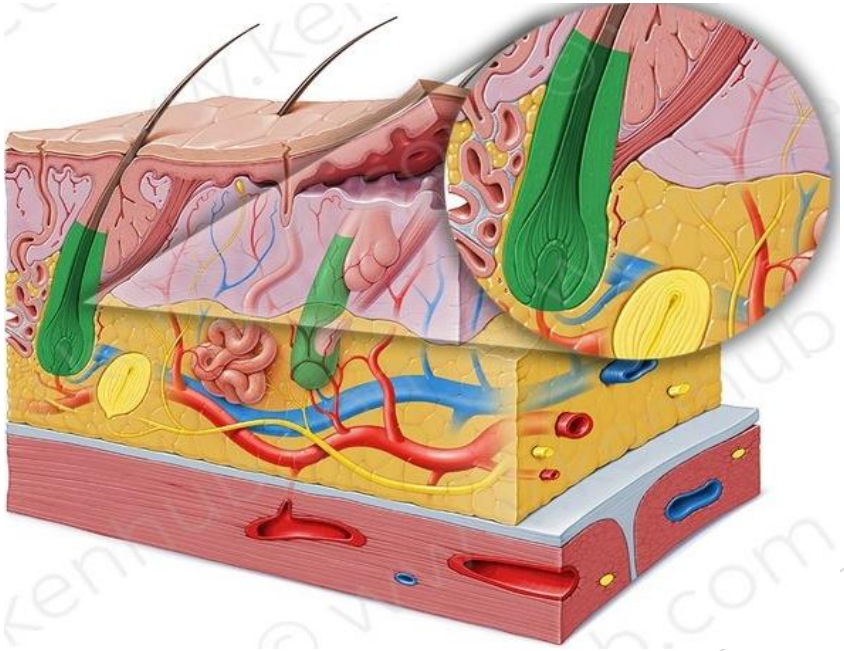
Comparative Anatomy of Vertebrates

(22ZOOC21)

Introduction of Integumentary system



Introduction

- The integumentary system is the largest organ of the body that forms a physical barrier between the external environment and the internal environment that it serves to protect and maintain.
- The integumentary system includes the epidermis, dermis, hypodermis, associated glands, hair and nails.
- In addition to its barrier function, this system performs many intricate functions such as body temperature regulation, cell fluid maintenance, synthesis of Vitamin D and detection of stimuli.

- The various components of this system work in conjunction to carry out these functions. **Eg-** body temperature regulation occurs through thermo receptors that lead to the adjustment of peripheral blood flow, degree of perspiration and body hair.

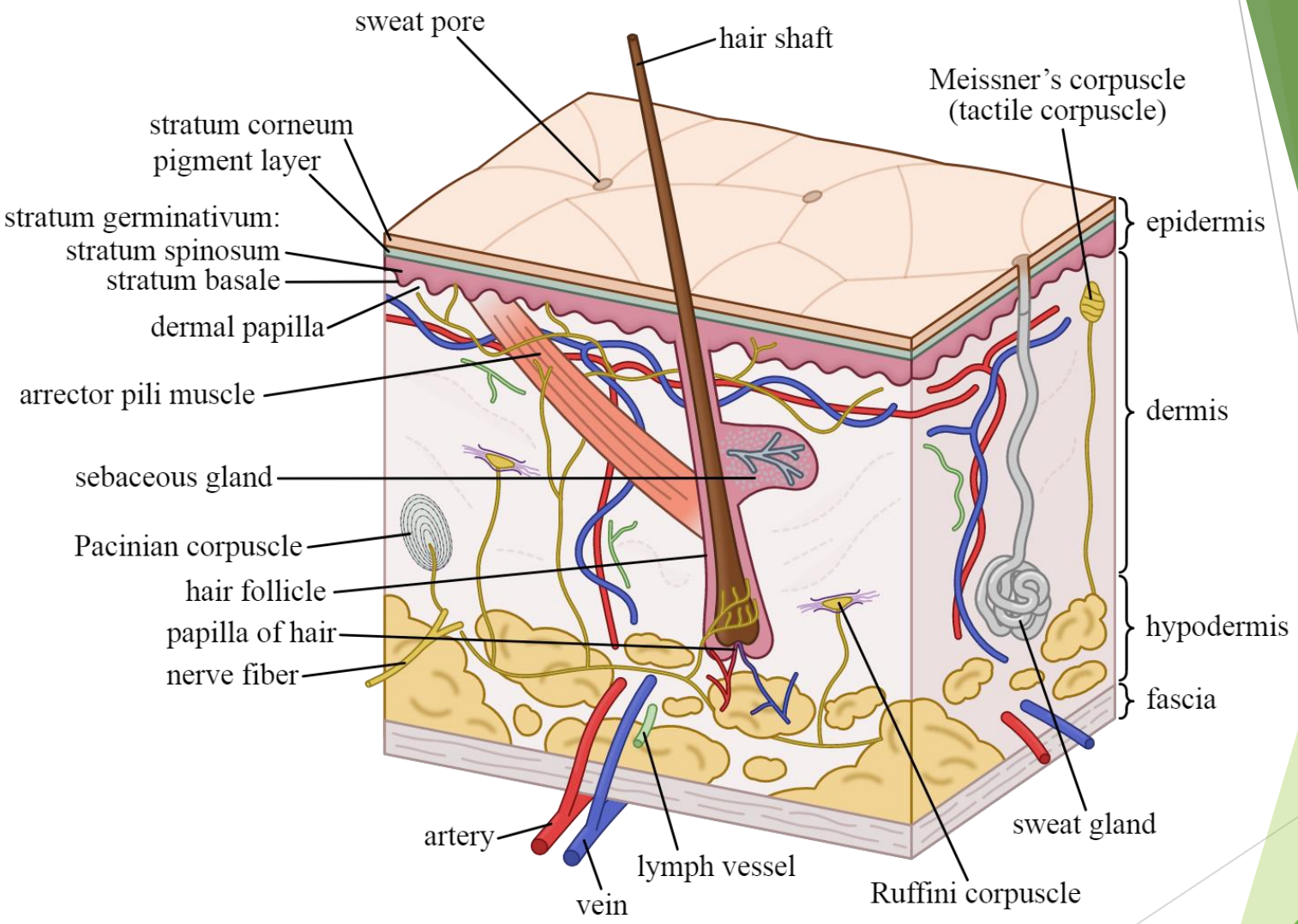
Definition

- The term integument is applied to the outermost protective covering of the animal body, the skin and its various derivatives.
- Skin also includes the conjunctiva of eyeballs and external surface of eardrums.
- It is directly continuous with the mucous epithelial lining of mouth, rectum, nostrils, eyelids and urinogenital ducts.

Components of the Integumentary System

- **Skin**: The skin is made up of two layers—the superficial epidermis and the deeper dermis.
- The **epidermis** is the tough outer layer that acts as the first line of defense against the external environment.
- It is composed of stratified squamous epithelial cells that further break down into four to five layers.
- From superficial to deep, the primary layers are the stratum corneum, stratum granulosum, stratum spinosum, and stratum basale.
- In the palms and soles, where the skin is thicker, there is an additional layer of skin between the stratum corneum and stratum granulosum called the stratum lucidum.

- Its cells accumulate a horny protein called keratin, gradually die and eventually wear off in the form of scurf or dandruff.
- Since keratin is , the keratinized stratum corneum provides protection against mechanical injuries, fungal and bacterial attacks and loss of body moisture.
- The innermost or basal region of epidermis includes a single row of living columnar cells, the Malpighian layer or stratum germinativum, which is separated from the underlying dermis by a basement membrane.
- Its cells actively divide and continually replace the worn out cells of the cornified layer.
- Epidermis is thin in aquatic vertebrates and rich in mucous glands. It is thicker in land vertebrates and structures such as scales, feathers, hairs, nails, claws, horns and enamel of teeth are derived from its Malpighian layer.


sweat pore
hair shaft
Meissner's corpuscle
(tactile corpuscle)
stratum corneum
pigment layer
stratum germinativum:
stratum spinosum
stratum basale
dermal papilla
arrector pili muscle
sebaceous gland
Pacinian corpuscle
hair follicle
papilla of hair
nerve fiber
epidermis
dermis
hypodermis
fascia
artery
vein
lymph vessel
Ruffini corpuscle
sweat gland

- The epidermis regenerates from stem cells located in the basal layer that grow up towards the corneum.
- The epidermis itself is devoid of blood supply and derives its nutrition from the underlying dermis.
- The dermis is the underlying connective tissue framework that supports the epidermis.
- It further subdivides into two layers—the superficial papillary dermis and the deep reticular layer.
- The papillary layer forms finger-like projections into the epidermis, known as dermal papillae, and consists of highly vascularized, loose connective tissue.

- The reticular layer has dense connective tissue that forms a strong network.
- The dermis as a whole contains blood and lymph vessels, nerves, sweat glands, hair follicles, and various other structures embedded within the connective tissue.
- **Hypodermis**: The hypodermis lies between the dermis and underlying organs.
- It is commonly referred to as subcutaneous tissue and is composed of loose areolar tissue and adipose tissue.
- This layer provides additional cushion and insulation through its fat storage function and connects the skin to underlying structures such as muscle.

- **Hair:** Hair is derived from the epidermis but grows its roots deep into the dermis.
- Its structure divides into the externally visible hair shaft and the hair ollicle within the skin.
- The hair follicle that contains the hair bulb that actively divides to extend the hair shaft vertically.
- Hair generally categorizes into hormone-dependent, thicker terminal hairs in regions such as the axilla, pubic areas, scalp, chest, etc., and androgen-independent vellus hairs that cover the rest of the areas.
- Hair growth has multiple phases called anagen (growth phase), catagen (nonproliferative phase), and telogen (resting phase) that cycles depending on hormones and nutrients.

- Hair covers the majority of the body with the few exceptions of the palms, soles, lips, and portions of external genitalia.
- Hair serves as mechanical protection for the skin, increases sensory function, and aids in regulating body temperature.
- Arrector pili muscles located in the dermis attach to hair follicles, helping the shaft to stand and trap air close to the epidermis for temperature control.

Nails:

Nails form as layers of keratin and appear at the dorsal tips of the fingers and toes.

- The nail growth begins at the nail matrix that creates new cells and pushes old cells out distally.
- The visible portion of the nail is the nail plate covering the nail bed, where it adheres to the finger.
- Nails function to protect the fingers and toes while increasing the precision of movements and enhancing sensation.

- **Associated Glands**: There are four types of exocrine glands within human skin—sudoriferous, sebaceous, ceruminous, and mammary glands.
- **Sudoriferous glands,** also known as sweat glands, are further divided into eccrine and apocrine glands.
- **Eccrine glands** are distributed throughout the body and primarily produce serous fluid to regulate body temperature.
- **Apocrine glands** are present in the axilla and pubic area and produce milky protein-rich sweat.
- These glands are responsible for odor as bacteria break down the secreted organic substances.
- **Sebaceous glands** are part of the pilosebaceous unit (**The hair follicle, hair shaft and sebaceous gland** are collectively known as the pilosebaceous unit), including the hair, hair follicle, and arrector pili muscle.
- It secretes an oily substance called sebum, a mixture of lipids that forms a thin film on the skin. This layer adds a protective layer, prevents fluid loss, and also plays an antimicrobial role.

Overall Comparison of Integumentary system

	FISH	AMPHIBIA	REPTILIA	AVES	MAMMALIA
Characters	**Dogfish (Scoliodon)**	**Frog (Rana)**	**Lizard (Uromastix)**	**Pigeon (Columba)**	**Rabbit (Oryctolagus)**
1.Skin surface & attachment	Skin hard, rough, rigid, leathery and firmly attached to body.	Skin thin, moist, slimy, smooth, fitting loosely on body enclosing large subcutaneous lymph spaces beneath dermis.	Skin thicker, dry, rough, and loosely folded along the sides of neck and trunk.	Skin thin, dry, hard flexible and loosely attached to achieve maximum freedom of movement for flight.	Skin thickest, dry, flexible and loosely attached. Variously modified.
2.Colouration	Colour of Scoliodon is dark, grey dorsally and pale white ventrally. Fishes in general show greatest colour patterns and brilliance amongst chordates.	Colour of Rana is green with black and brown patches above and lighter pale-yellow below.	Body of Uromastix is yellow-brown with dark spots above, and lighter and paler below. In reptiles in general color patterns elaborate for warning or concealment.	Rock pigeon is slaty-grey with green and purple sheen around neck and breast and 2 black bars on each wing. Birds in general are beautifully coloured.	Colour of rabbit is dusty-brown and protective. Mammals, in general, are dull coloured.

3. Colour change	Body colour does not change. Some fishes have protective colouration.	Frog has protective colouration for camouflage and can change body colour to match with the surroundings.	Uromastix has no power to change colour. However, Calotes and chamaeleons can change body colours	No capacity for change of body colouration in birds in general.	Usually, no capacity to change body colouration.
4. Pigmentation	Pigment containing chromatophores and guanin containing iridophores located in dermis.	Chromatophores located in dermis.	Chromatophores located in dermis.	Pigment cells found in feathers, not in dermis. Colours also due to reflection and refraction of light by feathers.	Pigment granules located in hairs and epidermis, pigment cells in dermis.
5. Cutaneous respiration	Skin protective and sensory. Not permeable to water, hence no cutaneous respiration.	Skin protective and permeable to water hence serves as an organ of respiration.	Skin protective and water-proof, without cutaneous respiration.	Skin protective, insulating and water-proof. No skin respiration.	Skin protective, insulating and water-proof. No cutaneous respiration.

6. Epidermis	Epidermis many layered or stratified, but simple, thin and without a cornified stratum corneum. No moulting.	Many-layered or stratified epidermis with a thin stratum corneum of flat and dead keratinized cells continuously shed in patches.	Epidermis stratified with a relatively thicker stratum corneum periodically shed in bits or in one piece.	Epidermis stratified, relatively thinner, and seasonally shed and replaced.	Epidermis greatly stratified. Stratum corneum highly specialized with several modifications.
7. Epidermal glands	Epidermis contains numerous unicellular mucus- secreting goblet gland cells. Multicellular poison glands and luminescent glands or photophores also occur in some fishes.	Epidermis is rich in multicellular mucous glands. Some amphibians have poison glands like parotid glands of toad.	Lizard has few but no mucous glands. Male lizard has femoral glands on thighs. Some reptiles have scent or musk glands.	No skin glands occur in birds except a single large preen or uropygial gland on tail. No mucous glands present.	Skin richly glandular containing characteristic mammary, sweat and sebaceous glands besides scent glands. No mucous glands present

8. Dermis	Dermis is typical with connective tissue fibres, blood and lymph vessels and pigment cells. But all connective tissue fibres run parallel to surface.	Dermis is thin and typical. It consists of an outer loose layer or stratum spongiosum, and an inner compact layer of collagen fibres called stratum compactum. Connective tissue fibres are vertical as well as horizontal.	Dermis is thick and typical, containing connective tissue fibres, muscle and nerves, blood capillaries and lymphatic vessels, and also pigment cells..	Dermis is mostly thin and typically made of muscle fibres, nerves, blood capillaries and connective tissue. It has no pigment.	Dermis is proportionately thickest of all vertebrates, containing intricate fibres, tactile organs, nerves, blood vessels and pigment cells.
9. Dermal scales	Dermal scales are present as placoid scales.	Dermal scales are absent in frog, although embedded in the skin of some Gymnophiona.	Dermal scales absent in Uromastix, but dermal scales, scutes or plates, called osteoderms, occur in some lizard, crocodilians and turtles.	Dermal scales are absent in birds.	Dermal scales or plates occur only in armadillos and whales.

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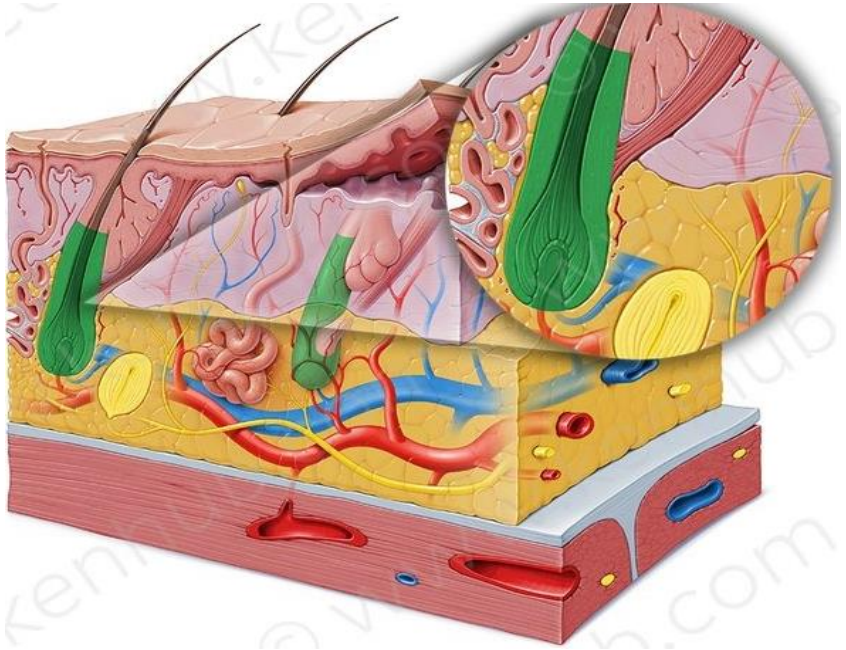
Derivatives of the Integumentary system



Derivatives of Integument

1. Epidermal derivatives

These are formed by the epidermis and comprise :

Epidermal glands. Hard horny structures including epidermal scales, scutes, beaks, horns, claws, nails and hoofs, feathers and hairs, etc.

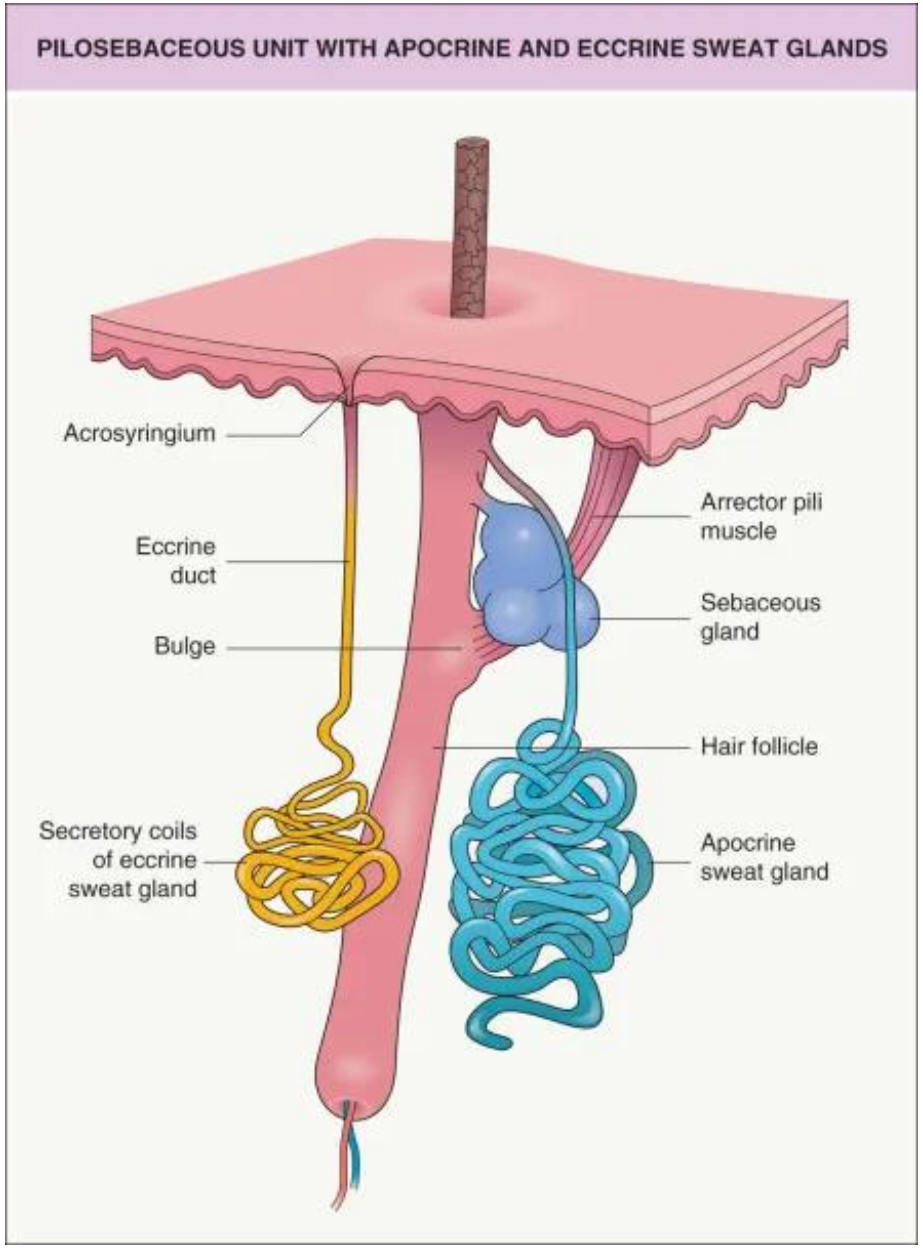
All the hard horny structures together form the exoskeleton of an animal.

2. Dermal derivatives

- These arise from dermis and comprise bony or dermal scales, plates or scutes, fin-rays and antlers, etc.

(1). Epidermal glands

- Integumental or epidermal glands are formed by the Malpighian layer of epidermis.
- They arise in epidermis but often invade the dermis.
- They may be unicellular or multicellular, tubular or alveolar in shape, and simple,compound or branched.
- They are lined by cuboidal cells or columnar epithelium.
- They are usually named after their nature or function.
- The 9 major types described below are :
- mucous, poison, luminescent, femoral,uropygial, sweat, sebaceous, scent and mammary.



1. **Mucous glands** :- They secrete mucin which forms slimy or sticky mucous on coming in contact with water.

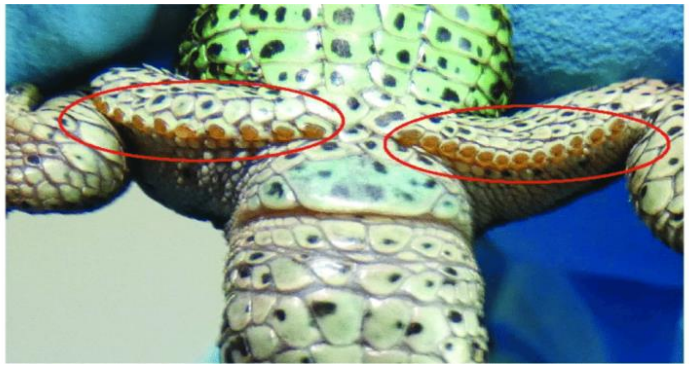
Mucous keeps the skin moist and slippery and protects against harmful bacteria and fungi. They are abundantin amphibian skin. They may be unicellular or multicellular eg., granular cells, beaker cells of amphioxus,cyclostomes, fishes etc.

2. **Poison glands :-** Many fishes and amphibians have poison glands. These are modified multicellular cutaneous glands, larger but fewer than mucous glands. The parotid glands behind the head of toads areaggregations of poison glands. Secretion of poison glands may be bitter, irritating and even dangerous to the predators.

Poison glands of amphibians are granular glands collected into masses called, Parotid glands. The poison secreted by it is alkaloid and similar in action like digitalis.

4.Femoral glands :- These are found in male lizards (e.g. Uromastix) on the ventral surface of each thigh, in a single row 12-18 femoral pores from knee to cloacal aperture.

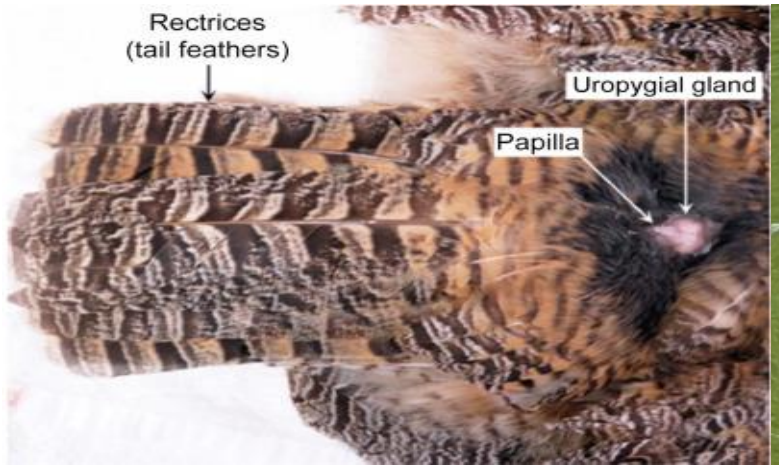
Their sticky secretion hardens in air to form temporary tiny spines that serve to hold the female during copulation.



5. **Uropygial gland :-** It is one of the few integumentary glands found in birds, forming a prominent swelling just above the tail or uropygium.

It is branched and alveolar and exudes an oily secretion used for lubricating beak, preening feathers and attracting the opposite sex during breeding season due to odoriferous nature.

- The oil secreted by it contains pomatum which is picked up by beak and used for preening and waterproofing.



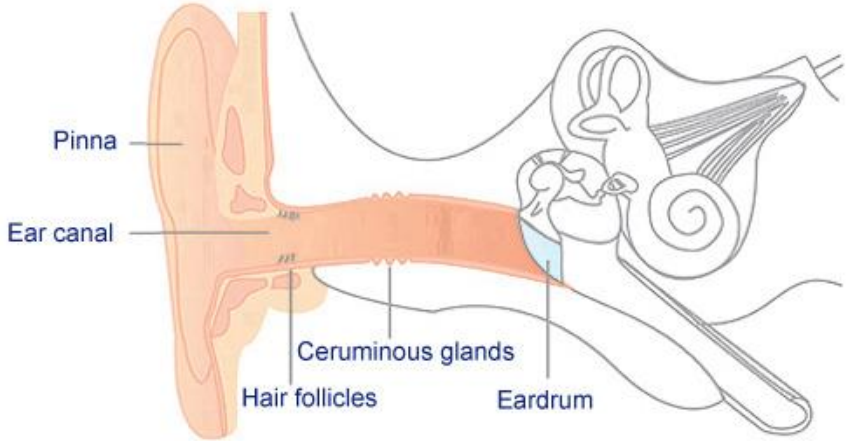
- The oil gland, technically called the uropygial gland, is found on budgies, parrots, canaries, most finches, cockatoos.
- Doves, pigeons, Amazon parrots and Hyacinth macaws do not have one.
- This gland secretes a thick, transparent, preening oil consisting of waxes, fats and fatty acids.
- While the bird is preening, it transfers this oil to its feathers by rubbing its head and beak against the oil gland and then spreading the oil over the feathers on the rest of the body.

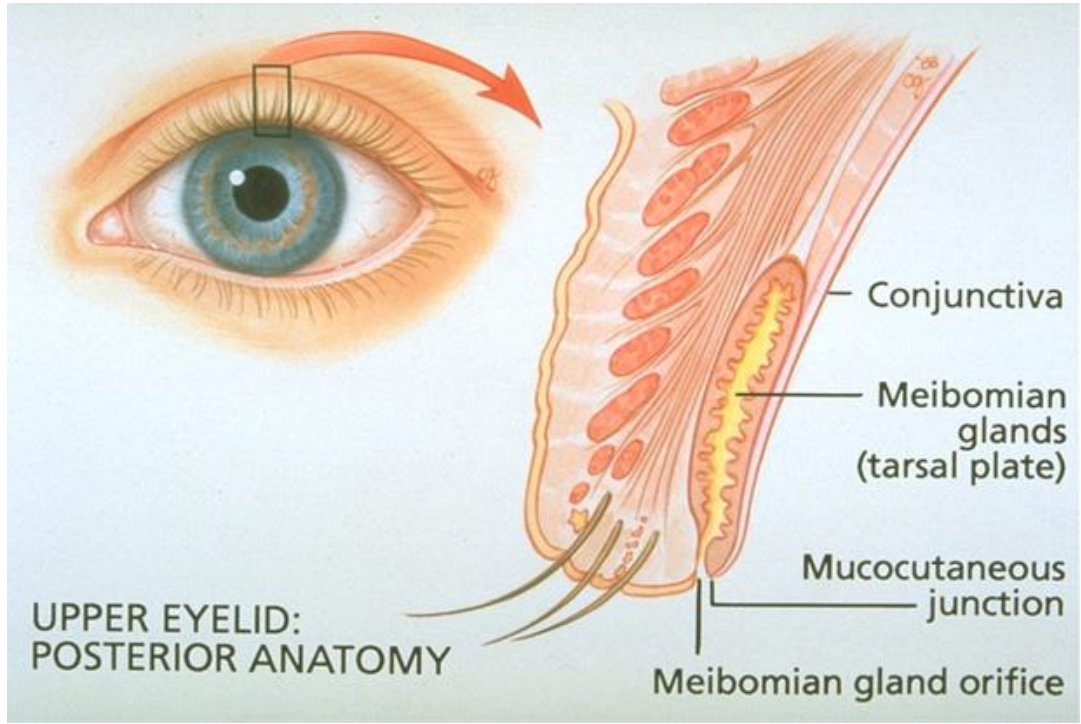
6. **Sweat glands** :- Sweat glands or sudoriferous glands (sudor = sweat) are abundant in the skin of most mammals.

- slender coiled tubes embedded deep in the dermis, opening on skin surface.
- some salts are eliminated dissolved in water in the sweat produced by these glands.
- Evaporation- helps to cool and regulate body temperature in hot environments.
- Sweat glands are absent in spiny scaly ant eaters and marine forms such as Sirenia and Cetacea.
- Some animals occur only on the soles of feet (cats and mice), lips(rabbits), muscle and skin between toes (ruminants), sides of head (bats), ears (hippopotamus), etc.
- Male giant Kangaroo (Macropus rufus) and hippopotamus secrete red-coloured sweat. Ciliary glands in eyelashes and along margins of eyelids are modified sweat glands.

7. **Sebaceous glands** :- These are branched alveolar glands opening into hair follicles of mammals.

- They may open directly onto skin surface such as around the genital organs, tip of nose or edges of lips.
- Their oily secretion, called sebum (=grease), keeps the skin and hairs soft, greasy, water-proof and glistening.
- Sebaceous glands absent in pangolins and marine mammals (Sirenia, Cetacea) which are practically devoid of hairs.
- Ceruminous glands of external ear canals are modified sebaceous glands.
- Their waxy or greasy secretion, called cerumen, helps trap insects or dust particles.
- Similarly, meibomian glands of eyelids, which spread their oily secretion over the exposed surface of eyeball, are modified sebaceous glands.


Pinna
Ear canal
Ceruminous glands
Hair follicles
Eardrum

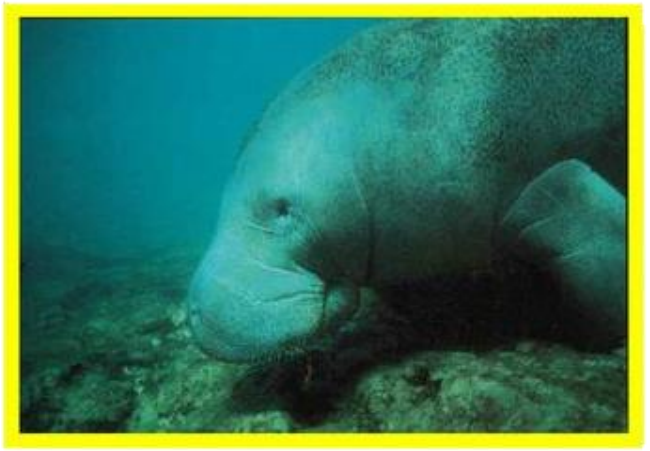

Conjunctiva
Meibomian glands (tarsal plate)
Mucocutaneous junction
UPPER EYELID: POSTERIOR ANATOMY
Meibomian gland orifice

8. **Scent glands :-** These are modifications either of sebaceous or sudoriferous glands of mammals.

- Their odorous secretions serve to repel foes or attract members of opposite sex.
- Scent glands may occur between toes on feet (goat, rhino, horse), near eyes on head (deer family), navel on abdomen (musk deer), mid-dorsally on back (Kangaroo rats Dipodomys), around anus (skunks, many carnivores and rodents), etc.
- foul odours may due to unhygienic conditions but caused by the scent glands of mammals in the pens and cages.

Cetacean

Sirenian



Pangolins

Kangaroo rats Dipodomys

SHUNK

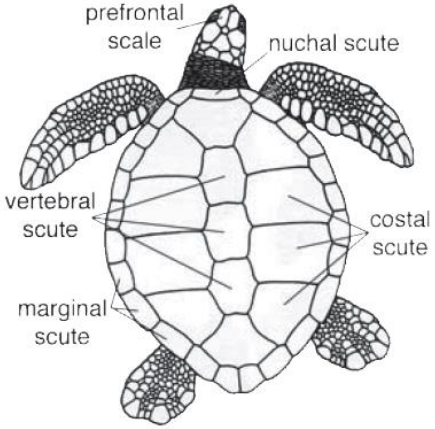
Musk deer

9. **Mammary glands :-**

- In mammals, these are compound tubular glands that produce milk during lactation period for feeding the young ones.
- Usually they occur only on females, but are also present on males in monotremes, primates and some others.
- In monotremes, the mammary glands lack nipples or teats and resemble modified sweat glands.
- In other mammals, they possess nipples and are modifies sebaceous glands Distribution and number of mammary glands and nipples vary with the species.
- A nipple is a raised conical or elongated elevation of body surface bearing the opening of milk gland.
- In true teats (man, apes),ducts of mammary glands open separately on the nipple.
- In false teats (ungulates), all ducts empty into one cistern from which a single tube leads to the tip of the nipple.

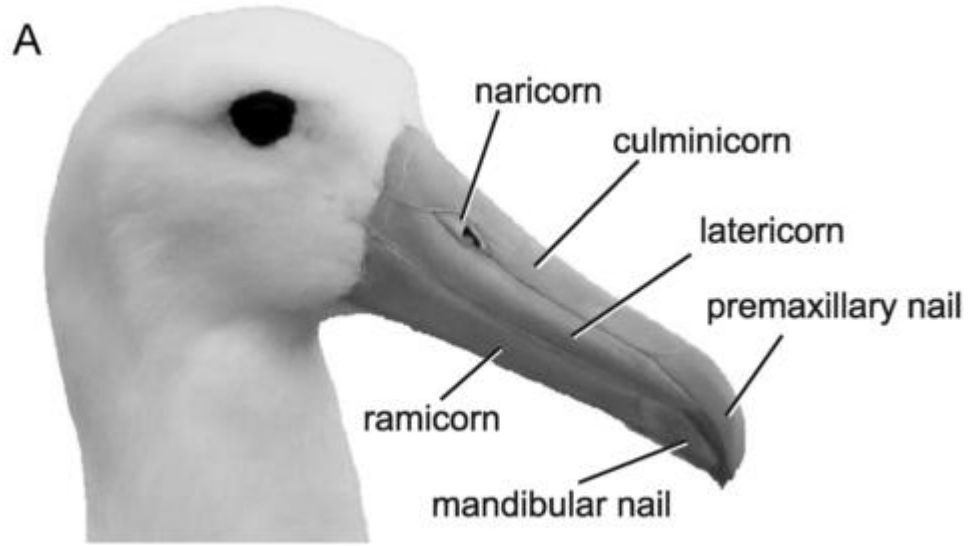
2) Epidermis scales and scutes

- All the hard horny structures develop by the accumulation of a scleroprotein, known as keratin, in the cells of epidermis.
- Such cells are said to be keratinized or cornified, and they become dead.
- All stratum corneum cells are cornified and form hard horny exoskeletal structures like scales, beaks, horns, claws, nails, hoofs, feathers, hairs, etc. in different vertebrates.
- Reptiles have a continuous outer covering of horny epidermal scales that prevents water loss through skin surface.
- In lizards, scales are thin, small, overlapping and periodically moulted in small pieces.
- In snakes also the scales are overlapping, enlarged on head, called shields, and on ventral surface, called scutes, which aid in locomotion.



- Crocodilians and turtles have large thick, rectangular scutes, not overlapping but touching each other, and supported beneath by dermal bones
- The toothless horny beak of turtles, the rattle at the end of the tail of rattle snakes and horns of the horned toad (a lizard) are other modifications of stratum corneum in reptiles

- In birds, small epidermal scales are present on the lower leg, foot and base of beak.
- The sheath of beak(rhamphotheca) is also a modification of stratum corneum.



Reptile-like epidermal scales occur in some mammals also, such as on the feet and tails of rats and beavers, etc.

The large scales on the body of a scaly anteater undergo ecdysis individually.

In armadillos, large body scales become fused into plates and bands.

They are supported beneath by dermal bony scales and do not moult.

1. Dermal scales of fishes :- As mentioned above bony or dermal scales develop in the dermis. In fishes, the overlying epidermis wears off so that the scales become exposed forming the exoskeleton.

- Five types of dermal scales are known, depending on their structure, in fishes,
- Cosmoid scales occurred in extinct lobe-finned fishes (Crossopterygii).
- Placoid scales are characteristic of elasmobranchs (Chondrichthyes).
- Ganoid scales are present in ganoid fishes (chondrosteans and holosteans).
- Cycloid and Ctenoid scales are characteristic of modern teleosts.

2. **Dermal scales and scutes of tetrapods** :- Dermal scales or bony plates measuring 1 to 2 mm, called osteoderms, are found embedded in the pockets of dermis below epidermis, in some caecilians or Apoda(Amphibia).

- They also occur in the back of some tropical toads. A few lizards exhibit small dermal scales.
- Crocodiles and alligators have many oval bony plates embedded in the dermis of their back and neck.
- In turtles, below horny epidermal scutes, are present large bony plates or osteoderms, forming a box-like continuous rigid dermal skeleton around trunk and including a dorsally arched carapace and a ventral flattened plastron.
- Amongst mammals, bony plates or osteoderms occur in armadillos and whales.

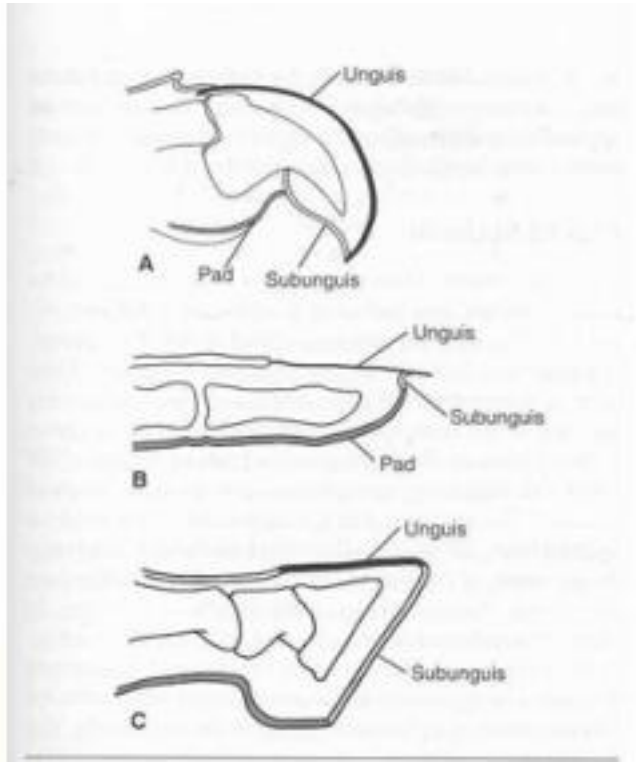
3. **Dermal fin rays :-** Supporting the fins of fishes are long, flexible fin rays embedded in dermis.

In Chondrichthyes, they are horny, hair-like, made of fibrous connective tissue and called ceratotrichia (cerato =horn + tricho =hair).

In Osteichthyes, they are branched, made of a series of segments or scales, and called lepidotrichia (lepido = scale). Unsegmented, sharp and spine-like fin rays are termed actinotrichia.

(4). Digital cornifications

- All digital cornifications, that is, claws, nails and hoofs, are built on the same plan.
- They are modification of stratum corneum at the tips of digits and grow parallel to the skin.
- 1. **Claws** :-Claws of reptiles, birds and mammals are identical in structure. A claw is made by a hard, pointed, narrow, curved, horny dorsal plate, called unguis, and a less hard ventral plate, called subunguis, both enclosing the tip of the digit covering the last tapering phalanx.
- **2. Nails :-** Claws are modified into nails which are characteristic of Primates (mammals). Dorsal plate or unquis is broad and flat, while subunguis is softer and much reduced. The tip of the digit forms a greatly sensitive and highly vascular pad over which the epidermis in vaginates to form a nail groove containing the nail root.



- 3. **Hoofs** :- Hoofs are characteristic of ungulates (hoofed mammals).
- The horny unguis is neither pointed nor flat, but U- or V-shaped. Subunguis is also U-shaped, greatly thickened and touching ground.
- The horse's shoe can be nailed into it. Subunguis surrounds a softer horny substance, the cuneus.
- The tip of digit forms a pad and contains a blunt phalanx. Other modifications of stratum corneum include the whalebone plates of toothless whales, and the horny coverings of horns of sheep and cattle and prong horns of antelopes.

Horns

- Horns are found in hoofed mammals (Artiodactyla and Perissodactyla) only. They are present on their head and form organs of offense and defense. At least 5 types of horns are recognized, but all are not true horns, that is, product of stratum corneum.
- **True horns :-** True or hollow horns usually occur in both the sexes in goats, sheep, cattle and others. They are unbranched, cylindrical and tapering. They are permanent structures that continue to grow throughout life and are never shed.
- The true horn is made of a hollow dermal bony core arising from frontal bone of skull and covered by an epidermal horny hollow cap.

3. Antlers :

- – Antlers are characteristic of deer family. They are found only on males but on both the sexes in reindeer and caribou. Antlers are annual growths and not true horns. An antler is a branching solid outgrowth of dense connective tissue connected basally to the frontal bone of skull. Deposition of calcium salts makes the antler hard. During growth, it is covered on the surface with typical hairy and vascular skin, or ‘velvet’. When growth is complete, the velvet wears off, exposing the naked, branched antler. After the breeding season is over, the antlers are also shed and new antlers develop the following year.

4. Giraffe horns

- Horns of giraffes are stunted, unbranched and permanent antlers present in both sexes.Each consists of a short bony dermal core, projecting from frontal bone and remains covered with simpleunmodified skin or velvet which is never shed.

5. Hair horns

- Hair horns or fibre horns are found in rhinoceros of both sexes.
- Perched upon a roughened area of nasal bones. Indian rhino has a single horn, while the African species has two, one behind the other.
- These horns are entirely made of thick hairy and keratinized epidermal fibres fused together.
- These are permanent structures and if broken they again grow out. Rhinoceroses are still slaughtered illegally because these horns are in great demand in Oriental countries as a love charm.

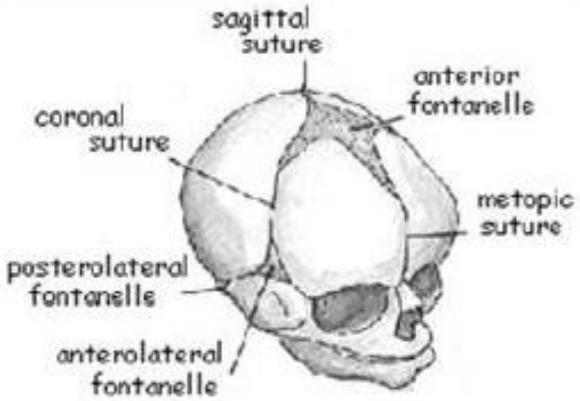
(6). Feathers

- Birds are covered by feathers which are not found in any other group of animals. They are dry, non-living andcornified products of stratum corneum of epidermis. These unique structures are light in weight, but strong,elastic and water-proof. They show different colours due to presence of pigments of various shades andstructural arrangement. They mainly streamline and protect the body, conserve body heat and make broadsurfaces of wings and tail used for flight. The mode of development of feathers is like that of scales. Feathers aremoulted and replaced seasonally. Generally, three types of feathers are recognized countour, down (plumules)and filoplumes (hair-like).

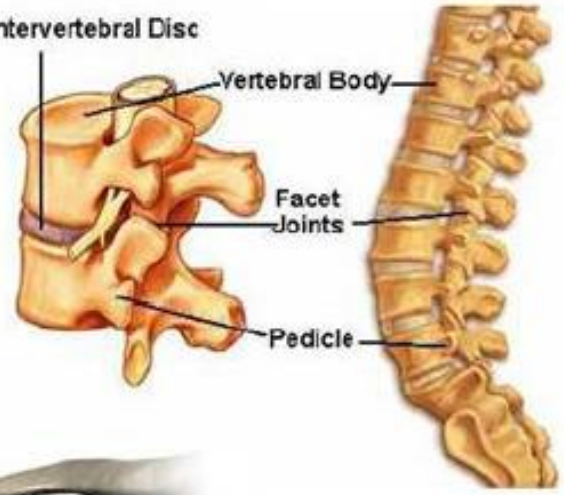
Skeletal Muscle in Tetrapods

CLASSIFICATION OF JOINTS

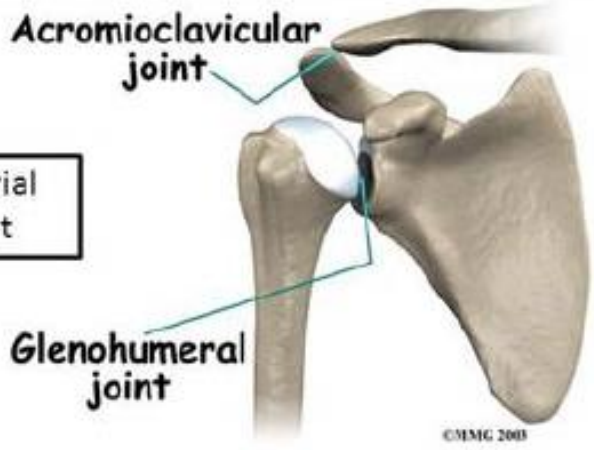
Fibrous Joint



Cartilaginous Joint



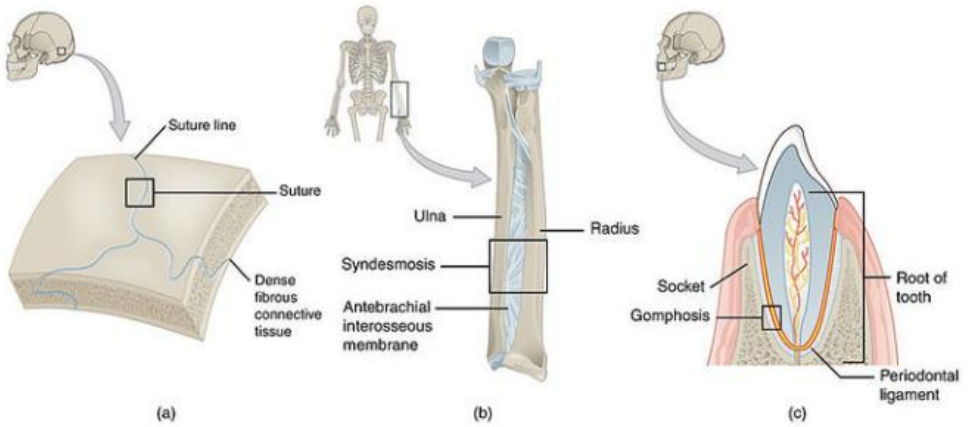
Synovial Joint



- Classification of joints
- On the basis of structure
- On the basis of extent of their function (degree of movement)
- 2. Classification of joints on the basis of structure:
- This classification is based on the presence or absence of joint cavity and kinds of supporting tissue that binds two bones together.

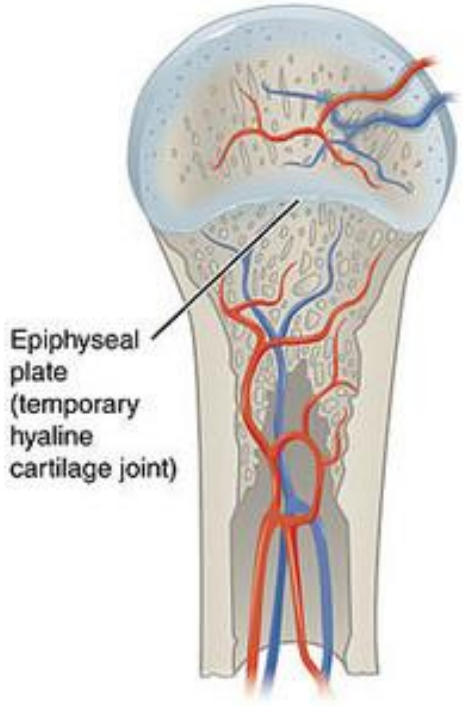
- **I. Fibrous joint**
- **II. Cartilaginous joint**
- **III. Synovial joint1.**

- I. Fibrous joint:
- Fibrous joint lacks joint cavity.
- Two bones are joined together by fibrous connective tissue.
- Fibrous joints are joined together tightly so they are generally immobile in adults although some allows slight movement.
- 1. Suture
- 2. Syndesmosis
- 3. Gomphosis

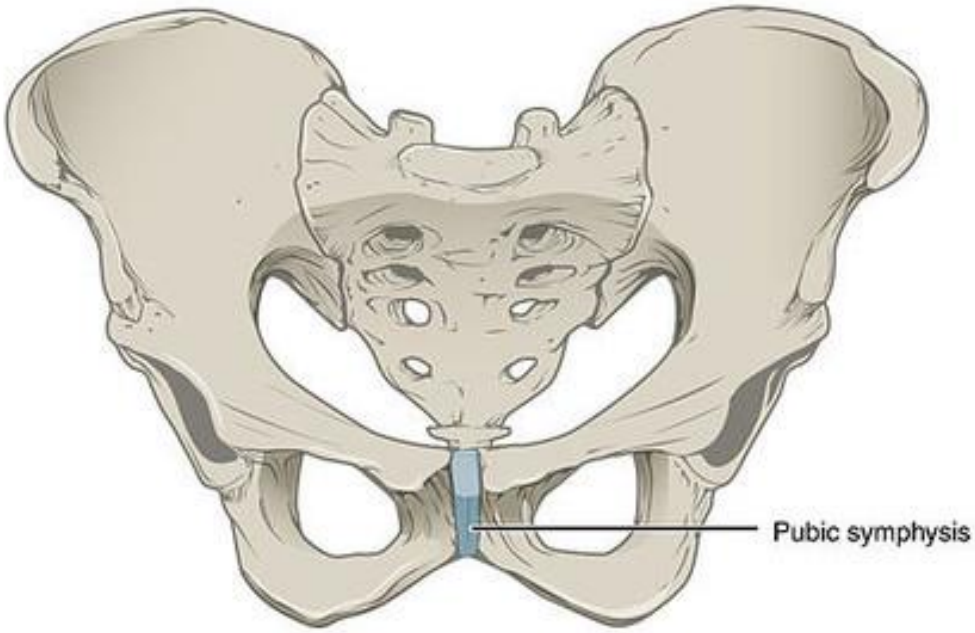


- 1. Suture:
- A suture is a tight union between two or more bones in a skull of adult.
- They are rarely movable.
- Example; sagital suture, squamousal suture, lambdoidal suture and coronal suture
- 2. Syndesmosis:
- In this joints, bones are close together but not touching each other
- Bones are held together by collagen fibers
- Examples; inferior Tibio-fibula joint, Radius-ulna joint
- 3. Gomphosis:
- It is fibrous joint made up of peg and socket.
- Example; the root of each teeth is anchored into its socket by fibrous ligament

- II. Cartilaginous joints:
- In cartilaginous joints, bones are united together by a plate of hyaline cartilage.
- Cartilaginous joints lack joint cavity
- They are slightly movable or immobile



(a)



(b)

- basis of degree of movement
- **Immobile joint (Synarthrosis)**: examples;
- suture of skull, syndesmosis, gomphosis, s ynchondrosis
- **Slightly movable joint (Amphi-arthrosis**):
- examples; symphysis
- **Freely movable joint (Diarthrosis):**
- examples; Synovial joints

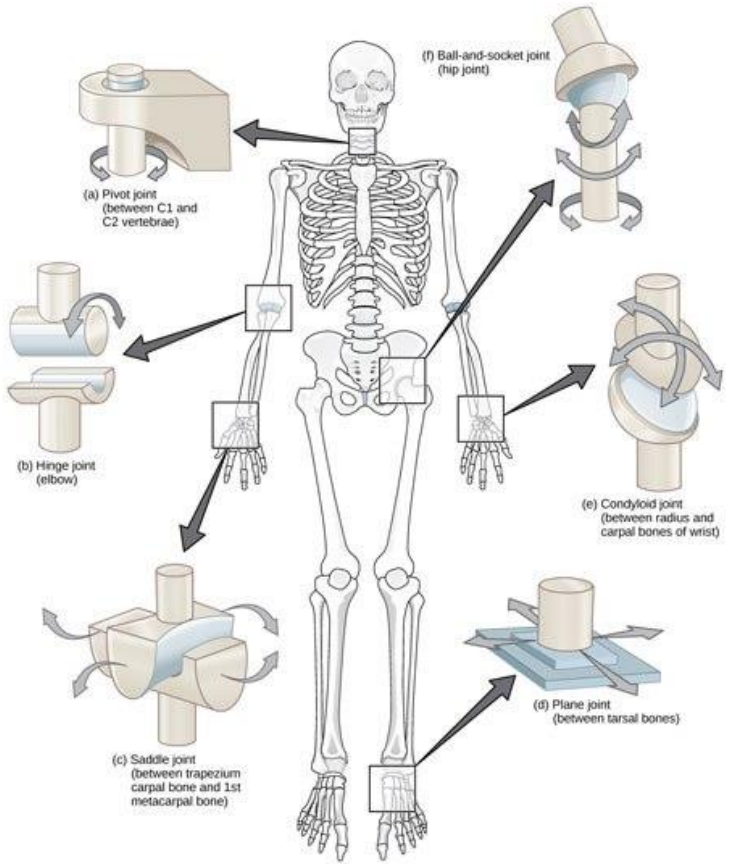


Table 7–5 MUSCLES OF THE SHOULDER AND ARM

Muscle	Function	Origin	Insertion
Deltoid	Abducts the humerus	• scapula and clavicle	• humerus
Pectoralis major	Flexes and adducts the humerus	• clavicle, sternum, 2nd–6th costal cartilages	• humerus
Latissimus dorsi	Extends and adducts the humerus	• last 6 thoracic vertebrae, all lumbar vertebrae, sacrum, iliac crest	• humerus
Teres major	Extends and adducts the humerus	• scapula	• humerus
Triceps brachii	Extends the forearm	• humerus and scapula	• ulna
Biceps brachii	Flexes the forearm	• scapula	• radius
Brachioradialis	Flexes the forearm	• humerus	• radius

Table 7–6 MUSCLES OF THE HIP AND LEG

Muscle	Function	Origin	Insertion
Iliopsoas	Flexes femur	• ilium, lumbar vertebrae	• femur
Gluteus maximus	Extends femur	• iliac crest, sacrum, coccyx	• femur
Gluteus medius	Abducts femur	• ilium	• femur
Quadriceps femoris group: Rectus femoris Vastus lateralis Vastus medialis Vastus intermedius	Flexes femur and extends lower leg	• ilium and femur	• tibia
Hamstring group Biceps femoris Semimembranosus Semitendinosus	Extends femur and flexes lower leg	• ischium	• tibia and fibula
Adductor group	Adducts femur	• ischium and pubis	• femur
Sartorius	Flexes femur and lower leg	• ilium	• tibia
Gastrocnemius	Plantar flexes foot	• femur	• calcaneus (Achilles tendon)
Soleus	Plantar flexes foot	• tibia and fibula	• calcaneus (Achilles tendon)
Tibialis anterior	Dorsiflexes foot	• tibia	• metatarsals

Table 7–7 MUSCLES OF THE PELVIC FLOOR

Muscle	Function	Origin	Insertion
Levator ani	Supports pelvic organs, especially during defecation, urination, coughing, and forced exhalation; constricts anus, urethra, and vagina	• pubis and ischium	• coccyx, anal canal, urethra
Coccygeus	Supports pelvic organs, especially during defecation, urination, coughing, and forced exhalation	• ischium	• coccyx and sacrum
Ischiocavernosus	Erection of clitoris in female, penis in male	• ischium and pubis	• clitoris or penis
Bulbospongiosus	Assists urination; erection in female; erection and ejaculation in male	• central tendon of perineum	• fasciae, pubic arch, clitoris, or penis
Transverse perineus (superficial and deep)	Assists urination in female; urination and ejaculation in male	• ischium	• central tendon of perineum
External anal sphincter	Closes anus	• anococcygeal ligament	• central tendon of perineum

Fishes' gill arch	Muscle	Action
First arch	Adductor mandibulae	closes jaw
	Intermandibularis	compresses throat
Second arch	Constrictor	compresses gills/pharynx
	Levator	lifts gill bars
Third to seventh arch	Constrictors	compresses gills/pharynx
	Levators	lifts gill bars

The **cucullaris** is attached to the last branchial arch but is associated with the pectoral girdle

In tetrapods the branchiometric musculature changed in tandem with changes in the visceral skeleton to make the animals more adapted to a terrestrial environment - resulted in a loss of many branchiometric muscles

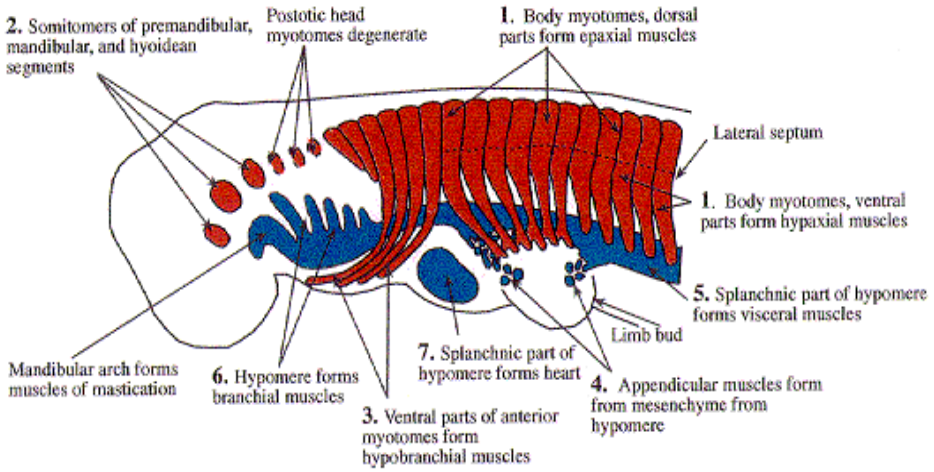
Tetrapod gill arch	Muscle	Action
First arch	Masseter	closes jaw
	Temporalis	closes jaw
	Pterygoids	function in jaw movement
	Digastric	opens the jaw
	Mylohyoid	opens the jaw
Second arch	Platysma	moves skin of face and neck
Other arches	Sternomastoid	turn head
	Cleidomastoid	turn head

Epibranchial and hypobranchial muscles - dorsal and ventral muscles associated with the head and trunkregion that perform functions associated with jaw and tongue movement

☐ muscles of fishes associated with feeding and breathing include:

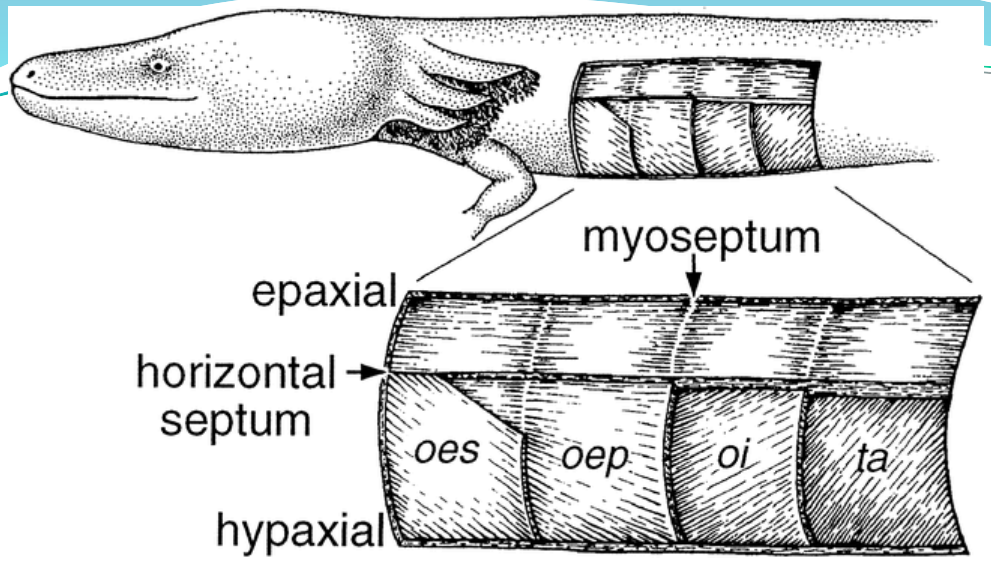
- Coracoarcuals - opens mouth-
- Coracomandibular - opens mouth-
- Coracohyoid - helps in feeding-
- Coracobranchial - helps in swallowing

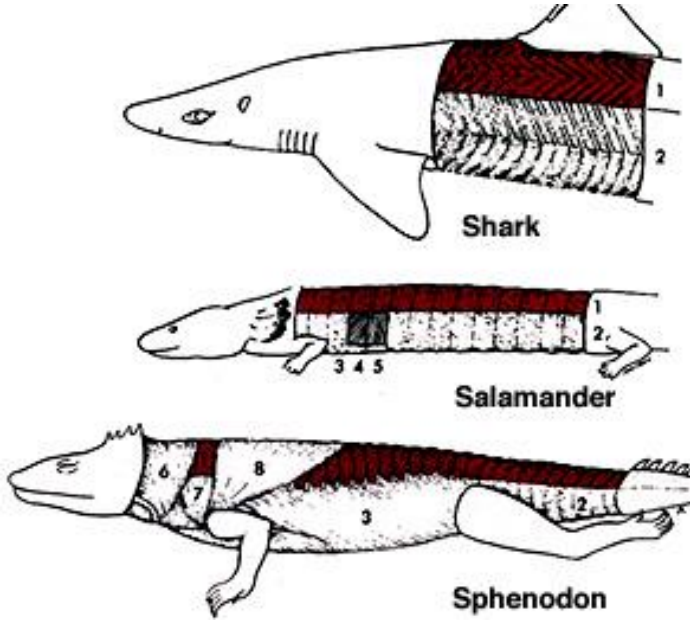
- muscles in tetrapods are associated with the hyoid apparatus and the tongue:-
- Tongue muscles - hyoglossus, styloglossus, genioglossus
- Geniohyoid - draws hyoid cranially
- - Sternohyoid - draws hyoid posteriorly
- - Sternothyroid - draws larynx caudally
- - these muscles are also used in speech and sound production in tetrapods



Stylized embryo--derivation of muscles from myotomes and hypomere

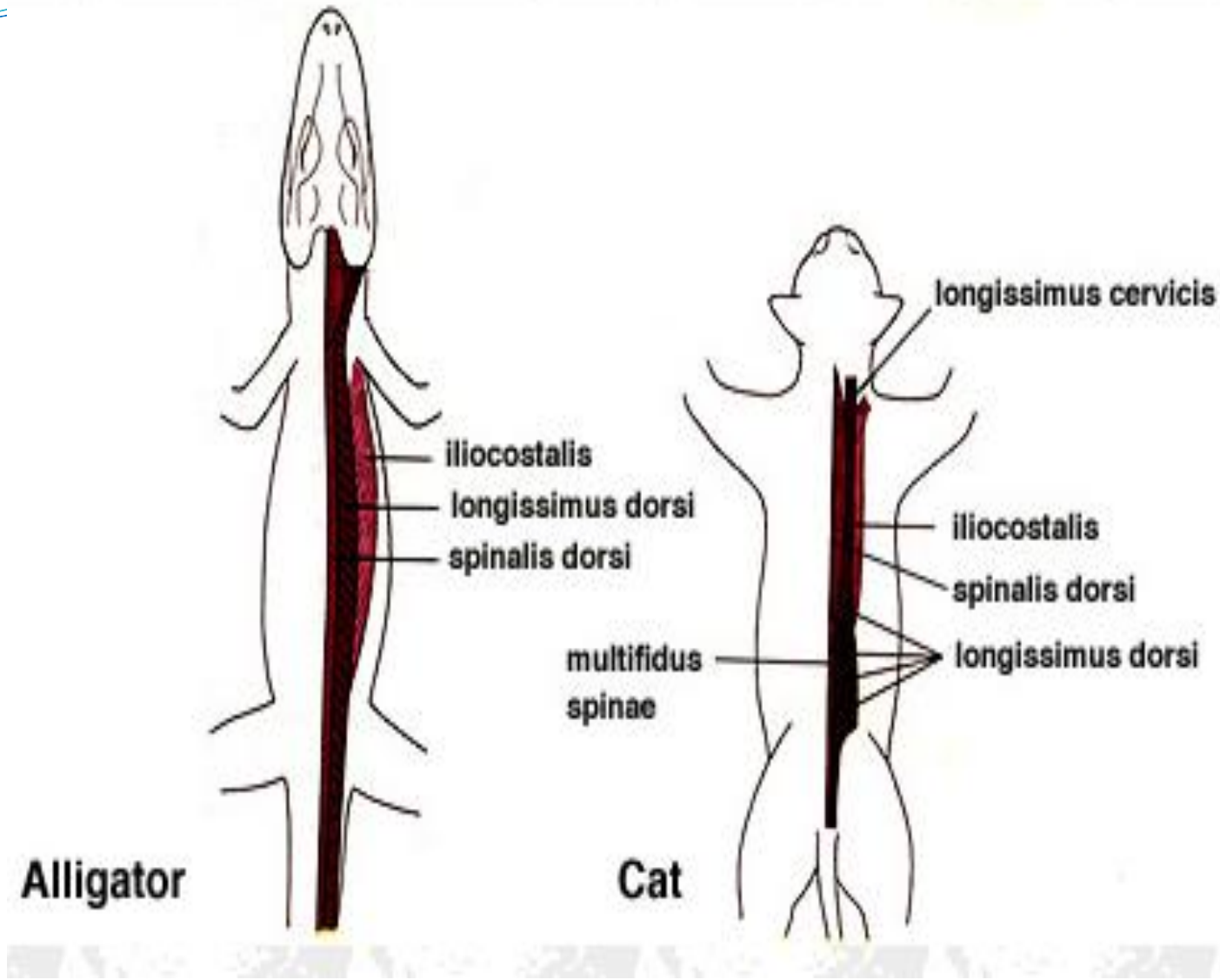
- **Trunk/axial muscles**
- The axial musculature associated with the trunk can function either in locomotion or breathing Axial musculature begins as myotomes separated by myosepta which are then further divided into two regions:
- ☐ **epaxial muscles -** muscles on the dorsal part of the body
- ☐ **hypaxial muscles -** muscles on the ventral part of the body that are separated by the lateral septum



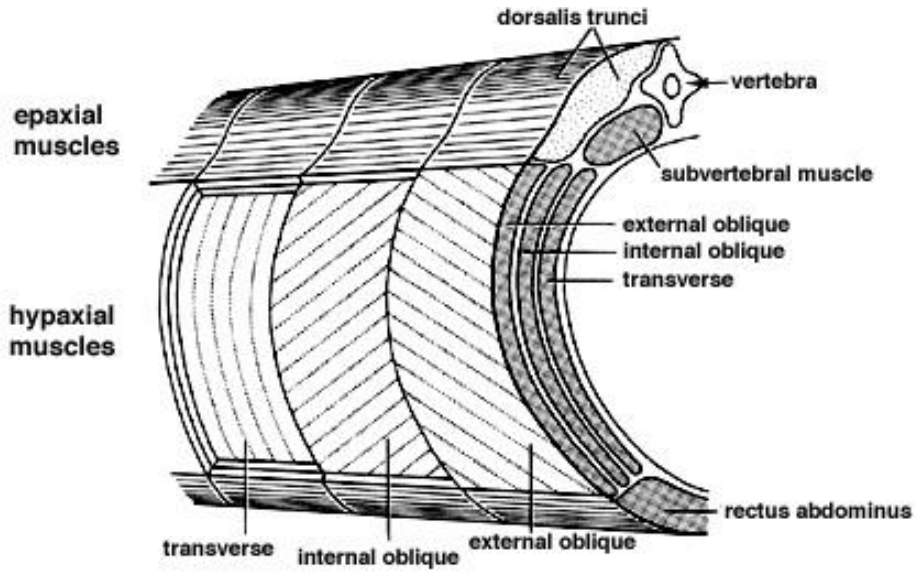


1. epaxials
2. hypaxials
3. external oblique
4. internal oblique
5. transverse abdominis
6. trapezius
7. dorsalis scapulae
8. latissimus dorsi

- **Tetrapods**
- In tetrapods, the trunk muscles function more in maintenance of posture, head movement, and respiration ratherthan in locomotion, which has shifted to the appendicular muscles
- The epaxial muscles of the tetrapod trunk skeleton include:
- Longissimus dorsi - extends vertebral column
- Iliocostalis - draws ribs together
- Multifidus spinae - extends vertebral column
- Spinalis dorsi - extends vertebral column


iliocostalis
longissimus dorsi
spinalis dorsi
Alligator
longissimus cervicis
iliocostalis
spinalis dorsi
multifidus
spinae
longissimus dorsi
Cat

- The hypaxial muscles of the tetrapod trunk skeleton include:
- Abdominal muscles:
- Rectus abdominis - compresses abdomen
- Internal oblique - compresses abdomen
- External oblique - constricts abdomen
- Internal oblique - constricts abdomen
- Respiratory muscles:
- Serratus - draw ribs cranially)
- Scalenus - flexes the neck)
- Diaphragm - separates the thoracic/abdominal cavities, functions in breathing
- Intercostals - protract/retract ribs



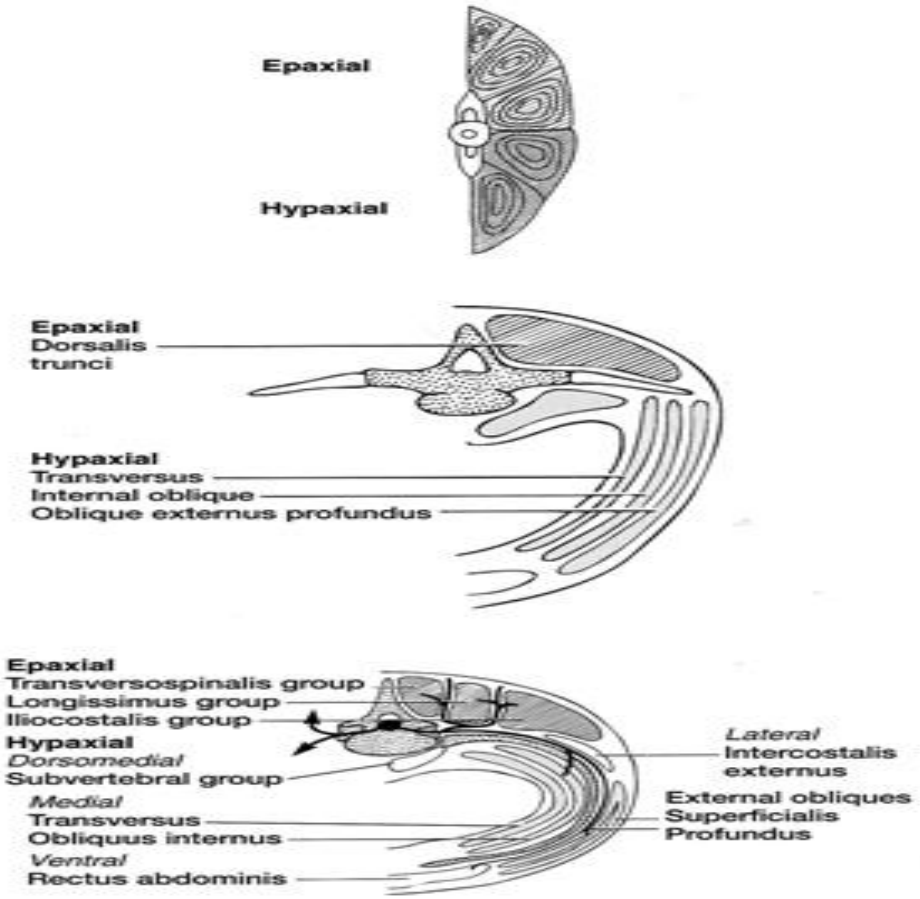
- **Fishes**
- Locomotion dependent on the action of the axial musculature, which undergoes alternate contraction and relaxation to produce undulating movements of the body
- Fins (appendicular appendages) function more in maintaining stability, the range of movement of fins is much more limited than that of tetrapod limbs
- □ **ventral muscles** in fishes go to the formation of the **abductor muscle,** which pulls the fins ventrally and cranially
- □ **dorsal muscles** go to the formation of the **adductor muscle** found on the posterodorsal part of the fin and moves the fin dorsally and caudally

Tetrapods

- The tetrapod appendicular musculature is more complex than that of fishes because the limbs function in both support and locomotion
- In tetrapods the **function** of the dorsal and ventral muscle groups is **reversed** from that seen in fishes
- □ the **dorsal** muscles, which in fishes were responsible for adduction will instead **abduct or extend the appendages**
- □ the **ventral** muscles formerly used for abduction are instead used for **adduction or flexion**

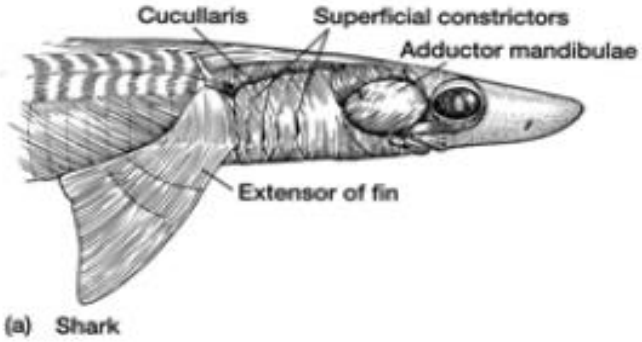
Pectoral region	**Dorsal muscles (extensors)**	**Ventral muscles (flexors)**
Muscles of the back	Latissimus dorsi Cutaneous maximus	
Muscles of the chest Muscles of the shoulder	Deltoids Subscapularis Teres major	Pectoralis Supraspinatus Infraspinatus
Muscles of the arm	Triceps Supinator Extensors of the digits	Biceps Pronator Flexors of the digits
Pelvic region	**Dorsal muscles (extensors)**	**Ventral muscles (flexors)**
	Gluteal muscles Quadriceps rectus femoris vastus medius vastus intermedius vastus lateralis Sartorius Iliopsoas Extensors of the digits	Adductor femoris Semimembranosus Semitendinosus Gracilis Biceps femoris Gastrocnemius Caudofemoralis Flexors of the digits

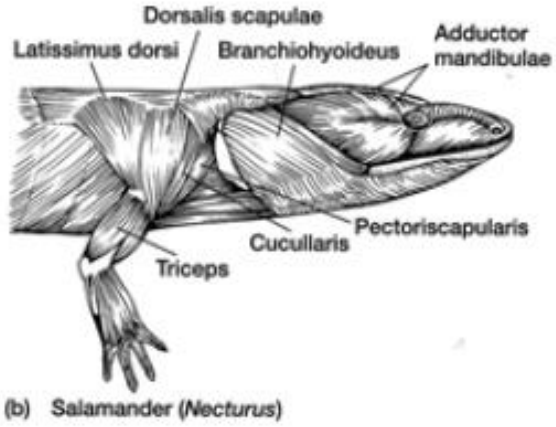
- In tetrapods, the appendicular muscles take over the major role of locomotion.
- In salamanders and lizards, however, the axial skeleton still plays a large role in locomotion due to the lateral undulations of the body and the epaxial muscles are still prominent.
- In birds and mammals, the epaxial muscles take on the role of stabilizing the vertebral column.
- The hypaxial muscles in tetrapods form much of the body wall and while they do participate in moving the trunk, primarily, however, they are associated with breathing in reptiles, birds and mammals.

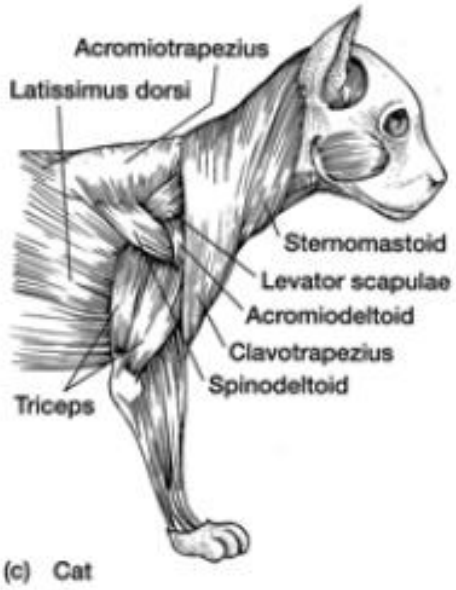


- In tetrapods, the dorsal and ventral appendicular muscles become more prominent as the limbs assume the role of producing locomotor forces (from fins for stabilizing to limbs for locomotion).
- These muscle masses tend to split and divide forming many distinct muscles that increase the complexity of the limb musculature.

- The dorsal and ventral limb muscles also receive contributions from axial muscles from adjacent parts of the body wall as well as from the branchiomeric muscles of the gill arches in the case of the forelimbs.
- The hindlimb muscles are primarily derived from the dorsal and ventral appendicular muscle masses.
- There is a small contribution from the axial muscles. Again, however, there is a trend for these muscle masses to split and divide forming many distinct muscles that increase the complexity of the limb musculature.



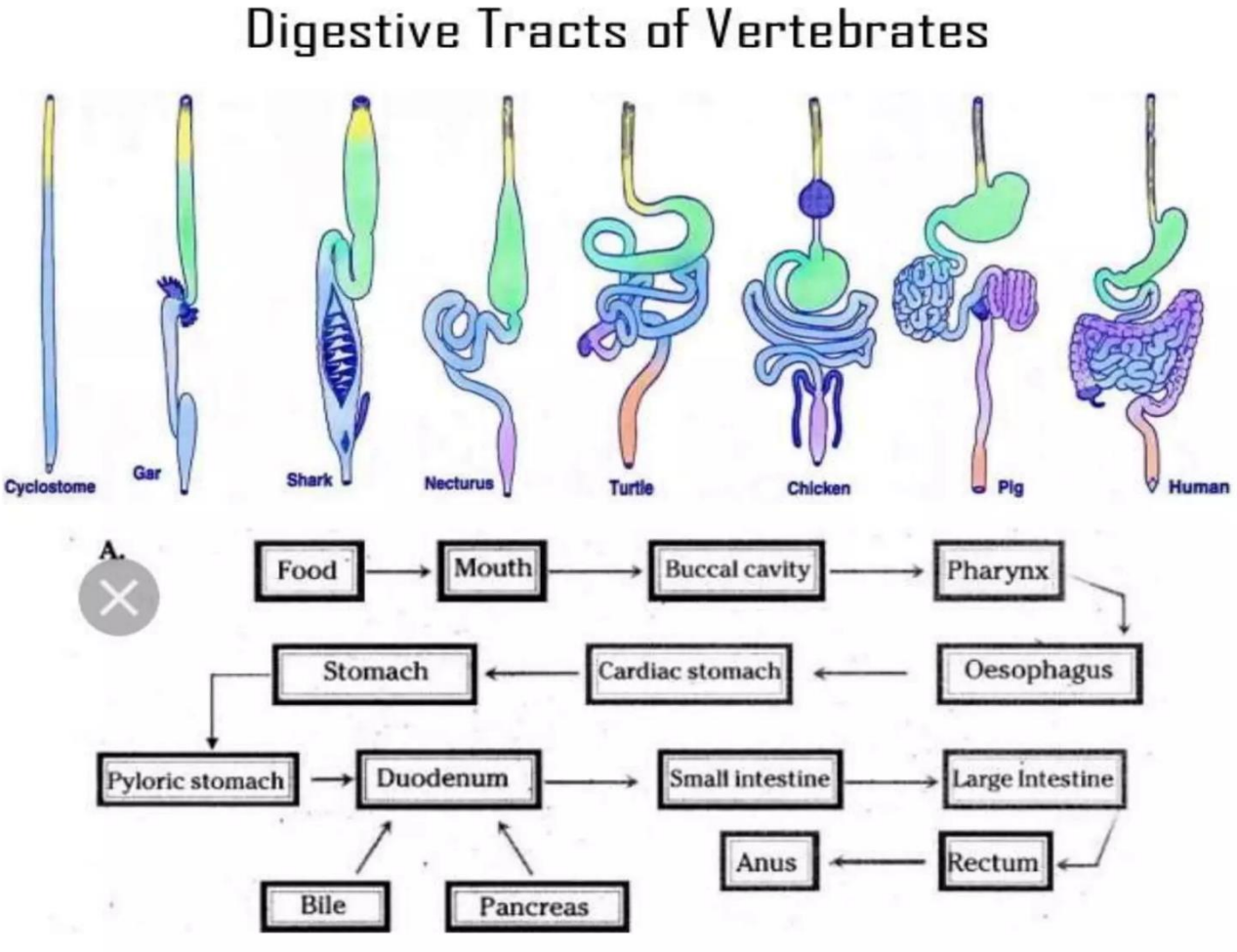


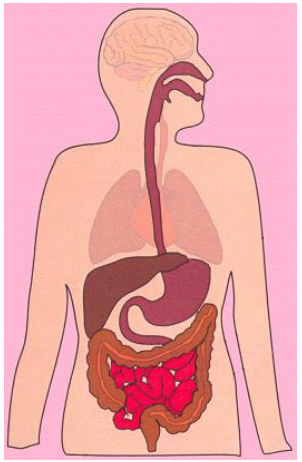


- **Cursorial tetrapods,** adapted for speed, tend to have their appendicular muscles bunched proximally near the trunk.
- Their forces are distributed distally through long tendons to the distal portion of the limbs.
- This reduces the mass carried by the limb, which reduces the inertia that must be overcome when the limb changes direction and allows the end of the limb to be moved more quickly

- **In birds,** the hind limbs show similar adaptations, which keep the muscle mass close to the body in flight but the long tendons allow precise movement of the toes for perching and capturing prey.
- The muscles of the pectoral girdle and forelimb are also massive and bunched proximally, especially the pectoralis which attaches to the sternum and provides the majority of the force required for flight.

Anatomy and Function of Digestive System in vertebrates

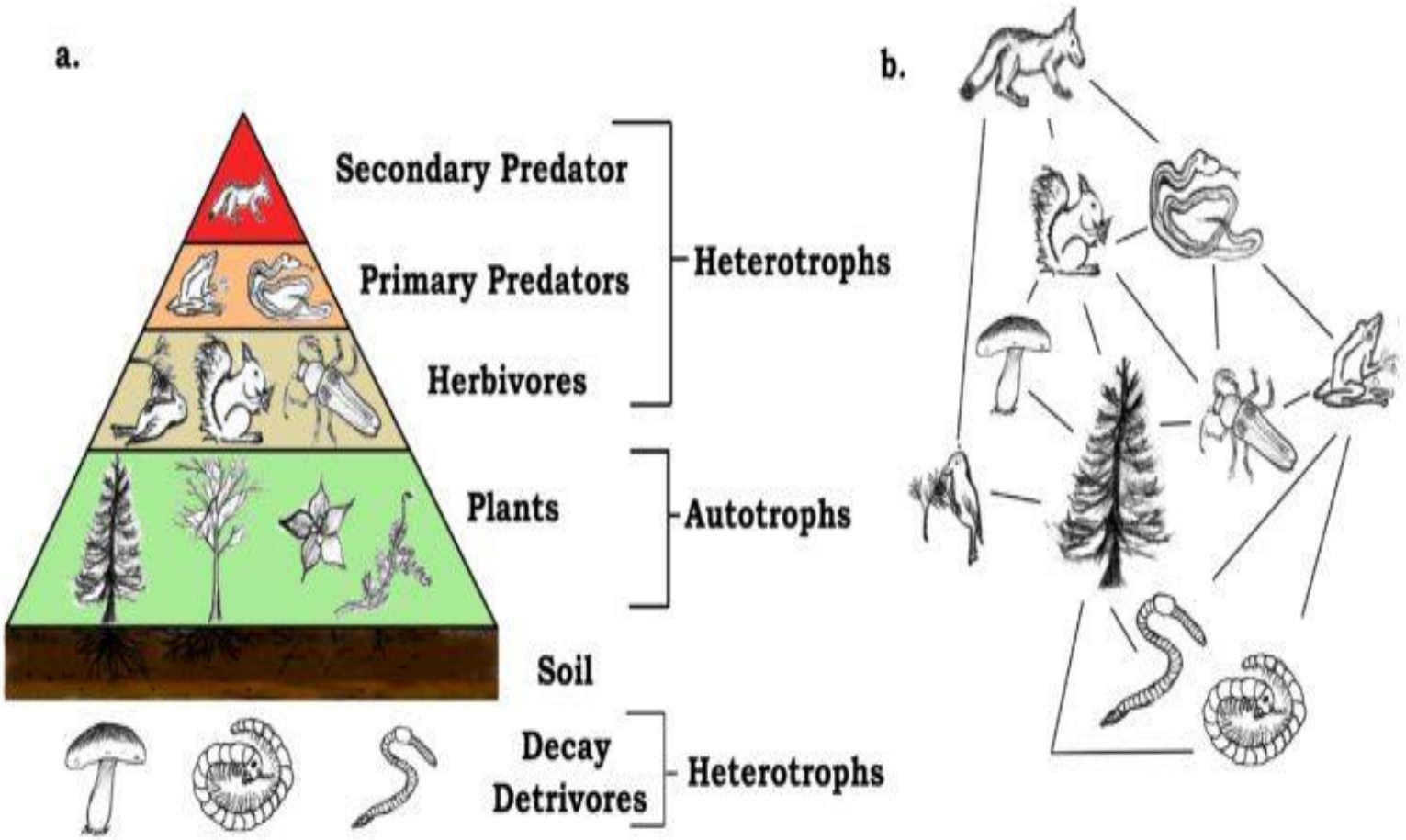




INTRODUCTION

- The term **alimentary canal or digestive tract** in vertebrates refers to an internal tube, seldom straight running from an anterior mouth opening in head to a posterior anal or cloacal aperture at the base of tail.
- It is designed for ingestion, digestion and absorption of food stuffs and egestion of undigested wastes.
- Major parts of alimentary canal are :
- oral cavity, pharynx, oesophagus, stomach and small and large intestines.

MODE OF NUTRITION



TYPE OF ANIMAL NUTRITION

Autotrophic nutrition: When organisms synthesize the organic nutrients directly from available inorganic substances utilizing energy in any form.

- Autotrophic nutrition is typical of plants.
- It is also called holophytic nutrition. Autotrophic nutrition is of two types :

Chemosynthetic : The primitive autotrophic prokaryotes used chemical (glycolytic) energy to make carbohydrates from H_2S and CO_2.

- **Photosynthetic :** Plants or chlorophyll containing organisms utilize solar energy (light) to synthesize food from CO_2 and H_2O.
- **Heterotrophic :** When organisms derive food from available products prepared by plants. All animals, fungi, bacteria etc. have this mode of nutrition.

EMBRYONIC DEVELOPMENT OF DIGESTIVE TRACT

Archenteron:

- The embryonic archenteron becomes the lining of the adult digestive tract and of all its derivatives.
- Splanchnic mesoderm adds layers of connective tissue and smooth muscles around the archenteron.
- Ectodermal invagination of the head forms the stomodaeum leading into oral cavity, and a similar mid-ventral ectodermal invagination forms proctodaeum, which leads into the hindgut.
- The stomodaeum becomes the adult buccal cavity and gives rise to teeth enamel, epithelial covering of tongue, glands, e.g., mucous, poison and salivary, etc., and Rathke's pouch of anterior pituitary gland.
- The proctodaeum forms either a small terminal part of the cloaca in lower vertebrates and rectum in mammals.

- The alimentary canal in embryos from stomach to cloaca is attached to the dorsal body wall by a double fold of peritoneum, called the dorsal mesentery and to ventral body wall by a ventral mesentery.
- In adults, dorsal mesentery persists but the ventral mesentery disappears leaving only in the region of liver and urinary bladder.

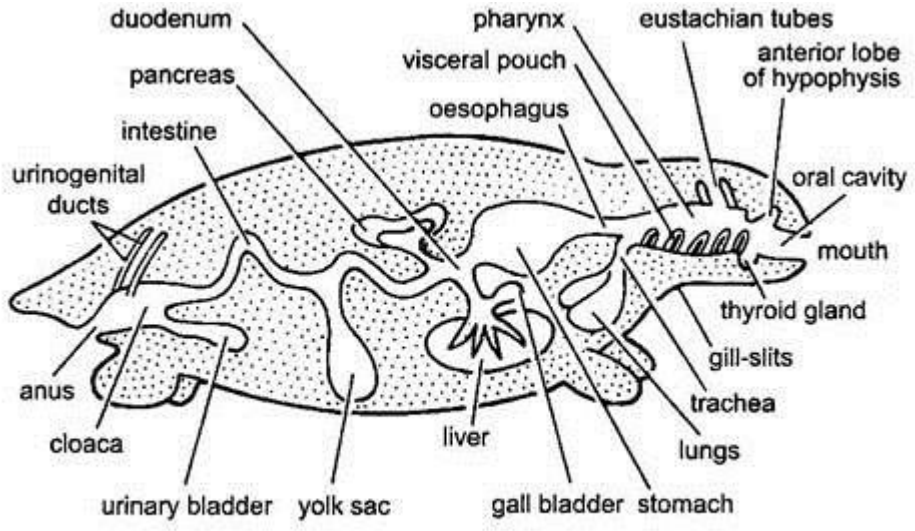


Fig. 43.4. Alimentary canal and its chief derivatives in a vertebrate.

- **Histology:**
- The wall of the alimentary canal is made of four concentric layers.
- (i) An outermost visceral peritoneum or serous coat is made of mesothelial cells and thin layer of connective tissue. It is lacking in the oesophagus,
- (ii) Below this is a muscular layer formed of smooth muscle fibres arranged in outer longitudinal and inner circular muscle fibres. Between the two layers of muscles is a network of nerve cells and nerve fibres of the autonomic nervous system, known as myenteric plexus.
- (iii) Beneath the muscle layer is a submucosa made of connective tissue having elastic fibres, fat, blood and lymph vessels, nerve cells and fibres glands,

- **VERTEBRATE DIGESTIVE SYSTEMS**
- Vertebrates have evolved more complex digestive systems to adapt to their dietary needs.
- Some animals have a single stomach, while others have multi-chambered stomachs.
- Birds have developed a digestive system adapted to eating un-masticated(un-chewed) food.

MONOGASTRIC: SINGLE-CHAMBERED STOMACH

- Monogastric - consists of one ("mono") stomach chamber ("gastric").
- Humans and many animals have a monogastric digestive system.

. The gastric juices, which include enzymes in the stomach, act on the food particles and continue the process of digestion.

In the small intestine, enzymes produced by the liver, the small intestine, and the pancreas continue the process of digestion. The nutrients are absorbed into the blood stream across the epithelial cells lining the walls of the small intestines. The waste material travels to the large intestine where water is absorbed and the drier waste material is compacted into feces that are stored until excreted through the rectum.

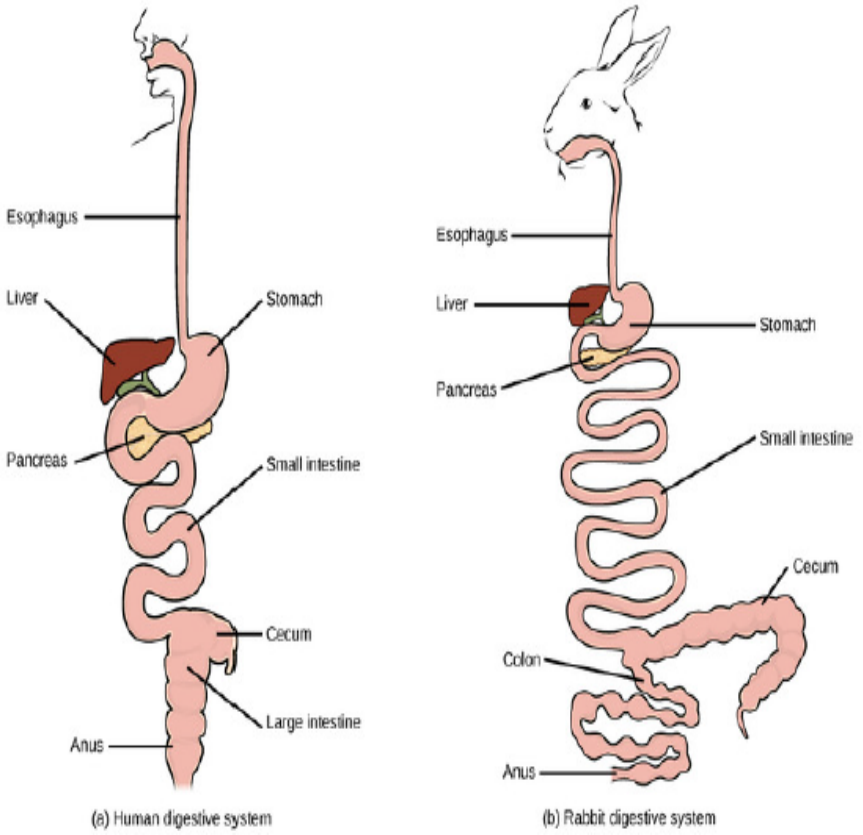
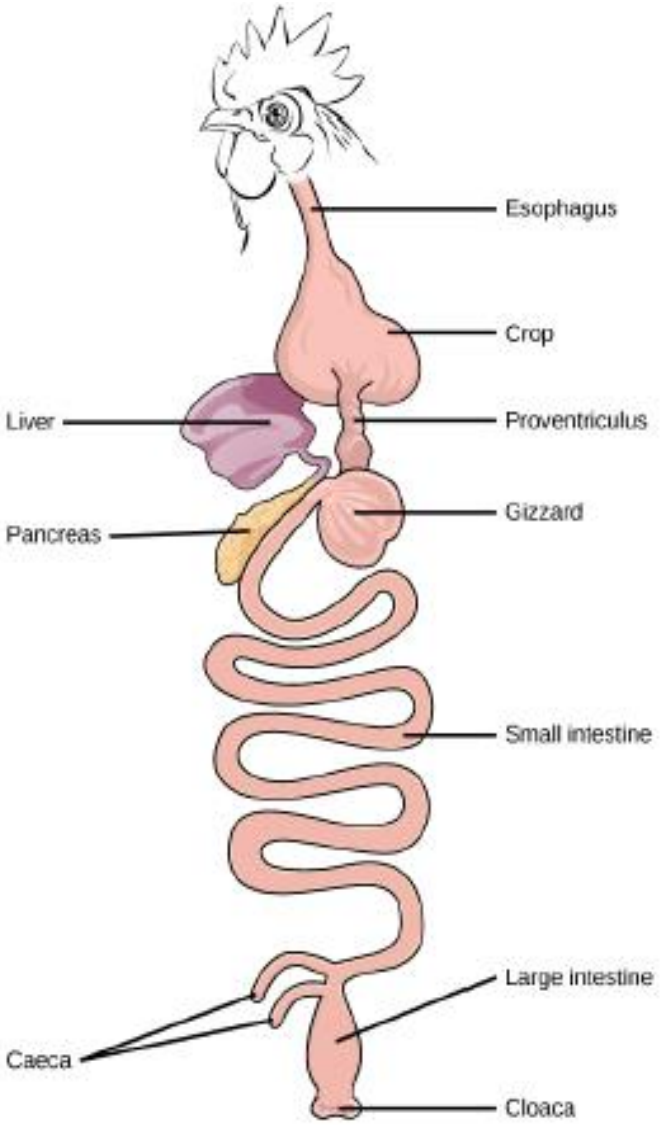


Figure 34.4.1: Mammalian digestive system (non-ruminant): (a) Humans and herbivores, such as the (b) rabbit, have a monogastric digestive system. However, in the rabbit, the small intestine and cecum are enlarged to allow more time to digest plant material. The enlarged organ provides more surface area for absorption of nutrients.

- Bird digestive system:
- The avian oesophagus has apouch, called a cro which stores food.
- Food passes from the cropto the first of tw stomachs, called the proventriculus, whic contains digestive juices that break down foo From the proventriculus, the food enters th second stomach, called the gizzard, which grind food. Some birds swallow stones or grit, which ar stored in the gizzard, to aid the grinding proces Birds do not have separate openings to excret urine and feces.
- Instead,uric acid from the kidneys is secreted int the large intestine and combined with waste fro the digestive process. This waste is excrete through an opening called the cloaca.



- RUMINANTS
- Ruminants are mainly herbivores, such as cows, sheep, and goats, eating large amounts of roughage or fiber.
- They have evolved digestive systems that help them process vast amounts of cellulose.
- An interesting feature of the ruminants'mouth is that they do not have upper incisor teeth.
- They use their lower teeth, tongue, and lips to tear and chew their food. From the mouth, the food travels through the esophagus and into the stomach.
- To help digest the large amount of plant material, the stomach of the ruminants is a multi-chambered organ. The four compartments of the stomach are called the rumen, reticulum,omasum, and abomasum.

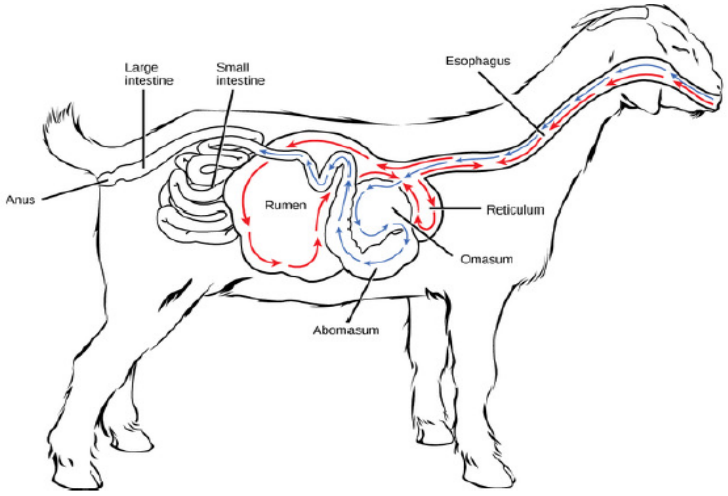


Figure 34.4.1: Ruminant mammal digestive system: Ruminant animals, such as goats and cows, have four stomachs. The first two stomachs, the rumen and the reticulum, contain prokaryotes and protists that are able to digest cellulose fiber. The ruminant regurgitates cud from the reticulum, chews it, and swallows it into a third stomach, the omasum, which removes water. The cud then passes onto the fourth stomach, the abomasum, where it is digested by enzymes produced by the ruminant.

ANATOMY OF THE DIGESTIVE SYSTEM

- The GI tract has four different layers: the mucosa, the submucosa, the muscle layer and the serosa.
- The **mucosa has three different layers:**
- A layer of simple columnar epithelium lining the lumen
- A thin layer of connective tissue
- A thin layer of smooth muscle
- The **submucosa is comprised of loose connective tissue with blood vessels, lymphatic vessels and nerves.**
- The **muscular is has an inner layer of smooth muscle and an outer, longtiduinal layer of smooth muscle.**
- The **serosa is made up of connective tissue with simple squamous epithelium.**

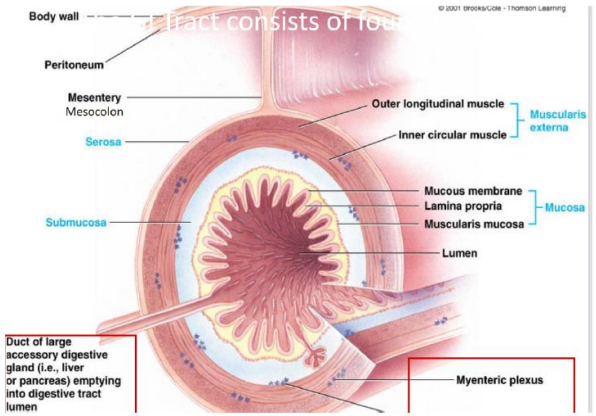


Figure 7.2: Layers of the GI Tract

- **Functions**
- It **moves food through the intestines via a combination of peristalsis (i.e., propulsive movement) and segmentation (i.e., mixing movement).**
- The digestive system also secretes hormones from endo- and exocrine glands).
- Lastly, the digestive system also digests food via degrading ingested food into monomeric units. Absorption of these "monomeric units" also take place in the small and large intestine.

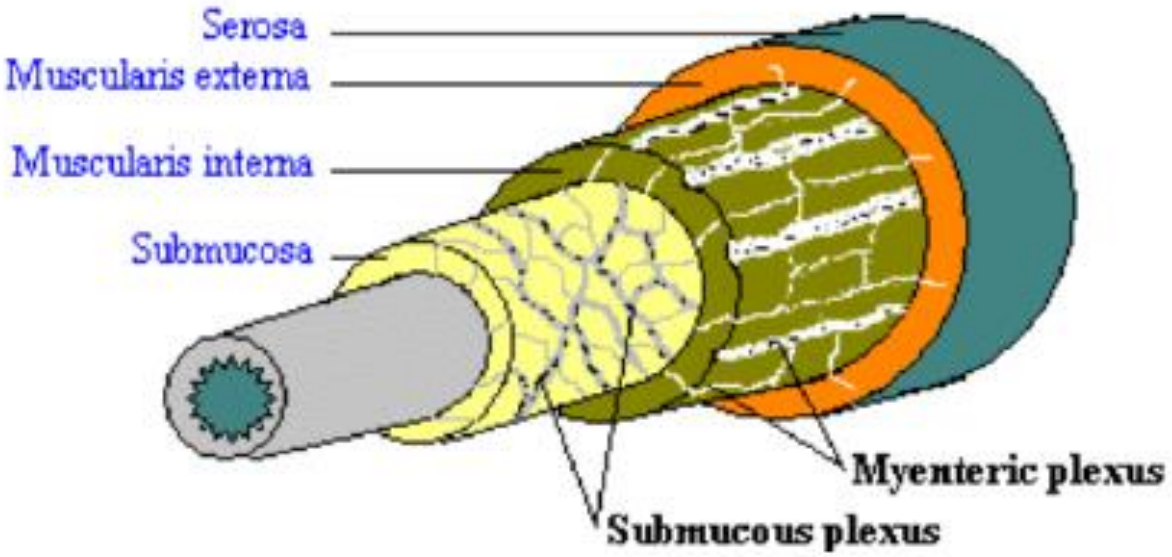


Figure 7.5: Myenteric and Submucosal Plexuses

- **Gastrointestinal hormones**
- Gastrin is secreted by the G cells of the stomach.
- Not only does it encourage secretions from the parietal cells (secretes HCl) and chief cells (secretes pepsinogen) of the stomach, but it also relaxes the pyloric sphincter (prevents food from travelling from the stomach to the duodenum - the first part of the small intestine) and encourages the movement of food through the gastrointestinal tract.
- Secretin is released in response to acid being in the duodenum. This hormone encourages NaHCO secretion by the pancreas and the liver.

Cholecystokinin stimulates the pancreatic secretion of digestive enzymes and promotes the relaxation of the gallbladder and the sphincter of Oddi.

- Gastric inhibitory peptide (i.e., GIP) stimulates insulin production.
- It is important to note that secretin, cholescystokinin, and GIP inhibits gastric emptying and secretions!

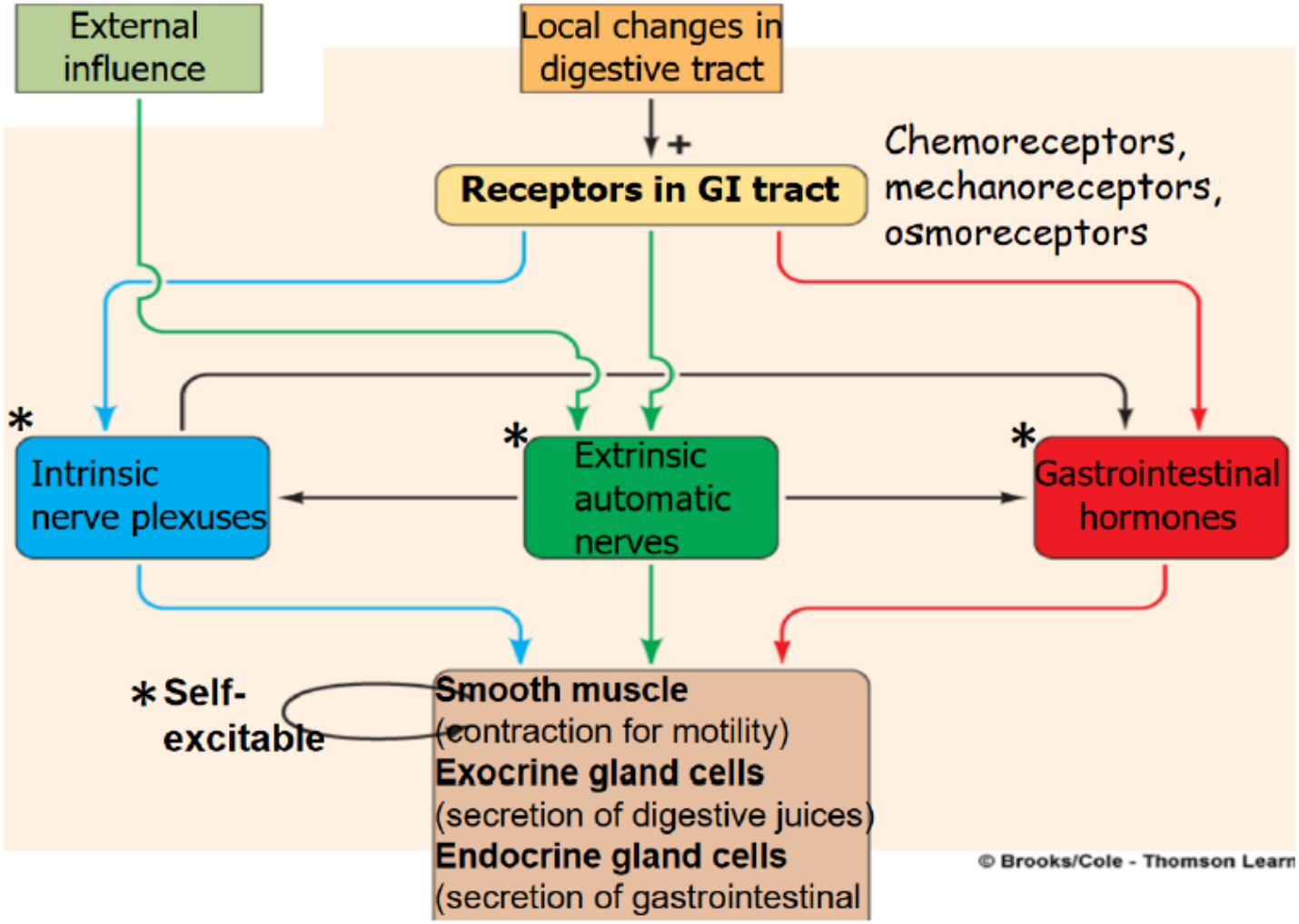


Figure 7.6: Regulation of the Digestive System

The Stomach

- This is the most distensible part of the gastrointestinal tract; gastric pits are "trenches" in the epithelial lining of the stomach:

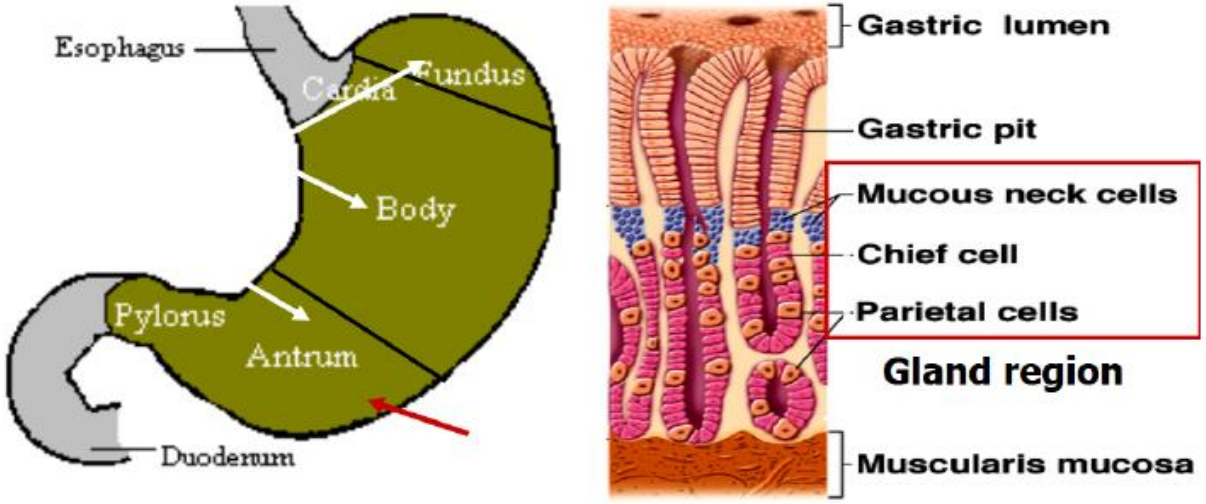


Figure 7.7: Anatomy of the Stomach

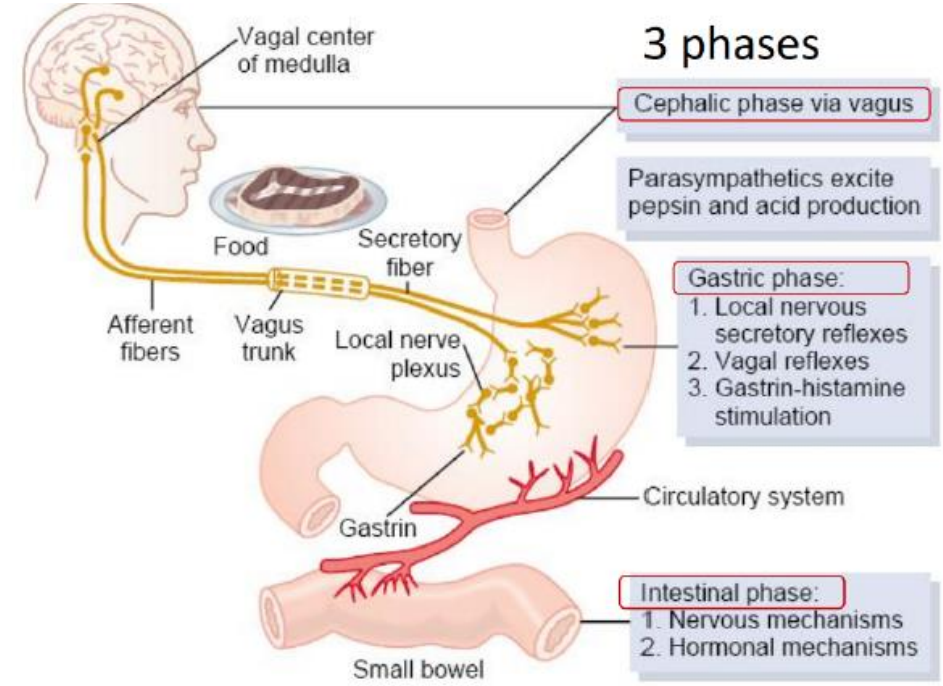


Figure 7.8: Regulating Gastric Secretions

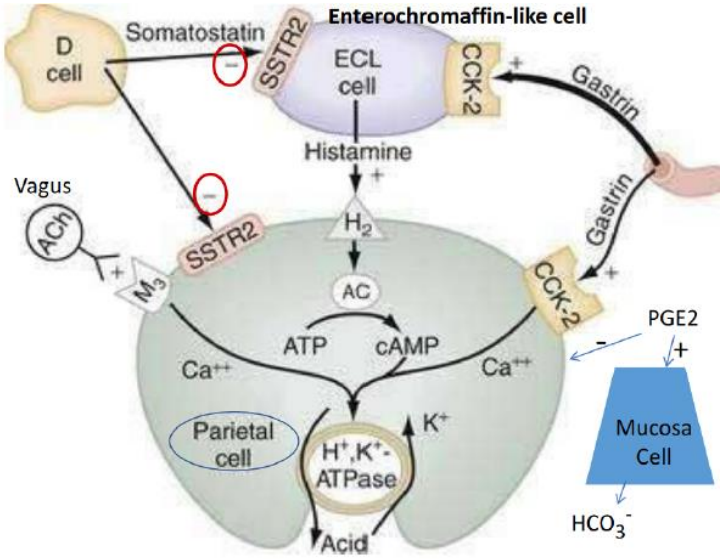


Figure 7.9: Regulating HCl Secretions

Furthermore, **D cells also regulate the production of HCl in parietal cells:**

- **Hepatic lobules (the functional unit of the liver)**

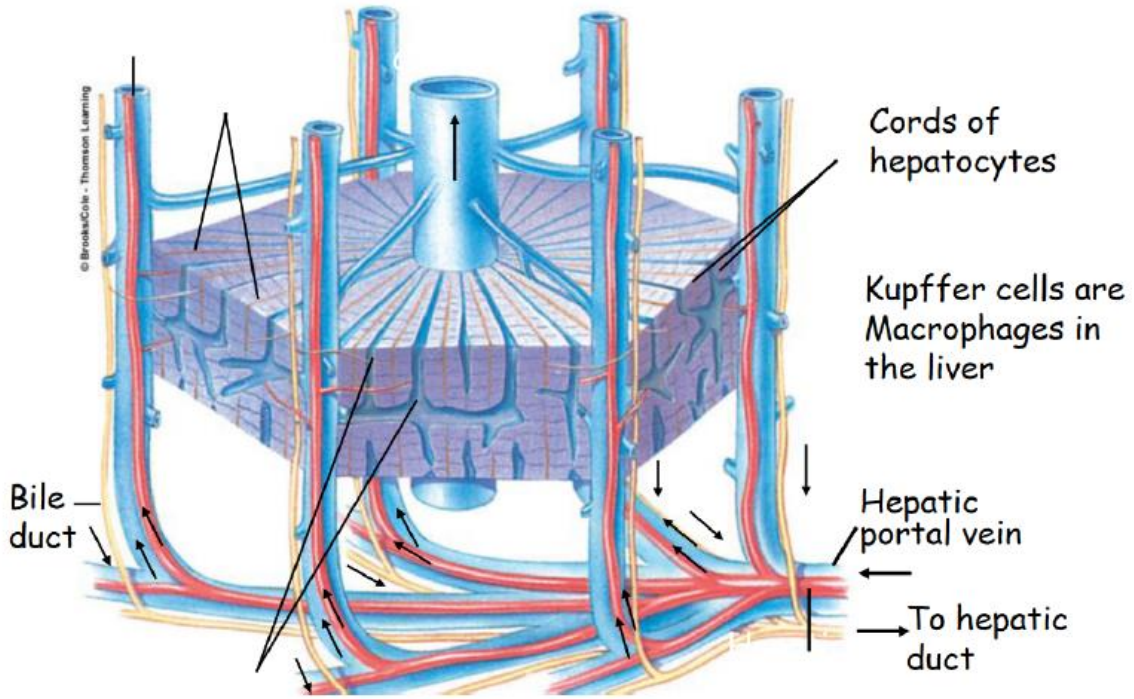


Figure 7.11: Hepatic Lobule Anatomy

Interestingly, the liver seems to have an infinite capacity for regenerating itself.

90% of liver cells (i.e., hepatocytes) are replaced within a day of the injury. However, the liver does not heal very well when it is scarred (caused by a condition known ascirrhosis - the scarring and hardening of the liver).

- **Bile salts**
- These are amphipathic substances that emulsify lipids to increase the surface area of fat.
- Bilesalts also solubilize lipids.
- Bile salts are responsible for the majority of cholesterol digestion in the body:

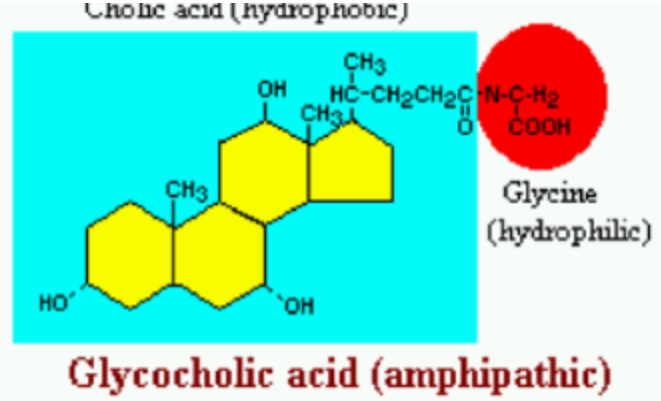


Figure 7.12: General Structure of a Bile Salt

Up to 95% of bile salts end up back in the liver for re-secretion!

- **The Small Intestine**
- The small intestine includes the duodenum, jejunum, and the ileum.
- It is also the site where the bulk of digestion and absorption takes place.
- The inner surface of the small intestine also contains many folds to increase the amount of surface area of digestion:
- villi increase the surface area by an order of 10;
- microvilli arise from the brush borders of epithelial cells and increases the surface area by another 20 times.

- **Enzymes in the small intestine**
- Enzymes here are contained in brush borders - these enzymes have their active sites exposed to the lumen.
- The main enzymes in the small intestine
- 1. Enterokinase
- 2. Aminopeptidase
- 3. Maltose, sucrase, and lactose

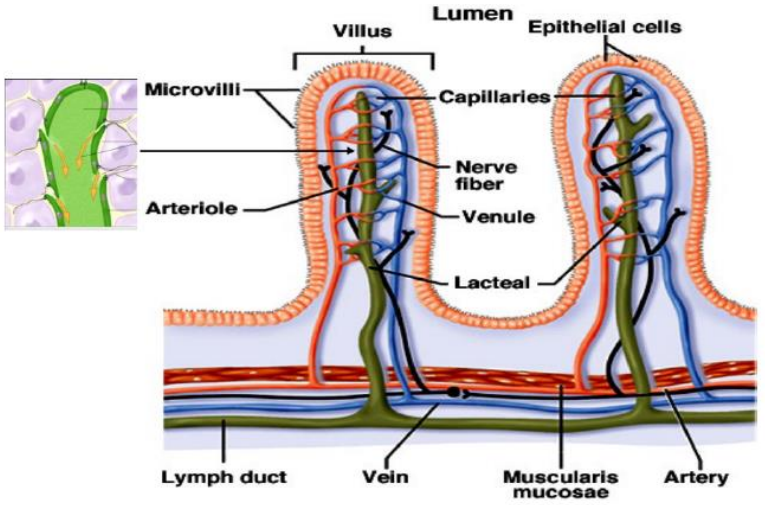
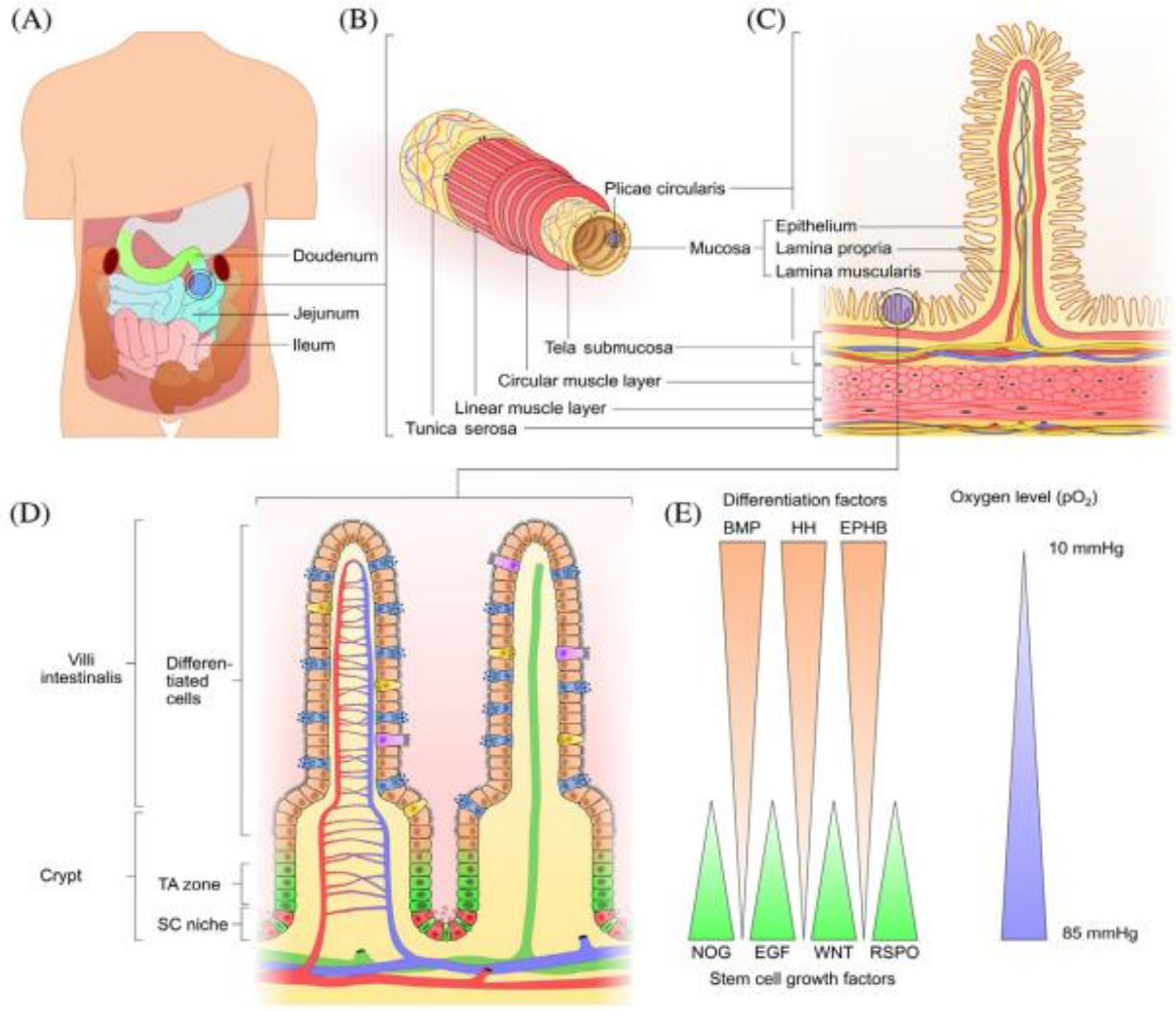


Figure 7.13: Blood Supply to the Small Intestine



(F)

	Enterocytes	Goblet cells	Enteroendocrine cells	Tuft cells	Paneth cells	Stem cells (SCs)
Function:	Nutrient absorption Epithelial barrier Secretion of antimicrobial peptides	Mucus secretion Secretion of antimicrobial peptides	Chemosensing Hormone sensing	Helminth detection	Niche protection Stem Cell support Secretion of antimicrobial peptides	Source of cell renewal
Abundance:	70%–80%	~ 7%	≤ 1%	≤ 1%	~ 5%	≤ 1%
Turnover:	3–5 days	3–5 days	5–7 days	7–10 days	~ 20 days	Long-living

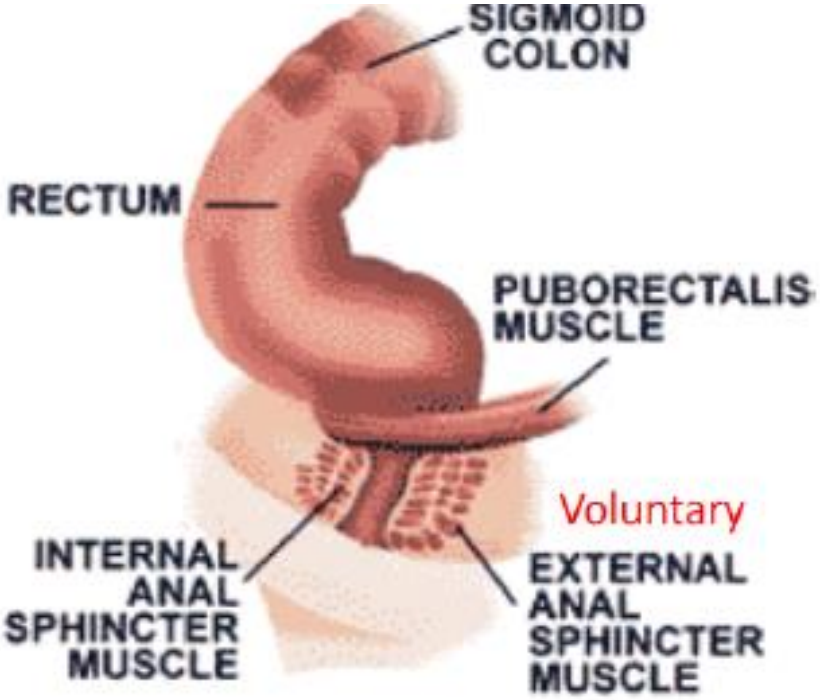
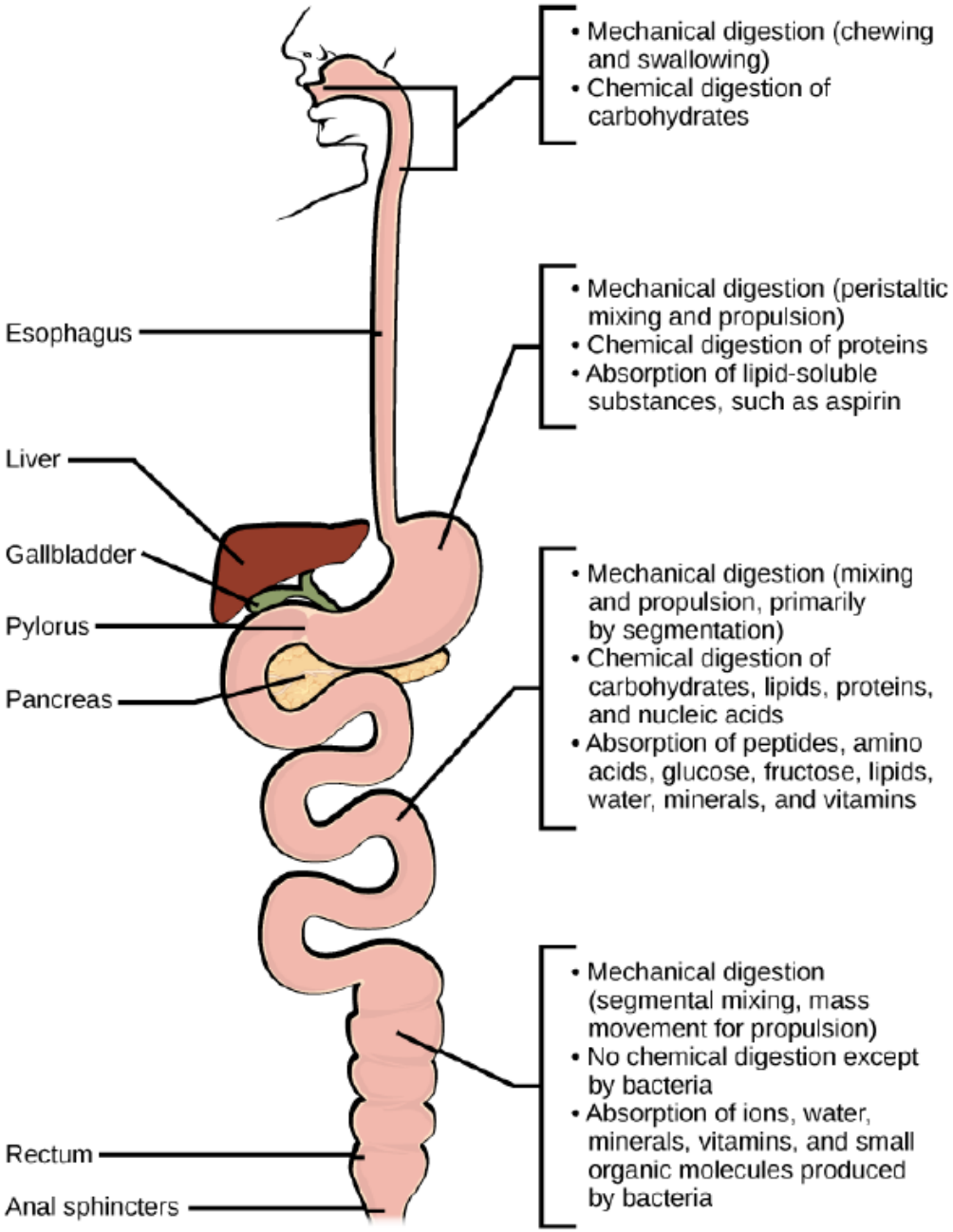


Figure 7.14: Rectum and Anal Canal Anatomy

Mechanism of Digestion



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