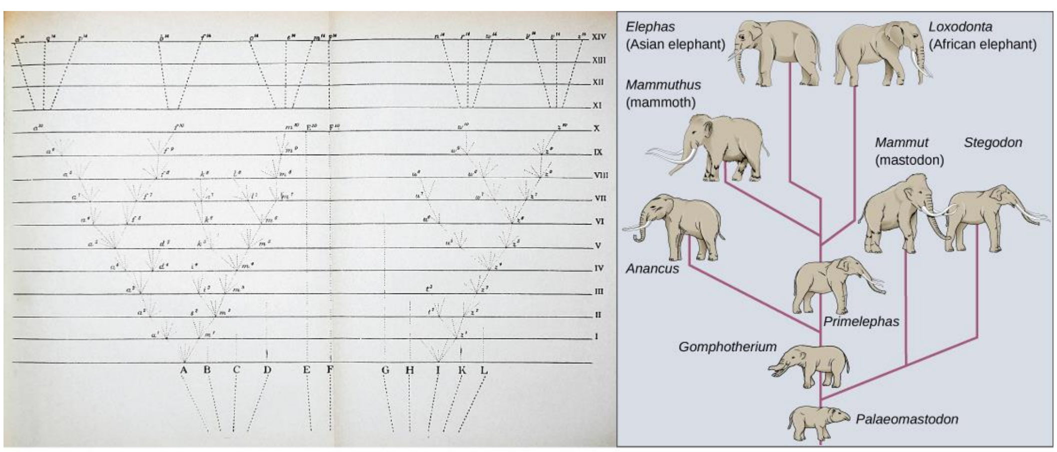
Figure 18.10 The (a) African fish eagle is similar in appearance to the (b) bald eagle, but the two birds are members of different species. (credit a: modification of work by Nigel Wedge; credit b: modification of work by U.S. Fish and Wildlife Service)

Populations of species share a gene pool: a collection of all the variants of genes in the species. Again, the basis to any changes in a group or population of organisms must be genetic for this is the only way to share and pass on traits. When variations occur within a species, they can only be passed to the next generation along two main pathways: asexual reproduction or sexual reproduction. The change will be passed on asexually simply if the reproducing cell possesses the changed trait. For the changed trait to be passed on by sexual reproduction, a gamete, such as a sperm or egg cell, must possess the changed trait. In other words, sexually-reproducing organisms can experience several genetic changes in their body cells, but if these changes do not occur in a sperm or egg cell, the changed trait will never reach the next generation. Only heritable traits can evolve. Therefore, reproduction plays a paramount role for genetic change to take root in a population or species. In short, organisms must be able to reproduce with each other to pass new traits to offspring.

Speciation

The biological definition of species, which works for sexually reproducing organisms, is a group of actually or potentially interbreeding individuals. There are exceptions to this rule. Many species are similar enough that hybrid offspring are possible and may often occur in nature, but for the majority of species this rule generally holds. In fact, the presence in nature of hybrids between similar species suggests that they may have descended from a single interbreeding species, and the speciation process may not yet be completed.

Given the extraordinary diversity of life on the planet there must be mechanisms for **speciation**: the formation of two species from one original species. Darwin envisioned this process as a branching event and diagrammed the process in the only illustration found in *On the Origin of Species* (Figure 18.11**a**). Compare this illustration to the diagram of elephant evolution (Figure 18.11**b**), which shows that as one species changes over time, it branches to form more than one new species, repeatedly, as long as the population survives or until the organism becomes extinct.



(a) (b)

Figure 18.11 The only illustration in Darwin's *On the Origin of Species* is (a) a diagram showing speciation events leading to biological diversity. The diagram shows similarities to phylogenetic charts that are drawn today to illustrate the relationships of species. (b) Modern elephants evolved from the *Palaeomastodon*, a species that lived in Egypt 35–50 million years ago.

For speciation to occur, two new populations must be formed from one original population and they must evolve in such a way that it becomes impossible for individuals from the two new populations to interbreed. Biologists have proposed mechanisms by which this could occur that fall into two broad categories. **Allopatric speciation** (allo- = "other"; -patric = "homeland") involves geographic separation of populations from a parent species and subsequent evolution. **Sympatric speciation** (sym- = "same"; -patric = "homeland") involves speciation occurring within a parent species remaining in one location.

Biologists think of speciation events as the splitting of one ancestral species into two descendant species. There is no reason why there might not be more than two species formed at one time except that it is less likely and multiple events can be conceptualized as single splits occurring close in time.

Allopatric Speciation

A geographically continuous population has a gene pool that is relatively homogeneous. Gene flow, the movement of alleles across the range of the species, is relatively free because individuals can move and then mate with individuals in their new location. Thus, the frequency of an allele at one end of a distribution will be similar to the frequency of the allele at the other end. When populations become geographically discontinuous, that free-flow of alleles is prevented. When that separation lasts for a period of time, the two populations are able to evolve along different trajectories. Thus, their allele frequencies at numerous genetic loci gradually become more and more different as new alleles independently arise by mutation in each population. Typically, environmental conditions, such as climate, resources, predators, and competitors for the two populations will differ causing natural selection to favor divergent adaptations in each group.

Isolation of populations leading to allopatric speciation can occur in a variety of ways: a river forming a new branch, erosion forming a new valley, a group of organisms traveling to a new location without the ability to return, or seeds floating over the ocean to an island. The nature of the geographic separation necessary to isolate populations depends entirely on the biology of the organism and its potential for dispersal. If two flying insect populations took up residence in separate nearby valleys, chances are, individuals from each population would fly back and forth continuing gene flow. However, if two rodent populations became divided by the formation of a new lake, continued gene flow would be unlikely; therefore, speciation would be more likely.

Biologists group allopatric processes into two categories: dispersal and vicariance. **Dispersal** is when a few members of a species move to a new geographical area, and **vicariance** is when a natural situation arises to physically divide organisms.

Scientists have documented numerous cases of allopatric speciation taking place. For example, along the west coast of the United States, two separate sub-species of spotted owls exist. The northern spotted owl has genetic and phenotypic differences from its close relative: the Mexican spotted owl, which lives in the south (Figure 18.12).

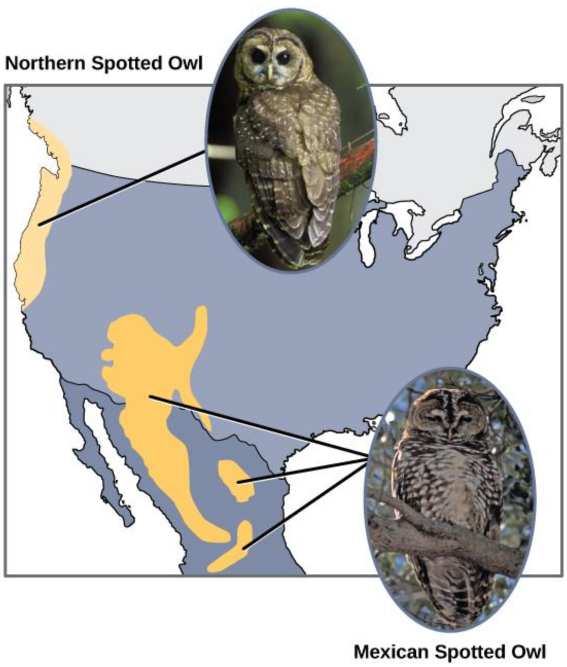


Figure 18.12 The northern spotted owl and the Mexican spotted owl inhabit geographically separate locations with different climates and ecosystems. The owl is an example of allopatric speciation. (credit "northern spotted owl": modification of work by John and Karen Hollingsworth; credit "Mexican spotted owl": modification of work by Bill Radke)

Additionally, scientists have found that the further the distance between two groups that once were the same species, the more likely it is that speciation will occur. This seems logical because as the distance increases, the various environmental factors would likely have less in common than locations in close proximity. Consider the two owls: in the north, the climate is cooler than in the south; the types of organisms in each ecosystem differ, as do their behaviors and habits; also, the hunting habits and prey choices of the southern owls vary from the northern owls. These variances can lead to evolved differences in the owls, and speciation likely will occur.

Adaptive Radiation

In some cases, a population of one species disperses throughout an area, and each finds a distinct niche or isolated habitat. Over time, the varied demands of their new lifestyles lead to multiple speciation events originating from a single species. This is called **adaptive radiation** because many adaptations evolve from a single point of origin; thus, causing the species to radiate into several new ones. Island archipelagos like the Hawaiian Islands provide an ideal context for adaptive radiation events because water surrounds each island which leads to geographical isolation for many organisms. The Hawaiian honeycreeper illustrates one example of adaptive radiation. From a single species, called the founder species, numerous species have evolved, including the six shown in Figure 18.13.

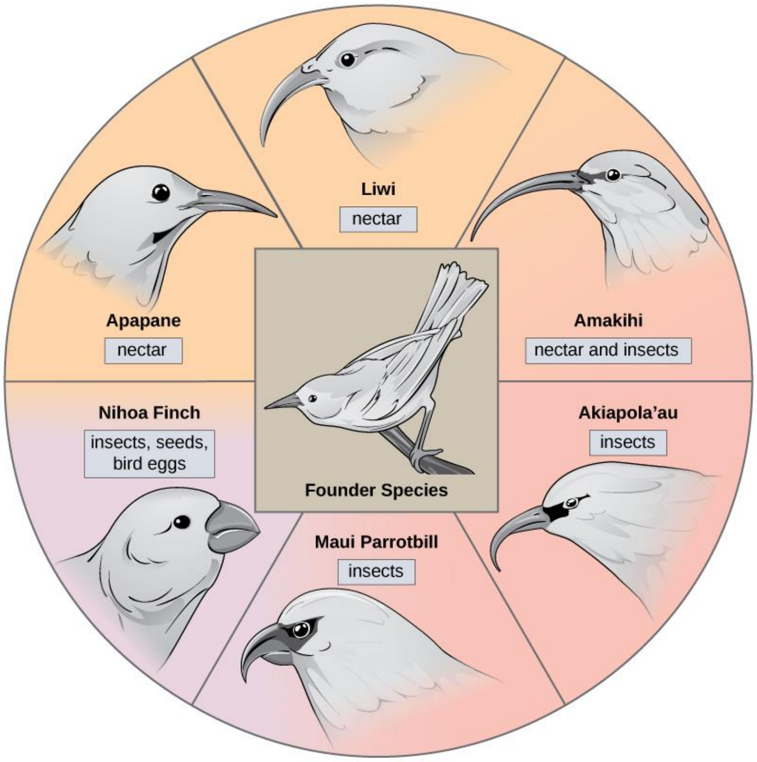


Figure 18.13 The honeycreeper birds illustrate adaptive radiation. From one original species of bird, multiple others evolved, each with its own distinctive characteristics.

Notice the differences in the species' beaks in Figure 18.13. Evolution in response to natural selection based on specific food sources in each new habitat led to evolution of a different beak suited to the specific food source. The seed-eating bird has a thicker, stronger beak which is suited to break hard nuts. The nectar-eating birds have long beaks to dip into flowers to reach the nectar. The insect-eating birds have beaks like swords, appropriate for stabbing and impaling insects. Darwin's finches are another example of adaptive radiation in an archipelago.

Habitat Influence on Speciation

Sympatric speciation may also take place in ways other than polyploidy. For example, consider a species of fish that lives in a lake. As the population grows, competition for food also grows. Under pressure to find food, suppose that a group of these fish had the genetic flexibility to discover and feed off another resource that was unused by the other fish. What if this new food source was found at a different depth of the lake? Over time, those feeding on the second food source would interact more with each other than the other fish; therefore, they would breed together as well.

Offspring of these fish would likely behave as their parents: feeding and living in the same area and keeping separate from the original population. If this group of fish continued to remain separate from the first population, eventually sympatric speciation might occur as more genetic differences accumulated between them.

This scenario does play out in nature, as do others that lead to reproductive isolation. One such place is Lake Victoria in Africa, famous for its sympatric speciation of cichlid fish. Researchers have found hundreds of sympatric speciation events in these fish, which have not only happened in great number, but also over a short period of time. Figure 18.21 shows this type of speciation among a cichlid fish population in Nicaragua. In this locale, two types of cichlids live in the same geographic location but have come to have different morphologies that allow them to eat various food sources.

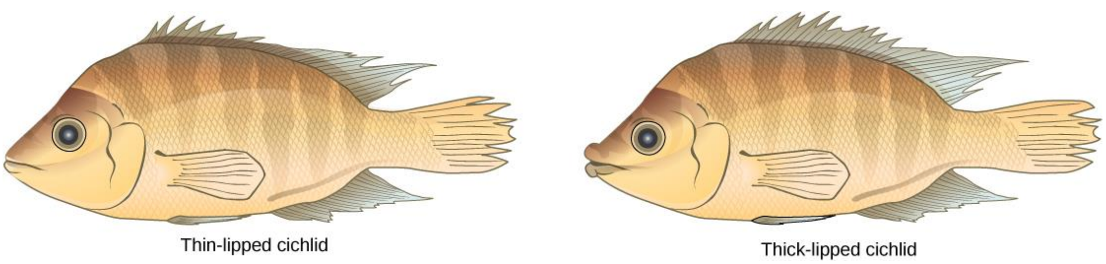


Figure 18.21 Cichlid fish from Lake Apoyeque, Nicaragua, show evidence of sympatric speciation. Lake Apoyeque, a crater lake, is 1800 years old, but genetic evidence indicates that the lake was populated only 100 years ago by a single population of cichlid fish. Nevertheless, two populations with distinct morphologies and diets now exist in the lake, and scientists believe these populations may be in an early stage of speciation.

Reconnection

After speciation, two species may recombine or even continue interacting indefinitely. Individual organisms will mate with any nearby individual who they are capable of breeding with. An area where two closely related species continue to interact and reproduce, forming hybrids, is called a **hybrid zone**. Over time, the hybrid zone may change depending on the fitness of the hybrids and the reproductive barriers (Figure 18.22). If the hybrids are less fit than the parents, reinforcement of speciation occurs, and the species continue to diverge until they can no longer mate and produce viable offspring. If reproductive barriers weaken, fusion occurs and the two species become one. Barriers remain the same if hybrids are fit and reproductive: stability may occur and hybridization continues.

VISUAL CONNECTION

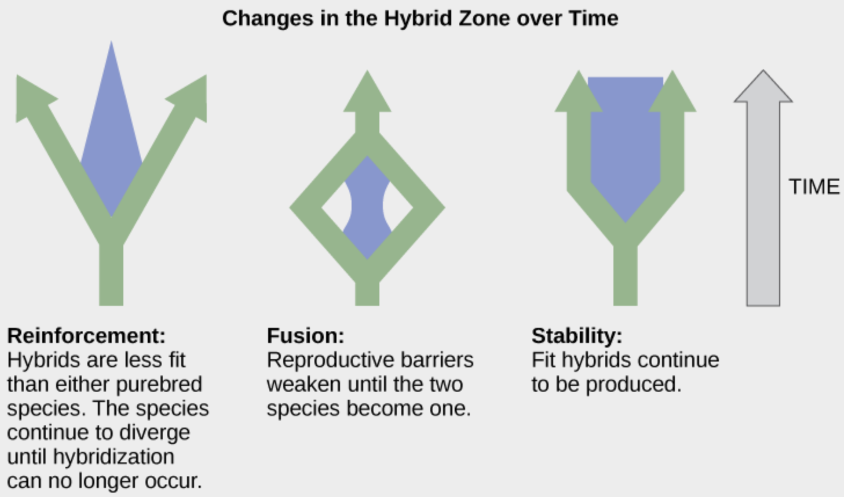


Figure 18.22 After speciation has occurred, the two separate but closely related species may continue to produce offspring in an area called the hybrid zone. Reinforcement, fusion, or stability may result, depending on reproductive barriers and the relative fitness of the hybrids.

If two species eat a different diet but one of the food sources is eliminated and both species are forced to eat the same foods, what change in the hybrid zone is most likely to occur?

Hybrids can be either less fit than the parents, more fit, or about the same. Usually hybrids tend to be less fit; therefore, such reproduction diminishes over time, nudging the two species to diverge further in a process called **reinforcement**. This term is used because the low success of the hybrids reinforces the original speciation. If the hybrids are as fit or more fit than the parents, the two species may fuse back into one species (Figure 18.23). Scientists have also observed that sometimes two species will remain separate but also continue to interact to produce some hybrid individuals; this is classified as stability because no real net change is taking place.

Varying Rates of Speciation

Scientists around the world study speciation, documenting observations both of living organisms and those found in the fossil record. As their ideas take shape and as research reveals new details about how life evolves, they develop models to help explain rates of speciation. In terms of how quickly speciation occurs, two patterns are currently observed: gradual speciation model and punctuated equilibrium model.

In the **gradual speciation model**, species diverge gradually over time in small steps. In the **punctuated equilibrium** model, a new species undergoes changes quickly from the parent species, and then remains largely unchanged for long periods of time afterward (Figure 18.23). This early change model is called punctuated equilibrium, because it begins with a punctuated or periodic change and then remains in balance afterward. While punctuated equilibrium suggests a faster tempo, it does not necessarily exclude gradualism.

VISUAL CONNECTION

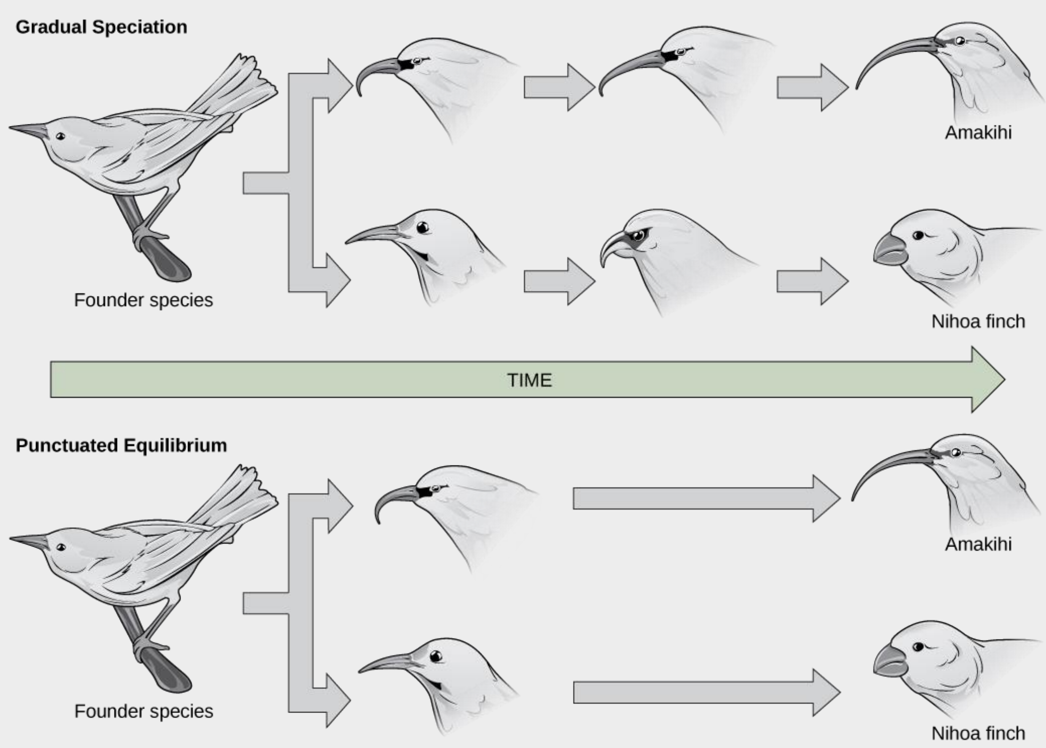


Figure 18.23 In (a) gradual speciation, species diverge at a slow, steady pace as traits change incrementally. In (b) punctuated equilibrium, species diverge quickly and then remain unchanged for long periods of time.

Which of the following statements is false?

a. Punctuated equilibrium is most likely to occur in a small population that experiences a rapid change in its environment.
b. Punctuated equilibrium is most likely to occur in a large population that lives in a stable climate.
c. Gradual speciation is most likely to occur in species that live in a stable climate.
d. Gradual speciation and punctuated equilibrium both result in the divergence of species.

The primary influencing factor on changes in speciation rate is environmental conditions. Under some conditions, selection occurs quickly or radically. Consider a species of snails that had been living with the same basic form for many thousands of years. Layers of their fossils would appear similar for a long time. When a change in the environment takes place—such as a drop in the water level—a small number of organisms are separated from the rest in a brief period of time, essentially forming one large and one tiny population. The tiny population faces new environmental conditions. Because its gene pool quickly became so small, any variation that surfaces and that aids in surviving the new conditions becomes the predominant form.

Reference:

https://openstax.org/books/biology/pages/18-1-understanding-evolution

2. The Hardy-Weinberg Principle

By: Christine A. Andrews (*Biological Sciences Collegiate Division, University of Chicago*) © 2010 Nature Education

Citation: Andrews, C. (2010) The Hardy-Weinberg Principle. *Nature Education Knowledge* 3(10):65

The Hardy-Weinberg theorem characterizes the distributions of genotype frequencies in populations that are not evolving, and is thus the fundamental null model for population genetics.

Basic Mendelian Genetics

Under the now-discredited theory of blending inheritance, the hereditary material was conceived as a fluid that combines the traits from two individuals into phenotypically intermediate offspring. Given observed patterns of resemblance between parents and offspring, blending inheritance may seem intuitively reasonable, as it did to many of Charles Darwin's contemporaries. This mode of inheritance, however, posed problems for Darwin's theory of natural selection (1859), which depends on the existence of heritable trait variation in populations of organisms. Blending inheritance would quickly erode such variation, since all traits would be combined from one generation to the next until all individuals shared the same blended phenotype. In his famous experiments on pea plants, Gregor Mendel rejected this hereditary mechanism in favor of particulate inheritance by demonstrating that alternative versions of genes (alleles) account for variations in inherited characters, though he didn't actually know about genes as such. Although Mendel published his results in 1866, his work remained obscure until its rediscovery in 1900 (reviewed in Monaghan & Corcos 1984), which helped give rise to the modern field of genetics.

Mendel's Law of Segregation, in modern terms, states that a diploid individual carries two individual copies of each autosomal gene (i.e., one copy on each member of a pair of homologous chromosomes). Each gamete produced by a diploid individual receives only one copy of each gene, which is chosen at random from the two copies found in that individual. Under Mendel's Law of Segregation, each of the two copies in an individual has an equal chance of being included in a gamete, such that we expect 50% of an individual's gametes to contain one copy, and 50% to contain the other copy (Figure 1).

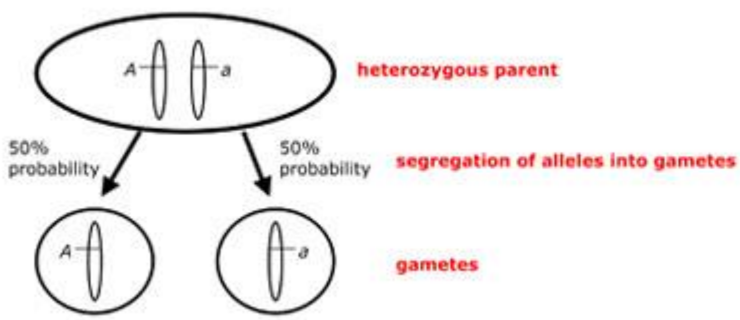


Figure 1: Mendel's Law of Segregation

Figure 2: G. H. Hardy

An individual’s genotype is the combination of alleles found in that individual at a given genetic locus. If there are two alleles in a population at locus A (*A* and *a*), then the possible genotypes in that population are *AA*, *Aa*, and *aa*. Individuals with genotypes *AA* and *aa* are homozygotes (i.e., they have two copies of the same allele). Individuals with genotype *Aa* are heterozygotes (i.e., they have two different alleles at the A locus). If the heterozygote is phenotypically identical to one of the homozygotes, the allele found in that homozygote is said to be dominant, and the allele found in the other homozygote is recessive.

Even after many geneticists had accepted Mendel’s laws, confusion lingered regarding the maintenance of genetic variation in natural populations. Some opponents of the Mendelian view contended that dominant traits should increase and recessive traits should decrease in frequency, which is not what is observed in real populations. Hardy (1908; Figure 2) refuted such arguments in a paper that, along with an independently published paper by Weinberg (1908; Figure 3) laid the foundation for the field of population genetics (Crow 1999; Edwards 2008).

The Hardy-Weinberg Equilibrium

Figure 3: Wilhelm Weinberg

The Hardy-Weinberg Theorem deals with Mendelian genetics in the context of populations of diploid, sexually reproducing individuals. Given a set of assumptions (discussed below), this theorem states that:

1. allele frequencies in a population will not change from generation to generation.
2. if the allele frequencies in a population with two alleles at a locus are p and q, then the expected genotype frequencies are p^2, $2pq$, and q^2. This frequency distribution will not change from generation to generation once a population is in Hardy-Weinberg equilibrium. For example, if the frequency of allele *A* in the population is p and the frequency of allele *a* in the population is q, then the frequency of genotype $AA = p^2$, the frequency of genotype $Aa = 2pq$, and the frequency of genotype $aa = q^2$. If there are only two alleles at a locus, then $p + q$, by mathematical necessity, equals one. The Hardy-Weinberg genotype frequencies, $p^2 + 2pq + q^2$, represent the binomial expansion of $(p + q)^2$, and also sum to one (as must the frequencies of all genotypes in any population, whether it is in Hardy-Weinberg equilibrium). It is possible to apply the Hardy-Weinberg Theorem to loci with more than two alleles, in which case the expected genotype frequencies are given by the multinomial expansion for all k alleles segregating in the population: $(p_1 + p_2 + p_3 + . . . + p\mathrm{k})^2$.

The conclusions of the Hardy-Weinberg Theorem apply only when the population conforms to the following assumptions:

1. Natural selection is not acting on the locus in question (i.e., there are no consistent differences in probabilities of survival or reproduction among genotypes).
2. Neither mutation (the origin of new alleles) nor migration (the movement of individuals and their genes into or out of the population) is introducing new alleles into the population.
3. Population size is infinite, which means that genetic drift is not causing random changes in allele frequencies due to sampling error from one generation to the next. Of course, all natural populations are finite and thus subject to drift, but we expect the effects of drift to be more pronounced in small than in large populations.
4. Individuals in the population mate randomly with respect to the locus in question. Although nonrandom mating does not change allele frequencies from one generation to the next if the other assumptions hold, it can generate deviations from expected genotype frequencies, and it can set the stage for natural selection to cause evolutionary change.

If the genotype frequencies in a population deviate from Hardy-Weinberg expectations, it takes only one generation of random mating to bring them into the equilibrium proportions, provided that the above assumptions hold, that allele frequencies are equal in males and females (or else that individuals are hermaphrodites), and that the locus is autosomal. If allele frequencies differ between the sexes, it takes two generations of random mating to attain Hardy-Weinberg equilibrium. Sex-linked loci require multiple generations to attain equilibrium because one sex has two copies of the gene and the other sex has only one.

Given these conditions, it is easy to derive the expected Hardy-Weinberg genotype frequencies if we think about random mating in terms of the probability of producing each genotype via random union of gametes into zygotes (Table 1). If each allele occurs at the same frequencies in sperm and eggs, and gametes unite at random to produce zygotes, then the probability that any two alleles will combine to form a particular genotype equals the product of the allele frequencies. Since there are two ways of generating the heterozygous genotype (*A* egg and *a* sperm, or *a* egg and *A* sperm), we sum the probabilities of those two types of union to arrive at the expected Hardy-Weinberg frequency of the heterozygous genotype (2*pq*).

		sperm	
		A (p)	a (q)
eggs	A (p)	*AA* (p^2)	*Aa* (pq)
	a (q)	*Aa* (pq)	*Aa* (q^2)

Table 1: A Punnett square depicting the probabilities of generating all possible genotypes at a diallelic Mendelian locus in a population that conforms to Hardy-Weinberg assumptions.

It is important to recognize that the Hardy-Weinberg equilibrium is a neutral equilibrium, which means that a population perturbed from its Hardy-Weinberg genotype frequencies will indeed reach equilibrium after a single generation of random mating (if it conforms to the other assumptions of the theorem), but it will be a *new* equilibrium if allele frequencies have changed. This property distinguishes a neutral equilibrium from a stable equilibrium, in which a perturbed system returns to the same equilibrium state. It makes sense that the Hardy-Weinberg equilibrium is not stable, since a change from the equilibrium genotype frequencies will generally be associated with a change in allele frequencies (p and q), which will in turn lead to new values of p^2, $2pq$ and q^2. Thereafter, a population that meets Hardy-Weinberg assumptions will remain at the new equilibrium until perturbed again.

Given a population in which we know the number of individuals with each genotype, we can test for statistical deviation from Hardy-Weinberg equilibrium using a simple chi-square goodness-of-fit test or a more powerful exact test. The latter class of methods has proved particularly useful for large-scale genomic studies, in which scientists evaluate thousands of loci segregating for multiple alleles (Wiggington *et al.* 2005). Observed genotype proportions in natural populations typically conform to Hardy-Weinberg expectations, as we might expect given that a population perturbed from equilibrium can achieve new equilibrium frequencies after only one generation of random mating.

Although statistical deviation from Hardy-Weinberg expectations generally indicates violation of the assumptions of the theorem, the converse is not necessarily true. Some forms of natural selection (e.g., balancing selection, which maintains multiple alleles in a population) can generate genotypic frequency distributions that conform to Hardy-Weinberg expectations. It may also be true that migration or mutation is occurring, but at such low rates as to be undetectable using available statistical methods. And, of course, all real populations are finite and thus susceptible to at least some evolution via genetic drift.

Evolutionary Implications of the Hardy-Weinberg Theorem

The Hardy-Weinberg Theorem demonstrates that Mendelian loci segregating for multiple alleles in diploid populations will retain predictable levels of genetic variation in the absence of forces that change allele frequencies. A common way of visualizing these expectations is to plot p^2, $2pq$ and q^2 as a function of allele frequencies (Figure 4). This graphical presentation emphasizes two important consequences of the Hardy-Weinberg principle:

1. Population heterozygosity (the frequency of heterozygotes) is highest when $p = q = 0.5$.
2. Rare alleles are found primarily in heterozygotes, as they must be, given that q^2 is much smaller than $2pq$ when q is near zero, and p^2 is much smaller than $2pq$ when p is near zero.

The second point takes on particular significance if we consider the potential for natural selection to influence the frequencies of new mutations. If a population conforms to all other Hardy-Weinberg assumptions, selection will eventually fix an advantageous allele in the population such that all individuals are homozygous for that allele. The initial increase in frequency of a rare, advantageous, dominant allele is more rapid than that of a rare, advantageous, recessive allele. This is because, as we have seen, rare alleles are found mostly in heterozygotes, such that a new recessive mutation can't be "seen" by natural selection until it reaches a high enough frequency (perhaps by drift in a real, finite population) to start appearing in homozygotes. A new dominant mutation, however, is immediately visible to natural selection because its effect on fitness is seen in heterozygotes. Thus, although Hardy (1908) demonstrated that dominance alone does not change allele frequencies at a locus, the dominance relationships among alleles can have substantial influence on evolutionary trajectories.

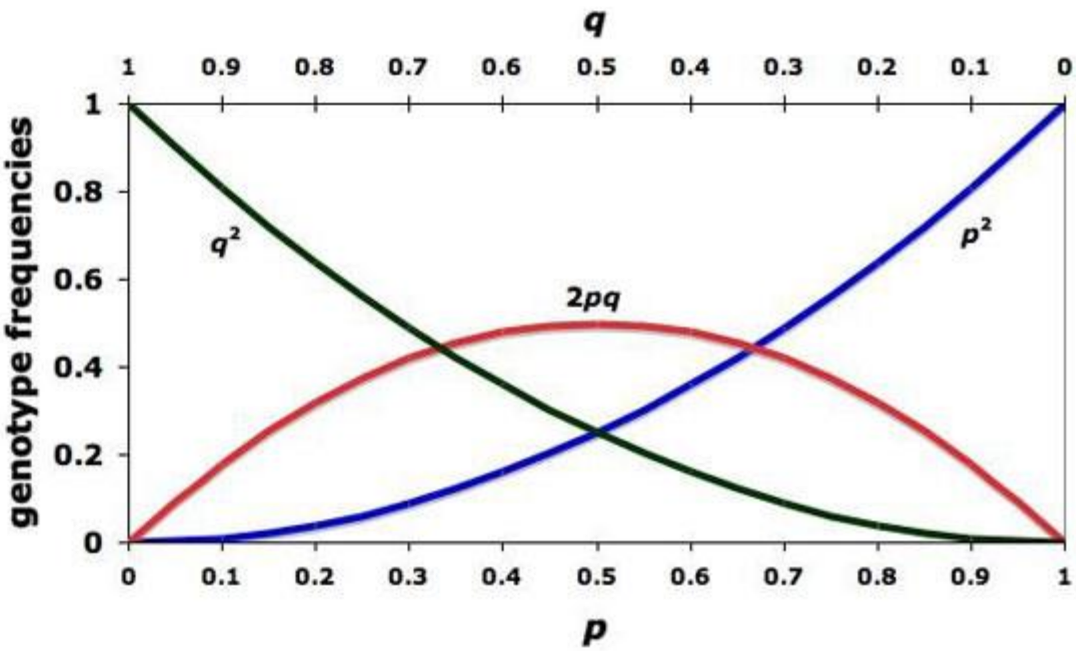


Figure 4: A plot of Hardy-Weinberg equilibrium genotype frequencies (p to the 2, 2pq, q to the 2) as a function of allele frequencies (p and q).

Selection, mutation, migration, and genetic drift are the mechanisms that effect changes in allele frequencies, and when one or more of these forces are acting, the population violates Hardy-Weinberg assumptions, and evolution occurs. The Hardy-Weinberg Theorem thus constitutes a null model for the discipline of population genetics, and is fundamental to the study of evolution.

Development and Evolution

The relationships that obtain between development and evolution are complicated and under ongoing investigation (for a review, see Love 2015). Two main axes dominate within a loose conglomeration of research programs (Raff 2000; Müller 2007): (a) the evolution of development, or inquiry into the pattern and processes of how ontogeny varies and changes over time; and, (b) the developmental basis of evolution, or inquiry into the causal impact of ontogenetic processes on evolutionary trajectories—both in terms of constraint and facilitation. Two examples where the concepts and practices of developmental and evolutionary biology intersect are treated here: the problematic appeal to functional homology in developmental genetics that is meant to underwrite evolutionary generalizations about ontogeny (Section 5.1) and the tension between using normal stages for developmental investigation and determining the evolutionary significance of phenotypic plasticity (Section 5.2). These cases expose some of the philosophical issues inherent in how development and evolution can be related to one another.

5.1 Functional Homology in Developmental Genetics

The conserved role of *Hox* genes in axial patterning is referred to as functionally homologous across animals (Manak and Scott 1994), over and above the relation of structural homology that obtains between DNA sequences. And yet "functional homology" is a contradiction in terms (Abouheif et al. 1997) because the definition of a homologue is "the same organ in different animals under every variety of form and function" (Owen 1843: 379)—the descendant, evolutionary distinction between homology (structure) and analogy (function) is founded on this recognition. Therefore, the idea of functional homology appears theoretically confused and there is a conceptual tension in its use by molecular developmental biologists.

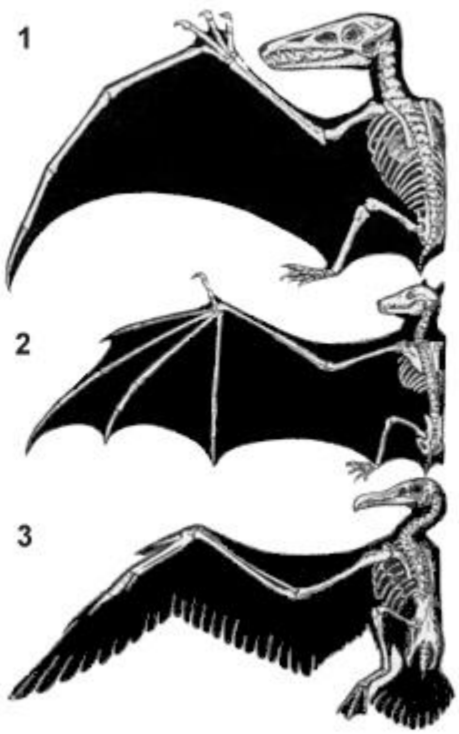


FIGURE 6: Vertebrate wings are homologous as forelimbs; they are derived by common descent from the same structure. The function of vertebrate wings (i.e., flight) is analogous; although the wings fulfill similar functions, their role in flight has evolved separately.

The reference to "organ" in Owen's definition is indicative of a structure (an entity) found in an organism that may vary in its shape and composition (form) or what it is for (function) in the species where it occurs. Translated into an evolutionary context, sameness is cashed out by reference to common ancestry. Since structures also can be similar by virtue of natural selection operating in similar environments, homology is contrasted with analogy. Homologous structures are the same by virtue of descent from a common ancestor, regardless of what functions these structures are involved in, whereas analogous structures are similar by virtue of selection processes favoring comparable functional outcomes, regardless of common descent (Figure 6).

This is what makes similarity of function an especially problematic criterion of homology (Abouheif et al. 1997). Because functional similarity is the appropriate relation for analogy, it is not necessary for analogues to have the same function as a consequence of common ancestry—similarity despite different origins suffices (Ghiselin 2005). Classic cases of analogy involve taxa that do not share a recent common ancestor that exhibits the structure, such as the external body morphology of dolphins and tuna (Pabst 2000). Thus, functional homology seems to be a category error because what a structure does should not enter into an evaluation of homologue correspondence and similarity of function is often the result of adaptation via natural selection to common environmental demands, not common ancestry.

Although we might be inclined to simply prohibit the terminology of functional homology, its widespread use in molecular and developmental biology should at least make us pause.[18] While it is important to recognize this pervasive practice, some occurrences may be illicit. Swapping structurally homologous genes between species to rescue mutant or null phenotypes is not a genuine criterion of functional homology, especially when there is little or no attention to establishing a phylogenetic context. This makes a number of claims of functional homology suspect. To not run afoul of the conceptual tension, explicit attention must be given to the meaning of “function.” Biological practice harbors at least four separate meanings of function (Wouters 2003, 2005): activity (what something does), causal role (contribution to a capacity), fitness advantage or viability (value of having something), and selected effect or etiology (origination and maintenance via natural selection). Debate has raged about which of them (if any) is most appropriate for different aspects of biological and psychological reasoning or most general in scope (i.e., what makes them all function concepts?) (see discussion in Garson 2016). Here the issue is whether we can identify a legitimate concept of homology of function.

If we are to avoid mixing homology and analogy, then the appropriate notion of function cannot be based on selection history, which is allied with the concept of analogy and concerns a particular variety of function. Similarly, viability interpretations concentrate on features where the variety of function is critical because of conferred survival advantages. Any interpretation of function that relies on a particular variety of function (because it was selected or because it confers viability) clashes with the demand that homology concern something “under every variety of form and function.” A causal role interpretation emphasizes a systemic capacity to which a function makes a contribution. It too focuses on a particular variety of function, though in a way different from either selected effect or viability interpretations. Only an activity interpretation (‘what something does’) accents the function itself, apart from its specific contribution to a systemic capacity and position in a larger context. Therefore, the most appropriate meaning to incorporate into homology of function is “*activity*-function” because it is at least possible for activity-functions to remain constant under every variety. An evaluation of sameness due to common ancestry is made separately from the role the function plays (or its use), whether understood in terms of a causal role, a fitness advantage, or a history of selection.[19] *Activity*-functions can be put to different uses while being shared via common descent (i.e., homologous). More precisely, homology of function can be defined as the same activity-function in different animals under every variety of form and use-function (Love 2007). This unambiguously removes the tension that plagued functional homology.

Careful discussions of regulatory gene function in development and evolution recognize something akin to the distinction between activity- and use-function (i.e., between what a gene does and what it is for in some process within the organism).

When studying the molecular evolution of regulatory genes, their biochemical and developmental function must be considered separately. The biochemical function of *PAX-6* and *eyeless* are as general transcription factors (which bind and activate downstream genes), but their developmental function is their specific involvement in eye morphogenesis (Abouheif 1997: 407).

The biochemical function is the activity-function and the developmental function is the use-function. This distinction helps to discriminate between divergent evolutionary trajectories. Biochemical (activity-functions) of genes are often conserved (i.e., homologous), while simultaneously being available for co-option to make causal role contributions (use-functions) to distinct developmental processes. The same regulatory genes are evolutionarily stable in terms of activity-function and evolutionarily labile in terms of use-function.[20] By implication, claims about use-function homology for genes *qua* developmental function are suspect compared to those concerning activity-function homology for genes *qua* biochemical function because developmental functions are more likely to have changed as phylogenetic distance increases.

The distinction between biochemical (activity) function and developmental (use) function is reinforced by the hierarchical aspects of homology (Hall 1994). A capacity defining the use-function of a regulatory gene at one level of organization, such as axial patterning, must be considered as an activity-function itself at another level of organization, such as the differentiation of serially repeated elements along a body axis. (Note that “level of organization” need not be compositional and thus the language of “higher” and “lower” levels may be inappropriate.) The developmental roles of *Hox* genes in axial patterning may be conserved by virtue of their biochemical activity-function homologies but *Hox* genes are not use-function homologues because of these developmental roles. Instead of focusing on the activity of a gene component and its causal role in axial patterning, we shift to the activity of axial patterning and its causal role elsewhere (or elsewhen) in embryonic development.

Introducing a conceptually legitimate idea of homology of activity-function is not about keeping the ideas of developmental biology tidy. It assists in the interpretation of evidence and circumscribes the inferences drawn. For example, *NK-2* genes are involved in mesoderm specification, which underlies muscle morphogenesis. In *Drosophila*, the expression of a particular *NK-2* gene (*tinman*) is critical for both cardiac and visceral mesoderm development. If *tinman* is knocked out and transgenically replaced with its vertebrate orthologue, *Nkx2-5*, only visceral mesoderm specification is rescued; the regulation of cardiac mesoderm is not (Ranganayakulu et al. 1998). A region of the vertebrate protein near the 5′ end of the polypeptide differs enough to prevent appropriate regulation in cardiac morphogenesis. The homeodomains (stretches of sequence that confer DNA binding) for vertebrate *Nkx2-5* and *Drosophila tinman* are interchangeable. The inability of *Nkx2-5* to rescue cardiac mesoderm specification is not related to the activity-function of differential DNA binding. One component of the orthologous (homologous) proteins in both species retains an activity-function homology related to visceral mesoderm specification but another component (not the homeodomain) has diverged. This homeobox gene does not have a single use-function (as expected), but it also does not have a single activity-function. Any adequate evaluation of these cases must recognize a more fine-grained decomposition of genes into working units to capture genuine activity-function conservation. We can link activity-function homologues directly to structural motifs within a gene, but there is not necessarily a single activity-function for an entire open reading frame.

Defusing the conceptual tensions between developmental and evolutionary biology with respect to homology of function has a direct impact on the causal generalizations and inferences made from model organisms (Section 4). Activity-function homology directs our attention to the stability or conservation of activities. This conservation is indicative of when the study of mechanisms in model organisms will produce robust and stable generalizations (Section 1.3). The widespread use of functional homology in developmental biology is aimed at exactly this kind of question, which explains its persistence in experimental biology despite conceptual ambiguities. Generalizations concerning molecular signaling cascades are underwritten by the coordinated biochemical activities in view, not the developmental roles (though sometimes they may coincide). Thus, activity-function details about a signaling cascade gleaned from a model organism can be generalized via homology to other unstudied organisms even if the developmental role varies for the activity-function in other species.

Adaptive Radiation

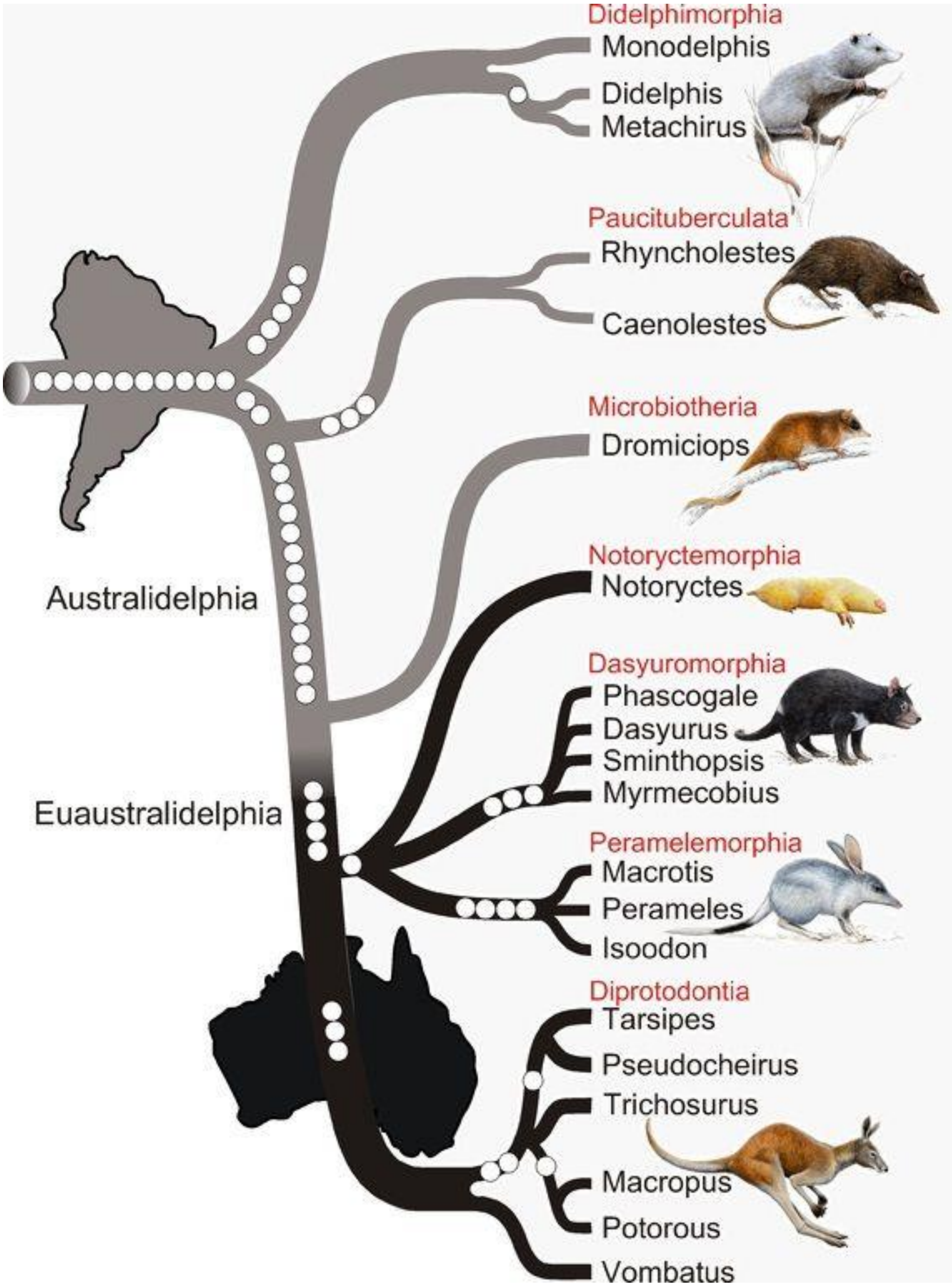
Adaptive Radiation Examples

Examples of adaptive radiation are all around us, in every living organism. No organism today is exactly the same as its original ancestor. Some species have changed significantly, such as the diversification from a single species into the elephant and the hyrax. One only has to look at the image below to understand how the selection of a different habitat or even a similar habitat but a different choice of diet can cause huge anatomical and physiological changes during the process of adaptive radiation.

Bush hyrax – the elephant's closest relative

Marsupials

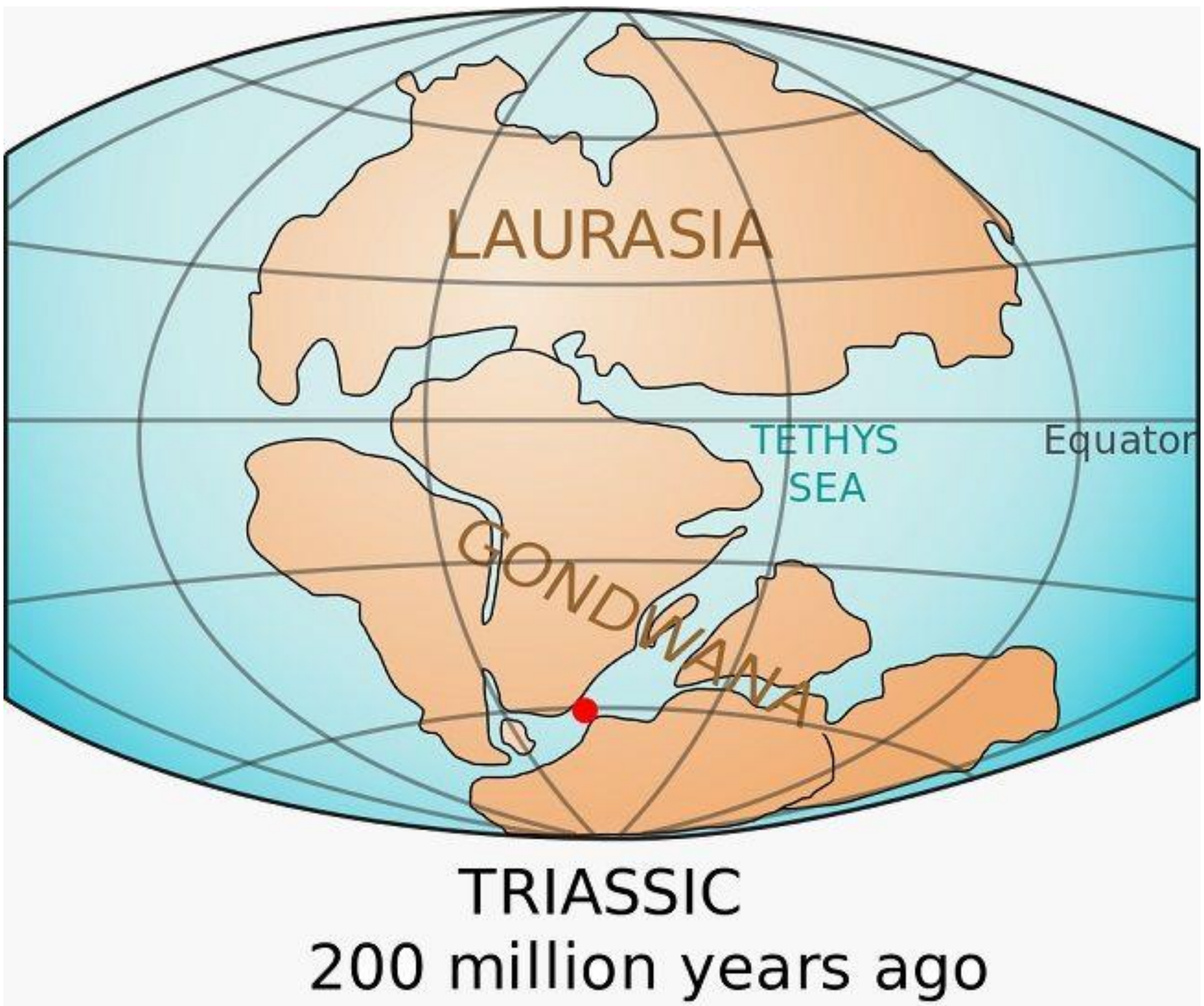
One of the most common examples of the theory of adaptive radiation is the dispersion and diversification of the marsupials (metatherians) into different orders and species. Marsupials have **developed from a single ancestor into multiple, diverse forms**. This has happened in a continent completely cut off from the influence of many other species.



Marsupial radiation

In the image above, seven orders of marsupials are shown with grey and black lines indicating South American and Australian habitats respectively. Yet each order has diversified from its superorder (Euaustralidelphia) through [adaptation](). Each order can better survive thanks to a specific adaptation to a different habitat.

This independent evolution in response to particular aspects of the environment is also mimicked across the globe by placental mammals. Many marsupials have developed in extremely similar ways to placental mammals living in similar environments, even though they have been cut off from these other populations since the breakup of the supercontinent known as Gondwana. This process has not yet ended. Today, Australia crawls to the north at a rate of about 3 centimeters per year.



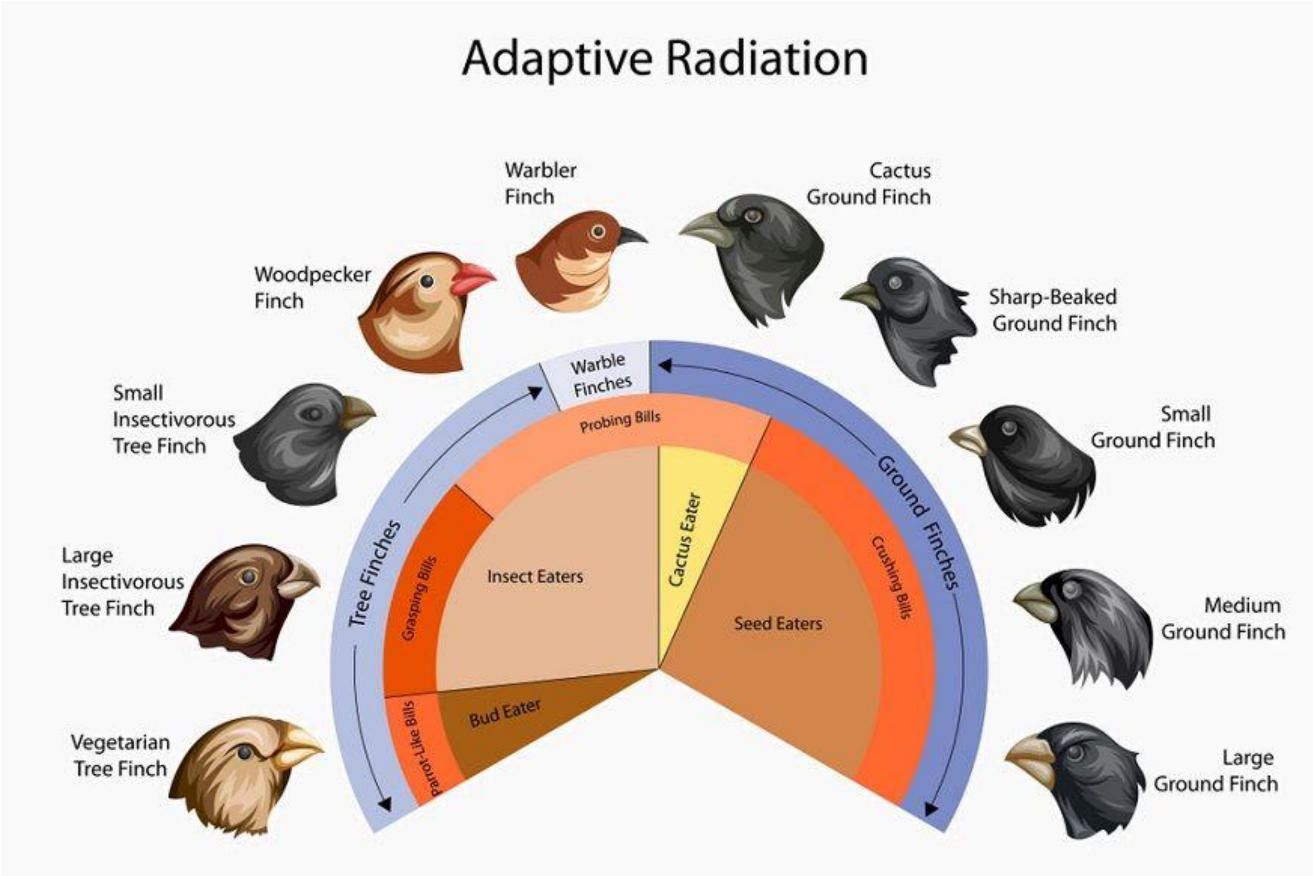
Early supercontinents – Gondwana and Laurasia

This separation of species, yet with similarities in both adaptations and environments, tells us that **biodiversity is usually the result of adaptive radiation**.

Darwin's Finches

The most commonly quoted example of adaptive radiation is Darwin's finches, discovered during Darwin's voyage to the Galápagos archipelago. **Speciation is the development of one of multiple new species in the evolutionary process**, where the original species produces mutated forms which successfully survive in other environments due to these mutations. In the case of Darwin's finches, adaptations occurred relatively rapidly. Blown over to various islands with different flora and fauna, beak morphology might ensure either the survival or the death of a bird. For example, warbler finches and ground finches have evolved from a common ancestor. Warbler finches have long, thin beaks perfect for eating insects. Ground finches have thick, blunt beaks ideal for breaking over the husks of nuts and seeds.

The fifteen species of finches found at the Galápagos archipelago make up a monophyletic group, or **a group of organisms all descended from one ancestral species**. The common ancestor is not known due to a lack of DNA, but fossils from two species of ground finches, *Geospiza nebulosi* and *Geospiza magnirostris* have the thick, blunt beaks of their descendants. This would indicate that warbler finches are the result of speciation through the process of adaptive radiation. Upon landing on an island with few nuts and seeds but many insects, those specimens with longer, thinner beaks (mutations) were more likely to survive and reproduce. **Natural selection** increased the survival rates of long-beaked birds on this island where they interbred, eventually leading to a phenotype common to this new species.



Adaptive radiation in Galápagos finches

Skin Color

Human skin color is another example of adaptive radiation. The color of the skin is regulated by the presence of melanin, a natural pigment which in higher quantities can absorb ultra-violet light and protect the dermis. People with light complexions mainly produce pheomelanin which has a reddish-yellow hue, while those with dark-colored skin primarily produce eumelanin which is dark brown in color.

Under the rays of the sun, vitamin D synthesis is stimulated, while folate degrades. Folate is necessary for early fetal development and is partially regulated by UV exposure. Too little or too much sun can dysregulate folate levels. While the current theories of the human race originating from an African location are under discussion, using this model to explain adaptive radiation is helpful. In fact, **this model can be used to explain two different types of adaptive radiation**.

The first concerns very early ancestors of man (the hominids) who were largely covered with hair to keep them warm in largely forested areas. Hominid skin, protected by hair, was almost definitely not as dark as his early descendants. We do not have the fossil evidence to prove this, but mammals usually have much lighter skin when covered in thick layers of hair or fur, as opposed to mammals with thin coats. Upon migrating to more open savannahs where the hominids could hunt more successfully but directly under the rays of the equatorial sun, this hair became superfluous. To be protected from the UV rays of the sun they developed darker skin. This darker skin reduced the degradation of folic acid, meaning higher pregnancy and birth rates, while the constant availability of the equatorial sun meant that vitamin D production was sufficient to ensure good health.

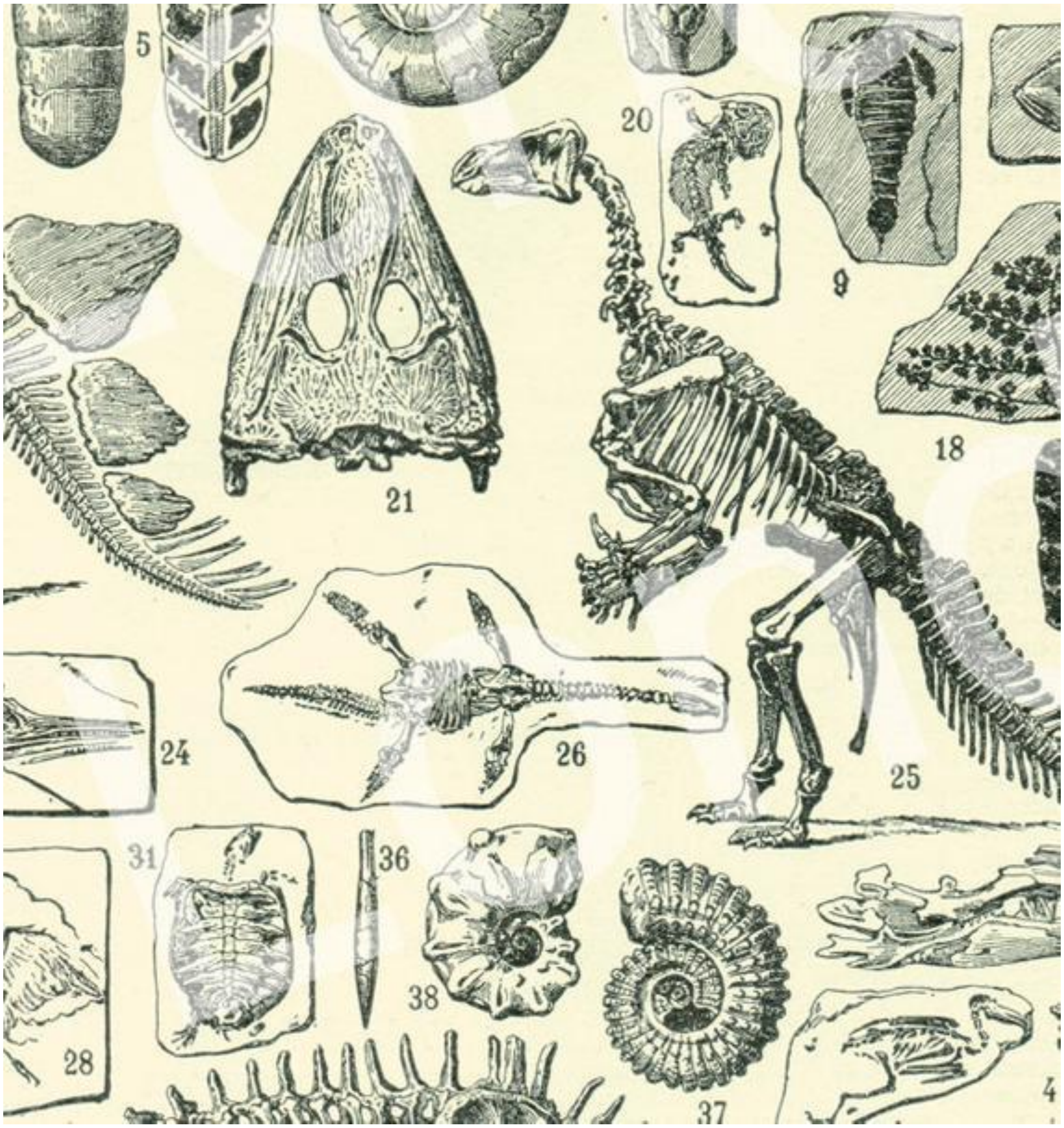
When these populations eventually moved away from the heat of the equator and into colder regions high levels of melanin became more of a hindrance to the **health and reproductive capacity** of this migrating population. Skin did not need as much melanin to protect it from the meager sun; those with darker skin would block what little UV light there was and synthesize less vitamin D, leading to lower levels of health and fitness (rickets) and dysregulated folate levels (miscarriages).

Those who migrated to the far northern regions of the Arctic Circle became slightly lighter in color, but darker than would usually be expected according to this theory. This has been explained by their seafood diets which provide ample dietary vitamin D during the colder seasons, while a darker skin color protected these populations from the UV radiation of the sun further reflected by the snow-covered landscape during spring and summer months. Research today tells us that the female Inuit population are more likely to experience folic acid deficiencies than lighter-skinned females in colder, temperate regions unless they eat folate-fortified foods. This is perhaps the reason why the color of their skin is not darker.

Reference:

https://biologydictionary.net/adaptive-radiation/

Paleontology



Paleontology is the study of the history of life on Earth as based on fossils. Fossils are the remains of plants, animals, fungi, bacteria, and single-celled living things that have been replaced by rock material or impressions of organisms preserved in rock.

Paleontology is the study of the history of life on Earth as based on fossils. Fossils are the remains of plants, animals, fungi, bacteria, and single-celled living things that have been replaced by rock material or impressions of organisms preserved in rock. Paleontologists use fossil remains to understand different aspects of extinct and living organisms. Individual fossils may contain information about an organism's life and environment. Much like the rings of a tree, for example, each ring on the surface of an oyster shell denotes one year of its life. Studying oyster fossils can help paleontologists discover how long the oyster lived, and in what conditions. If the climate was favorable for the oyster, the oyster probably grew more quickly and the rings would be thicker. If the oyster struggled for survival, the rings would be thinner. Thinner rings would indicate an environment not favorable to organisms like the oyster—too warm or too cold for the oyster, for example, or lacking nutrients necessary for them to grow.

Some fossils show how an organism lived. Amber, for instance, is hardened, fossilized tree resin. At times, the sticky resin has dripped down a tree trunk, trapping air bubbles, as well as small insects and some organisms as large as frogs and lizards. Paleontologists study amber, called "fossil resin," to observe these complete specimens. Amber can preserve tissue as delicate as dragonfly wings. Some ants were trapped in amber while eating leaves, allowing scientists to know exactly what they ate, and how they ate it. Even the air bubbles trapped in amber are valuable to paleontologists. By analyzing the chemistry of the air, scientists can tell if there was a volcanic eruption or other atmospheric changes nearby.

The behavior of organisms can also be deduced from fossil evidence. Paleontologists suggest that hadrosaurs, duck-billed dinosaurs, lived in large herds, for instance. They made this hypothesis after observing evidence of social behavior,including a single site with approximately 10,000 skeletons.

Fossils can also provide evidence of the evolutionary history of organisms. Paleontologists infer that whales evolved from land-dwelling animals, for instance. Fossils of extinct animals closely related to whales have front limbs like paddles, similar to front legs. They even have tiny back limbs. Although the front limbs of these fossil animals are in some ways similar to legs, in other ways they also show strong similarities to the fins of modern whales.

Subdisciplines of Paleontology

The field of paleontology has many subdisciplines. A subdiscipline is a specialized field of study within a broader subject or discipline. In the case of paleontology, subdisciplines can focus on a specific fossil type or a specific aspect of the globe, such as its climate.

Vertebrate Paleontology

One important subdiscipline is vertebrate paleontology, the study of fossils of animals with backbones. Vertebrate paleontologists have discovered and reconstructed the skeletons of dinosaurs, turtles, cats, and many other animals to show how they lived and their evolutionary history.

Using fossil evidence, vertebrate paleontologists deduced that pterosaurs, a group of flying reptiles, could fly by flapping their wings, as opposed to just gliding. Reconstructed skeletons of pterosaurs have hollow and light bones like modern birds.

One type of pterosaur, *Quetzalcoatlus*, is considered one of the largest flying creatures in history. It had a wingspan of 11 meters (36 feet). Paleontologists have competing theories about if and how *Quetzalcoatlus* flew. Some paleontologists argue it was too heavy to fly at all. Others maintain it could distribute its weight well enough to soar slowly. Still other scientists say *Quetzalcoatlus* was muscular enough to fly quickly over short distances. These theories demonstrate how vertebrate paleontologists can interpret fossil evidence differently.

Invertebrate Paleontology

Invertebrate paleontologists examine the fossils of animals without backbones—

mollusks, corals, arthropods like crabs and shrimp, echinoderms like sand dollars and sea stars, sponges, and worms. Unlike vertebrates, invertebrates do not have bones—they do leave behind evidence of their existence in the form of fossilized shells and exoskeletons, impressions of their soft body parts, and tracks from their movement along the ground or ocean floor.

Invertebrate fossils are especially important to the study and reconstruction of prehistoric aquatic environments. For example, large communities of 200-million-year-old invertebrate marine fossils found in the deserts of Nevada, in the United States, tell us that certain areas of the state were covered by water during that period of time.

Darwin's *On The Origin of Species* observed somewhat similar sequencing in the living world. Darwin suggested that new species evolve over time. New fossil discoveries supported Darwin's theory that creatures living in the distant past were different from, yet sometimes interconnected with, those living today. This theory allowed paleontologists to study living organisms for clues to understanding fossil evidence. The *Archaeopteryx*, for example, had wings like a bird, but had other features (such as teeth) typical of a type of dinosaur called a theropod. Now regarded as a very early bird, *Archaeopteryx* retains more similarities to theropods than does any modern bird. Studying the physical features of *Archaeopteryx* is an example of how paleontologists and other scientists establish a sequence, or ordering, of when one species evolved relative to another.

The dating of rock layers and fossils was revolutionized after the discovery of radioactivity in the late 1800s. Using a process known as radiometric dating, scientists can determine the age of a rock layer by examining how certain atoms in the rock have changed since the rock formed. As atoms change, they emit different levels of radioactivity. Changes in radioactivity are standard and can be accurately measured in units of time.

By measuring radioactive material in an ancient sample and comparing it to a current sample, scientists can calculate how much time has passed. Radiometric dating allows ages to be assigned to rock layers, which can then be used to determine the ages of fossils.

Paleontologists used radiometric dating to study the fossilized eggshells of *Genyornis*, an extinct bird from Australia. They discovered that *Genyornis* became extinct between 40,000 and 50,000 years ago. Fossil evidence from plants and other organisms in the region shows that there was abundant food for the large, flightless bird at the time of its extinction. Climate changes were too slow to explain the relatively quick extinction.

By studying human fossils and ancient Australian cave paintings that were dated to the same time period, paleontologists hypothesized that human beings—the earliest people to inhabit Australia—may have contributed to the extinction of *Genyornis*.

Paleontology Today

Modern paleontologists have a variety of tools that help them discover, examine, and describe fossils. Electron microscopes allow paleontologists to study the tiniest details of the smallest fossils. X-ray machines and CT scanners reveal fossils' internal structures. Advanced computer programs can analyze fossil data, reconstruct skeletons, and visualize the bodies and movements of extinct organisms.

Paleontologists and biologists used a CT scan to study the preserved body of a baby mammoth discovered in Siberia in 2007. A CT scanner allows scientists to construct 3-D representations of the bones and tissue of the organism. Using this technology, scientists were able to see that the baby mammoth had healthy teeth, bones, and muscle tissue. However, the animal's lungs and trunk were full of mud and debris. This suggested to scientists that the animal was healthy, but most likely suffocated in a muddy river or lake.

Scientists can even extract genetic material from bones and tissues.

Paleontologists made a remarkable genetic discovery when the bones of a *Tyrannosaurus rex* were broken during an excavation in the 1990s. Soft tissue was discovered inside the bones. Soft tissue is the actual connective tissue of an organism, such as muscle, fat, and blood. Soft tissue is rarely preserved during fossilization. Paleontologists usually must rely on fossilized remains—rocks. Paleontologists now hope to use this rare discovery of 68-million-year-old tissue to study the biology and possibly even the DNA of the *T. rex*.

Even with all these advancements, paleontologists still make important discoveries by using simple tools and basic techniques in the field.

The National Geographic Society supports field work in paleontology throughout the world. Emerging Explorer Zeresenay "Zeray" Alemseged conducts studies in northern Ethiopia.

There, Alemseged and his colleagues unearth and study fossils that contribute to the understanding of human evolution.

Emerging Explorer Bolortsetseg Minjin is a paleontologist who has found fossils of dinosaurs, ancient mammals, and even corals in the Gobi Desert of Mongolia. She also works to teach Mongolian students about the dinosaurs in their backyard, and is hoping to establish a paleontology museum in the country.

Reference:

https://www.nationalgeographic.org/encyclopedia/paleontology/#:~:text=Paleontology%20is%20the%20study%20of,of%20organisms%20preserved%20in%20rock.

Evolution of modern humans

The origin of modern humans has probably been the most debated issue in evolutionary biology over the last few decades.

Where did we come from?

"The exact origin of modern humans has long been a topic of debate.

Our evolutionary history is written into our genome[?]. The human genome looks the way it does because of all the genetic changes that have affected our ancestors. The exact origin of modern humans has long been a topic of debate.

KEY FACT

Modern humans originated in Africa within the past 200,000 years and evolved from their most likely recent common ancestor, *Homo erectus*.

Modern humans (*Homo sapiens*), the species[?] that we are, means 'wise man' in Latin. Our species is the only surviving species of the genus *Homo* but where we came from has been a topic of much debate. Modern humans originated in Africa within the past 200,000 years and evolved from their most likely recent common ancestor, *Homo erectus*, which means 'upright man' in Latin. *Homo erectus* is an extinct species of human that lived between 1.9 million and 135,000 years ago.

Historically, two key models have been put forward to explain the evolution[?] of *Homo sapiens*. These are the 'out of Africa' model and the 'multi-regional' model. The 'out of Africa' model is currently the most widely accepted model. It proposes that *Homo sapiens* evolved in Africa before migrating across the world.

On the other hand, the 'multi-regional' model proposes that the evolution of *Homo sapiens* took place in a number of places over a long period of time. The intermingling of the various populations eventually led to the single *Homo sapiens* species we see today.

"Current genomic evidence supports a single 'out-of Africa' migration of modern humans.

This is still very much an area of active research, however, current genomic evidence supports a single 'out-of Africa' migration of modern humans rather than the 'multi-regional' model. Although, studies of the genomes? of the extinct hominids Neanderthals and Denisovans suggest that there was some mixing of genomes (1-3 per cent) with humans in Europe and Asia. This interbreeding between two previously separated populations is called 'admixture' and results in a mixing of genes? between the populations.

'Out of Africa': what's the evidence?

'Mitochondrial Eve'

KEY FACT

There is more genetic diversity in Africa compared with the rest of the world put together.

Genetic studies tend to support the 'out of Africa' model. The highest levels of genetic variation? in humans are found in Africa. In fact there is more genetic diversity in Africa compared with the rest of the world put together. In addition, the origin of modern DNA? in the mitochondria (the 'powerhouses' of our cells) has been tracked back to just one African woman who lived between 50,000 and 500,000 years ago – 'Mitochondrial Eve'.

Our genomes are a combination of DNA from both our mother and father. However, mitochondrial DNA (mtDNA) comes solely from our mother. This is because the female egg contains large amounts of mitochondrial DNA, whereas the male sperm contains just a tiny amount. The sperm use their small amount of mitochondria to power their race to their egg before fertilisation. Once a sperm merges with an egg, all the sperm mitochondria are destroyed.

KEY FACT

Your mitochondrial DNA is almost exactly the same as your mother's and her mother's.

As a result, mitochondrial DNA is described as being matrilineal (only the mother's side survives from generation to generation). So, your mitochondrial DNA is almost exactly the same as your mother's and her mother's. Mitochondrial DNA has been extensively used by evolutionary biologists, as it is easier to extract than DNA found in the nucleus[?] and there are many copies to work with.

However, Mitochondrial Eve wasn't the first or only woman on Earth at that time. She was simply the point from which all modern generations of human appear to have grown. Evolutionary biologists think the most likely reason for this is that an evolutionary 'bottleneck' occurred during the time Eve was alive. This is when the majority of a species suddenly dies out, perhaps due to a sudden catastrophe, bringing it to the brink of extinction. If Mitochondrial Eve was one of the few women to survive then this could explain why her 'matrilineal' mitochondrial DNA ended up being passed along so many generations.

Similarly, DNA from the Y chromosome[?] is only passed on from fathers to sons and a evolutionary tree relating all present day male individuals also supports the 'out of Africa' model.

Mapping skulls

Further evidence for the 'out of Africa' model can be found in the size of human skulls. After studying the genetics and skull measurements of 53 human populations from around the world, scientists found that as you move further away from Africa, populations are less varied in their genetic makeup. This may be because human populations became smaller as they spread out from their original settlements in Africa and so genetic diversity within these populations was less. As a result the scientists stated that modern humans could not have emerged in different places, but instead had to have come from one region, Africa.

KEY FACT

The oldest known remains of anatomically modern humans are the Omo I and Omo II skulls.

The oldest known remains of anatomically modern humans are the Omo I and Omo II skulls. These were found in 1967 in Omo National Park in south-western Ethiopia. The skulls have been dated to 195,000 years ago, highlighting how humans have evolved relatively recently.

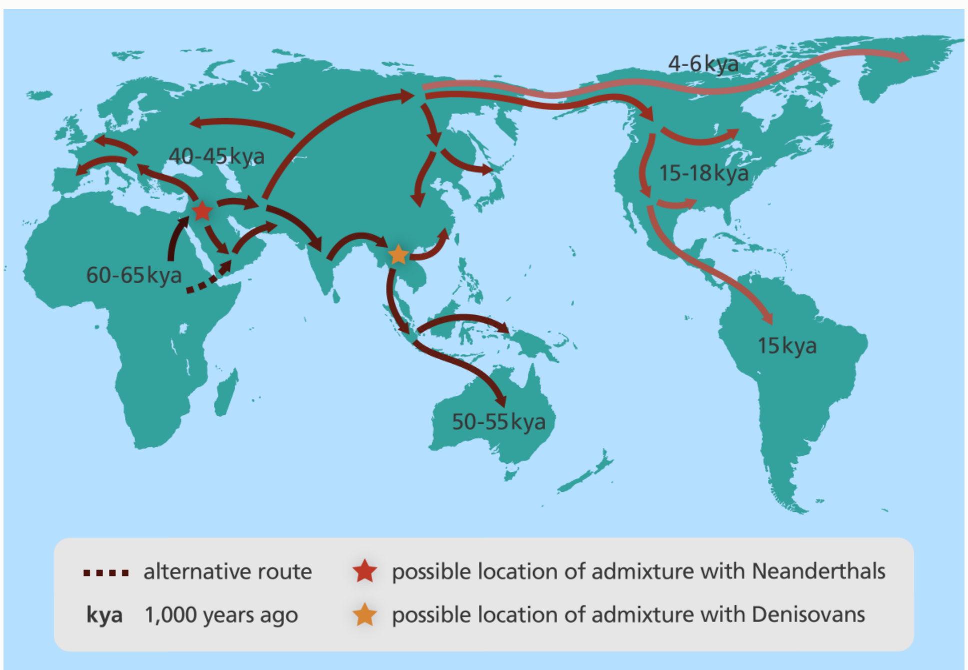
Moving out of Africa

Evidence shows that the first wave of humans to move out of Africa did not have too much success on their travels. At times it appears they were on the brink of extinction, dwindling to as few as 10,000.

The eruption of a super volcano, Mount Toba, in Sumatra 70,000 years ago may have led to a 'nuclear winter', followed by a 1,000-year ice age. This sort of event would have put immense pressure on humans. It may be that humans were only able to survive these extreme conditions through cooperating with each other. This may have led to the formation of close family groups or tribes and the development of some of the modern human behaviours we are familiar with today, such as cooperation.

“Genetically, the six billion people of today’s world vary very little from the Homo sapiens *that ventured out of Africa.*

Between 80,000 and 50,000 years ago another wave of humans migrated out of Africa. These humans are likely to have been ‘modern’ in terms of their appearance and behaviour. Due to their newly cooperative behaviour they were more successful at surviving and covered the whole world in a relatively short period of time. As they migrated they would have encountered earlier, primitive humans, eventually replacing them. Genetically, the six billion people of today’s world vary very little from these earlier *Homo sapiens* that ventured out of Africa.



A map showing human migration out of Africa. Image credit: Genome Research Limited

Admixture with extinct humans: what's the evidence?

Are Neanderthals our cousins or ancestors?

Homo neanderthalis, or Neanderthals as they are more often known, are an extinct species of human that was widely distributed in ice-age Europe and Western Asia between 250,000 and 28,000 years ago. They were characterised as having a receding forehead and prominent brow ridges. In 1856 the first Neanderthal fossil was discovered in the Neander Valley near Düsseldorf in Germany. Since then, researchers have been striving to uncover the position of *Homo neanderthalis* in modern human evolution. *Homo neanderthalis* appeared in Europe about 250,000 years ago and spread into the Near East and Central Asia. They disappeared from the fossil record about 28,000 years ago.

"Have Neanderthal genes contributed to the modern human genome?

Their disappearance has been put down to competition from modern humans, who expanded out of Africa at least 125,000 years ago (100,000-year-old remains of modern humans have been found in Israel), suggesting that there would have been a period of co-existence. Did the two species interbreed? Have Neanderthal genes therefore contributed to the modern human genome?

Initial studies of DNA from the mitochondria of Neanderthals showed that their mitochondrial DNA looks quite different to that of modern humans, suggesting that *Homo neanderthalis* and *Homo sapiens* did not interbreed.

Sequencing the Neanderthal genome

In 2010, scientists from Germany and the USA sequenced the DNA of an entire Neanderthal genome. They also identified another archaic human group called 'Denisovan', named after the Siberian cave in which the fossil finger, from which the DNA was obtained, was discovered. In 2013 they obtained a more refined Neanderthal genome sequence from a 50,000-year-old Neanderthal toe bone, found in the same cave in southern Siberia.

"The genome sequence suggested that early modern non-African humans interbred with their now extinct ancient human cousins.

DNA can survive in bone long after an animal dies. Over time the DNA from various microbes that encounter the skeleton will also invade the bone. As a result, the DNA can be contaminated with microbe DNA. Scientists therefore have to ensure that they sequence only the Neanderthal genome and get rid of any DNA material left behind by these microbes or resulting from contamination by modern humans who handle these bones. As with the human genome sequence, the Denisovan and Neanderthal genome sequences were made available online for free. The genome sequence suggested that early modern non-African humans interbred with their now extinct ancient human cousins as they journeyed along coastlines and over mountains.

KEY FACT

Inbreeding is generally bad for the genetic fitness of a species as it reduces the variation in a population making it more susceptible to disease and illness.

Analysis of the Neanderthal genome revealed that the toe bone came from a woman as it had two X chromosomes. Further analysis showed that each pair of chromosomes was similar in sequence. This suggests that her parents were closely related, perhaps an uncle and a niece. Inbreeding is generally bad for the genetic fitness of a species as it reduces the variation in a population making it more susceptible to disease and illness. This reduced genetic variation could explain why Neanderthals became extinct.

When comparing human genomes to the Neanderthal genome, human genomes resemble each other more than any of them resemble the Neanderthal genome. Some Neanderthal DNA is similar to DNA from people of European and Asian origin but these similarities are not seen in African DNA. This suggests that modern humans evolved in Africa and then expanded out into Asia and Europe, where Neanderthals lived. A degree of interbreeding between Neanderthals and early *Homo sapiens* then occurred in these areas. A study carried out in 2012 estimated that this interbreeding probably took place about 37,000-85,000 years ago and it is estimated that the proportion of Neanderthal-derived DNA in people outside Africa is 1.5-2.1 per cent.

From the past, to the future

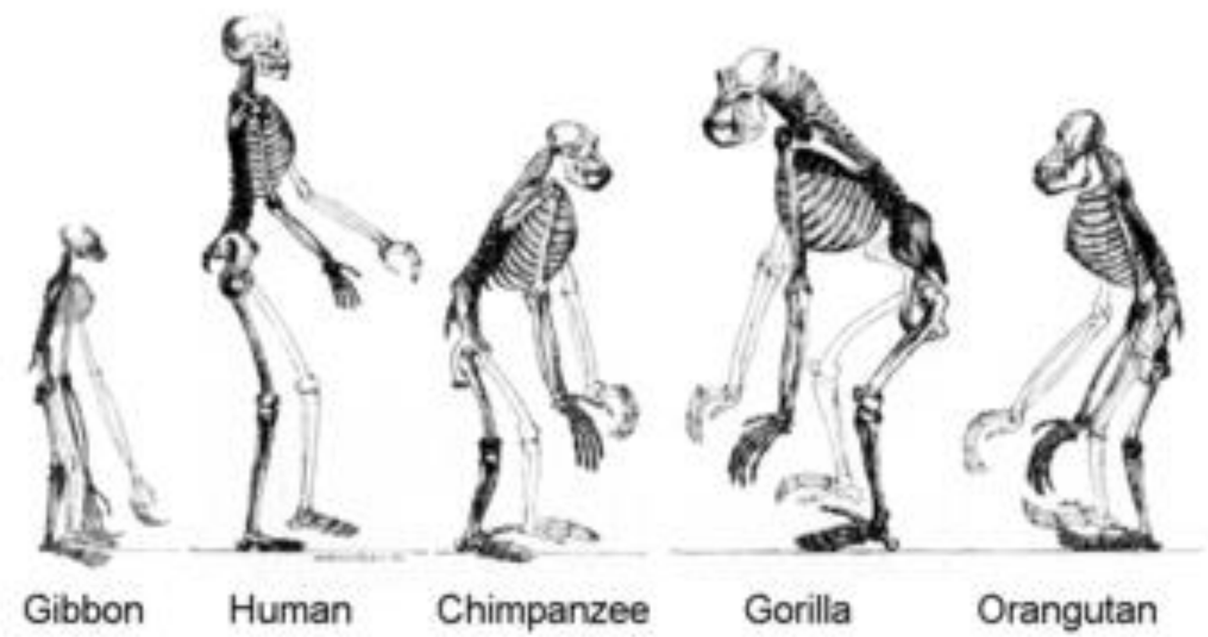
KEY FACT

Scientists have found nine Neanderthal genes in living humans known to be associated with susceptibility to conditions such as type 2 diabetes.

Nowadays, many of us carry a small fraction of DNA from our archaic Neanderthal and Denisovan ancestors. This shared DNA could have shaped our individual susceptibility to modern-day diseases or adaptation to new environments and climates. Scientists have found nine Neanderthal genes in living humans known to be associated with susceptibility to conditions such as type 2 diabetes, lupus and Crohn's disease. It has also been shown that high-altitude adaptation in Tibetans may be a consequence of archaic Denisovan DNA sequence in a region of DNA associated with haemoglobin concentration at high altitudes. Additional research is being carried out to investigate these links further.

Reference:

https://www.yourgenome.org/stories/evolution-of-modern-humans#:~:text=of%20much%20debate.-,Modern%20humans%20originated%20in%20Africa%20within%20the%20past%20200%2C000%20years,million%20and%20135%2C000%20years%20ago.



UNIT – IV

PART-A

Q.NO	QUESTIONS	CO (LEVEL)
1	Assess the value of evolution	4 (5)
2	List the theories of origin of life	4 (1)
3	Analyse the role of natural selectionin animals	4 (5)
4	List the theories of evolution with suitable examples	4 (1)
5	Explain the Hardy-Weinberg principle	4 (2)
6	Establish the formula used by the animals to protect themselves from threat	4 (6)
7	Explain the methods used to determine their age	4 (2)
8	Discuss the significance of determination of age of fossils	4 (1)
9	Criticize the Darwinism in your own views	4 (5)
10	List the advantages and disadvantage of the evolution of human	4 (1)

PART-B

Q.NO	QUESTIONS	CO (LEVEL)
1	Compare the different concepts of evolution	4 (4)
2	Assess the Origin of life with Darwin's theory	4 (5)
3	Formulate the modern synthetic theories of evolution	4 (6)
4	Analyse the fact behind the concept called Natural selection	4 (4)
5	Investigate the importance of Hardy-Weinberg principle	4 (5)
6	Explain the structural and functional adaptations of vertebrates with reference to evolution	4 (2)
7	Grade the animal species based on the Zoo-Geographical distribution	4 (5)
8	Prepare an essay on Palaeontology	4 (3)
9	Sketch the evolution of man with proper explanation.	4 (3)
10	Relate the protective coloration of animals and their survival	4 (4)

SCHOOL OF BIO & CHEMICAL ENGINEERING

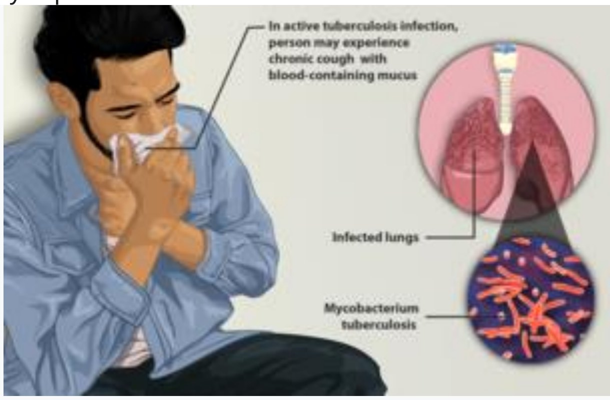
DEPARTMENT OF BIOTECHNOLOGY

SBC1201: ZOOLOGY

UNIT – V - APPLIED ZOOLOGY– SBC1201

Tuberculosis

From Wikipedia, the free encyclopedia



Depiction of a man with tuberculosis .

Tuberculosis (**TB**) is an infectious disease usually caused by *Mycobacterium tuberculosis* (MTB) bacteria.[1] Tuberculosis generally affects the lungs, but can also affect other parts of the body.[1] Most infections show no symptoms, in which case it is known as latent tuberculosis.[1] About 10% of latent infections progress to active disease which, if left untreated, kills about half of those affected.[1] Typical symptoms of active TB are a chronic cough with blood-containing mucus, fever, night sweats, and weight loss.[1] It was historically called **consumption** due to the weight loss.[8] Infection of other organs can cause a wide range of symptoms.[9]

Tuberculosis is spread from one person to the next through the air when people who have active TB in their lungs cough, spit, speak, or sneeze.[1][10] People with latent TB do not spread the disease.[1] Active infection occurs more often in people with HIV/AIDS and in those who smoke.[1] Diagnosis of active TB is based on chest X-rays, as well as microscopic examination and culture of body fluids.[11] Diagnosis of latent TB relies on the tuberculin skin test (TST) or blood tests.[11]

Prevention of TB involves screening those at high risk, early detection and treatment of cases, and vaccination with the bacillus Calmette-Guérin (BCG) vaccine.[3][4][5] Those at high risk include household, workplace, and social contacts of people with active TB.[4] Treatment requires the use of multiple antibiotics over a long period of time.[1] Antibiotic resistance is a growing problem with increasing rates of multiple drug-resistant tuberculosis (MDR-TB).[1]

As of 2018 one quarter of the world's population is thought to have latent infection with TB.[6] New infections occur in about 1% of the population each year.[12] In 2018, there were more than 10 million cases of active TB which resulted in 1.5 million deaths.[7] This makes it the number one cause of death from an infectious disease.[13] As of 2018, most TB cases occurred in the regions of South-East Asia (44%), Africa (24%) and the Western Pacific (18%), with more than 50% of cases being diagnosed in eight countries: India (27%), China (9%), Indonesia (8%), the Philippines (6%), Pakistan (6%), Nigeria (4%) and Bangladesh (4%).[13] The number of new cases each year has decreased since 2000.[1] About 80% of people in many Asian and African countries test positive while 5–10% of people in the United States population test positive by the tuberculin test.[

Dengue fever

From Wikipedia, the free encyclopedia

Dengue fever is a mosquito-borne tropical disease caused by the dengue virus.[1] Symptoms typically begin three to fourteen days after infection.[2] These may include a high fever, headache, vomiting, muscle and joint pains, and a characteristic skin rash.[1][2] Recovery generally takes two to seven days.[1] In a small proportion of cases, the disease develops into a more severe **dengue hemorrhagic fever**, resulting in bleeding, low levels of blood platelets and blood plasma leakage, or into **dengue shock syndrome**, where dangerously low blood pressure occurs.[1][2]

Dengue is spread by several species of female mosquitoes of the *Aedes* genus, principally *Aedes aegypti*.[1][2] The virus has five serotypes;[7][8] infection with one type usually gives lifelong immunity to that type, but only short-term immunity to the others.[1] Subsequent infection with a different type increases the risk of severe complications.[1] A number of tests are available to confirm the diagnosis including detecting antibodies to the virus or its RNA.[2]

A vaccine for dengue fever has been approved and is commercially available in a number of countries.[4][9] As of 2018, the vaccine is only recommended in individuals who have been previously infected, or in populations with a high rate of prior infection by age nine.[10][5] Other methods of prevention include reducing mosquito habitat and limiting exposure to bites.[1] This may be done by getting rid of or covering standing water and wearing clothing that covers much of the body.[1] Treatment of acute dengue is supportive and includes giving fluid either by mouth or intravenously for mild or moderate disease.[2] For more severe cases, blood transfusion may be required.[2] About half a million people require hospital admission every year.[1] Paracetamol (acetaminophen) is recommended instead of nonsteroidal anti-inflammatory drugs (NSAIDs) for fever reduction and pain relief in dengue due to an increased risk of bleeding from NSAID use.[2][11][12]

Dengue has become a global problem since the Second World War and is common in more than 120 countries, mainly in Southeast Asia, South Asia and South America.[5][13][14] About 390 million people are infected a year and approximately 40,000 die.[5][6] In 2019 a significant increase in the number of cases was seen.[15] The earliest descriptions of an outbreak date from 1779.[14] Its viral cause and spread were understood by the early 20th century.[16] Apart from eliminating the mosquitos, work is ongoing for medication targeted directly at the virus.[17] It is classified as a neglected tropical disease.[18]

Malaria

From Wikipedia, the free encyclopedia

Malaria is a mosquito-borne infectious disease that affects humans and other animals.[4][5][2] Malaria causes symptoms that typically include fever, tiredness, vomiting, and headaches.[1] In severe cases, it can cause yellow skin, seizures, coma, or death.[1] Symptoms usually begin ten to fifteen days after being bitten by an infected mosquito.[2] If not properly treated, people may have recurrences of the disease months later.[2] In those who have recently survived an infection, reinfection usually causes milder symptoms.[1] This partial resistance disappears over months to years if the person has no continuing exposure to malaria.[1]

Malaria is caused by single-celled microorganisms of the *Plasmodium* group.[2] The disease is most commonly spread by an infected female *Anopheles* mosquito.[2] The mosquito bite introduces the parasites from the mosquito's saliva into a person's blood.[2] The parasites travel to the liver where they mature and reproduce.[1] Five species of *Plasmodium* can infect and be spread by humans.[1] Most deaths are caused by *P. falciparum*, whereas *P. vivax*, *P. ovale*, and *P. malariae* generally cause a milder form of malaria.[1][2] The species *P. knowlesi* rarely causes disease in humans.[2] Malaria is typically diagnosed by the microscopic examination of blood using blood films, or with antigen-based rapid diagnostic tests.[1] Methods that use the polymerase chain reaction to detect the parasite's DNA have been developed, but are not widely used in areas where malaria is common due to their cost and complexity.[6]

The risk of disease can be reduced by preventing mosquito bites through the use of mosquito nets and insect repellents or with mosquito-control measures such as spraying insecticides and draining standing water.[1] Several medications are available to prevent malaria in travellers to areas where the disease is common.[2] Occasional doses of the combination medication sulfadoxine/pyrimethamine are recommended in infants and after the first trimester of pregnancy in areas with high rates of malaria.[2] As of 2020, there is one vaccine which has been shown to reduce the risk of malaria by about 40% in children in Africa.[7][8] Efforts to develop more effective vaccines are ongoing.[8] The recommended treatment for malaria is a combination of antimalarial medications that includes artemisinin.[9][1][2] The second medication may be either mefloquine, lumefantrine, or sulfadoxine/pyrimethamine.[10] Quinine, along with doxycycline, may be used if artemisinin is not available.[10] It is recommended that in areas where the disease is common, malaria is confirmed if possible before treatment is started due to concerns of increasing drug resistance.[2] Resistance among the parasites has developed to several antimalarial medications; for example, chloroquine-resistant *P. falciparum* has spread to most malarial areas, and resistance to artemisinin has become a problem in some parts of Southeast Asia.[2]

The disease is widespread in the tropical and subtropical regions that exist in a broad band around the equator.[1] This includes much of sub-Saharan Africa, Asia, and Latin America.[2] In 2018 there were 228 million cases of malaria worldwide resulting in an estimated 405,000 deaths.[3] Approximately 93% of the cases and 94% of deaths occurred in Africa.[3] Rates of disease have decreased from 2010 to 2014 but increased from 2015 to 2017, during which there were 231 million cases.[3] Malaria is commonly associated with poverty and has a significant negative effect on economic development.[11][12] In Africa, it is estimated to result in losses of US$12 billion a year due to increased healthcare costs, lost ability to work, and adverse effects on tourism.[13]

Swine/Variant Influenza

Swine influenza is a respiratory disease of pigs caused by type A influenza viruses that regularly cause outbreaks of influenza in pigs. Influenza viruses that commonly circulate in swine are called “swine influenza viruses” or “swine flu viruses.” Like human influenza viruses, there are different subtypes and strains of swine influenza viruses. The main swine influenza viruses circulating in U.S. pigs in recent years have been, swine triple reassortant (tr) H1N1 influenza virus, trH3N2 virus, and trH1N2 virus.

Integrated Pest Management (IPM)

BY **JOLENE HANSEN**

Even if you do everything right when building a healthy garden, pests inevitably show up. But managing your garden with a thoughtful, proactive approach helps prevent pests from doing serious damage. Integrated Pest Management (IPM) combines different types of controls — from hands-on pest removal to traditional synthetic pesticides — in a sensible, long-term plan. Designing your own program around proven IPM principles can help protect your garden and keep it healthy.

Managing Garden Pests Through IPM

IPM sees your garden and its pests as part of a larger ecosystem and manages both with the big picture in mind. By creating an environment that's inhospitable to pests, you can take away their advantage and give it to your plants.

Under IPM, a pest is any organism you don't want around. This not only includes harmful bugs, but also weeds, disease-causing pathogens and uninvited critters. Effective, integrated pest management includes the following tasks:

- **Identify** good and bad bugs.
- **Monitor** pest activity regularly.
- **Set thresholds** for tolerable pest damage — with limits!
- **Establish a plan** before pests cause concern.
- **Take prompt, effective action** when needed.

A solid IPM program wards off pests, but it has minimal impact on the environment and beneficial garden creatures such as birds, bees and butterflies you want to stick around.

Balancing Pest Controls in Your Garden

Four main categories of pest controls form IPM's foundation: cultural, biological, mechanical/physical and pesticide controls. The four work hand in hand to provide targeted, effective, long-term pest management, and each category plays a special role.

Cultural Controls

Cultural pest controls start with the decisions you make when choosing and caring for plants. Prevention is your first line of defense; healthy, nurtured plants resist pests and diseases better than weak, unhealthy plants. Cultural controls in good IPM programs include these simple recommendations:

- **Choose plants suited to your area and its challenges.** Arid, drought-prone regions, for example, call for water-wise plants with low moisture needs.
- **Select disease- and pest-resistant plant varieties.** Plants proven to withstand your region's most common pests hold up better under attack.
- **Plant at appropriate times.** In many regions, fall is prime planting time. Fall and winter planting allow roots to establish before summer heat arrives. This is especially important in southern or western regions. In far northern climates, spring planting is often best for plants with less cold hardiness.
- **Choose proper sites.** Plants have more problems and fail to thrive in inappropriate conditions. For example, sun-loving plants are more vulnerable to pests and other problems when planted in shady areas, and vice versa.
- **Maintain lawn and garden tools.** Sharp mower blades and proper mowing heights lead to healthier lawns. Sharp, sterile pruners help prevent the spread of disease.
- **Avoid overhead watering**. Some leaf diseases, such as common garden fungal diseases or black spot on roses, spread with the help of water. Water the soil at the base of plants, instead of watering leaves.
- **Water in early morning.** If leaves do get wet, they'll dry thoroughly before evening.
- **Test your soil pH**. A simple soil test reveals adjustments that can help your soil's structure and nutrients, so you can feed plants right.

Knowing what your plants need — and providing all they require — gives you the upper hand over pests. Simple, common-sense cultural controls are integral to good IPM.

Biological Controls

All pests, from weeds and insects to diseases, have natural enemies. A balanced pest management program conserves, supports and encourages those foes. Biological IPM controls include:

- **Predator insects:** Adult lady beetles and their larvae are voracious aphid-eaters. Green lacewing larvae feed on all kinds of pests, including mealybugs, whiteflies, mites and thrips. These and other beneficial bugs are probably already in your garden.
- **Parasitic insects:** Parasitic wasps lay their eggs on and in their living targets. Eggs hatch, and then feed inside the pest. A mummified aphid with a round hole in its back is evidence that parasitic wasps have been at work.
- **Biological pathogens:** *Bacillus thuringiensis*, also known as Bt, is a soil-borne bacterium that fights mosquitoes and insects in the larval, caterpillar stage. This and other pathogens are effective biological pesticides for very specific pests.

(Published image, GTech media link in comments)

Knowing the difference between good and bad bugs is essential for IPM. You can buy beneficial predators and parasites, but self-managing your garden's free, natural populations is effective. Keep the good guys plentiful and they'll help keep bad bugs at bay, reducing the need for other measures.

Mechanical and Physical Controls

Mechanical and physical IPM controls go directly after pests to capture or kill them and prevent them from reaching their destinations. IPM recommends proactive lawn and garden controls and actions, including:

- **Use mulch in garden areas**. Mulch prevents weeds and weed seeds from getting light and sprouting.
- **Hoe or pull weeds before they establish roots.** If weeds escape the hoe, mow or cut them before they set and drop their seeds.
- **Place collars in the soil around susceptible vegetable stems.** Simple barriers prevent hungry cutworms and other crawling pests from reaching their goal.
- **Stretch netting over your favorite berry bushes.** This stops marauding birds from settling in and helping themselves to your raspberry and blackberry harvest.
- **Stop destructive rodents with mechanical traps.** Easy-to-use products such as AMDRO® Gopher Traps provide control for troublesome pocket gophers.
- **Hand-pick pests off plants.** This physical control puts an immediate end to pests' plant-damaging days.

Using mechanical and physical controls in concert with other IPM methods keeps many types of pest damage low.

Pesticide Controls

An effective IPM program includes pesticides for prevention and active treatment. Pesticides pack necessary and powerful punches, especially when other IPM controls fall short. Invasive Japanese beetles, for example, devastate gardens and skeletonize leaves and blossoms. In Japan, the beetle's natural enemies control it, but its native predators don't exist in the United States. Pesticides help fill that gap.

IPM-appropriate pesticides include the following types:

- **Traditional or synthetic pesticides:** IPM programs include pesticides manufactured from synthetic ingredients. These include products such as GardenTech® Sevin® brand insecticides, trusted by gardeners for more than 50 years. Sevin® Insect Killer, available in ready-to-use, ready-to-spray, concentrate and granular forms and Sevin®-5 Ready-To-Use Dust are effective on ornamental and edible gardens, lawns and home perimeters to kill Japanese beetles and a broad spectrum of other insect pests as part of a successful IPM program.

- **Natural or non-synthetic pesticides:** Botanical-based pesticides fall into this IPM group. Based on extracts from different types of plants, these natural insecticides include products such as neem oil, based on extracts from the neem tree, or pyrethrins extracted from special chrysanthemum blossoms. Pesticides in this category may or may not be organic. They also require the same types of safety precautions as synthetic pesticides.
- **Preventive pesticides:** IPM incorporates traditional fungicides to help treat fungal disease and prevent it from spreading. The University of California Statewide Integrated Pest Management Program recommends clorothalonil-based products, such as GardenTech® Daconil® Fungicide, to protect healthy plants and prevent botrytis blight and black spot in roses.[1]

By establishing a personalized Integrated Pest Management program for your garden, you can take action — with the right controls — when pests show up, and then rest easy. With IPM principles in mind and GardenTech® brands as your partners, you can build a healthy, harmonious garden.

Always read product labels thoroughly and follow instructions carefully, including guidelines for pre-harvest intervals (PHI) on edible crops and frequency of applications.

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Amdro is a registered trademark of Central Garden & Pet Company.

Daconil is a registered trademark of GB Biosciences Corp.

GardenTech is a registered trademark of Gulfstream Home & Garden, Inc.

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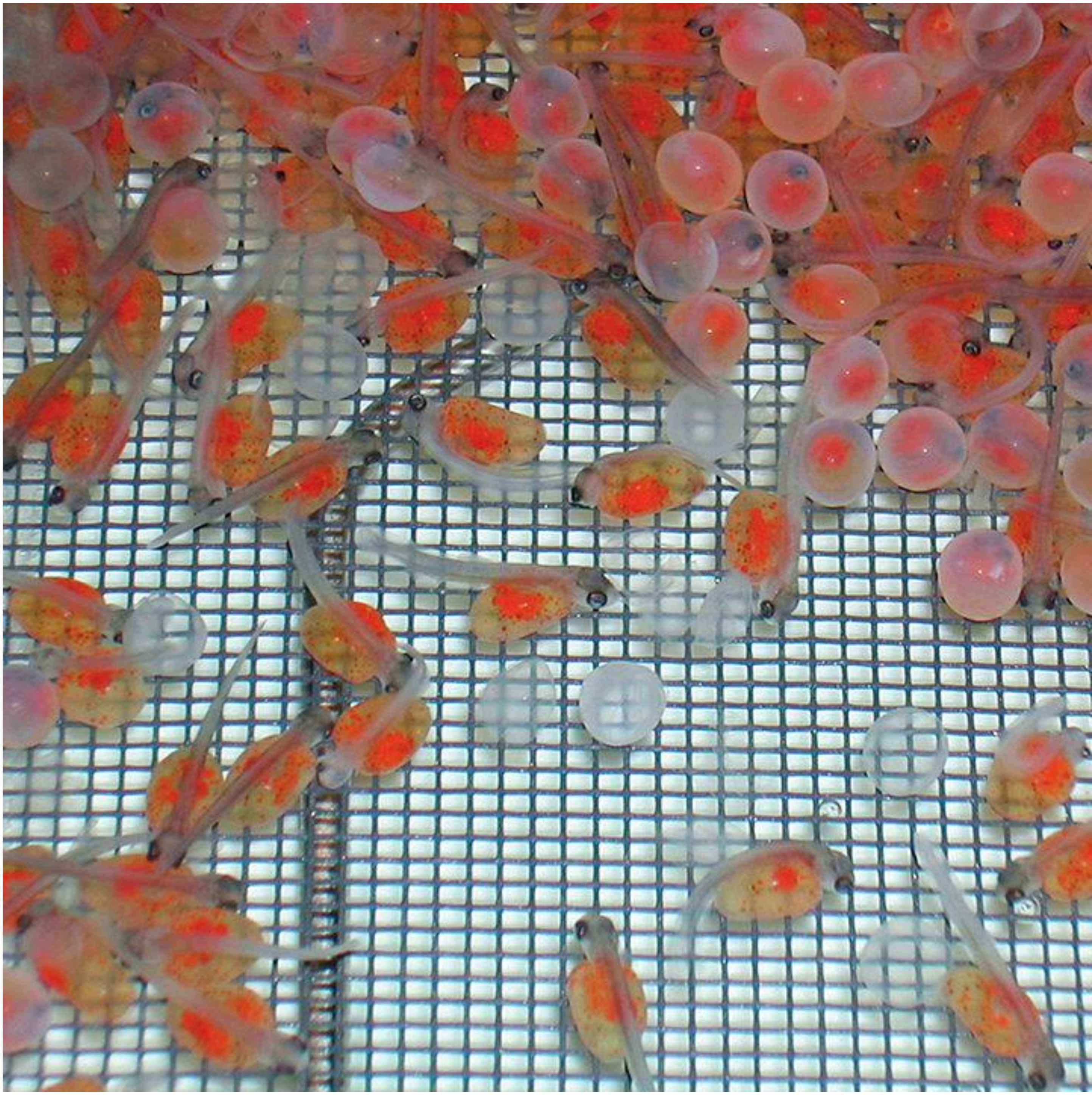
Genetic improvement in aquaculture

Tuesday, 1 February 2005Jeffrey T. Silverstein, Ph.D.

Major challenge will be improving multiple traits in aquatic species



A “batch” of young trout emerge from their eggs during genetic improvement research.

In the transition from wild harvest of a product to agricultural production, genetic improvement is always an important developmental step. The first stage is usually the process of domestication.

Further genetic improvement in agriculture or aquaculture typically has a human focus on enhanced production characteristics.

Just as in terrestrial production scenarios, aquaculturists value faster growth, improved efficiency, less loss to disease, and high quality. Several tools are available to accomplish such genetic improvements.

Domestication

Most stocks of the aquatic organisms most widely grown in captivity are domesticated to some degree, and a few have undergone further genetic improvement. Just as terrestrial livestock and crops are bred to be not only productive, but productive in convenient proximity to humans, aquatic plants and animals are now undergoing these same pressures.

Although the domestication process is arguably at a much earlier stage for aquatic organisms than their terrestrial counterparts, aquaculture is undergoing the process at a time when the technologies and tools available could remarkably speed up domestication and genetic improvement.

Trout from the genetic improvement program at the USDA/ARS National Center for Cool and Cold Water Aquaculture. A challenge for continued genetic development will be to improve multiple performance traits because the relationships among commercially important traits are not well known.

Selective breeding

The basic tool available for genetic improvement, selective breeding, entails choosing the animals with the highest genetic value as breeders for the next generation. To determine this genetic value, populations are raised in a standardized environment so identified differences will be due to differences in genes, not the environment.

This sort of testing is expensive in terms of the facilities required to standardize the environment, maintain consistent rearing, and measure hundreds to thousands of groups. The elite performers are selected for breeding to produce subsequent generations.

This “classical quantitative genetics” approach has been around since the early 20th century, and most of the genetic gains realized through today can be attributed to traditional selective-breeding methods. Yet to think this branch of science has remained static would miss the mark greatly. Improvements in experimental designs, tagging technologies to identify individuals and groups, and computational tools have revolutionized the accuracy and power of these classical techniques.

Selective breeding can be an expensive affair that requires many replicated tanks for estimating genetic effects in a controlled environment.

Genetic markers

Genetic markers include several classes. Amplification fragment length polymorphisms and microsatellite markers are two of the most frequently used genetic markers in aquaculture. They reflect regions of DNA that are used to keep track of specific locations within the genome. The markers are distributed throughout the DNA of an organism and transmitted from parent to offspring.

Genetic markers are useful for determining parentage because offspring share markers with their parents. They are also expected to be useful for identifying regions of DNA that confer performance advantages.

If a particular marker is always found associated with resistance to a coldwater bacterial disease, for example, selection for breeding could be based on the presence of this marker without doing a challenge trial under tightly controlled environmental conditions. This application of selective breeding is referred to as marker-assisted selection.

An important consideration for marker-assisted selection is that traditional approaches relying on direct trait measurements in organisms are expensive. Furthermore, elite performers in disease challenges are usually not used for breeding for fear of transmitting disease, but their close relatives could be used.

A similar situation occurs if traits of interest are measured after test animals are slaughtered. Individuals with high meat quality or fillet yield may not be available for breeding after the traits are measured.

Genetic engineering

Genetic engineering is a broad heading that includes chromosome set manipulations and transgenesis. Chromosome set manipulation is a group of techniques in which sets of chromosomes in organisms are modified.

Whereas normal organisms have two sets of chromosomes – one from each parent – one type of chromosome set manipulation can result in triploids, organisms with three sets of chromosomes. These animals are generally sterile, which can be advantageous under conditions where reproduction is undesirable.

This technology has been applied in the United States to the nonindigenous weed-controlling grass carp to prevent unwanted reproduction. Chromosome manipulation has also been used in oysters, which typically undergo a loss of quality during the spawning season.

Transgenesis

Transgenesis refers to the technique of incorporating a gene or genes through biotechnological methods, not breeding. Soybean plants that have been made resistant to the effects of herbicides are an example of transgenic crops. With a gene from bacteria transferred into and expressed in the plants, their use reduces labor costs for cultivating and weeding. Golden rice, a transgenic rice plant, has three foreign genes inserted from bacteria and daffodils to allow the production of vitamin A in the rice.

The Glofish, a fluorescent zebra-fish which came on the U.S. market in January 2004, is the first transgenic aquatic organism to be marketed. The proteins responsible for making the zebrafish fluoresce are transgenes derived from jellyfish and coral. These fish are not intended for food.

Atlantic salmon with a growth hormone gene from Chinook salmon and a promoter, or switch, from the ocean pout are currently being reviewed by the United States Food and Drug Administration for approval as food fish. Research on other aquatic transgenics with the potential for greater disease resistance, enhanced nutritive value, and other characteristics is ongoing around the world.

Ongoing challenges

Artificial fertilization of trout eggs.

The use of classical breeding techniques remains the foundation upon which genetic improvement will be built for the foreseeable future. These techniques will continue to be refined to offer faster rates of improvement in performance. Incorporating marker information into selective breeding is a challenge, both in terms of the practicalities of identifying marker-trait associations and how to incorporate the information.

Perhaps the major ongoing challenge will be to improve multiple traits in aquatic species. Fast, efficient growth; disease resistance; and product quality are major traits of interest, but the relationships among these traits are not well known. Since the genetic values for traits are not well defined, or multiple traits of interest are not measured on the same individuals, the genetic relationships have not been determined.

In limited cases, the relationships among a subset of these traits are known. For example, the genetic relationship between growth and resistance to viral hemorrhagic septicemia (VHS) in one farmed population of rainbow trout, *Oncorhynchus mykiss*, was shown to be negative. This unfortunately suggested that simply selecting for improvement in growth would result in lowered resistance to VHS.

Especially in cases like this, knowledge of markers associated with disease resistance and improved estimates of genetic value for multiple traits will enable solutions. Current developments in genetic improvement hold the promise that the relatively rare individuals with superior performance for several traits of interest can be identified and selected for breeding.

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Apiculture

Bees are economically important social insects. They not only provide us with honey and wax, they are also responsible for pollination of flowers of the majority of damaged bee larvae, pollen grains, etc. of commercially important plants. The common Indian honey bees are Apis (Megapis) dorsala (Fig. 47.5), A. (microapis) florea and A. indica.

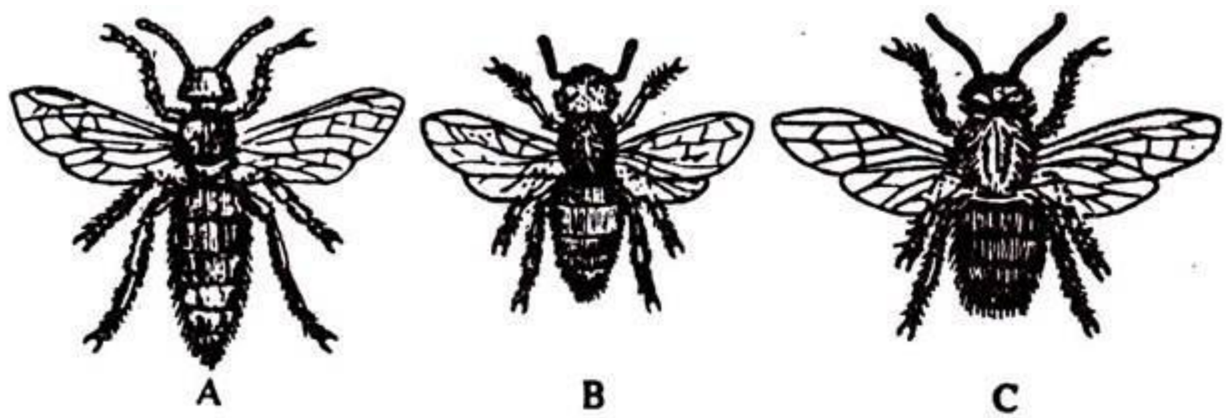

Fig. 47.5. Apis dorsata. A. Queen, B. Worker, C. Drone

Apiculture or bee-keeping is the technique of rearing honey bees for honey and wax from their comb or beehives. Selection of sites for quality honey and protection of bees and combs from pests and diseases are part of apiculture.

Methods of Bee-Keeping in India:

1. Indigenous methods:

a. Immovable structures:

It is practiced in villages from time immemorial. Small structures are made in secluded and protected places. During construction of dwelling houses, small permanent chambers are made in the outer wall of the house for bees to build combs. Sometimes mud chambers are constructed.

On the outer-side of the chamber a horizontal slit is made for the entry of bees, while on the inside wall a large opening is left for removal of comb.

b. Movable structures:

Bee chambers are made up of hollow bags, empty wooden boxes, earthen pots, etc. which can be moved from place to place, and put in a suitable location for the bees. These methods are not much satisfactory, as the comb is lost in the process of extraction of honey. The quality of honey is inferior due to presence of dust, tissues of damaged bee larvae, pollen grains, etc., in it.

2. Modern methods:

Beehive:

In modern apiary, Longs troth's frame hive is most suitable and used commercially for production of honey.

1. It is a two-tier structure. The chambers can be removed from or added to, as required.

2. The hive is made up of wooden box.

a. It has a basal plate or bottom board on which is placed a wooden box called brood chamber.

b. A small opening at the bottom of brood chamber permits passage for bees.

c. Inside the brood chamber several frames hang vertically from the top. These frames can be removed independently. For this arrangement, a modern hive is also called movable frame hive.

d. The distance between the two frames, the bee space is narrow and serves as a passage for the workers but small for building a comb.

e. Above the brood chamber is placed another similar chamber, but of lesser height.

f. It is meant for storage of honey only and known as honey chamber. The queen is never allowed to enter the chamber. In some cases two honey chambers are used.

3. Above the honey chamber an inner covering is placed over which lies the roof.

Tools for Bees Keeping:

1. Comb foundation:

A small piece of comb is necessary to tie with one of the frames from where the bees will start comb-building.

2. Bee gloves:

Leather gloves are used to prevent bees from stinging during handling of the comb and bees.

3. Bee veil:

A bee veil is required to cover neck, face and head of the keeper during handling. Usually it is made of linen.

4. Smoker:

A smoker must be used while capturing bees in a hive. Smoke from paper, wood and coconut cover makes the bees inactive. There is fire box in a smoker in which smoke-producing materials and fire are put. A bellow system is fitted to blow the smoke.

5. Hive tool:

It is a long, narrow and flat piece of steel with a slightly bent head to scrap away dirty materials deposited by bees or some other factors.

6. Honey extractor:

It is used for extraction of honey from the frames without damaging the comb. It consists of a metal drum with several pockets around a rotating wheel. The frames are hanged from the pockets and the pockets are made to rotate round a central axis.

The centrifugal force created by rotation separates honey from the comb which is collected in the drum. The honey is taken out from the drum through a hole at the bottom.- The combs and frames are again placed in the hive.

Typical Location of Apiary:

A locality for apiary must have different varieties of pollen and nector-producing plants in sufficient number within a distance of 1.5 to 2.5 km. area. Neem, Rita, Tamarind, Cheery, Apple, and Citrus, Lily, Lotus, various wild plants and crops are good sources for both nectar and honey.

Diseases of the Bees:

Bees suffer from different contagious diseases and are very often subjected to curious organic disorders. The organisms for contagious diseases are Aspergillus, viruses, mites and Protozoa.

a. Aspergillus, a fungus, causes paralysis in worker bees.

b. Virus cause paralysis and high percentage of mortality to all categories of bees.

c. Gut protozoa, particularly Nosima apis, cause death of bees.

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Sericulture

Dr. Sangeeta Soi

What is Sericulture?

Sericulture is an agro-based industry. It involves rearing of silkworms for the production of raw silk, which is the yarn obtained out of cocoons spun by certain species of insects. Cultivation to feed the silkworms that spin silk cocoons and reeling the cocoons to unwind the silk filament for value added advantages like process and weaving are the major activities of sericulture. Silk has been blended with the life and culture of the Indians.

India encompasses an upscale and sophisticated history in silk production and its silk trade dates back to fifteenth century. Silk is the most elegant textile in the world with distinctive grandeur, natural radiance, and inherent affinity for dyes, high absorbance, lightweight weight, soft touch and high sturdiness and called the "Queen of Textiles" the world over Sericulture business provides employment to roughly 8.25 million persons in rural and semi-urban areas in India throughout 2015-16.

It stands for livelihood opportunity for millions owing to high employment oriented, low capital intensive and remunerative nature of its production. From these, a sizeable number of workers belong to the economically weaker sections of society, including girls. India's ancient and culture bound domestic market and a tremendous diversity of silk clothes that replicate geographic specificity have helped the country to attain variety one position in silk business.

Silk production in India

India is the second largest producer of silk within the globe. Among the four kinds of silk created in 2015-16, Mulberry accounts for 71.8% (20,434 MT), Tasar 9.9% (2,818 MT), Eri 17.8% (5,054 MT) and Muga 0.6% (166 MT) of the total raw silk production of 28,472 MT.

Mulberry sericulture is principally practised in 5 states i.e. Karnataka, Andhra Pradesh, Assam and Bodoland, West Bengal, Jharkhand and Tamil Nadu are major silk producing states in the country. North East has the distinctive distinction of being the sole region manufacturing four kinds of silk like Mulberry, Oak Tasar, Muga and Eri. Overall NE region contributes eighteen of India's total silk production.

Advantages of Sericulture:

High employment potential

- 60 lakh persons are engaged in various sericulture activities in the country.

- It is calculable that Sericulture can generate employment @ 11 man days per kg of raw silk production (in on-farm and off-farm activities) throughout the year. This potential ispar-excellence and no other business generates this type of employment, especially in rural areas, hence, sericulture is used as a tool for rural reconstruction.

Eco-friendly Activity

- As a perennial crop with good foliage and root-spread, mulberry contributes to conservation and provides green cover.

- Waste from silkworm rearing will be recycled as inputs to garden.

- Dried mulberry twigs and branches are used as fuel in place of firewood and therefore reduce the pressure on vegetation/forest.

- Being a labour intensive and predominantly agro-based activity, involvement of smoke-emitting machinery is minimal.

- Developmental programmes initiated for mulberry plantation are mainly in upland areas where un-used cultivable land is made productive.

- Intercropping can also be done with numerous plantations.

- Being a deep-rooted perennial plant it can be raised in vacant lands, hill slopes and watershed areas.

- Currently, only concerning 0.1 % of the cultivable land in the country is beneath mulberry cultivation.

Women friendly Occupation

Women constitutes over hour of those employed in down-stream activities of sericulture in the country. This is the result of sericulture activities ranging from mulberry garden management, leaf harvesting and silkworm rearing is more effectively taken up by the women folks. Even silk reeling business together with weaving is largely supported by them.

Low Gestation, High Returns

- Estimated investments of Rs.12,000 to 15,000 (excluding cost of land and rearing space) is adequate for undertaking mulberry cultivation and silkworm rearing in one acre of irrigated land.

- It takes only six months for mulberry to grow for commencement of silkworm rearing. Once planted, it will go on supporting silkworm rearing year after year for 15-20 years depending on inputs and management provided.

- Five crops can be taken in one year under tropical conditions.

- By adopting stipulated package of practices, a farmer can attain net income levels up to Rs.30000 per acre per annum.

Policy initiatives for the development of silk industry

Sericulture is the purposeful area under the Ministry of Textiles. Few of the recent policy initiatives taken by the Ministry to promote sericulture unit are as follows.

- Sericulture is considered as agriculture allied activity under RKVY. This enables the sericulturists to avail the advantages of the theme for the complete sericulture activities up to reeling.

- The CSB (Amendment) Act, Rules and regulations are notified by the govt. of country to bring quality standards in egg production.

- Amendment in Forest Conservation Act to treat non mulberry sericulture as forest based activity enabling the farmers to undertake Vanya silkworm rearing in the natural host plantation in the forests.

- Anti dumping duty on Chinese raw silk - The Director General of Antidumping & Allied Duties (DGAD), New Delhi has recommended imposition of antidumping duty on Chinese raw silk of 3A Grade & Below in the form of fixed duty of US$ 1.85 per kg on the landed price of imported raw silk vide notification No.14/17/2014/DGAD dated 4-12-2015.

- CDP-MGMREGA convergence guideline have been finalized and issued jointly by the MOT and MORD. Farmers can avail assistance from MGNREGA scheme to get benefit from these guidelines.

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Lac Culture

Article shared by : Samiksha S

Lac-insect for Lac Culture in India: Life Cycle of Lac-insect!

Nature has given much for welfare of human beings through animals and their products.

On the other hand human beings never seem to tire of discovering the mysteries of nature. But the animals seem to be greater experimenters as some of them have astounded most human beings by their complex, strange and at times bizarre performance. One of such performer known to man from good old days is the tiny insect that has given a very valuable product in the form of lac, to the civilization of man.

Lac is a natural resin of animal origin. It is secreted by an insect, known as lac-insect In order to obtain lac, these insects are cultured and the technique is called lac-culture. It involves proper care of host plants, regular pruning of host plants, propagation, collection and processing of lac.

History:

Lac has been used in India from time immemorial for several purposes, from the epic of Mahabharat it has been recorded that Kauravas built a palace of lac for the destruction of Pandavas. We come across references of lac in the Atharvaveda and Mahabharata, so it can be presumed that ancient Hindus were quite familiar with lac and its uses.

Scientific study of lac started much later. In 1709 Father Tachard discovered the insect that produced lac. First of all Kerr (1782) gave the name Coccus lacca which was also agreed by Ratzeburi (1833) and Carter (1861). Later Green (1922) and Chatterjee (1915) called the ac- insect as Tachardia lacca (kerr). Finally, the name was given as Laccifer lacca.

Systematic Position:

A number of species of lac insects are known, of this Laccifer lacca is by far the most important and produces the bulk of the lac for commerce. It belongs to—

Phylam — Arthropoda

Class — Insecta

Order — Hemiptera

Super-family — Coccidae

Family — Lacciferidae

Genus — Laccifer

Species — Lacca

Food Plants:

The insects live as a parasite, feeding on the sap of certain trees and shrubs. The important trees on which the lac insects breed and thrive well are –

Kusum (Schleichera trijuga)

Palas (Butea frondosa)

Ber (Zizyphus jujuba)

Babul (Acacia arabica)

Khair (Acacia catcchu)

Arhar (Ca]anus indicus)

Before coming to the actual mechanism of lac secretion and its processing, it is advisable for a lac-culturist to have detailed knowledge of lac insect and its life cycle. The adult lac insect

Shows a marked phenomenon of sexual dimorphism. The male and female insect varies in shape, size and also in presence or absence of certain body parts.

Structure of Male Lac-insect:

It is larger in size and red in colour. The body is typically divided into head, thorax and abdomen. The head bears a pair of antennae and a pair of eyes. Mouth parts are absent so a male adult insect is unable to feed. Thorax bears three pairs of legs. Wings may or may not be found. (Fig. 33 a, b).Abdomen is the largest part of the body bearing a pair of caudal setae and sheath containing penis at the posterior end.

Structure of Female lac-insect:

It is smaller in size. Head bears a pair of antennae and a single proboscis. Eyes are absent. Thorax is devoid of wings and legs. (Fig. 34. b) The loss of eyes, wings, and legs are due to the fact that the female larvae after settling down once never move again and thus these parts become useless and ultimately atrophy. Abdomen bears a pair of caudal setae. It is female lac insect which secretes the bulk of lac for commerce.

Fertilization:

After attaining the maturity, males emerge out from their cells and walk over the lac incrustations. The male enters the female cell through anal tubular opening and inside female cell it fertilizes the female.

After copulation, the male dies. One male is capable of fertilizing several females. Females develop very rapidly after fertilization. They take more sap from plants and exude more resin and wax.

Life Cycle:

The females after fertilization are capable of producing eggs. But it has been noticed in case of lac insects that the post fertilization developments start when the eggs are still inside the ovary. These developing eggs are oviposited into the incubating chambers (formed inside the female cell by the body contraction of females). A female is capable of producing about one thousand eggs (average 200-500). Inside incubating chamber, the eggs hatch into larvae.

The larvae are minute, boat shaped, red coloured and measure little over half millimeter in length. Larva consists of head, thorax and abdomen. Head bears a pair of antennae, a pair of simple eyes and a single proboscis. All three thoracic segments are provided with a pair of walking legs. Thorax also bears two pairs of spiracles for respiration. Abdomen is provided with a pair of caudal setae.

These larvae begin to wander in search of suitable centre to fix them. This mass movement of larvae from female cell to the new off-shoots of host plant, is termed as “swarming”.

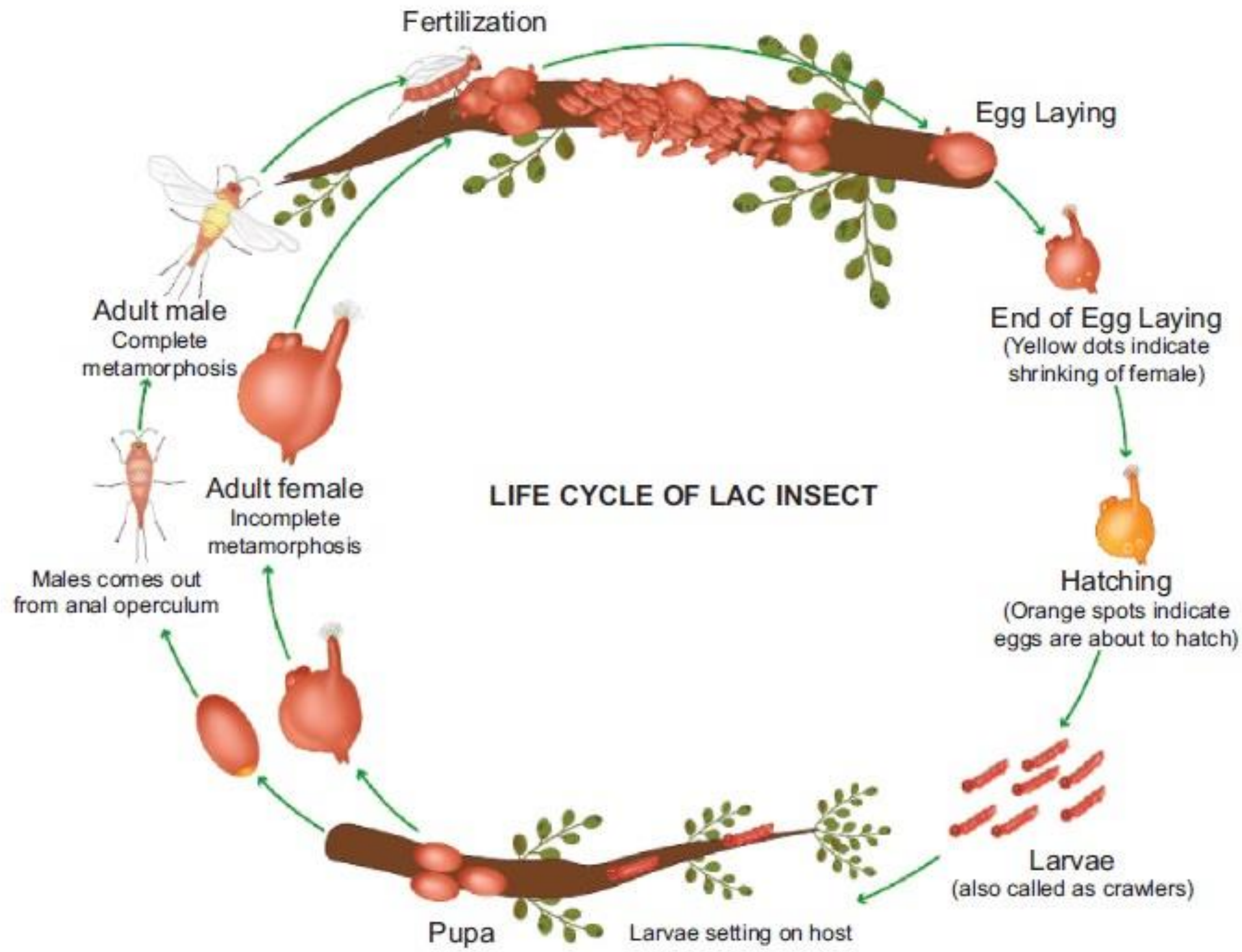

Figure 13. 7 – Life cycle of lac insect

The emergence of larvae from female cell occurs through anal tubular opening of the cell and this emergence may continue for three weeks. The larvae of lac are very sluggish and feed continuously when once they get fixed with the twig. In the meantime the larvae start secreting resinous substance around their body through certain glands present in the body. After some-time the larvae gets fully covered by the lac encasement, also known as lac cell. Once they are fully covered, they moult and begin to feed actively.

The cell produced by male and female differ in shape, and can be easily distinguished sometimes later. Male cells are elongated and cigar shaped. There is a pair of branchial pores in the anterior side and a single large circular opening covered by the flap in the posterior side. (fig. 26, a). It is through the posterior circular opening that the matured male lac insect emerges out of its cell.

Female cell is oval, having a pair of small branchial pores in anterior side and a single round anal tubular opening in posterior side. Through the anal tubular opening are protruding waxy white filaments, secreted by the glands in the insects body, which is an indication that the insect inside the cell is alive and is in healthy condition. These filaments also prevent the blocking of the pore during excess secretion of lac.

Larvae moult in their respective cells. It is the second stage larva which undergoes pseudopupation for a brief time, whereby it changes into adult stage. Now the male emerges out from its cell, moves on lac incrustation and enters the female cell for fertilization. In this way the life cycle is completed.

Lac Secretion:

Lac is a resinous substance secreted by certain glands present in the abdomen of the lac insects. The secretion of lac begins immediately after the larval settlement on the new and tender shoots. This secretion appears first as a shining layer which soon gets hardened after coming in contact with air.

This makes a coating around the insect and the twig on which it is residing. As the secretion continues the coating around one insect meet and fuses completely with the coating of another insect. In this way a continuous or semi-contmuous incrustation of lac is formed on the tender shoots.

Cultivation of Lac:

Cultivation of lac involves proper care of host plants, regular pruning of host plant, infection or inoculation, crop-reaping, control of insect pests, and forecast of swarming, collection and processing of lac.

The first and perhaps the most important prerequisite for cultivation of lac is the proper care of the host plant. It is the host plants on which lac insects depend for their food, shelter and for completion of their life cycle. There are two ways for the cultivation of host plants. One is that plants should be allowed to grow in their natural way and the function of lac-culturist is only to protect and care for the proper growth of plants.

Another way is that a particular piece of land is taken for the purpose and systematic plantation of host plant is made there. Regular watch is necessary in this case by providing artificial manures, irrigation facilities, ploughing and protecting the plants from cattle and human beings for which the land should be fenced. The larvae of lac insects are inoculated on host plants only after the host plants have reached a proper height.

The lac larvae feed on the cell sap by inserting their proboscis in the tender twigs. The proboscis can only be inserted in the tender young off-shoots. For this before inoculation, prunning of lac host plants is necessary. The branches less than an inch in diametre are selected for pruning. Branches half inch of less in diametre should be cut from the very base of their origin. But the branches more than half inch diametre should be cut at a distance of 1 ½ inch from the base.

Inoculation:

The method by which the lac insects are introduced to the new lac host plant is known as inoculation. This may be of two types, namely “Natural infection” and “Artificial infection”. When infection from one plant to other occurs by natural movements of insect, it is called natural infection. This may be due to overcrowding of insect population and nonavailability of tender shoots on a particular tree.

Artificial infection takes places through the agencies other than those of nature. Prior to about two weeks of hatching, lac bearing sticks are cut to the size of six inches. They are called“Brood lac”. Brood lacs are then kept for about two weeks in some cool place.

When the larvae start emerging from this brood lac, they are supposed to be ready for inoculation. Strings co be used for tieding the brood lac with the host plant may be of different types in longitud infection the brood lac is tied in close contact with host branches. In lateral infection the brood lac is tied across the gaps between two branches. In interlaced method, brood lac is tied among the branches of several new shoots.

Lac Crop:

The lac insects repeat its life cycle twice in a year. There are actually four lac crops since the lac insects behave in two ways either they develop on Kusum plants or devlop on plants other than Kusum. The lac which grows on Non-Kusum plants is called as “Ranjeem lac,” and which grows on Kusum plant is called as “Kusumi lac. Four lac crops have been named after four Hindi months in which they are cut from the tree. They are as follows:

Ranjeeni Crop:

(i) Katki:

Lac larvae are inoculated in June-July. Male insect emerges m August-September. Female give rise to swarming larvae in October-November and the crop is reaped in Kartik (October and November).

(ii) Baisakhi:

Larvae produced by Katki crop are inoculated in October-November, male insects emerges in February-March, females give rise to swarming larvae m June-July, the crop is reaped in Baisakh (April-May).

Kusumi Crop:

(i) Aghani:

Lac larvae are inoculated in June-July, male insect emerges m September, female give rise to swarming larvae in January-February and crop is reaped in Aghan (December-January).

(ii) Jethoi:

The larvae produced by Aghani crop is inoculated in the month of January- February, male emerges in March-April, female give rise to swarming larvae in June- July and the crop is reaped in the month of Jeath (June-July).

The time of infection with swarming larvae, the time of emergence of male insects, the time of reaping the crop, and the time of producing swarming larvae by female etc., are shown m tabular form below

Scraping and Processing of lac:

Lac cut from the host plant is called as “stick lac”. Lac can be scraped from the twigs before or after the emergence of larvae. If it is used for manufacturing before the emergence of larvae, the type of lac produced is called as “Ari lac” and if it is used for manufacturing purpose after swarming of larvae has occurred, the lac is said to be Phunki lac”.

The scraping of lac from twig is done by knife, after which they should not be exposed to sun. The scraped lac is grinded in hard stone mills. The unnecessary materials are sorted out In order to remove the finer particles of dirt and colour, this lac is washed repeatedly with cold water.

Now at this stage it is called as “Seed lac” and is exposed to sun for drying. Seed lac is now subjected to the melting process. The melted lac is sieved through cloth and is given the final shape by molding. The final form of lac is called “Shellac”. Colour or different chemicals may be mixed during melting process for particular need.

Lac Enemies and Their Control:

A lac enemy imposes a challenge to the lac culturist, as they not only decreases the population of lac insects, but also retard the production and quality of lac. Damage caused to lac insects may be grouped under two heads, (a) damage caused by insects (b) damage caused by animals other than insects. Insect enemies of lac crop may be predators and parasites.

The common parasites of lac insect are known as “Chalcid.” They are small, winged insects which lay their eggs inside the lac coat either on the body of the lac insect or inside the body of the lac insect. The larva which hatches from these eggs feed upon the lac insects, thereby causing mortality of their host. Damage done by this parasite constitute about 5-10% of the total destruction of the lac crop.

Damage done by the predators is of greater intensity (35% of the total destruction). The major predators of lac insects are Eublemma amabilis (the white moth) and Holococera pulverea (the blackish grey moth). They not only feed on lac insects but also destroy the lac produced by term. Squirrels, monkey, rat, bat, birds (wood peckers), man etc., are the enemies other than insects which destruct the lac crop in different ways. Damage is also done by climatic factors such as excess heat, excess cold, heavy rain, and storm and partly by the faulty cultivation methods.

Control:

Damage caused by the above mentioned animals can be reduced to certain extent by the use of the following methods.

Cultural Method:

The amount of damage by infection can be reduced to a greater extent by taking care during the culture of lac insects, especially at the time of inoculation. The brood lac showing the minimum enemy attack should be selected for inoculation and should be cut from the host plant very near to the time of emergence of larvae (about one week before the emergence). This will reduce the chances of parasite attack on the emerging larvae at new place (host).

The brood lac used for inoculation should be removed from the new host's branches as soon as the emergence of larvae stops (approx. 3 weeks after inoculation). It reduces the chance of transference of enemies to the new host plant from the brood lac. The infected brood lac not fit for inoculation or the used up brood lac should not be retained for long. The lac should be scrapped at once and t e rest may be crushed or dropped into fire in order to destroy the predators and parasites.

The delay m processing also gives chances to the enemy insects to escape into field. So the manufacturers should try to convert stick lac into seed lac as soon as possible. By these cultural methods the future production can be saved from infection to some extent.

Artificial Method:

During the crop reaping, it is not always possible for the manufacturers to convert the huge amount of stick lac to seed lac at a time. To avoid the spreading of enemies at this time from stocked stick lac simple artificial method can be used. Bundles of stick lac should be tied with stones and immersed in fenced water (river or ponds) for about a week. This kills all the parasitic and predator insects as they cannot survive in water.

Biological Method:

It is an indirect method for killing the parasitic and predator insects. For this purpose hyper-parasitic insects are used which attacks the parasitic insects of lac and kill them. These hyper-parasitic insects are however, not harmful for lac crop.

Use of Lac:

Lac has been used for the welfare of human beings from the great olden days No doubt the development of many synthetic products have made its importance to a little lesser degree, but still it can be included in the list of necessary articles. Lac is used in making toys, bracelets, sealing wax, gramophone records etc.

It is also used in making grinding stones, for filling ornaments, for manufacturing of varnishes and paints, for silvering the back of mirror, for encasing cable wires etc., Waste materials produced during the process of stick lac is used for dying purpose. Nail polish is a good example of the by-product of lac.

Composition of Lac:

Lac is a mixture of several substances, of which resin is the main constituent. The approximate percentage of different constituents of lac is given below:

Resin – 68 to 90%

Dye – 2 to 10%

Wax – 5 to 6%

Mineral matter – 3 to 7%

Albuminous matter – 5 to 10%

Water – 2 to 3%

Present Position of this Industry in India:

Lac is produced in a number of countries including India, Thailand, Mayanmar, China, Indonesia, Vietnam and Laos. India and Thailand are the major producers, producing on the average 1700 tonnes of lac annually, followed by China. India alone, accounts for about 70/o of global lac production.

Former Bihar is the most important lac producing state of India. The Indian council of Agriculture Research has established Indian Lac Research Institute at Namkum in Ranchi district of Jharkhand.

The average of different states in the total quantity of stic lac produced in this country is given below:

Bihar – 55.5%
Madhya Pradesh – 22%
West Bengal – 10%
Maharashtra – 7.1%
Gujrat – 2.7%
Uttar Pradesh – 1.8%
Assam – 0.6%
Orissa – 0.1%

Total annual global production of pure lac is estimated to be 20,000 tonnes. The average total production of stick lac in India is about 24,000 tonnes, while the annual average pure lac produced in the country is 11,890 tonnes. About 6000 tonnes of pure lac produced in India is exported to different countries of the world, with an average earning of Rs. 202.38 million in term of foreign exchange. It has been estimated that 3-4 million people mostly tribals are engaged in the cultivation and several thousands in addition are engaged in the trade and manufacture of lac.

Two main competitors of Indian lac are (i) Thailac, which accounts 50% of the total lac exported, and (ii) Synthetic resion, which have replaced lac in certain field. Shellac being a versatile resion, there is immense scope of increasing its utilisation in various fields and there is also scope to modify it to meet particular need.

Reference:

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UNIT – V

PART-A

Q.NO	QUESTIONS	CO (LEVEL)
1	List the infectious diseases caused by animals	5 (1)
2	Summarize the epidemiology of Tuberculosis	5 (2)
3	Investigate the epidemiology of Dengue	5 (5)
4	Investigate the epidemiology of Malaria	5 (5)
5	Investigate the epidemiology of Swine flu	5 (5)
6	Assess the current status of Integrated Pest Management	5 (5)
7	Review on the genetic improvements in aquaculture	5 (5)
8	Design an apiculture setup for your start up business	5 (6)
9	Design a sericulture model for your future business	5 (6)
10	Develop a Lac culture for doing business.	5 (1)

PART-B

Q.NO	QUESTIONS	CO (LEVEL)
1	Categorizethe infectious agents causing diseases to humans and explain how to control it	5 (6)
2	Explain the epidemiology of Tuberculosis	5 (2)
3	Write a review on Dengue fever	5 (5)
4	Discuss the epidemiology of Malaria	5 (1)
5	Discuss the epidemiology of Swine flu	5 (1)
6	Investigate how best agricultural productivity can be improved through Integrated Pest Management	5 (5)
7	Judge the effect of Genetic improvements in aquaculture industry	5 (5)
8	Apiculture will improve the crop yield – Justify.	5 (5)
9	Review in present status of sericulture	5 (5)
10	Assess the different methods followed in Lac culture.	5 (5)