-2022
2023

Fish Biology &Special Environments

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For / Fourth Chemistry and Zoology students

Faculty of Science
[Type the company name]
2022-2023

How to identify a fish?

How to preserve specimen:-

Formalin is generally a reliable representative after which they can be transferred to alcohol for lengthy preservation .

Commercial formaldehyde [trade- name formalin] is concentrated [about 40%] and must be diluted before use 1 part formalin to 9 parts water [about 10%]

Large fish need [up to 20%] but small fishes can be fixed in a more dilute solution[down to 5%formalin].

Containers:-

well-galvanized or heavily-tinned cans make good temporary storage for use in the field, as do large plastic containers .

wide mouth bottles and glass or polyethylene plastic tubes are also required.

****The Key to identification a fish****

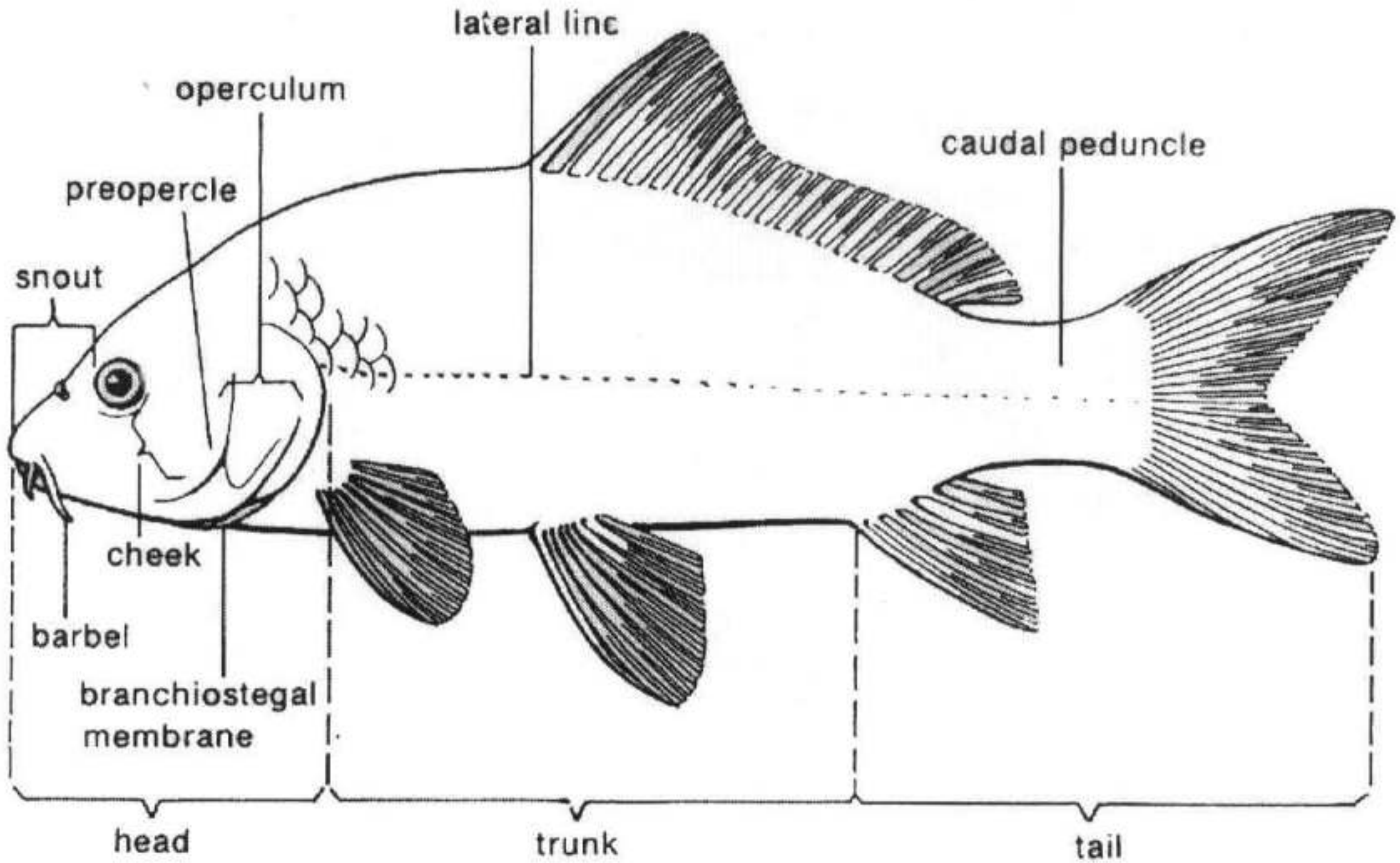


FIGURE 2–1. Diagram of bony fish, showing external features.

1- **Body shapes in fishes**:

Fusiform, Compressiform, Depressiform, Anguilliform, Filiform, Taeniform, Sagittiform or globiform.

2- **General outline of the body**: **(Head & Trunk)**:

compressed or Depressed

- Dorsoventrally depressed (head of *catfish)*
- Bilaterally compressed (rest of *catfish)*

3- **Cross section of the body**: [cylindrical, ovoid, global, triangular]

4- **Color**: **of lateral and ventral side + with** [spots, patches, lines, bars…etc.]

5- **Skin** : Scaless (naked) **or** Scales present

6- **Kind of scales**: placoid, cycloid, ctenoid, ciliated, ganoid. …etc.

Scale Formula = No. of scales along lateral line $\dfrac{\textbf{No. of scales above lateral line}}{\textbf{No. of scales below lateral line}}$

Body shapes in fishes

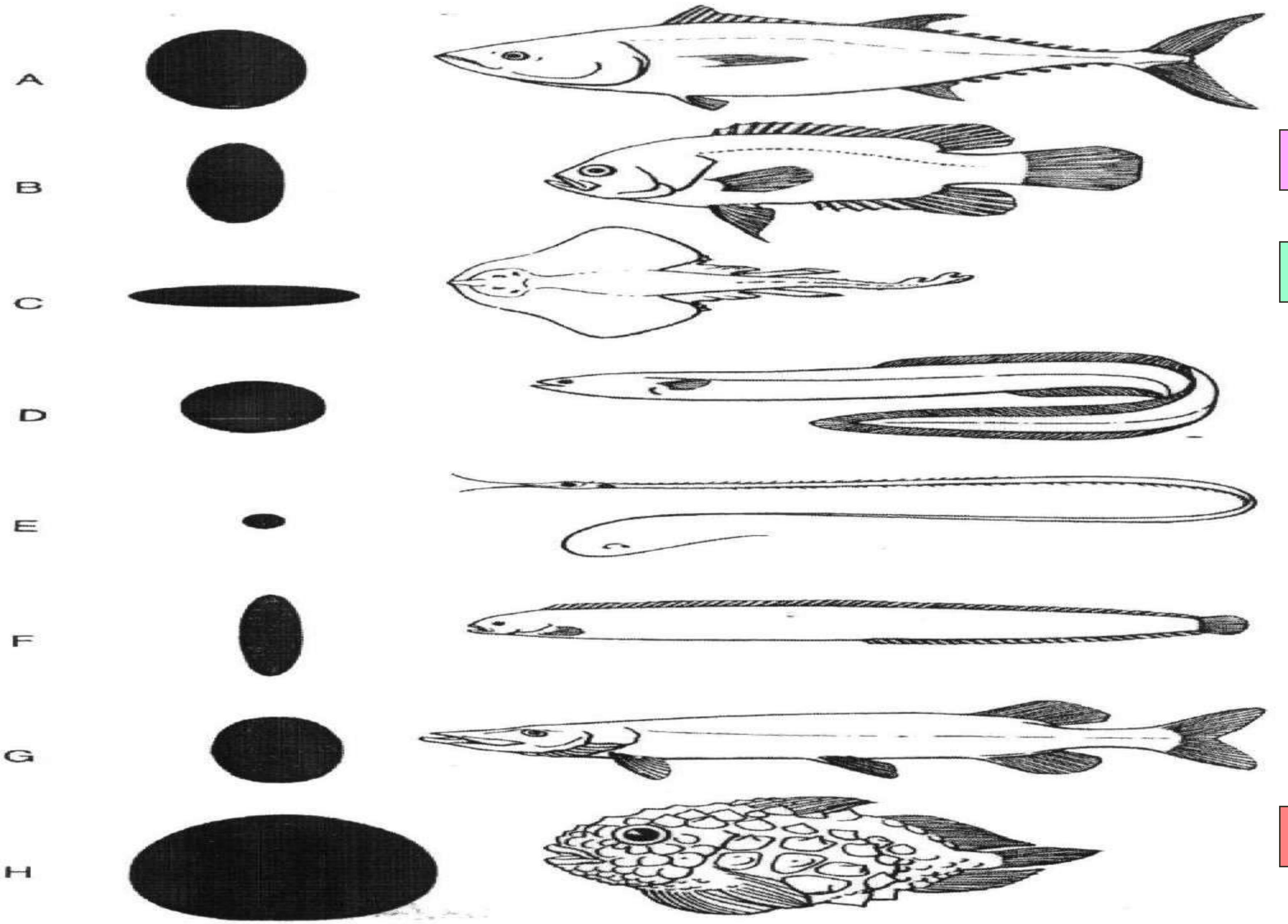


FIGURE 2–8. Representative body shapes in fishes, with typical cross sections. *A*, Fusiform (tuna, Scombridae); *B*, compressiform (sunfish, Centrarchidae); *C*, depressiform (skate, Rajidae), dorsal view; *D*, anguilliform (eel, Anguillidae); *E*, filiform (snipe eel, Nemichthyidae); *F*, taeniform (gunnel, Pholidae); *G*, sagittiform (pike, Esocidae); *H*, globiform (lumpsucker, Cyclopteridae). (*H* based on Jordan and Evermann, 1900.)

16

Fusiform, tuna

Compressiform, tilapia

Depressiform, skate

Anguilliform, eel

Filiform, snipe eel

Taeniform, tunagunnel

Sagittiform, pike

globiform, lumbsucker

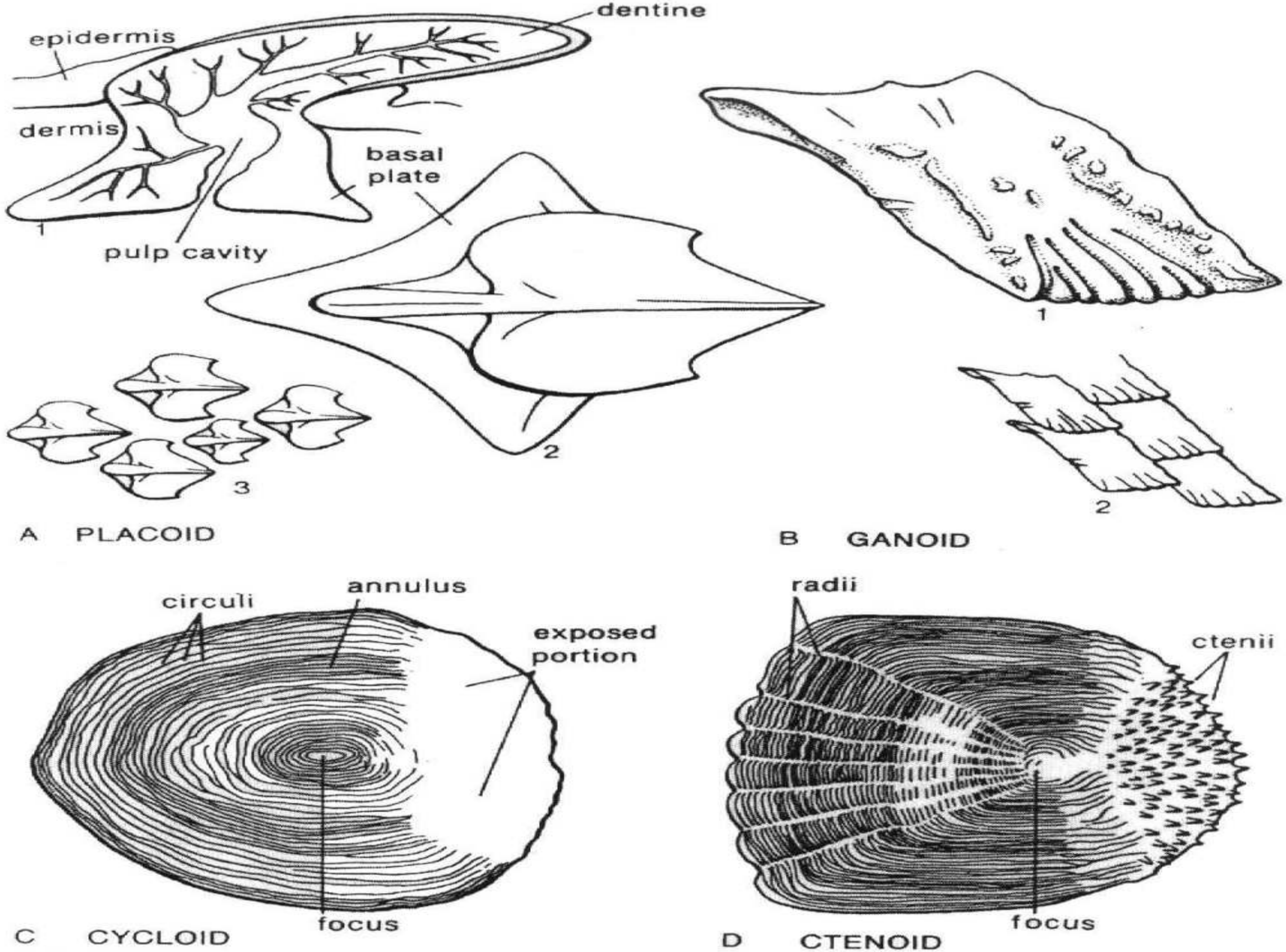
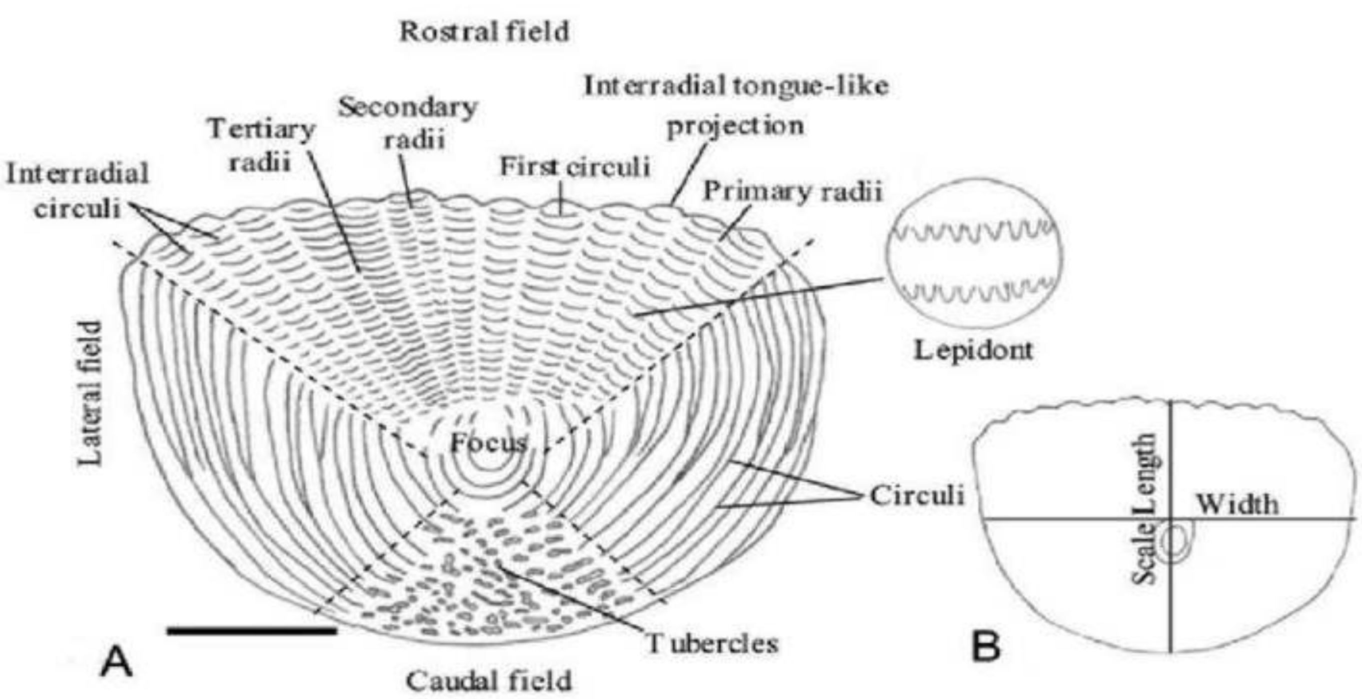
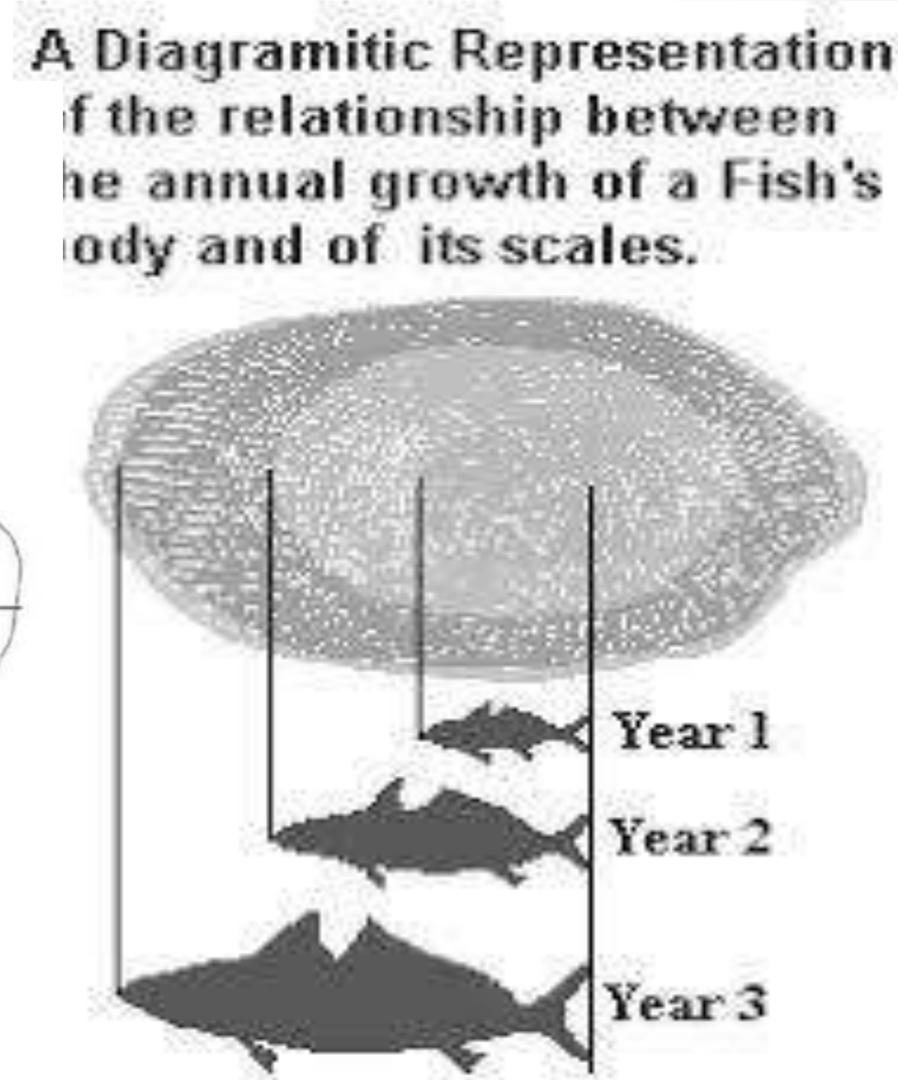


FIGURE 2–20. Examples of types of scales (anterior to left). *A*, Placoid— *1*, sagittal section, *2*, top view, *3*, disposition on skin; *B*, ganoid—*1*, single scale, 2, disposition on fish; *C*, cycloid; *D*, ctenoid.


Rostral field
Interradial tongue-like projection
Tertiary radii
Secondary radii
First circuli
Interradial circuli
Primary radii
Lateral field
Lepidont
Focus
Circuli
Scale Length
Width
Tubercles
A
B
Caudal field


A Diagramitic Representation
f the relationship between
he annual growth of a Fish's
ody and of its scales.
Year 1
Year 2
Year 3

7- Lateral line → absent
→ Present [pores]

Complete line, incomplete, interrupted [two lateral lines]

Dorsal , ventral

8- Head : large , small, any other form

9- mouth: → terminal
→ inferior (ventral)
→ superior (dorsal)
→ subterminal

Protractile **OR** Non-protractile

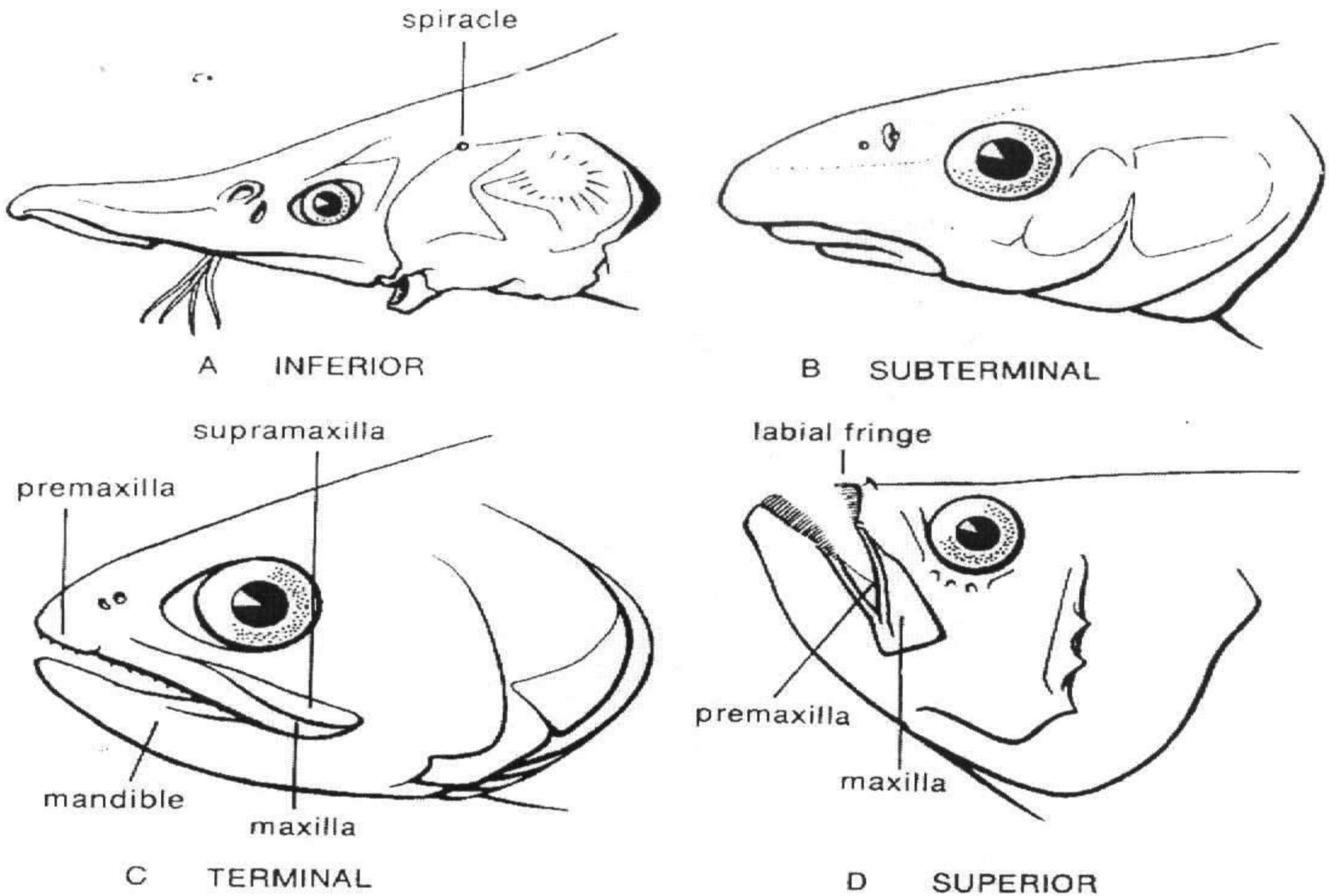
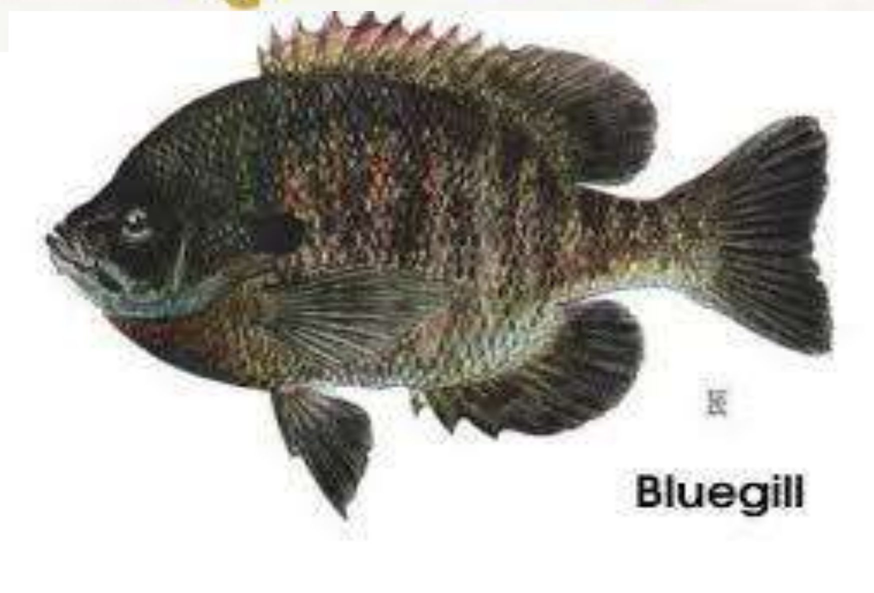


FIGURE 2–2. Examples of mouth positions in fishes. *A*, Inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout); *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)

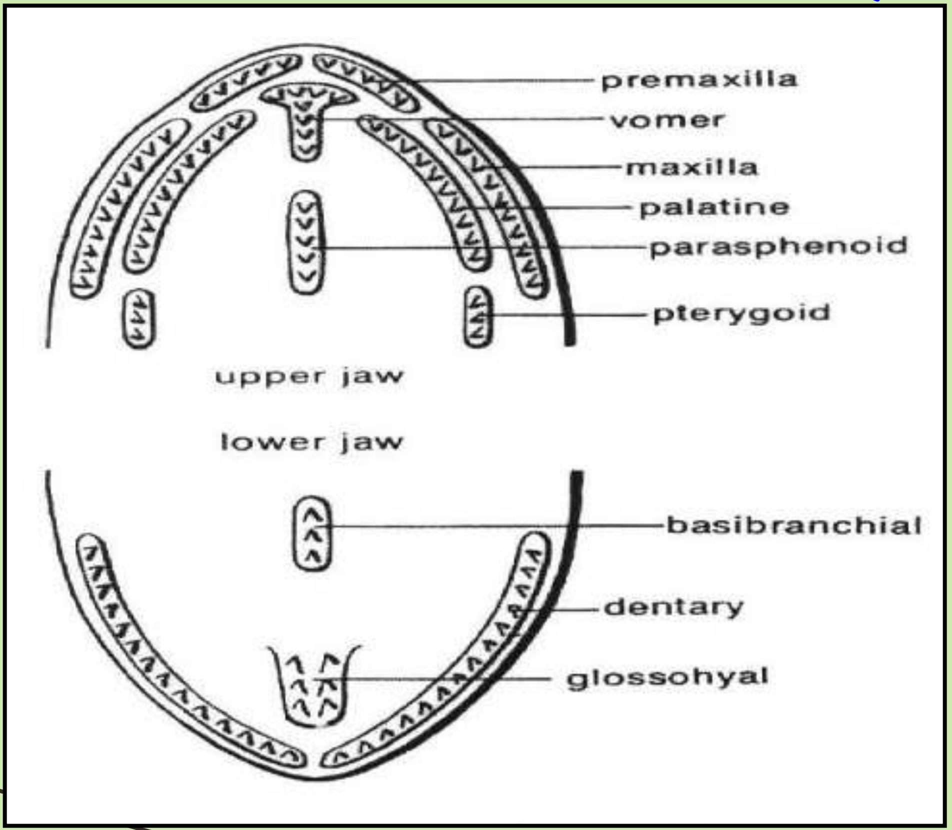

Bluegill

10- lips small, large, fleshy

11- buccal cavity: with **or** with out teeth

12- teeth pointed, rounded

Diagram of positions of bones that can bear teeth in bony fishes.



Shape: truncate, unicusped ,bicuspid, tricuspid, polycusped

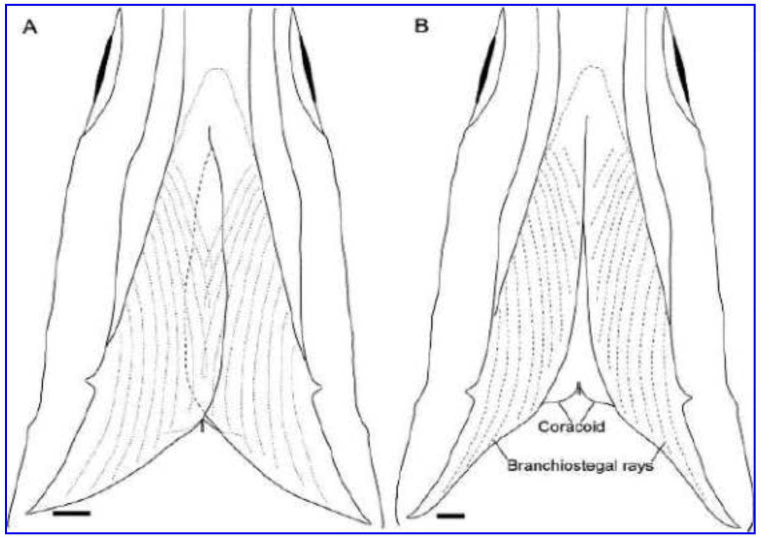
Position: premaxillary, maxillary, Vomerin, palatal teeth ….etc

12- Barbles : absent OR present

If present: Nasal, maxillary OR mandibular (relative length of each).
long, short OR barbules

13- Eyes: small OR large

dorsal, ventral OR lateral
oval OR rounded



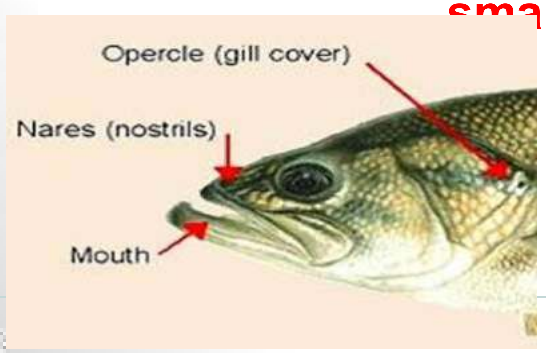
14- Operculum: absent [No. of gill slits]

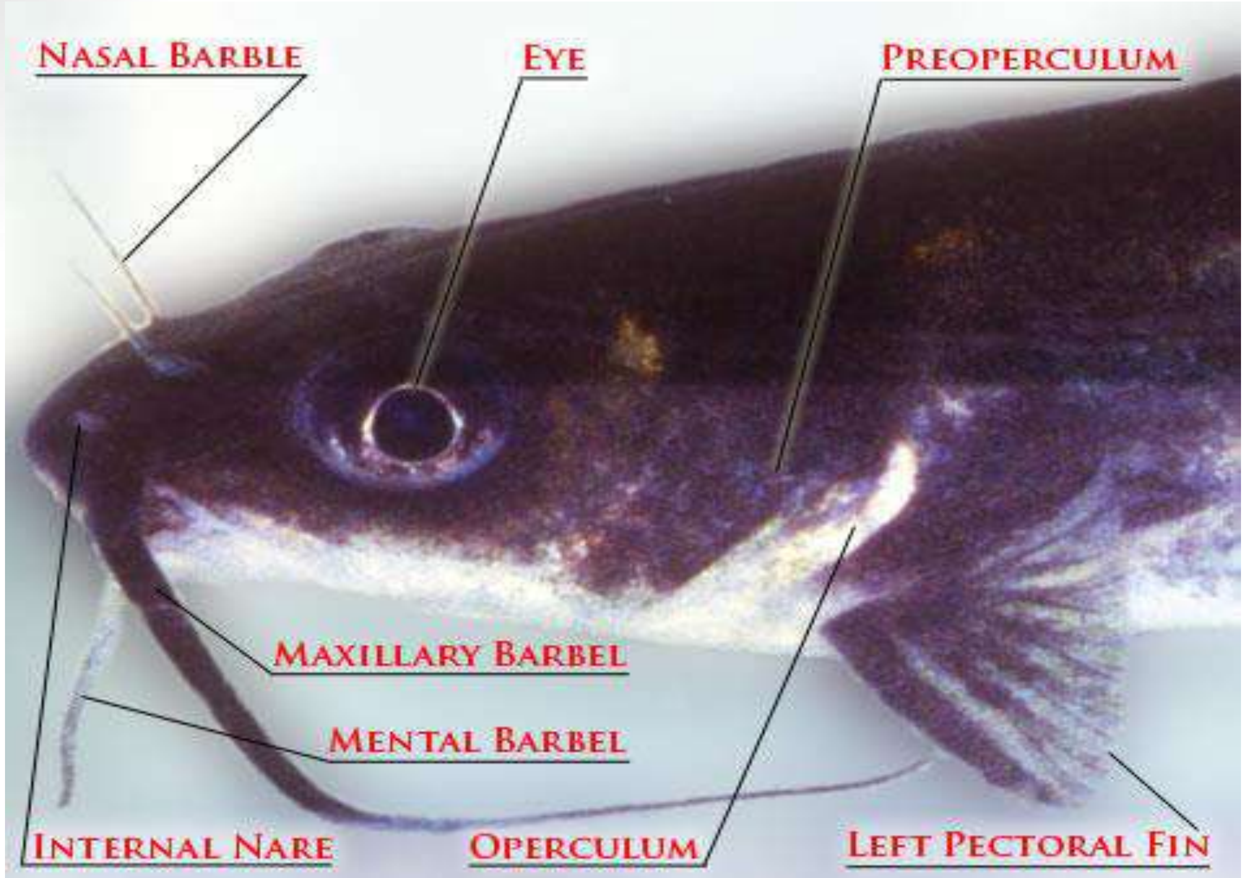
OR
present

If present:
Lateral OR ventral
Branchiostegal membrane Free OR attached at the isthmus.
Overlapped OR Non-overlapped.

15- Nostril (Nares): Paired OR single

dorsal, ventral OR lateral …….
small OR large




Nasal Barble
Eye
Preoperculum
Maxillary Barbel
Mental Barbel
Internal Nare
Operculum
Left Pectoral Fin

16- gill rakers:

No. of gill rakers on the 1st right gill arch, (on upper limb & on lower limb)

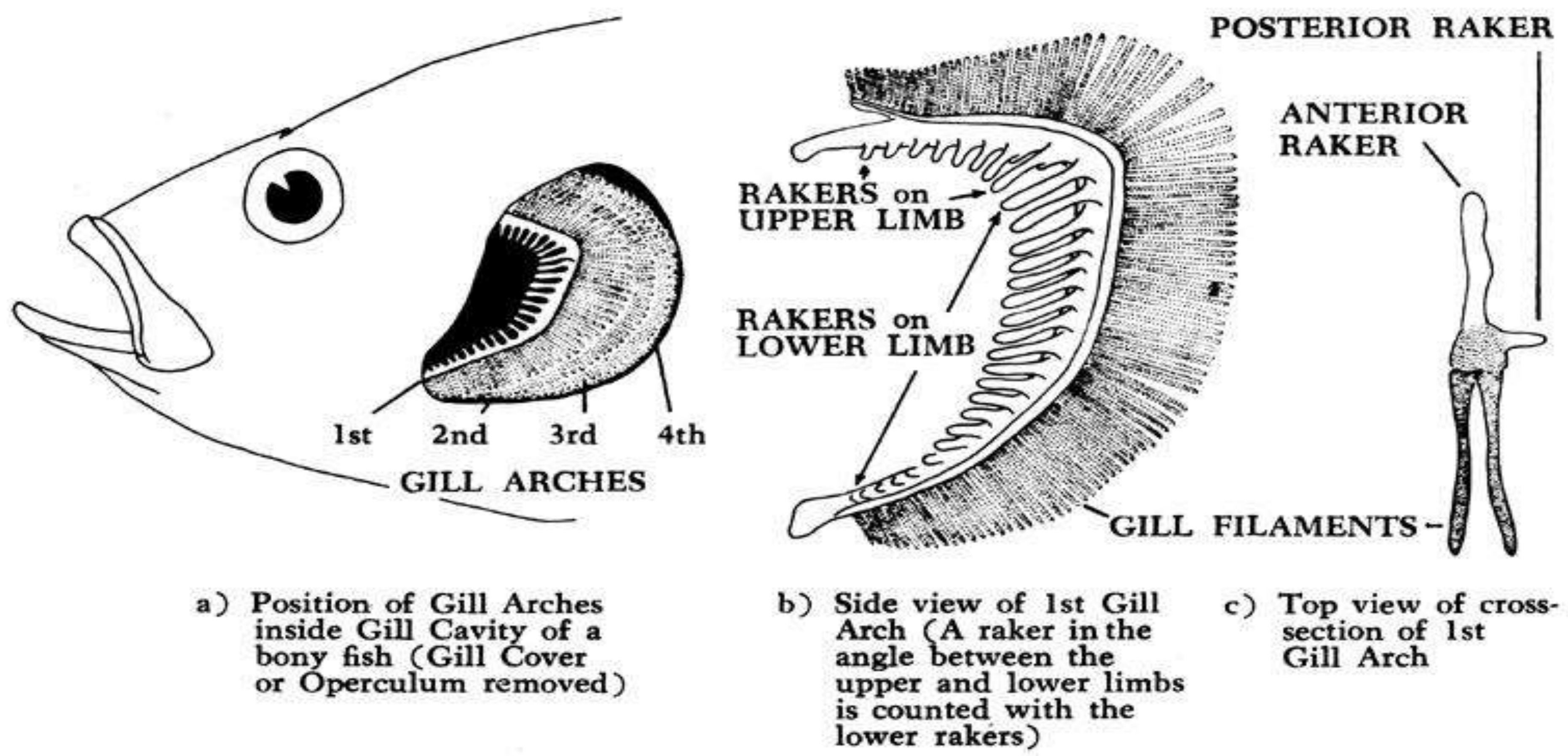


FIGURE 7. Gill rakers and gill arches of a bony fish.

17- Fins:

Paired fins: **pectoral** & **pelvic fin.**

Unpaired fins:

dorsal,
anal,
caudal (shape of the caudal fin).
adipose fin.

Fin ray count: for the **dorsal & anal fins)**

Rays: may be spines or soft fin rayes.

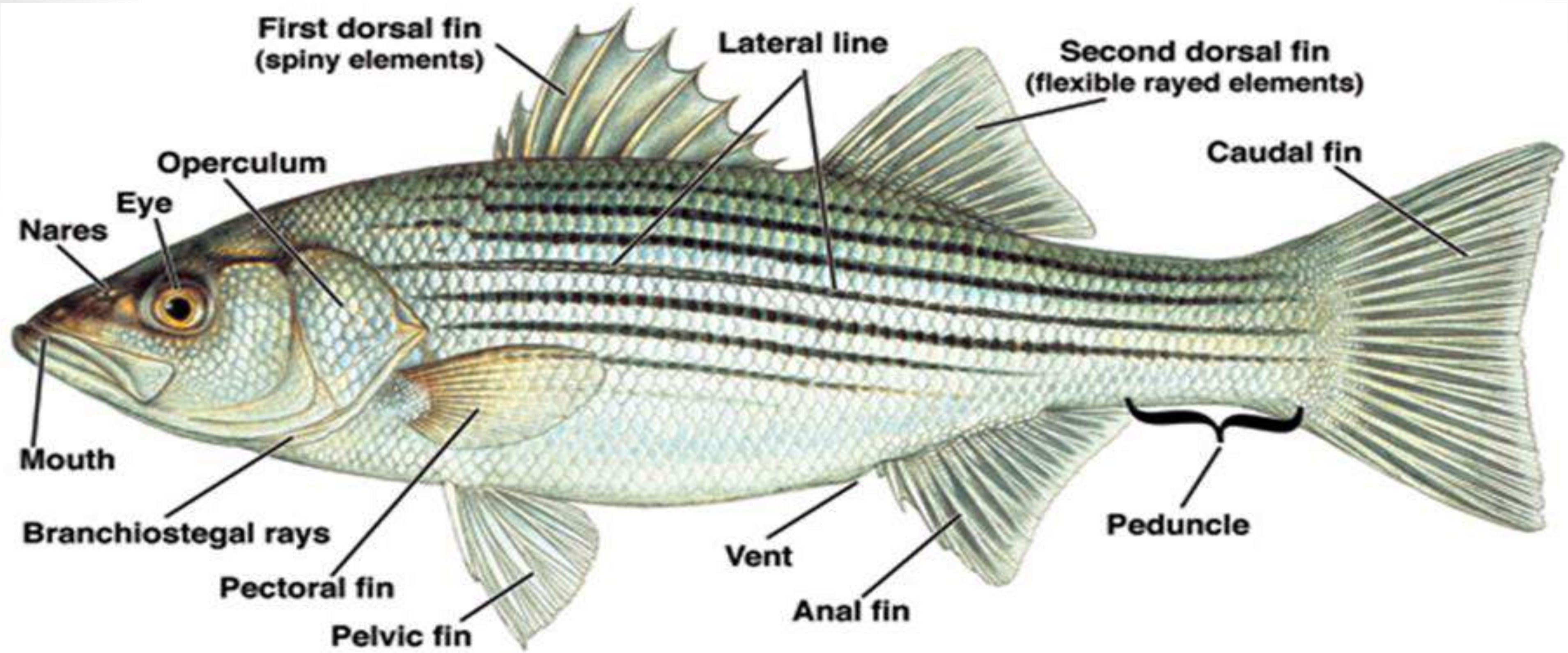
Soft rayes: may be branched **OR** unbranched.

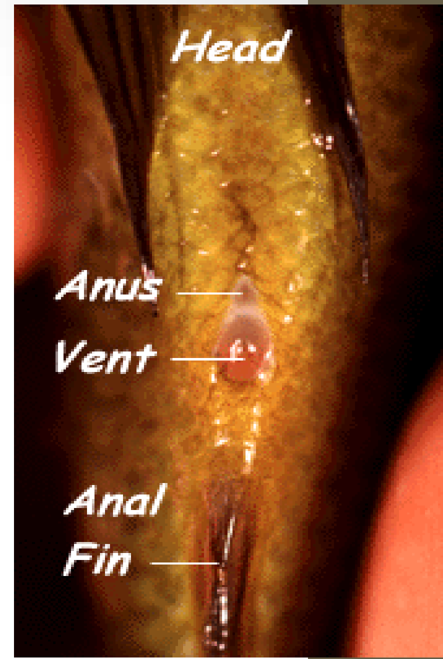
Fin ray formula *:* Roman numbers **for** spines, Arabic numbers **for** soft- rays

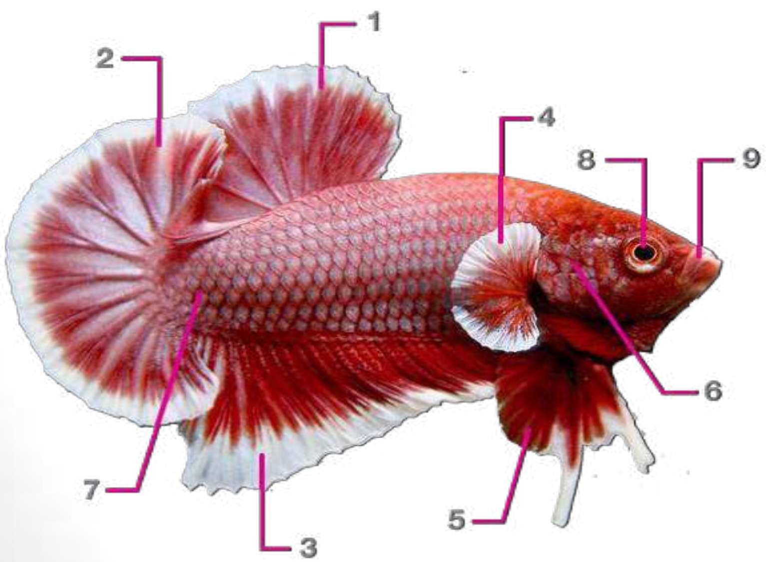
Ex; d.f.r: IIIV,10 = IIIV, 3, 7

Caudal fin types: as figure

Truncate, Pointed, Rounded, Emarginate, Crescentic [lunate], Forked







1 DORSAL FIN
2 CAUDAL FIN
3 ANAL FIN
4 PECTORAL FIN
5 VENTRAL OR PELVIC FIN
6 OPERCULUM OR GILL COVER
7 CAUDAL PEDUNCLE
8 EYE
9 MOUTH

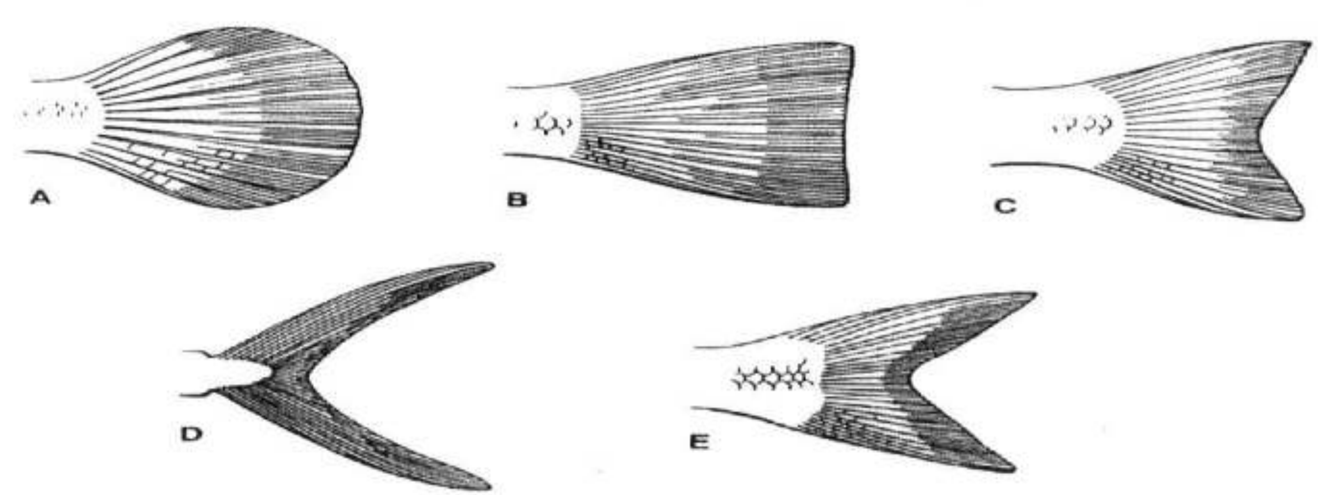


FIGURE 2–16. Representative shapes of caudal fins. *A*, Rounded; *B*, truncate; *C*, emarginate; *D*, lunate; *E*, forked.

Measurements :-

1-Total length:-[TL]

It is the length of fish, and it is not commonly used in the systematic work.

2- Standard length:-[SL]

It is the distance from the anterior margin of snout or upper lip to caudal base in a straight line.

3- Head length:-[HL]

The distance from the upper lip to the posterior edge of opercula bone .

4-Body depth:-[BD]

It is taken from the deepest point.

5- Eye width: [EW]

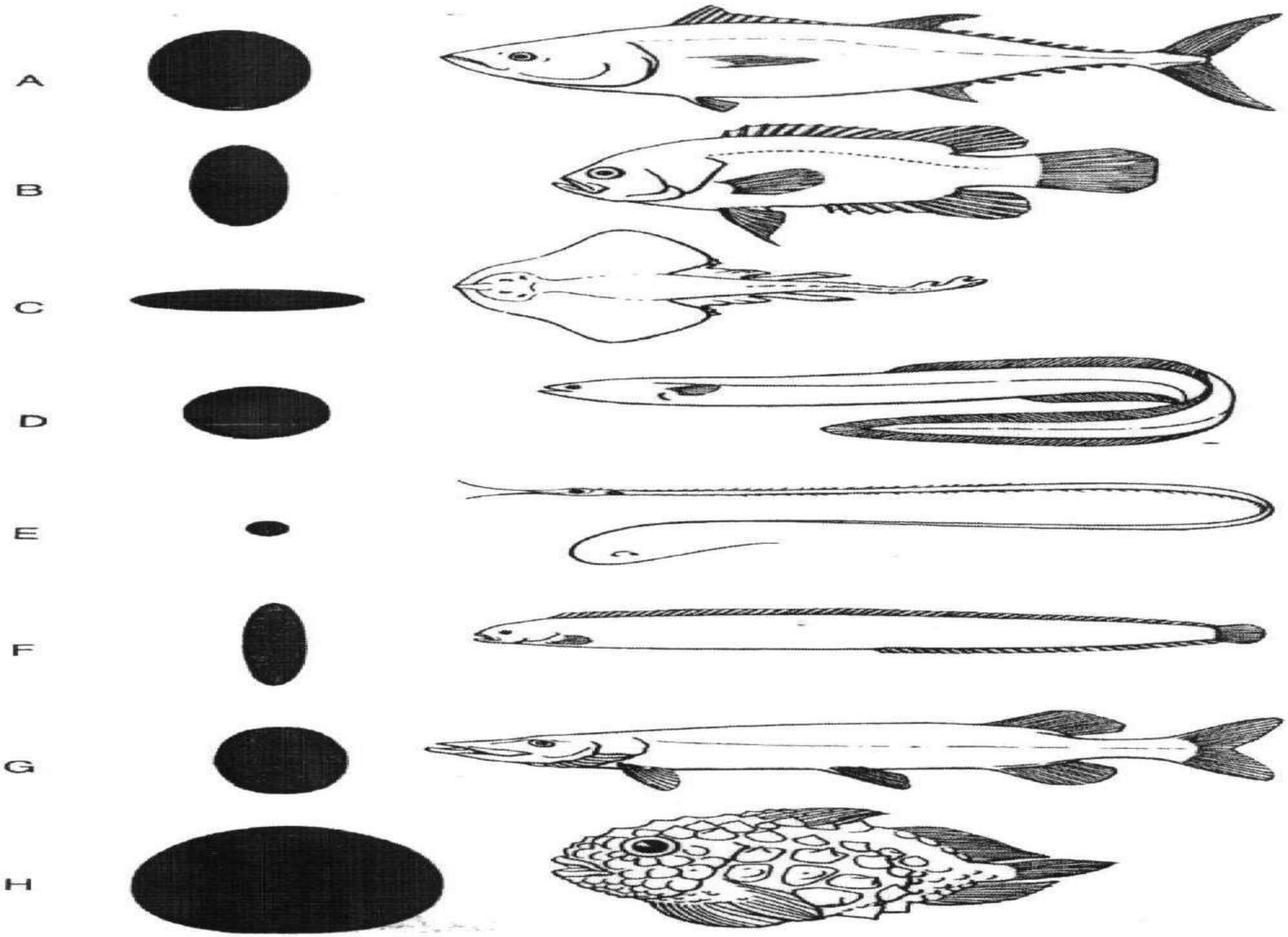
6- Snout length:[SnL]

7- Caudal peduncle length:[CPL]

Lectures 2

External features

Body shapes in fishes



Fusiform, tuna

Compressiform, tilapia

Depressiform, skate

Anguilliform, eel

Filiform, snipe eel

Taeniform, tunagunnel

Sagittiform, pike

globiform, lumbsucker

FIGURE 2–8. Representative body shapes in fishes, with typical cross sections. *A*, Fusiform (tuna, Scombridae); *B*, compressiform (sunfish, Centrarchidae); *C*, depressiform (skate, Rajidae), dorsal view; *D*, anguilliform (eel, Anguillidae); *E*, filiform (snipe eel, Nemichthyidae); *F*, taeniform (gunnel, Pholidae); *G*, sagittiform (pike, Esocidae); *H*, globiform (lumpsucker, Cyclopteridae). (*H* based on Jordan and Evermann, 1900.)

*Other examples of body shapes in fishes

فراشة البحر Sea moth

السمك البقرى Cowfish

Catfish bullhead

Seahorse

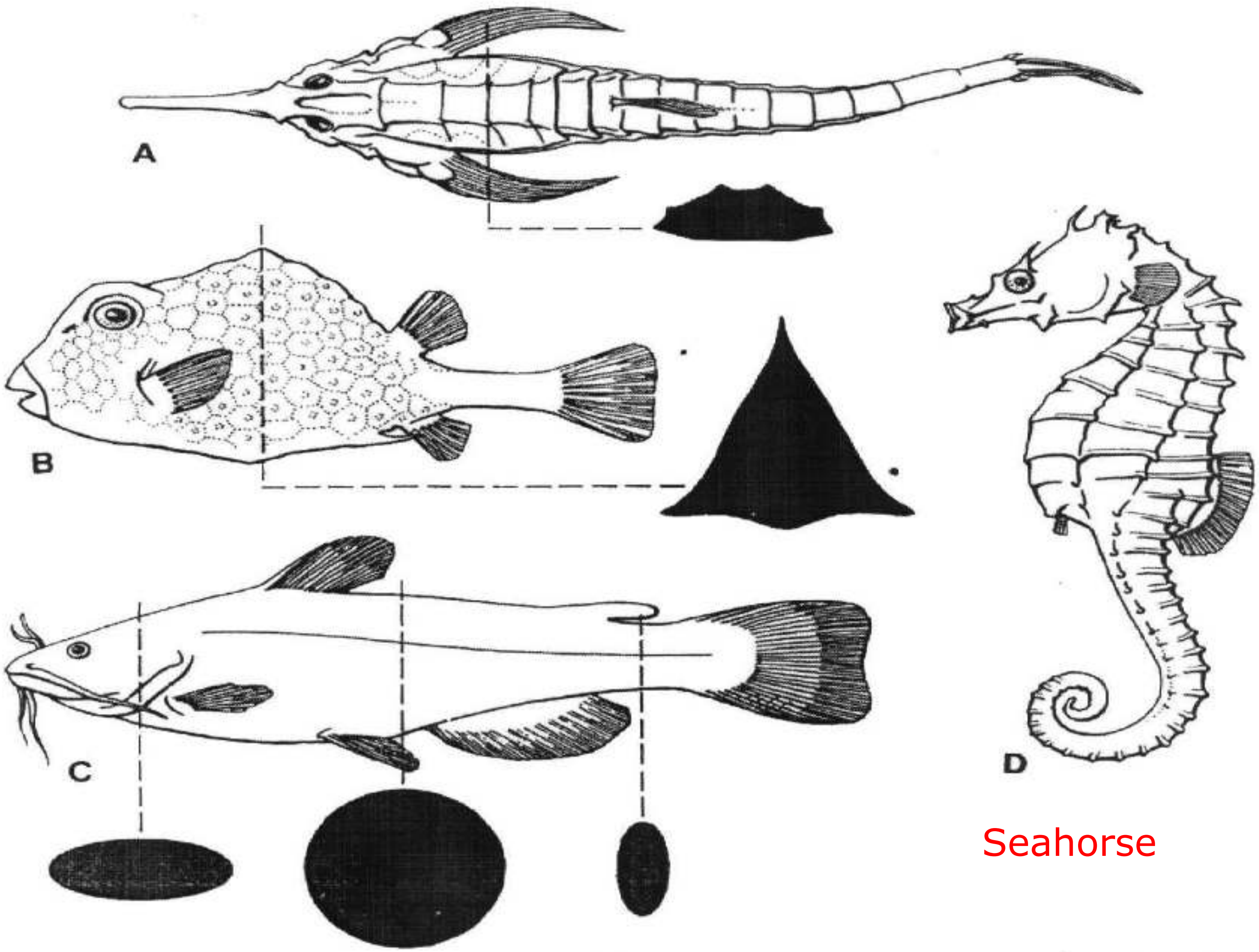


FIGURE 2–9. Examples of body shapes in fishes: *A*, Sea moth (Pegasidae); *B*, cowfish (Ostraciidae); *C*, *bullhead* (Ictaluridae); *D*, seahorse (Syngnathidae). (*B* and *C* based on Jordan and Evermann, 1900.)

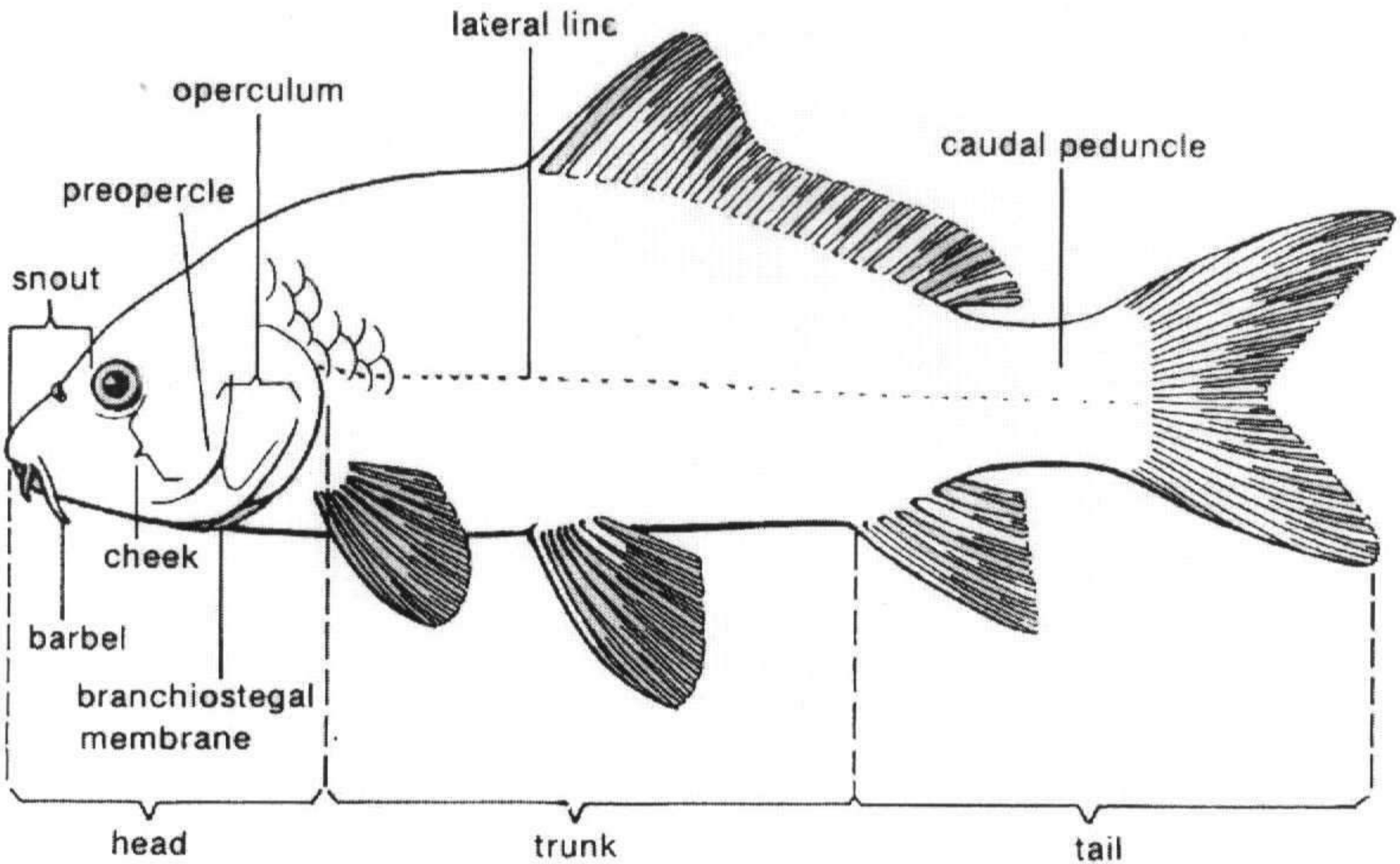
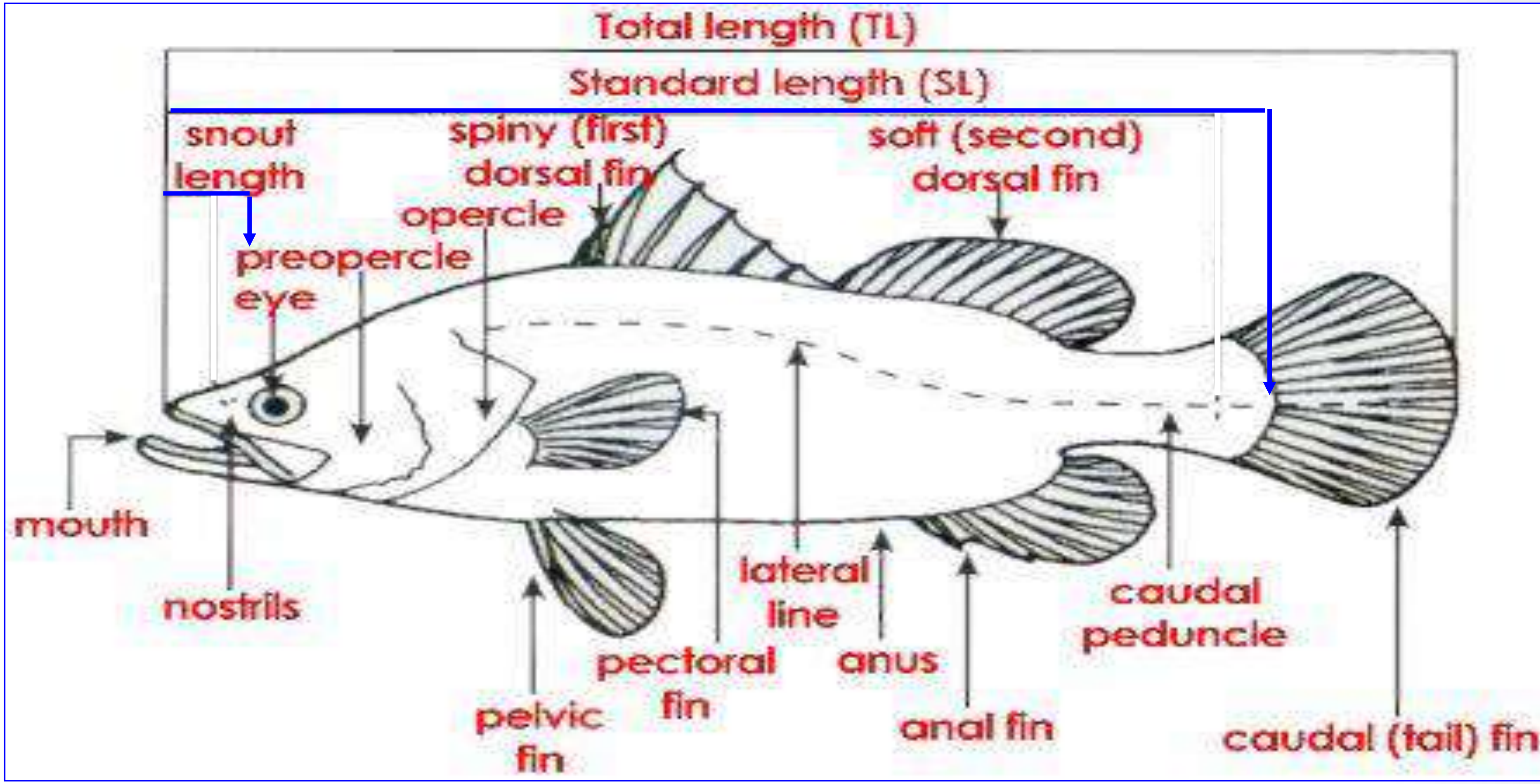
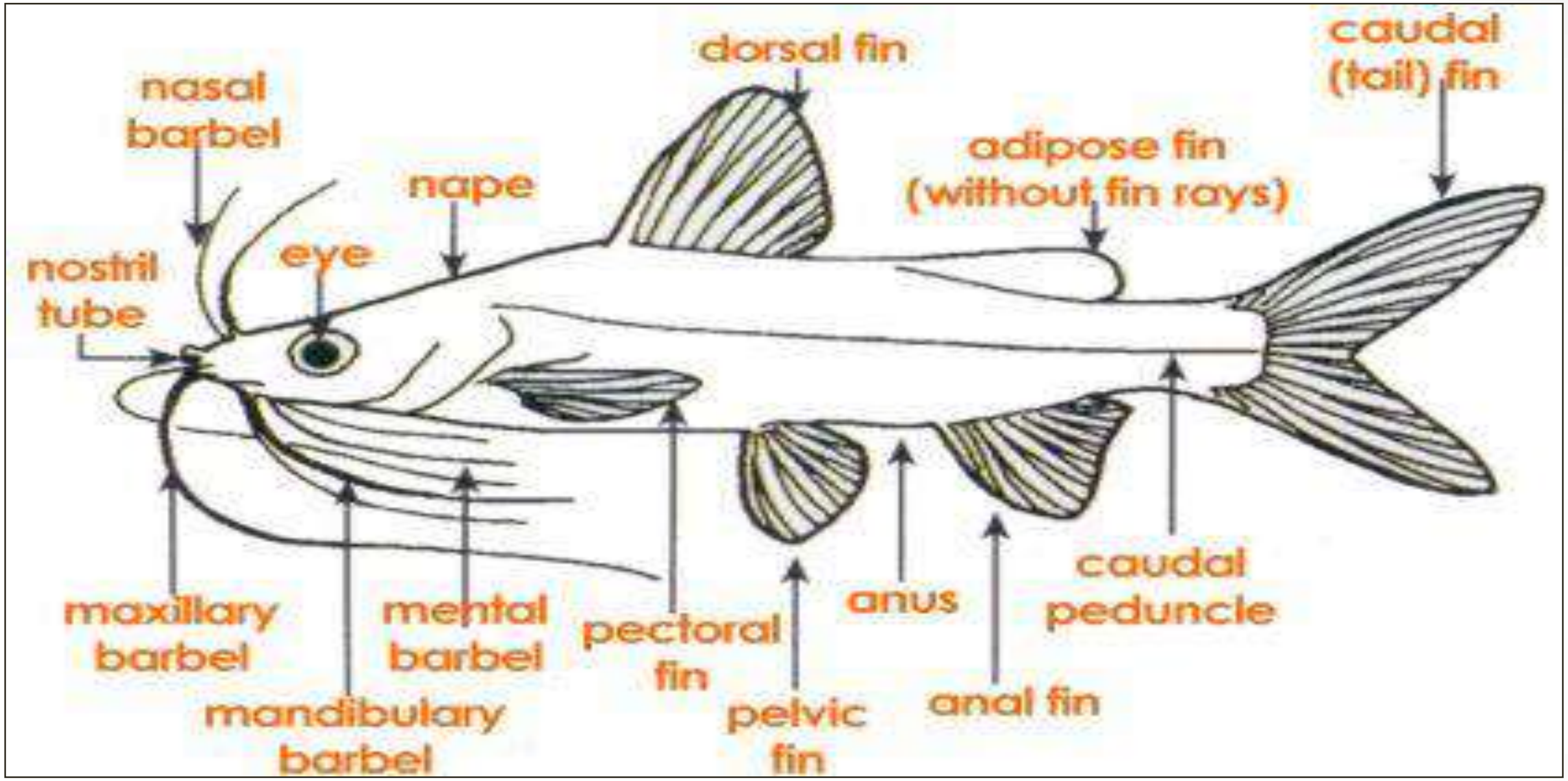
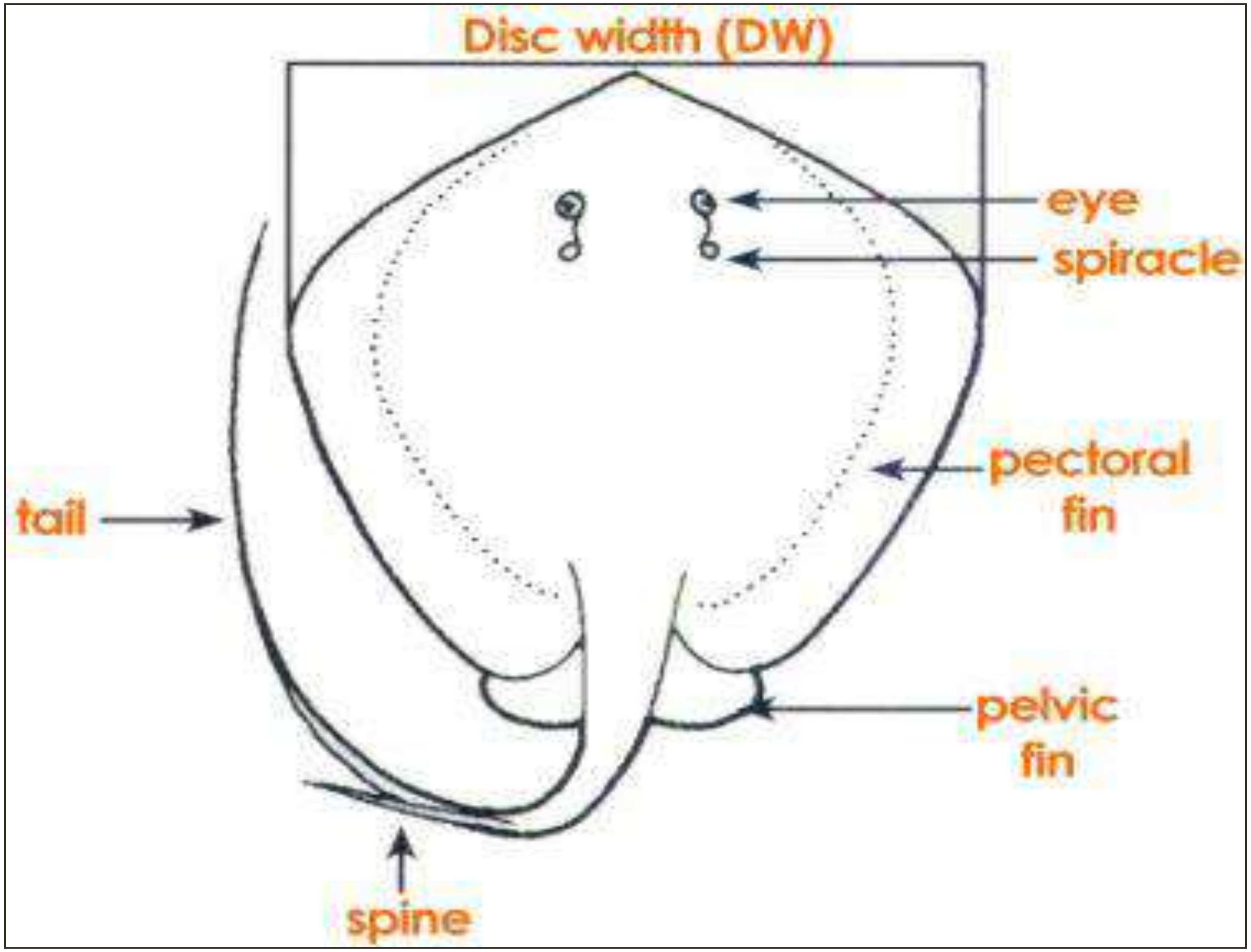


FIGURE 2–1. Diagram of bony fish, showing external features.


Total length (TL)
Standard length (SL)
snout
length
spiny (first)
dorsal fin
soft (second)
dorsal fin
opercle
preopercle
eye
mouth
nostrils
lateral
line
anus
caudal
peduncle
pectoral
fin
pelvic
fin
anal fin
caudal (tail) fin

A bony fish

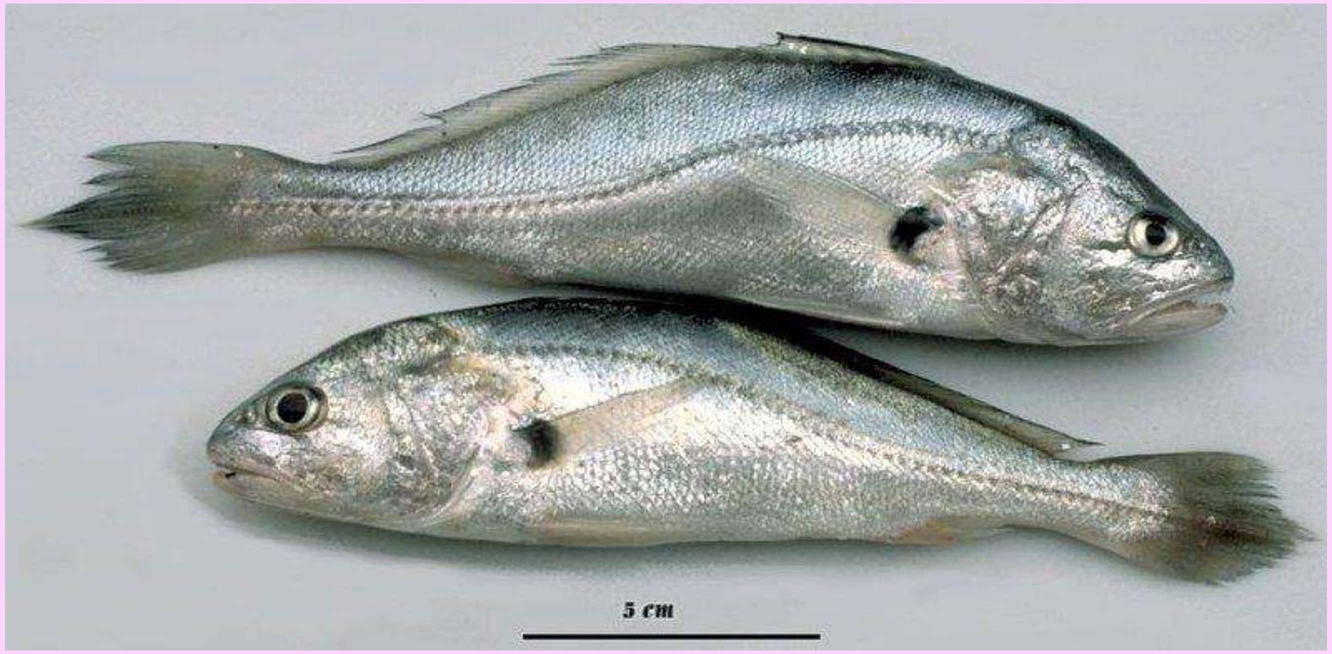

dorsal fin
caudal (tail) fin
nasal barbel
nape
adipose fin (without fin rays)
eye
nostril tube
maxillary barbel
mandibulary barbel
mental barbel
pectoral fin
pelvic fin
anus
anal fin
caudal peduncle


Disc width (DW)
eye
spiracle
pectoral
fin
tail
pelvic
fin
spine

A stingray

The lateral line :

- **Lateral line system, also called lateralis system, unique to aquatic vertebrates from cyclostome fishes (lampreys and hagfish) to amphibians.**
- **In amphibians, the lateral line system occurs only in larval forms and in adult forms that are completely aquatic.**
- **It is a sensory system that plays an essential role in orientation, predatory behaviour, and social schooling; also, it allows fishes to detect weak water motions and pressure changes in the surrounding water.**



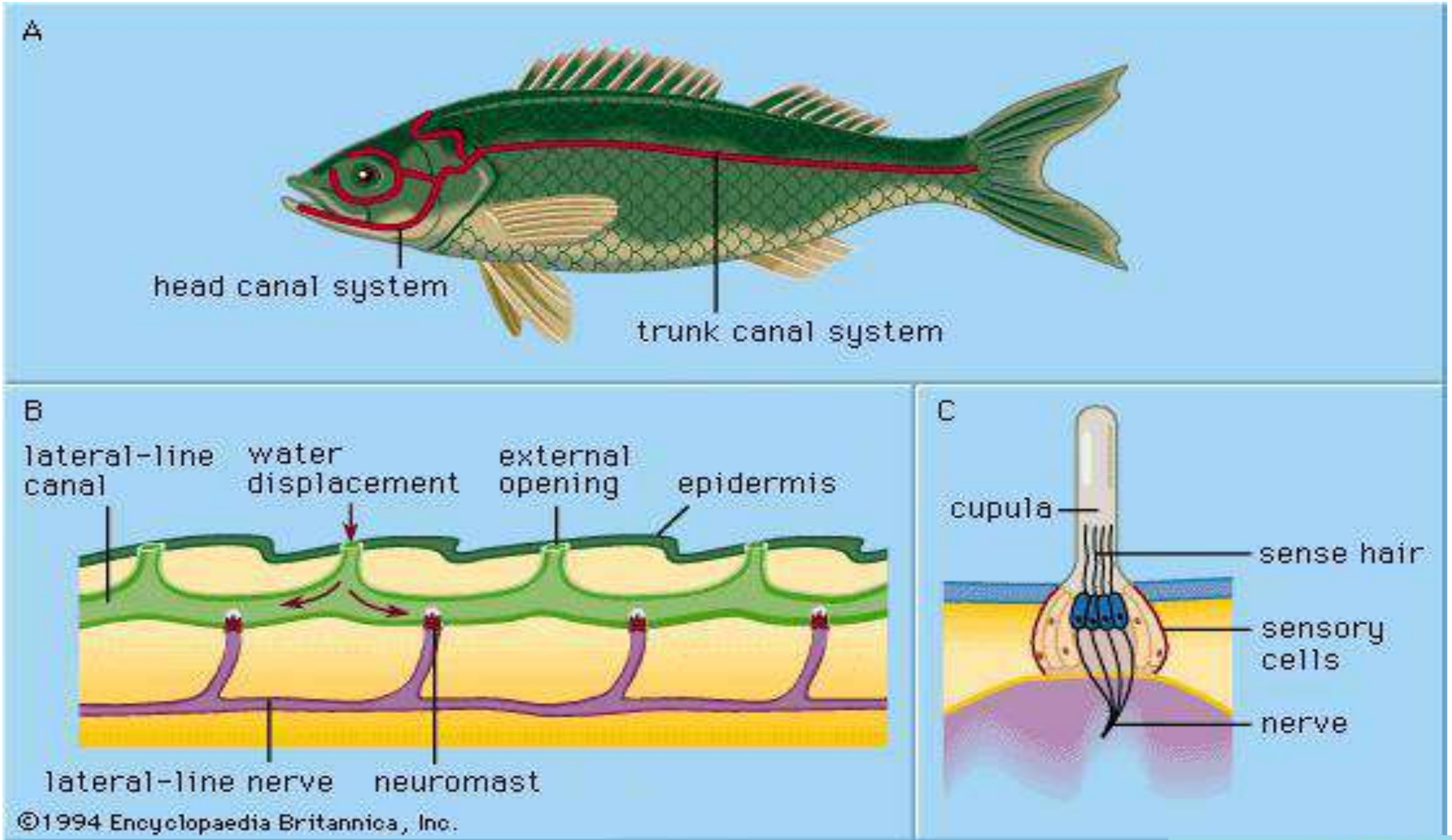
- Lateral line system consists of jelly-filled canals just below the skin. It opens to the water outside by a series of tiny pores.

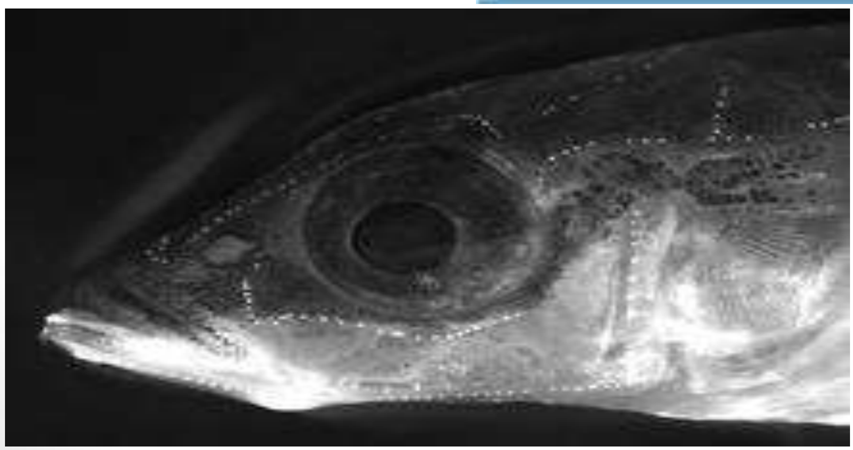
- The functional unit of the lateral line is the neuromast (mechanoreceptors).

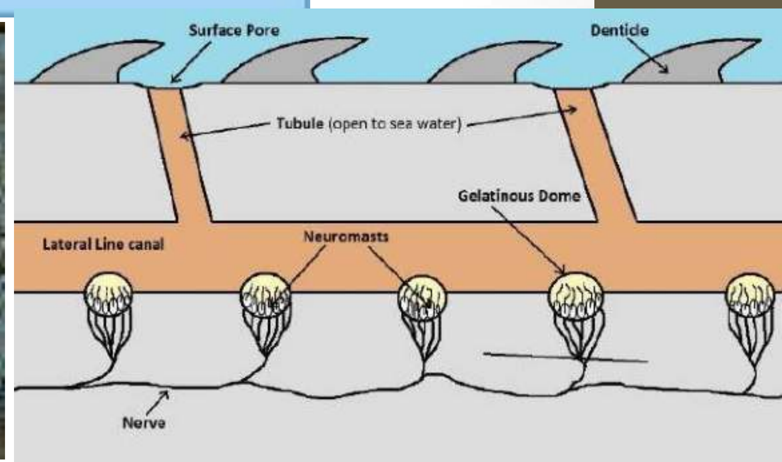
- The neuromast is a sensory structure that consists of a hair cell epithelium and a cupula.
- the cupula connects the ciliary bundles of the hair cells with the surrounding water.

- The rows of neuromasts appear on the surface of the skin & spread over the head, trunk and tail; however, for most fishes, they lie embedded in the floor of mucus-filled lateral line canals.
- The sensitivity of this system makes blind fish very difficult to be catched by hand.

The lateral line in fishes



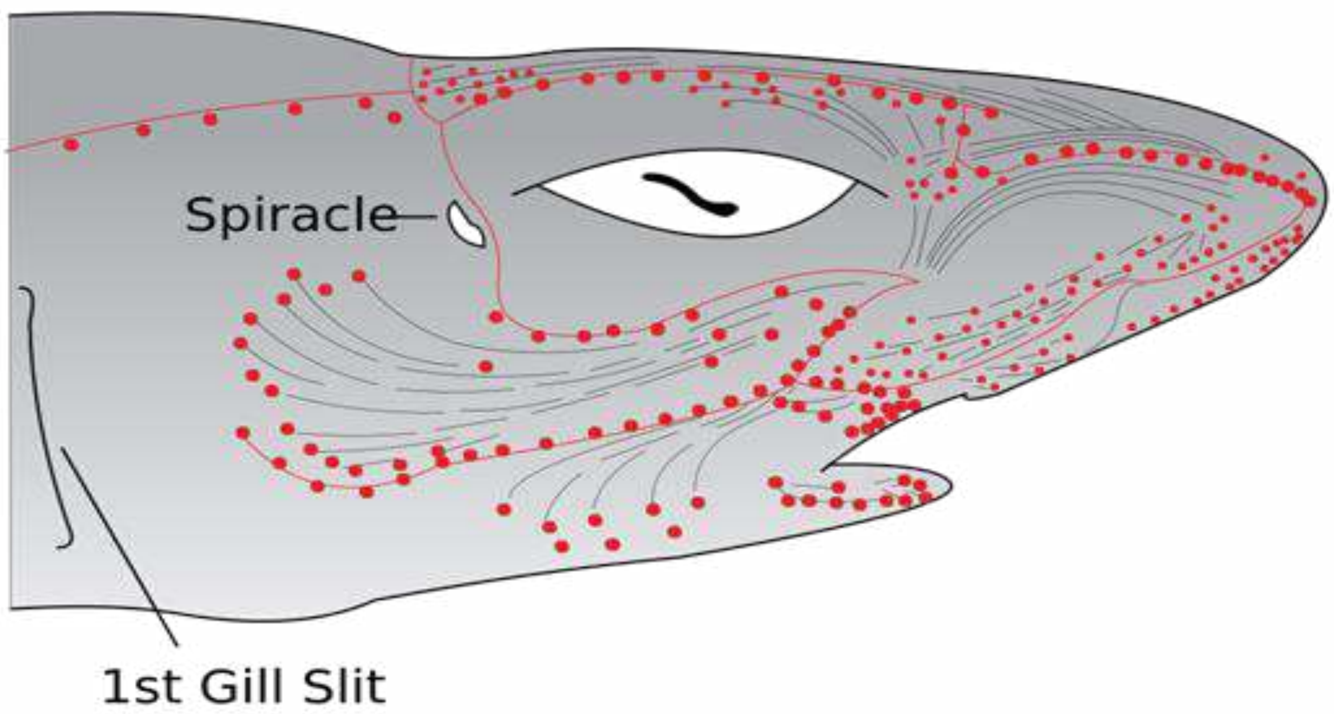




Ampullae of Lorenzini

- The ampullae of Lorenzini are highly specialized sense organs called electroreceptors,
- They are mostly found in cartilaginous fish (sharks, rays, and chimaeras); and also, found in some other fishes.
- The ampullae of Lorenzini provide fish an additional sense capability of detecting electric and magnetic fields as well as temperature gradients in the water.
- They are used by the fish for important biological functions such as prey detection, navigation (الملاحة) and mate locations.
- Ampullae are composed of an enlarged terminal portion and a canal. The internal part of the ampulla is filled with a gelatinous mucopolysaccharide substance which plays an important role in the conductivity of the electric signals.
- The ampullae are plainly visible as dark spots in the skin.

- **Interspecific variation** **in the anatomical organization of the ampullae <u>could</u> <u>reflect</u> relationships with taxonomic and ecological features.**



Electroreceptors (ampullae of Lorenzini) in the head of a shark

Mouth:

Fish mouths come in a variety of sizes, shapes and orientations, each of which tells a great deal about what and where the fish eats, as well as about its behaviour.

The mouth serves for taking in food; also for the breathing current of water.

Some fish: filter microscopic plants and animals as they swim along, trapping them in gill rakers before the water is expelled from the operculum.

Predatory fish generally have the largest mouths with sharp teeth. Some species have specialized mouth parts that allow them to rasp algae of rocks.

Other species have mouths with teeth in the back, nearly in their throat. These pharyngeal teeth assist in grasping and swallowing prey.

Most fish mouths fall into one of the following general types.

1- Superior, **or** sometimes called supra-terminal, mouths are upturned.

2- Terminal mouths point straight forward, and are the most common mouth type.

3- sub-terminal, mouths are turned lightly downward.
4- Inferior, mouths are turned downward.

The inferior mouth type is often found in bottom dwelling species, such as the catfish family.

Superior Mouth

The superior mouth is oriented upwards, with the lower jaw being longer than the upper jaw. Usually, fish with this type of mouth feed at the surface. They lay in wait for prey to appear above them, then strike suddenly from below.

Many species of fish with a superior mouth feed largely on insects, however some may feed on other fish that swim near the surface.

Terminal Mouth

Terminal mouths are located in the middle of the head, pointed straight forward, with both jaws being the same length. Most fishes have this mouth type than any other. Fish having a terminal mouth are generally mid water feeders, however they can feed at any location. These species of fish are often omnivores, eating anything that is available. They typically feed on the move, either grabbing bits of food that they pass close to, or prey on other fish that they chase down.

Inferior Mouth

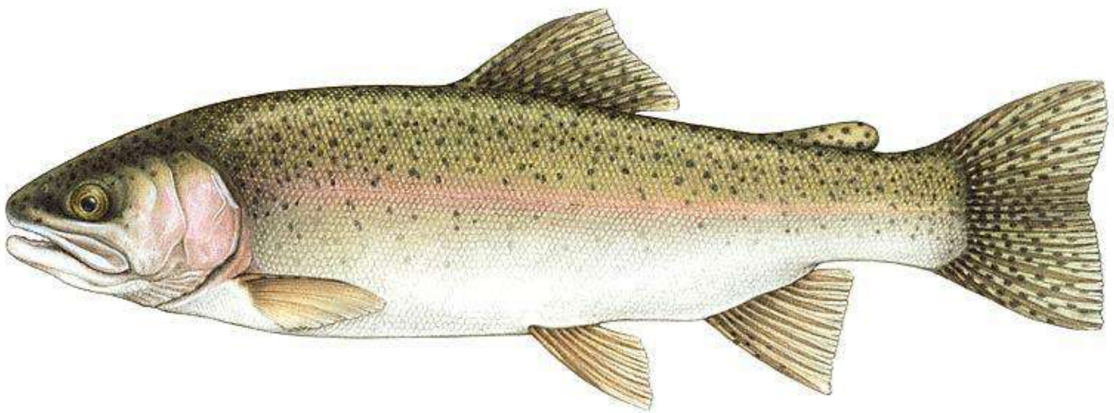
Also called a sub-terminal or ventral mouth, the inferior mouth is turned downward. The lower jaw is shorter than the upper jaw. Fish with inferior mouths are bottom feeders that often possess barbels that assist in locating food particles.

The diet of fish with inferior mouths include algae, invertebrates such as snails, as well as detritus and any food that falls to the bottom.

Positions of fish-mouth

A. Inferior (sturgeon)

B. Subterminal (dace)



C. Terminal (trout)

D. Superior (sandfish)

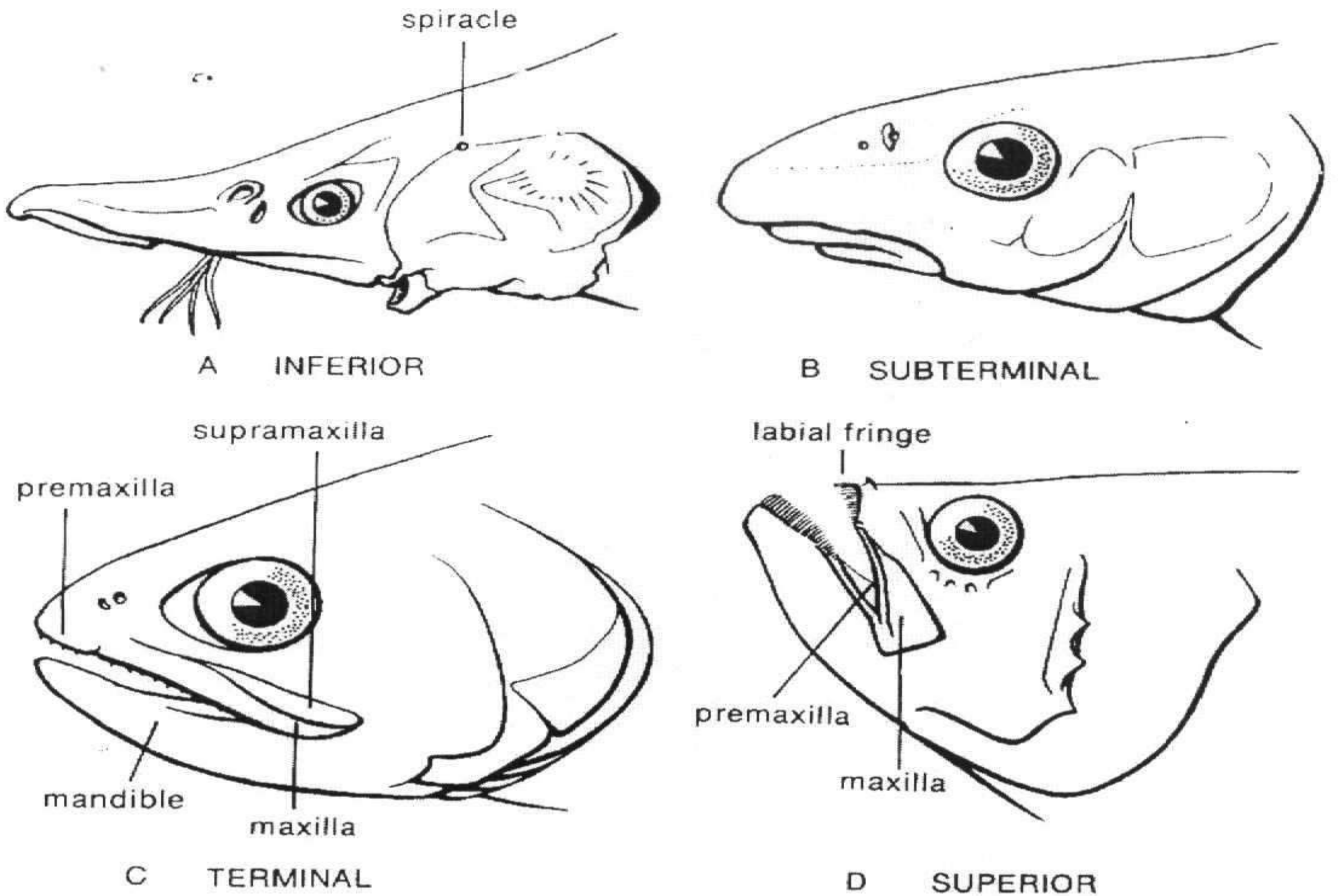


FIGURE 2–2. Examples of mouth positions in fishes. *A*, Inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout); *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)

Mouth Adaptations

Protrusile Mouth

Often fish will have a protrusile mouth feature, which allows them to extend their reach when attempting to snatch prey or food particles. This feature can be seen in all mouth types.

Sucker Mouth

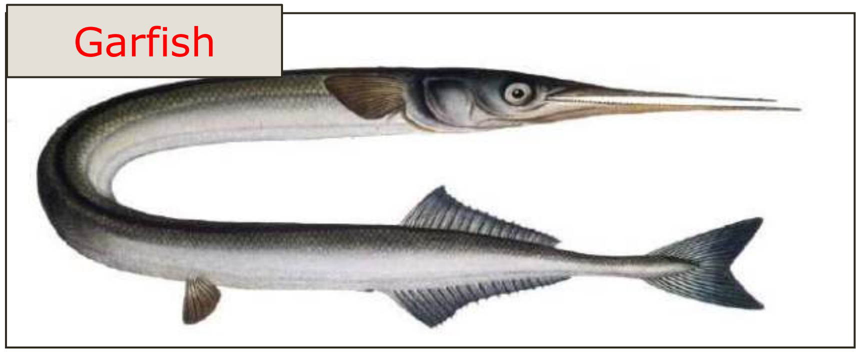
Sucker mouths are a common feature in fish with inferior mouths. Catfish such as the popular pleco, use their sucker mouth to rasp algae off driftwood or rocks. Some species may also use the sucker to help them combat currents. By attaching themselves to a rock via their sucker mouth, they are able to stay where they wish, even in a strong current.

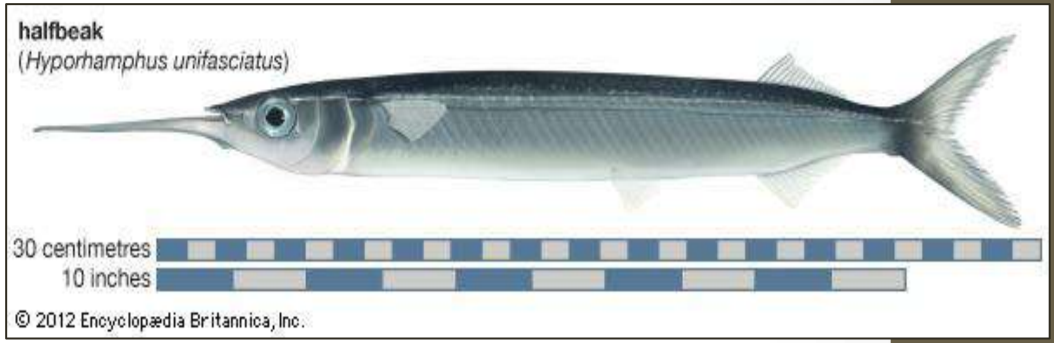
Protrusile Mouth

Sucker Mouth

Elongated Mouth

Elongated mouth allows the fish to poke into small crevices and holes to find food. The fish also use such a mouth to dig through the substrate to reach buried food. Elongated mouth allows the fish to scoop insects and food particles from the surface.
Freshwater species with elongated mouths include the Halfbeaks, Gars.



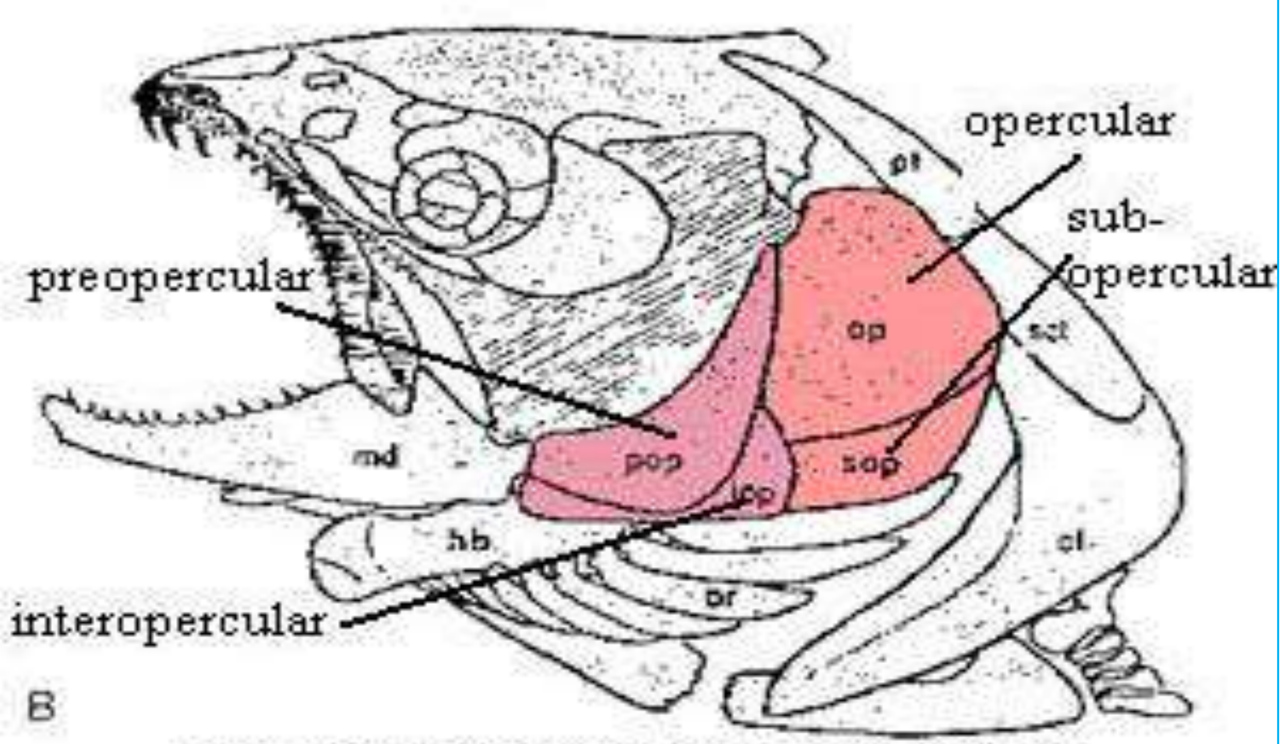


Beak Mouth

An interesting mouth variation is the beak mouth, also known as a rostrum. In this cases the mouth consists of two very hard pieces that are hinged and come together in a scissor-like fashion. This allows them to crush hard shells on invertebrates.
Pufferfish & Saltwater Parrotfish are fish with a beak mouth.

The operculum:

Is a bony structure, covering and protecting the gills in teleosts; it plays an important part in the breathing mechanism. In most fish, the edge of the operculum roughly marks the division between the head and the body. The operculum is composed of four fused bones; the opercle, preopercle, interopercle, and subopercle. The posterior rim of the operculum is equipped with a flexible, ribbed structure which acts as a seal to prevent reverse water flow during respiration. Elasmobranchs do not have an operculum but there are separate gill slits for each gill.

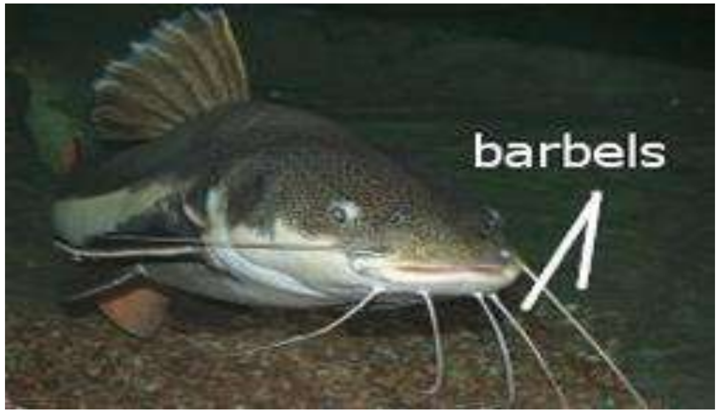


Opercular series in (A) a generalized basal actinopterygian and (B) Amia

Barbals

* **Barbals** may be minute and simple or conspicuous and complex.

* Other structure as barbels are cirri or fimbria.



Lampreys have a series of fleshy fimbria surrounding the mouth, which is a jawless sucking disc

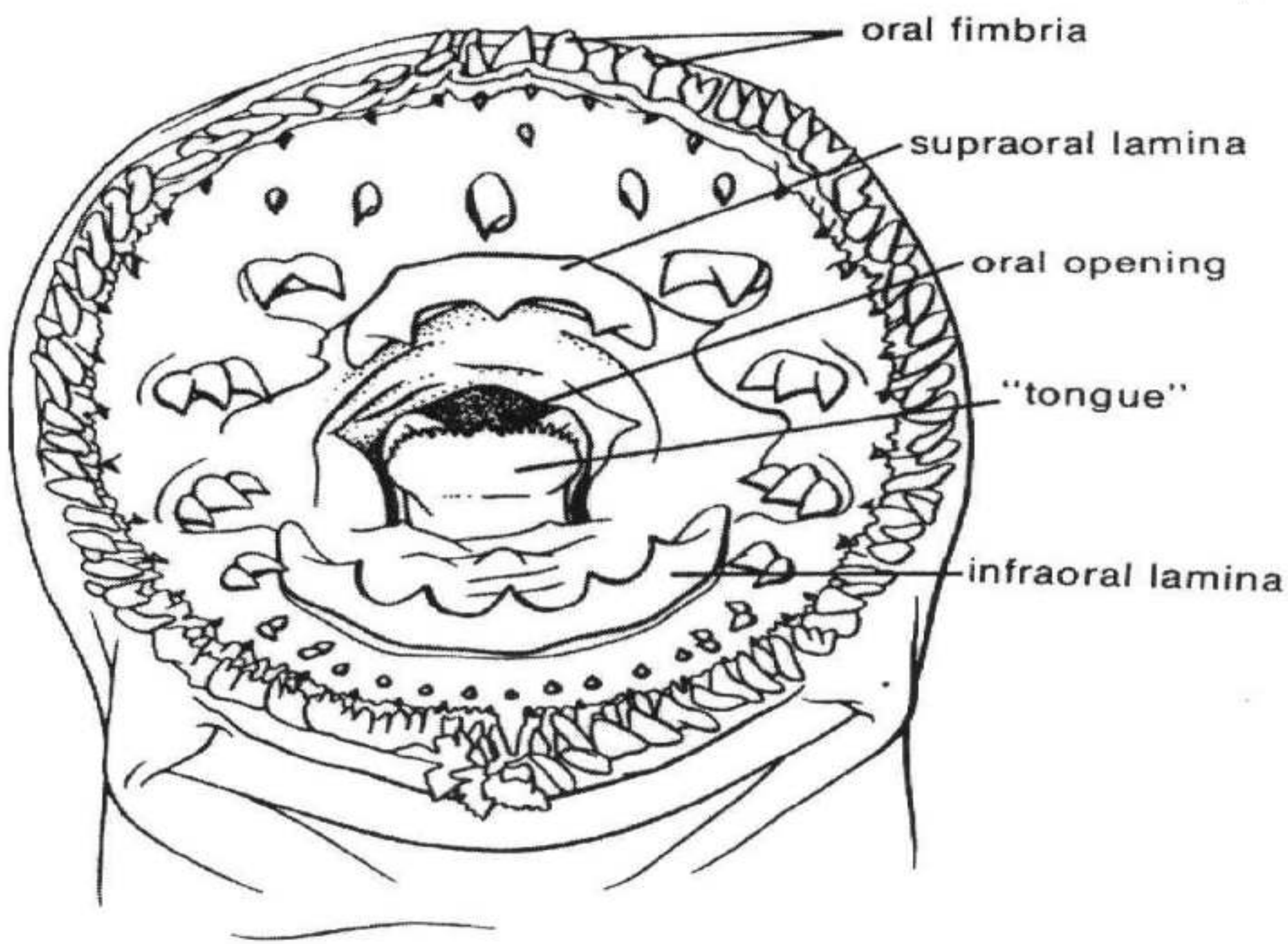


FIGURE 2–4. Oral disc of lamprey (*Lampetra minima*).

*Sharks may have oronasal grooves and labial folds in the mouth region

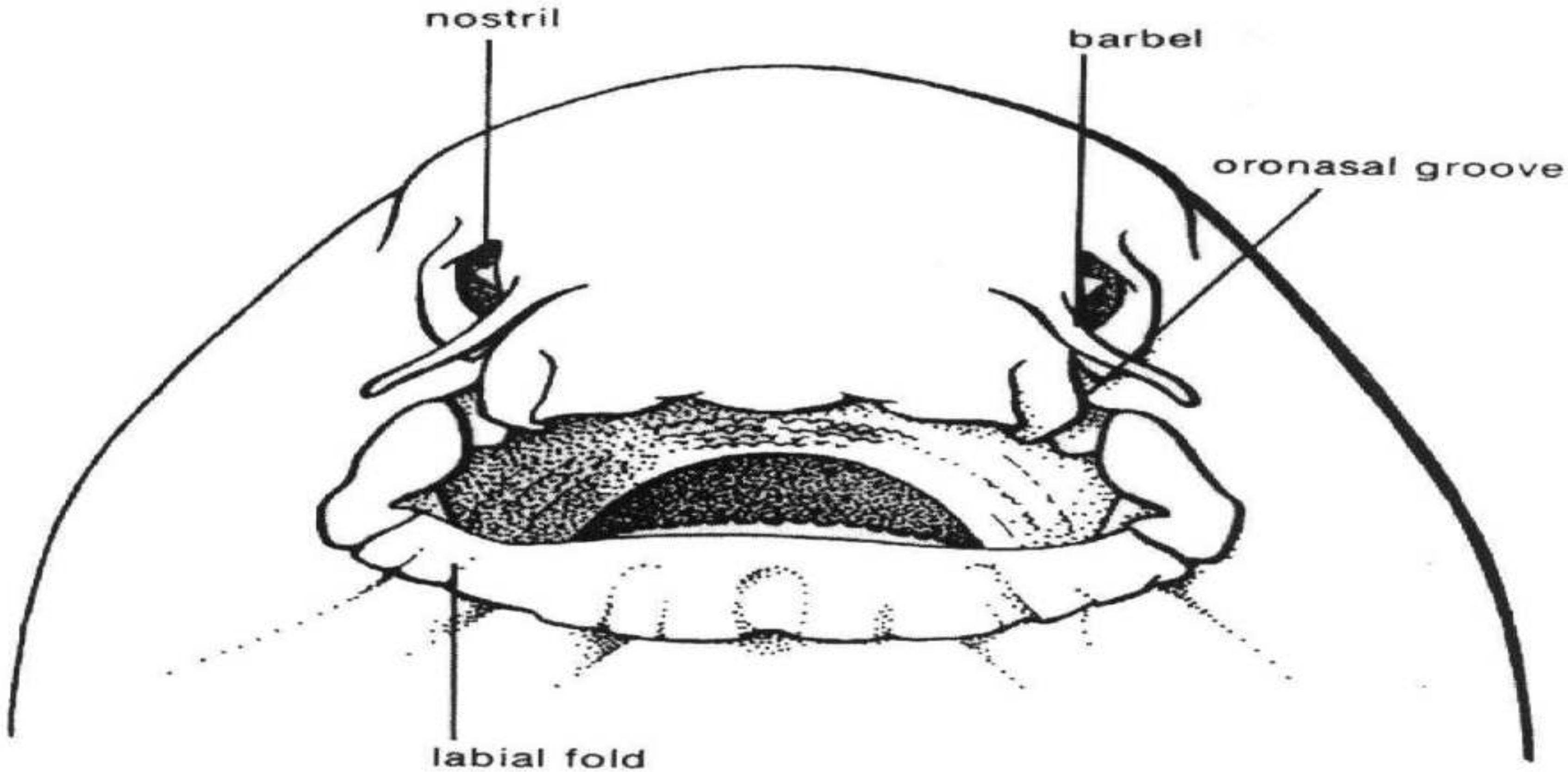


FIGURE 2–3. Ventral view of mouth and rostrum of shark (*Chiloscyllium indicum*) showing grooves and labial folds.

Some other prominent features of the head are spines on various bones

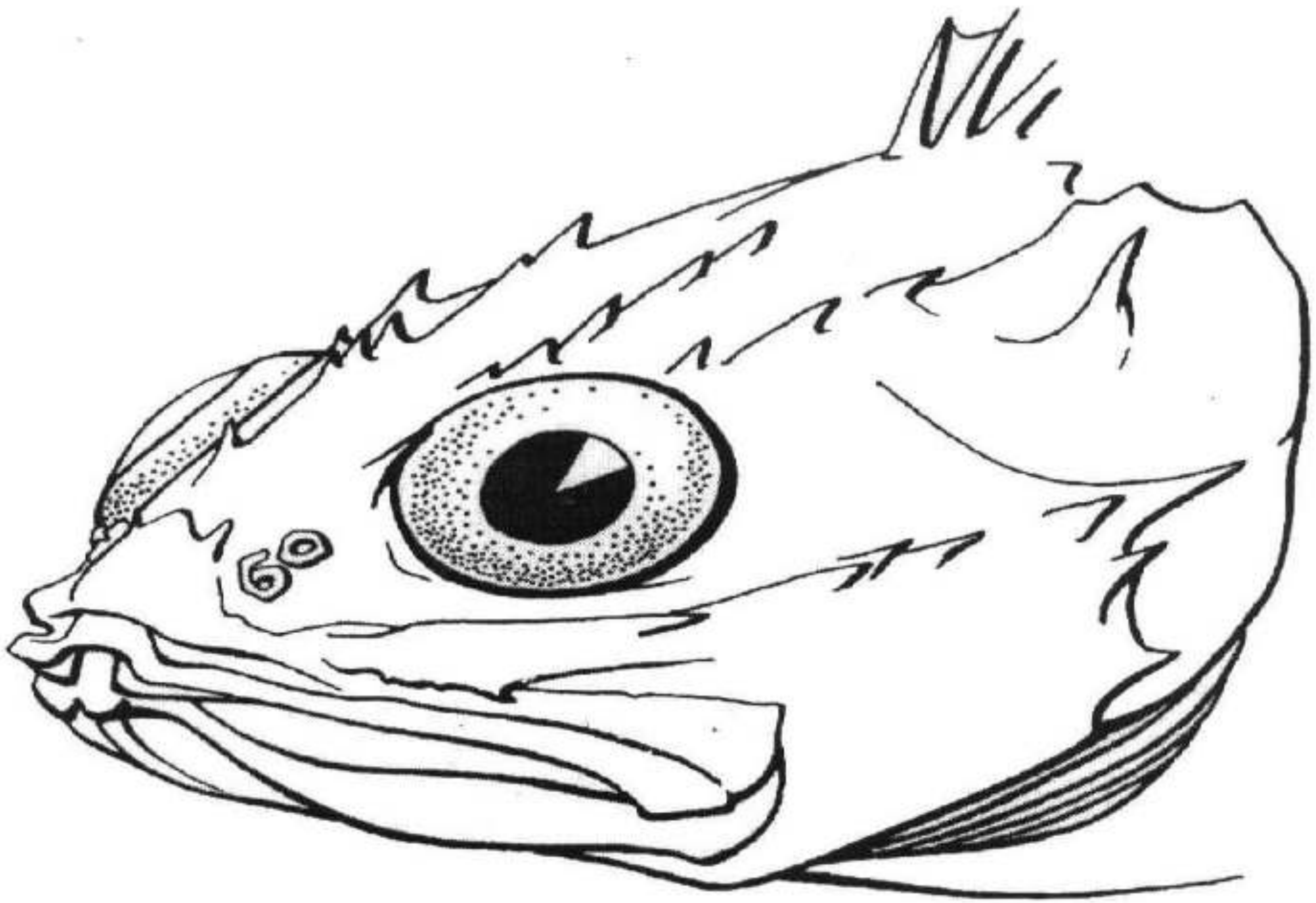


FIGURE 2–5. Diagram of head of rockfish (Scorpaenidae), showing spines.

Nostrils:

The nostrils of fish do not open into the back of the mouth as do those of mammals, and are not for breathing. They lead into organs of smell which are very sensitive, so that a fish can detect the presence of food in the water at considerable distances.

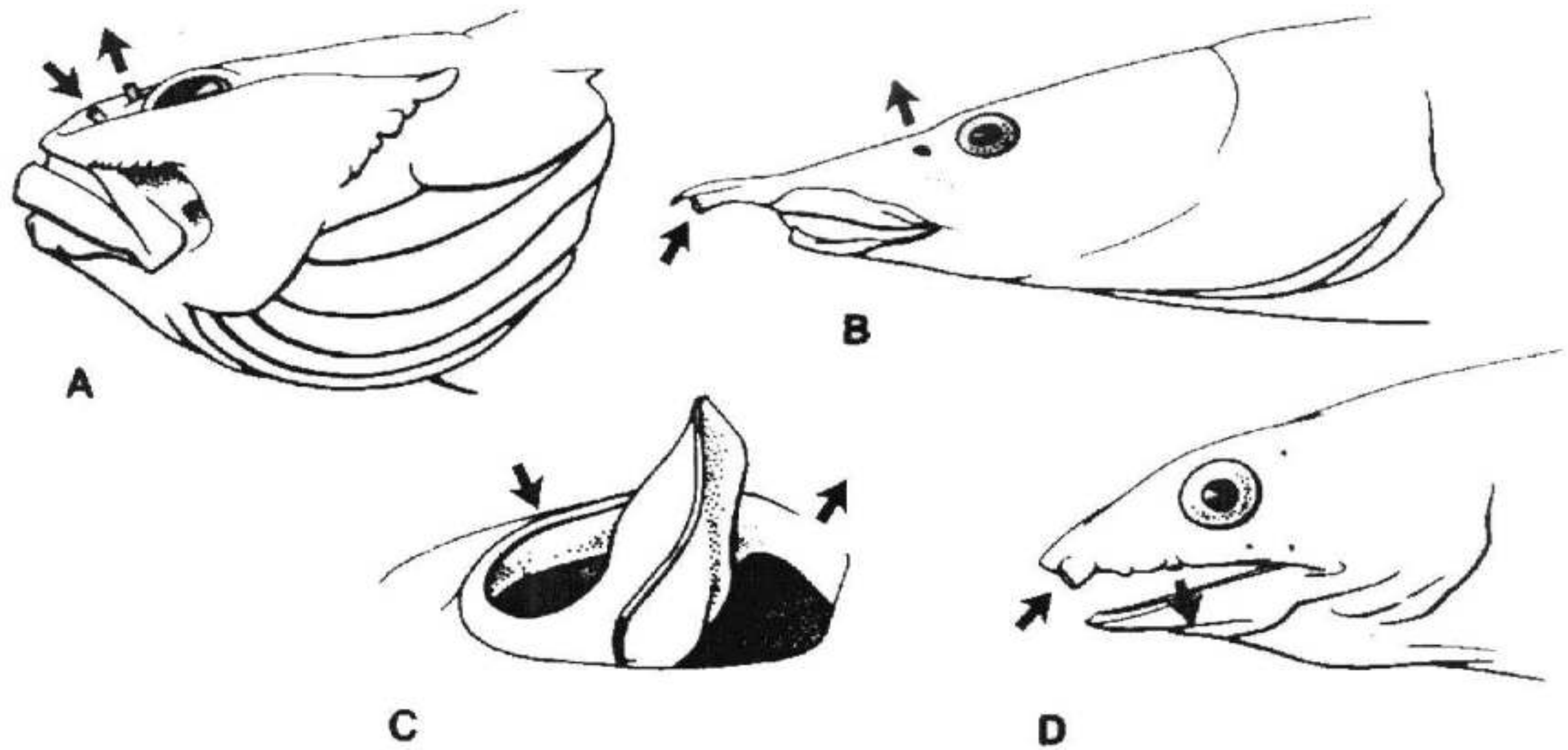


FIGURE 2–7. Nostril positions. *A*, Sculpin (Cottidae); *B*, spiny eel (Mastacembelidae); *C*, typical bony fish nostrils divided by flap of skin (Catostomidae); *D*, eel (*Myrophis*).

*Fins of fishes

Fins give stability, and control the direction of movement during swimming.

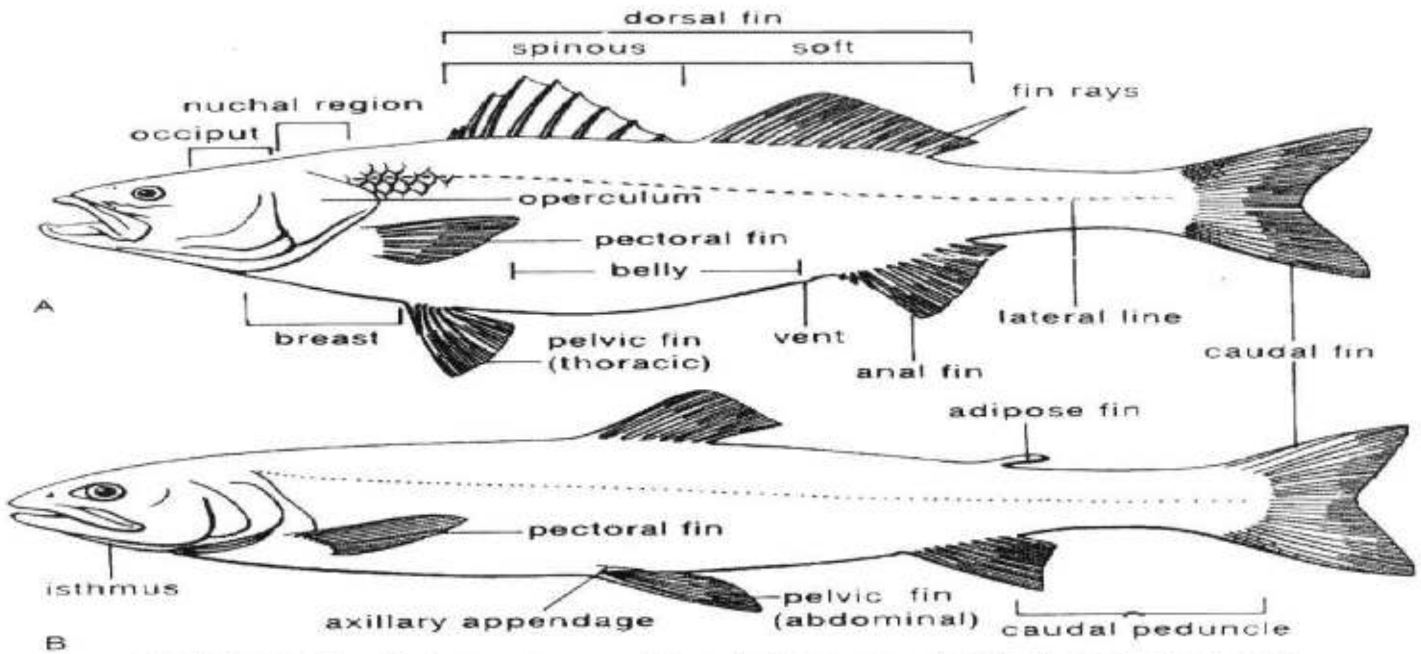


FIGURE 2–10. Body regions and fins. *A*, Spiny-rayed fish; *B*, soft-rayed fish.

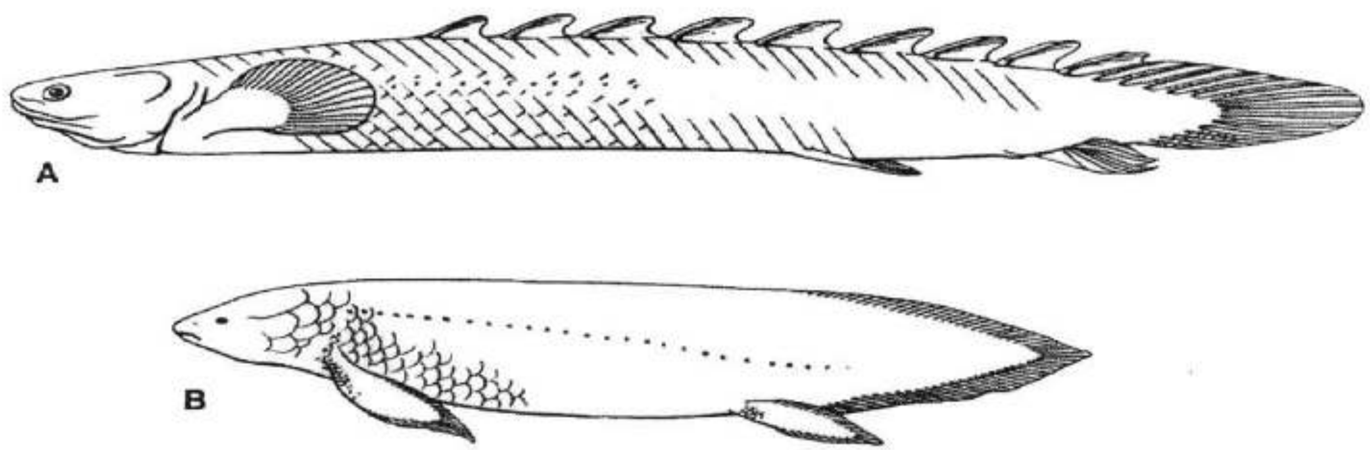


FIGURE 2–11. Examples of fishes with lobate paired fins. *A*, Bichir (*Polypterus*); *B*, Australian lungfish (*Neoceratodus*). (*B* based on Goodrich, in Lankester, 1909.)

1. Paired fins

*Fishes with modified pectoral fins

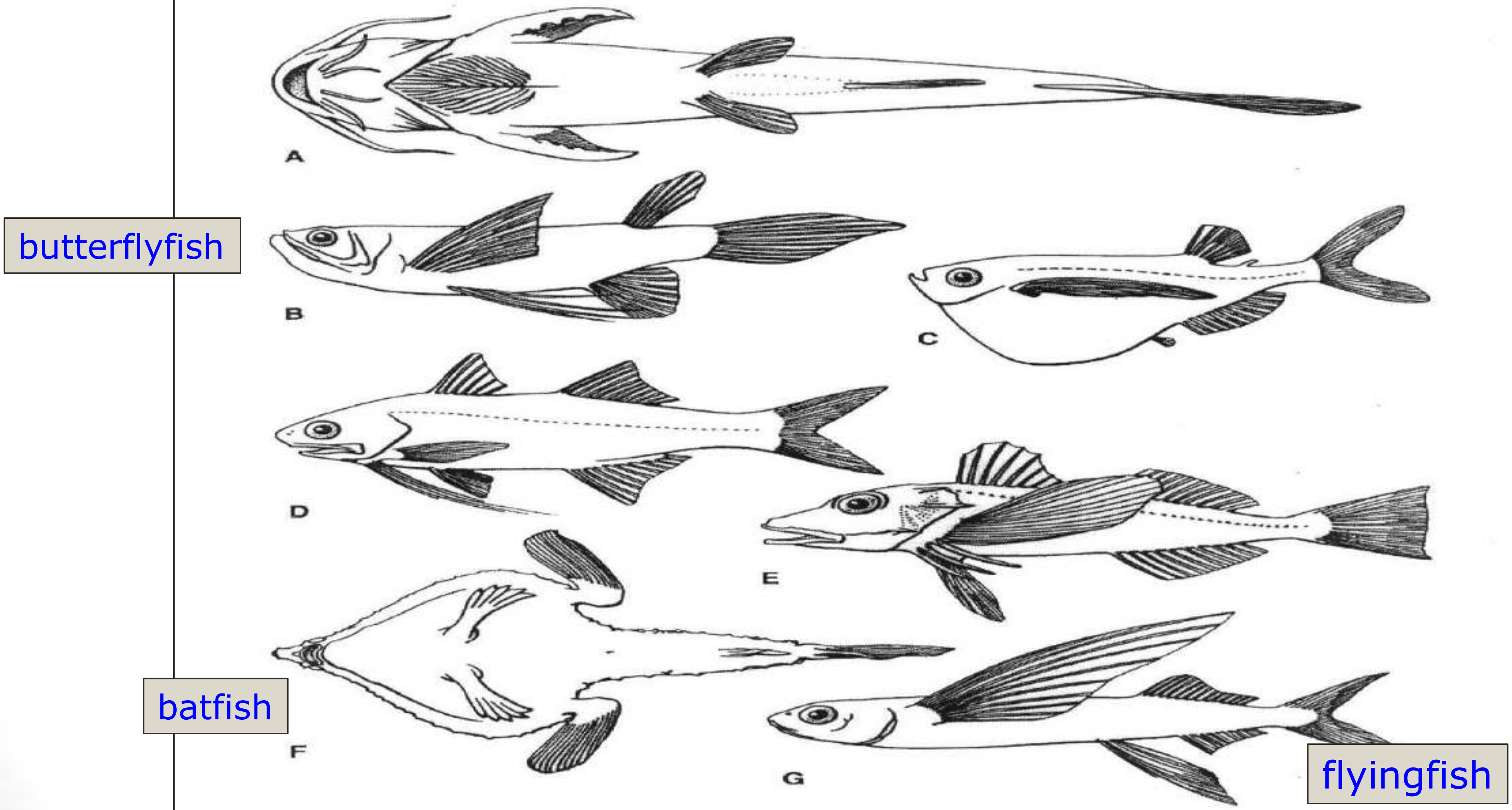


FIGURE 2–12. Examples of fishes with modified pectoral fins. *A*, Sisorid catfish (*Glyptothorax*); *B*, freshwater butterflyfish (*Pantodon*); *C*, hatchetfish (*Gastropelecus*); *D*, threadfin (Polynemidae); *E*, gurnard (Triglidae); *F*, batfish (Ogcocephalidae); *G*, flyingfish (Exocoetidae). (*B* based on Herald, 1961; *D*, *E*, and *G* based on Jordan and Evermann, 1900.)

*Position of pelvic fins in fishes

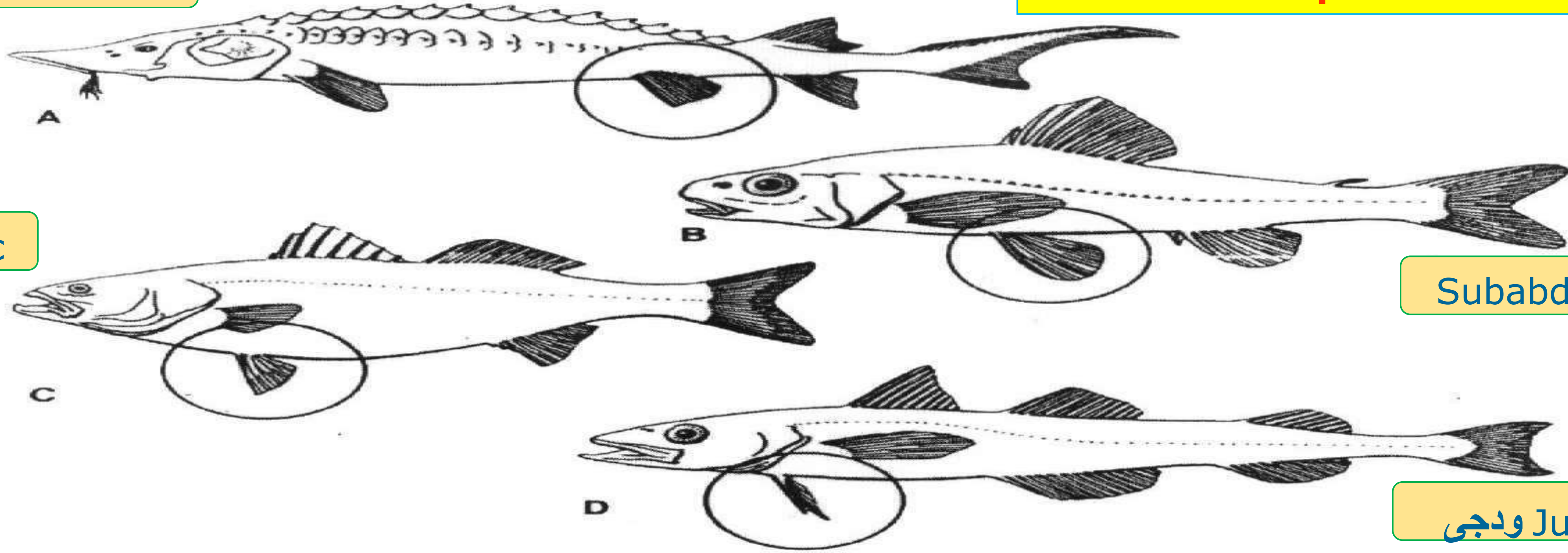


FIGURE 2–13. Examples of pelvic fin placement, pelvic fins circled. *A*, Abdominal (sturgeon, Acipenseridae); *B*, subabdominal (sand roller, Percopsidae); *C*, thoracic (bass, Percichthyidae); *D*, jugular (pollock, Gadidae). (Based on Jordan and Evermann, 1900.)

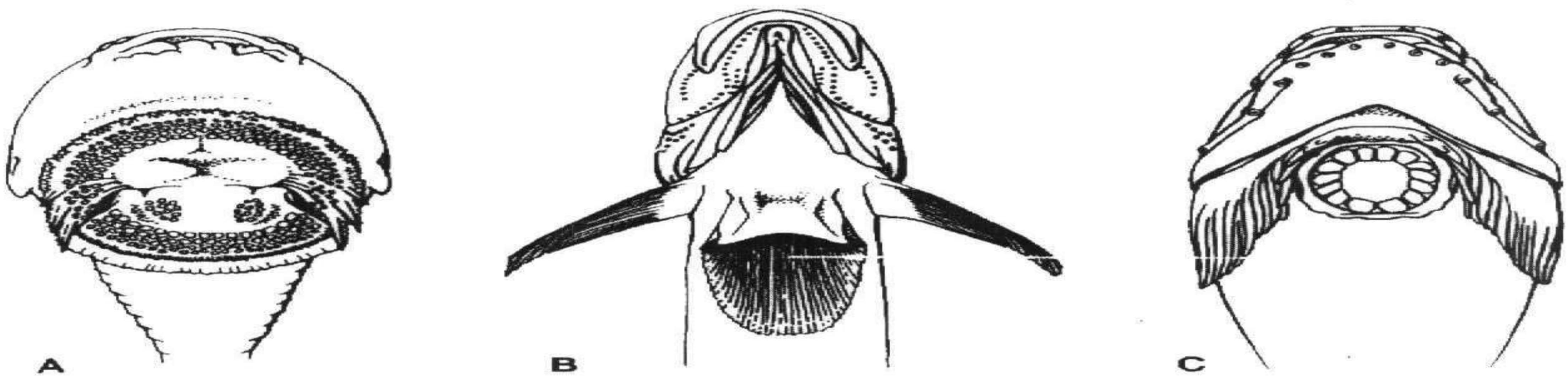


FIGURE 2–14. Pelvic fins modified as sucking devices. *A*, Clingfish (Gobiesocidae); *B*, goby (Gobiidae); *C*, Snailfish (Liparidae).

*Pelvic fins modified as sucking devices

*median fins

Dorsal fins modified into:

(A)- sucking disc. (B)- fishing rod and lure. قصبة الصيد و خداع

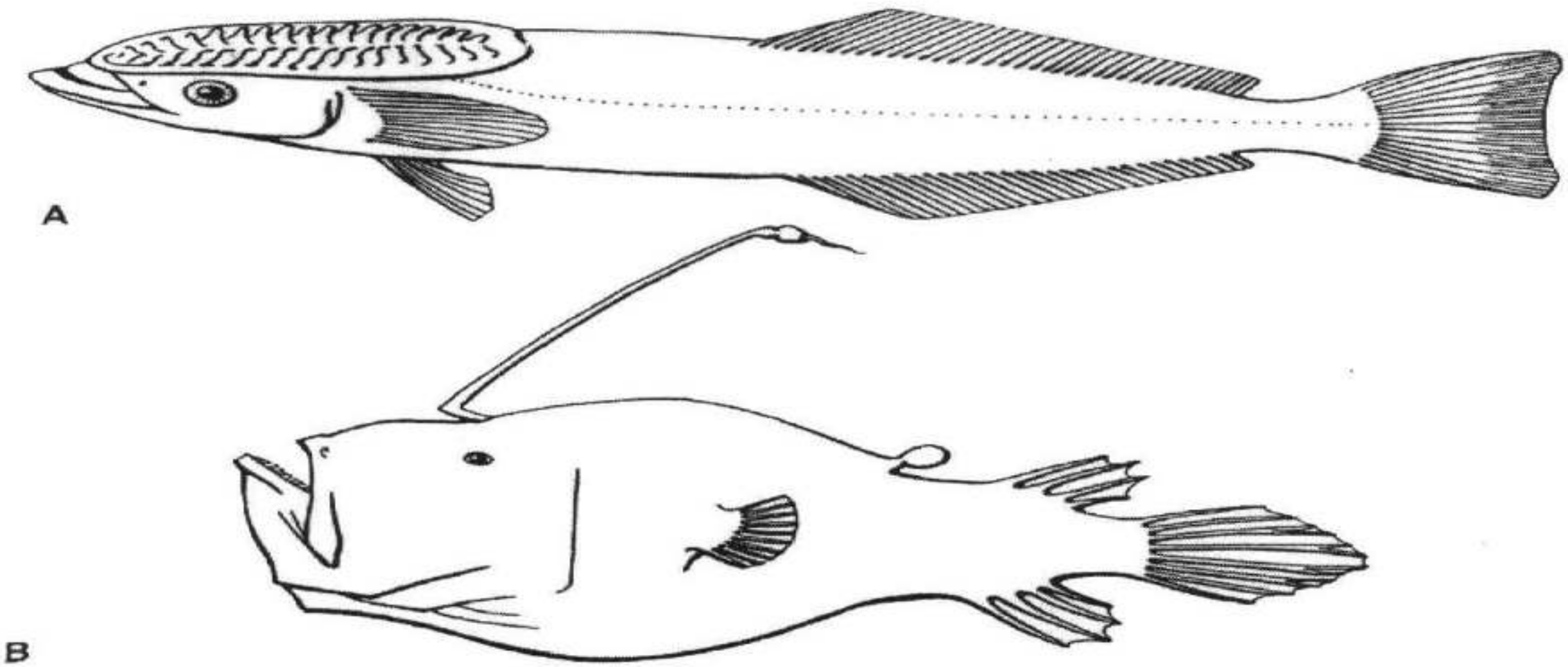
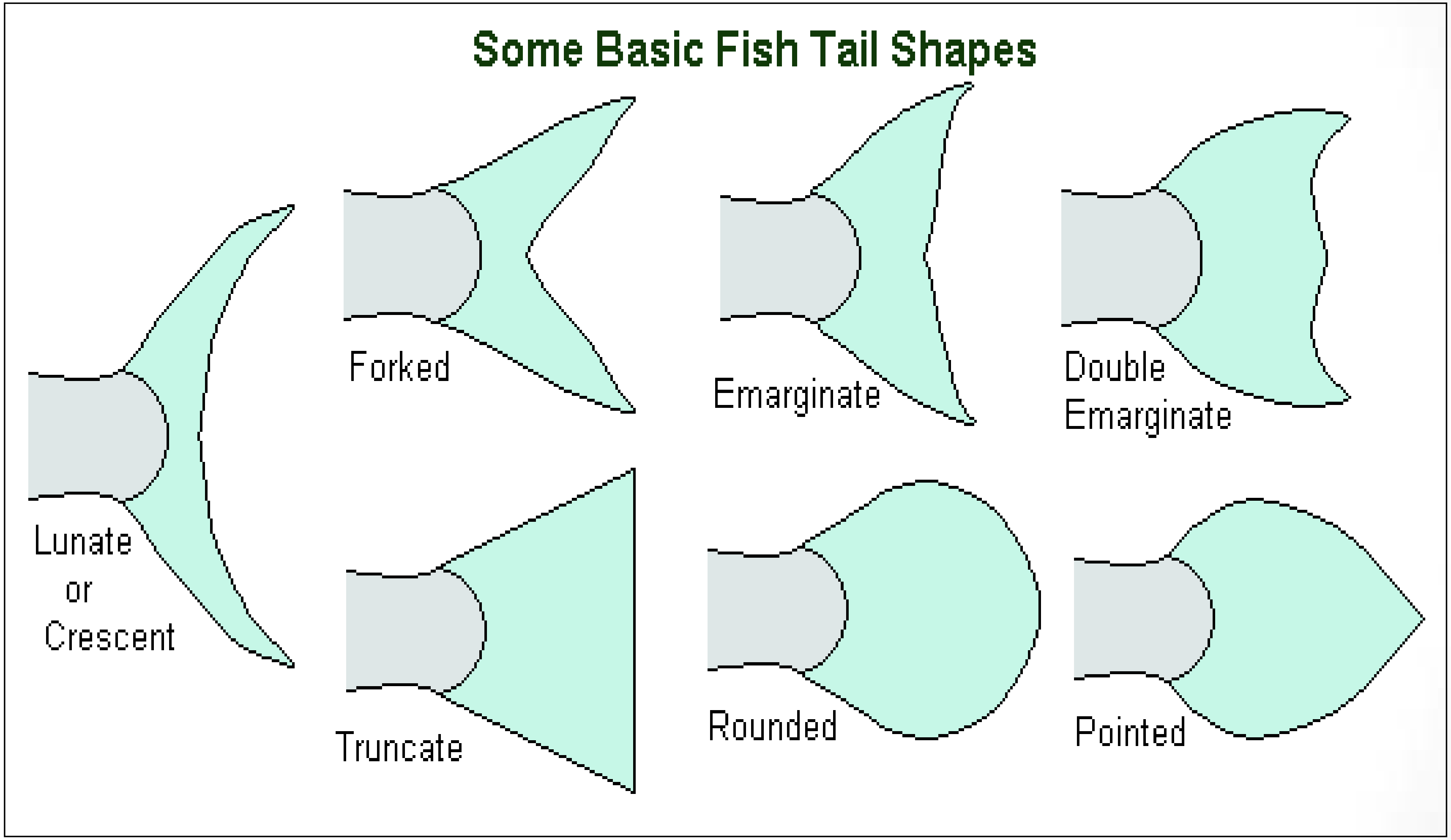


FIGURE 2–15. Modified dorsal fins. *A*, Sucking disc (remora, Echeneidae); *B*, fishing rod and lure (angler, Ceratiidae): (*B* based on Jordan and Evermann, 1900.)

*Representative shapes of caudal fins



Types of caudal fins

a)- Heterocercal, b)- Abbreviate heterocercal
c)- Homocercal d)- Isocercal

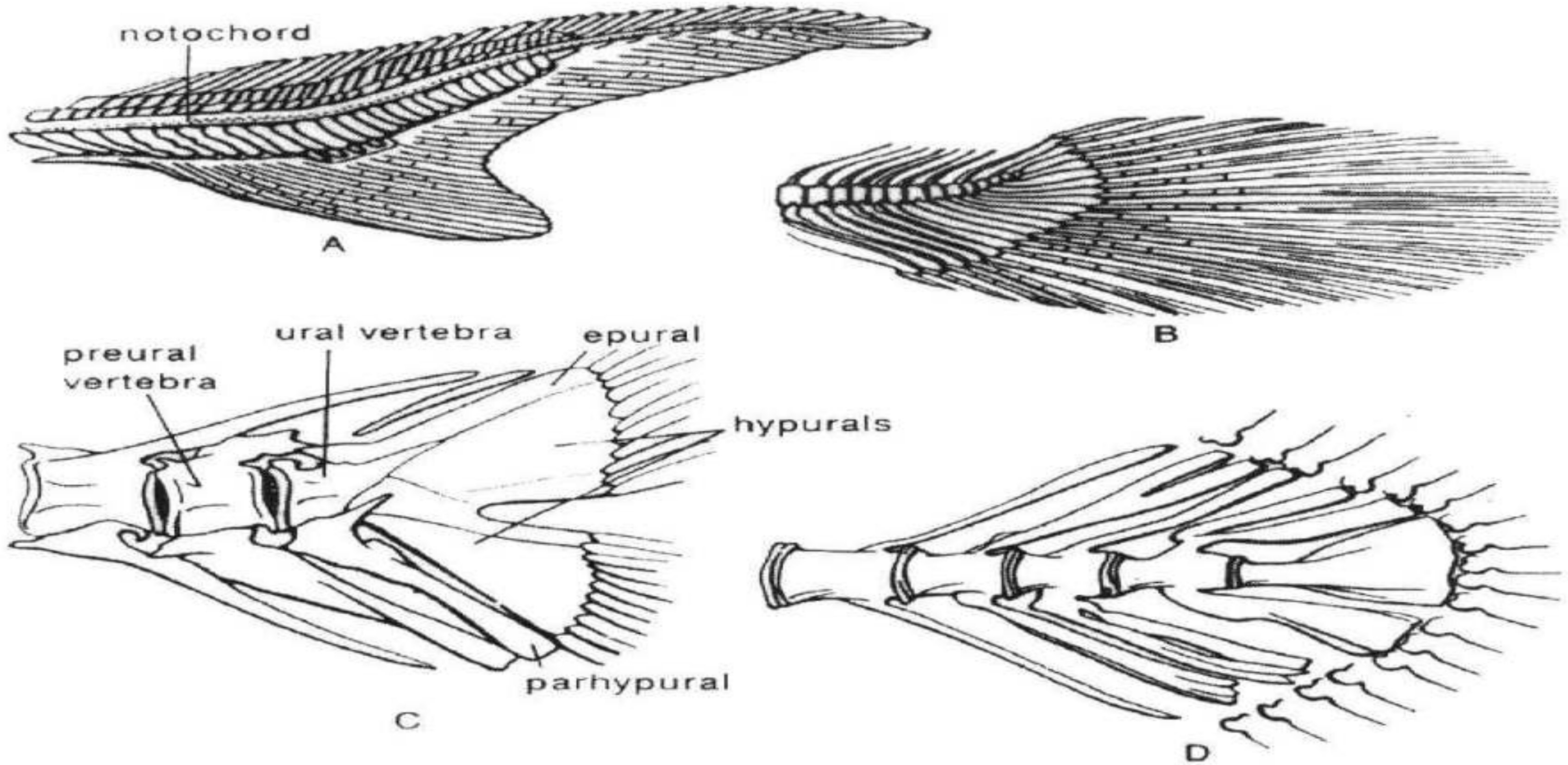
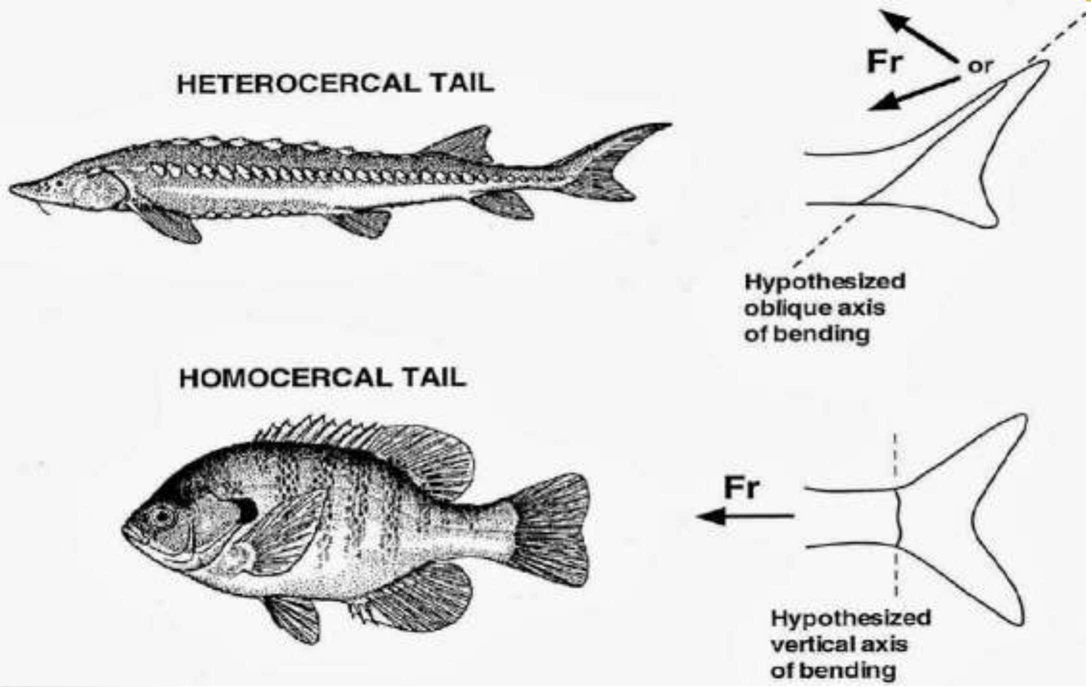


FIGURE 2–17. Types of caudal fins, showing structure. *A*, Heterocercal (sturgeon, Acipenseridae); *B*, abbreviate heterocercal (bowfin, Amiidae); *C*, homocercal (striped bass, Percichthyidae); *D*, isocercal (cod, Gadidae). (*A* based on Goodrich, 1930; *B* based on Jordan and Evermann, 1900.)

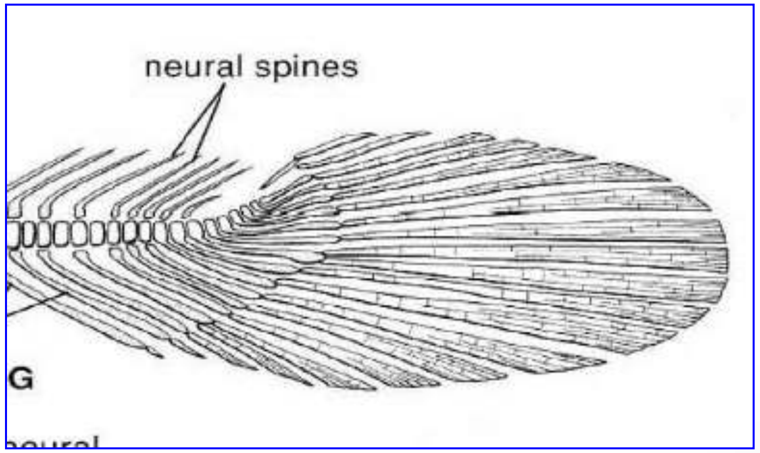
Heterocercal:
A tail in which the tip of the vertebral column turns upward, extending into the dorsal lobe of the tail fin; the dorsal lobe is often larger than the ventral lobe. Consequently the tail becomes asymmetrical, both externally and internally.
Such a type of tail is mainly found among the elasmobranchs (in the sharks (Chondrichthyes) and in the lower forms in general.

Abbreviated heterocercal: Vertebral column goes into upper lobe, but fin looks symmetrical.
Homocercal: Describing the symmetric tail of a fish that has two lobes extending from the end of the vertebral column.

Isocercal: Vertebral column extends along and straight. The fin fold develops, both, above & below it. The fin fold continues with the dorsal & the anal fins to form continuous fold.
Such a type of tail is mainly found in Anguilliformes.



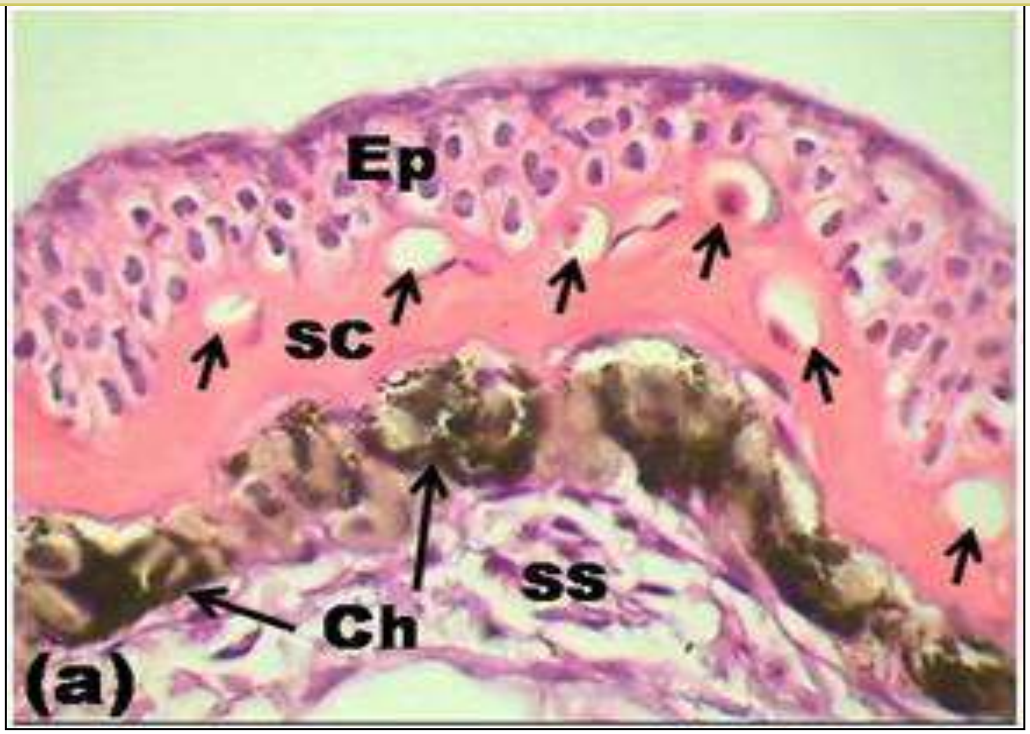
Isocercal

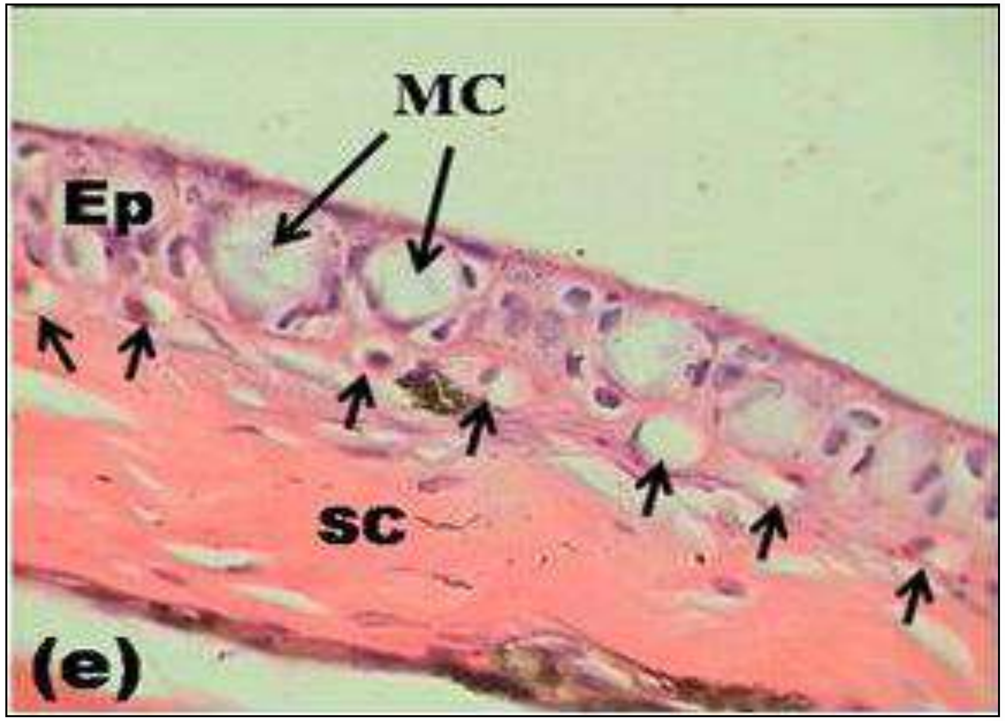


Abbreviated heterocercal

*Skin

Usually, Fish skin is made up of two layers , an outer layer (epidermis) and an inner layer (dermis)





T.S. of the skin of different body regions of *Alticus kirkii,* (a) crest, (e) dorsal-lateral region of the trunk.

1)- The superficial epidermis (Ep).
2)- lower dermis which consists of:
A)- outer stratum compactum (SC) of collagenous fibers.
B)- inner stratum spongiosum (SS).
Note blood capillaries (small arrows), mucous cell (MC), chromatophores (Ch).

*Skin

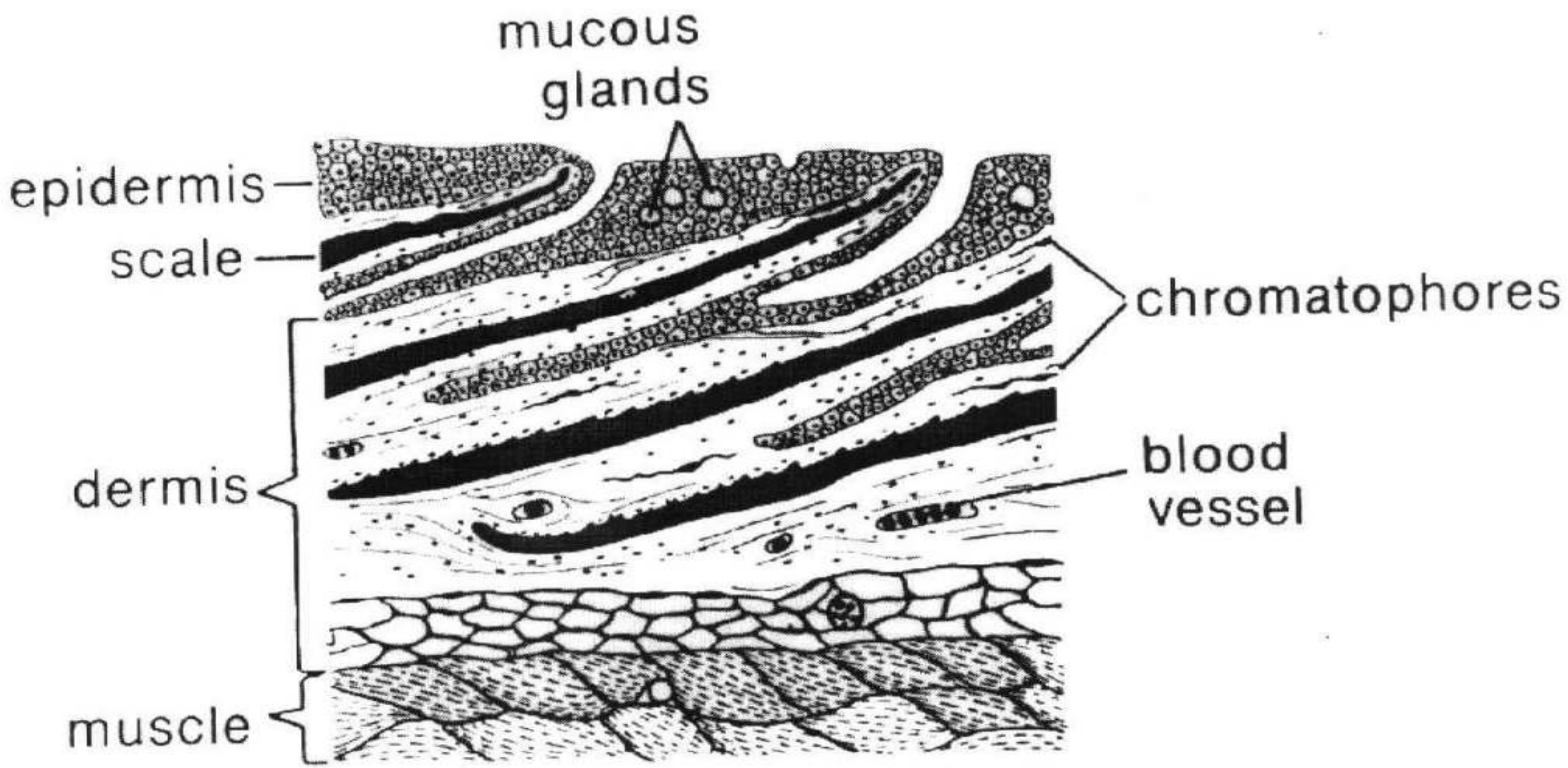


FIGURE 2–18. Section of fish skin. (Based on Wunder, 1936.)

* Scales

* **Cartilaginous fishes:** are covered by one type of scales known as placoid scales.
* **Bony fishes:** Some bony fishes are **naked** as catfishes; Most of them are covered by **bony scales** which are dermal in origin. The scales may be modified into bony plates, scutes as in sturgeons.

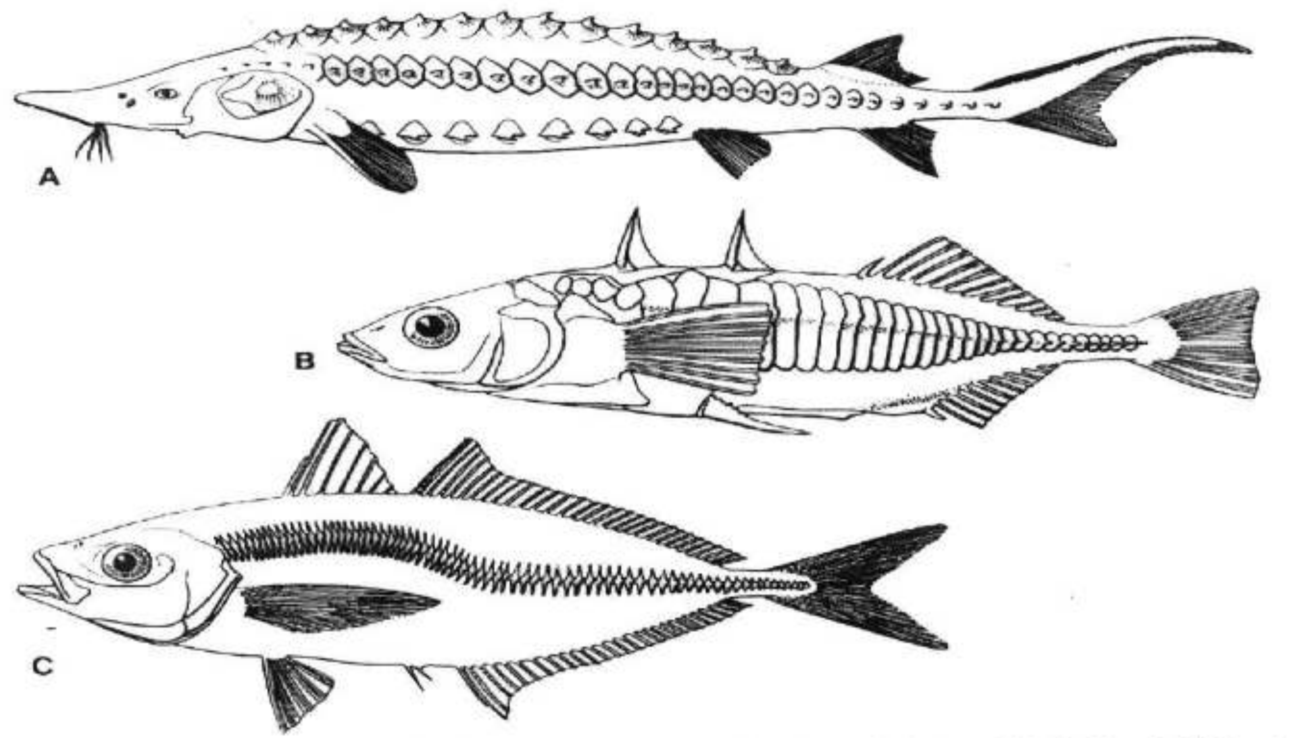


FIGURE 2–19. Examples of fishes with scutes. *A*, Sturgeon (Acipenseridae); *B*, stickleback (Gasterosteidae); *C*, jack (Carangidae). (*A* and *C* based on Jordan and Evermann, 1900.)

Types of scales in fishes

1-Placoid

2-Ganoid

3-Cycloid

4-Ctenoid

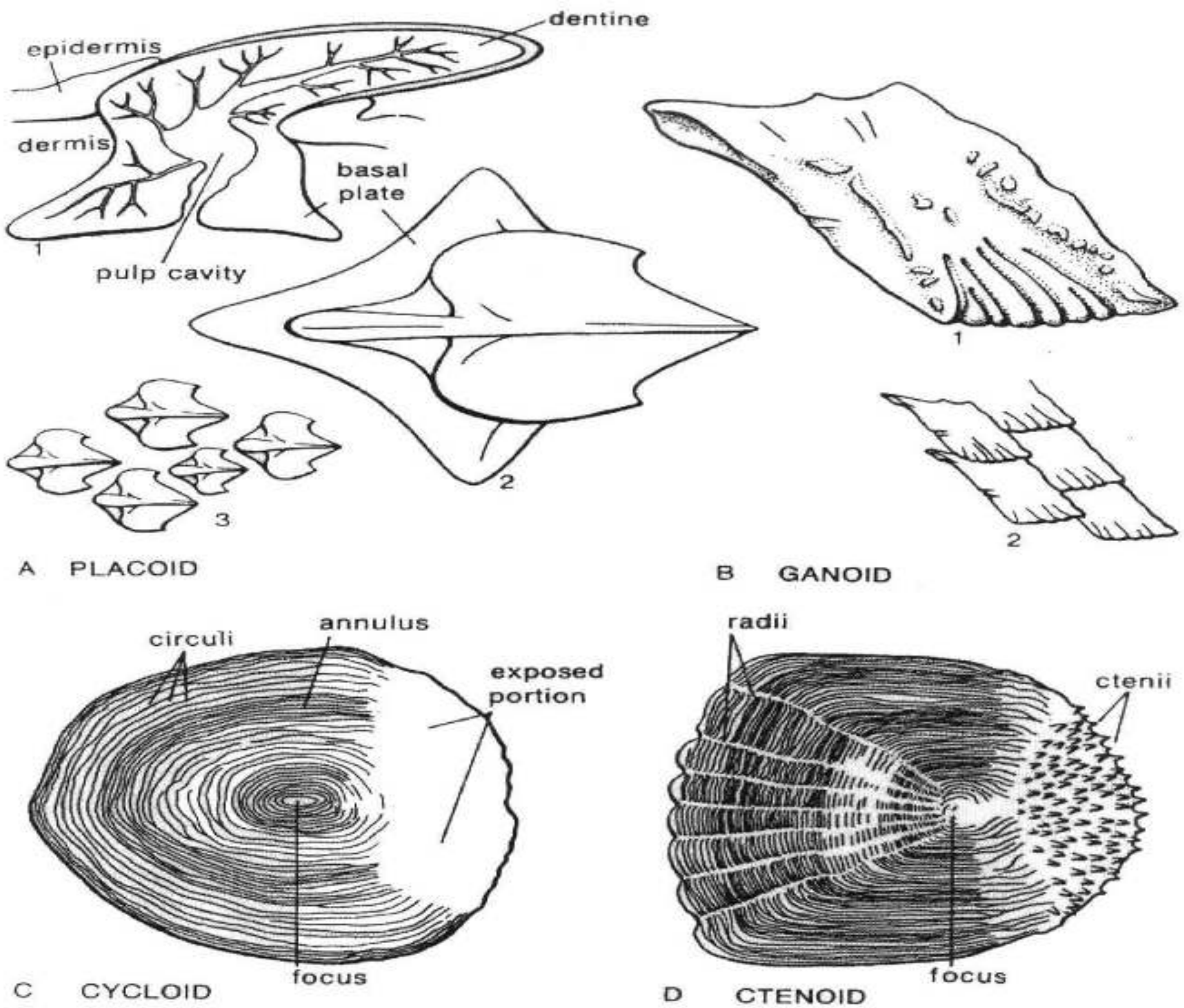


FIGURE 2–20. Examples of types of scales (anterior to left). A, Placoid— 1, sagittal section, 2, top view, 3, disposition on skin; B, ganoid—1, single scale, 2, disposition on fish; C, cycloid; D, ctenoid

Lecture 3

*Alimentary canal and associated structures

Positions of bones that bearing teeth in bony fishes

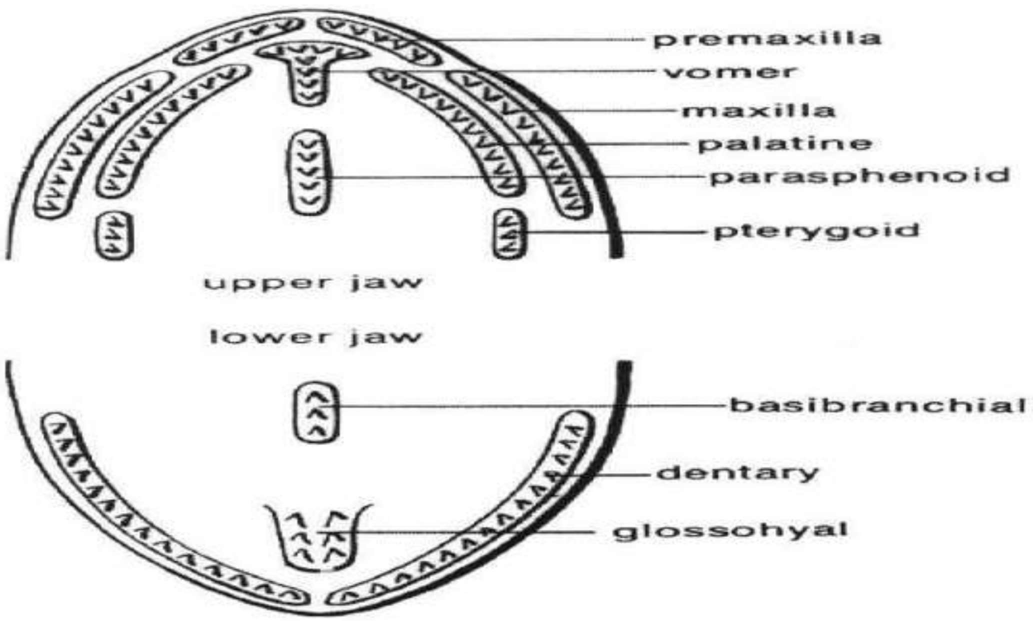


FIGURE 2–22. Diagram of positions of bones that can bear teeth in bony fishes.

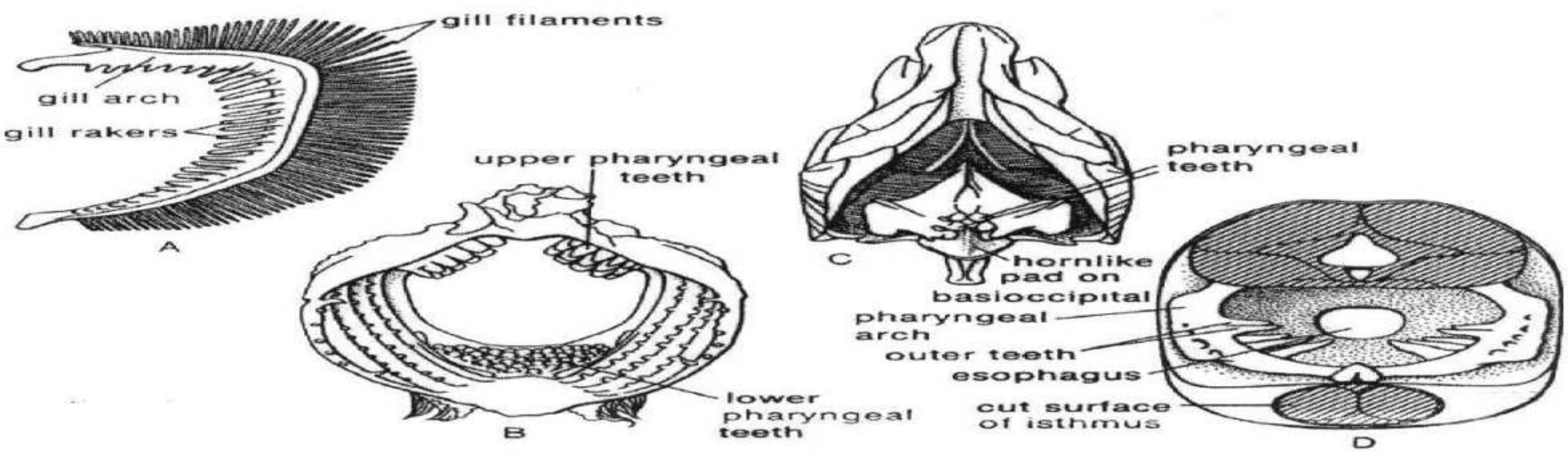


FIGURE 2–23. Examples of gill rakers and pharyngeal teeth. *A*, Diagram of gill arch with rakers and gills; *B*, anterior view of gill arches and pharyngeal teeth of surfperch (Embiotocidae); *C*, ventral view of the pharyngeal region of a carp (*Cyprinus*), with the pharyngeal arch displaced anteriorly to expose the basioccipital pad; *D*, anterior aspect of pharyngeal teeth of the squawfish (*Ptychocheilus*), cross section behind last gill arch with musculature and other soft tissue removed.

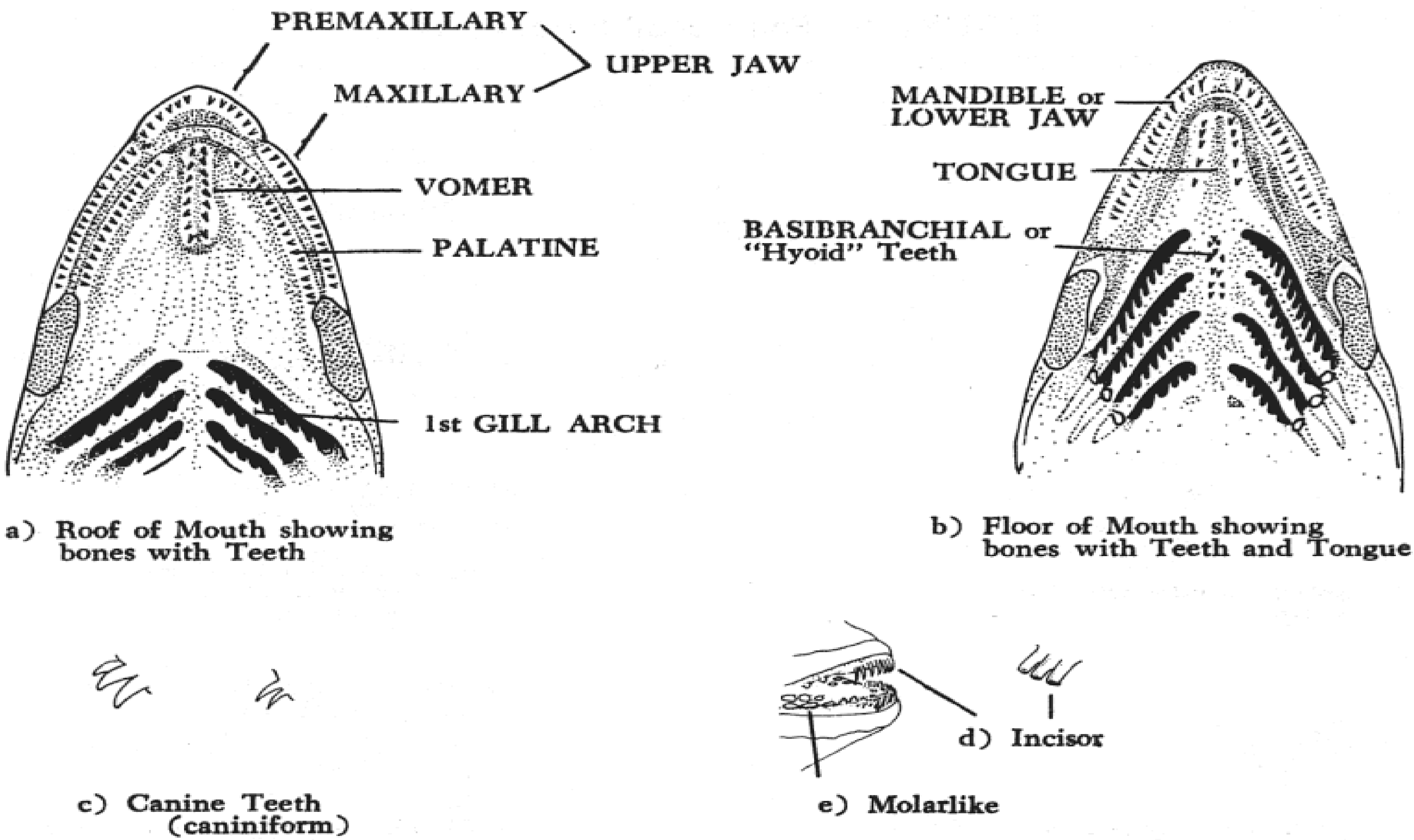
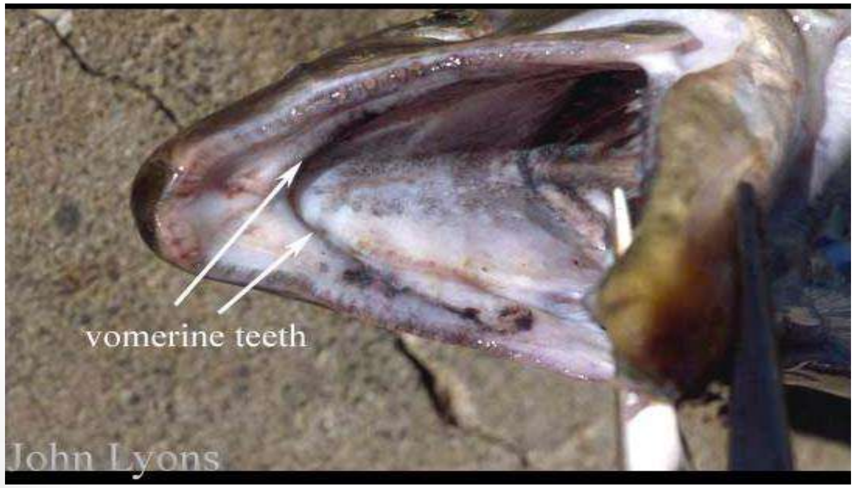


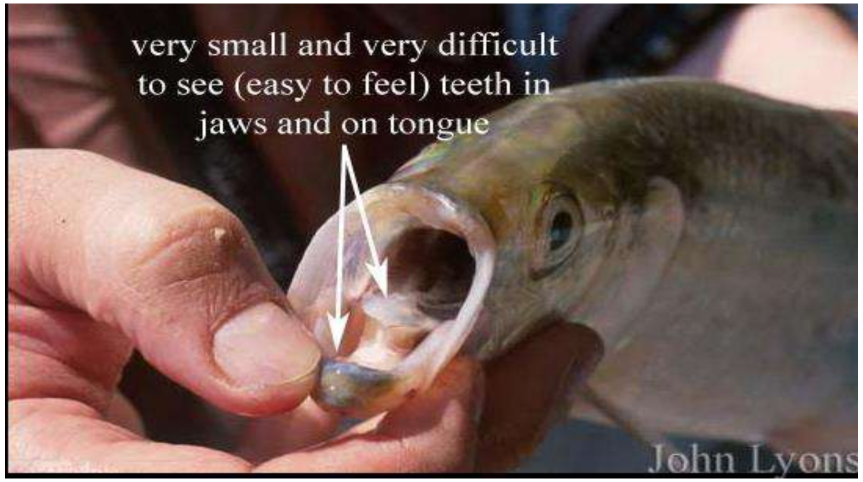
FIGURE 8. Bones and teeth inside mouth or bucal cavity.

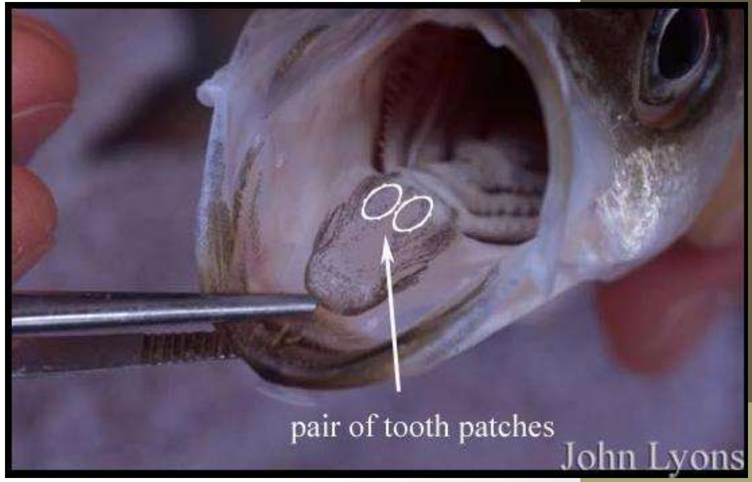
The sea lamprey uses its suction disk mouth which is liend with small sharp, rasping teeth

Megalodon jaw The ancestors of fish

Red-bellied piranha, showing mouth and teeth







Gill rakers

- Gill rakers are bony or cartilaginous projections which point forward and inward from the gill arches.
- They aid in fish feeding.
- They are widely varied in number, spacing, and the form, therefor, their shape and number are good indications of the diet of the fish.

A)- Carnivores and omnivores, fishes which eat large preys, have short & widely spaced gill rakers. This type of gill rakers prevents the prey item from escaping between the gills.

B)- Fishes which eat smaller prey have longer, thinner and more numerous gill rakers.

C)- Filter feeders, Species which feed on plankton and other tiny suspended matter have the longest, thinnest and most numerous gill rakers; some species have over 150 on the lower arch alone. Because gill rakers characters often vary between closely related taxa, they are commonly used in the classification and identification of fish species.

Gill rakers and pharyngeal teeth

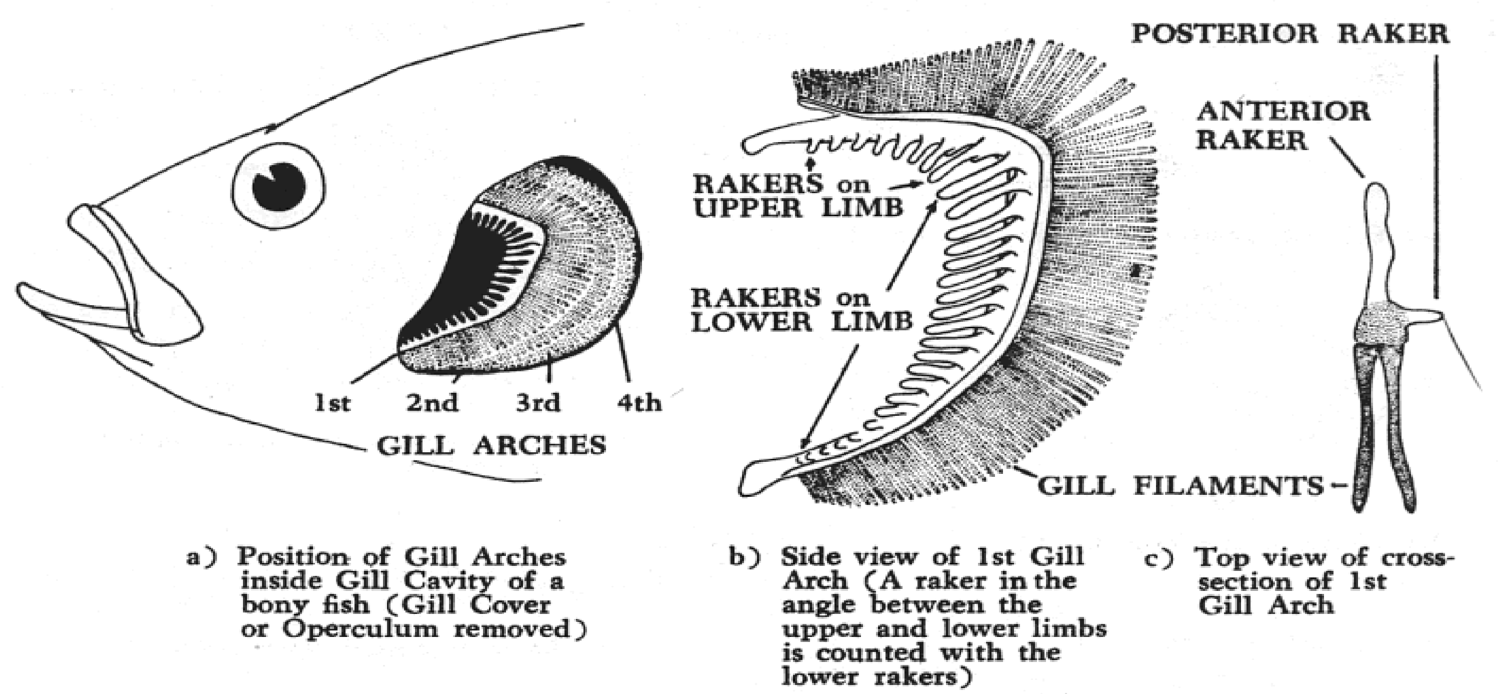
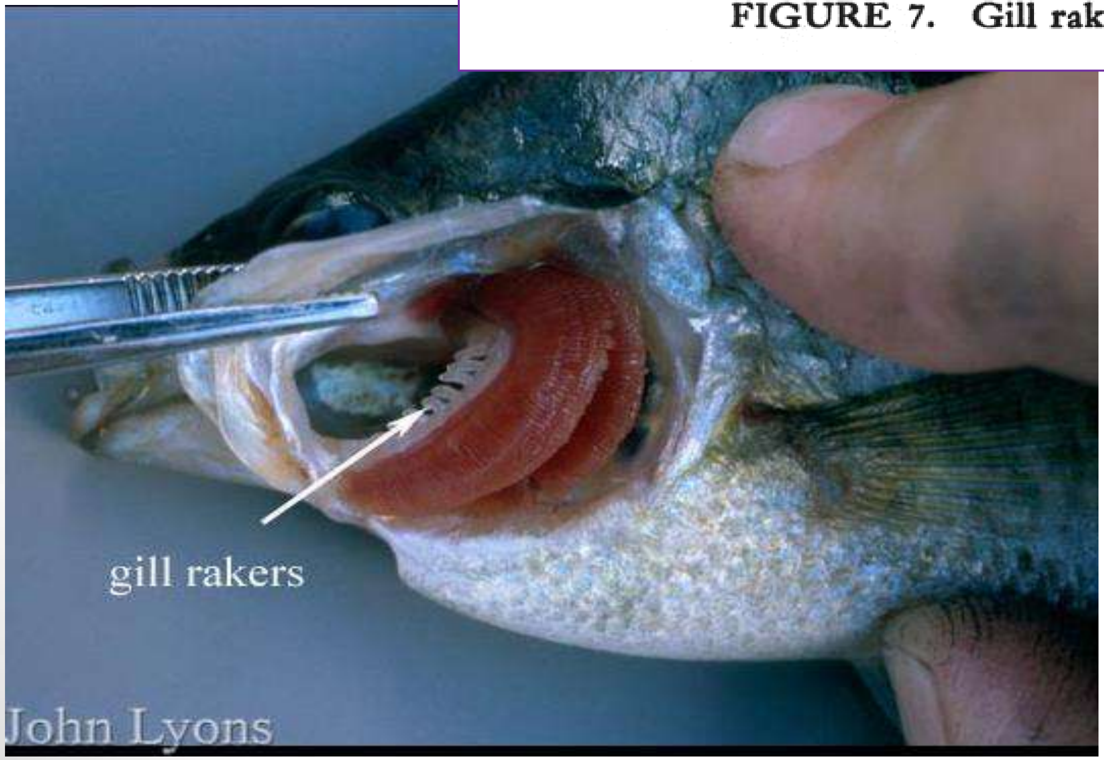
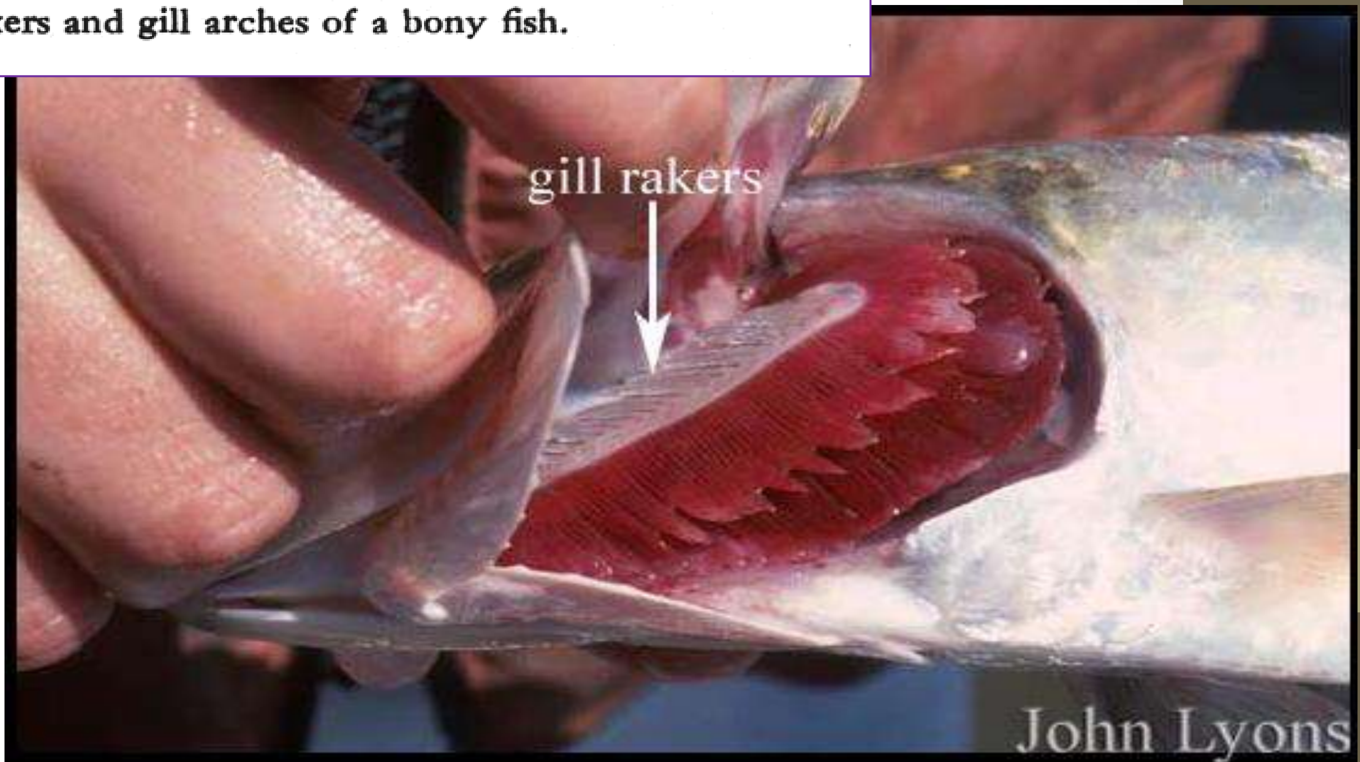


FIGURE 7. Gill rakers and gill arches of a bony fish.





Esophagus, stomach, and intestine

- Esophagus, short with mucous cells or glands.

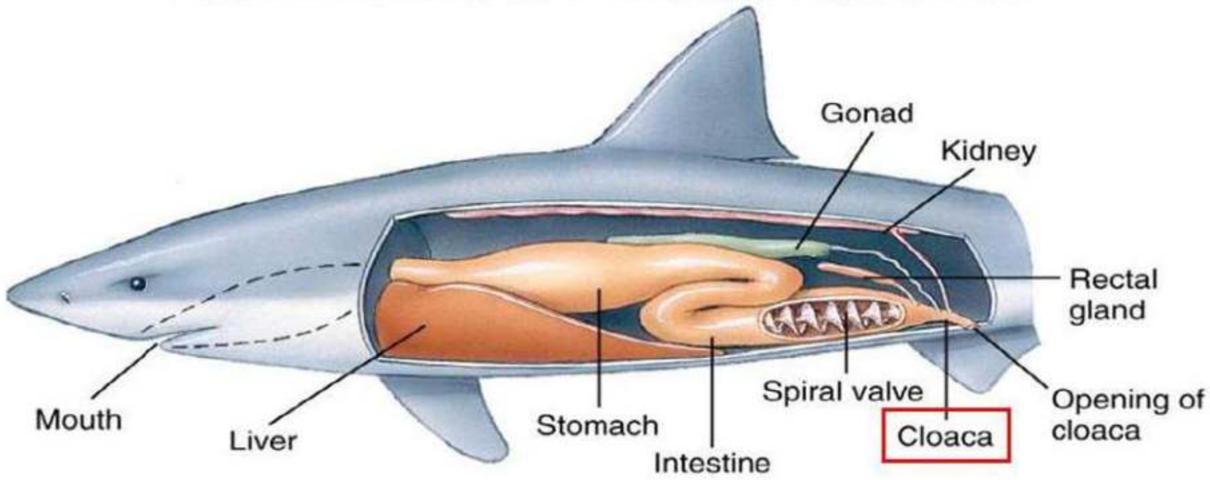
-Stomach take **U** or **V** shape.

-Intestine differs in

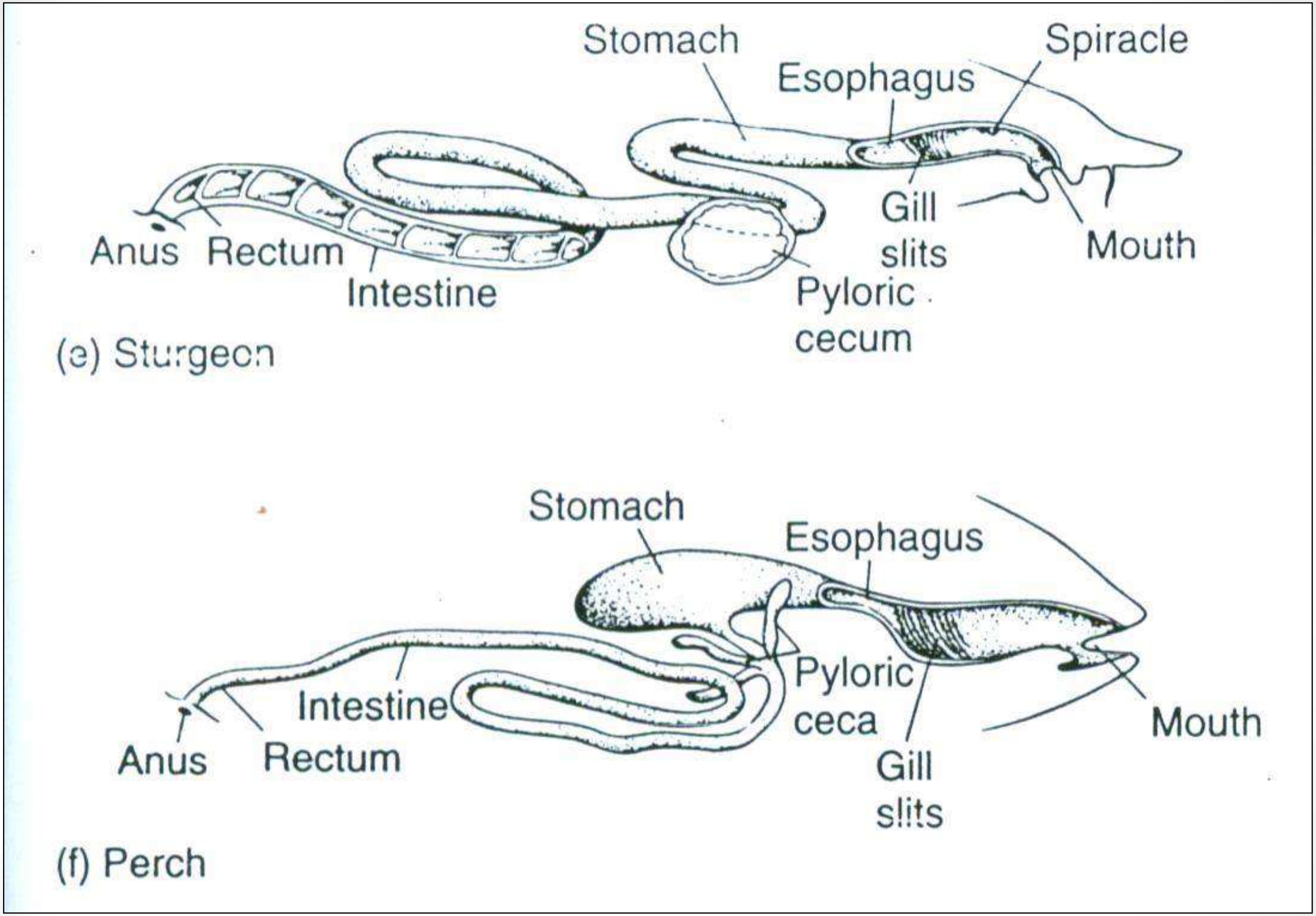
Herbivorous carnivores omnivorous

* A spiral valve present in intestine of cartilaginous fishes

-- The intestine of cartilaginous fishes and a few primitive bony fish contain spiral valve; increase internal surface area



(a) Cartilaginous fishes


Stomach
Spiracle
Esophagus
Gill
slits
Mouth
Anus
Rectum
Intestine
Pyloric
cecum
(e) Sturgeon
Stomach
Esophagus
Pyloric
ceca
Intestine
Mouth
Anus
Rectum
Gill
slits
(f) Perch

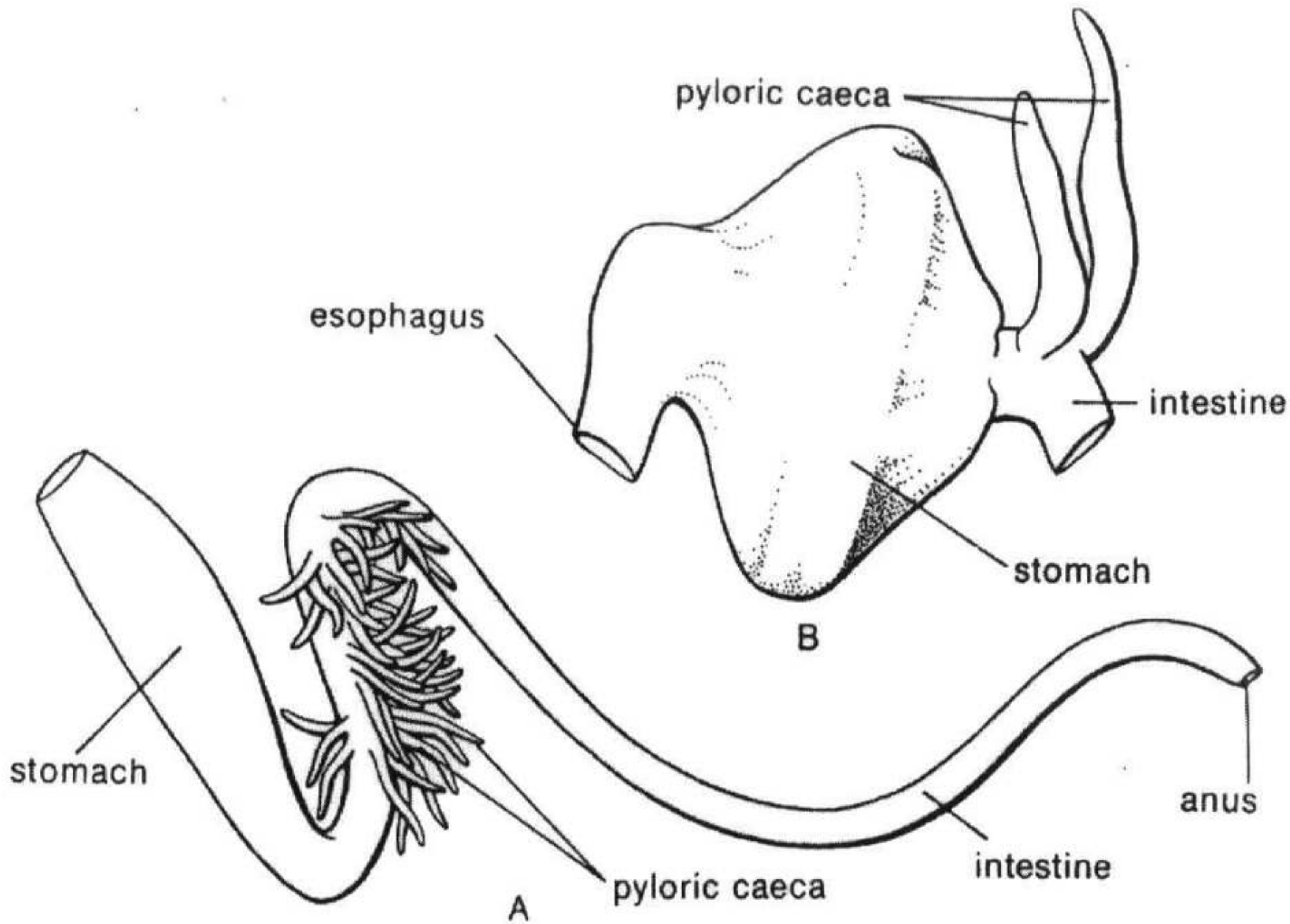


FIGURE 2–24. Examples of stomachs and pyloric caeca (anterior to left). *A*, Stomach, caeca, and intestine of trout (Salmonidae); *B*, stomach and pyloric caeca of mullet (Mugilidae).

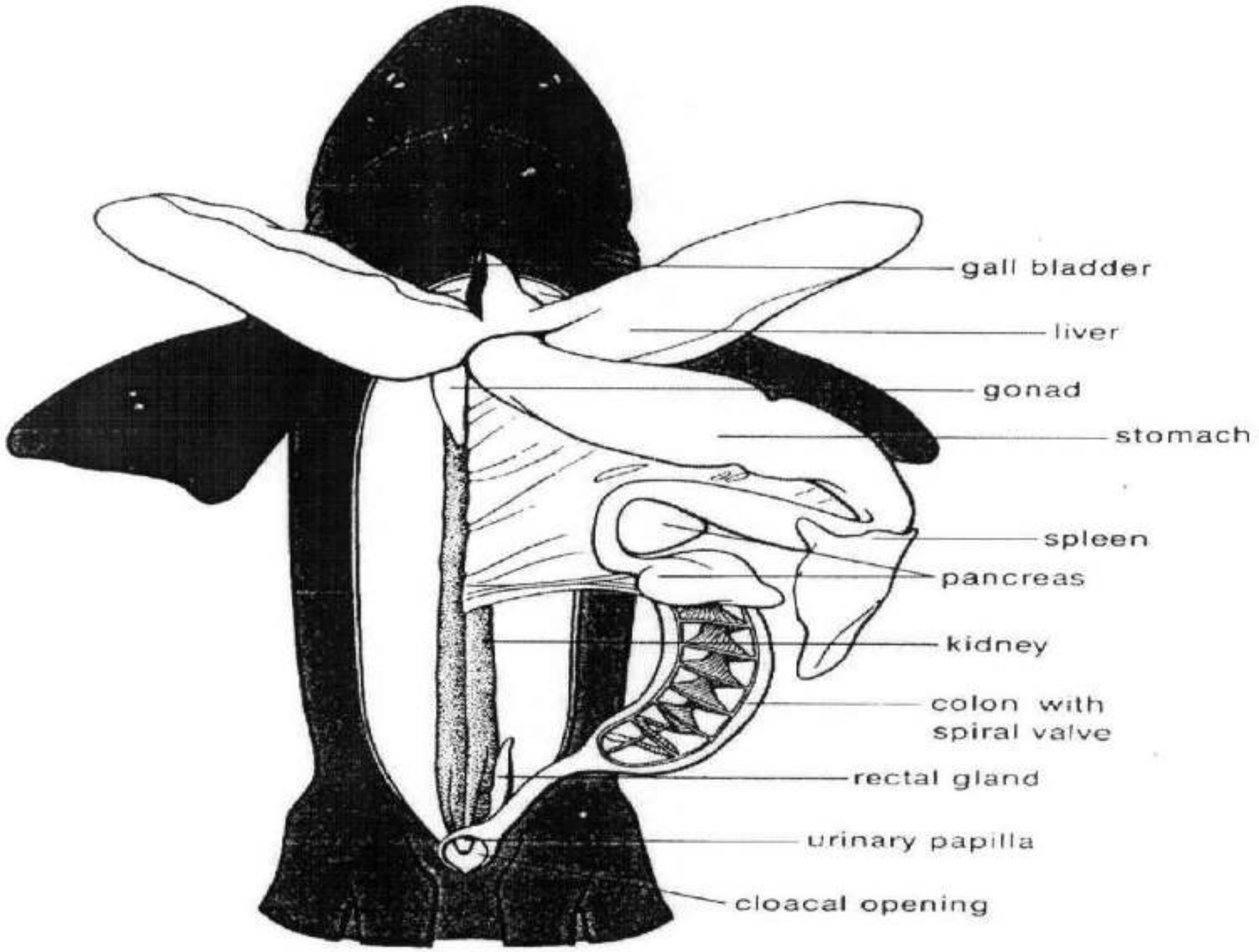


FIGURE 2–27. Diagram of viscera of shark (spiral valve opened to show internal structure). (Based on Daniels, 1934.)

The rectal gland of the dogfish secretes a fluid which is essentially a sodium chloride solution with a concentration about twice that of the plasma and greater than that of sea water; and is responsible for the active transport of chloride across other biological membranes.

Swim bladder

Because a weightless, or buoyant, body requires a minimum of energy to keep it at a given depth.

- Also, a weightless body requires less energy than a weighted body to move at a given speed.

Therefore, many fishes have means to reduce their body weight, or density relative to the density of water.

1)- A fish whose total body density equal to that of water would be effectively weightless, neither rising nor sinking.

- Because fats are less dense than water, one method of reducing body density would be to increase the proportion of fats within the body.

- Theoretically, in order to make the fish weightless in seawater, about one-third of a fish's body weight would have to be made up of fat. In some species of deep-sea, sharks, have very large livers that contain a great amount of squalene, a fatty substance that is significantly less dense than seawater.

2)- Another method of reducing density is to include gases within the body. Many fishes have a **gas bladder** that serves in this function.

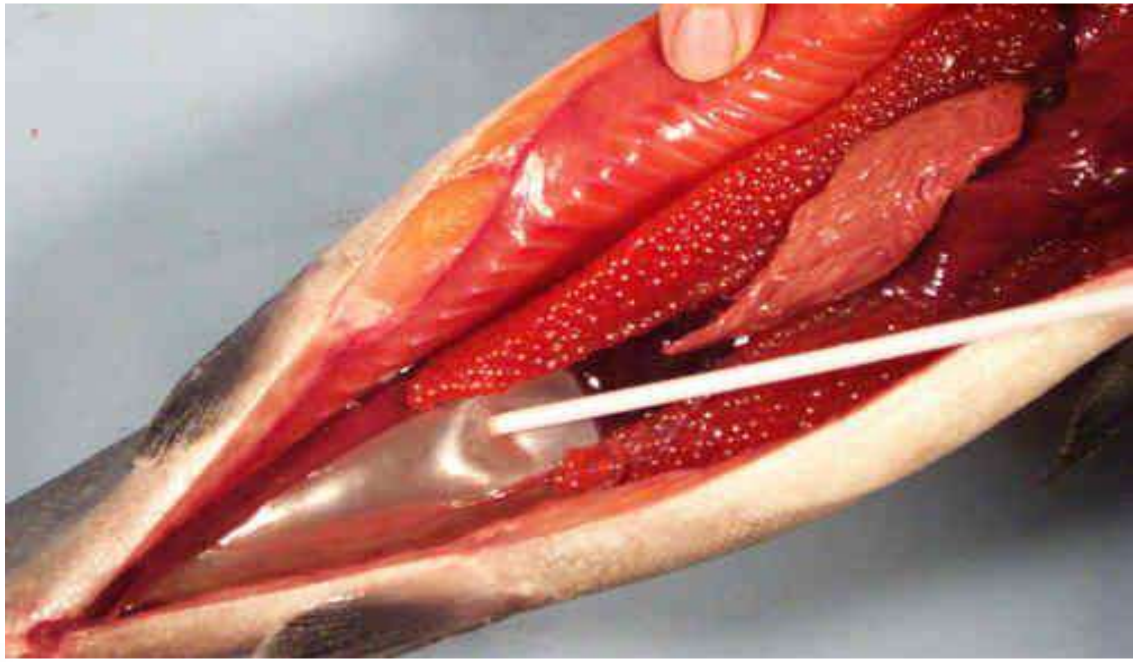
Swim bladder, also called **air bladder**, **buoyancy organ** possessed by most bony fish.

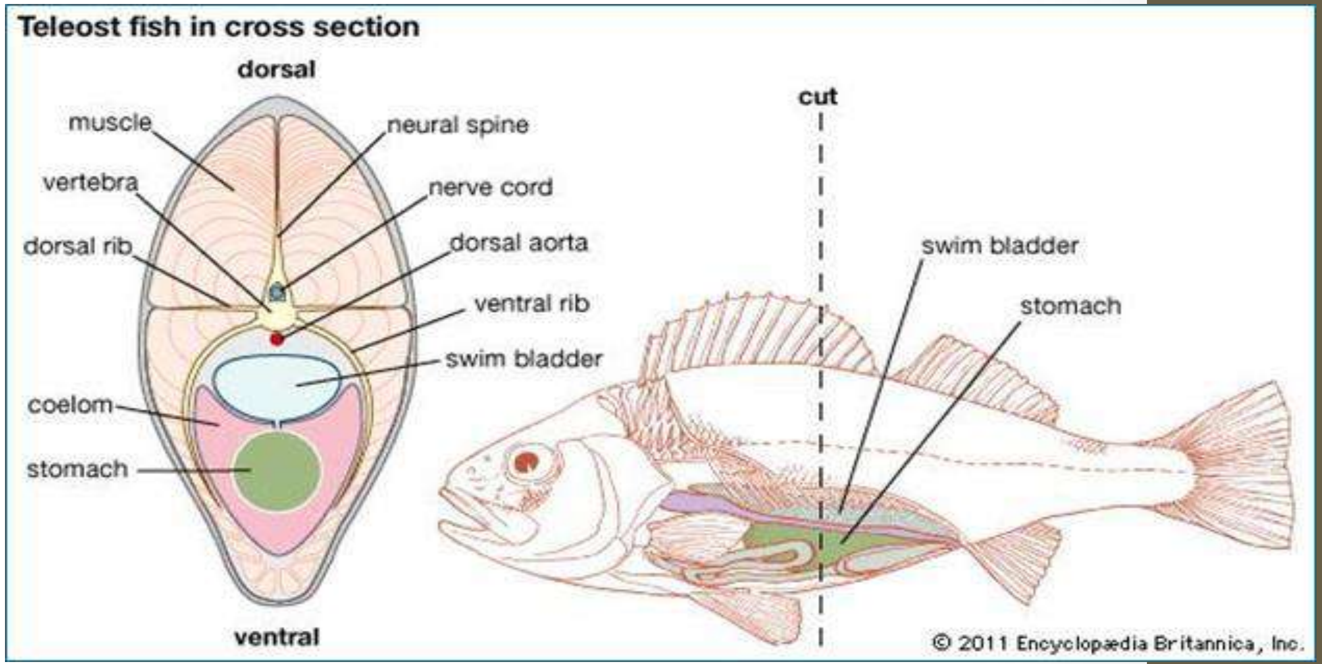
- The swim bladder is located in the body cavity and is derived from an outpocketing of the digestive tube.
- A)- It contains gas (usually oxygen) and functions as a hydrostatic organ, enabling the fish to maintain fish's depth without floating upward or sinking.
- It also serves as a resonating chamber to produce or receive sound.
- ** Fresh water is less dense than seawater and consequently provides less buoyancy. Therefore, Freshwater fishes, require a larger gas bladder than marine fishes to keep them from sinking.
- According to calculations, the capacity of a gas bladder should be about **7%** of body volume for a freshwater fish and **5%** for a marine fish.
- In actual measurements, gas bladders of freshwater fishes are ranged from 7 to 11% of body volume, while those of marine fishes are ranged from 4 to 6% of body volume.

B)- In some species the swim bladder contains **oil** instead of **gas**.

C)- In certain primitive fish the swim bladder functions **as** a **lung** **or** respiratory aid instead of a hydrostatic organ.

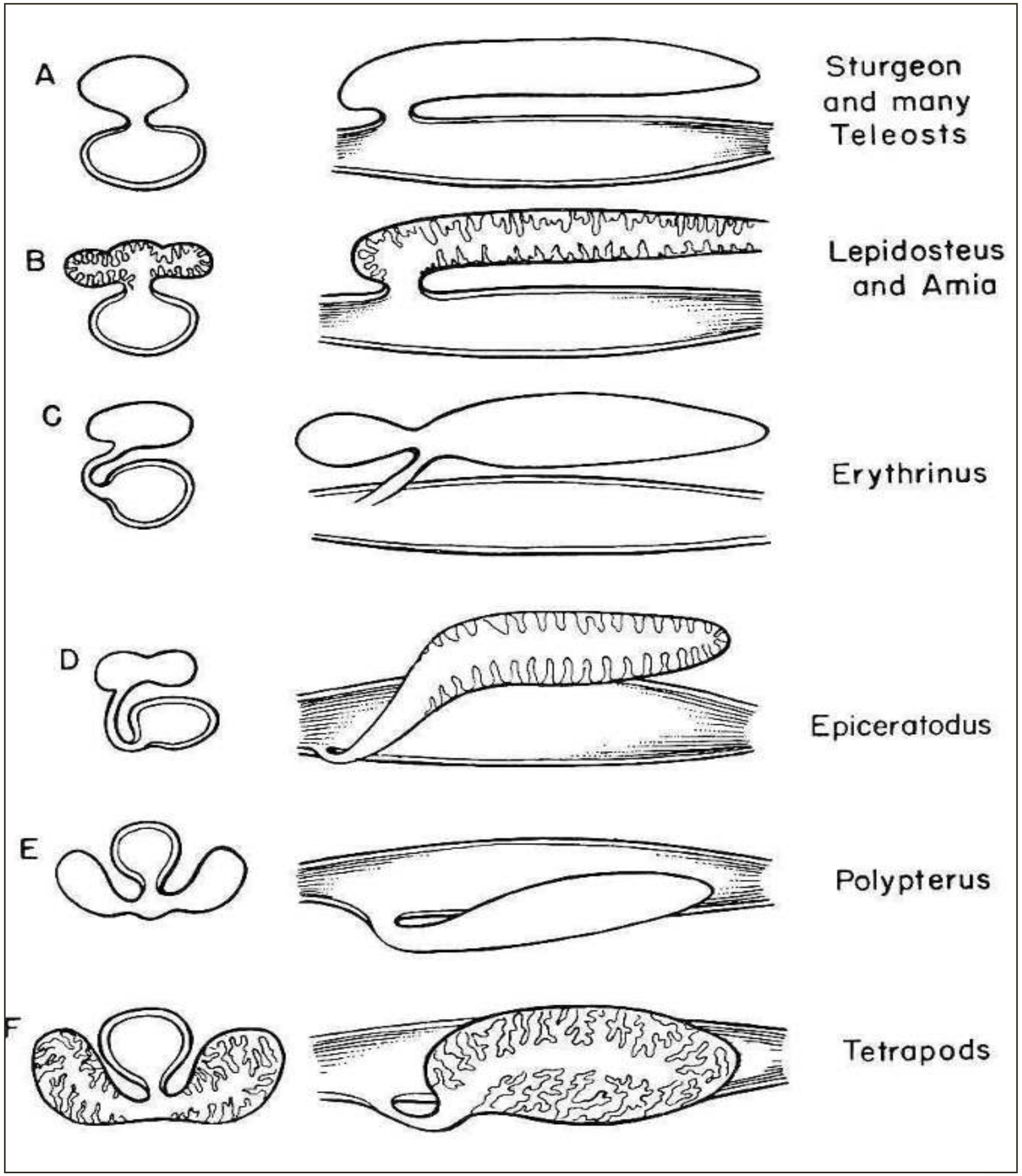
D)- The swim bladder is missing in some bottom-dwelling teleosts (deep-sea bony fish) and in all cartilaginous fish (sharks, skates, and rays).





A swim bladder

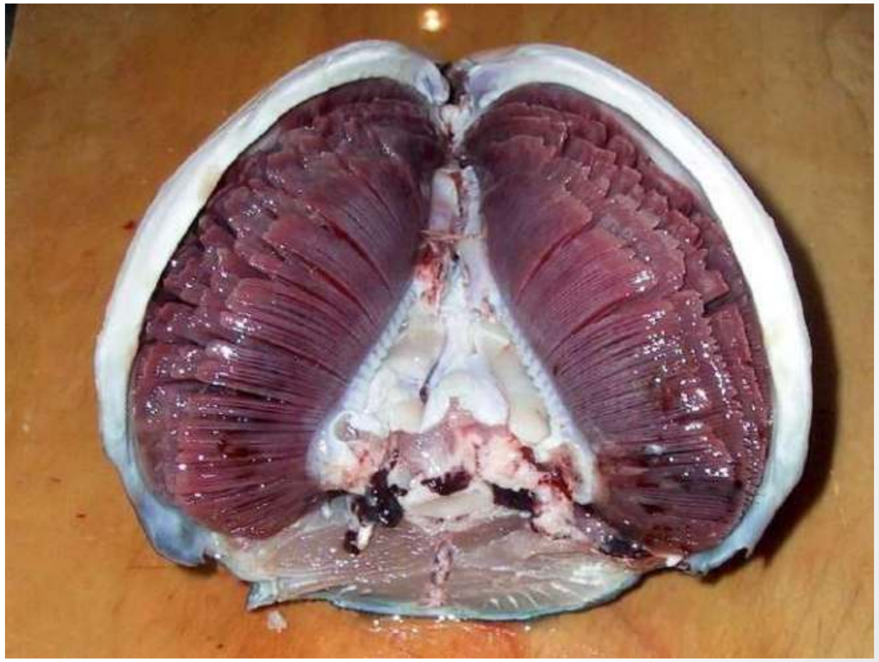
Examples of gas bladder



Gills

*Gills have different types of arrangement in frontal section in different fishes.

* Types of gills in fishes.



Diagrams showing the arrangement of gills in frontal section.

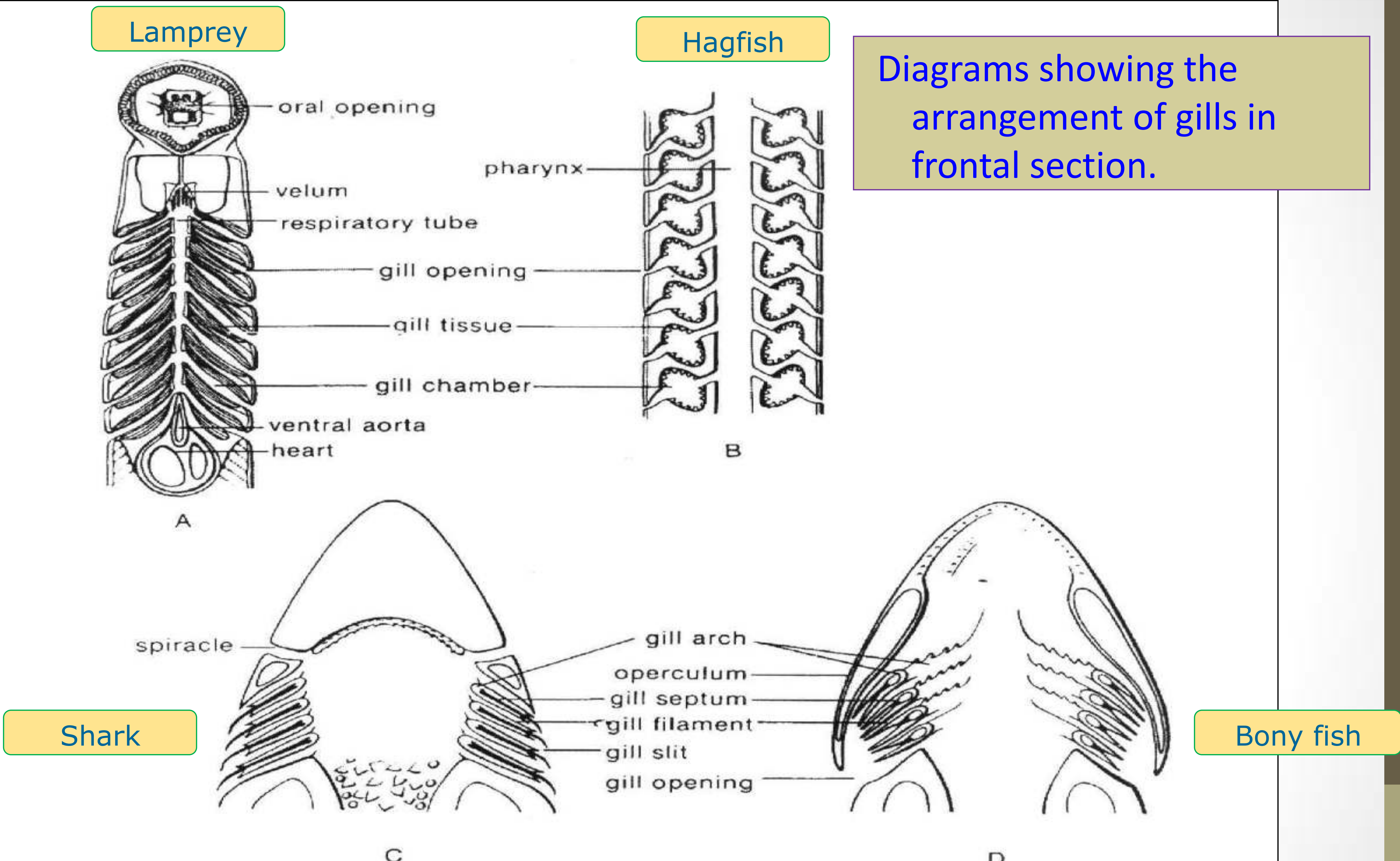


FIGURE 2–29. Diagrams showing arrangement of gills in frontal section. *A*, Lamprey (*Lampetra*); *B*, hagfish (*Eptatretus*); *C*, shark; *D*, bony fish. (*C* based on Weichert, 1951.)

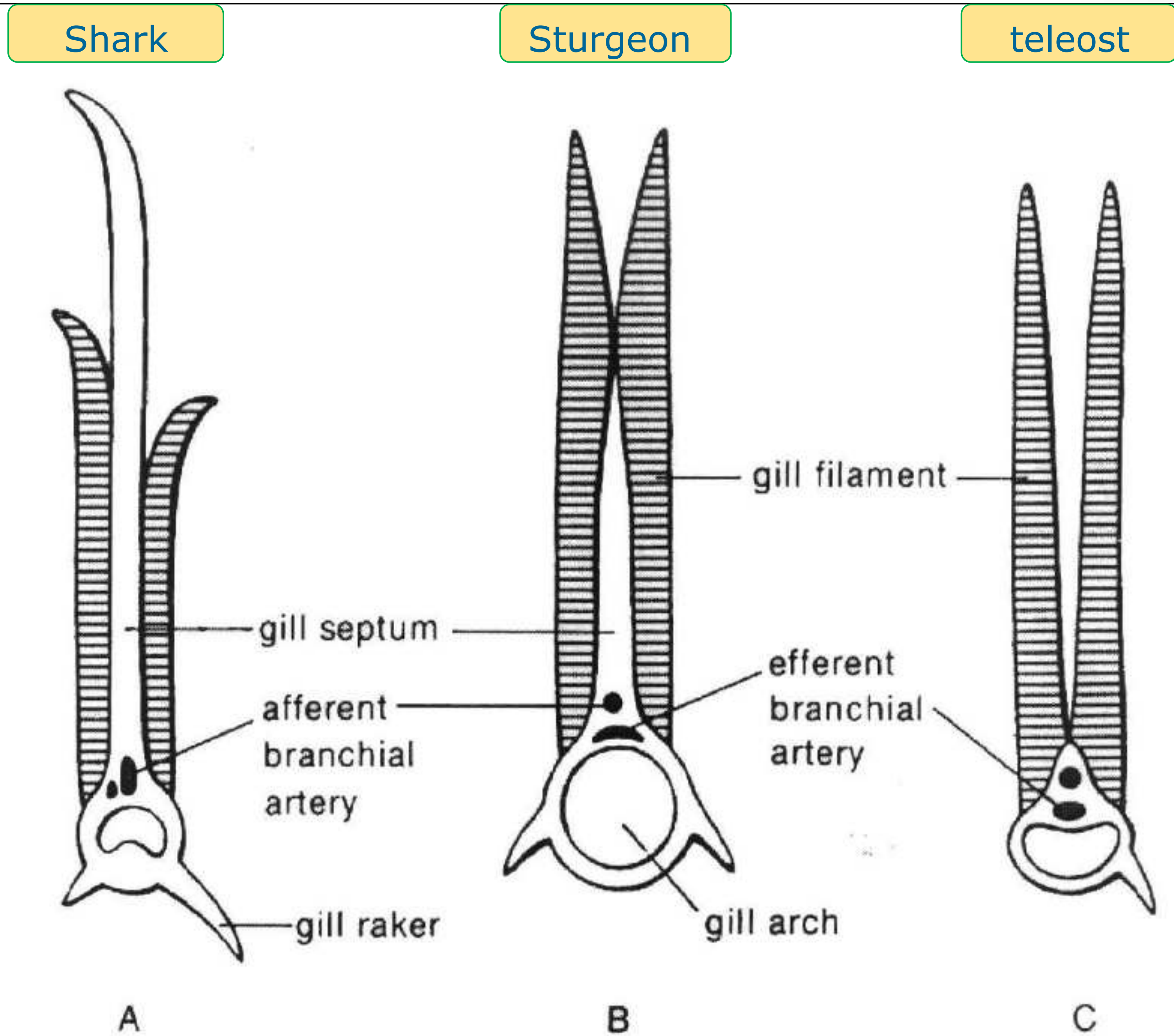


FIGURE 2–30. Relationship of branchial septum and gill tissue. *A*, Shark; *B*, sturgeon; *C*, teleost.

*The **pseudobranch** is the reduced 1st gill arch of a fish (on the inner surface of the opercle.

In teleost fish, the pseudobranchs are mostly without respiratory function.

In elasmobranchs they are the gill arch of the spiracle.

The function of the pseudobranch is unknown, but it is believed that it supplies highly oxygenated blood to the optic choroid and retina. , and may have baroreception (pressure) and thermoregulation functions. It may also be a site of oxygen chemoreception.

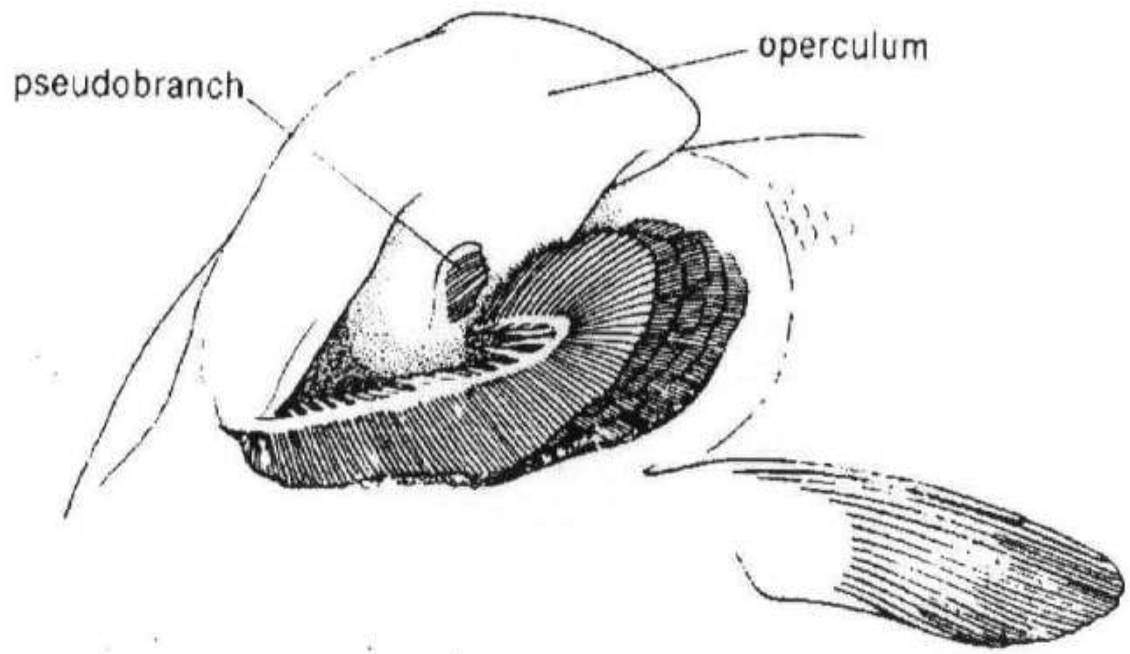


FIGURE 2-31. Position of pseudobranch in trout (Salmonidae).

Sturgeon الحفش سمك

Their evolution dates back to 245 to 208 million years ago. (2-3.5 - 5.5 m long)

Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)	
Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Superclass:	Osteichthyes
Class:	Actinopterygii
Order:	Acipenseriformes
Family:	**Acipenseridae** Bonaparte, 1831

Vascular system

*Heart structure
*blood circulation

The circulatory system of the bony fish is:

- a "closed system" (it includs a heart, vessels and blood capillaries).
- One main circuit, from the heart to the gills, to the cells.

Structure of Heart in fishes:

The heart of fishes is known as branchial heart, because its main function is to pump venous blood to ventral aorta into gills (branchial) and then to somatic vasculature.

The heart of fishes consists of four portions, a sinus venosus, an atrium, a ventricle and a conus arteriosus **or** a bulbus arteriosus.

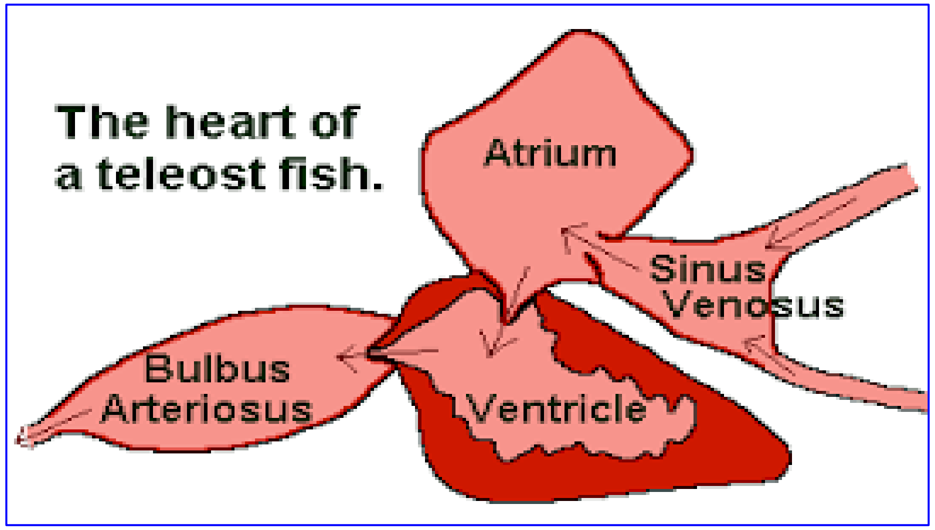
Some authors considered atrium and ventricles as the chambers of heart; while some considered sinus venosus and conus arteriosus also as the chambers of the heart.

There is some confusion in bulbus and conus arteriosus in fishes.
In elasmobranchs the 4th chamber is designated as conus arteriosus whereas it is known as bulbus arteriosus in teleost, a specialized ventral aorta in teleosts.

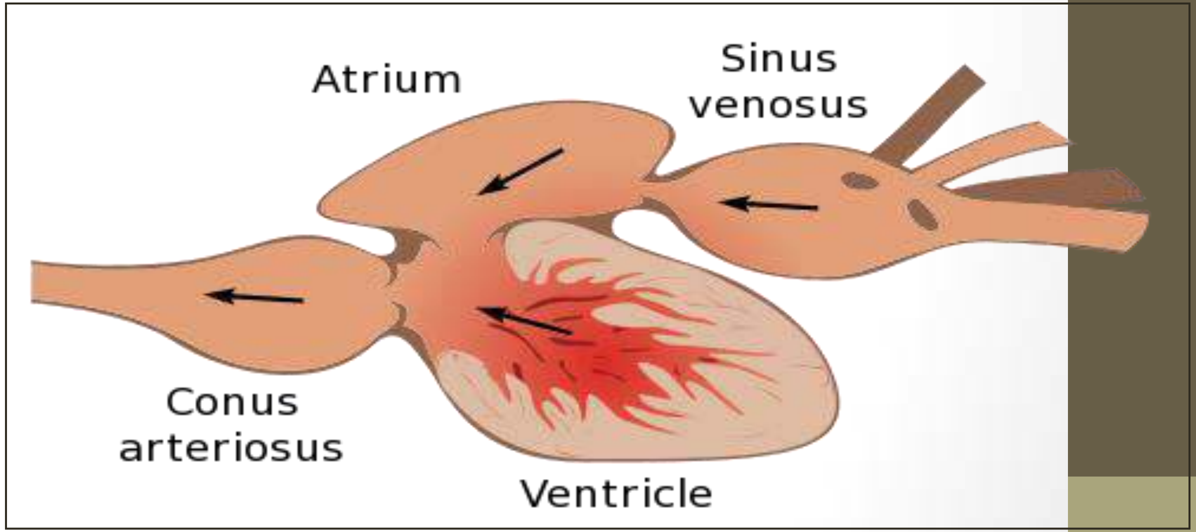
The distinction between the two is that: **the conus** arteriosus consists of cardiac musculature similar to the ventricle and is provided by a large number of valves arranged in successive rows; **while bulbus** arteriosus consists of only smooth muscle fibres and elastic tissues.

Heart of bony fish:

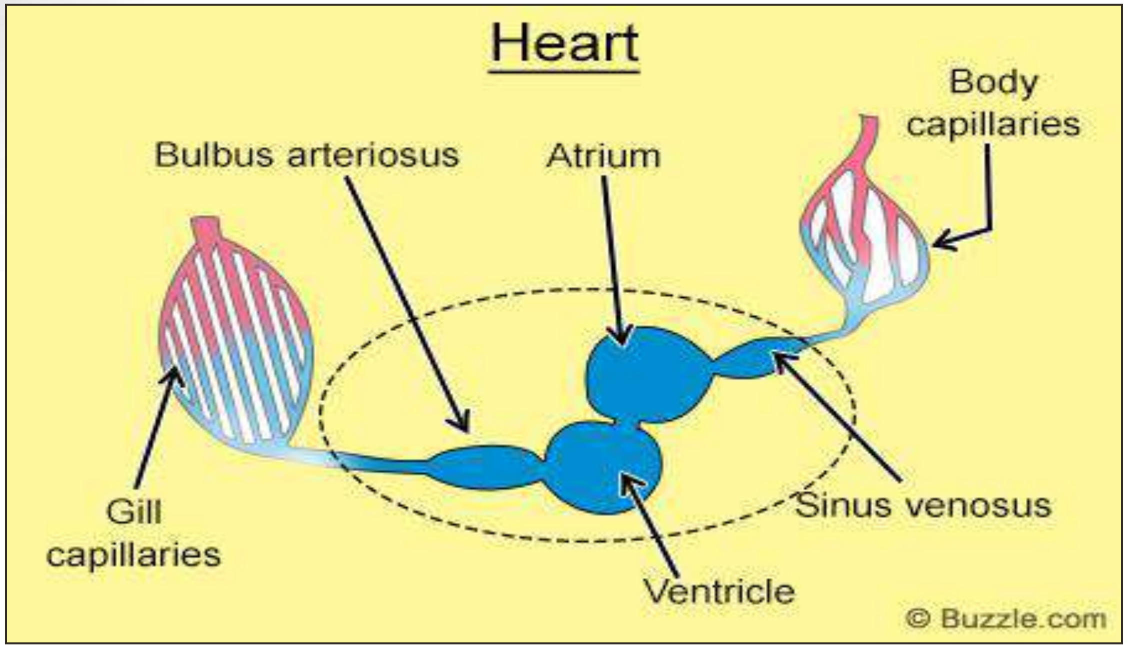
- A bony fish's **heart** has two chambers: an **atrium** and a **ventricle**.
- **The venous** side of the heart is preceded by an enlarged chamber called the **sinus venosus**.
- **The arterial** side of the heart is followed by a thickened muscular cavity called the **bulbus arteriosus**.



Heart of bony fish



Heart of cartilaginous fish


Heart
Body capillaries
Bulbus arteriosus
Atrium
Gill capillaries
Sinus venosus
Ventricle
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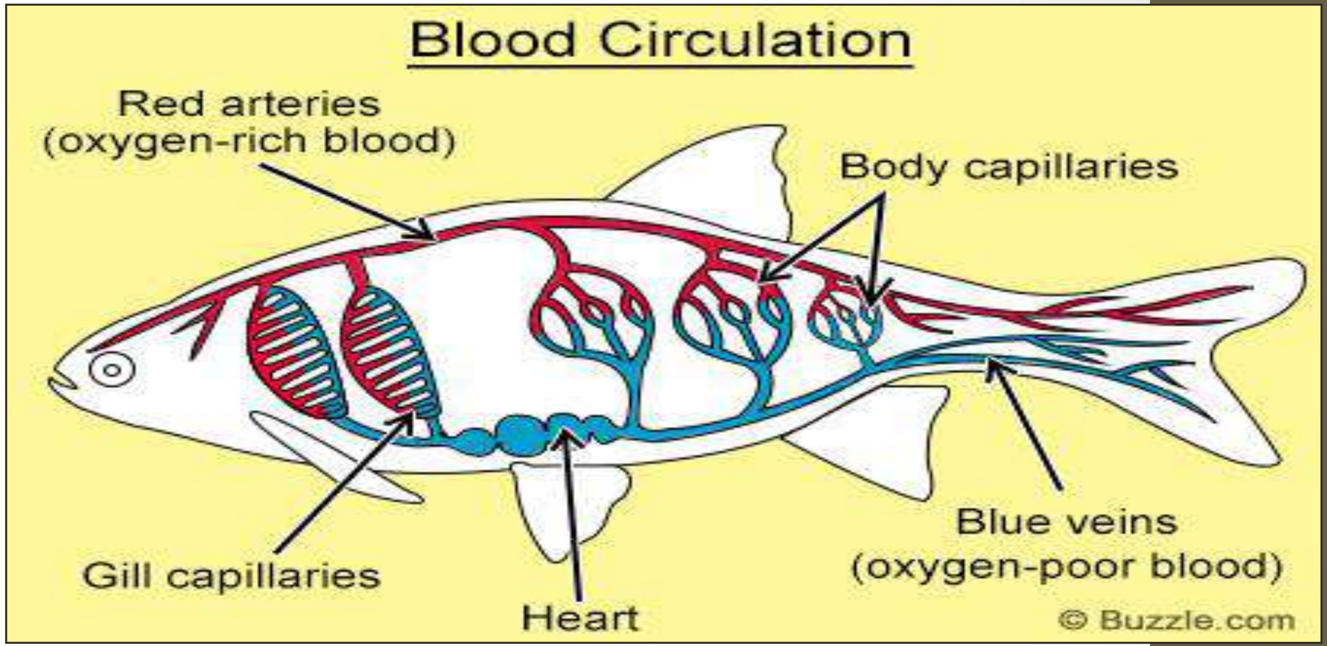
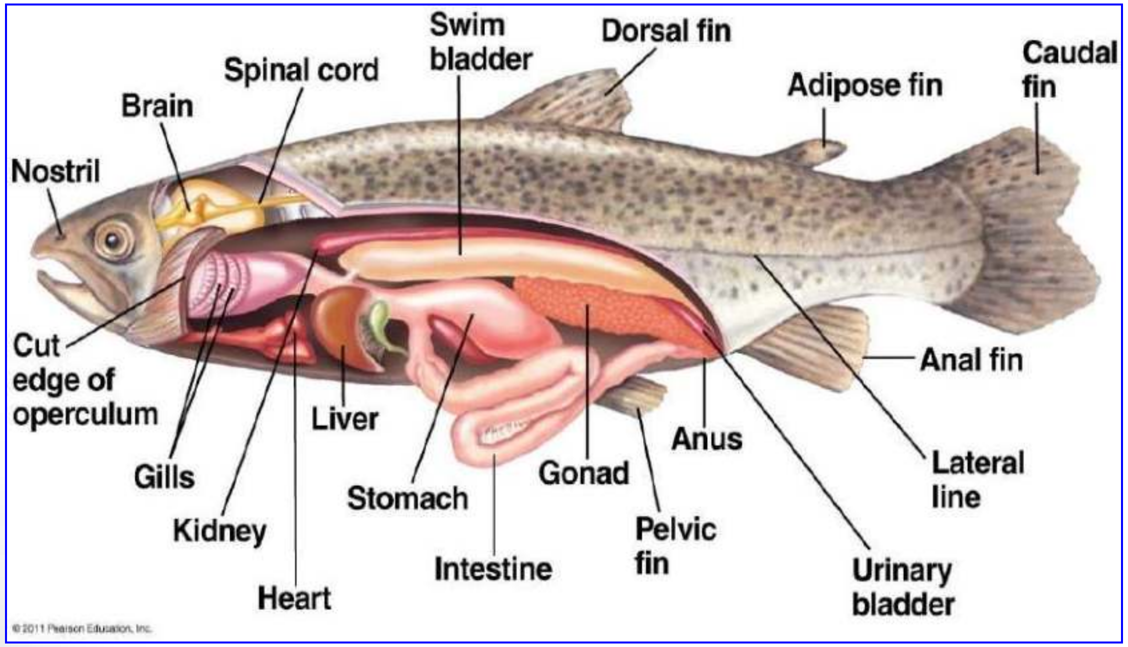

Blood Circulation
Red arteries (oxygen-rich blood)
Body capillaries
Blue veins (oxygen-poor blood)
Gill capillaries
Heart
© Buzzle.com


Swim bladder
Dorsal fin
Spinal cord
Adipose fin
Caudal fin
Brain
Nostril
Cut edge of operculum
Liver
Anal fin
Gills
Stomach
Gonad
Anus
Lateral line
Kidney
Intestine
Pelvic fin
Urinary bladder
Heart
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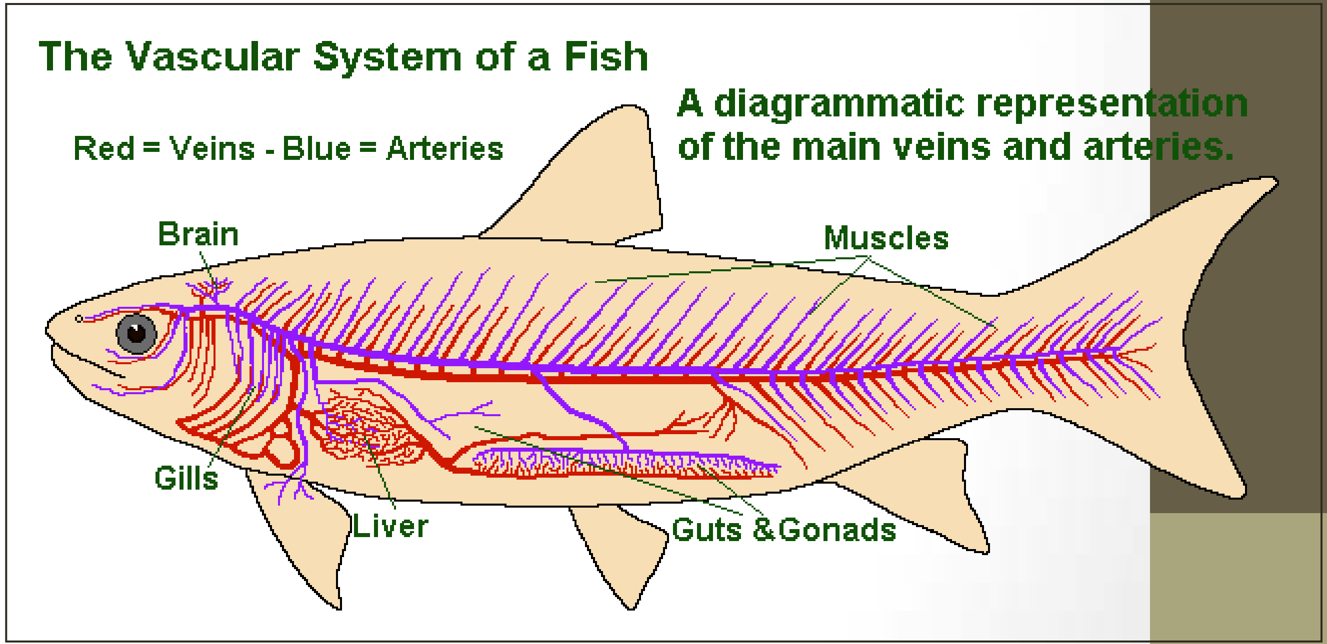
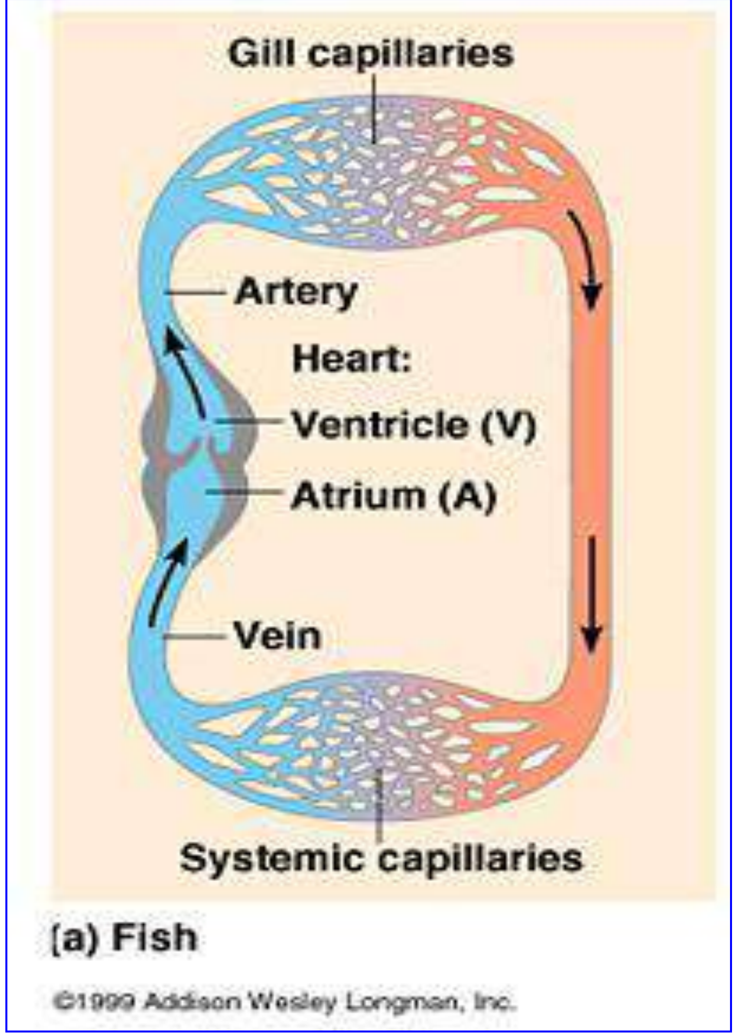
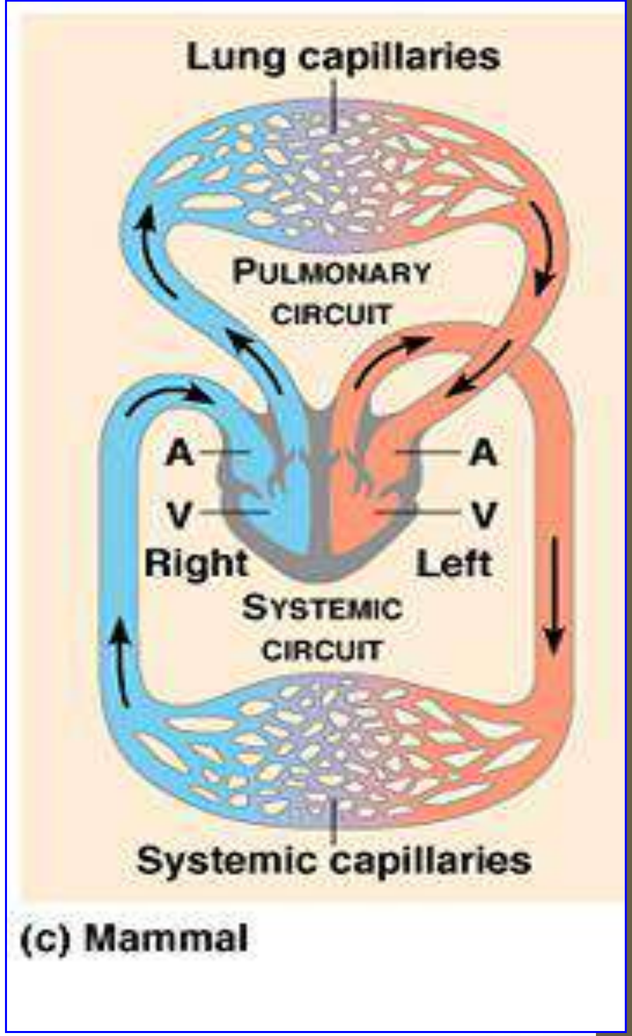

The Vascular System of a Fish
A diagrammatic representation of the main veins and arteries.
Red = Veins - Blue = Arteries
Brain
Muscles
Gills
Liver
Guts &Gonads

Fishes have a Single-circuit closed circulatory system.

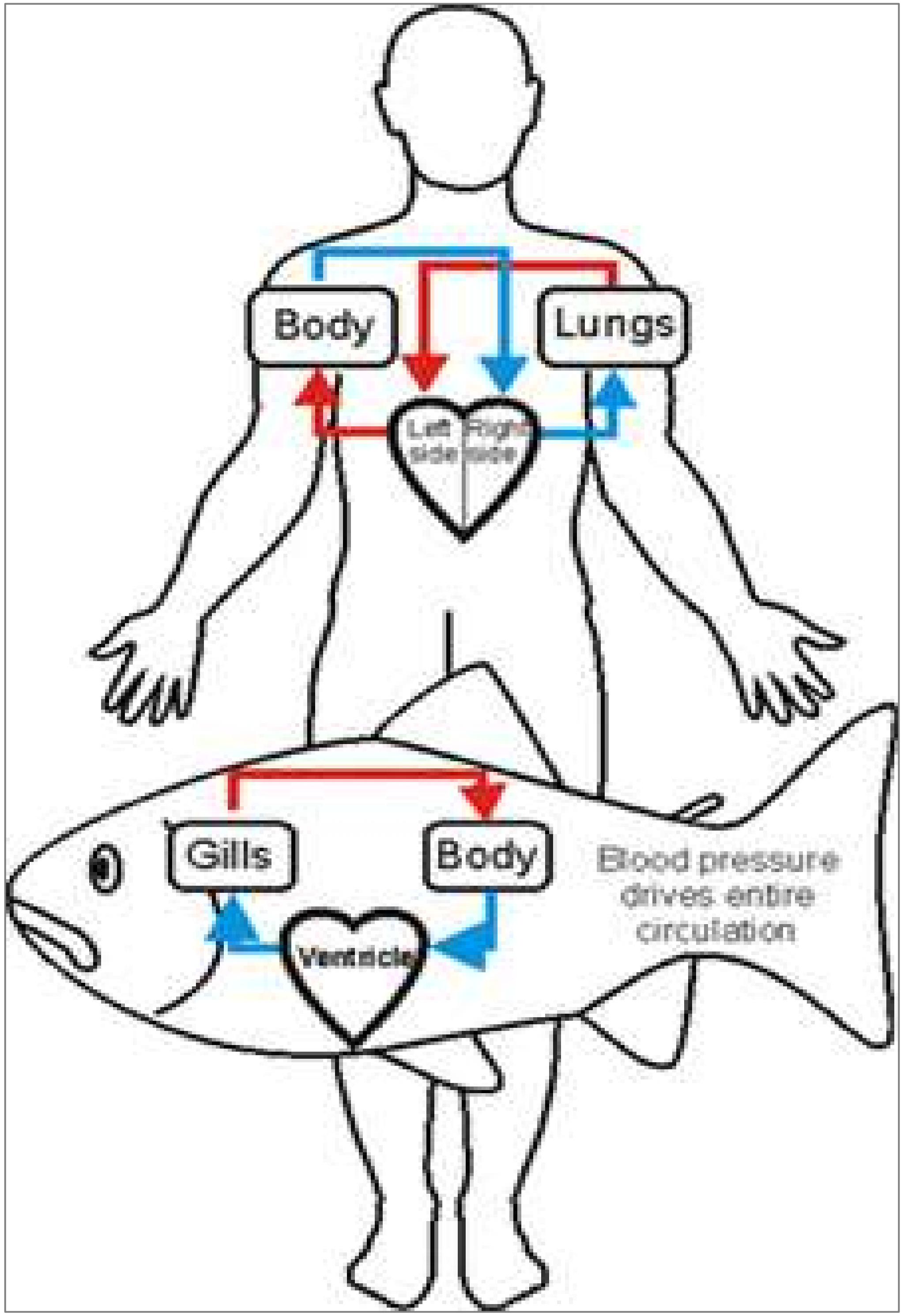




There are two types of closed blood circulation systems:

A)- Single Circulation Systems (Single circuit Circulation)
B)- Double Circulation Systems

Fish have single circuit circulatory systems in which blood passes through the heart **only once** each time it completes a full circuit around the fish's body.
Where the heart pumps the blood to the gills to be re-oxygenated (gill circulation), after which the blood flows to the rest of the body (systemic circulation) and then back to the heart.



Body
Lungs
Left side
Right side
Gills
Body
Ventricle
Blood pressure drives entire circulation

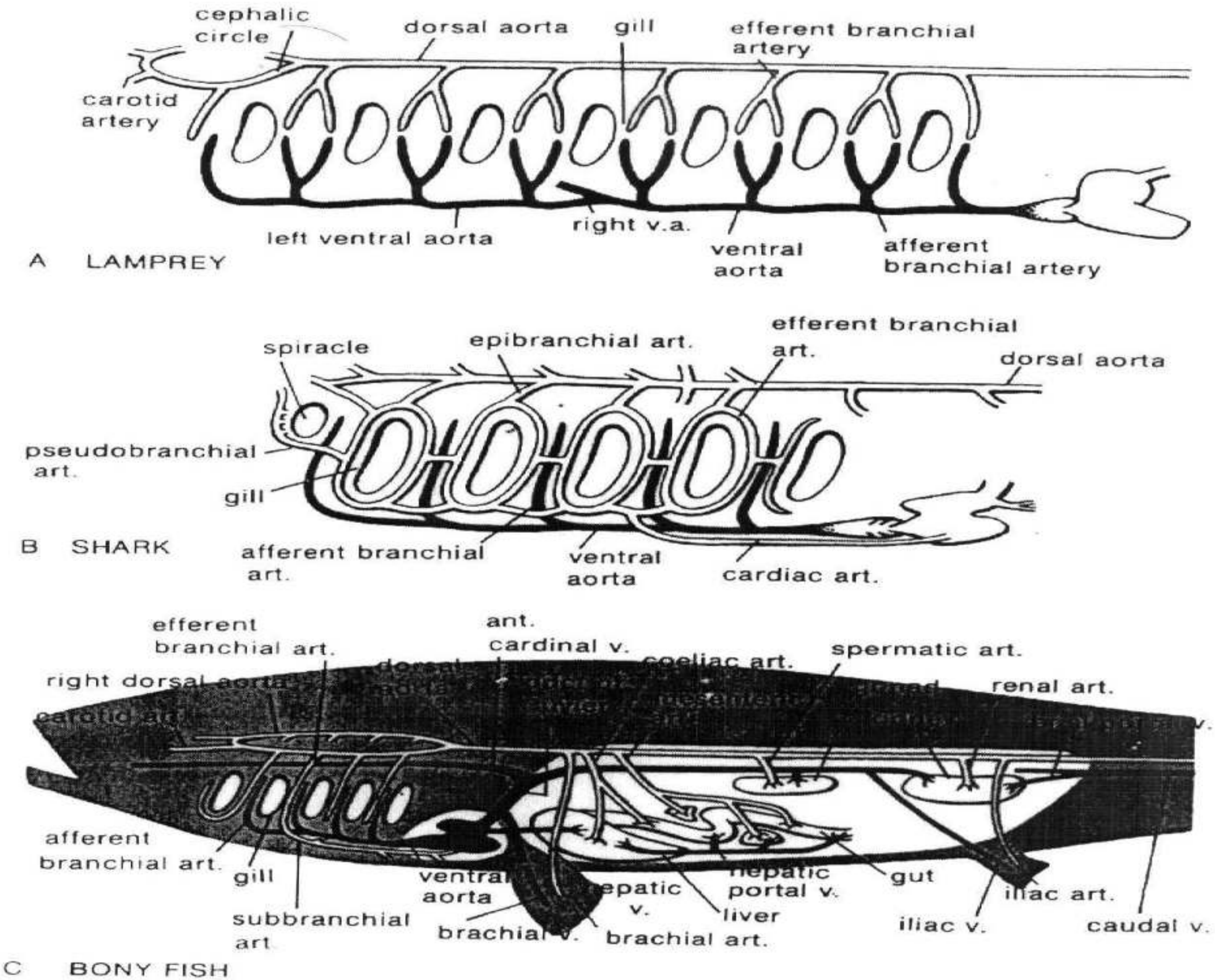


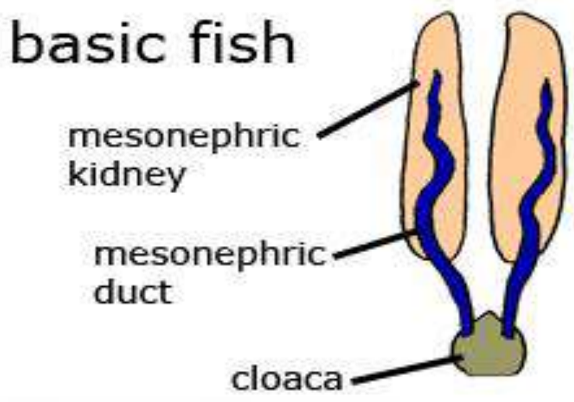
FIGURE 2–33. Diagrams of blood circulation. *A*, Lamprey, branchial arteries; *B*, shark, br arteries; *C*, bony fish, showing major blood vessels.

Urinogenital system

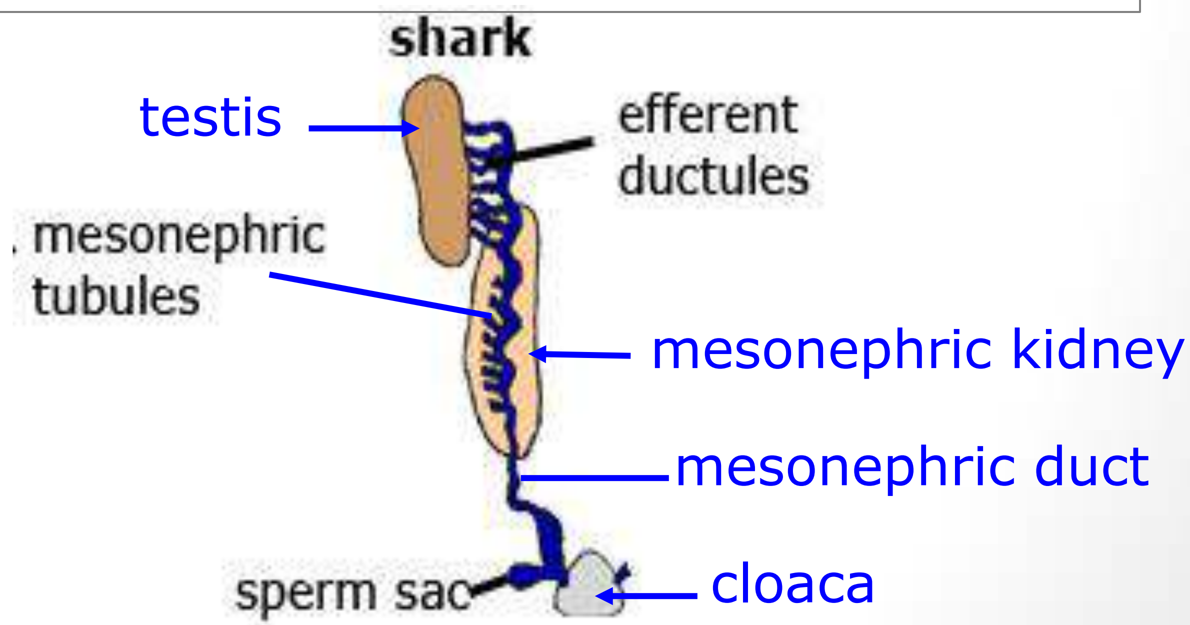
* kidney.

**Gonads

Urinary passages of fishes are composed of mesonephric kidney, mesonephric ducts, and the cloaca.

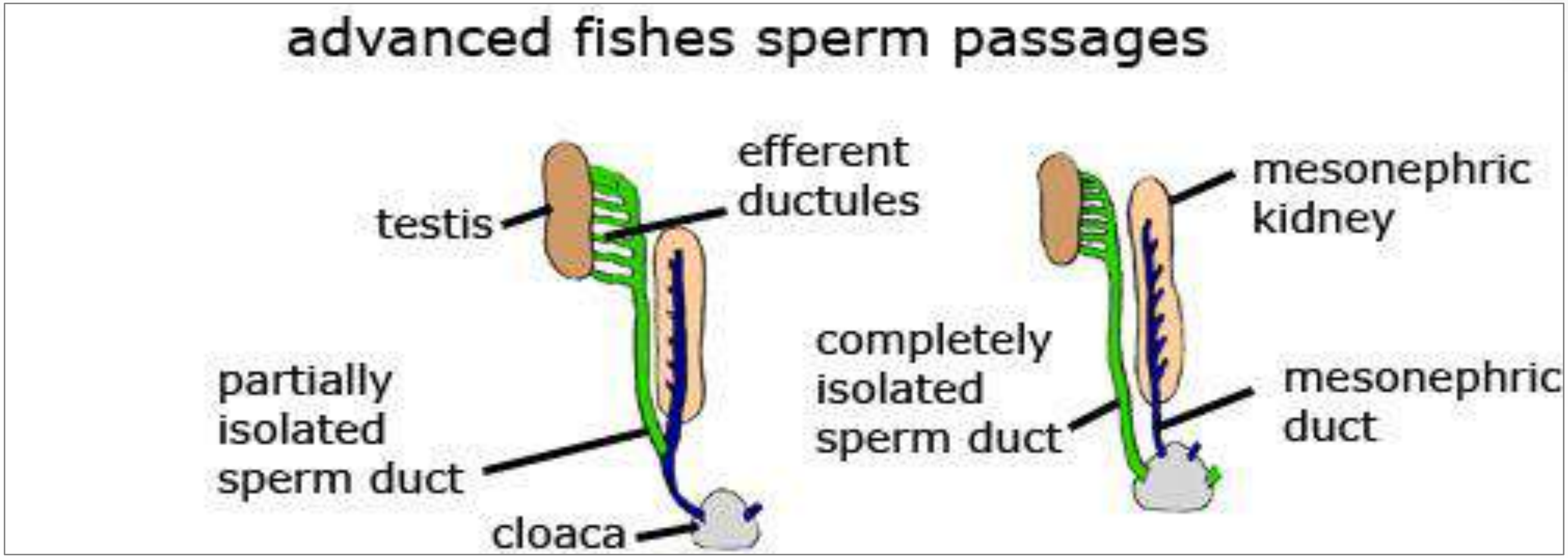


In sharks, and some other primitive bony fish, the testis is connected to the mesonephric duct by a series of small tubules (efferent ductules). In some instances these ducts are shared with the urinary system, in other species the efferent ductules from the testis are separated from the nephric tubules, but still drain into the same mesonephric duct.



Sharks & primitive bony fish kidney & sperm passage

Some species of fishes have a sperm duct which is either partially or completely separate from the mesonephric duct.



The mullerian ducts (**oviducts**) of fishes, are paired ducts which extend to the cloaca. Eggs typically move into the ducts at the anterior end, and in most fishes, these eggs are deposited and fertilized externally. A few fish species experience internal fertilization and the embryos develop within a portion of the duct called the uterus.

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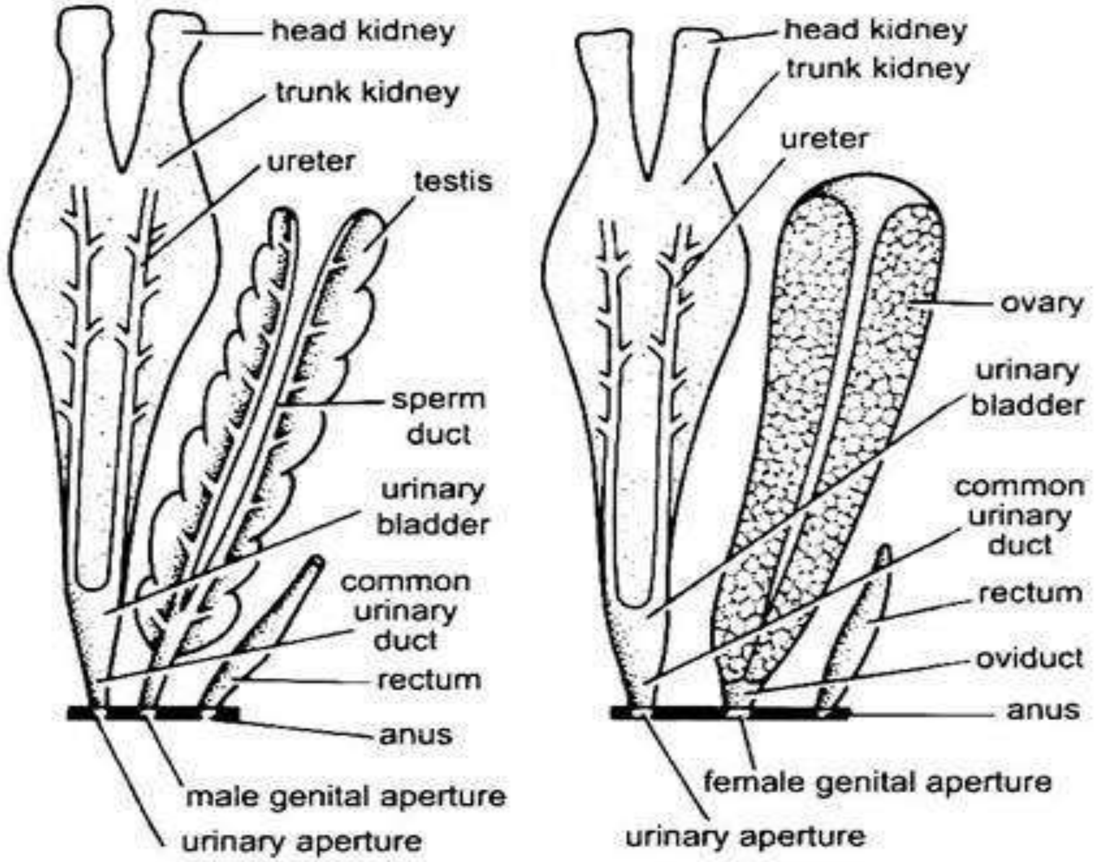
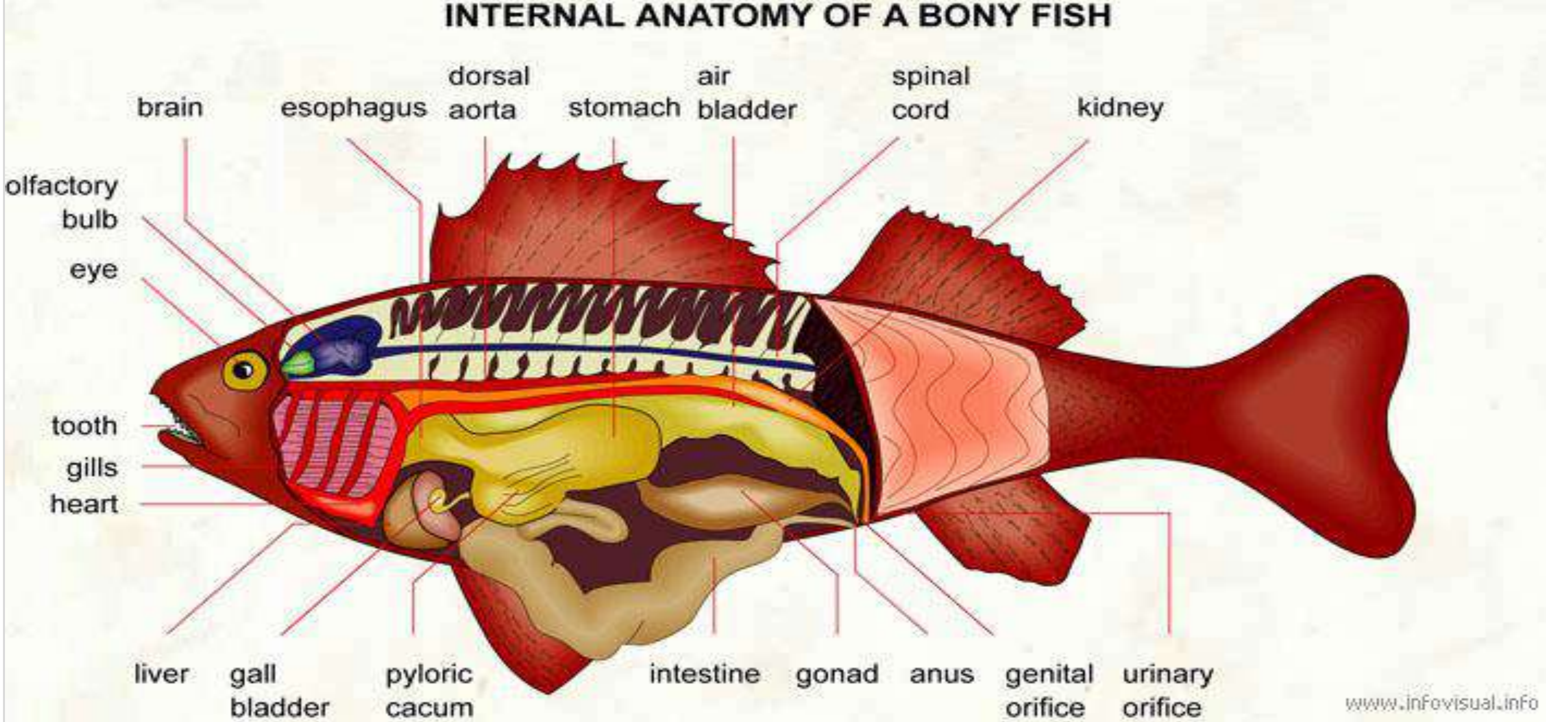
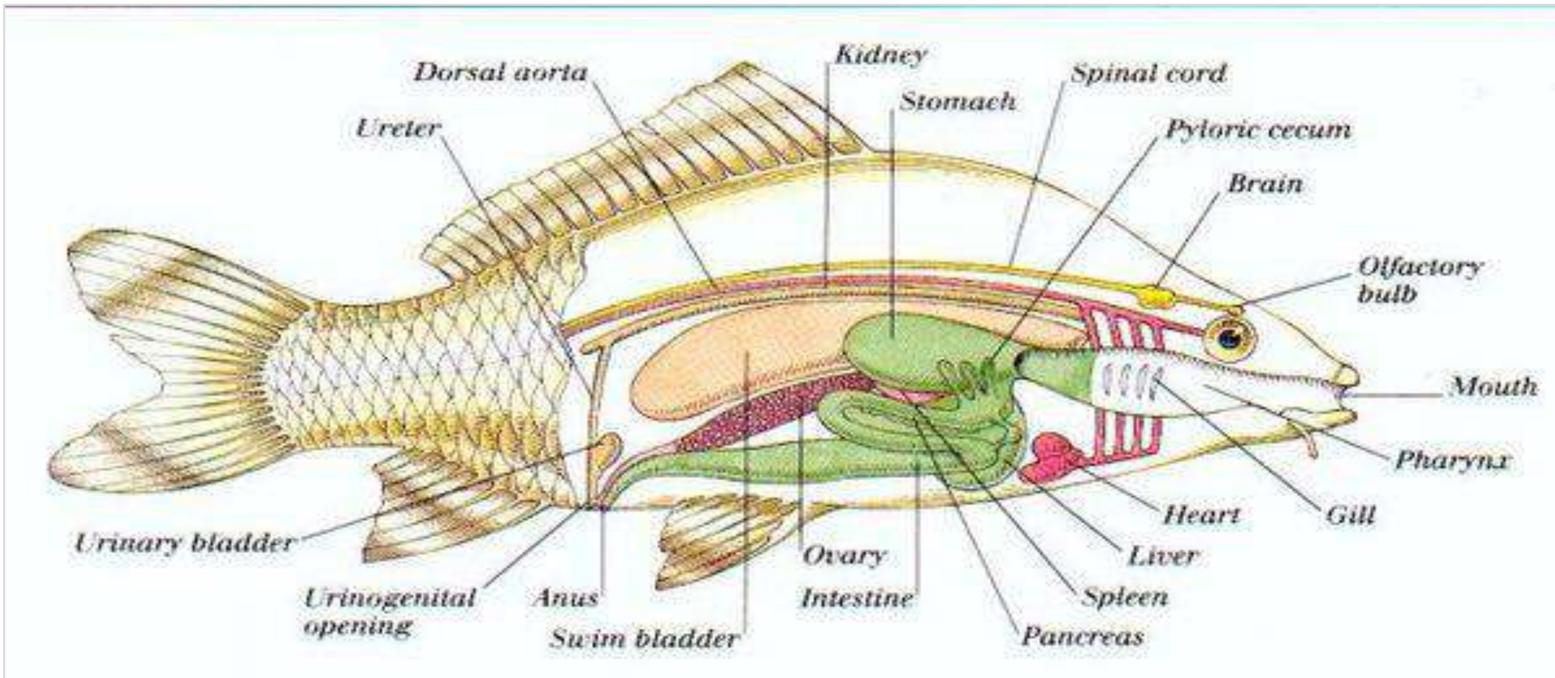


Fig. 15.14. *Labeo*. Urinogenital organs. A–Male; B–Female.


INTERNAL ANATOMY OF A BONY FISH
brain
esophagus
dorsal aorta
stomach
air bladder
spinal cord
kidney
olfactory bulb
eye
tooth
gills
heart
liver
gall bladder
pyloric cacum
intestine
gonad
anus
genital orifice
urinary orifice
www.infovisual.info


Dorsal aorta
Kidney
Spinal cord
Stomach
Ureter
Pyloric cecum
Brain
Olfactory bulb
Mouth
Pharynx
Gill
Heart
Liver
Spleen
Pancreas
Ovary
Intestine
Swim bladder
Anus
Urinogenital opening
Urinary bladder

Pronephros the most basic type of the three excretory organs that develop in vertebrates.

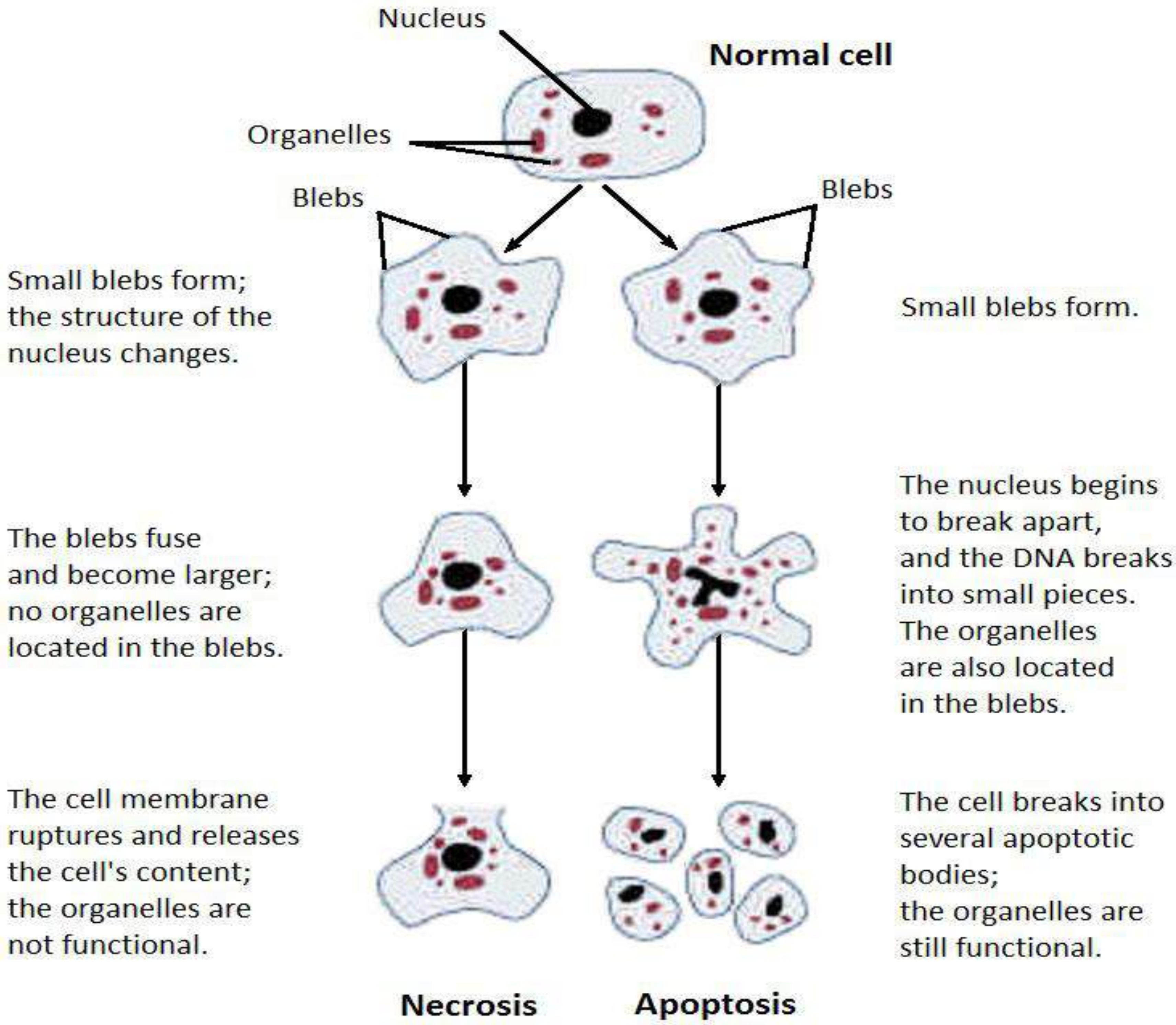
The pronephros is active in adult forms of some primitive fish, like lampreys or hagfish.

The pronephros is present **at** the embryo of more advanced fish **and** at the larval stage of amphibians where it plays an essential role in osmoregulation.

Mesonephros: is present in the adults of fish and amphibians .

Metanephros: In amniotes the mesonephros is the embryonic kidney and a more complex metanephros acts as the adult kidney.

Once a more advanced kidney is formed, the previous version typically degenerates by apoptosis or becomes part of the male reproductive system.


Nucleus
Normal cell
Organelles
Blebs
Blebs
Small blebs form; the structure of the nucleus changes.
Small blebs form.
The blebs fuse and become larger; no organelles are located in the blebs.
The nucleus begins to break apart, and the DNA breaks into small pieces. The organelles are also located in the blebs.
The cell membrane ruptures and releases the cell's content; the organelles are not functional.
The cell breaks into several apoptotic bodies; the organelles are still functional.
Necrosis
Apoptosis

Fish kidneys

- Diffuse organs on either side of vertebral column
- Varying degree of connection with reproductive system
- Little connection in most advanced fishes

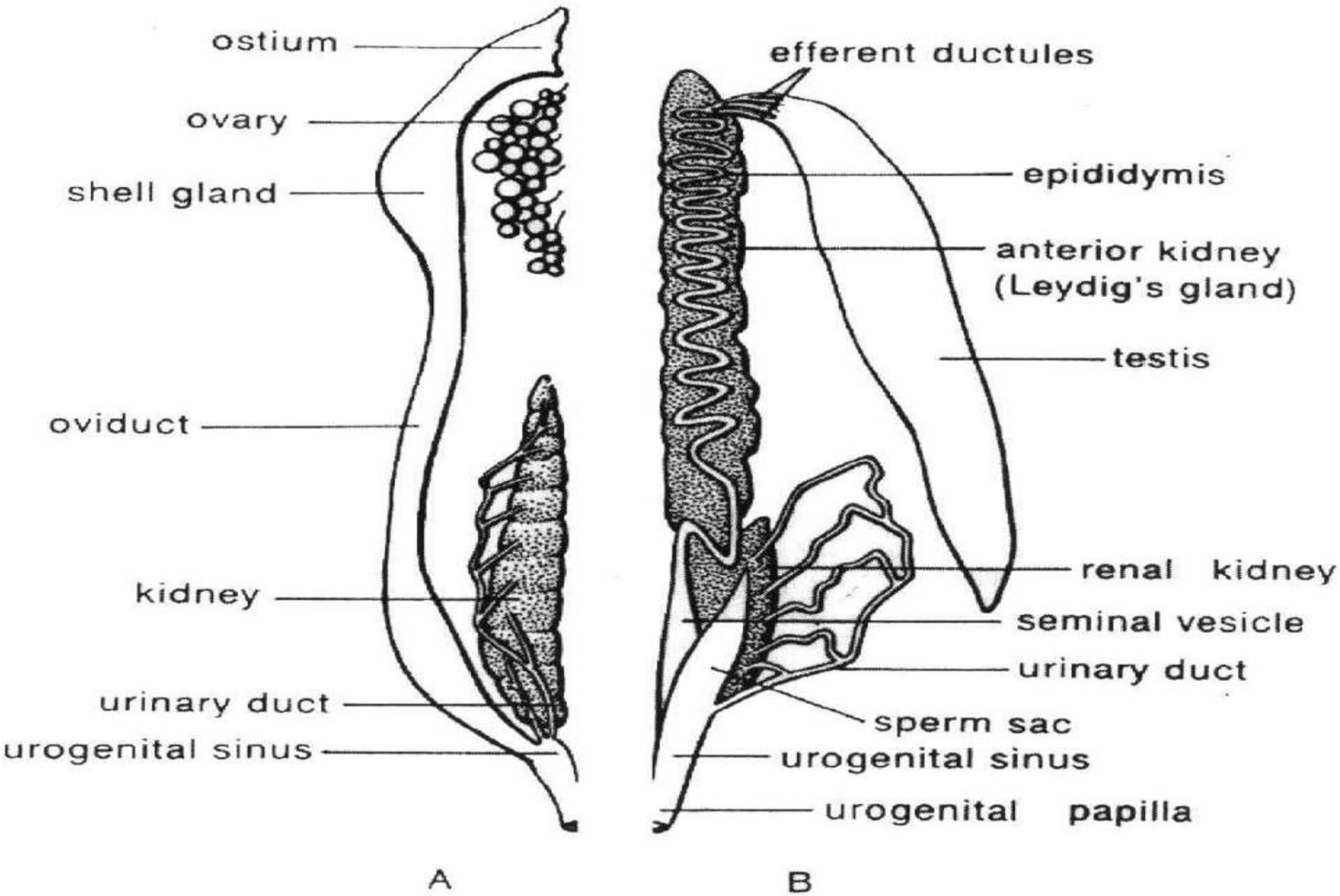


FIGURE 2–35. Diagram of urogenital organs of shark. *A*, Female; *B*, male. (Based on Goodrich, in Lankester, 1909.)

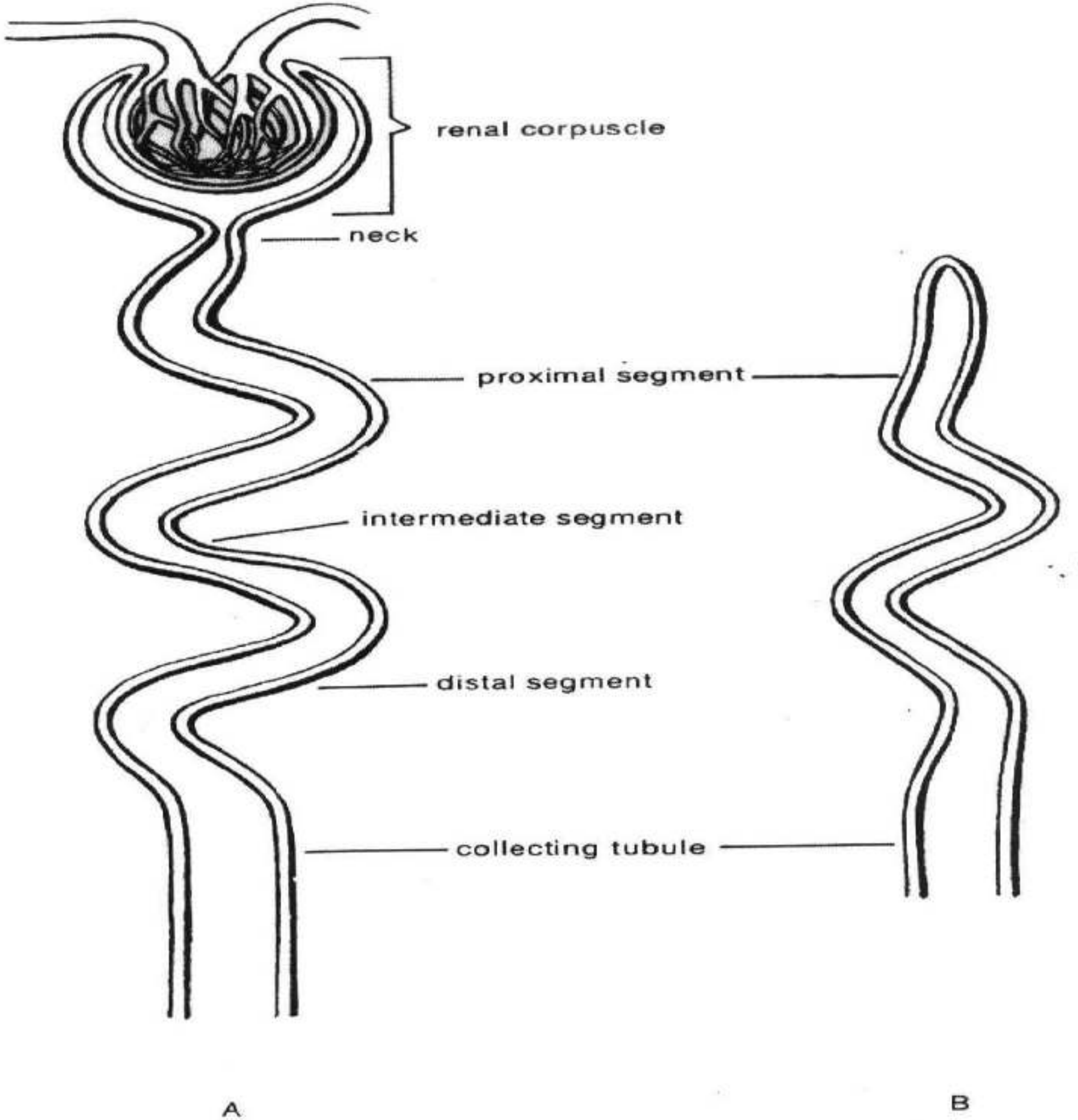


FIGURE 2–36. Schematic diagrams showing components of two types of nephrons found in bony fishes. *A,* Glomerular; *B,* aglomerular (in some marine fishes).

Lecture 4

Food and feeding habits of fishes

The food supply is a determining factor for

- Distribution
- Abundance
- Rate of growth
- Condition
- Movements
- Fertility

There are three ways for studying the food data (knowledge on food)

- Direct observation
- Observation in captivity
- Examination of contents of the stomach

Classification of fishes according to their food and feeding habits

(1)- Herbivorous fishes

As *Tilapia mossambicus* which feeds on algae , diatoms , flowering plants and seeds

(2)- Carnivorous fishes

These may be :-

- Piscivorous as in case of *Hydrocyon* sp
- Insectivorous as in case of cichlids.
- Mollusc-feeders as in case of *Tetradon* .
- Worm feeders.
- Living animals feeders.

(3) Omnivorous fishes

They may feed on plants **&** animals as in case of *Clarias gariepinus*

(4) Scavengers (detrivorous or bottom feeders)

These feed on the particles of organic matter as in case of *Oreochromis niloticus* and certain species of *Labeo*.

(5) Plankton feeders

(phytoplankton or zooplankton)

Factors affecting food and feeding habits of fishes

. **There are six factors affecting the food and feeding habits of fishes, these are:-**

SEASON

LOCALITY

LIGHT

TEMPERATURE

LENGTH OF THE FISH

SEX

(1)- Season

The season may affect the food items or the intensity of feeding (degree of fullness of the stomach).

Example : -

Labeo niloticus: Increases the intensity of feeding during April-September and decreases it during October-March, and the reverse occur in case of *Schilbe mystus.*

The seasonal differences result from the abundance of food in the different seasons.

(2)Sex

The females of the bream feed on *Hypaniola kovalevskii* while males feed on *Nereis succinea.*

The females of the deep-water anglers live predatory life while males live as parasites on females.

(3)- Locality

The pond specimens differ from the Nile specimens in the kind of food and also in it's intensity.

(4)Length of the fish (and consequently age)

-Small cod, *Gadus calarias*:

Individuals at 11-30 cm length: feed on pelagic crustaceans, fish and benthic invertebrates.

Individuals at 70 cm *length:* feed on pelagic and bottom forms.

-*Schilbe mystus:*

As the length increases they increase the consumption of the adult insects and decrease the consumption of the smaller insects and daphnia.

(5)Temperature

Micropterus salmoides:

It consumes at 20Cº three times than at 10Cº.

Some other fishes stop feeding during the winter as they are sensitive to temperature as :-

Cirrhina mrigala and Labeo rohita

*(6)*Light

it is a detrmining factor for food and feeding habits where :-

the catfish *Ictalurus locustris punctatus* feeds actively from sundown to midnight.

The adaptation of the alimentary tract of fishes to their normal diet and feeding habits.

(1)The mouth:

According to the size (a) Small : herbivorous & scavengers

(b) Large : piscivorous fishes

According to the position (a) Terminal

(b) Dorsal

(c) Ventral & (d) subterminal

(2)- Dentition

(a)- strong and a cutely pointed teeth in piscivorous (Godus perch).

(b)- single plate in fishes which feed on hard corals & mollusks.

(c)- Nibbling mouth with incisiform teeth (incisors) (herbivorous).

(d)- Plankton feeders (Herring : as small teeth).

(e)- Scavengers toothless mouth but with pharyngeal teeth pad.

(3) gill rackers: (a)- Well developed in plankton feeders.

(b)- Shorter ones in larger food items.

(4) Stomach:

(a)- Thick-walled muscular stomach (feed on shell or fishes).

(b)- No stomach, gizzard like stomachs decomposing vegetables and organic matter (mud).(gray mullets)

(5)Pyloric coecae

predators – a large number, its number differ inside one Sp.

(6) Relative length of gut (R.L.G)

(a)- Highest (herbivorous fishes) *Labeo niloticus* (17 in adult, 10 in young)

(b)- Inbetween (omnivorouse) *Clarias gariepinus*

(c)- Low (in carnivores) Sharks, Rays & Skates.

(d)- Lowest (in plankton feeders) *Atherina*

(7) enzymatic activity of the intestine

Differ among species.

Anatomy of Alimentary Canal

Alimentary Canal:

Headgut = Mouth and Pharynx

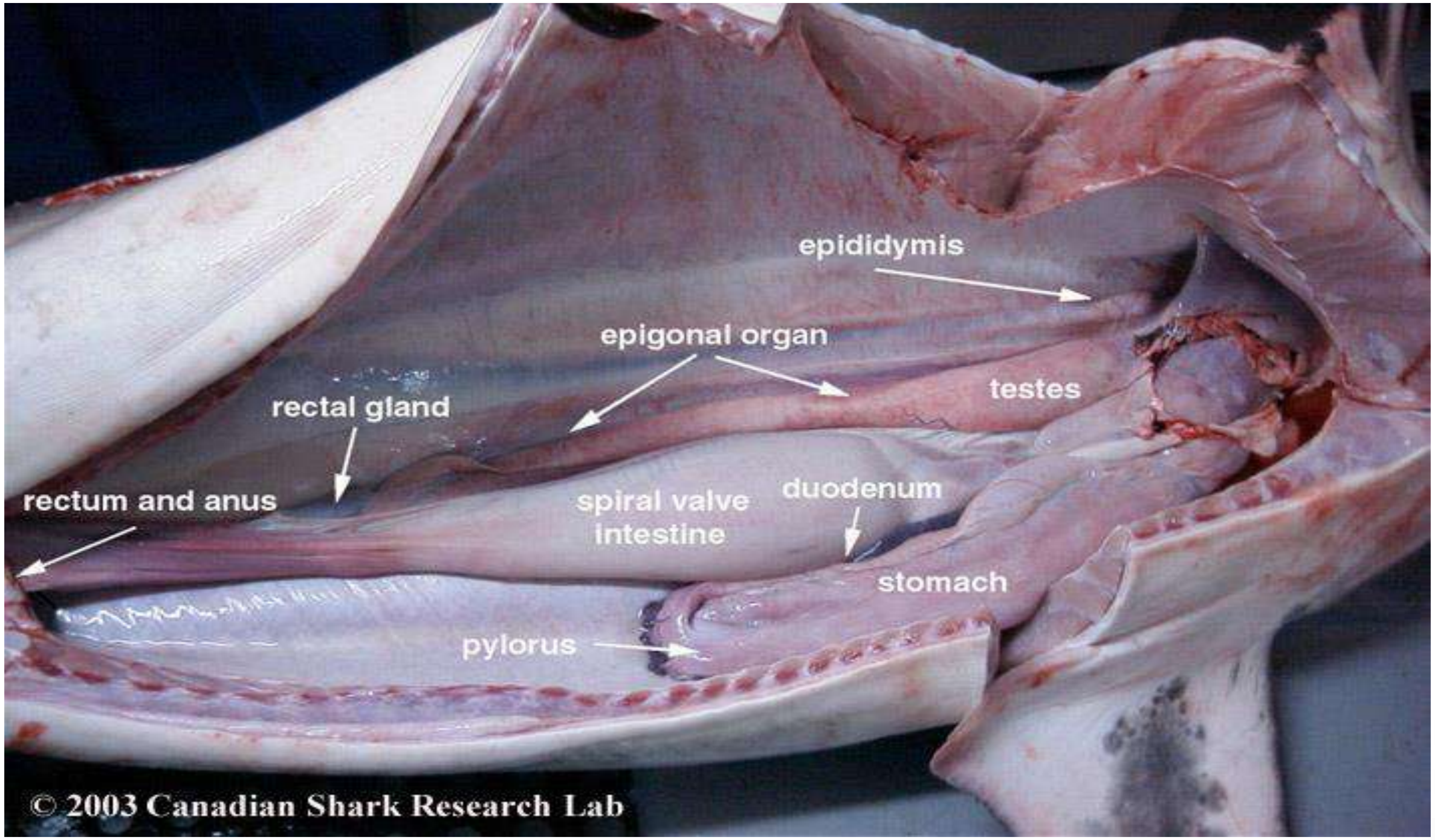
Foregut = Esophagus and Stomach

Midgut = Intestine (Duodenum and Spiral)

Hindgut = Rectum and Cloaca

Digestive tract Anatomy

Sharks



www.mar.dfo-mpo.gc.ca/.../ internal%20anatomy.htm

Digestive tract Anatomy
Skates and Rays

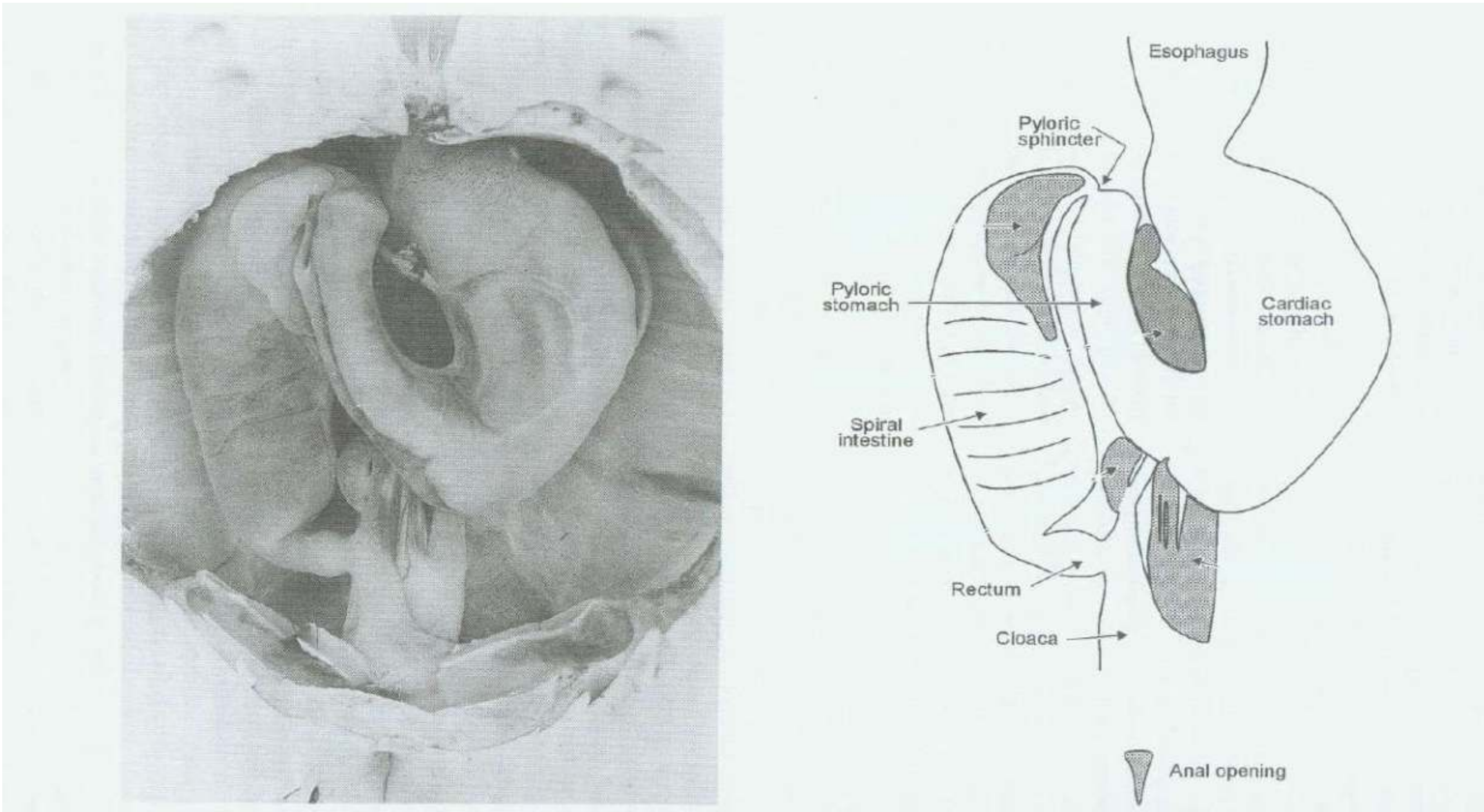


FIGURE 6-1 Photograph and diagramatic representation of the gut of the skate *Raja clavata*. The body wall has been dissected away and the liver removed.

From: Holmgren and Nilsson, 1999 In:Sharks, Skates, and Rays, Hamlett (ed.)

Spiral Valves

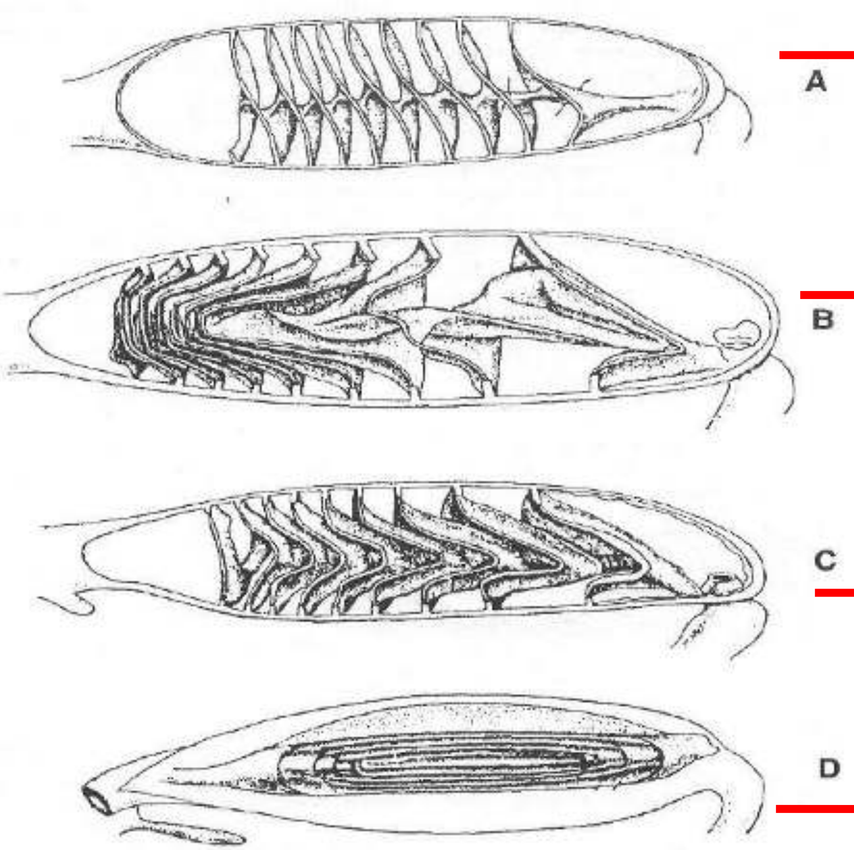


FIGURE 6-4 Examples of the arrangement of the spiral valve of the elasmobranch intestine. Columnar spiral (A), funnels pointing backward (B), funnels pointing forward (C) (all from *Raja* species), and cylindrical valve (scroll valve) from *Zygaena malleus* (D). (From Bertin 1958a, after Parker 1885.)

Spiral winding around central column and attached to outer wall.

Scroll valve with central border free and outer border attached along the length of intestine wall.

Series of interconnecting cones directed anteriorly.

Series of interconnecting cones directed posteriorly.

What do Fish Eat?

The different fish species have their specific feeding habits:

A great diversity is observed in the diet of fish depending on the types and species.

- **The jawless fish:**
- **i.e. the Agnathans have limited options for feeding since they don't have jaws that move up and down.**
- **Their only tool for eating is the sharp set of horny teeth.**
- **The hagfish is known to feed mainly on dead animals.**

Fish Diet

The dietary habits of fish differ from one species to another. It is very difficult to come up with a detailed list of marine plants and animals on which they feed.
Some species are herbivorous or carnivorous in nature feeding on either marine plants or animals, and others are omnivorous in nature feeding on both.

The diet of fish is classified on the basis of their feeding habits:

Algae: The algae form the diet of herbivorous as well omnivorous fish. Omnivorous fish eat macro algae along with crustaceans for which they have to go hunting.

Sea Grasses and Algae: The fish that feed on algae and sea grass are totally herbivorous.

Algae and Detritus: Coral slime, the solid waste matter released from fish and organic matter which gets accumulated over time on the sea floor constitute the detritus.
This detritus forms the diet of many different types of fish.

Sponges: The omnivorous fish like Angelfish feed on
Sponges which form the bulk of their diet.

Plankton: The plankton which includes different types of fish, shrimp, copepods, mysids and amphipods are a supplementary part of the diet of fish.

Mixed Diet: Omnivorous fish that feed at the bottom of the ocean have a mixed diet. They survive on almost any kind of food they obtain near the bottom. Their diet includes worms, small fish, crustaceans and almost everything that is edible.

Other Fish: There are few species of fish which prey on other fish by means of ambush (كمين).

Crustaceans: Shrimp, crabs and such crustaceans form a major diet of some of the fish species.

Invertebrates: Small invertebrates which form the diet of generalized invertebrate feeders include snails, sea urchins, worms and star fish. Sedentary or sessile organisms like the corals, polyps and clams too form the diet of these invertebrate feeders.

Parasites: Some of the fish feed as parasites on other fish species.

Things to consider after capture

- Fish may regurgitate
- Digestion continues
- Fish may eat each other when confined

17.3 Sampling strategies -

- Amount and Type of Food
  - Diel cycle
  - Seasonal changes
  - Size of fish
  - Territoriality of fish
  - Differential digestion rates

Sampling strategies (cont.)

- Fish should be collected when the stomach is fullest

- maximum information attained

Sampling strategies (cont.)

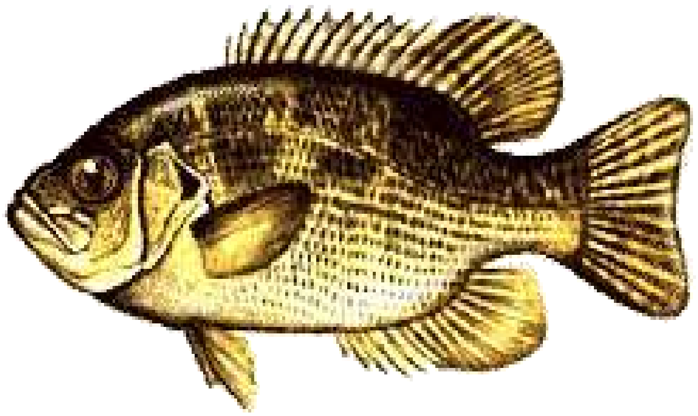
- Fish are sensitive to seasonal changes eg
  - Bluegill switch from invertebrates to algae at the end of the summer

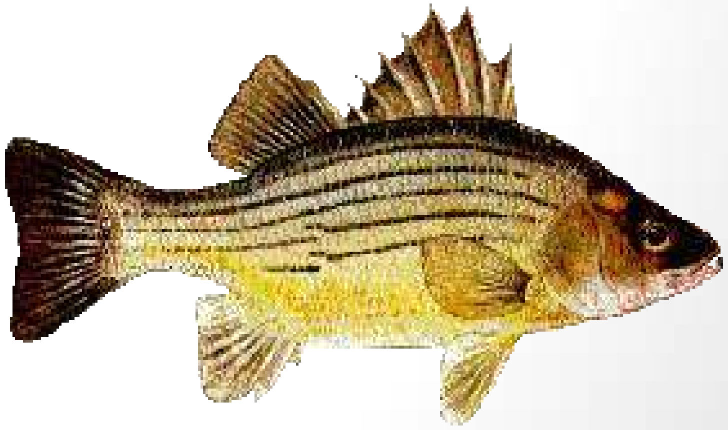
– Amazon river fish switch from invertebrates to detritus in the rainy season.

- Sampling should be frequent throughout the year.

Sampling strategies (cont.)

- Effects of fish size and territoriality
  - Diets vary with fish size and sex
  - As fish grow, they may switch from one prey type to another
  - Adult males and females may have different diets





Sampling strategies - Differential digestion rates

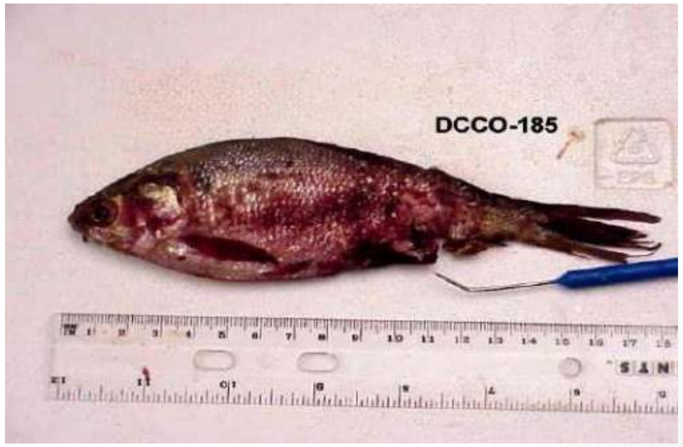
- Stomach contents may not accurately reflect
- diet. Why?

- Some prey, eg protozoans, are digested faster with little trace

-Watch fish feeding in aquarium and compare with gut contents

Sampling strategies - Differential digestion rates

- **Slowly digested prey may accumulate and thus be over represented in the gut**
  - **Collect fish at peak of daily feeding intensity**

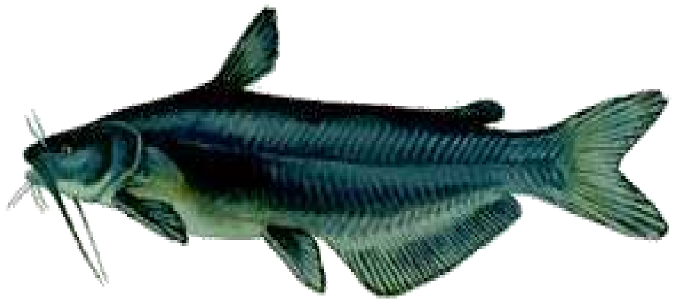


17.4 Removal, fixation and preservation

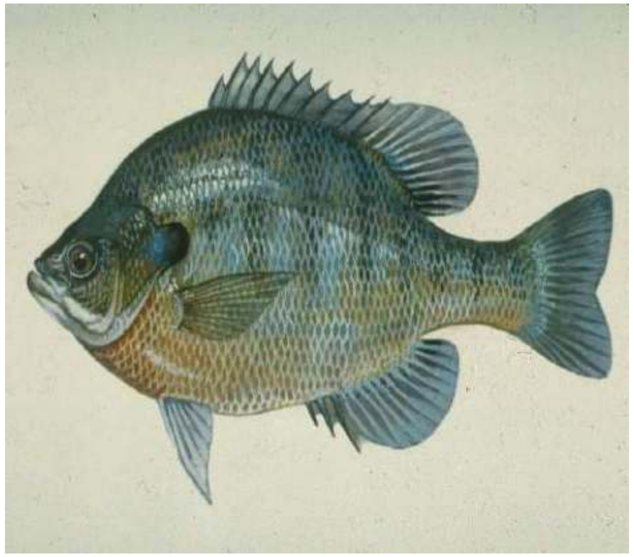
- Removal of gut contents

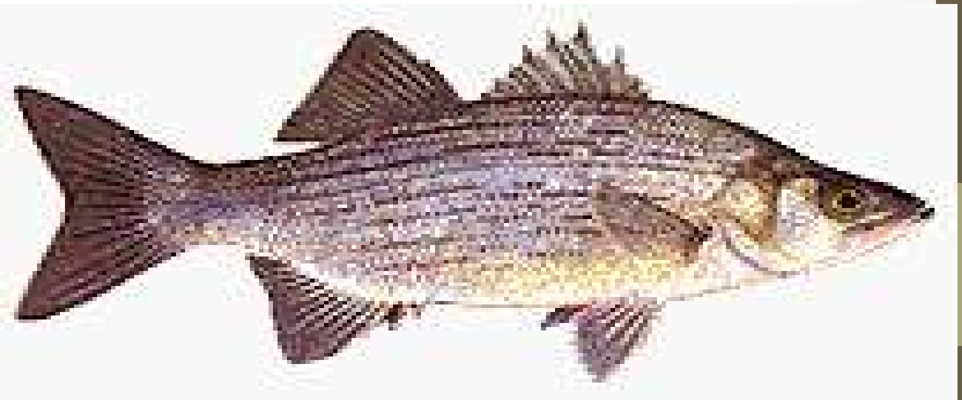
  - Flushing of stomach with one or more volumes of water
  - Insertion of acrylic tubing through digestive tract
  - Dissection

Collection from live animals works best on



- Perches
- Sunfishes
- Catfishes
- Trout





Dissection - Fish are killed as humanely as possible

- Anesthetic
- Sharp blow to head

- Severing spinal cord column (small fish)

Fixation and preservation of gut contents

- 10% formalin initially
- Wash and soak in water
- Preserve in 45-70% aqueous alcohol

- Wear plastic gloves
- Work in fume hood

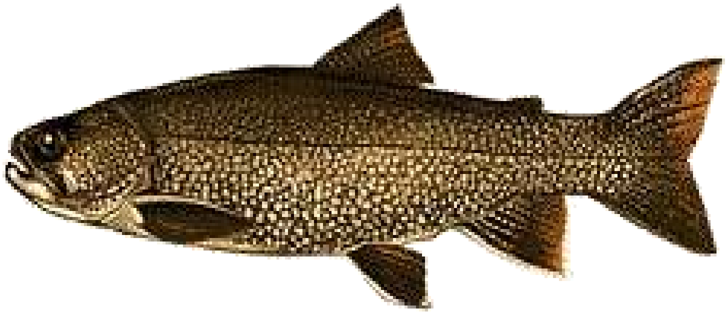
If possible

- Fix gut samples immediately after capture to avoid post capture digestion
- Hold fish in ice
- Slit the coelom to allow entry of formalin
- Inject formalin directly into the coelom

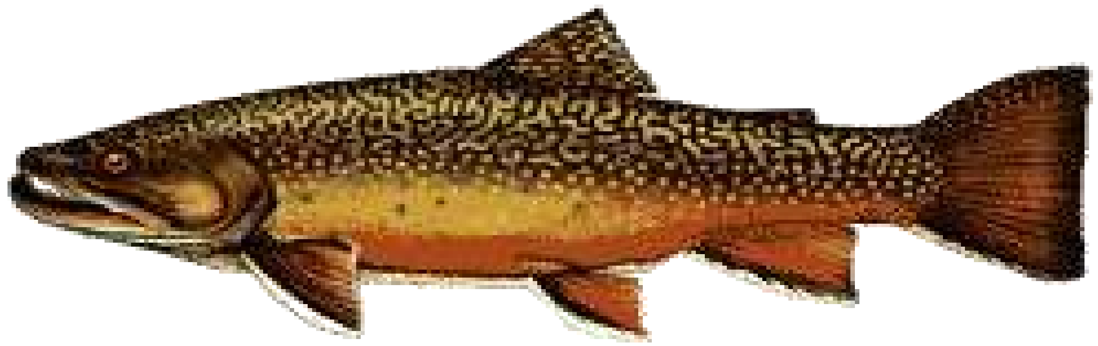
17.5 Identification - partly digested prey

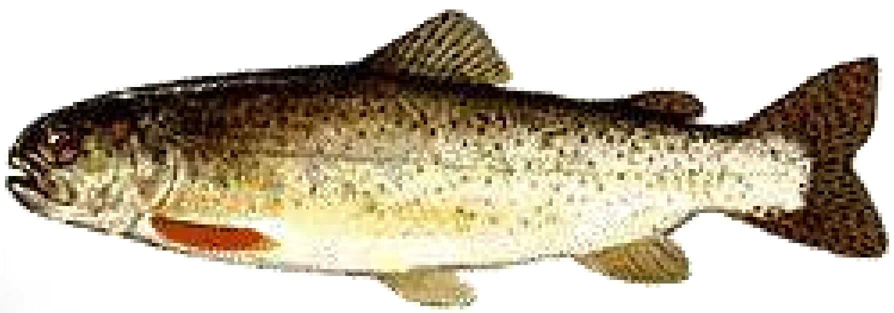
- Made difficult by digestion
- Find part of organism that is easily recognized
  - Exoskeleton in invertebrates
  - Otolith count for fish
  - Sculpturing along edges of leaves for macrophytes
  - Algae is found intact

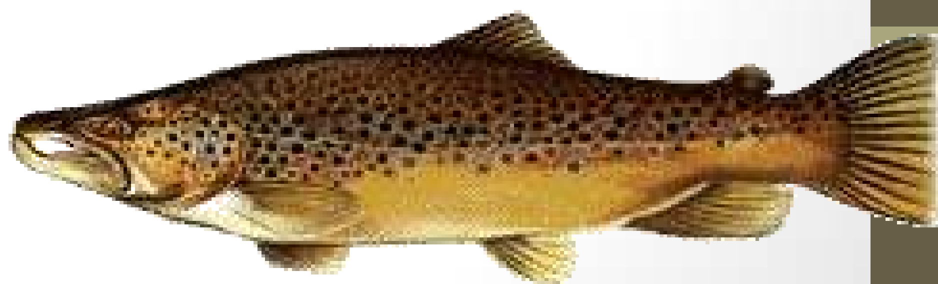
Level of identification.



- Family
- Order
- Relative size

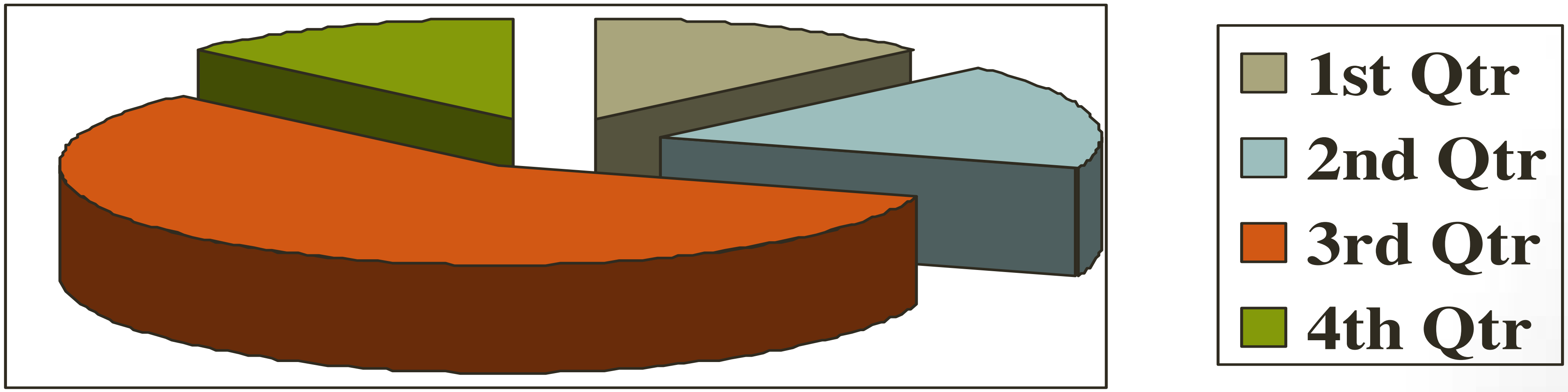






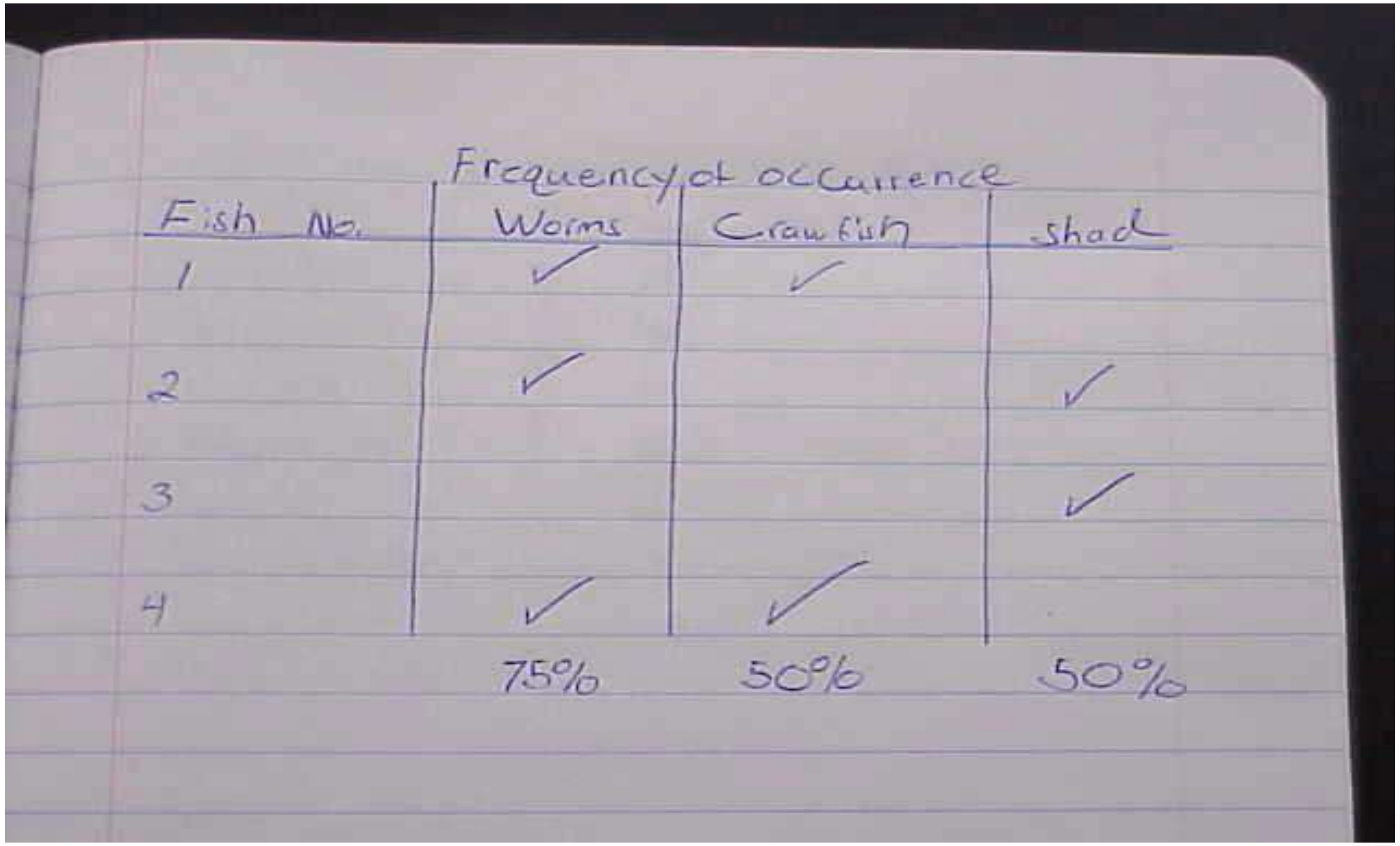
17.6 Quantitative description … 3 approaches

- Frequency of occurrence
- Percent composition by number
- Percent composition by weight



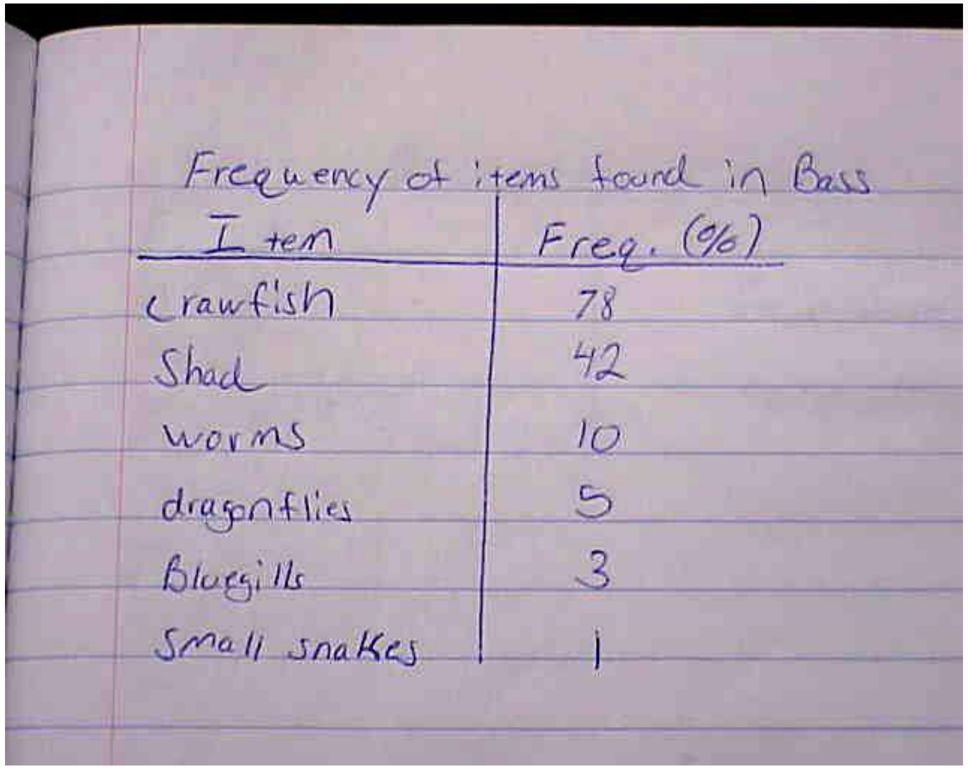
Frequency of occurrence

- Fastest approach to quantitative analysis of gut content



When examining gut samples from fish

- Compile cumulative list of foods found
- Record presence or absence of each food for each specimen



- One or more of each food is calculated as the frequency of occurrence

This method gives valuable insights...BUT

- There are no limits to the information that it provides
- High frequency does not mean given food is of nutritional importance
- Does not give the importance of the various foods found

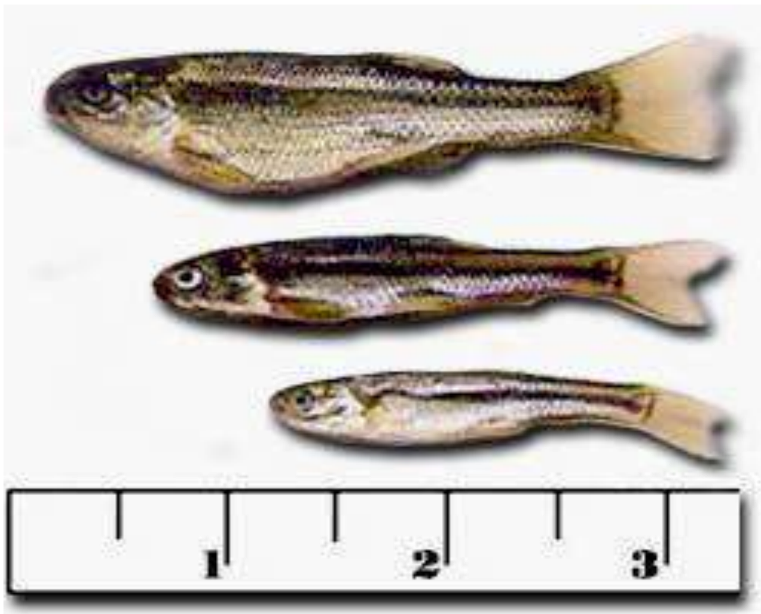
≠

Frequency of occurrence

- describes the uniformity with which groups of fish select their food
- does not indicate the importance of the various types of food selected.

Percent Composition by number

- Number of food items examined for each fish
- Metric is the percentage of each food item

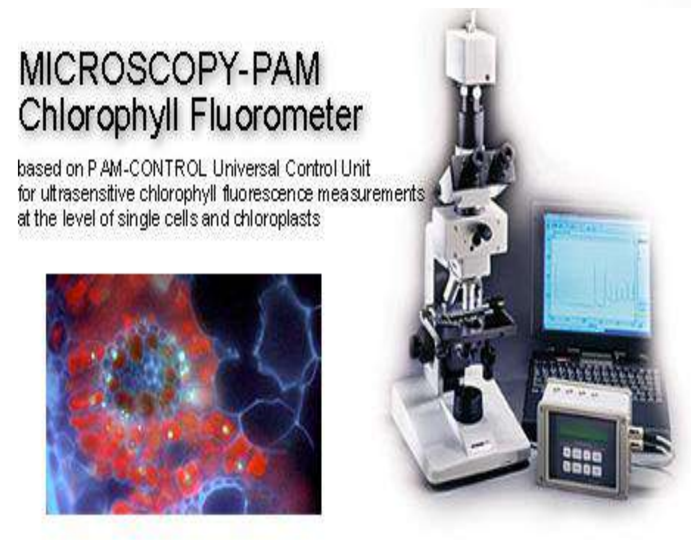


Choose fragment found only once per prey

- Sub-sample for fish that eat smaller prey

- Sub-sample has to be smaller for fish that eat microscopic foods

- Epifluorescence microscope used for counting bacteria



Percent composition by weight

- Each food type expressed as a percentage of all food ingested
- Both wet and dry weights are used
  - Dry-weigh until you attain constant weight
  - Wet-blot fluid from surface and then weigh

- Dry weights are more precise than wet weights

Percent composition

- Quantifies food types in directly comparable weight units
- Suggests relative importance of individual food types in the nutrition of fish

10  = 1 

17.7 Analysis & interpretation - Selectivity Indices

- Comparison of relative abundance of a given prey type in the diet vs relative abundance of that prey type in the environment

- Index used is the Strauss index calculated as
  - L= ri-pi4

Diet overlap indices

- Allow comparison of diets that are similar among species
- Uses Schoener's proposed equation

(refer to text)

- Indices provides relative measures of the

extent to which species use the same food resources

- Does not produce absolute measures of competition

Lecture 5

Endoskeleton

Endoskeleton is important for the following functions:

- **To protect vital organs.**
- **To support soft tissues – fascia*, tendons, ligaments.**
- **The site of red blood cell production.**
- **As a reservoir for minerals - calcium, phosphate.**
- **As attachments for muscles.**
- **Gives the shape of the animal.**
- *** Fascia: a thin sheath of fibrous tissue enclosing a muscle or other organ.**

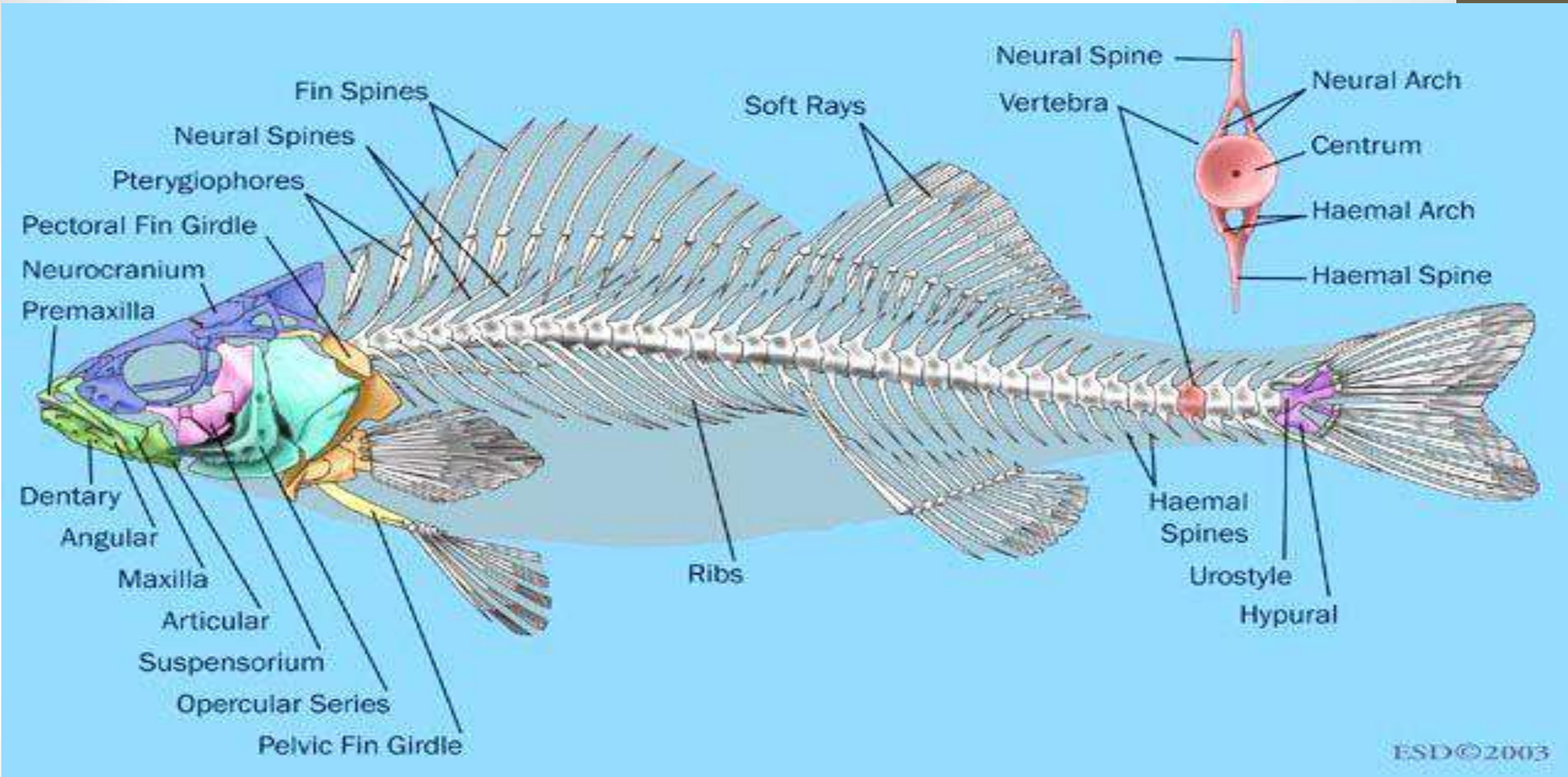
Axial skeleton

Its containing:

1- Skull

2- Vertebral column

3- Ribs

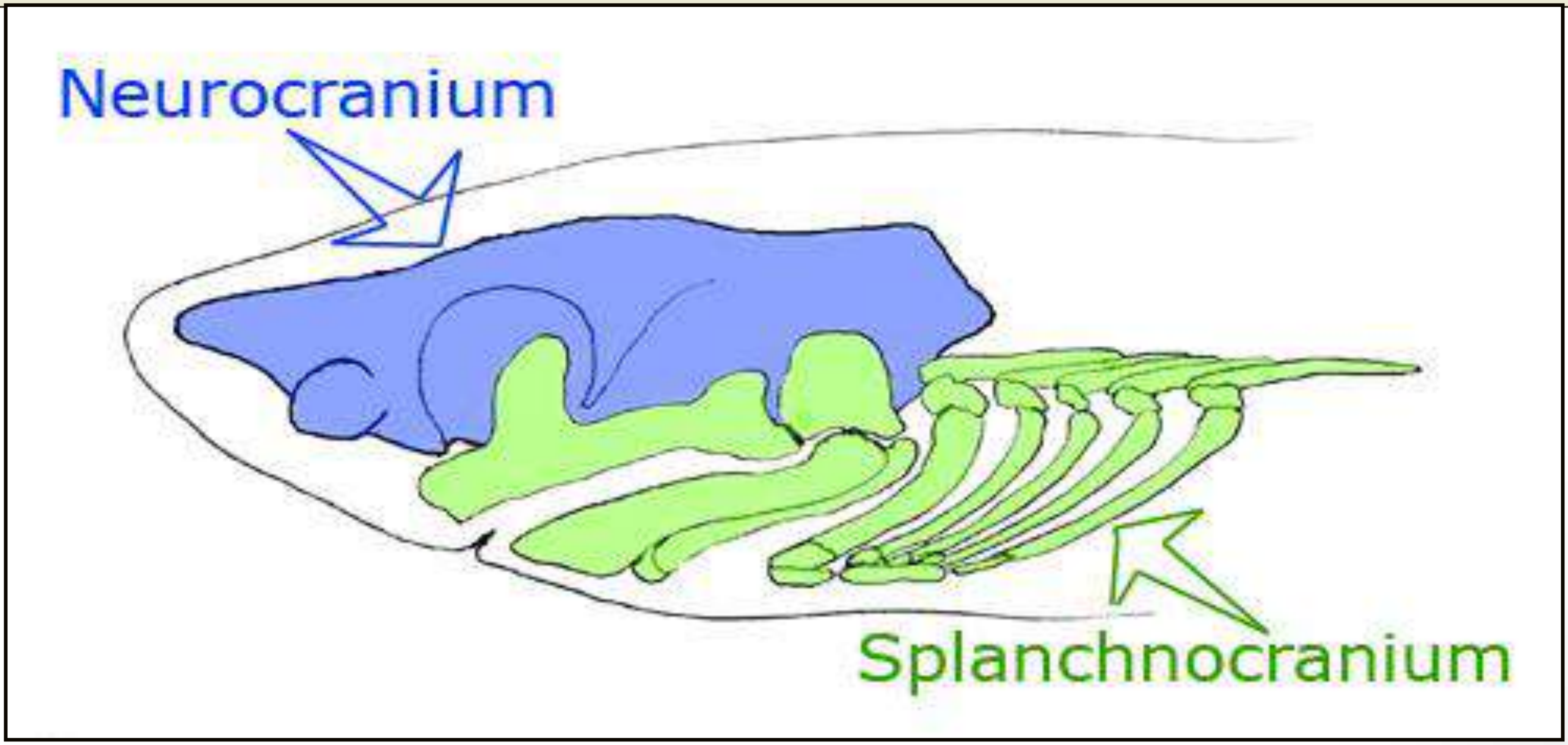

Neural Spine
Neural Arch
Vertebra
Centrum
Haemal Arch
Haemal Spine
Fin Spines
Soft Rays
Neural Spines
Pterygiophores
Pectoral Fin Girdle
Neurocranium
Premaxilla
Dentary
Angular
Maxilla
Articular
Suspensorium
Opercular Series
Pelvic Fin Girdle
Ribs
Haemal Spines
Urostyle
Hypural
ESD©2003

The head skeleton of living chondrichthian fish

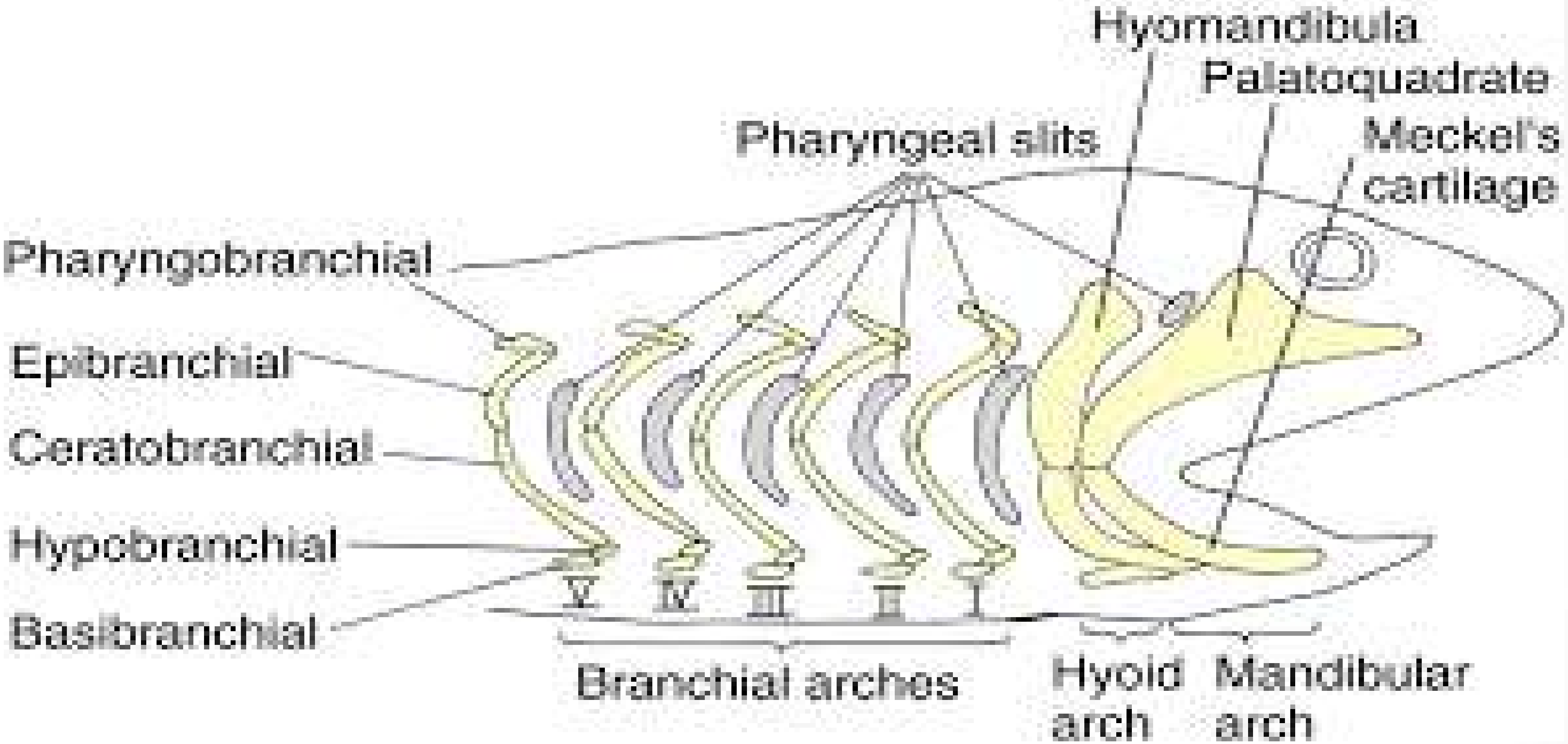
The head skeleton of living chondrichthian fish consists of A)- a highly developed neurocranium,

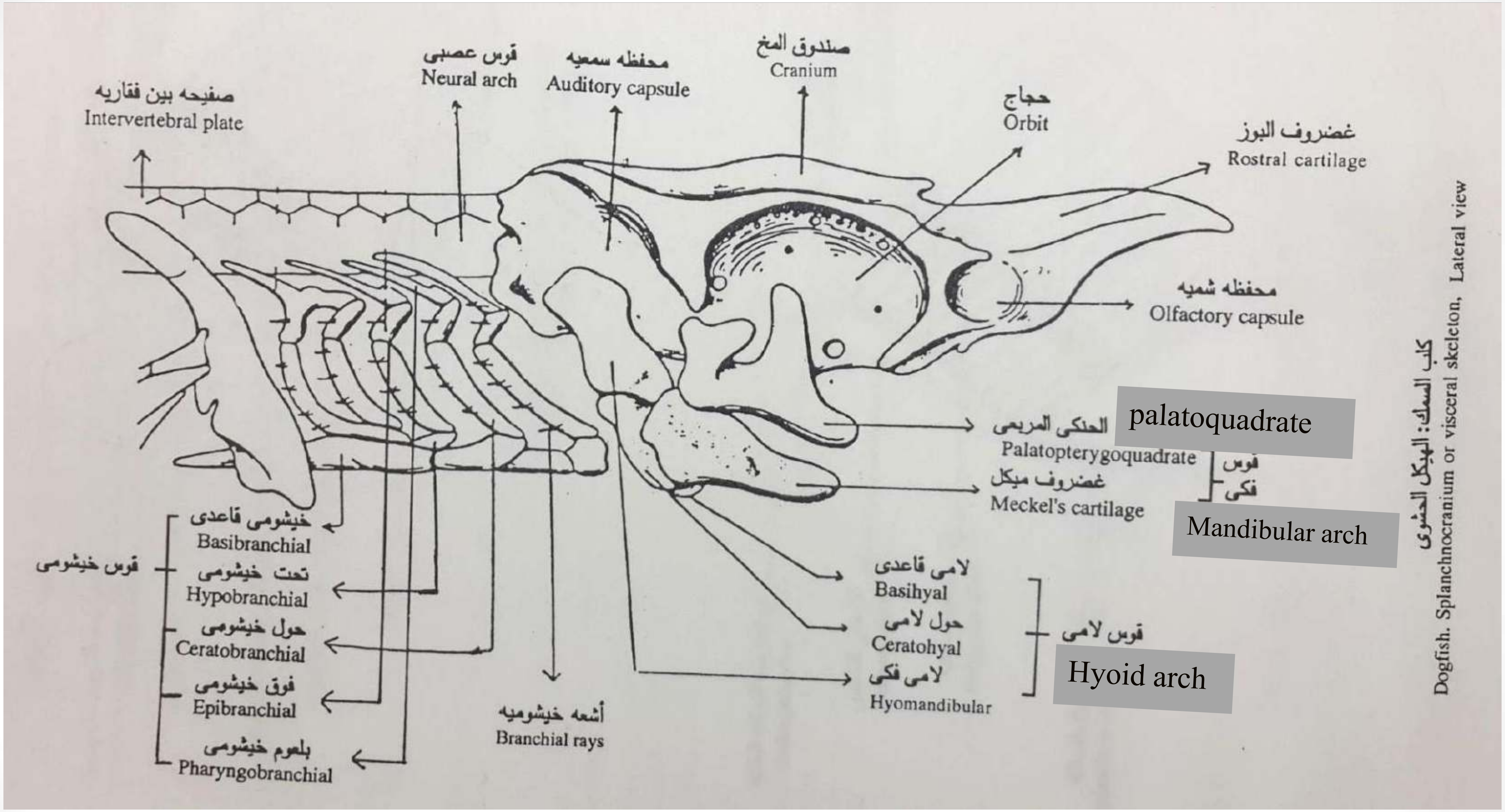
B)- Splanchnocranium (visceral arches) that consists of several cartilages around the mouth and pharynx.

- The visceral arches of bony fishes resemble that of sharks except that bone is added.



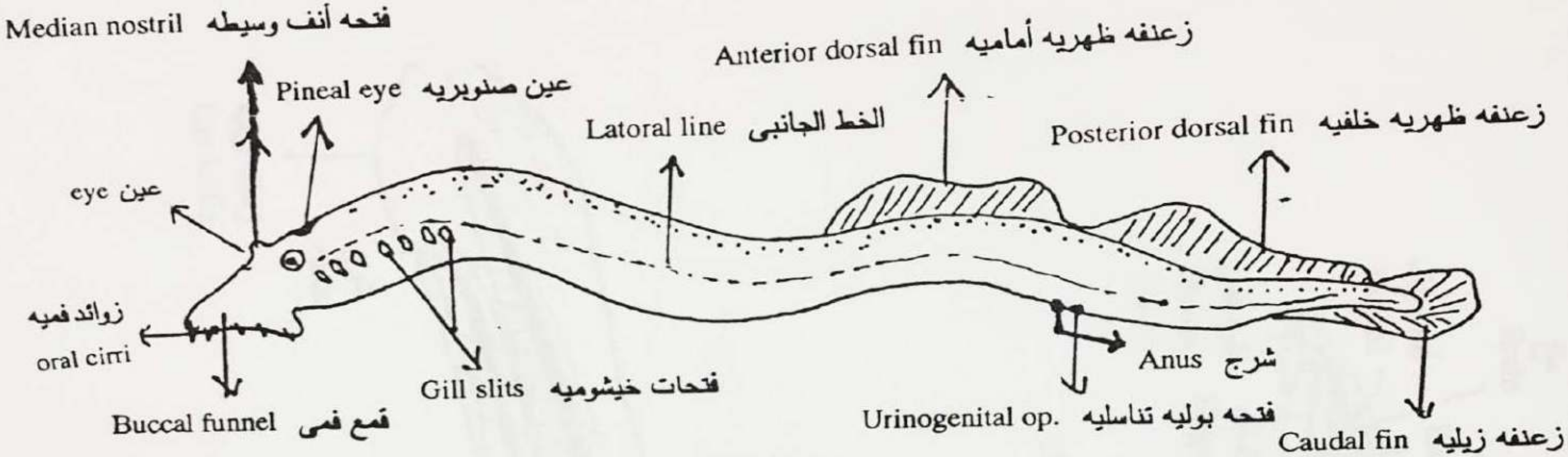
- Splanchnocranium (Visceral arches): are pieces of cartilages or bones that support the mouth and the pharyngeal region of vertebrates and also help attach the jaws with the skull.
- There are typically 7 pairs of visceral arches in vertebrates which modify in different groups depending upon the presence or absence of gills and type of jaw suspension.
- Visceral arches are numbered 1-7,
- The first visceral arch is known as mandibular arch having two cartilaginous pieces called palatoquadrate and meckel's cartilage.
- Second visceral arch, called hyoid arch, and consists of hyomandibular, ceratohyal and basihyal.
- From 3rd to 7th visceral arches are called branchialarches, since they support gills and typically each one consists of 4 pieces of cartilages, namely, pharyngobranchial, epibranchial, certobranchial and hypobranchial, and three unpaired branchial cartilages called basibranchials.


Hyomandibula
Palatoquadrate
Pharyngeal slits
Meckel's cartilage
Pharyngobranchial
Epibranchial
Ceratobranchial
Hypobranchial
Basibranchial
V
IV
III
II
I
Branchial arches
Hyoid arch
Mandibular arch

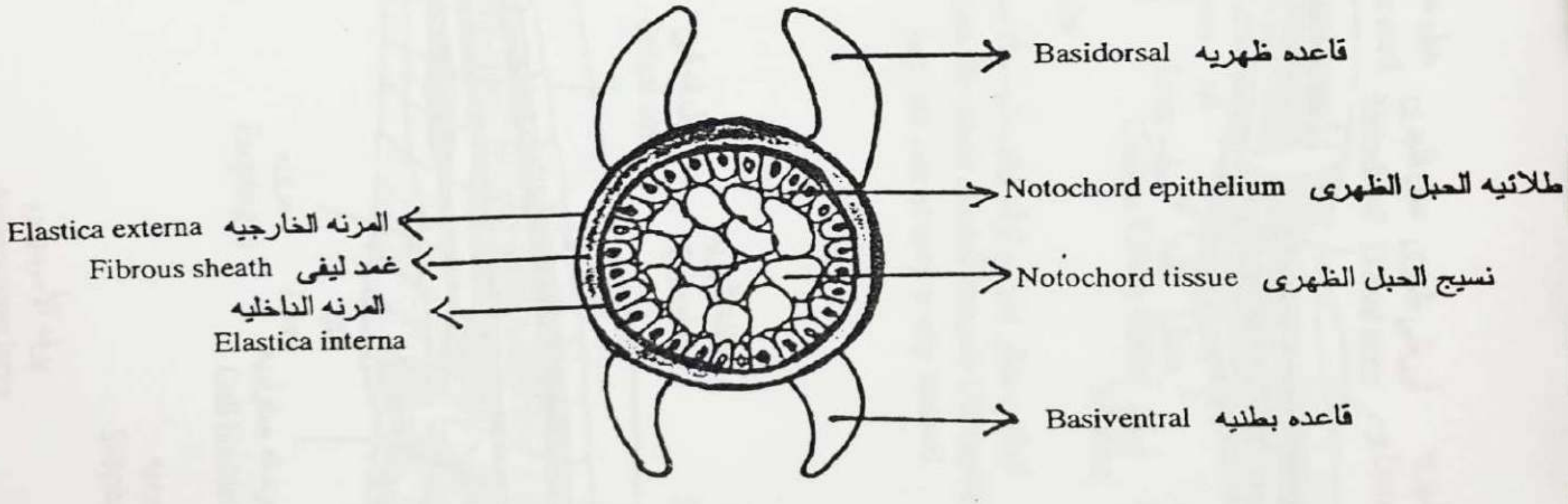

صفيحه بين فقاريه
Intervertebral plate
قوس عصبى
Neural arch
محفظه سمعيه
Auditory capsule
صندوق المخ
Cranium
حجاج
Orbit
غضروف البوز
Rostral cartilage
محفظه شميه
Olfactory capsule
الحنكى المربعى
Palatopterygoquadrate
palatoquadrate
غضروف ميكل
Meckel's cartilage
قوس فكى
Mandibular arch
لامى قاعدى
Basihyal
حول لامى
Ceratohyal
لامى فكى
Hyomandibular
قوس لامى
Hyoid arch
أشعه خيشوميه
Branchial rays
قوس خيشومى
خيشومى قاعدى
Basibranchial
تحت خيشومى
Hypobranchial
حول خيشومى
Ceratobranchial
فوق خيشومى
Epibranchial
بلعوم خيشومى
Pharyngobranchial
كلب السمك: الهيكل الحشوى
Dogfish. Splanchnocranium or visceral skeleton, Lateral view

The vertebral column

- In hagfishes the notochord persists without constriction, and the rudiments of vertebrae are small cartilages resembling neural arches in the caudal region.
- Lampreys show neural arch elements along the length of the notochord.
  - The notochord of elasmobranchs is constricted by cartilaginous vertebral centra.



الجلكى: الشكل الخارجى
Petromyzon fluviatilis: Externa features.

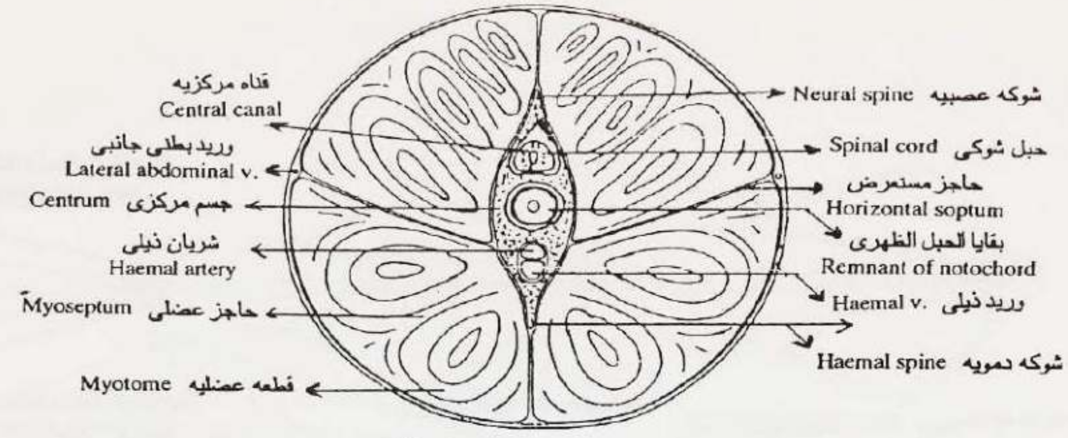


الجلكى: ق. ع. فى الحبل الظهرى
Petromyzon: T. S. of the notochord.

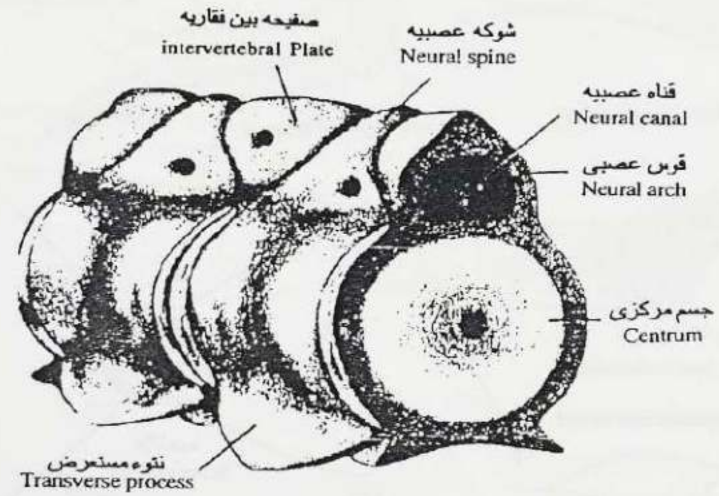
1)- The cartilaginous fishes

The vertebral column of fishes has two types of vertebrae, trunk vertebrae and caudal vertebrae; the anus marks the point of transition between the two types of vertebrae.

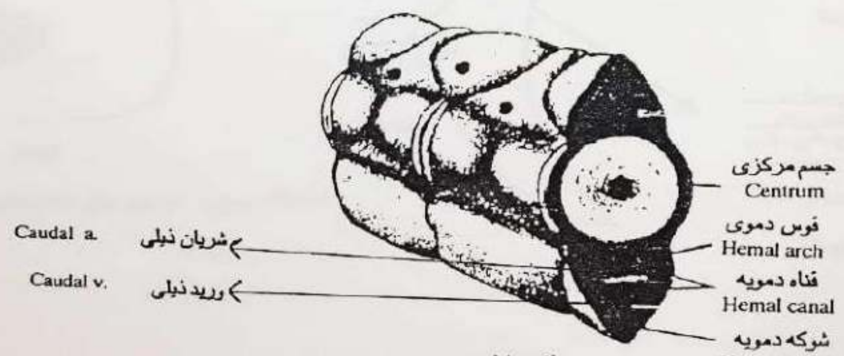
The vertebrae are amphicoelous.



Dogfish shark: Cross section through tail



Trunk vertebra



Caudal vertebrae

2)- The bony fishes:

- The typical teleost has ossified biconcave (amphicelous) centra.

- Neural arches and spines are present. And caudal vertebrae have haemal arches and spines.

- Zygapophyses may occur both anteriorly and posteriorly on centra. these are generally small in fishes.

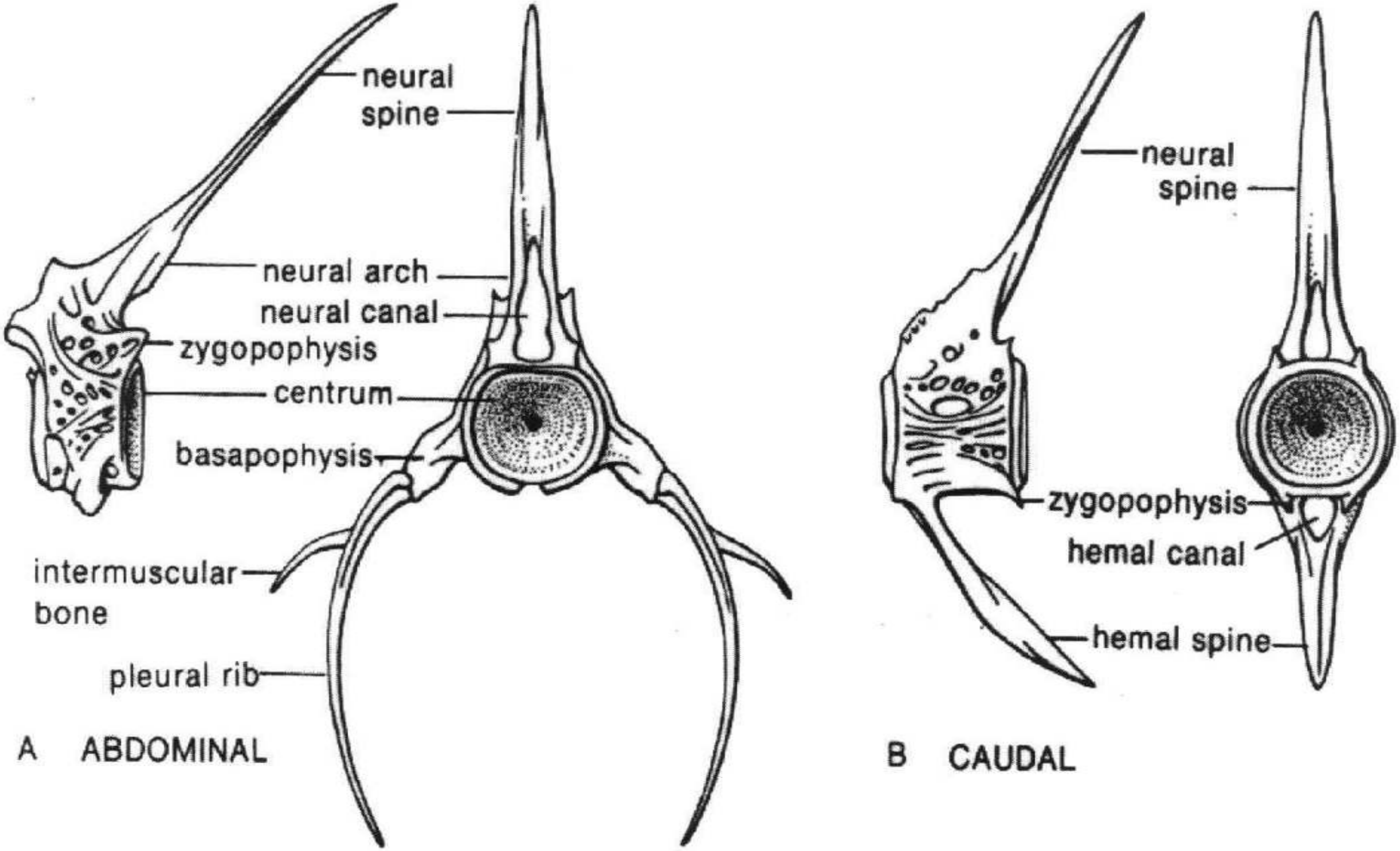
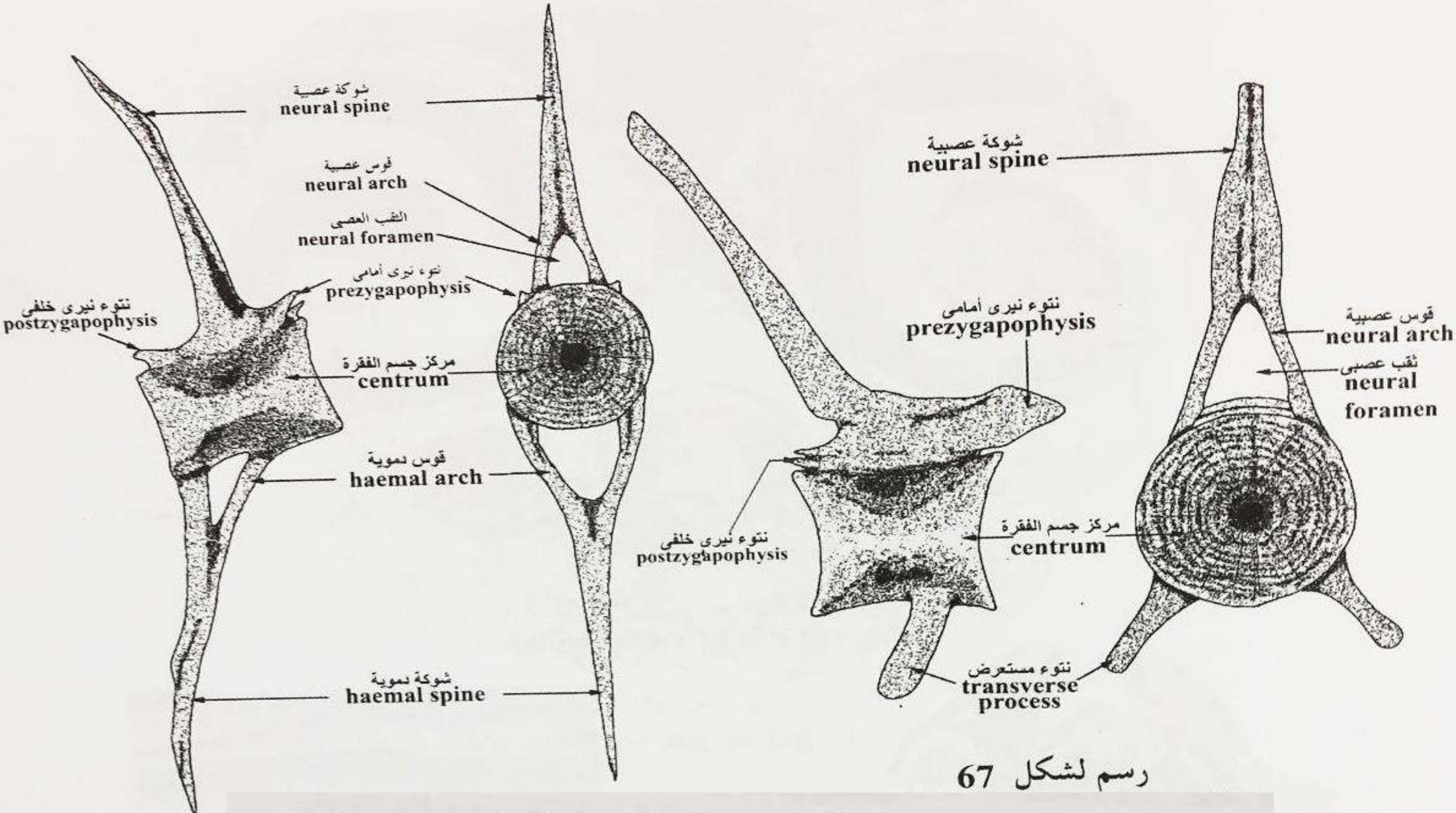


FIGURE 3–8. Vertebrae of teleost. *A*, lateral and posterior views of abdominal vertebrae; *B*, lateral and posterior views of caudal vertebrae.



رسم لشكل 67

لثرينس لينتيجان (الشعرى)
Lethrinus lentjan

The appendicular skeleton
(Fins and fin girdles)

- **A- The median fins**

- - In elasmobranchs the median fins are supported by basal cartilages .

  - In teleosts each ray of the median fins is typically supported by two ossified and one cartilaginous pterygiophores.

The median fins

A- Skeletal supports of unpaired fins in shark

B- Skeletal supports of unpaired fins in bony fish

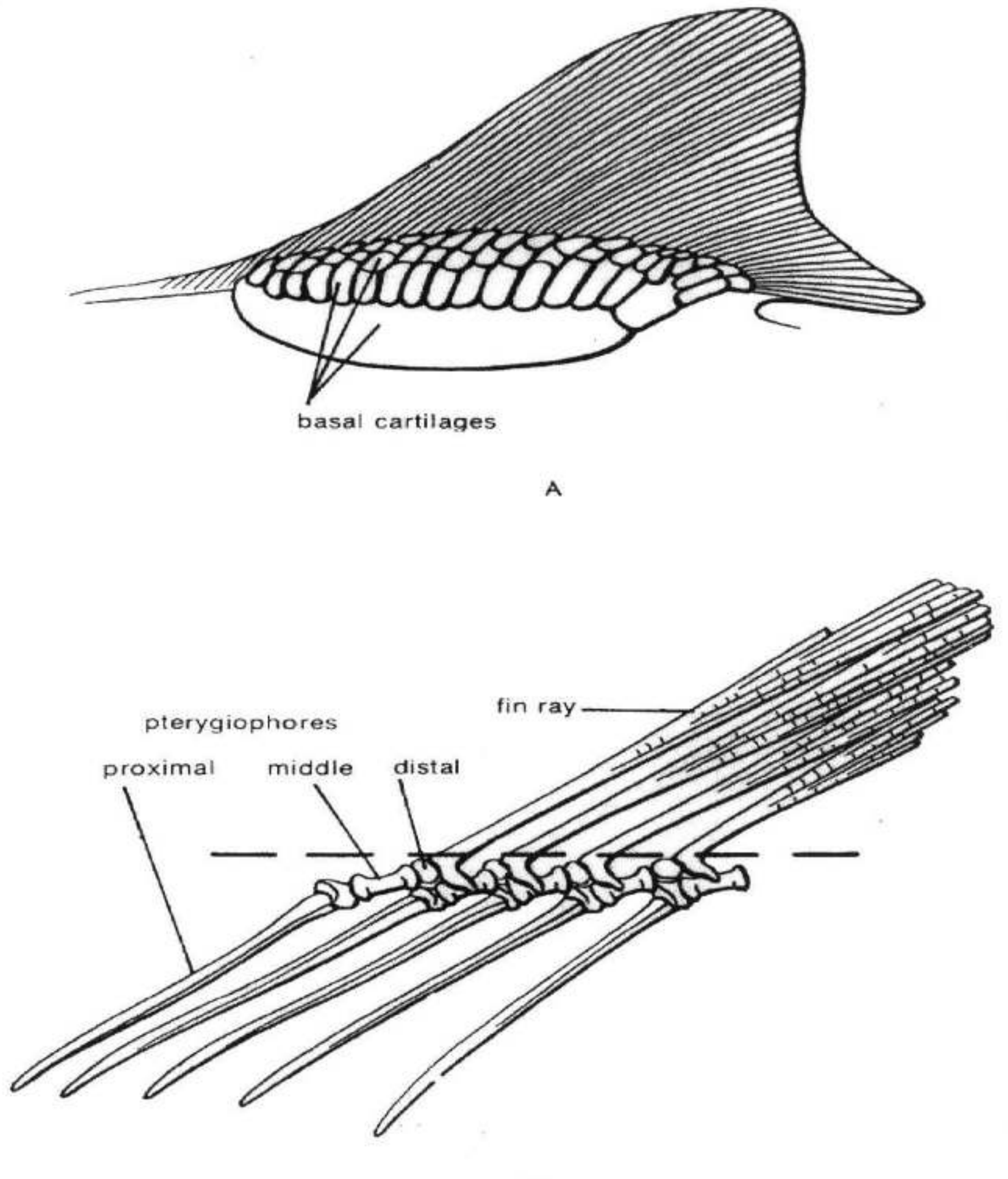


FIGURE 3–9. Skeletal supports of dorsal fin. *A*, Shark; *B*, bony fish (dashed line shows approximate body contour). (*A* based on Goodrich, 1930.)

B- The paired fins

1)- The cartilaginous fishes:

- The pectoral fins of elasmobranchs are supported by a cartilaginous girdle consisting of :

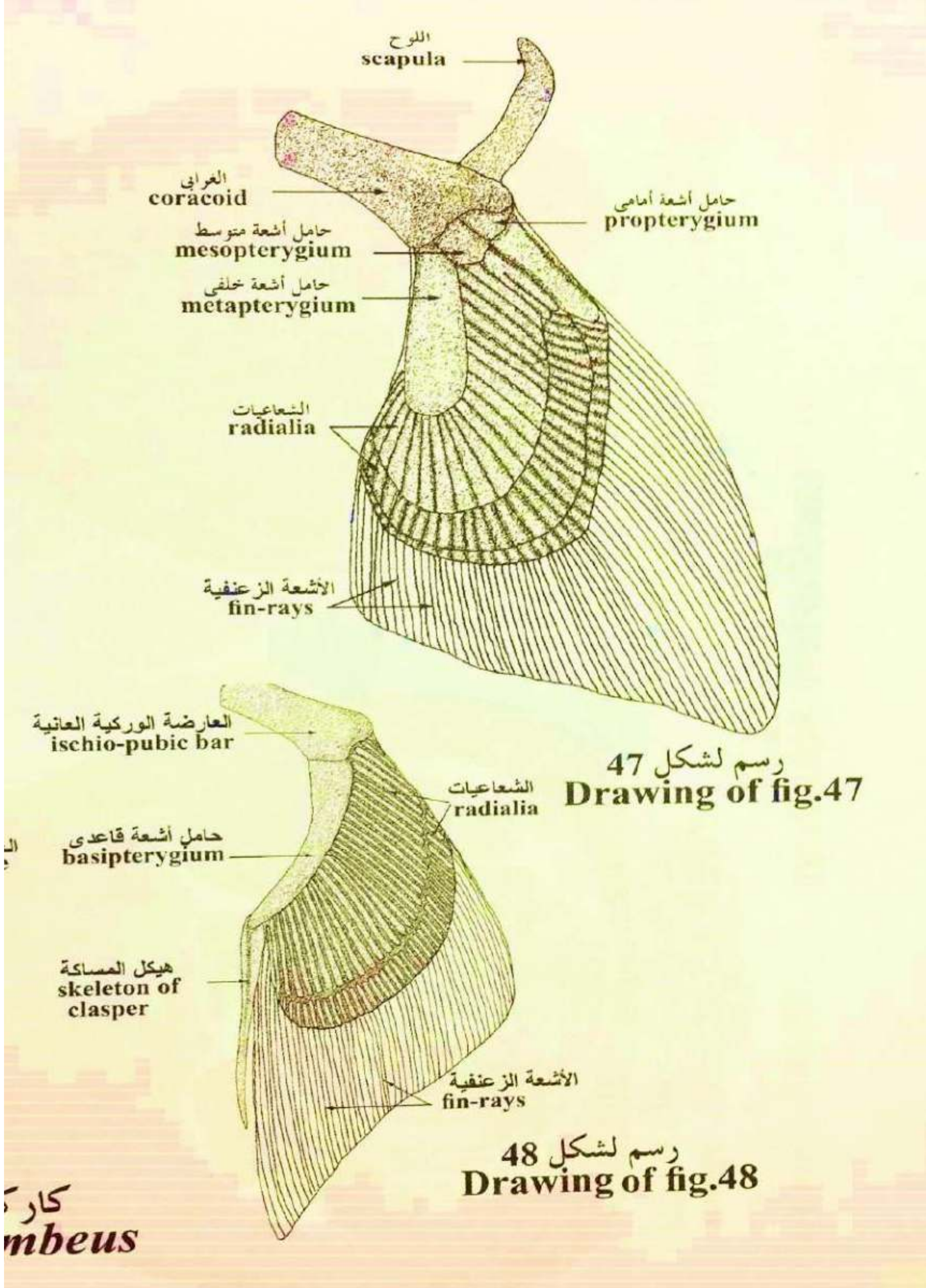
  - an upper section, or scapula
  - a lower coracoid piece.

- The pelvic fins of elasmobranchs are supported by a bar of cartilage crossing the ventral midline.
- basipterygium that bear the jointed radials of the fin.

Skeletal supports of paired fins in shark

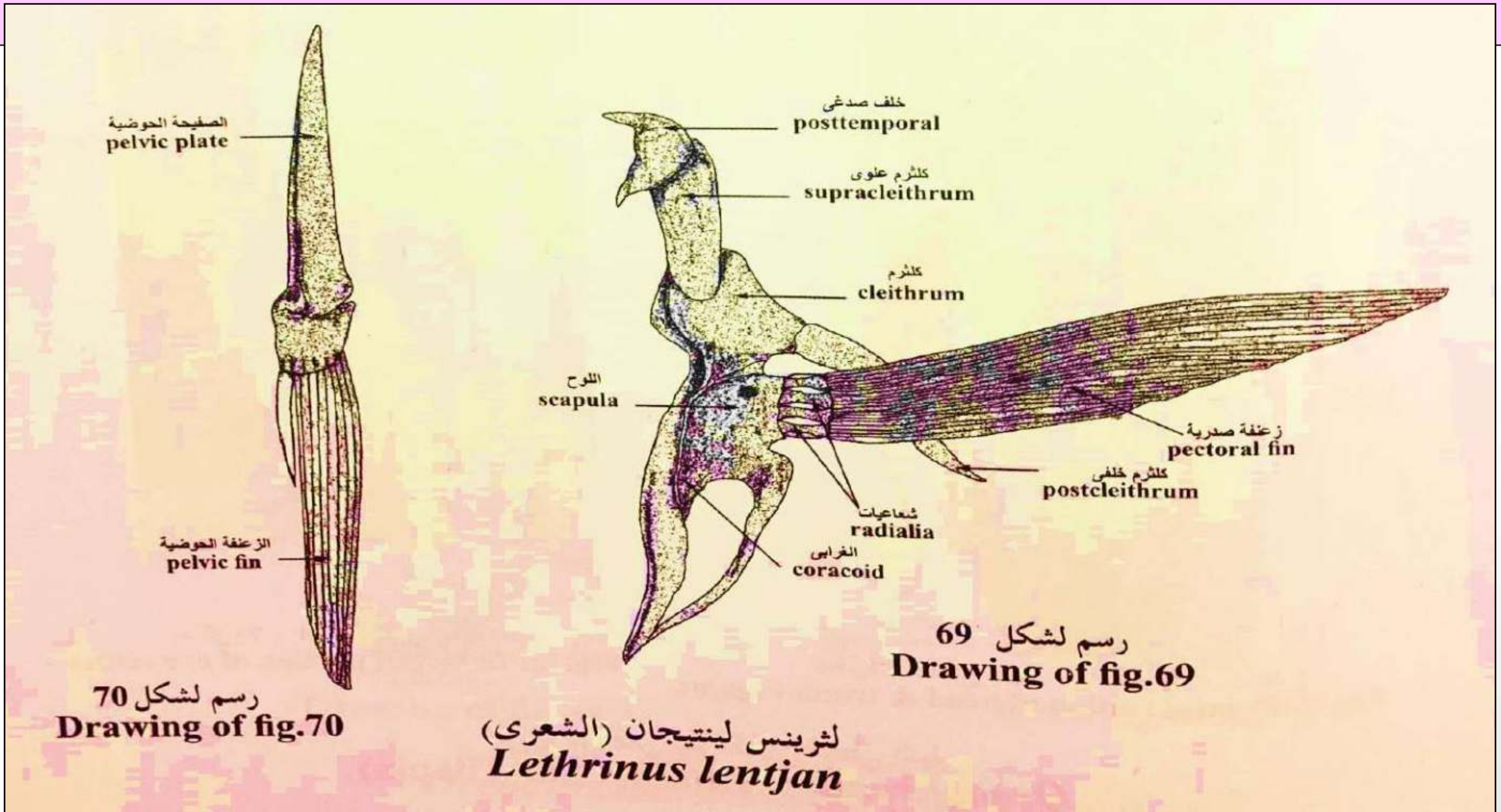
Skeletal supports of the pectoral fin of elasmobranchs

Skeletal supports of the pelvic fin of elasmobranchs



2)- The bony fishes:

The pectoral girdle of typical teleosts, the scapula and coracoid are ossified as endochondral bones and part of their outer edges form the articular surface for the radials of the pectoral fin.



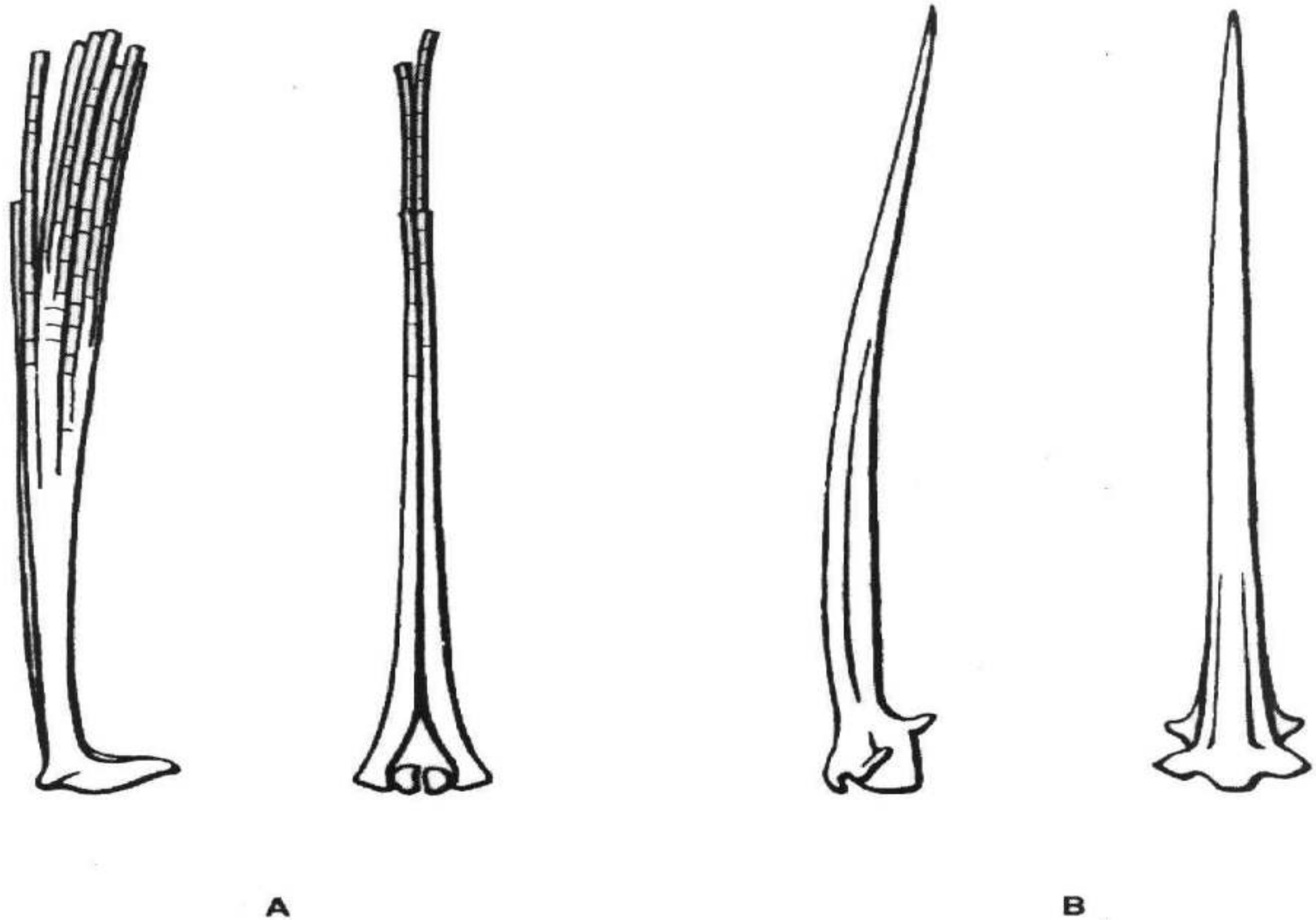


FIGURE 3–12. Comparison of soft and spinous rays. *A*, lateral and anterior views of soft ray; *B*, same views of fin spine. Note branching, segmentation, and double construction of soft ray.

Development of condrocranium

The neurocranium forms at the anterior end of the notochord.

Its formation begin with the formation of two parachordal cartilage one on each side of notochord enlarge and form a structure called a basal plate

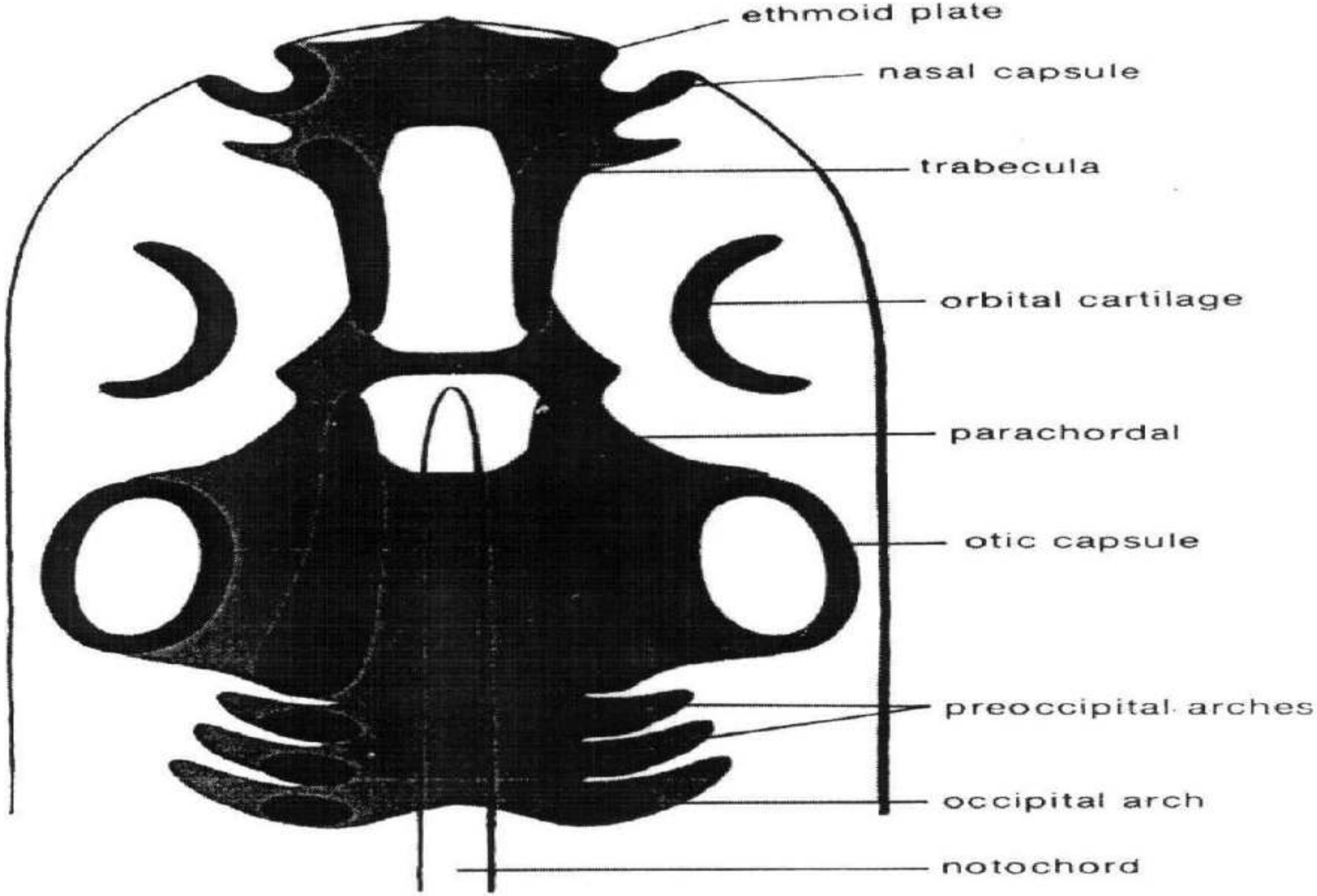


FIGURE 3–1. Generalized diagram of early stages of development of chondrocranium. *In black*, separate cartilages; *in gray*, the formation of ethmoid and basal plates.

The branchiocranium

A series of arches that form around the pharyngeal region are associated with the neurocranium.

In fishes most of the branchiocranium is associated with the support of gills but some arches have been modified and have other functions.

The anterior arch in living fishes is called the mandibular arch because of its contribution to the formation of the primary upper and lower jaw.

*The upper elements are called palatoquadrate cartilages.

*The lower elements are called the mandibular cartilages or Michel's cartilages.

The second arch is the hyoid arch

*The upper element on each side, the hyomandibular cartilage .

*The lower element is the ceratohyoid cartilage.

*The posterior arch of bony fishes is usually modified to bear pharyngeal teeth.

Skull of living Agnathans

A) Hagfish
B) Lamprey

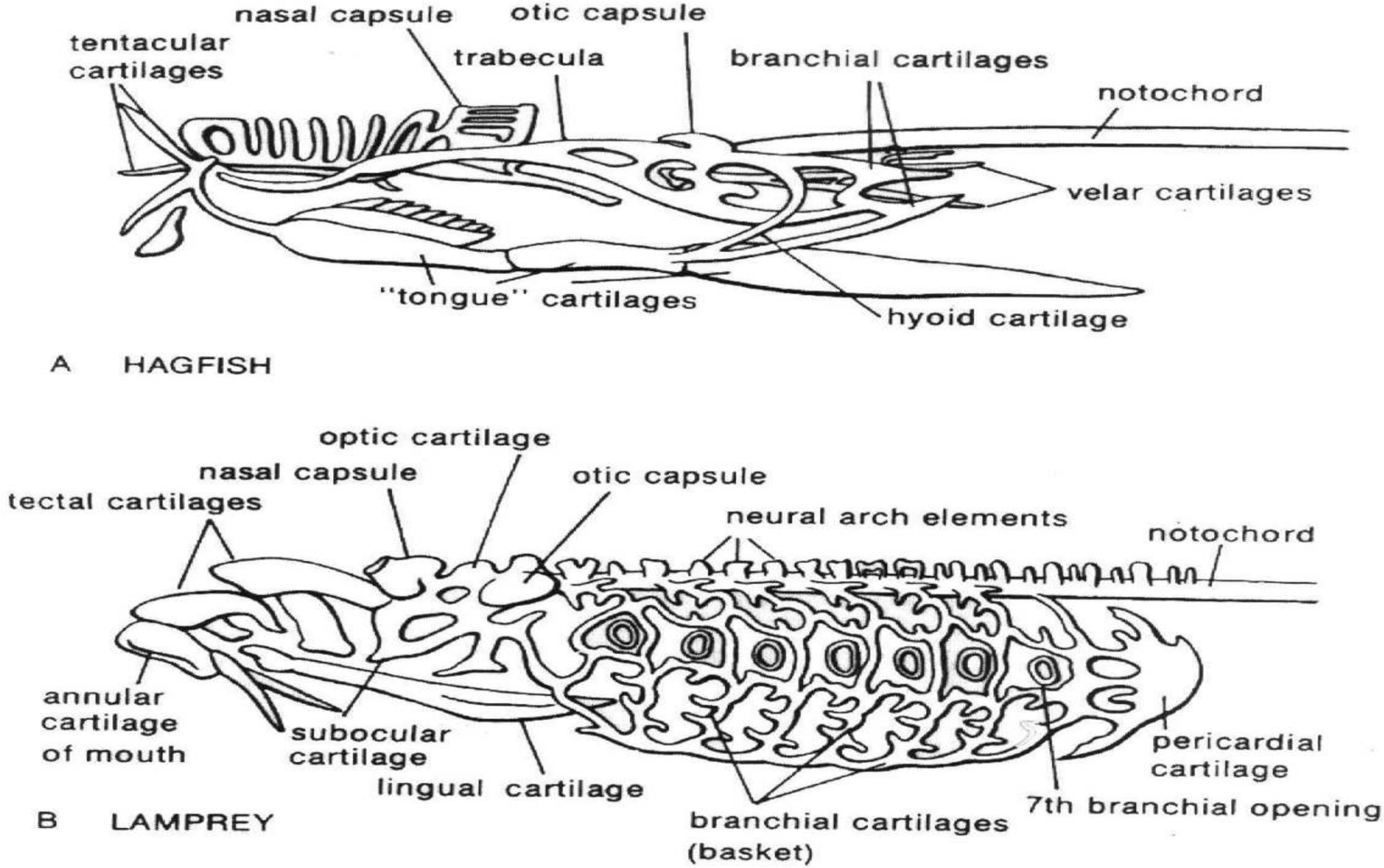


FIGURE 3–2. Diagrams of skulls of living agnaths. *A*, Hagfish; *B*, lamprey. (Based on Goodrich, in Lankester, 1909.)

Types of jaw suspensions

A) Hylostylic

B) Amphystylic

C) Holostylic

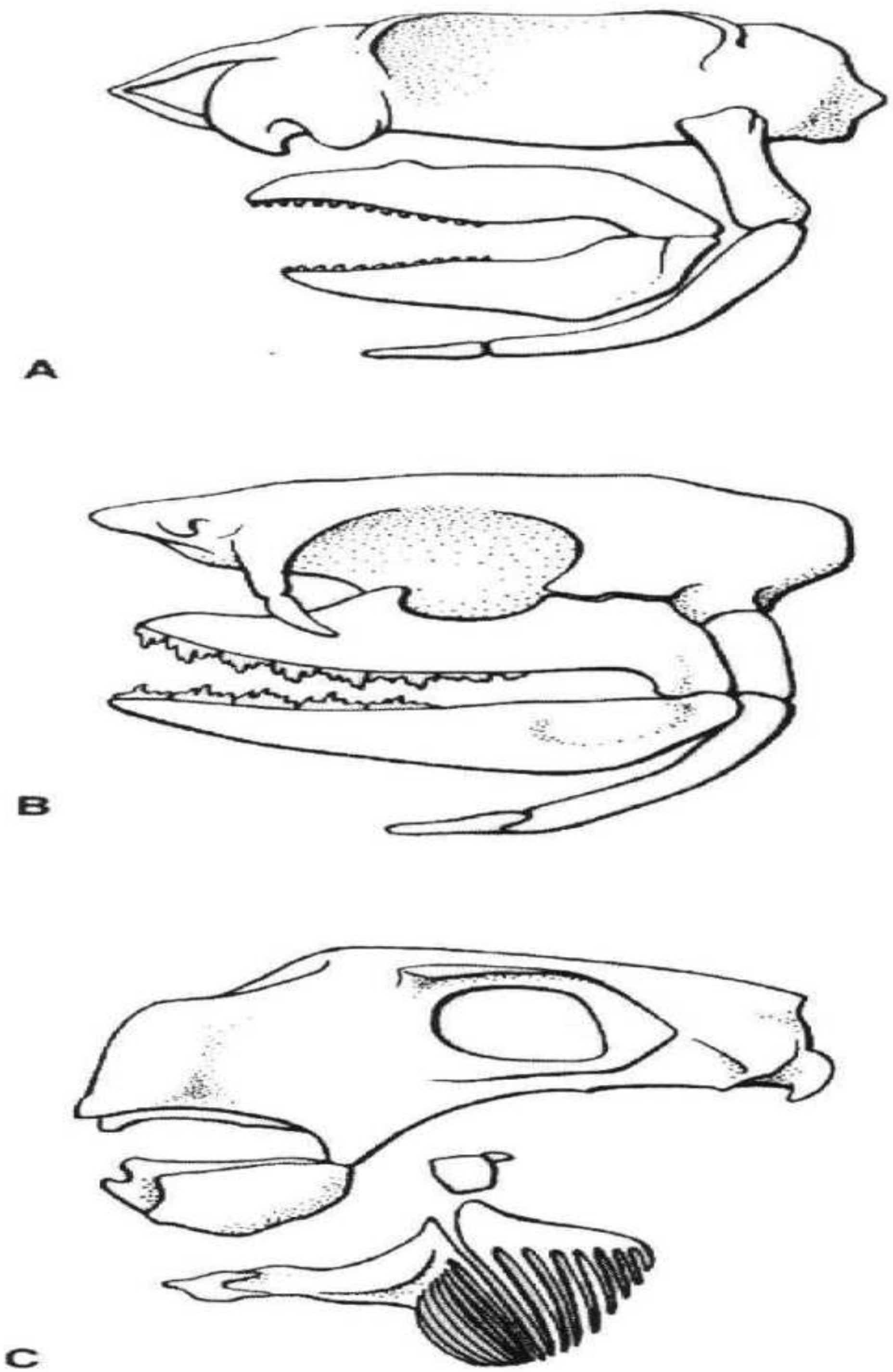
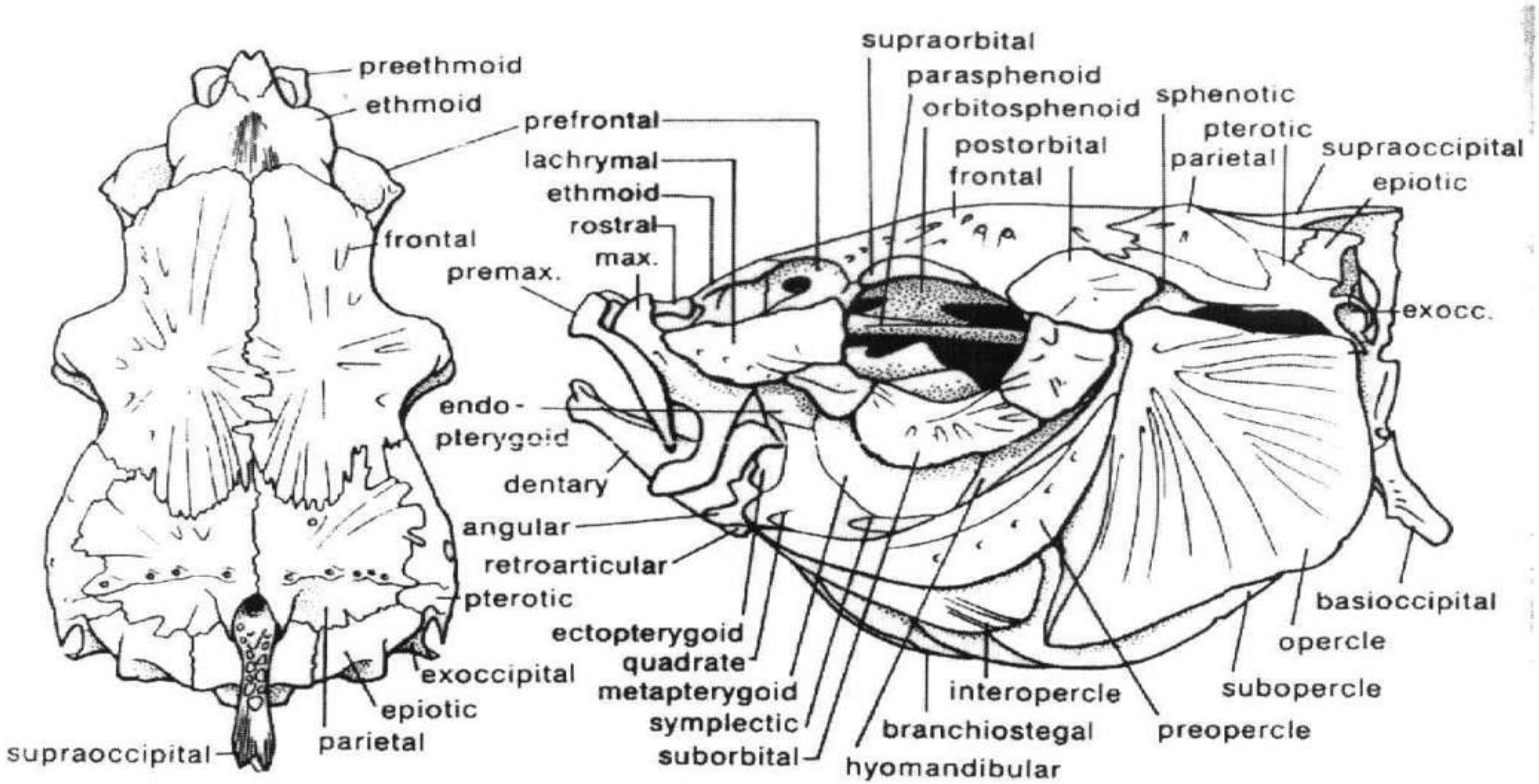


FIGURE 3–4. Schematic diagrams showing relationship of mandibular arch to neurocranium in three types of jaw suspensions. (The mandibular arch has been lowered in *A;* the hyoid arch has been flexed downward in *A* and *B,* and has been lowered in *C.*) *A,* Hyostylic (upper jaw not firmly attached to neurocranium, with ligamentous attachment to hyomandibular); *B,* amphistylic (upper jaw attaches anteriorly to basal angle of neurocranium and posteriorly to postorbital process); *C,* holostylic (upper jaw fused to neurocranium).

Skull of bony fishes



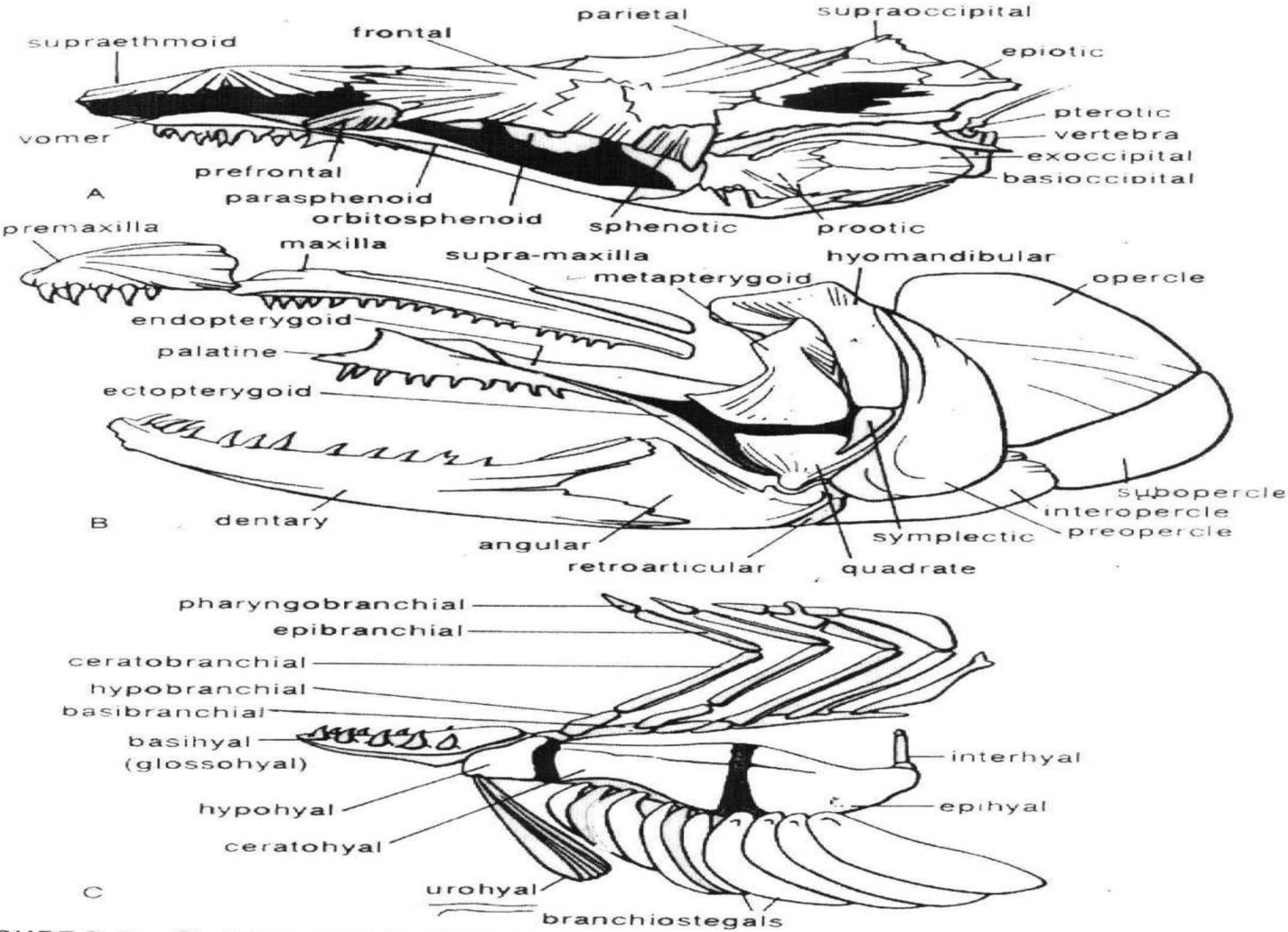


FIGURE 3–5. Skull bones of steelhead trout (*Salmo gairdneri*). *A.* Neurocranium; *B.* jaws, suspensorium, and operculum; *C.* branchiohyoid apparatus.

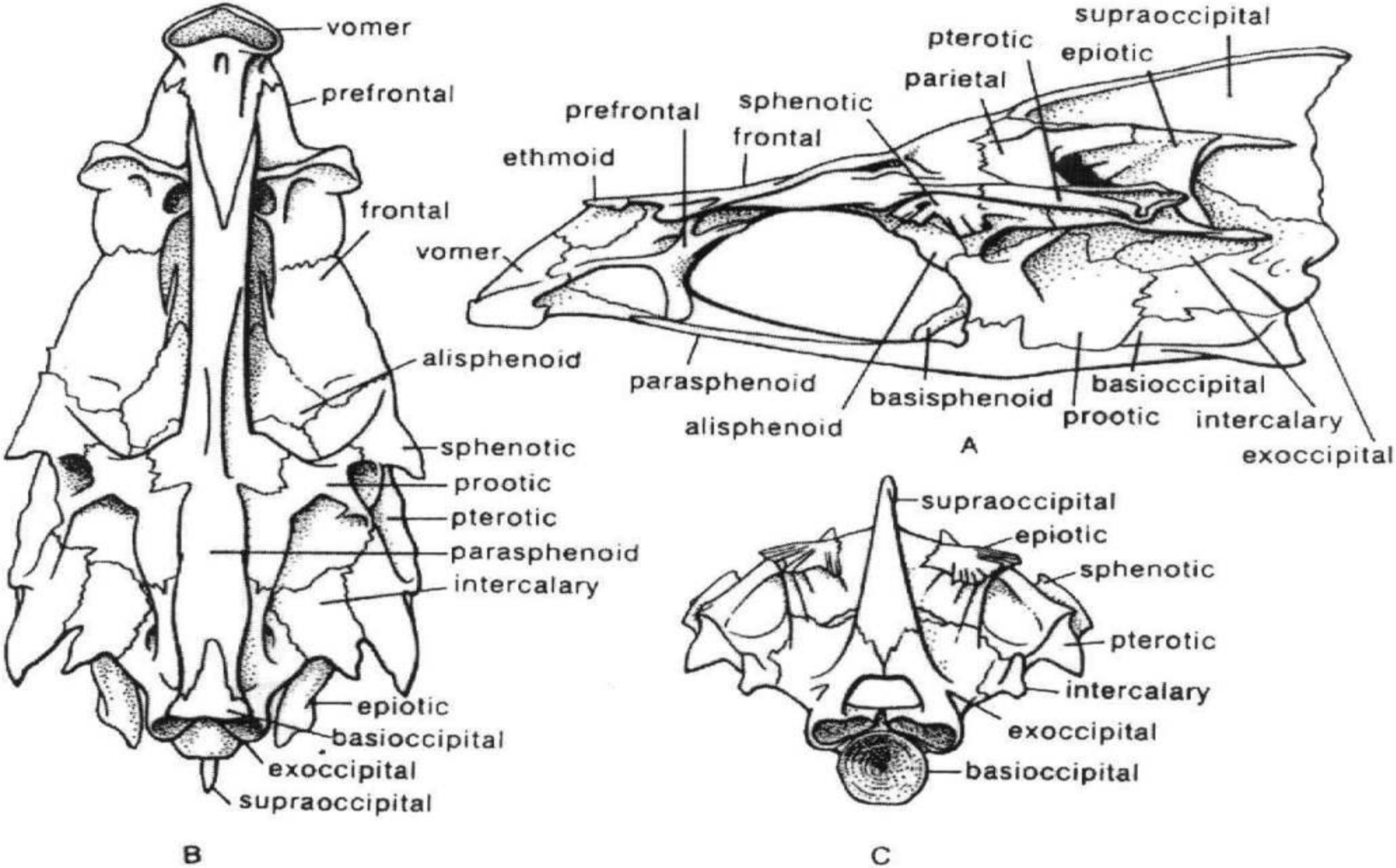
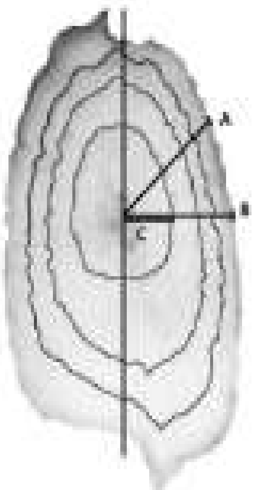


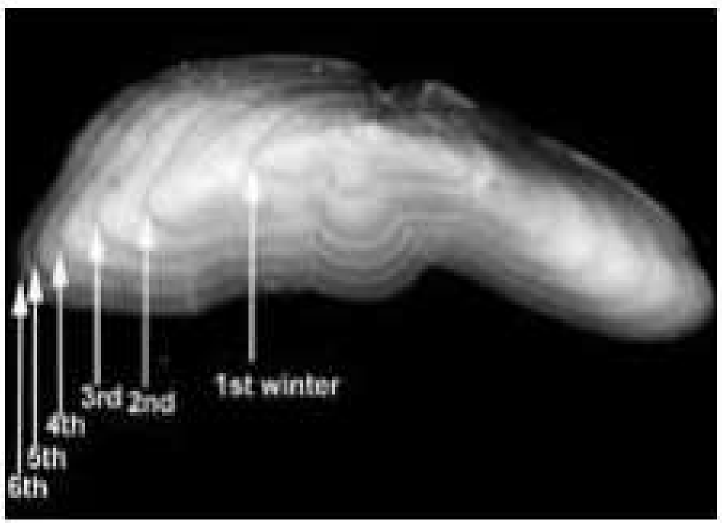
FIGURE 3–7. Neurocranium of percoid (based on *Morone saxatilis*). *A*, Lateral view; *B*, ventral view; *C*, posterior view.

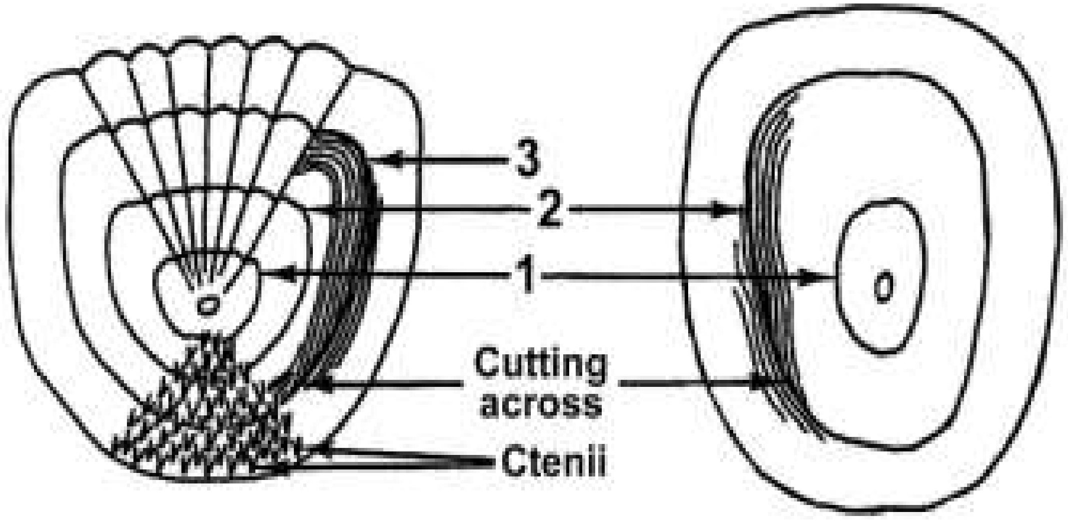
Lecture 6

The Growth

Age and growth Determination in fish







Growth

- Growth is a bio-energetic process and is defined as a change in its length and weight over a period of time. It indicates the health of the individual and of the population and has been extensively studied for a various species of fishes. The growth and age of a fish are closely related to each other and depends on several factors.

- The two parameters exhibit growth of a fish are length and weight. The growth in length indicates long term change, whereas growth in weight is more subject to seasonal variation.

- **Absolute growth**: means the highest or perfect growth of fish from embryonic to senescence period.

- **Relative growth**: means growth comparison from one life period to another. For obvious reasons growth is never similar during any two life periods.

- **Isometric growth**: means fish having equality of measure, having the plane of projection equally inclined to three perpendicular axes at right angles to one another. If the fish is following the cube law, the growth is called isometric.

- **Allometric growth**: it is lopsided growth. There may be various pattern of this type of growth. For example several fish grow more in length than width and weight.

Factors influencing growth of a fish

- Temperature
- Photoperiod
- Quantity and quality of food available
- Dissolved oxygen
- Ammonia in water
- Salinity
- Age and stage of maturity of fish
- Inter-specific and intra-specific competition
- Stocking density
- Disease

Condition factor or Ponderal Index

- The condition factor or Ponderal index, or co-efficient of correlation expresses the condition of a fish, such as the degree of well being, relative robustness, plumpness or fatness in numerical terms. The condition factor used to determined from length and weight of the fish.
- **Ponderal index or condition factor** $K=100W/L^3$

Where **L is length in cms** and **W is weight of fish in grams**. The cube of length is taken because the growth in weight is proportionate to the growth in volume.

- Condition factor is generally used by fish biologist as an indication of the health of a fish population.

- A high value of K shows that plenty of food is available to support both somatic and gonadal development of fish.

- The value of K differ with season and influenced by maturity and spawning. The value of K is maximum during spawning season.

Method for Determining Growth

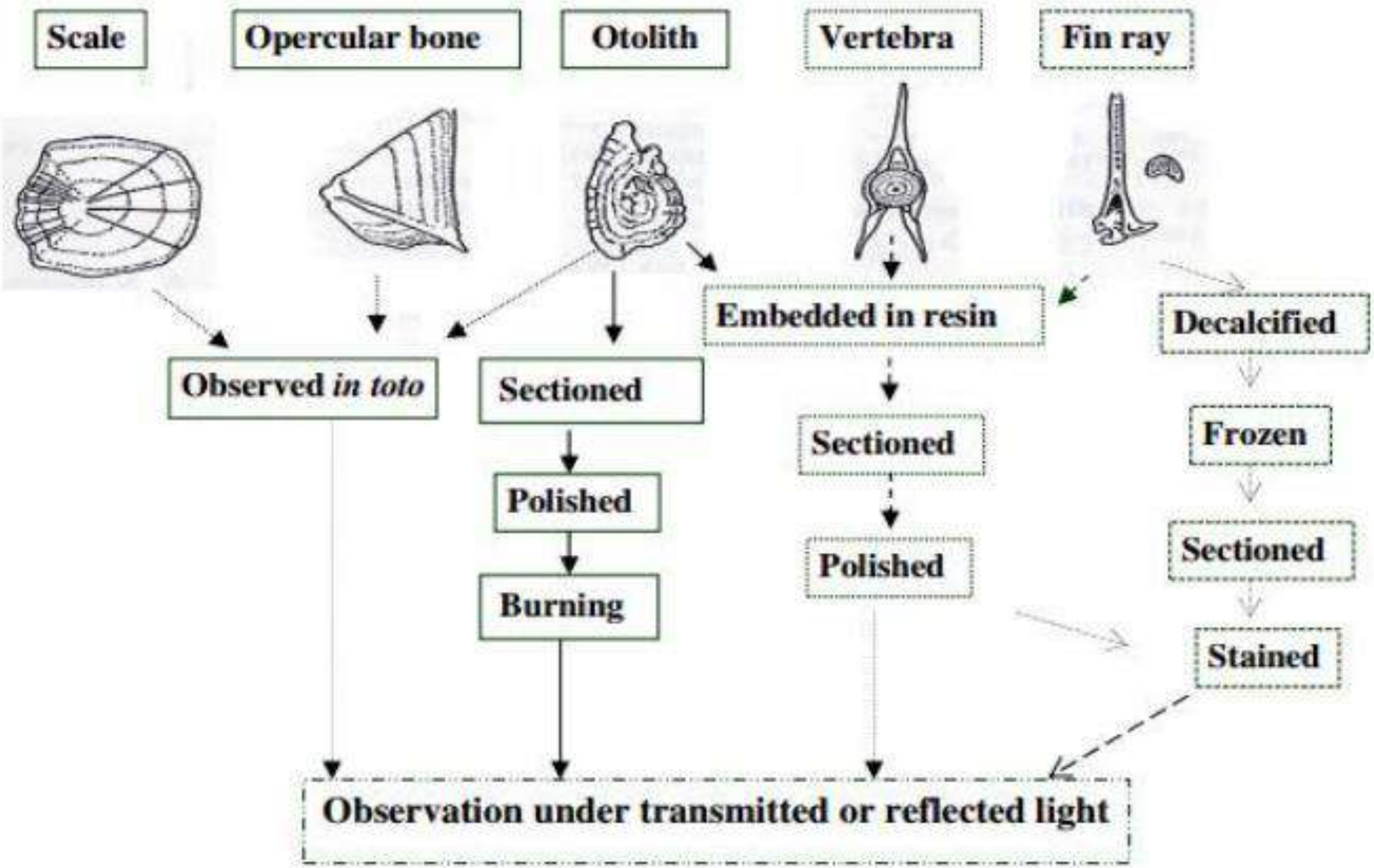
- **Direct method**: Growth rate of a fish can be determined directly by rearing the fish under controlled conditions. For this eggs or larvae of known age are kept in experimental pond. Length and weight of each are measured at known intervals of time for calculating growth rate.

- **Fish marking and tagging**: in this method fishes are marked or tagged after the length and weight for identification and are than released in the natural habitat. After the few months these fishes are recaptured and measured again. The change in size during the interval gives the growth rate.

Method for Determining Age

- By counting rings or annuli on Bones
- By counting rings or annuli on Otolith
- By counting rings or annuli on Scales

Preparation modes for each hard structure



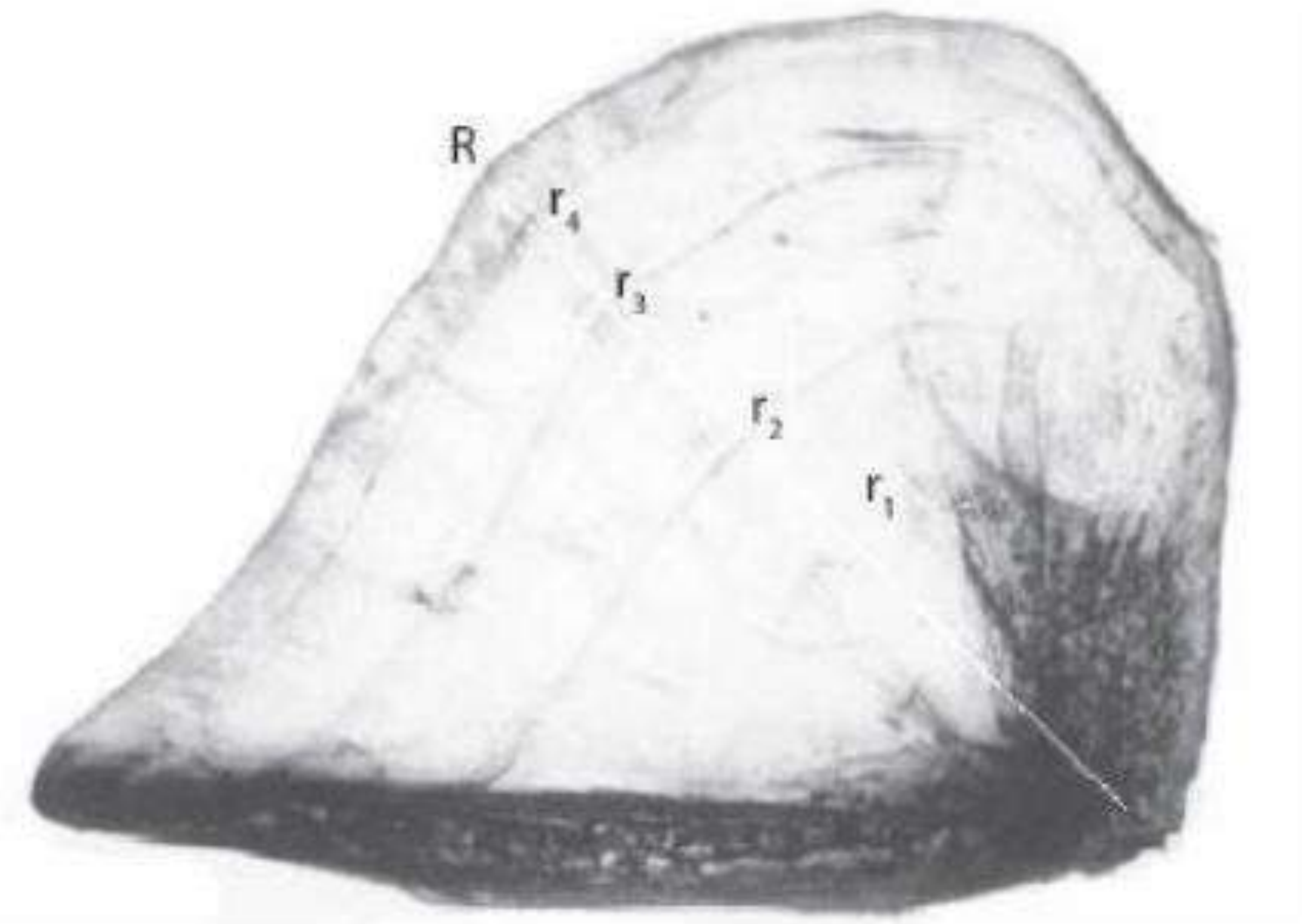
By counting annuli on Bones

- The choice of calcified structures for aging varies among species, a structure used in one species may not be the same structure used in another.

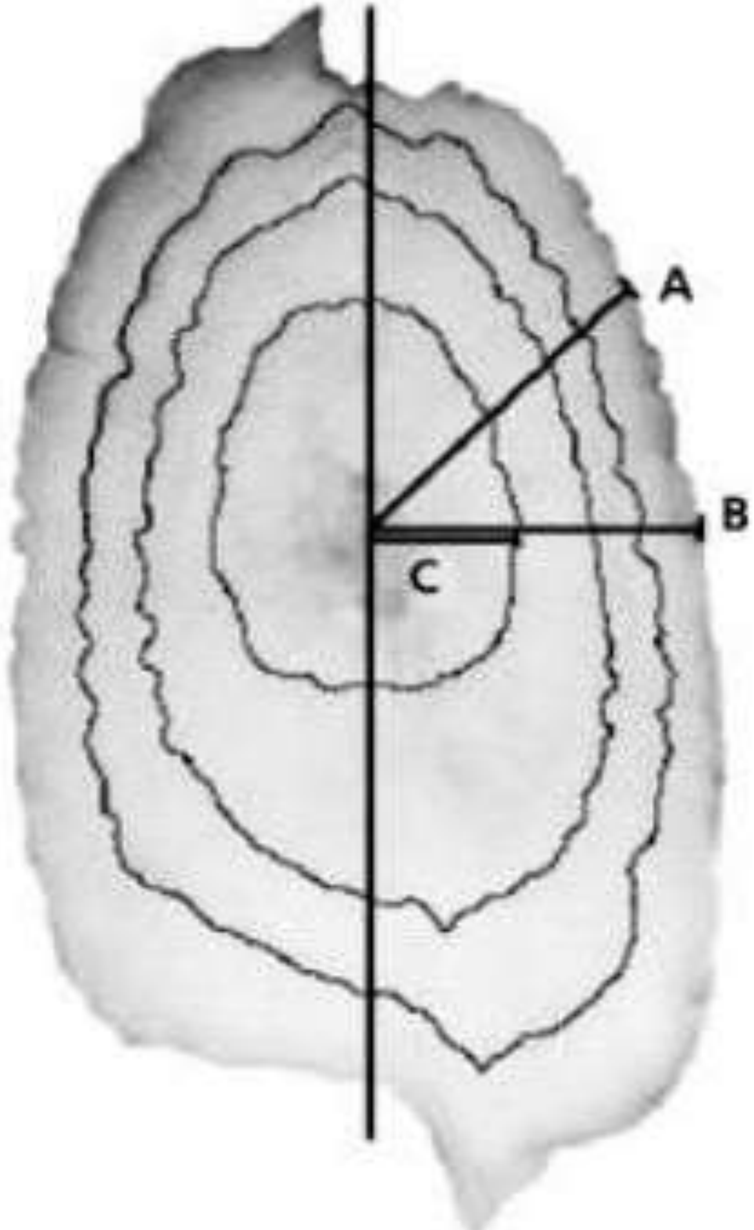
- Not all bony structures lay down growth rings equally. Such bony structures used for age estimation are vertebrae, opercula, fin rays, pectoral spines, among others.

- Preparation for bony parts involves first cleaning by soaking the structure in bleach or boiling to remove soft tissues. Depending on the size, shape, and structure of the calcified aging part it may be examined whole or more likely, sectioned.

Opercular Bone



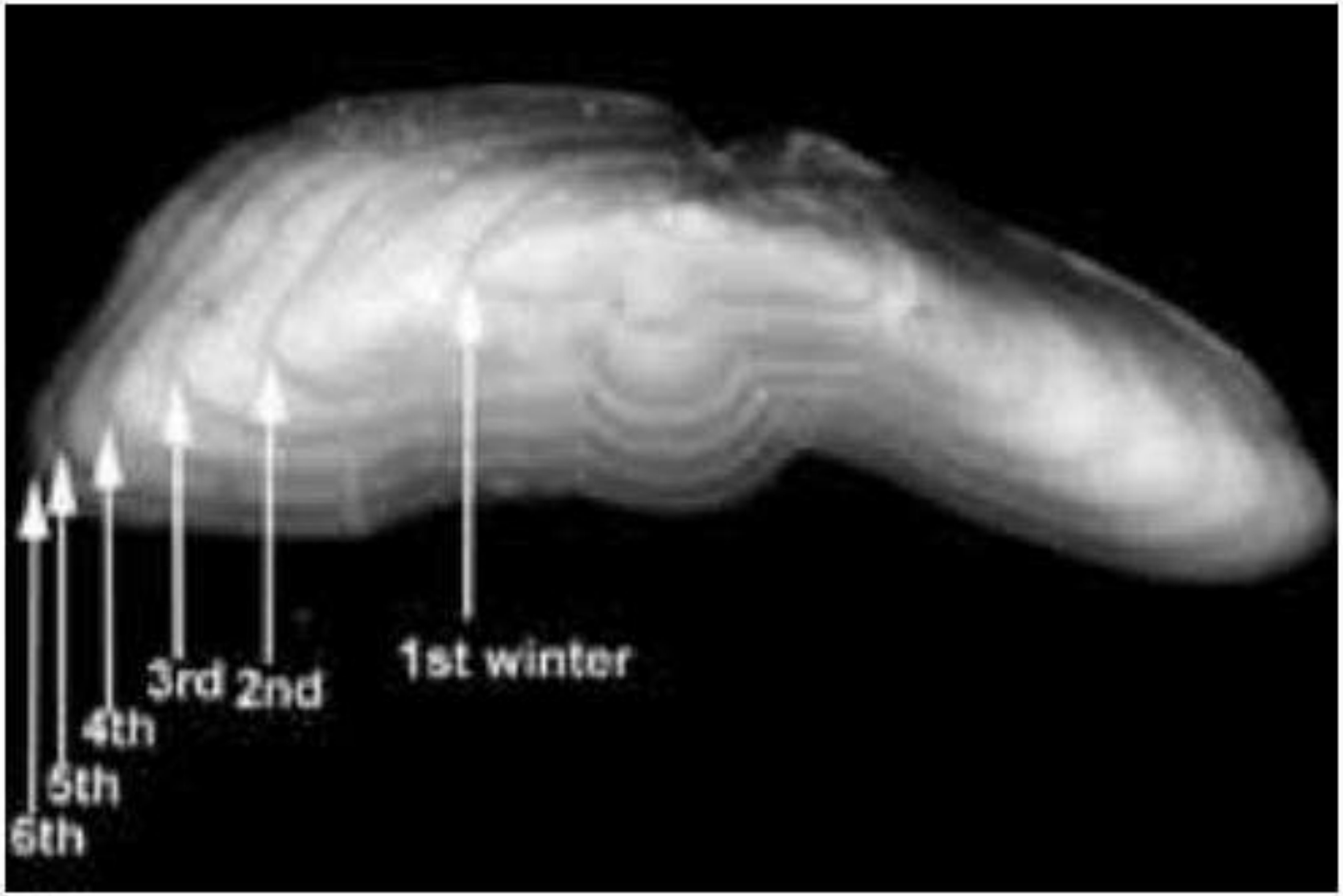
Pectoral Spine



By counting annuli on Otolith

- Otoliths are the earbones of a teleost (bony) fish and are present in pairs; fish have three pairs, the lapilli, the sagittae and the astersci.
- These three pairs of otoliths in teleost fishes differ in form, function, size, shape, and ultrastructure.
- Otoliths are generally easier to read than scales and are more accurate, being internal and never reabsorbing like scales.
- Often the sagittae are analyzed for growth as they are the largest of the three otoliths and therefore easiest to remove.
- When preparing to analyze otoliths, generally if the otolith is <300 mm than it can be analyzed intact, when >300 mm otoliths contain too much three dimensional material and must be sectioned to analyze it more clearly.

Otolith



By counting annuli on Scales

- Scales are the most widely used aging structure because of their non-lethal ease of collection.
- Counting the number of annuli (rings) on a scale provides the fish age and the spacing between rings is proportional to the growth of the fish.
- The general process for scale age analysis preparation is as follows.
- During collection, it is important to make sure to sample the same area on the same side of each individual. Insert the scale into a scale envelope, then press on acetate slides or it can be washed in distilled water and rubbed between the fingers. Mount the scale on glass slides and dry in moderate heat, 37˚C or 100˚ F.
- The annuli may be counted using a microscope, microfilm reader, or other such magnification device.

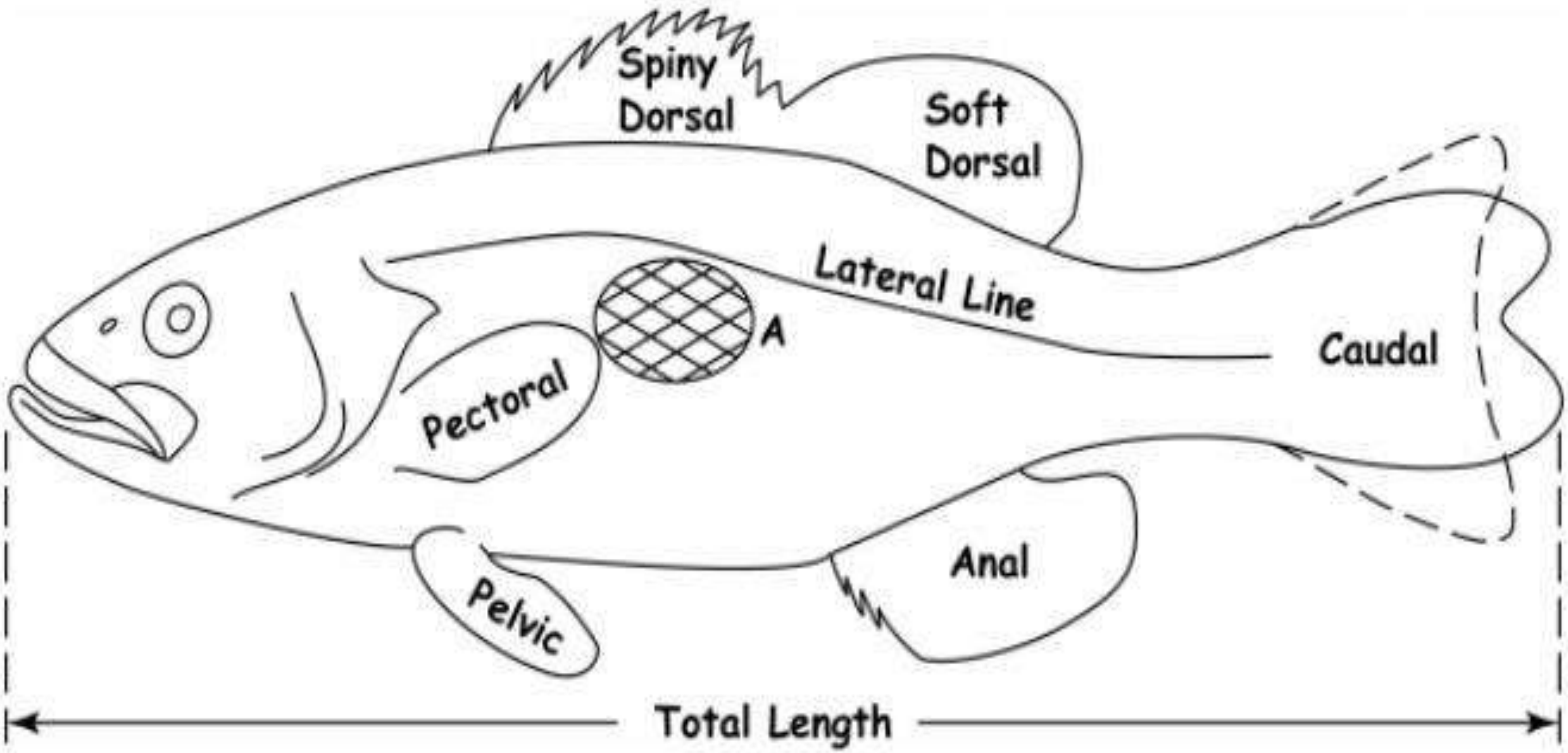


Figure 9.2–Area for taking scale samples from a spiny-rayed fish.

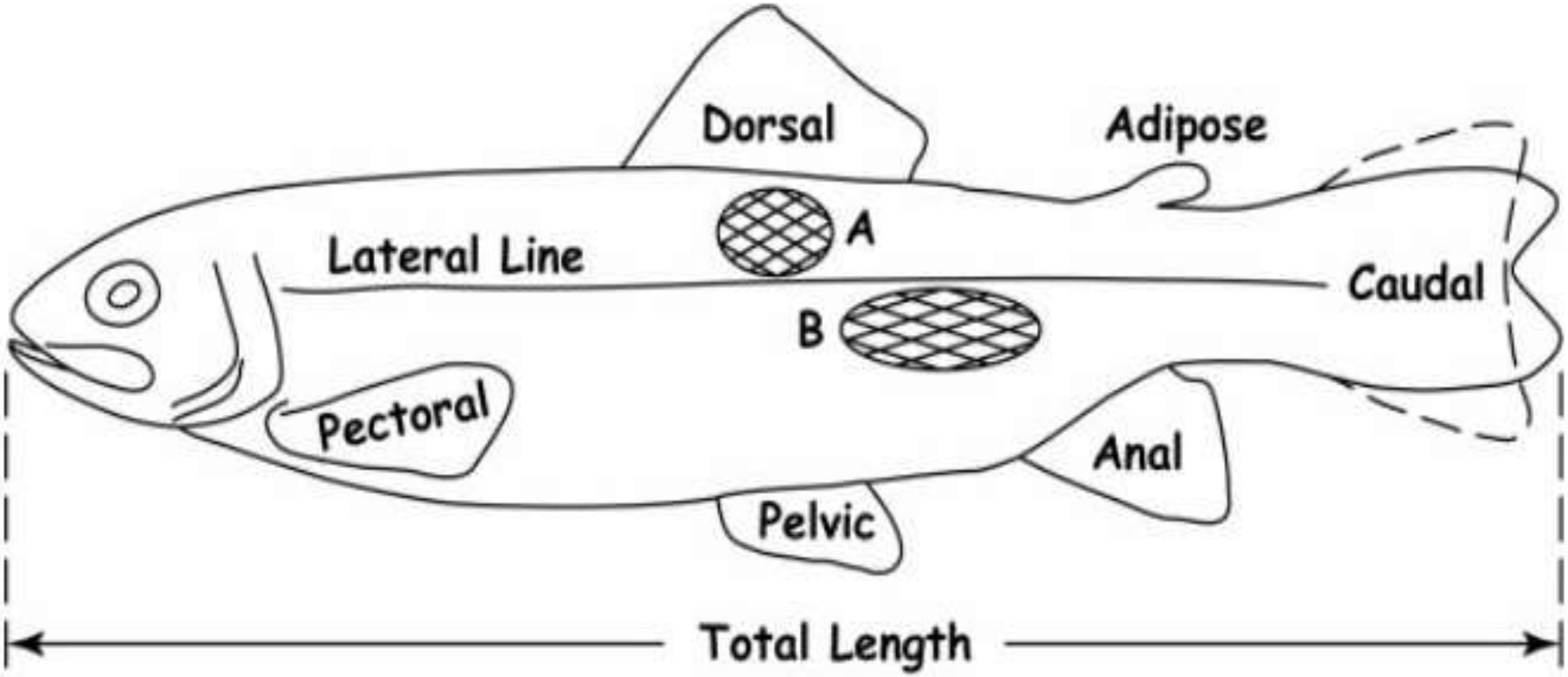
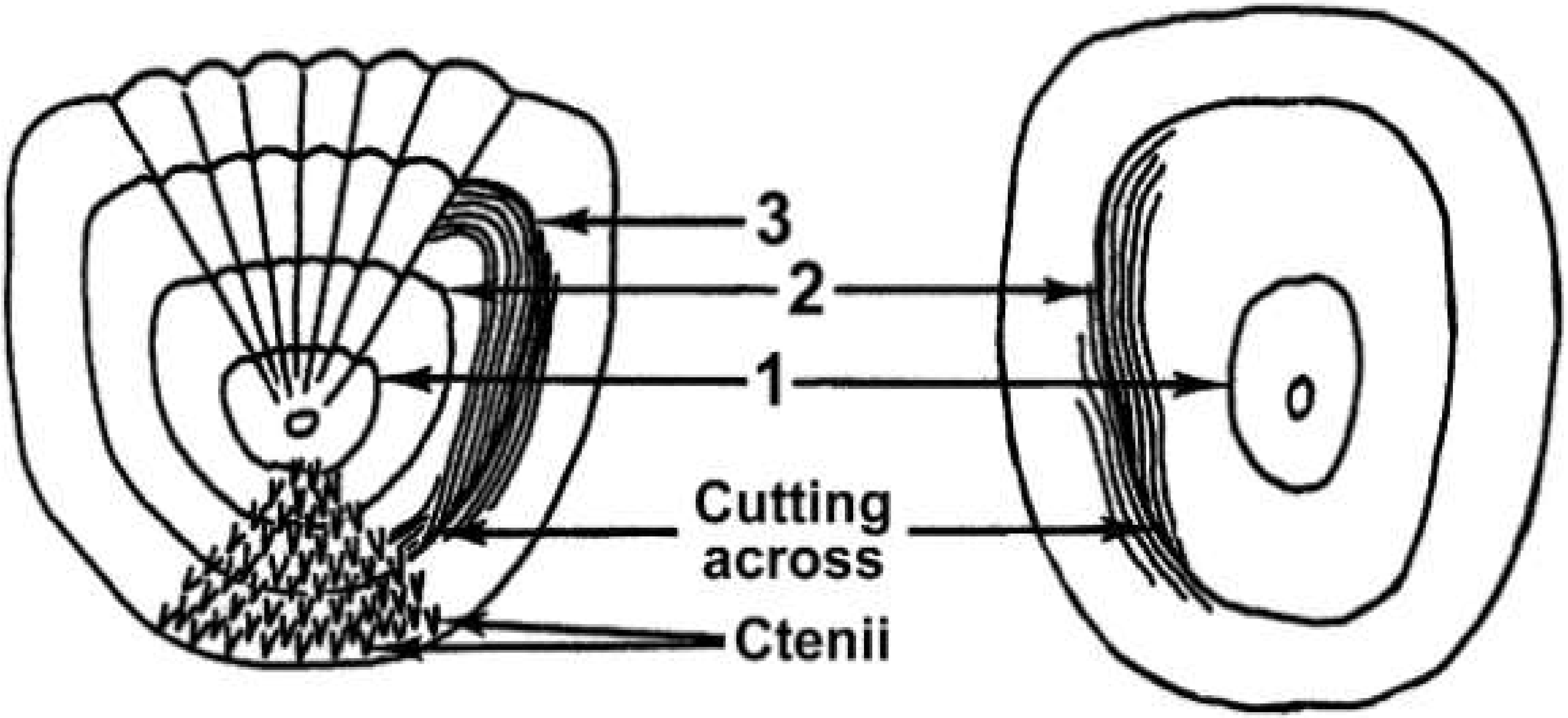


Figure 9.3–Areas for taking scale samples from most soft-rayed fish (A) or trout (B).

Scales



- The age of fish can be accurately determined using a scale. The relationship between body length and scale length (or radius) may be plotted as graph using body length on X-axis and scale length on Y-axis. The following formula used to depict the relationship.

$$\text{Log } L = \log c + n \log S$$

L= body length

S= scale length

c= intercept on the line on the axis of ordinate

n= slope

After the age of the fish has been determined by counting annuli, the fish length at each year can be back calculated by measuring the radius from the focus of the scale to each annulus. Thus the length of a fish at ‘n’ years

$$Ln = a + (L-a)(Vn)/Vr$$

Ln= calculated length of the fish at n year

L= length of the fish at the time of capture

Vn= radius (distance from the focus to the nth annulus)

Vr= scale radius (distance from the focus to edge of the scale)

a= a constant that often approx fish length at the time of scale formation

Lecture 7

Sensory Organs of Fishes

Introduction

- Fish have many well developed senses some such as **sight,** smell ect which are familiar to us and some like the sense which comes from their lateral line which we can only try to imagine.
- Fish rarely rely just one sensory system and can change their responses to events using several sensory systems at once depending on the demands and the sensory environment in which they are in.

Sight

The sight of fishes varies enormously, some species **have excellent vision while other no longer use sight at all like** the subterranean characins of Mexico which although born with eyes they are quickly covered by skin leaving the fish completely blind.

For most fish which live in well lit waters vision is a very important sense for both locating prey and for avoiding being prey.

Most fish which live at sallow depths where light easily penetrates have colour vision although some colours are seen more easily than others because even in fairly shallow water some colours penetrate better than others.

- **Red light penetrates 1 m**
- **Yellow light penetrates 10 m**
- **Green light penetrates 50 m**
- **Blue light penetrates 100 m**

Any fish which had eyes which were adapted to see red would quickly become extinct as it wouldn't see very much in water deeper than 1 m. However fish which are coloured bright red and living in deeper water would be almost invisible. Sharks do not see in colour at all.

As mentioned vision varies with species. Species which live in more open water and have a clear view of the horizon substrate - water or air - water have eyes which are adapted to give a panoramic view of their environment without the need to move their eyes.

- Such adaptions make the eye less sensitive to seeing movement. Species with an interrupted view of the horizon often possess good eye mobility and often have a frontal binocular vision. Some deep sea fish which live at depths where almost no light penetrates have very large eyes which can be 50% the head length these large eyes have a very large lens which is focused on a very small retina and this adaption greatly increases the amount of light reaching the eye.

Hearing

Aulonocara 'Cobue' like all other *Aulonocara* use sensory pores around their head to listen for prey buried in the substrate where they prey would ordinarily be hidden

Although fish don't possess external ears most species have some degree of hearing. Fish of the super order Ostariophysi which contains about 8,000 species which is 28% of all known fishes including some families which will be very familiar to fish keepers Cyprinidae, Characidae, Loricariidae, and Balitoridae have something called a Weberian apparatus.

The apparatus works by sending sound signals straight from the swim bladder, through the Weberian ossicles and then straight into the labyrinth structures of the inner ear. Most sound would go unnoticed but because the swim bladder acts as a resonating chamber the sound waves are greatly amplified. So sensitive is the hearing in some fish that they are able to detect the approximate distance and direction of the source of the sound waves. Most fish have a hearing range between 20 Hz to 1000 Hz compared to humans 12Hz to 20,000 Hz fish have restricted hearing.

Lateral line

The lateral line runs along the length of a fish's body and can easily be seen in most cases. The line is made up of a series of pores each containing a hair like structure (stereovilli) attached to a nerve ending. The lateral line is able to sense minute changes in pressure. This effectively allows the fish to "feel" at a distance. By feeling the difference in each pore the fish is able to tell the direction and distance from the source of the disturbance and this will warn them of any predator trying to sneak up on them even if they don't see it.

Blind cave fish rely extensively on their lateral line

Surface feeding fish are able to locate prey such as flies which have become trapped on the water surface using their lateral line while blind cave fish are able to successfully compete for food in a busy community tank using just their lateral line.

Smell & Taste

The sense of smell is very well developed in some fish and is better not only than ours but it is better than in most mammals. Other species of fish like the family Tetraodontidae have completely abandoned the sense of smell altogether.

Tetraodontiformes like this Pufferfish no longer have any sense of smell at all.

The olfactory organs are located in two pockets on either side of the fish's snout. The pockets are lined with nerves which are highly sensitive to dissolved substances in the water. Fish have two nares on each side of the snout, water enters the first and passes over the sensory nerves and then leaves via the back nare so that the fish is able to pick up any scent dissolved in the water as it swims. The nares are not used for breathing like in mammals. Like some other gouramis the pearl gourami has some taste buds on their long pelvic fins and they can often be observed touching various items in the tank using these fins.

Most fish have taste buds located in their mouth but these taste buds are not exclusively found in the mouth. Taste buds are found on the gill arches, gill rakers, barbels and even some fins but they are absent on the fish's tongue. In cyprinids and siluriformes taste buds cover the entire body of the fish with up to ٣٠٠ taste buds per mm.^{2}

Electroreception
Ampullae of Lorenzini

Like all sharks the black tipped reef shark are very sensitive to minute changes of voltage. They are even able to detect the electricity produced by a heartbeat of their hidden prey.

The Ampullae of Lorenzini is a series of pores found mostly on the head of sharks.

Each pore is filled with a special jelly like substance this Jelly like substance is a glycoprotein based substance with the same resistivity as seawater, and it has electrical properties similar to a semiconductor. There are special receptors in each pore which are called afferent fibers which transmit information to the nervous system.

This is a sense which we can only imagine. The Ampullae of Lorenzini can pick up minute changes in voltage. So sensitive is it that a difference in voltage of just 0.000,000,005 of a volt can be sensed. Sharks and rays use this sense to find prey which has buried itself in to the substrate in an attempt to hide. All living things use electricity to power muscles and it is this slight change in voltage around all living things which sharks and rays are able to sense.

Some other fish have this sense but it is less well developed than in sharks. The other fish include Reedfish, Sturgeons and lungfish.

Coloration of Fishes

1-Subject-Matter of Colouration
2. Sources of Colour
3. Significance
4. Factors
5. Effect of Diet
6. Effect of Water Quality.

Subject-Matter of Coloration:

Majority of fishes are vividly and brightly coloured. Colouration is one of the most common phenomena found among the fishes. The enormous range of colours and patterns that produced in fishes are generally related to their habits. Normally fishes are darker on the dorsal and lighter on sides or ventral side. This gives them protection from above and below.

However, some fishes have uniform colouration as found in the gold fish, Carassius, which has brilliant colour all over the body. The bottom dwellers are often strongly and intricately coloured above and pale below. Variation in colour may be seen in a single fish. The trunk fish (Ostracion) has green body, orange tail and yellow belly with blue bands on the body.

The pipe fish, Sea horse and angler living in weeds, often exhibit colour and pattern similar to weeds. Sometimes they also develop leaf like or filamentous processes on the body. Mahasheer (Tor tor) has dark grey colour on the back with golden or reddish on sides and silver on the abdomen.

However, paired fins are yellowish or reddish. Colour differences in both sexes are quite marked in fishes. The males are generally brighter. Males of small million fish, Lebistes, are variously coloured while females are of a single colour. The variation of colours in males is due to genetic factor of Y-chromosome.

Another important feature is lack of pigment causes transparency in pelagic, free- swimming young's of many species. Similarly cave fishes living in total darkness, do not possess pigment and are colourless.

Sources of Colour:

There are two main sources of colour production in fishes.

These are chromatophores or bio-chromes and iridiocytes or iridiophores.

)I) The Chromatophores:

They are large and branched specialized cells. They are mostly present in the dermis, just beneath the epidermis or scales. They are also present around the brain and spinal cord. Chromatophores may be monochromatic, viz., and possess only one type of pigment, di or polychromatic.

Cytoplasm of chromatophores contains different pigment granules, which are responsible for colour. These are flavines (yellowish green), carotenoides (yellow, red) and melanin (black and brown). Amalgamation of different chromatophores produces a wide range of colour, thus yellow and black (Fig. .(١٦.١)

Chromatophores inter-spread among one another to produce green or brown colour. Many fishes are able to change their colour of the body because of the migration of the pigment within the chromatophore.

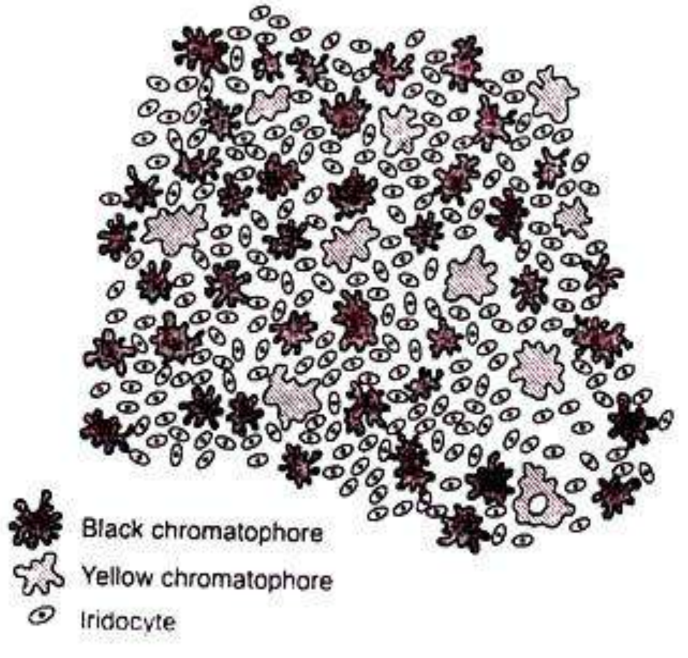


Fig. 16.1 : Coloration elements in the skin of the upper side of a flounder (*Platichthys*) (After Norman)

The pigment granules may disperse throughout the cell or aggregate in the center to give different tone and pattern to the fish. There are four basic types of chromatophores based on colour of pigment granules present therein.

These are erythrophores (red and orange), xanthophores (yellow), Melanophores (black or brown) and leucophores (white). The red and orange pigment granules of erythrophores and yellow pigment of xanthophores mainly consists of carotenoids.

Fish obtain carotenoids through plant food. However, the black pigment of melanin is synthesized from amino acid tyrosine, under the influence of enzyme tyrosinase. Sometimes a brown pigment called eumelanin is also found in the chromatophores.

Pigments of Chromatophore:

Fish chromatophore contains following types of pigments.

Melanins:

The melanin is the brown or black pigment derived from amino acid tyrosine. Melanin is synthesized usually in young melanophore and sometimes in adult melanophore. The first step of melanin synthesis is the oxidation of tyrosine to Dopa(3, 4-di-hydroxy-phenylalnine) under the influence of enzyme tyrosinase.

Dopa further oxidized to Dopa quinone, which is polymerized to synthesized melanin. It is generally considered that higher tyrosinase level causes higher pigmentation in fishes.

Carotenoids:

These are highly unsaturated hydrocarbon compounds containing carbon chain with ring structure at one or both ends.

Carotenoid is found in xanthophores or erythrophores causing red or yellow colour.

Carotenoid is insoluble in water but soluble in organic solvents, hence called as ‘lipophores’, the term widely used to denote xanthophores and erythrophores. It is reported that carotenoids cannot be synthesized in body of fishes and it is derived from food. In some species it comes from the pigment found in the yolk.

Ptridines:

This is a similar compound to purines and flavins. Fishes are reported to have both coloured and colourless ptridines. Drosopterines including drosopterin, isodrosopterin and neodrosopterin are responsible for red colour. However, sepiapterins and iso-sepiapterins are yellow.

Purines:

Guanine is a purine and is responsible for white or silvery tone in fishes. It is found in iridiocytes.

(II) The Iridiocytes:

They are also called as reflecting cells or mirror cells because they reflect light. The iridiocytes contain crystals of guanine, making them opaque and able to reflect light so as to produce either white or silvery appearance.

This material is used in the manufacture of artificial pearls. Iridiocytes when present outside the scales, produce an iridescent appearance and when they present inside them, forming a layer called argenteum produce a white or silvery appearance.

Colour Changes:

Colour change is both short and long term phenomenon due to pigment change. It is both physiological and morphological phenomena. A morphological change is a slow process as it involves formation of pigment granules in cells.

Physiological change is rapid (for a short period within a few minutes) and exhibits rearrangement of pigment granules in the chromatophores. Both of these changes occur due to visual and non-visual stimuli. The later involve nerve and hormones.

Physiological or Rapid Colour Change:

In some fishes rapid change in colour occurs to match the changing surroundings. This type of colour adaptation is done by redistribution of pigment granules within the chromatophores. This type of colour change makes the fish inconspicuous over different backgrounds. The rapid colour change in fishes is known as cryptic or concealing colouration and may be of two types.

(i) Assimilation with Background:

In this type of colouration the fish harmonizes its colour to the background. The most common example of this type is pelagic laptocephalus larvae of eel, which is devoid of pigment. Sea horse and pipefish often have the colour that resembles the seaweeds. The green colour of 'tench' resembles to that of surrounding by assimilation.

Another interesting example of rapid colour change is seen in the flat fish (Pleuronectiformes). These fishes have remarkable matching power. When they are kept on checkerboard, they will, after a short period, develop almost same colour and pattern as that of background.

)ii) :Disruptive Colouration or Breaking Up the Outline of the Fish

The disruptive colouration is beneficial for concealment of fish. This is a sort of camouflage. In this type of colouration the continuity of body adapting different colour and tone disrupts surface or shape. The disruptive outline of the body helps fish to conceal. Various types of spots, stripes, lines and bands of brilliant colours on fish body, break up the outline making the animal less conspicuous.

Sometimes disruptive colouration is used as a special camouflage, in which different parts of the body is concealed. Thus that particular part of the body is prevented from recognition on sight. In Nassau grouper a horizontal coloured line is present in continuation with the body, which makes the eye inconspicuous. Similarly, a vertical line is present in the head of Jack-knife fish, to conceal the eye.

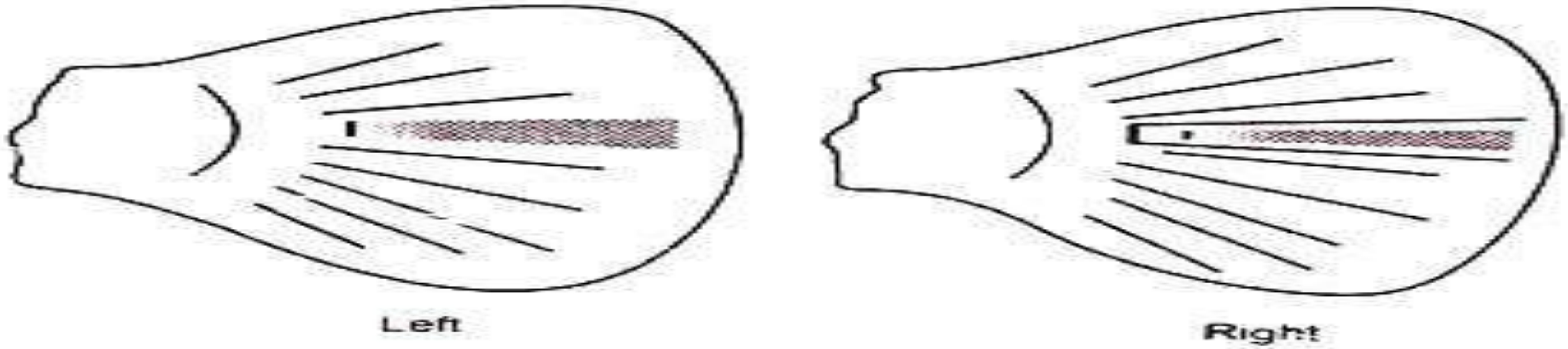


Fig. 16.3 : Diagrams showing, *left*, a cut in th tail of the fish *Fundulus* producing a band of dark melanophores; *right*, when the dark band had faded a second cut makes the melanophores again dark (After Parker, *Quart Rev. Biol*, 13)

(iii) Sematic or Warning Colouration:

Besides concealing, another kind of colouration is sematic or warning colouration. In this type fish is usually adopt striking pattern and colour that reveals the animal then top conceal. This is of special significance for defence, as animal likely to attack are able to resemble the pattern and harmful effects previously associated with it.

Torpedo ocellata has a prominent spot on electric organ for this purpose. In some fishes obliterating colouration is adapted for concealment. The body of fish is counter shaded so that observer gets third dimension of the fish body, which reduces the visibility of fish.

Control of Chromatophores:

The regulation and coordination of colour change in fish is generally by interaction of nervous and hormonal control.

Nervous Control:

The chromatophores are supplied with nerve-fibres (Fig. ١٦.٢), which are responsible for contraction of pigment granules, resulting the paling of skin colour. The nerve fibres are post-ganglionic sympathetic fibres. In some fishes the nerve fibres of any part of skin is cut, the chromatophores of that region expand making area darker.

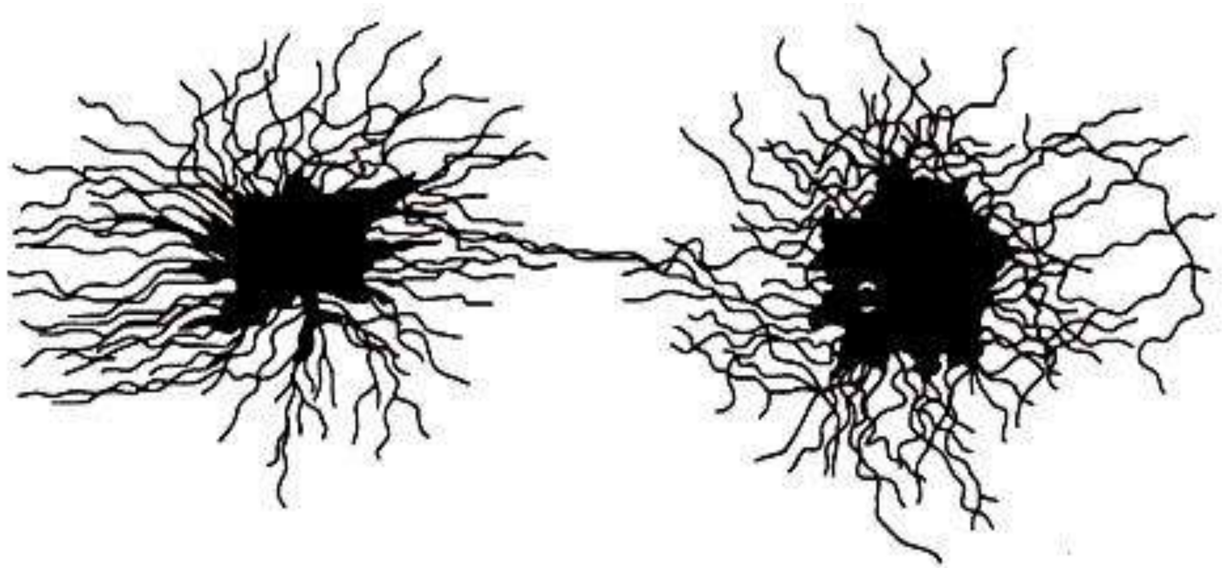


Fig. 16.2 : Nerves of the melanophores of a perch (From Ballowitz)

Hormonal Control:

The colour change is also controlled by the action of posterior lobe of pituitary. It is evidently observed in the Atlantic minnow Fundulus that hypophysectomy result in the lighter body colour than normal individual, due to contraction of chromatophores.

The injection of pituitary extracts causes expansion of the chromatophores resulting dark colour of the body. It is believed that the two hormones of pituitary are responsible for colouration.

The melanin dispersing hormone (MDH), i.e., intermedine causes darkening and the melanin-aggregating hormone (MAH) or W-substance causes paling of the body. It is evidently seen in Scyllum. Although the presence of MDH is found in many teleosts like Anguilla and Fundulus.

In addition to pituitary hormones, adrenaline is also considered to control the action of chromatophore. It has chromatophore aggregating effect. Thyroxin is also believed to be responsible for colour change by effecting chromatophores.

Significance of Colouration:

Colouration in fishes provides them power of adjustment with surroundings and also enables them to survive. The colour of fishes is used for concealment, communication, camouflage, sexual recognition and advertisement, warning or threat. Colouration also has taxonomic value.

Different colour pattern in fish is often considered as character for distinction among species and subspecies. The specific pattern due to exact distribution of chromatophores is under genetic control. The colour pattern is also used in distinction of genera of some species like Channa and Mystus.

- **Factors Affecting the Colouration:**
- There are various factors like temperature, light and stimuli which affect the functioning of the chromatophores. At low temperature chromatophores disperse causing darkening of the body while increase in temperature concentrates the chromatophores with substantial paling of the body.
- The light exerts its effect in two manners. In primary response the light affects the chromatophores by other sources then eyes. By secondary response chromatophores are affected by light through eyes.
- External stimuli like tactile or psychic type also influence colouration of fish. The psychic type also influences colouration of fish. The psychic type of stimuli contribute much for change in colour during mating behaviour of some fishes, when excited, shows psychological colour change in a short time, for example Tilapia.

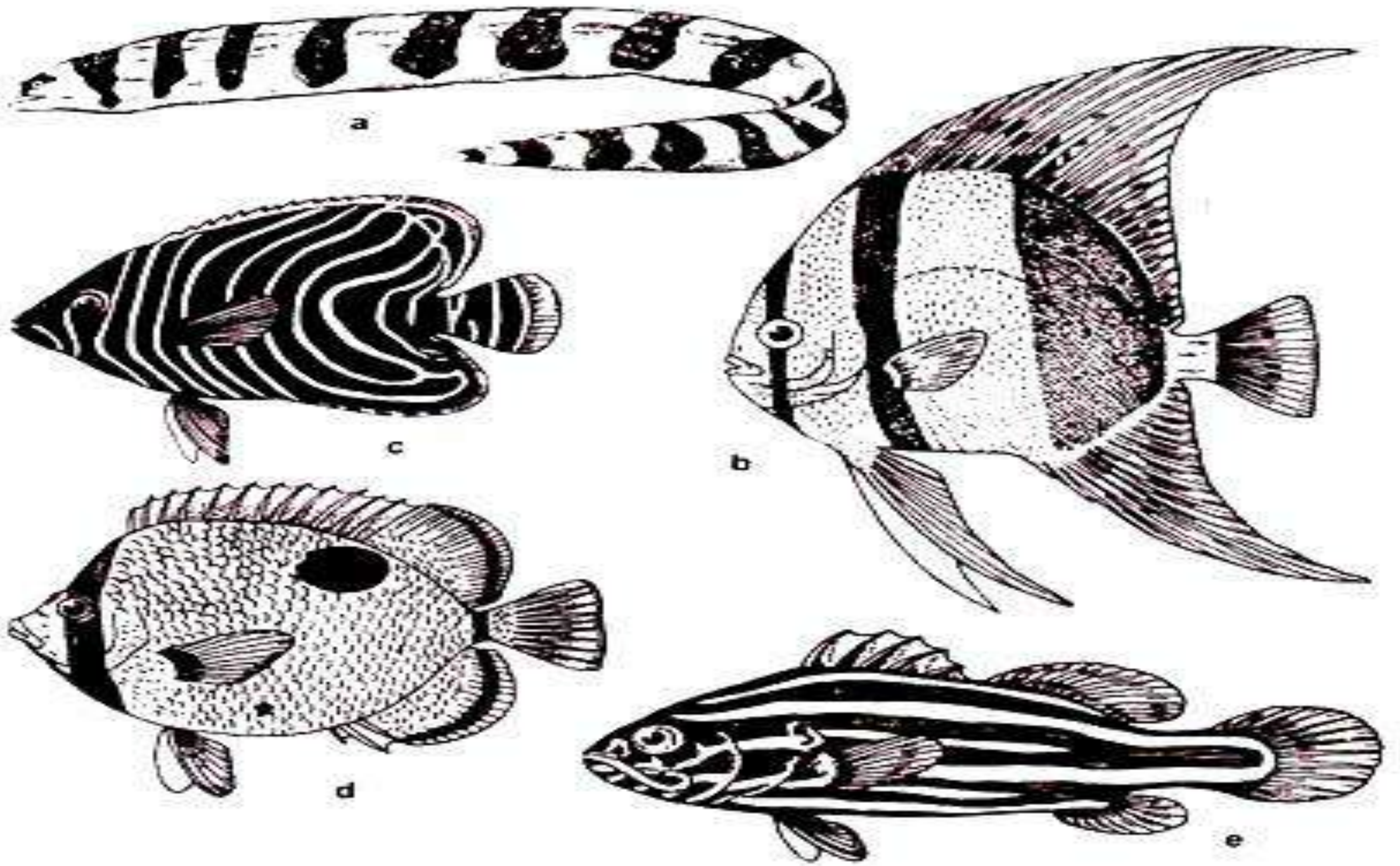


Fig. 16.4a-e : Colour patterns of various tropical fishes.
A, Muraena (*Gymnothorax*); B, bat-fish (*Platax*); C, butterfly fish (*Holacanthus*); D, butterfly fish (*Chaetodon*); E, perch (*Grammistes*) (From Norman)

Effect of Diet on Colouration:

The colour of many fishes is also depends on their diets. Such types of diets may contain additional natural pigments to enhance colours of ornamental fishes. The carotenoid pigment found in most marine and a few freshwater invertebrates is astaxanthin.

This pigment gives the characteristic colour to the flesh of salmon and is available in the diet of aquarium fish in shrimp and krill meals and salmon (fish) meal used as sources of protein in some feeds. Pure astaxanthin or canthaxanthin (synthetic astaxanthin) may also be added to fish feed to enhance red and orange coloration.

Effect of Water Quality on the Colouration:

Water quality may also play a support role in determining the colour of ornamental fish. Degraded water quality increases stress on captive fish and may dull fish colours.

A high quality biological filter and routine at least bi-weekly-water changes will provide an environment enabling fish displaying their brightest colours. Feeding a varied diet rich in sources of pigments along with good water quality will ensure captive fish develop vivid colours.

- These carotenoid pigments are often added to feeds for farm raised salmon and trout to give fillets a desirable red colour. Xanthophylls (yellow pigments) are found in corn gluten meal and dried egg that may be added to the diet to enhance yellows. The ground petals of marigold flowers have also been used as a source of xanthophyll’s.
- The blue-green algae spirulina is a rich source of phycocyanin and may be added to a died to enhance blue coloration. The expense of supplementary pigments often limits the amount used in tropical fish feeds. These natural sources of pigments are in contrast to several methods routinely used to enhance colours of ornamental fish.

Aging

Each fish is born with a fixed number of chromatophores, with this number remaining relatively constant throughout its life. As the fish ages and grows, these chromatophores have to cover a larger area of skin and therefore with some fish, there is a tendancy for the colour to become paler (due to the chromatophores becoming less dense) or to fragment.

Lecture 8

Osmoregulation

Definitions

- Homeostasis = maintaining steady state equilibrium in the internal environment of an organisms
- Solute homeostasis = maintaining equilibrium with respect to solute (ionic and neutral solutes) concentrations
- Water homeostasis = maintaining equilibrium with respect to the amount of water retained in the body fluids and tissues

Definitions, continued

- Osmotic concentration - Total concentration of all solutes in an aqueous solution: measured in units of osmolals = 1 mole of solute/liter of water or milliosmolals = 1/1000th of one osmolal

Osmoregulation in different environments

- Challenge to homeostasis depends on
- steady state concentration of solutes in the body fluids and tissues as well as
- concentration of solutes in the external environment
- marine systems: environment concentration = 34 - 36 parts per thousand salinity = 1000 mosm/l
- freshwater systems: environment concentration < 3 ppt = 1 - 10 mosm/l

Osmoregulation in different environments

- Each species has a range of environmental osmotic conditions in which it can function:
- stenohaline - tolerate a narrow range of salinities in external environment - either marine or freshwater ranges
- euryhaline - tolerate a wide range of salinities in external environment - fresh to saline:
- short term changes: estuarine - 10 - 32 ppt, intertidal - 25 - 40
- long term changes: diadromous fishes

Four osmoregulatory strategies in fishes

■**Osmoregulators:** The animal who can maintain the internal osmolarity different from the medium which they live

■**Osmoconformers:** Osmoconformers cannot regulate the solutes in their body fluids at a concentration different from that of the external medium

1. Isosmotic (nearly isoionic, osmoconformers)
2. Isosmotic with regulation of specific ions
3. Hyperosmotic (freshwater fish)
4. Hyposmotic (Marine fish)

Osmotic regulation by marine teleosts

marine teleost are hyposmotic and live in a medium having high salts concentration

- drink copiously to prevent osmotic dehydation
- Chloride cells eliminate Na^{+} and Cl^{-}
- kidneys eliminate Mg^{++} and SO_4^{-2}

Osmoregulation by marine teleost

1.Oral ingestion:
2.Extrusion/secretion mechanism of salts/ions in gills
3.Absorption and secretion of salts/ions by kidney and urinary Bladder

Osmoregulation by marine teleost continued…….

1. Oral Ingestion

The hyperosmotic external environment withdraw water from the animal across the gill. To compensate this exosmosis marine teleost drinks sea water but this further increase salt content of body.

NaCl and water absorbed across the gut/intestine, Ca^{+2}, Mg^{+2} and SO_4^{-2} are also absorbed in intestine and some amount of Mg^{+2} and SO_4^{-2} excreted rectally.

Ion transportation occurs in teleost intestine. Basolaetral membrane Na^+,K^+ ATPase at serosal side creates transmembrane electrochemical gradient for Na^+ and this drive movement of Na^+ through channels of mucosal side. Na^+ subsequently extruded by Basolaetral membrane Na^+,K^+ ATPase. Cl^- diffuse down its electrochemical gradient or is transported via Cl^-/HCO_3^- or K^+/Cl^- cotransporters.

Osmoregulation by marine teleost continued…….

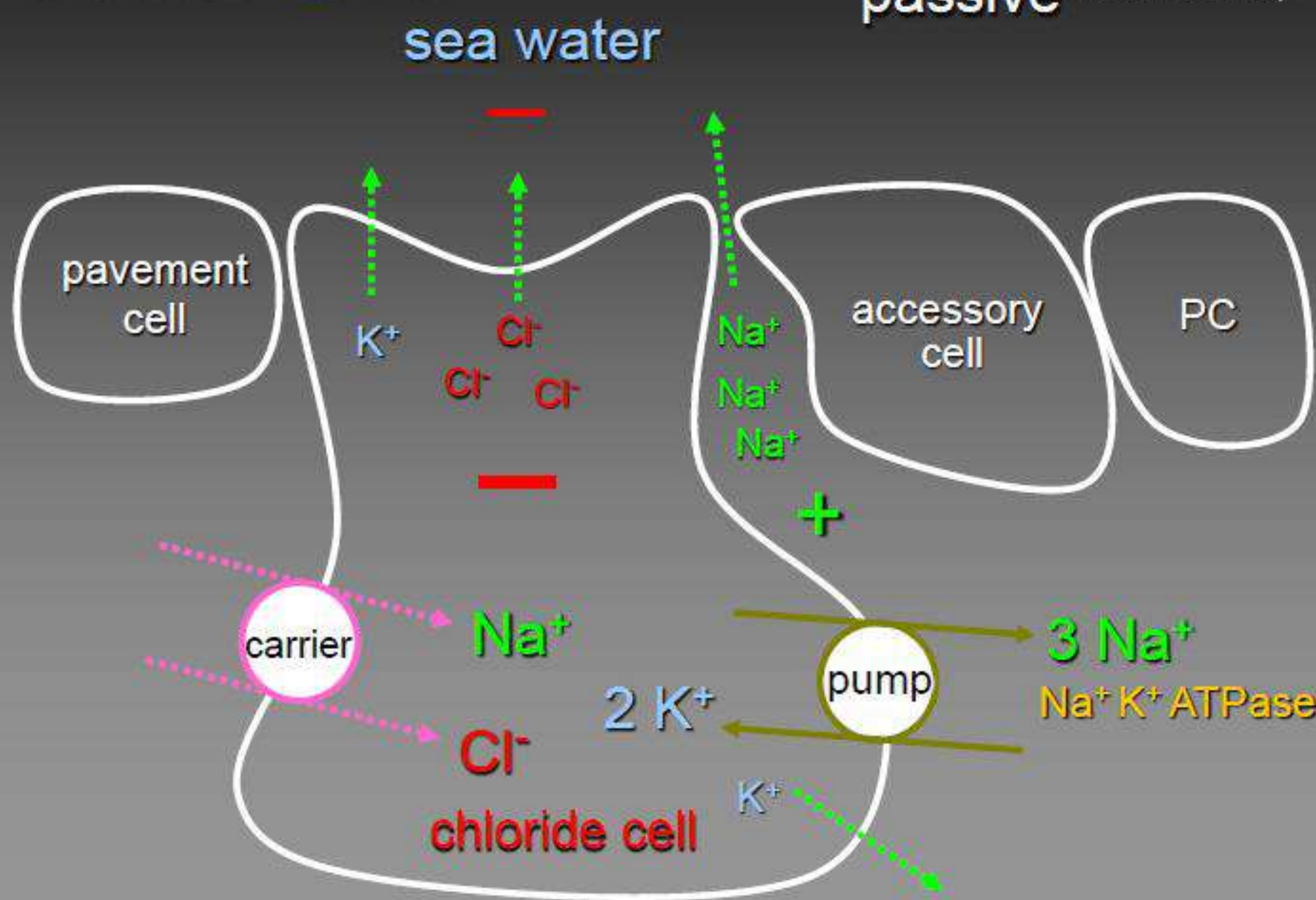
2. Extrusion mechanism in gills

❖Large acidophilic cells, the chloride secreting cells or chloride cella are found in the gills and oral membrane of marine and freshwater teleost

❖ Cl^- is co-transported by Na^+ ,K^+ / Cl^- co-transporters and secreted passively by these cells and rate of secretion is directly related to the number of chloride cells and Na+ also transported by active (Na^+ K^+ ATPase) and co transportation

Chloride Cell

active →
passive ⋯→

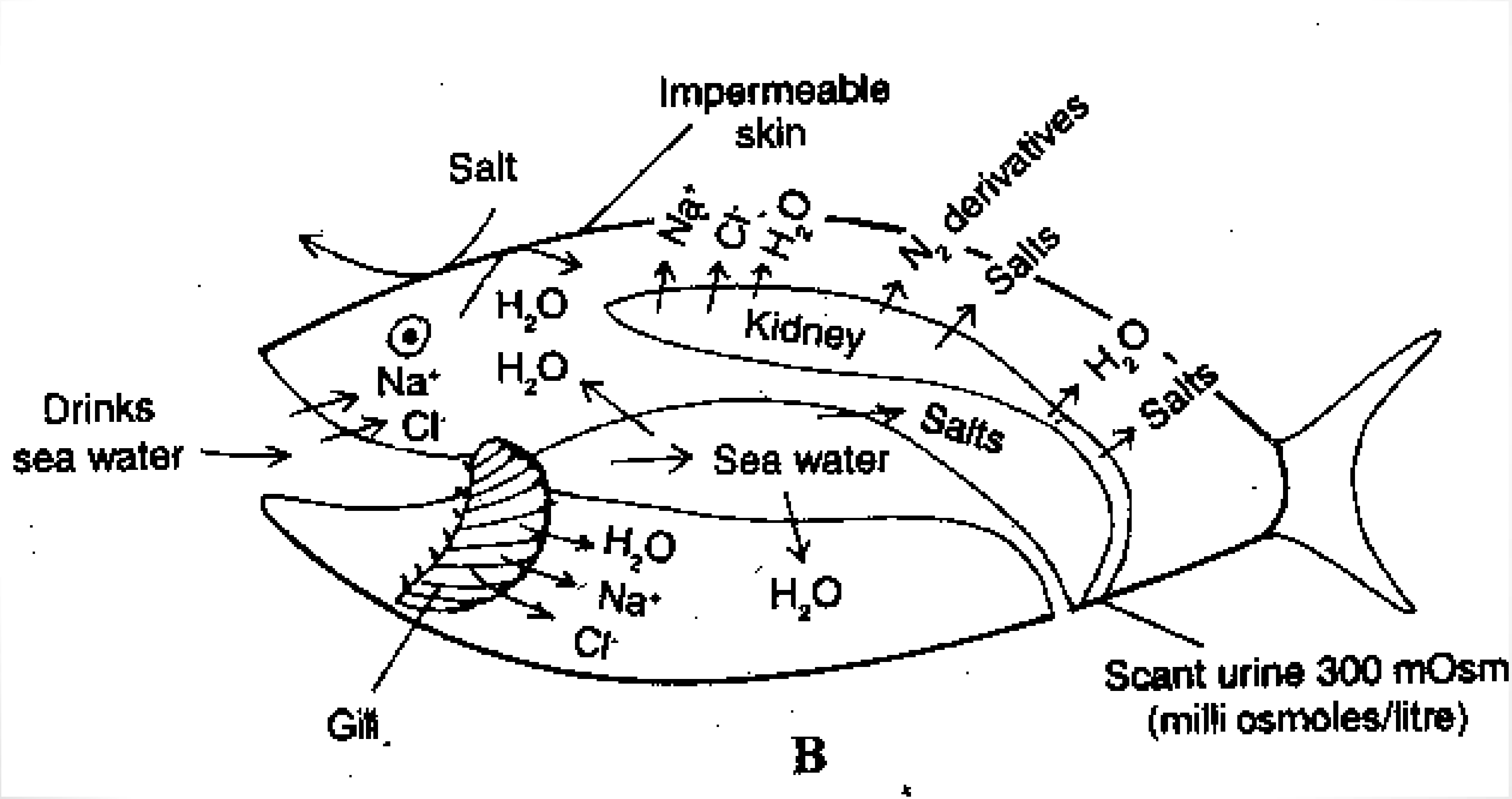


Osmoregulation by marine teleost continued…

3. Absorption and secretion kidney and urinary Bladder

- ❖ Kidney of marine teleost have relatively low number of glomeruli, small in size and reduced rate of FGR and urine flow.
- ❖ Reabsorption of NaCl followed by water in renal tubules
- ❖ Absorption or concenrtration of divalent ions like Mg^{+2} and SO_4^{-2} in urine.
- ❖ Marine teteost excrete very low amount of concentrated urine (300 mOsm or 1% of body weight) in order to conserve water

Saltwater teleosts



Osmotic regulation by FW teleosts

The hyperosmotic internal environment cause an influx of water, mainly across the gills

- To compensate endosmosis they Don't drink water
- Chloride cells work in reverse (Absorption of Na^+ and Cl^- ions)

- Ammonia & bicarbonate ion exchange mechanisms occurs in Chloride cells of freshwater gills

- Kidneys eliminate excess water and produced copious urine

Osmoregulation by Freshwater teleosts

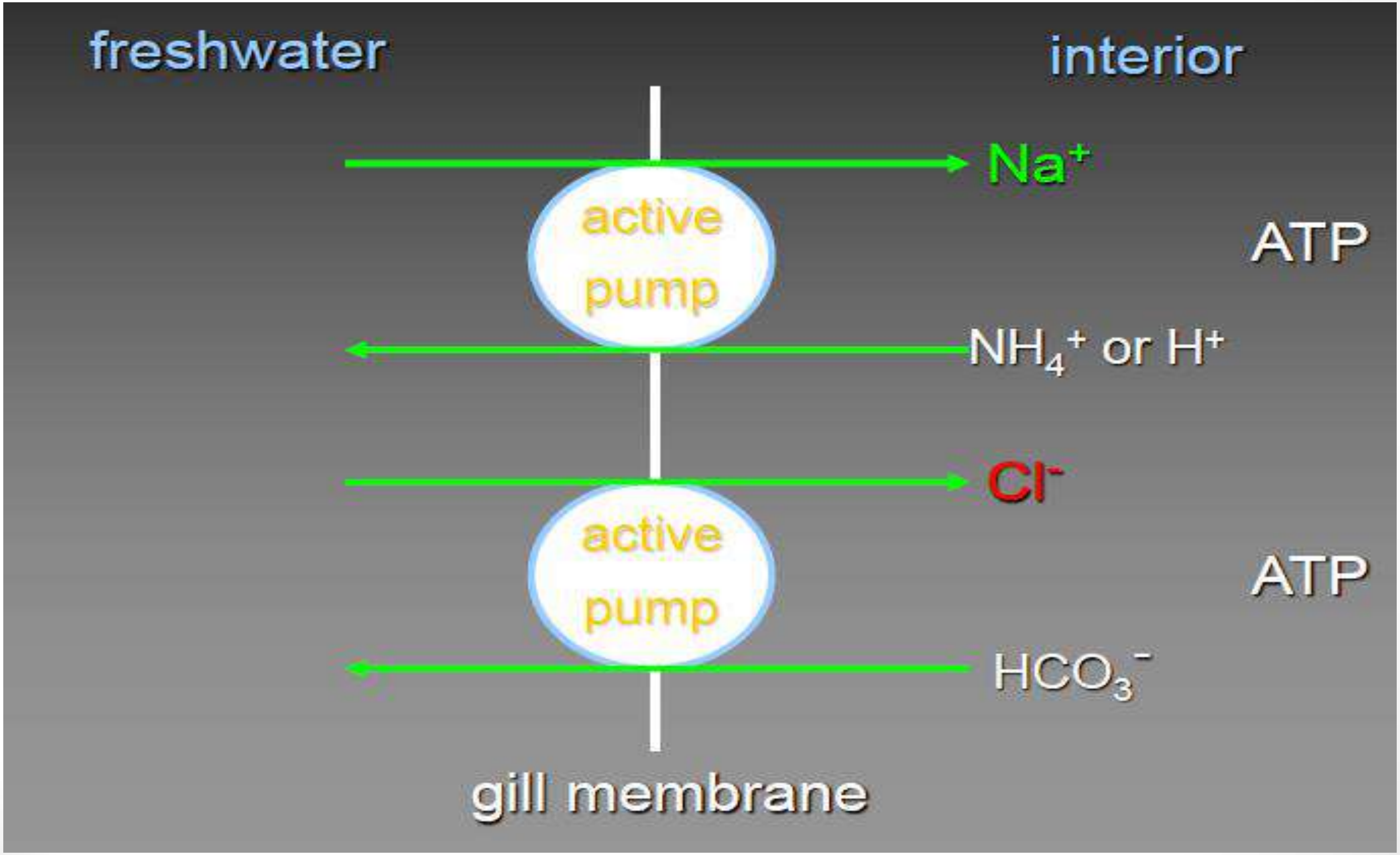
1.Uptake of salts/Ions mechanism by gills

2. Secretion and selective re-absorption in Kidney and urinary bladder

Osmoregulation by Freshwater teleosts continued........

1.Uptake mechanism by gills Hyperosmotic freshwater fishes partially compensate the loss of salts through food and absorption salt ions from the surrounding water mainly by the chloride cells present in the gills and oral membrane Absorption of Cl^- is effected by exchange of HCO_3^- and uptake of Na^+ is effected by NH_4^+ or H^+ by a mechanism present in the chloride cells of freshwater teleost.

Ion Exchange Mechanisms



Osmoregulation by Freshwater teleosts continued......

2. Secretion & selective re-absorption in Kidney and urinary bladder

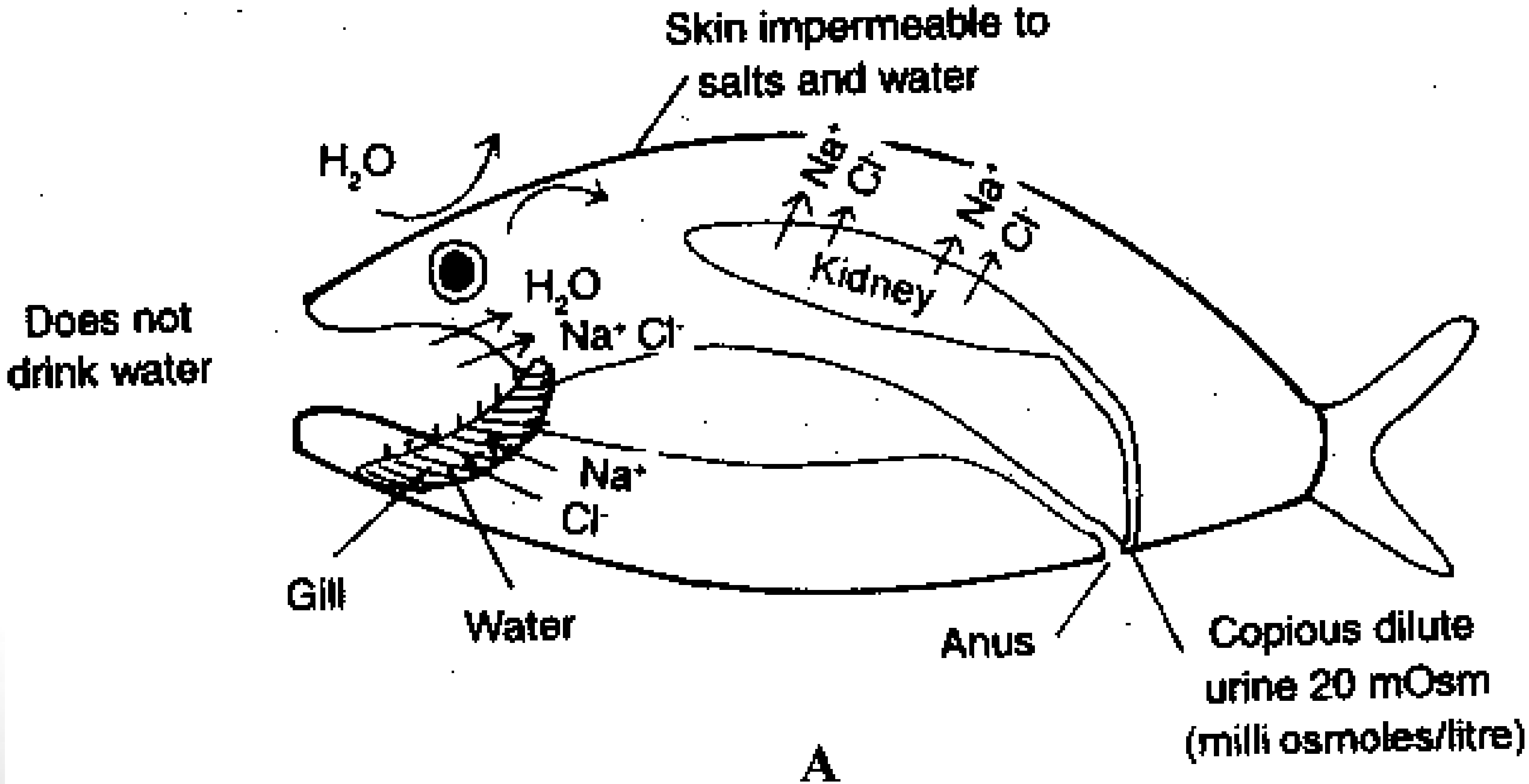
Kidney of these fishes have very large number of well developed glomeruli which has proximal tubule segment I and II, an intermediate segment, distal tubule and collecting duct.

These group of tubules allows almost all the NaCl to be reabsorbed and finally achieving the formation of diluted or copious urine(20 mOsm)

Some salts are lost through faces and also in urine, urine also contain some nitrogenous waste as creatine, creatinine, amino acids, urea and a little ammonia.

Loss of salts through urine is minimized by almost complete reabsorption of NaCl in renal tubules.

Freshwater teleosts



Osmoregulation Strategies of Chondrichthyes (Elasmobranchs) and Coelacanths

Sharks, skates and rays maintain internal salt concentration ~ 1/3 seawater, remaining 2/3 is urea and trimethylamine oxide (TMAO). So total internal osmotic concentration equal to seawater.

Gill membrane has low permeability to urea so it is retained within the fish. Because internal inorganic and organic salt concentrations mimic that of their environment, passive water influx or efflux is minimized

Retension of Urea and TMAO: these fishes retain urea and TMAO in blood by reabsorption of thease solute from urine filtrate by special segment of urinary tubule

Secretion of excess salt by Ractal Glands: Gill of these fishes do not have special salt secreting chloride cells, although some salts are excreted in urine but kidneys are not the major source of excess NaCl secretion. To maintain the salt balance rectal glands secrest fluids containing higher concentration of NaCl.

Osmoregulation Strategies in Hagfishes

Osmoconformes (no strategy) Hagfish internal salt concentration = seawater. However, since they live In the ocean. So no regulation required!

Hagfishes do not drink sea water and their requirement of water for urine formation is met from the blood of the host

Osmoregulation Strategies in Lampreys

They live in both fresh water and sea water and often euryhaline. Regardless of the external environment, they have osmotic and ionic concentration from ¼ to 1/3 that of concentration of seawater

Their osmotic and ionic concentration very much similar to teleost

Control of Osmoregulation

A) Regulatory or Hormonal control

i)Adrenocortical hormone

ii) Thyroid hormone

iii) Prolactin

B) Obligatory factors

i) Gradient between extracellular compartment and environment

ii) Surface/Volume ratio

iii) Permeability of the gills. iv) Feeding

Lecture 9

Endocrinology

Introduction

- The glands that secrete their products into the bloodstream and body tissues along with the central nervous system to control and regulate many kinds of body functions are known as endocrine gland.

- In fishes various endocrine gland has been found associated with different tasks and functions.

Endocrine glands of fishes:

Different types of endocrine glands are found in fishes; such as-

- The pituitary gland or Hypophysis
- Thyroid Gland
- Adrenal gland
- Corpuscles of Stannius
- Ultimobranchial Glands
- Urohypophysis
- Pancreatic islets
- Pineal gland

1. The pituitary gland or Hypophysis:

Location:

Ventral surface of brain below optic chiasma.

Origin:

Two parts of pituitary gland are derived from two different components.

Neurohypophysis develops from the floor of the embryonic diencephalons.

Adenohypophysis developes from the dorsal evagination of the ectodermal part of buccal cavity called Rathke's pouch.

This pouch later looses its connection from the buccal cavity and remains permanently connected to neurohypophysis during the rest of the life.

The hypophysis in adult fish remains attached with it by a stalk is called infundibular stalk or neurohypophyal stalk and occupies a position on the underside of the brain; in the region of diencephalon.

Part and division of pituitary, their cell types, secretions and action of their hormones: The part of this gland their division, cell types, secretion and functions are given below in a tabular form-

Part of Pituitary	Division	Cell types	Secretions	Functions
Adenohypophysis	Proximal pars distalis	Thyrotrophs	Thyrotropins e.g TSH	Regulates the growth and secretion from thyroid
		Gonadotrophs	Gonadotropin e.g. FSH (follicular stimulating hormone) and LH (leutinizing hormone)	Regulates secretion of gonadal hormone, spermatogenesis and oogenesis
		Somatotrophs	Somatotropins e.g.GH (Growth hormone)	Increase growth and BMR of the fish body
	Rostral pars distalis	Lactotrophs	Prolactin	Regulation of osmoregulation and melanogenesis

Part of Pituitary	Division	Cell types	Secretions	Functions
		Corticotrophs	Corticotropin viz. ACTH	Regulates secretion of corticotropins from adrenal gland.
	Pars intermedia		MSH and MCH (melanophore dispersing and melanophore contracting hormone)	Regulates the concentration and dispersion of pigments within melanophores.
Neurohypophysis	Pers-nervosa		Vasopression and oxytocin	Regulates osmoregulation, salt-water balance, mating and egg laying

2. Thyroid Gland:

Origin:

The thyroid gland in fishes arises from the floor of the pharynx as a median evagination.

Location:

The location of thyroid gland varies considerably in different fish species; such as-

- In cyclostomes, follicles of thyroid are dispersed around the ventral aorta and do not form compact capsulated structure.
- In bony fishes, it may lie under the 1st branchial arch on each side.
- In many teleosts, it is found along the afferent branchial arteries of the gills.
- In other teleosts, the follicles of thyroid migrate to distant unusual localities, such as the liver, kidney, brain, eye, gut, spleen, gonad etc. as in platyfish.

Shape:

The shape of the gland is also variable depending on various fish group; such as –

- In cyclostomes, the thyroid is in the form of follicles.
- In many teleosts, thyroid becomes a diffused structure as small masses of follicles.
- In elasmobranches and bony fishes, thyroid is compact structure.
- In dipnoi, thyroid comprises a pair of interconnected lobes.

Histology:

The thyroid gland is composed of a large number of follicles forming a shape of a hollow ball and consisting of a single layer of epithelial cells that encloses a fluid filled space.

These follicles are bound together by connective tissue.

The gland is highly vascular and the epithelium surrounding the follicle may be thick or thin and the height of the cells depends upon its secretory activity.

The epithelium mainly composed of two types of cells- the chief cells are cuboidal or columnar in shape with clear cytoplasm and colloid cells, contain droplets of secretory material.

Secretion:

Chiefly thyroxine

Function:

- Thyroid hormone's role is oxygen consumption in fishes have been pointed out though it lacks consistency.
- Thyroid hormone influences osmoregulation in *salmon* and *Gastrosteus.*
- Thyroid along with other endocrine glands also influences migration in fishes.
- It is also known to effect growth and nitrogen metabolism in gold fish.
- Thyroxine brings about maturation in fishes.
- Scale and bone formation in fishes is also influenced by thyroxine.

3. Adrenal gland:

Adrenal gland in fishes is quite different from that of mammals. The two components of adrenal gland i.e. cortex and medulla are separately found.

Location:

One of three layers of cells lying along cardinal veins in the region of the hemapoietic head kidney.

Origin: Mesodermal layer of embryo

Secretion: Adrenaline, Cortisol

Function:

- Promote utilization of steroid fat
- Carbohydrate metabolism
- Water metabolism
- Protein catabolism
- Sodium retention
- Electrolyte metabolism

4. The Corpuscles of Stannius:

Location:

Attached to or embedded in kidneys of holosteans and teleosts

Origin:

the corpuscles of stannius orginate as outgrowths from the pronephric or the mesonephric duct of the kidney.

Nature: Proteinous

Secretion: Hypocalcin

Colour: Pink or white

Function: Regulates calcium balance

5. The Ultimobranchial Glands:

It is also known as post-branchial bodies or suprapericardial bodies or ultimobranchial bodies.

Location: Sac-like structures between ventral wall of esophagus and sinus venosus.

Origin: Ultimobranchial gland develops embryologically from the epithelium of the last or ultimate gill pouch.

Secretion: Calcitonin

Function: Regulates calcium level in blood.

6. Urohypophysis: It is also known as Urophysis or caudal Neusecretory organ.

Location: This gland is in the form of a swelling at the posterior end of the caudal spinal cord i.e. in the tail of the teleosts.

Secretion: Urotensins

Function: Metabolic regulations.

7. Pancreatic islets:

Location: Gut walls in larval Lampreys; hepatopancreas, most bony fishes

Embryonic Origin: Mesoderm

Secretion: Insulin

Function: Carbohydrate metabolism

8. Pineal gland:

Location/Origin: The Pineal organ of the fish arises as a posteromid dorsal evagination of the epithalamus.

Secretion: Melatonin

Function: Photosensory and secretory function

Lecture 10

Reproduction

Reproduction

Reproduction is the biological process by which new "offspring" or individual organisms are produced from their "parents". Reproduction is a fundamental feature of all known life; each individual organism exists as the result of reproduction

The known methods of reproduction are broadly grouped into two main types:

a) Sexual (Bisexual, Hermaphrodite)

b) Asexual (Parthenogenetic)

Type of Reproduction

1) **Bisexual or heterosexual-** most of the fish (Gonochoristic (single sex, fixed at maturity)

2) **Hermaphrodite-** ***Perca, Stezostedon, Micropterus***

- Simultaneous hermaphrodites function as male and female at same time (23 families; ex. Anguilliformes, eels; Atheriniformes, killifish)

- Sequential hermaphrodites start life as one sex, change sex after maturity
  Protandrous: male first, female later
  Protogynous: female first, male later (most common, Wrasses)

3) **Parthenogenetic (asexual)- (Amazon molly *Poecilia formosa*)**

In parthenogenetic reproduction, unfertilized eggs develop into embryos.

Gynogenetic – sperm needed for egg development, but mating without fertilization, result is daughters are genetic clones of mothers
Hybridogenetic - egg development with fertilization by males of *other* species, but male genes discarded at next generation

Reproduction Strategies

Based on reproductive strategies adopted by different fishes, they are categorised into three groups:

1. **Non guarders**
2. **Guarders**
3. **Bearers**

Non Guarders (they do not guard their egg and larvae) are of two types

i) **Open substrate spawners** (lay eggs in open places)
ii) **Brood Hiders** (lay eggs in hidden places)

Guarders (Male or Female or both the parents guard the eggs and larvae after laying)

i) **Substrate choosers**
ii) **Nest spawners**

Bearers

i) **External Bearers**
ii) **Internal Bearers**

Mating System

- **Promiscuous** - both sexes with multiple partners - most common
- **Polygamy**-Either male or female will have multiple partners in a given breeding season
- **Polygynous** - males with multiple mates (cichlids)
- **Polyandry** - females with multiple mates – few (Anglerfish, males "parasitize" females
- **Monogamy** - mating pair remains together over time, long gestation of young (some cichlids, seahorses, pipefish)

Method of fertilization

- most fishes use **<u>external</u> fertilization**
  - less time and energy in courtship, pair bonding
  - increases number of potential mates
  - greater fecundity

- **<u>internal</u> fertilization** in few groups:
  - sharks, rays, skates, ratfishes (Chondrichthyes)
  - guppies, mollies, etc. - Poeciliidae, Goodeidae
  - surfperches - Embiotocidae

Method of fertilization *cont*……

- internal fertilization requires
  - **lengthy courtship, preparation for mating**
  - **intromittent organ**
    - **claspers (pelvic fins) in Chondrichthyes**
    - **modified anal fin in poeciliids, goodeids**
    - **modified genital papilla in embiotocids**
  - **male structure for storing sperm (seminal vesicle)**

- buccal fertilization

  Sperm swallowing (eg. Callichthyid catfish (*Corydoras*)

Reproduction Methods

1) Oviparous- egg layerer

Producing eggs that develop outside the maternal body (**many bony fishes)**

2) Live bearer

a) Viviparous

fertilization is internal and during gestation, there is maternal-embryonic transfer of nutrients. **Anablepidae, Jenynsiidae, Goodeidae, Poeciliidae**

b) Ovoviviparous

Fertilization is internal, but during gestation there is no maternal-embryonic exchange of nutrients and developing embryo sustain on yolk reserve of oocyte. **Scorpaenidae, Cottidae, Hexagrammidae**

In some ovoviviparous fishes the embryo develops in the egg while the egg is still within its follicular covering within the ovary, and ovulation (or release of the egg) and birth occur at the same time. In other ovoviviparous forms the eggs are released from the protective follicles into the cavity of the hollow ovary, where development continues. In some viviparous fishes the walls of the egg follicle are in intimate contact with the embryo, supplying it with nourishment. In the viviparous sharks, a part of the oviduct, or egg channel, is developed into a uterus, where the modified yolk sacs of the young are closely joined to pockets within the uterus.

Sexual Dimorphism

Most of the fishes exhibit sexual dimorphism or secondary sexual characters by which sex can be distinguished from each other. In few fishes secondary sexual characters are discernible throughout the life span and show some structural differences like

1. Show morphological peculiarities which facilitate fertilization of ova , as copulatory organ in male.
2. Structural peculiarities that are not related to fertilization but are meant for courtship and fighting with other males.

While in some fishes secondary sexual characters are discernible during breeding season and external morphological differences pertain to the following features

1. Size of fish
2. Length/shape/texture of fins
3. Coloration
4. Genital papilla
5. Ovipositor
6. Shape of mouth

Function of secondary sexual characters

a) Recognition of opposite sex, b) helping in the act of copulation such as sexual embrace, c) transfer of spermatozoa from male to female, d) facilitating parental care

Reproductive morphology

- **Cartilaginous fishes:**
  - male: testes -> Leydig's gland -> seminal vesicle -> cloaca -> claspers
  - female: ovary -> ostium tubae -> oviduct -> shell gland -> [uterus] -> cloaca
- **Most Bony Fishes:**
  - male: testes -> vas deferens -> urogenital pore
  - female: ovary -> oviduct -> urogenital pore

Reproductive organ

The fishes have one pair of bilateral gonad. Generally symmetrical.

Suspended from dorsal portion of body cavity by mesenteries in close association of kidneys. Mesentery is richly supported with blood vessels and nerve fibres.

In male mesentery is called mesorchium

In female mesentery is called mesovarium

Male Reproductive Organ

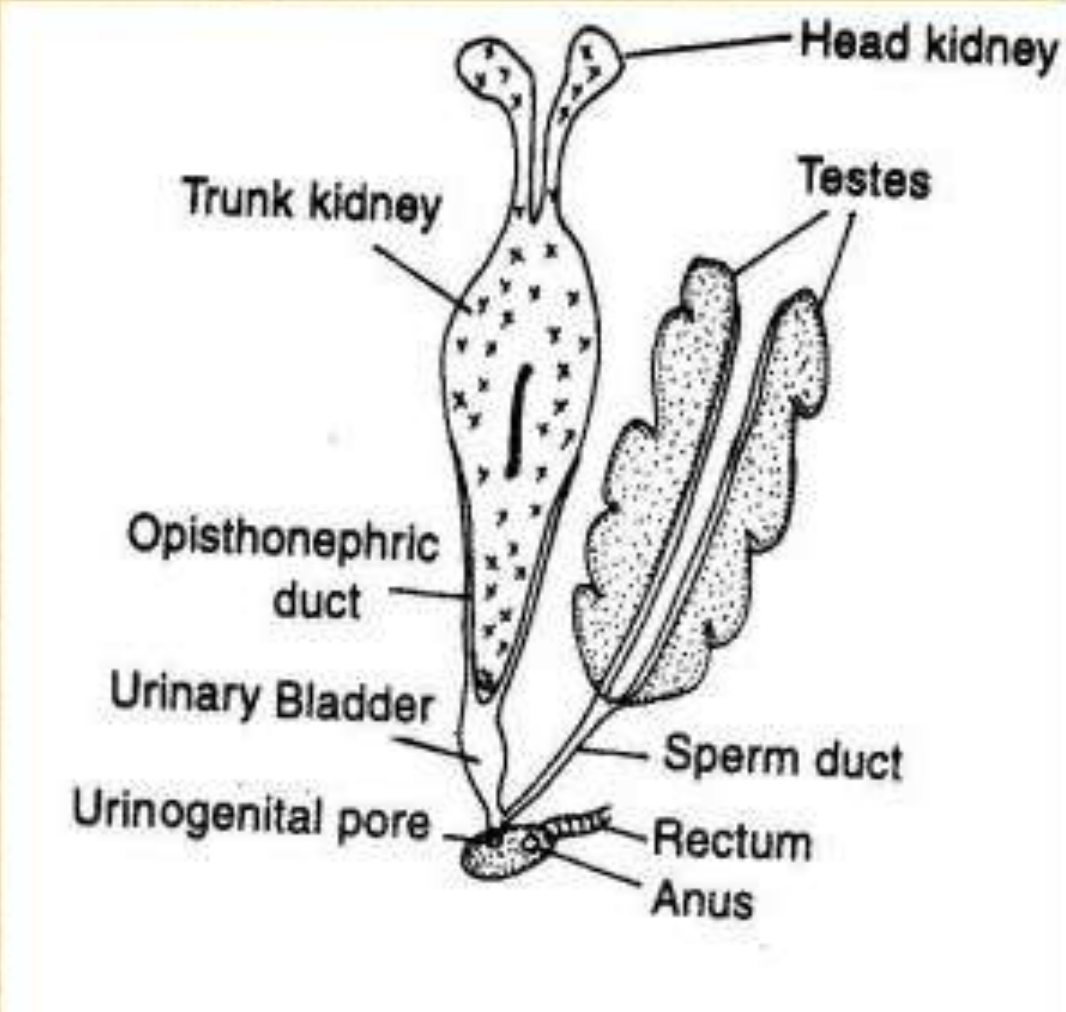
Male reproductive organ Composed of

i) Testis

It is paired, elongated, flattened structure present on either side of ventral to kidney in the abdominal cavity. Attached to the body wall by means mesorchium

ii) Sperm duct or vas deferens

iii) Genital pore or cloaca



Testis

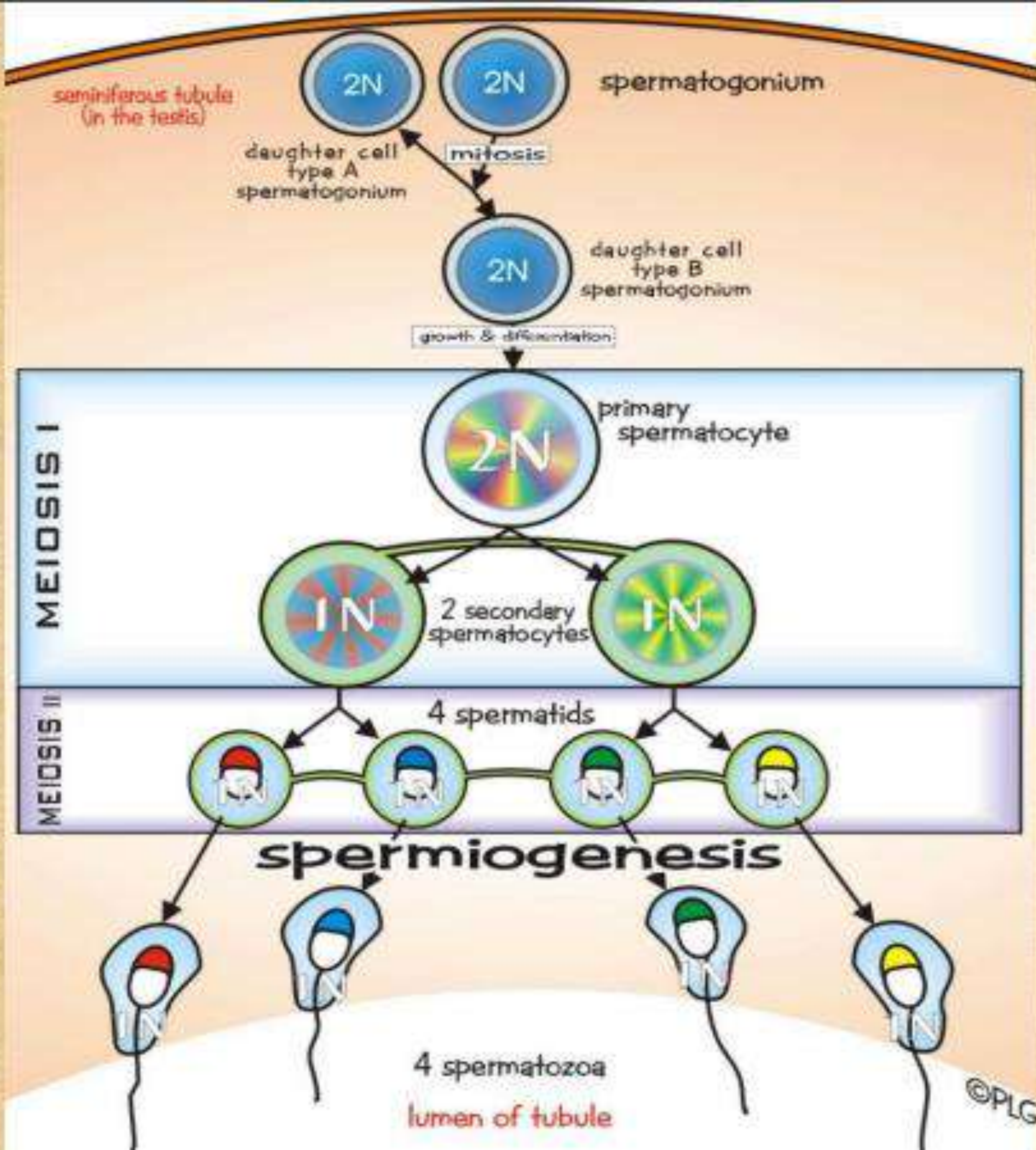
In most cases, testes are a pair of elongated structures composed of numerous seminiferous tubules embedded in the stroma.

The testis consists of thin-walled tubules or lobules that contain germ cells - the spermatogonia - which are endodermal in origin. Germ cells divide in clusters enclosed by a cyst.

Primary spermatogonia - which are present throughout the year, divide mitotically to give rise to secondary spermatogonia which get transformed into primary spermatocytes.

They divide by meiosis and give rise to spermatids from which spermatozoa are formed.

The seminiferous tubules are packed with spermatozoa in the pre-spawning and spawning periods,



Development of sperm or spermatozoa from primary germ cell or spermatogonium is called **spermatogenesis**

Spermatids undergo metamorphosis to produce sperm and this process is called **spermiogenesis**

Structure of sperm

a) Head piece

b) Middle piece

c) Tail

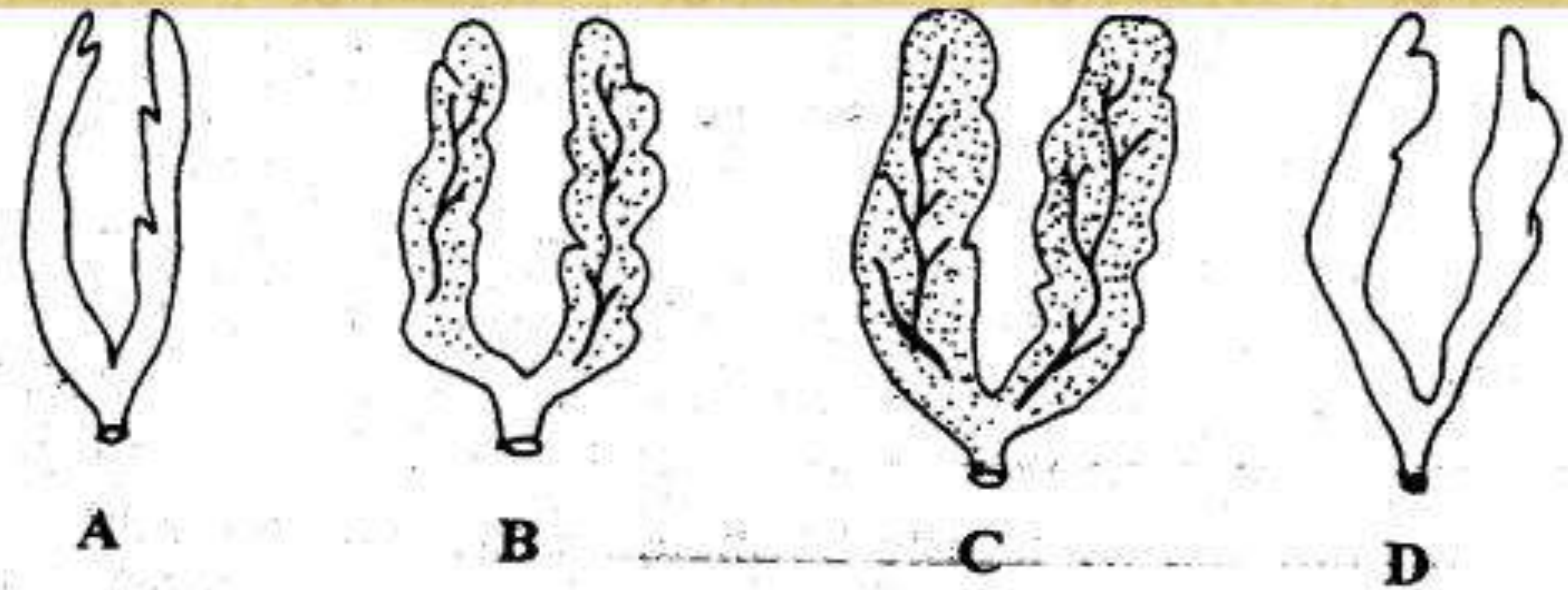
In fish sperm, acrosomes are absent

Reproductive cycle (Testicular)

Most of the fishes breed in one season every year (**seasonal spawners**) and some breed through out the year (**year round spanwers**). Seasonal breeders exhibit rhythmic changes in the structure and physiology of ovary and testes in different seasons. These changes in testis are demarcated into five phases

1. **Resting phase:** Testis remain in immature state, Seminiferous tubules are solid being filled with spermatogonial cells
2. **Preparatory phase:** During this phase cell proliferation and 1st and 2nd meiotic division occur as a result primary spermatocytes, secondary spematocytes and spermatids are produced **(spermatogenesis)**.
3. **Mature Phase:** during this spermatids undergo further development and metamorphosis and develop into mature spermatozoa or sperm. The preocces of development of spermatozoa from spermatids is called **spermiogenesis**.
4. **Spermiation Phase:** During courtship and mating process, male eject milt (spermatozoa in seminal fluid) out of its body through genital aperture to fertilized the eggs released by female. The seminal fluid is mostly secreted by the cells lining the vas deferens (sperm duct) and provide nourishment to the mature sperm. Both spermatogenesis and seminal fluid secretion are under control of gonadotropin of pituitary gland and male hormone testosterone.
5. **Post spermiation phase**: during this phase testis is characterized by the presence of evacuated seminiferous tubules.

Maturity stages of testes



Showing seasonal changes in the testes; A Immature (Resting), B Maturing testis, C Mature testis, D Spent testis.

Female Reproductive Organ

Female reproductive organ Composed of

i) Ovaries

It is paired, elongated sac like structure present on either side of ventral to kidney in the abdominal cavity. Attached to the body wall by means mesovarium

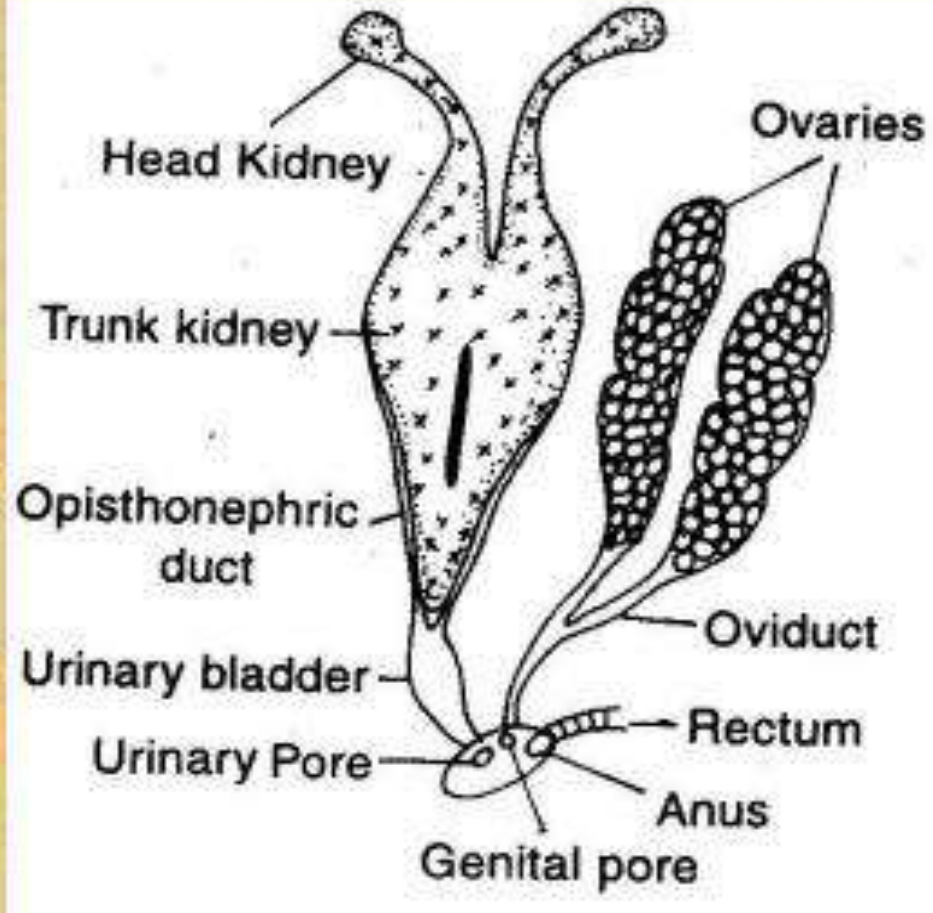
ii) Oviduct

iii) Genital pore or cloaca

Types of ovary:

1.Cystoarian: mature oocytes released in to ovoceal that is continued as oviduct to open into exterior (*Lepidosteus* and Teleost fishes)

2. Gymnoarian: mature oocytes released into body or coelomic cavity from where they passout through genital aperature (Chondrichthyes, Dipnoi, Chondrostei and *Amia*)



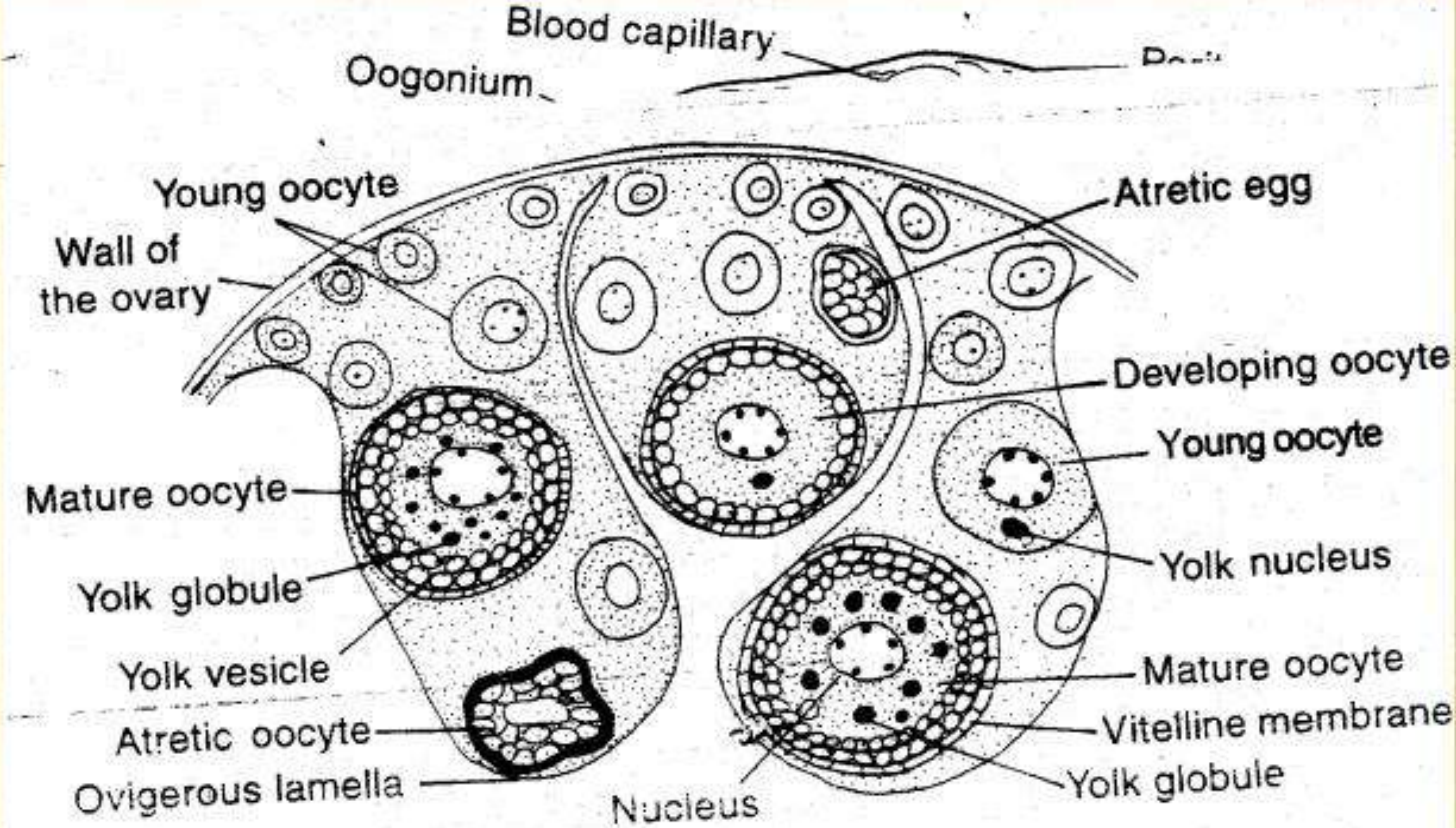
Ovary

The ovary in most teleost fishes is a hollow sac-like organ into which extend numerous ovigerous folds (lamellae) lined by germinal epithelium.

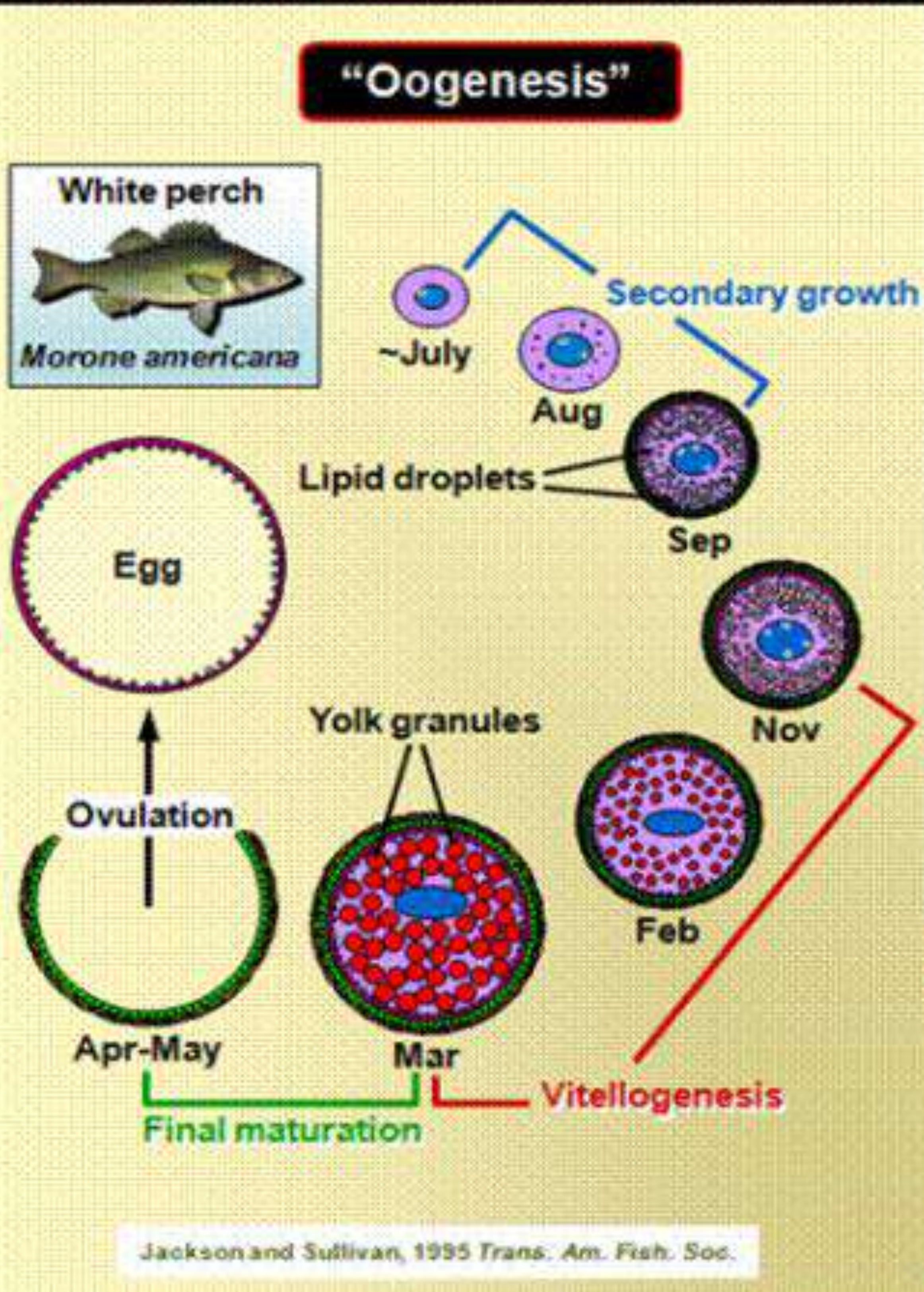
The germ cells, oogonia (originate from germinal epithelium) multiply mitotically and get transformed into non-yolky primary oocytes

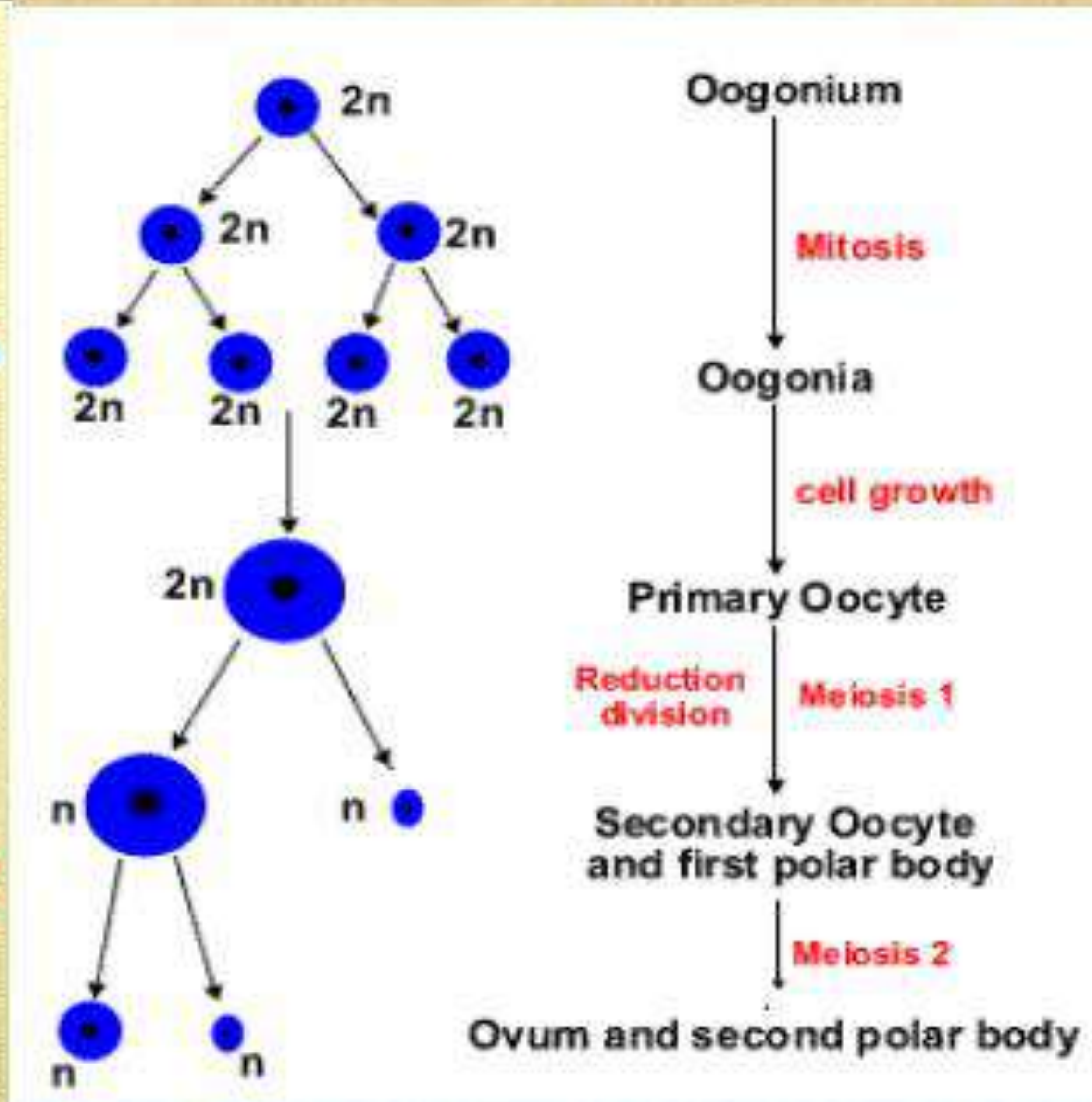
Primary oocytes, covered generally by two layers of follicle cells, an outer thecal layer and an inner granulosa layer, undergo vitellogenesis when yolk is deposited in the ooplasm.

Analysis of yolky eggs indicates that the egg-yolk is composed of lipovitellin and phosvitin, the former is rich in lipid and poor in phosphorus and the latter is rich in phosphorus and poor in lipid



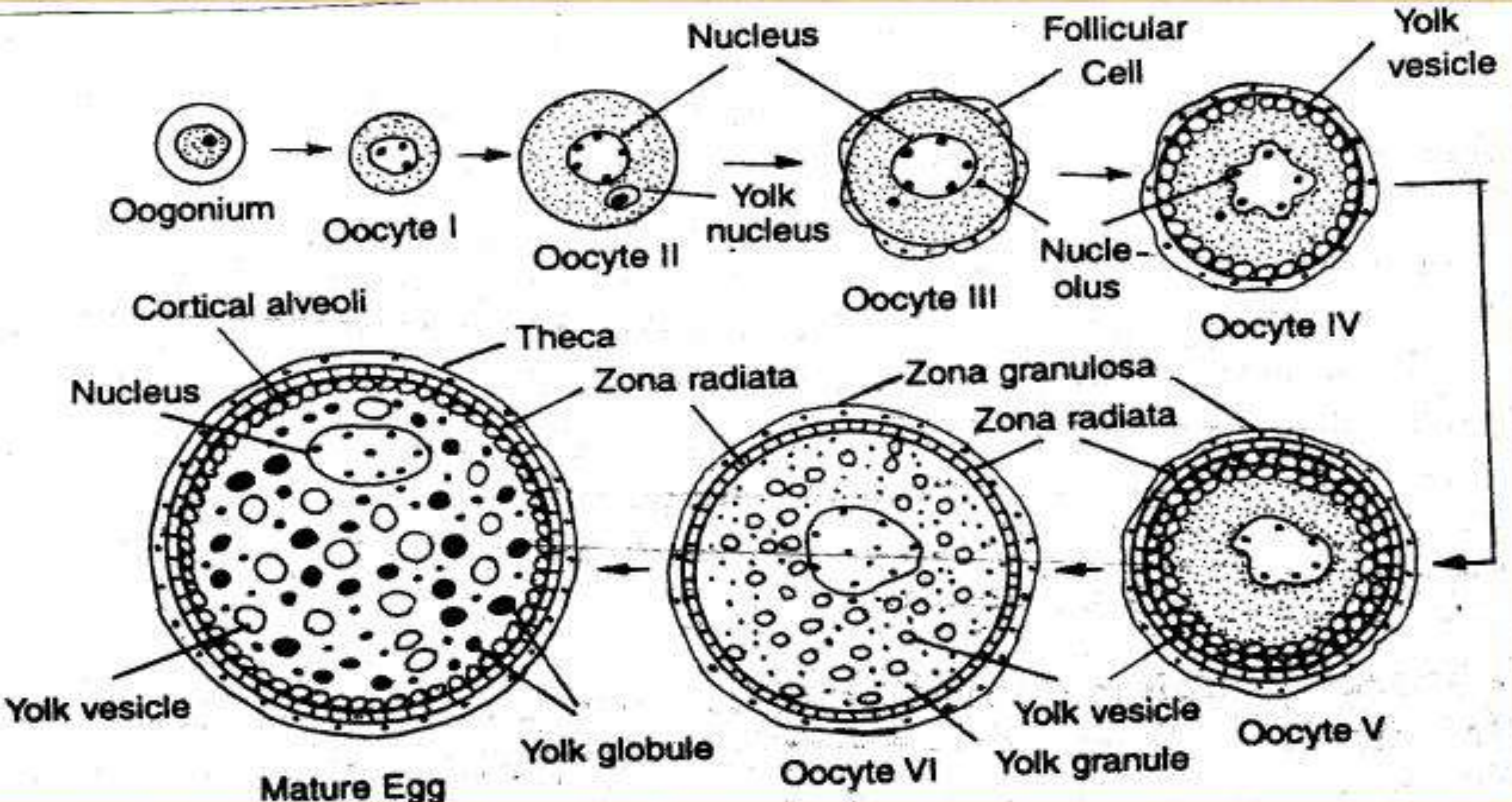
T.S. Mature ovary.





Process of development of mature egg from primordial germ cells called oogenesis

Stages in the maturation of oocytes



Reproductive Cycle (Ovarian)

Parallel to testicular cycle, the primary reproductive organ of female i.e. ovary also undergoes rhythmic change which is divided into five phases as follows:

1. Resting Phase: the ovary is in immature state containing nests of oogonial cells stage 1 oocytes at different phases of growth and few stage II oocytes. **During this stage the first meiotic division of nucleus is initiated** and the same is arrested at pachytene stage.

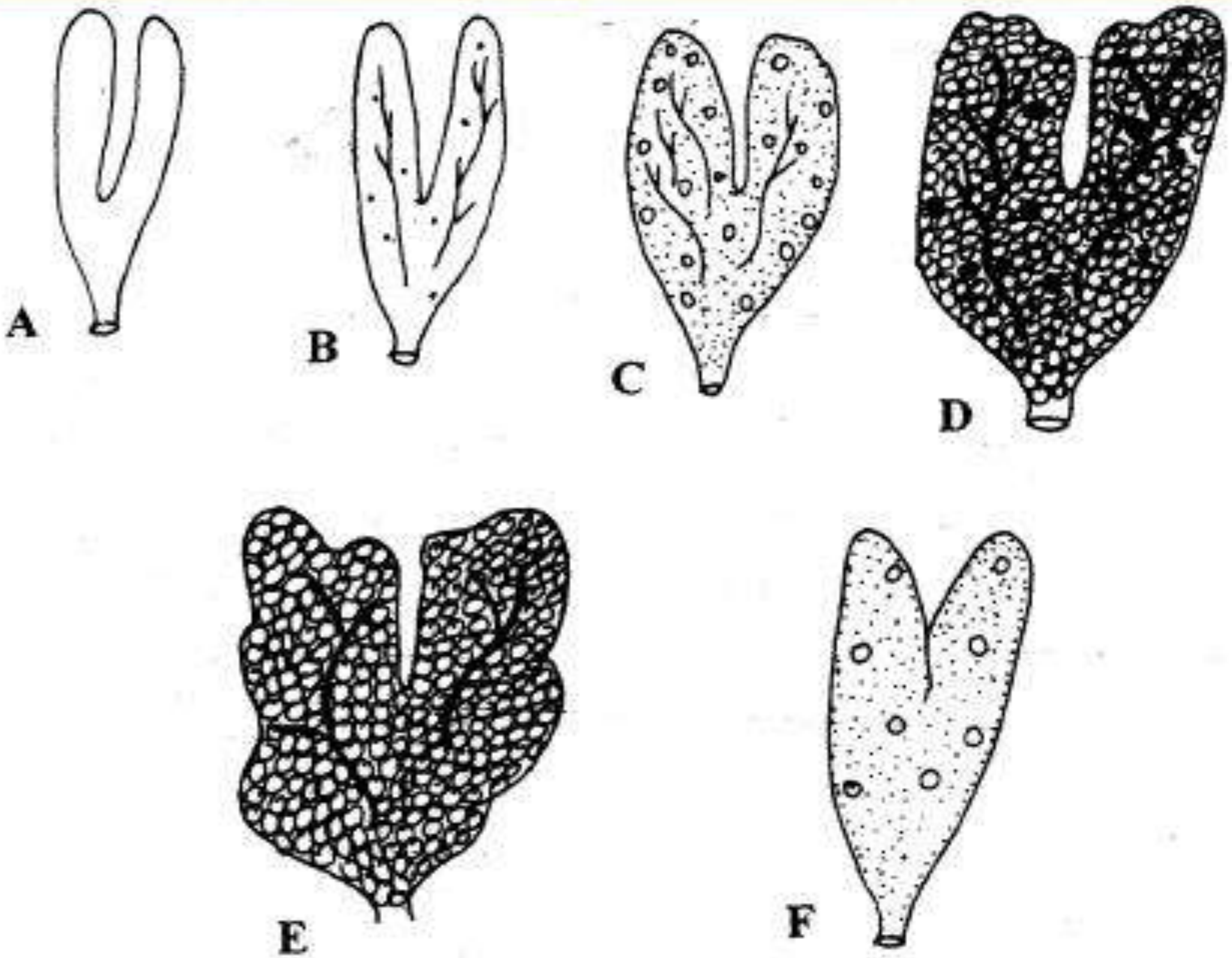
2. Preparatory phase: oocytes are in stage III. There is beginning of **vitellogenesis** in the oocyte cytoplasm. Oocyte envelops get differentiated with the thecal and granulosa layers assuming the steroidogenic function. Cells of granulosa layer **start producing female hormone, estradiol**.

3. Maturing or Prespawning phase: Characterized by intensive process of vitellogenesis by which ooplasm of an oocyte is loaded with yolk granules and in stage IV. **1st meiotic division completed and second meiotic division occures.** The size of the ovary and GSI will be maximum at this phase.

4. Spawning Phase: characterized by gravid ovary containing ripe oocyts. During spawning follicle of fully ripe oocytes rupture as a result oocytes released into ovocoel (cystovarian ovary) or body cavity (gymnovarian ovary) from where they pass out through genital pore into water.

5. Post spawning phase: the ovary exhibits a collapsed appearance as evaculated follicles are seen after the release of eggs.

Seasonal Changes in the ovary of teleost



Seasonal changes in the ovary of a teleost; **A** Resting phase, **B** Early maturing, C Advanced maturing, **D** Mature, **E** Spawning phase, **F** Spent phase.

Vitellogenesis

Accumulation of yolk substances in eggs called vitellogenesis

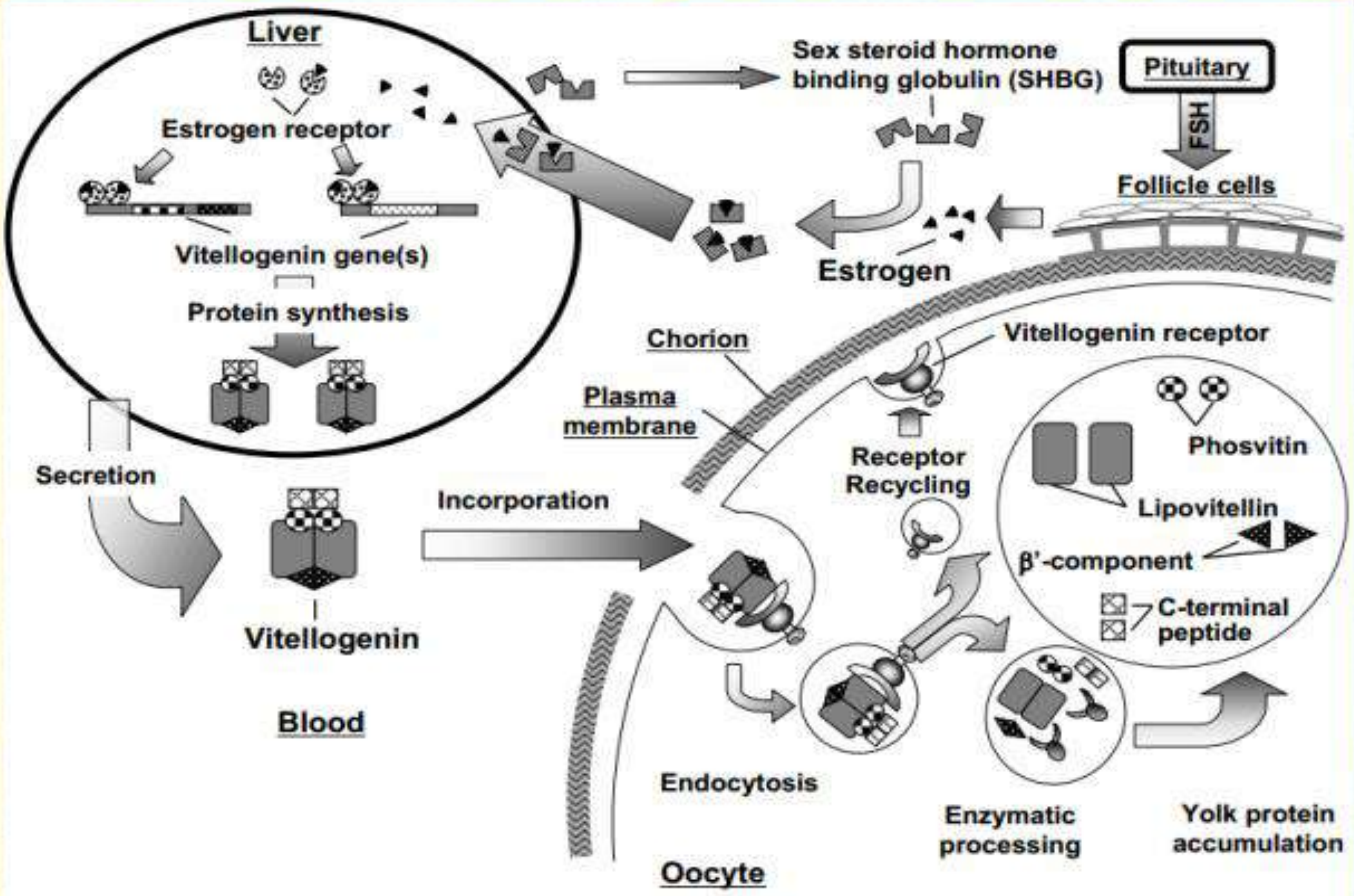
At the beginning there is no yolk. Blood of mature female contain a calcium binding lipophospoprotein called vitellogenin which is synthesized in the liver under the stimulation of female sex steroids. It passes from the plasma to oocyte and undergoes limited proteolysis give rise to yolk protein lipovitellin (Lv), phosvitin (Pv), β'-component (β'-c), and C-terminal peptide.

Yolk protein deposited as three yolk substances:

Yolk vesicles -contain glycoprotein
yolk globules-lipoprotein
oil droplets- Glycerides

After completion of vitellogenesis, movement of germinal vesicles to animal pole, Fusion of yolk granules and grouping of oil droplets occurs

Vitellogenesis



Gonadosomatic Index (GSI)

The Gonatosomatic index of a species can be calculated by the following formula

GSI= Weight of the gonads/weight of the fishX100

Gonadosomatic index of a species has been widely used to indicate the maturity and periodicity of the spawning of the fish. The GSI increases with the maturation of the fish and is maximum during the peak period of maturity. It decrease abruptly after spawning.

Fecundity

Fecundity is a measure of the reproductive capacity of a female fish and can be defined as **the number of ova that are likely to be laid by a fish during the spawning season**. It varies from species to species and different individual of same species may also exhibit variation depending upon size, age, nutritional status, environmental factors and genetic composition.

The fecundity of a species can be measured by any one of the following

(i) **Volumetric Method**: The mature ovaries are taken out of the abdomen and total volume is determined. Now small pieces of the ovary are taken as random samples from anterior, middle and posterior parts. The volume of each sample is determined and number of ova in each is counted under a lens. The total number of ova in the total volume of the ovaries is then calculated.

(ii) **Gravimetric Method**: mature ovaries are preserved in 10% formalin for estimating fecundity. Weight of the ovaries is determined. And three samples of 100 mg each are taken at random from anterior, middle and posterior parts. The the number of ova in each sample are counted under a binocular microscope. Tthe total volume of the ova are calculated as follows

Fecundity=average number of ova from three samples of 100 mg each X total weight of ovary/100

Lecture 11-12

Migration

- What is Migration?
- Sometimes, the life of a population of fishes cannot be met by a single habitat.
- This is due to variability in the habitat conditions (e.g., temperature), or to the changing needs of the population itself (e.g., foraging habitat vs. spawning habitat).
- The migration of fishes are an active mass movement from one habitat to another. Fishes migrate to places where they find the conditions they require at the particular phase of their life.
- The migration like other properties of the species have some adaptive significance, ensuring the favorable conditions for the existence and reproduction of the species.

- Approximately 2.5% of all fish species undertake migrations.
- The physical scale of migrations is highly variable and can range from hundreds of meters, as in some coastal and stream dwelling fishes, to thousands of kilometers, as in eels (*Anguilla* spp.; and tunas (*Thunnus* spp.)
- The timing of migration typically occurs on a seasonal scale, though some species display coordinated daily movements (e.g., vertical or tidal migrations).
- Some authors considered this types of migration (vertical or tidal migrations) represents migratory activity; and, some others considered these movements are a specialized form of foraging.

In this article, we focus on longer-distance migrations, not because short-distance and vertical migrations are ecologically or evolutionarily less important, but because long-distance migrations typically impose greater behavioural and physiological challenges on fishes than short ones.

- **Classifying Migrations**
- Fish migrations are typically grouped into three categories, based on their relationship to the seawater/freshwater boundary (Figure 1).
- 1. Oceanadromous migrations:
- Are Migrations that occur entirely within seawater, such as those performed by tunas, white sharks (*Carcharodon carcharias*), and plaice (*Pleuronectes platessa*),.
- 2. Potamadromous migrations:
- Are Migrations that occur entirely within freshwater. Potamadromous migrations can occur only in lakes (e.g., lake trout, *Salvelinus namaycush*), in rivers and streams (e.g., brook lampreys, Lampetra spp.), or can span both lake and fluvial habitats (e.g., white suckers, Catostomus commersoni).

- 3. Diadromous migrations:
- Migrations that cross the seawater/freshwater boundary are classified as **diadromous** (e.g., Pacific salmonids, Oncorhynchus spp.).
- There are three subcategories of diadromy:
- (a) Anadromy (Anadromus migration): occurs when most feeding and growth occurs in saltwater and fully grown adults move back into freshwater to spawn (e.g., Pacific salmon).
- (b) Catadromy (catadromus migration): occurs when most feeding and growth occur in freshwater and the fully grown adults move into saltwater to spawn (e.g., eels).
- (c) Amphidromy (Amphidromus migration): occurs when there is a brief excursion (trip) from freshwater to seawater during the juvenile stage, but the majority of feeding and growth and spawning occurs in freshwater. This last subcategory is most common in fishes inhabiting islands in the tropics and subtropics (e.g., sicydiine gobies, Sicydium spp.)
- هذه الفئة الفرعية الأخيرة هي الأكثر شيوعًا في الأسماك التي تسكن الجزر في المناطق الاستوائية وشبه الاستوائية

Figure 1 Map of the northeast coast of North America displaying example migratory patterns for the three major categories of fish migration. Migrations are categorized based on their relationship to the seawater/freshwater boundary – see text for details. Sources of map image: http://oversights.org.uk/.

Aims & the cycle of migration

- **1- Spawning migration:**

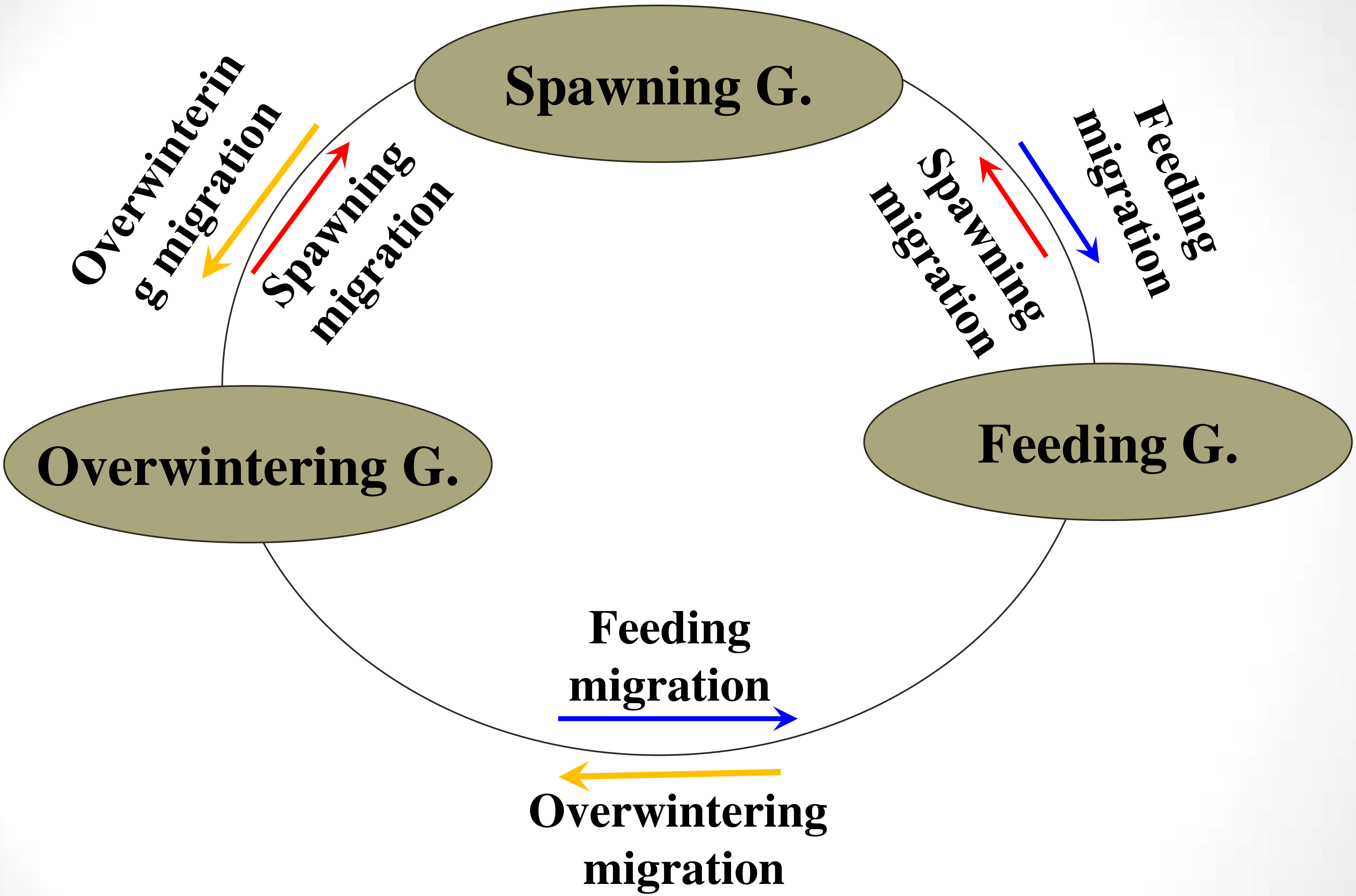
  The movement of fishes from the feeding or overwintering grounds to the spawning grounds.

- **2- Feeding migration :**

  The movement from the spawning or overwintering grounds to the feeding grounds.

- **3- Overwintering migration : الهجرة الشتوية (التشتية)**

  A movement away from the spawning or feeding grounds to the overwintering grounds.



The migration cycle of various fishes

- Some species don't perform migrations:

ex.: gobies, coral reefs fishes of the family Pomacentridae, Siganidae.

- The migration is not expressed identically in all species, such as:

- White fish:

The spawning and feeding migration are performed, but not the overwintering one.

- Many gudgeons:

The spawning grounds coincide with their feeding grounds, an overwintering migration related to movement into deeper waters.

Migration may be preformed by :

- **Adult only:-**

  In some species the migrations are performed only by the adult fishes which have attained maturity, example (salmon family).

- **Young fishes :-**

  On descending from the spawning to the feeding grounds, for example in the shad (*Capialosa brashnikovi*).

- **Both the adults and young:-** pass from the overwintering grounds in the Southern into the Northern Caspian (بحر قزوين) in which the spawning and feeding grounds of this fish are distributed.

- **The start of migration depends on both:-**
- ****** The state of the fish itself.

** The environmental changes.

Q**:

What are the factors which have led to the evolution of such a complex biological phenomenon as migrations in the serious groups of fishes?

There is no doubt that, the migration is an adaptation which ensures the existence of the species. In other words, the migration is an adaptation toward increasing the abundance of a species.

The transition into the migratory state is related to :

- A definite condition of the fish.
- Its state of nourishment.
- Fat content.
- The development of its gonad.
- Changes in the environment.

Methods for studying migration:

- Direct observation of fishes.
- Analysis of the size and composition of the commercial catches.
- Marking fishes.

Spawning migrations

- It is a movement away from the overwintering or feeding grounds to the spawning grounds.
- It has evolved as an adaptation for ensuring the most favorable conditions for the development of the eggs and larvae and especially for the protection of the early stages from predators.
- **Types of spawning migrations:**

1)- Anadromous migration:

Many migratory fishes and cyclostomes **feed in the sea, but enter the rivers to spawn** (Anadromous Fishes), Exs. Lampreys, Sturgeons, Salmon, some Shads, Cyprinoids.

- **2)- Catadromous migration:**

Some migratory fishes feed in the rivers, but pass out into the Sea to spawn (Catadromous Fishes), such as the eel fish (*Anguilla anguilla*).

3)- ** Some marine fishes, which usually live in deep water rise to spawn in the upper layers of the water.

4)- Some fishes move from the open parts of a lake to the shore zone to spawn among the weeds and in marshy places.

******The migration may be: against the current (contranatant) **or** with the current (denatant).

The time of spawning migration may vary among the migratory fishes:

- In autumn for many white fishes.
- In spring for the majority of Cyprinoids.

- Ex., The salmon (**feeds in the sea, and enters the rivers of the White Sea to spawn)** are of two forms:

  1)- One enters the rivers in the autumn when its gonads are feebly developed and spawns in the following year.

  2)- Other group enters the rivers in the summer with its gonad well developed and spawns in the same year.

-

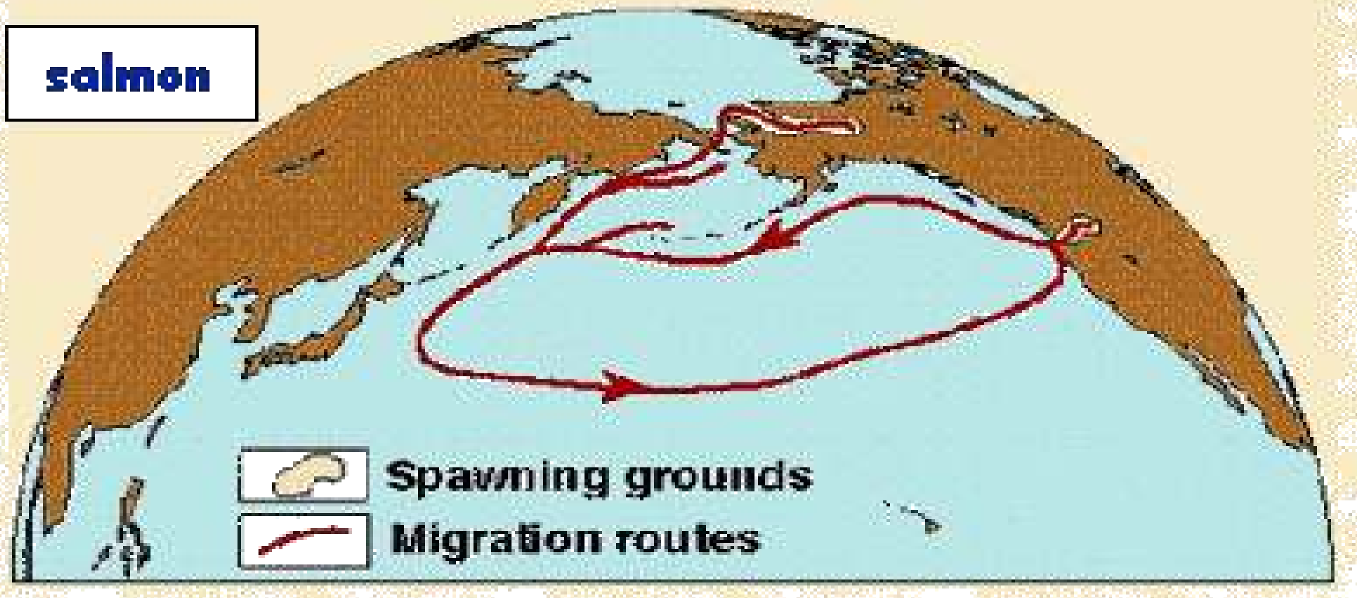
Fish Migration:

- Anadromous: e.g. salmon
  - spawn and grow in freshwater, live in ocean
  - in North Pacific spawn in Alaskan, Washington and B.C. rivers
- Catadromous: e.g. eels
  - spawn in Sargasso Sea, return to fresh waters in Europe, N. America

salmon

eels

salmon



Example for Catadromous spawning migration

European eels *Anguilla anguilla*

- After a variable growth period (from 3 to more than 20 years) during which they become subadults (silver eels), European eels *Anguilla anguilla* leave continental habitats and join the sea. These silver eels then make a journey of several thousand kilometres to reach the Sargasso Sea spawning zone and reproduce (Sargasso Sea is A part of the northern Atlantic Ocean).

The beginning of this migration depends on both: endogenous and exogenous factors.

- Eels migrate after they metamorphose into silver eels.
- The silvering process involves a series of morphological and physiological transformations that mark the transition between a sedentary growth phase (yellow eel) and a catadromous migration phase (silver eel) which prepares them for the deep sea migration.
- Because the silvering process preadapts eels to the marine conditions while they are still in freshwater, it generates a physiological instability (osmotic imbalance notably) that predisposes fishes to migrate (تهيئ).
- At the end of the silvering process that usually occurs in late summer, the silver eels wait for favourable environmental windows to begin their seaward migration.

- In natural environment, migrations generally take place in autumn when water temperature decreases.
- The moon periodicity may also be an important factor for the migration because eels tend to be more active during the second half of the lunar cycle.
- Furthermore, rain, and flow increases could also influence the migration behavior of silver eels as they are often caught during stormy nights.
- The onset of the migration, takes place during environmental windows, set by seasonal (e.g. temperature), monthly (e.g. moon) and daily (e.g. atmospheric pressure, and water flow) patterns.

- <u>During</u> the course of its journey <u>from</u> its feeding ground in the European rivers <u>to</u> its spawning grounds at the American coast, **the European eel undergoes many changes :**

1- The eyes of the eel become enlarge.

2- Its face becomes sharper.

3- Changes in coloration.

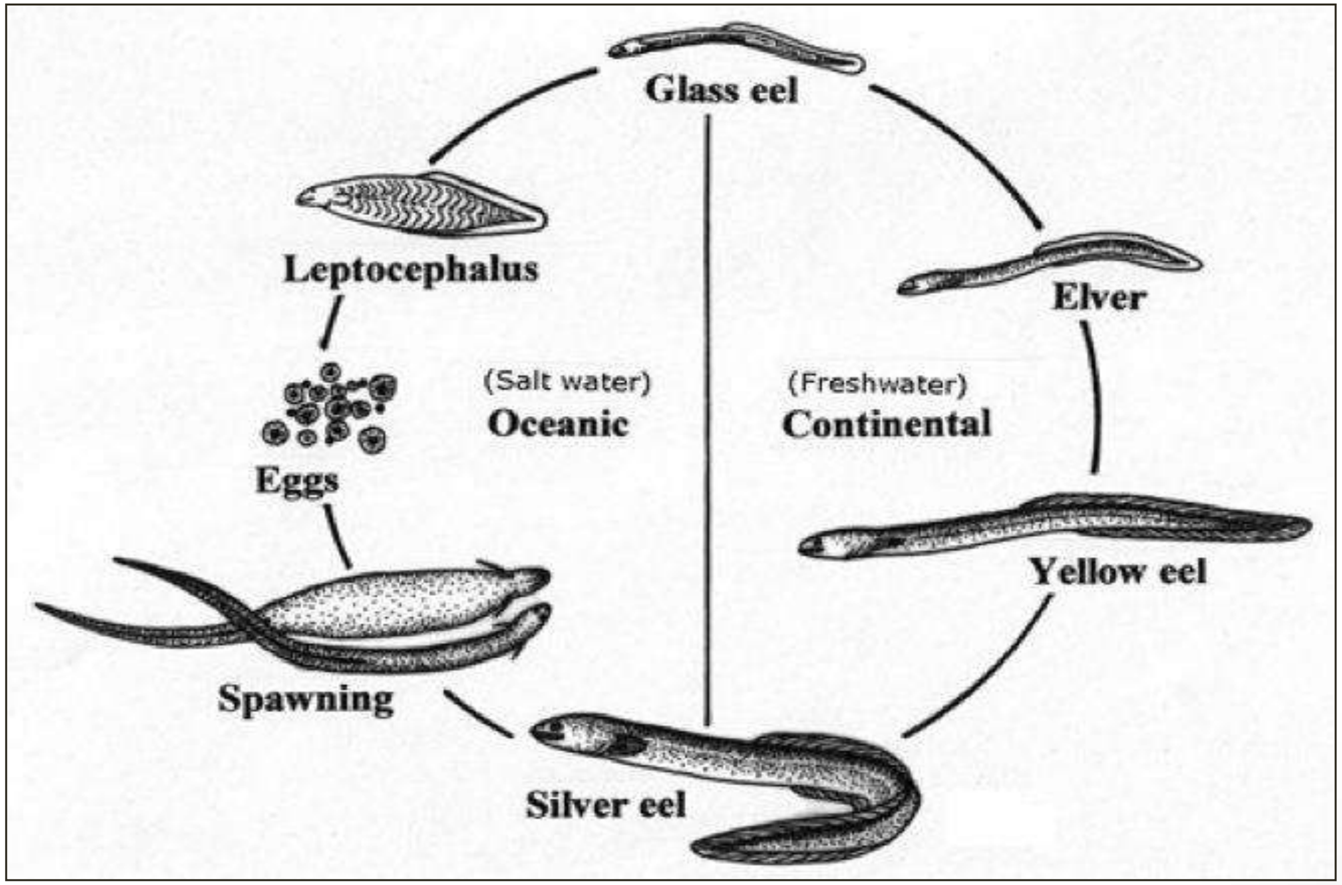
4- Expanded enormous amount of energy so become very thin.

5- Its alimentary canal degenerates.

6- Change of osmotic pressure.

7- The size of its swim-bladder decreases


NORTH AMERICA
SARGASSO SEA
SOUTH AMERICA


Glass eel
Leptocephalus
Elver
Eggs
(Salt water)
Oceanic
(Freshwater)
Continental
Yellow eel
Spawning
Silver eel

Feeding migrations

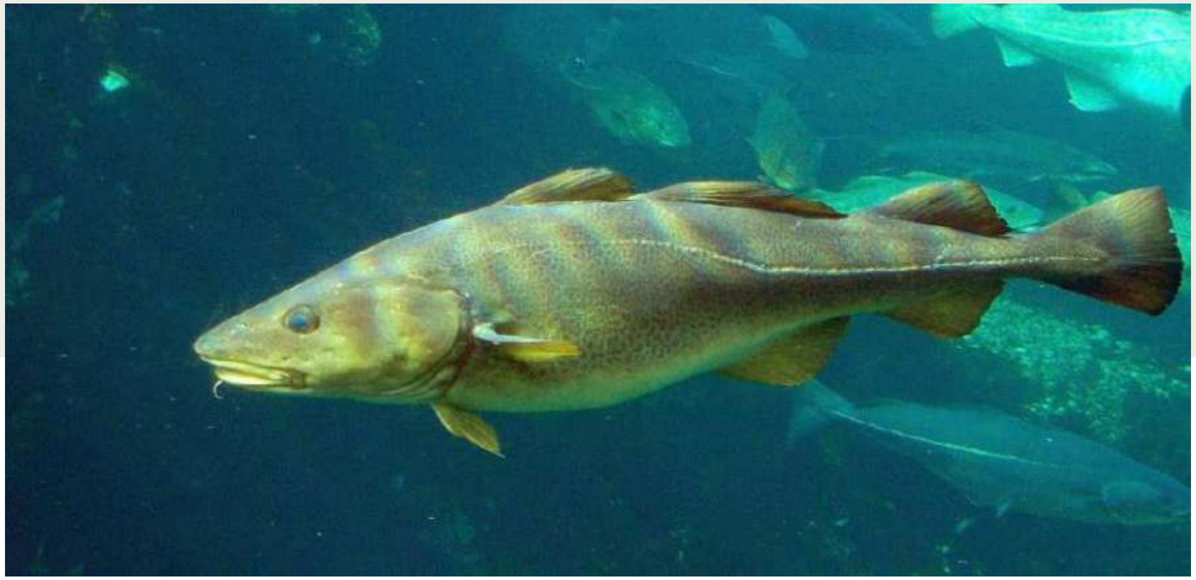
- Feeding migrations is a movement away from the spawning or overwintering grounds to the feeding grounds and begins in the egg stage.
- The transport of the pelagic eggs and free embryos from the place they were spawned to the feeding grounds is a passive feeding migration.
- The passive feeding migrations are found in migratory, marine and fresh water fishes.

1- Passive feeding migrations in marine fishes:

- The pelagic eggs and larvae of many fishes are transported by currents.
- E.g.: The eggs and larvae of the cod and the larvae of the herring are transported by the Atlantic current from the coast of Norway to their feeding grounds in the Barents sea.
- The eggs of the flying fishes are spawned in the surface layers of the ocean reaching a depth on hatching.
- The larvae are well protected from predators and have a sufficient food supply.

Active feeding migration

- Active feeding migration are very well marked among marine fishes, some perform regular Journeys from one good feeding ground to another.
- Ex.:migration of Norwegian cod after spawning at the Norwegian coast, moving eastward.



Fishes may perform:

- A)- Horizontal feeding migration:
- Marine fishes perform regular horizontal movement are related to the search for food.

- B)- Vertical feeding migration:
- They follow the vertical movements of their prey.
- It occur in marine & freshwater fishes.
- Vertical feeding migration may be diurnal or seasonal.
- Diurnal feeding migrations are very clearly marked in many freshwater fishes.

Overwintering migration

- The overwintering migration is a movement away from the feeding to the wintering grounds. It only occurs in those fishes which have a wintering ground**. e.g. Adult of the bream in the Aral sea.**
- Overwintering is the process by which some organisms wait out the winter season.
- Winter conditions (cold or sub-zero temperatures, ice, snow, limited food supplies) make normal activity or even survival difficult or near impossible.
- * Hibernation (البيات الشتوى) and migration are the two major ways in which overwintering is accomplished.
- * Aestivation: is a state of animal dormancy during the summer, similar to hibernation, characterized by inactivity and a lowered metabolic rate, that is entered in response to high temperatures and arid conditions. It takes place during times of heat and dryness, the hot dry season are often the summer months.

Hibernating fish comes to life! (Brown Mudfish).

Hibernation- A Long Winter

- **The overwintering migration is performed by:**
- Migratory fishes such as sturgeons, Atlantic salmon.
- Semi-migratory fishes such as adult roach, sea-roach, bream, pike-perch.
- Marine fishes such as many flat-fishes.
- Freshwater fishes.
- **The reason for the overwintering migrations of fishes:**
- The fishes are need to move from feeding grounds into overwintering regions to:

  1- Provide favorable a biotic conditions.

  2- provide some protection against predators.
- **The time of overwintering migration:**
- It is started by those fishes which are prepared for it , which have :

  1- certain condition and fat content.

  2- changes in the environmental factors as a natural migrating stimulus.

PRACTICAL OF FISH BIOLOGY

For students
4^{th} Grade Chemistry and Zoology
&
4^{th} Grade Zoology

Dr/Salwa Mansour Mohamed

2022-2023
FACULTY OF SCIENCE
Zoology department

Ichthyology: the study of fishes.   (Greek *Ichthys* = fish)

Fish extremes:

- **Largest (SW): whale shark (12 m)**
- **Smallest: fish range between (8.0 mm) and (7.9 mm).**


***Fish characters:**

Fishes are animals that are:

1. most always **aquatic**
2. most always **cold-blooded**
3. most always **gill-breathing**
4. **craniates**
5. Possess **fins** that are usually developed, (never pentadactyl limbs) .

What's the difference between "fish" and "fishes"?

"**Fish** "can be both singular and plural, but in all cases it refers to a single species . "**Fishes** "is always plural and always refers to more than one species .

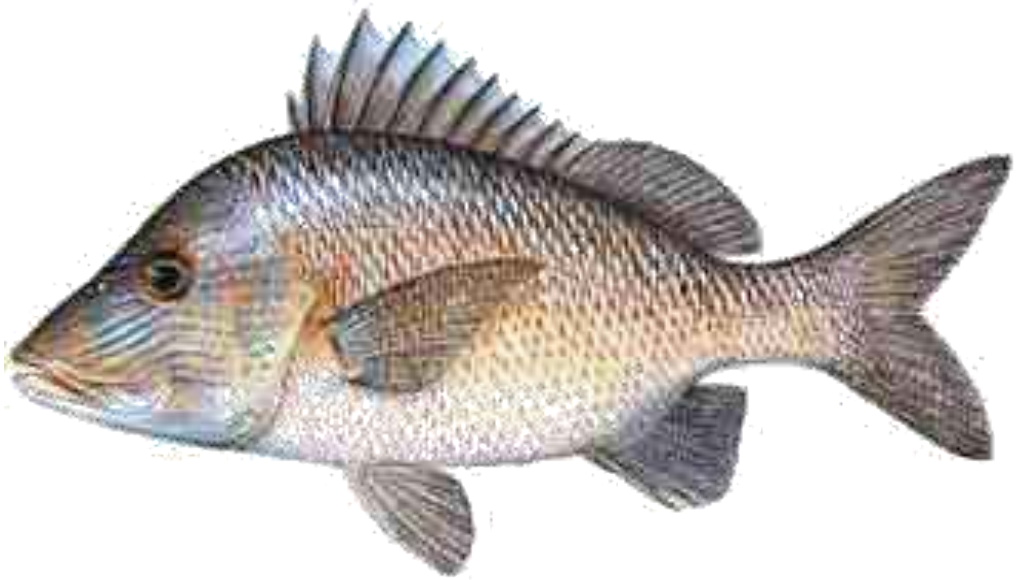
Fish **Fishes**


External description of fish

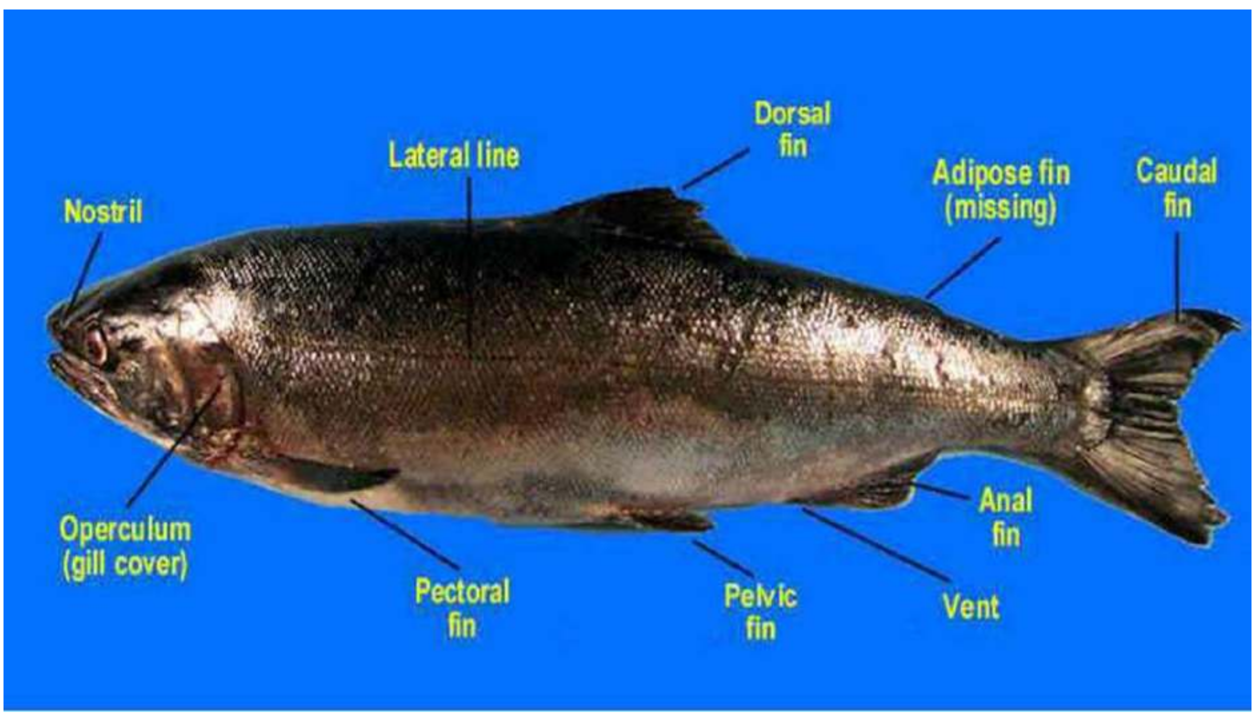
DORSAL VIEW "TOP

BILATERAL

SYMMETRY

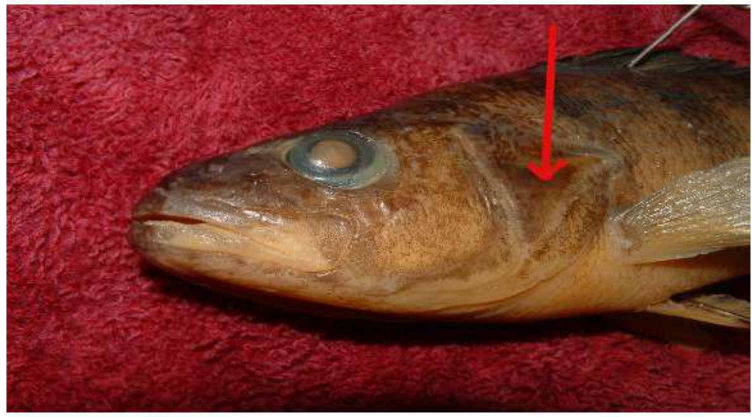


VENTRAL VIEW "BOTTOM"

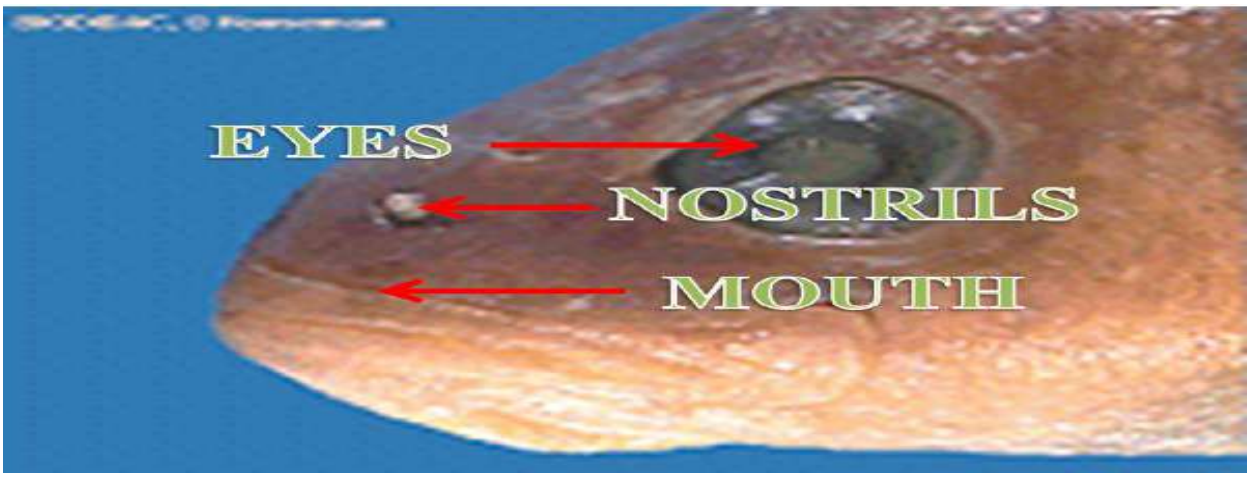


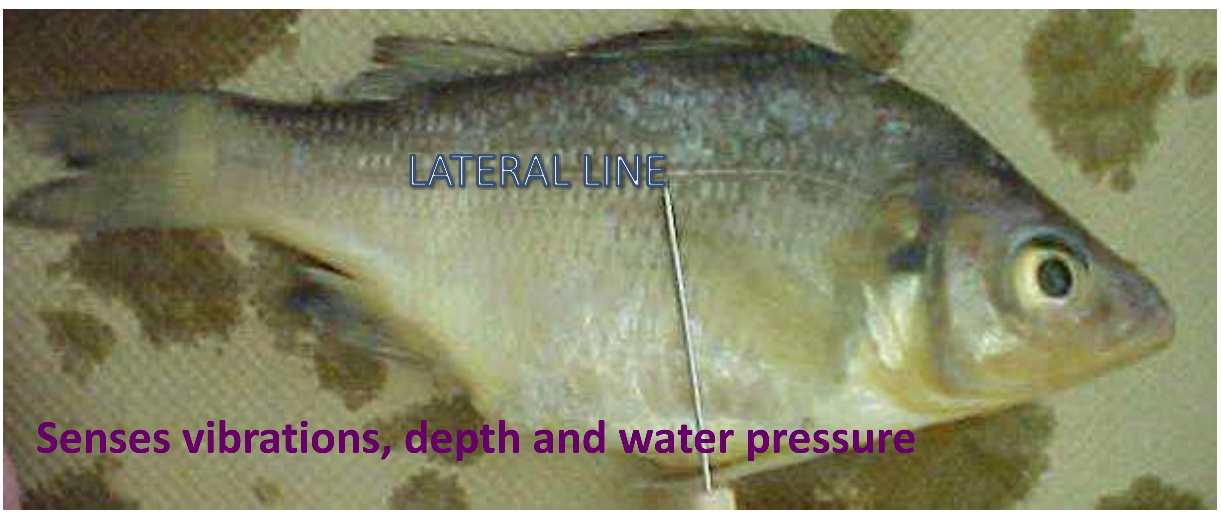
SCALES

OPERCULUM



Water goes in through mouth out through a slit behind operculum





*External description of fish:

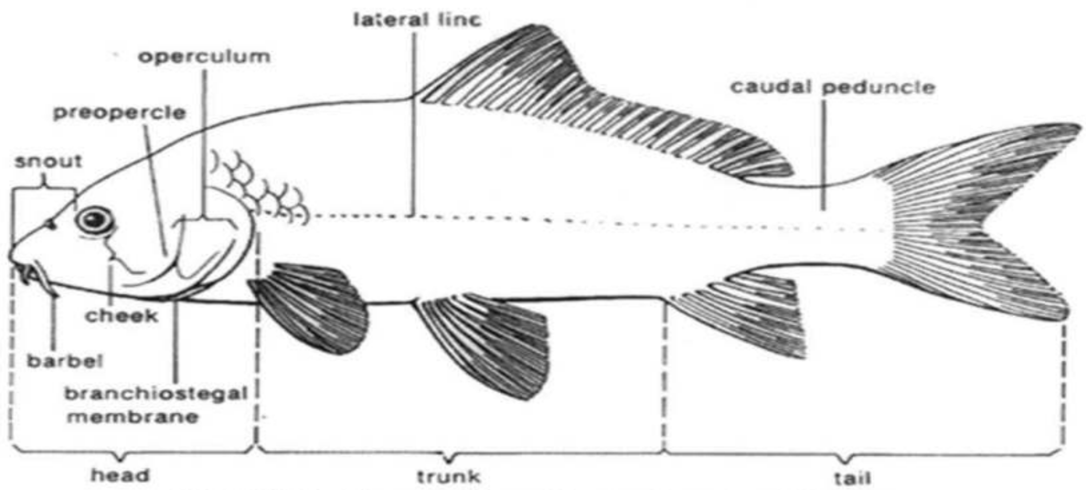


FIGURE 2–1. Diagram of bony fish, showing external features.

***The color:**

- Dorsal surface & Ventral surface

***Body shape:**

- Cylindrical (Fusiform).
- Dorsoventrally depressed (Flattened from top to bottom).
- Bilaterally compressed (Flattened from side to side).

Body size:

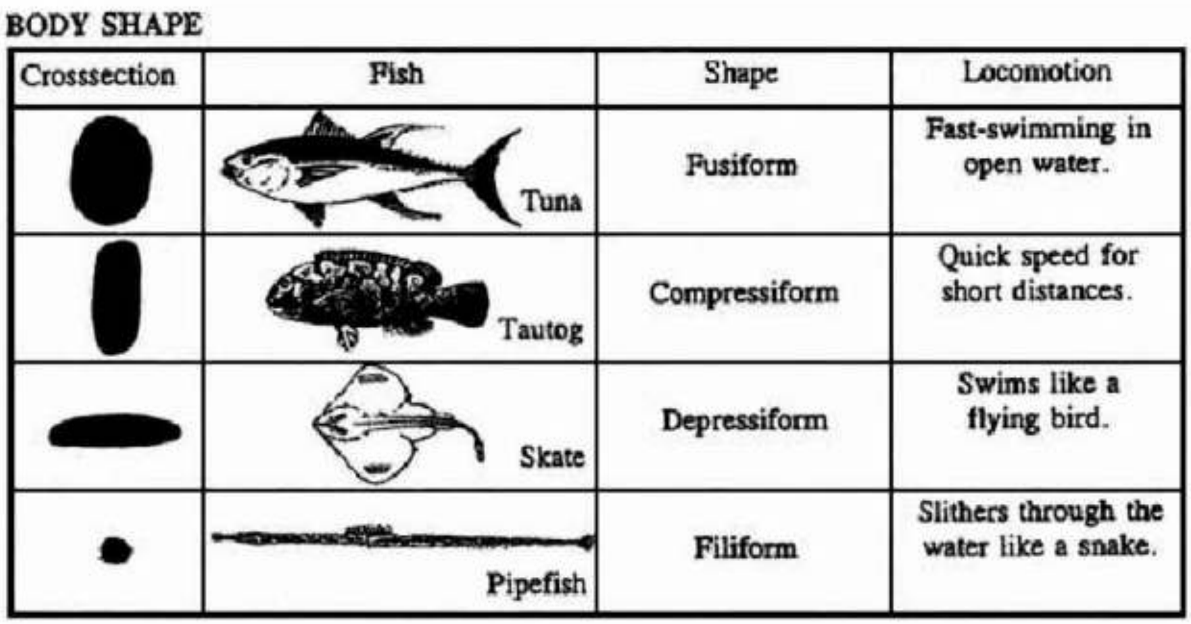
- Large - median - Small

***Head shape:**

- Cylindrical.
- Dorsoventrally depressed.
- Bilaterally compressed.

Head size:

- Large - median - Small



BODY SHAPE

Crosssection	Fish	Shape	Locomotion
	Tuna	Fusiform	Fast-swimming in open water.
	Tautog	Compressiform	Quick speed for short distances.
	Skate	Depressiform	Swims like a flying bird.
	Pipefish	Filiform	Slithers through the water like a snake.

***Eyes:**

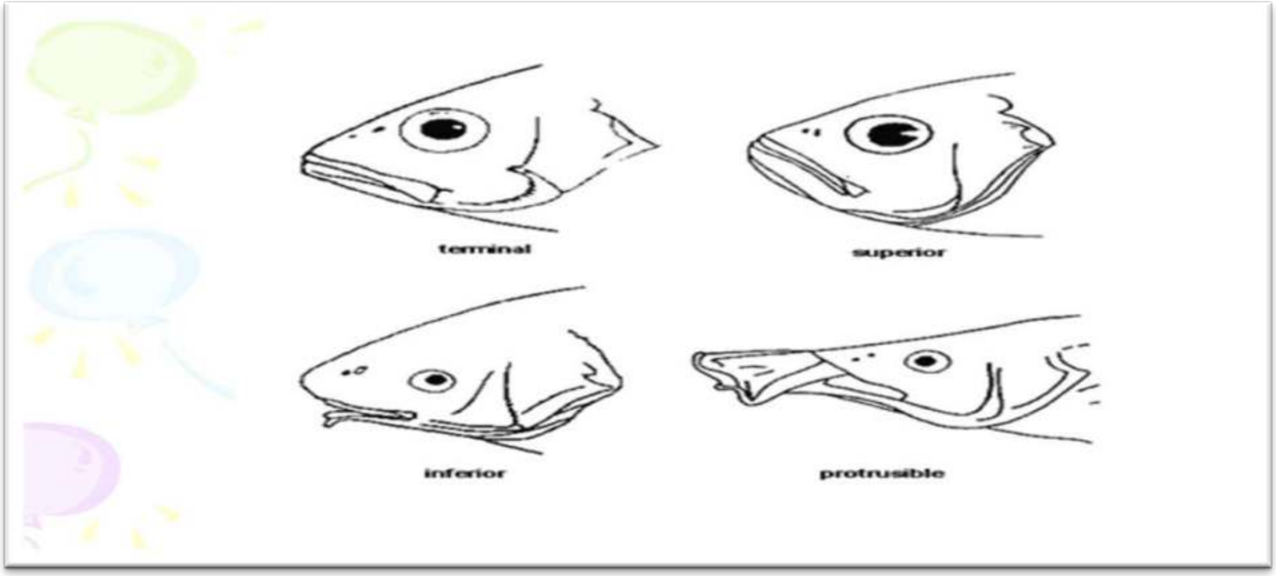
- **Shape**: (round – oval)
- **Position**: one on each side, two on the dorsal surface
- **Size**: (small – medium - large)

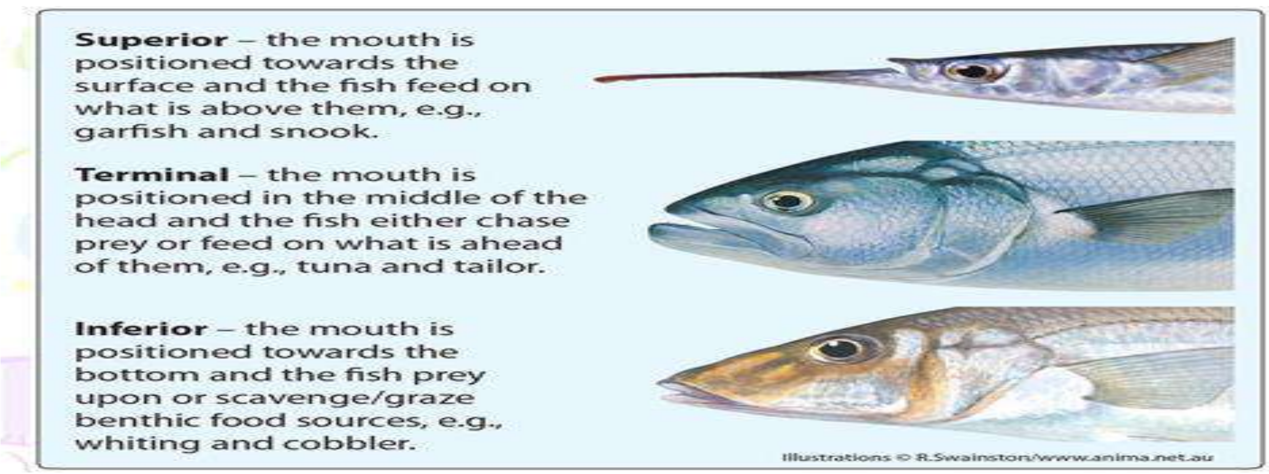
***Nostrils (Nasal opening):**

- **Shape**: (round – oval)
- **Position**: One or two on each side on the dorsal surface
- **Size**: (small – medium - large)

***Mouth:**

- **Position:** Terminal - Sub terminal- superior(dorsal)-inferior (ventral)
- **Size**: narrow - wide
- **Type**: Protracted or non-Protracted





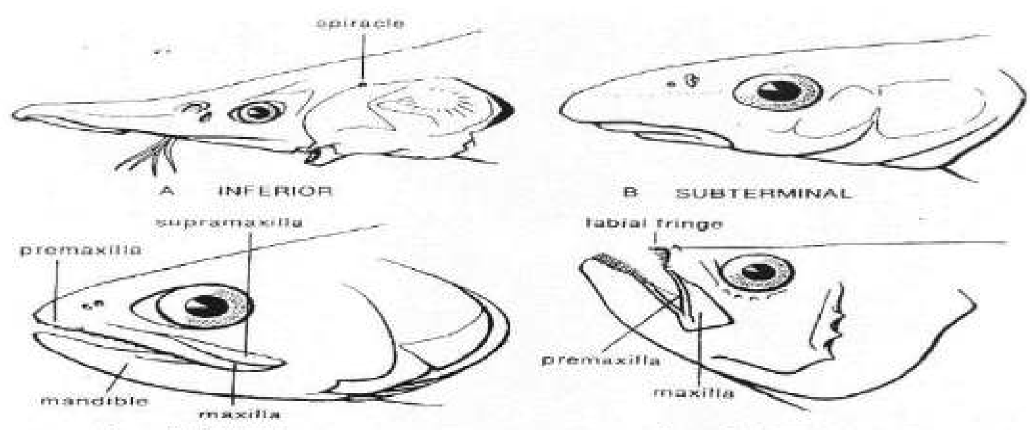
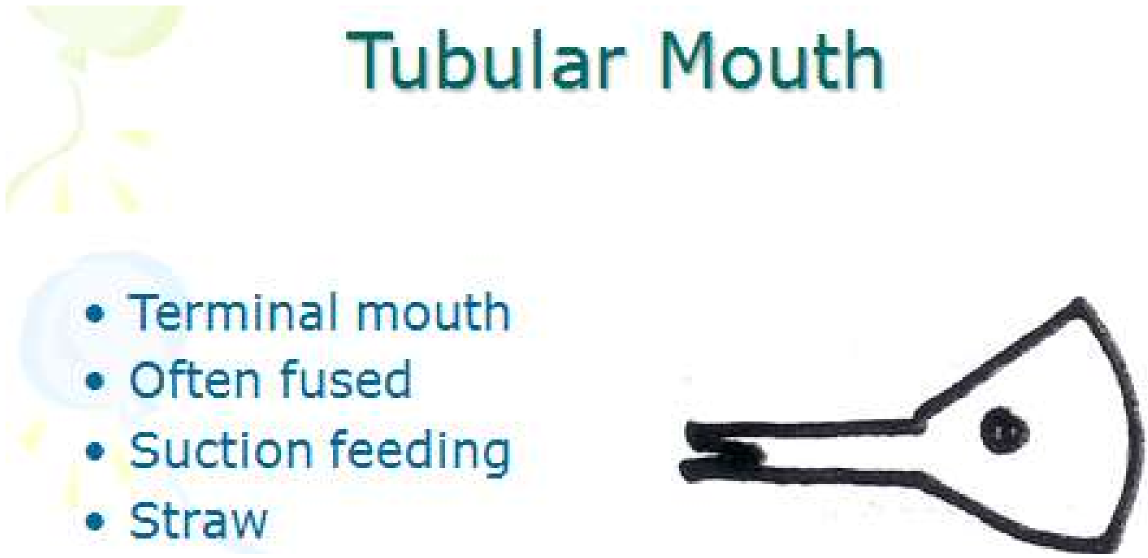


FIGURE 2–2. Examples of mouth positions in fishes. *A*, inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout); *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)

***Snout**: Normal or Tubular or Elongated.



***Teeth:**

Absent or Present

If Present: A- position

<u>**Upper jaw**</u>**:**

Premaxillary – Maxillary – Vomerine – Palatine.

<u>**lower jaw**</u>**:**

Mandibular - Tongue

B- type

Canine ناب - molars ضرس - Incisor قاطع

<u>**If canine**</u>**:**

Uni cuspid سن واحد – Bicuspid – poly cuspid.

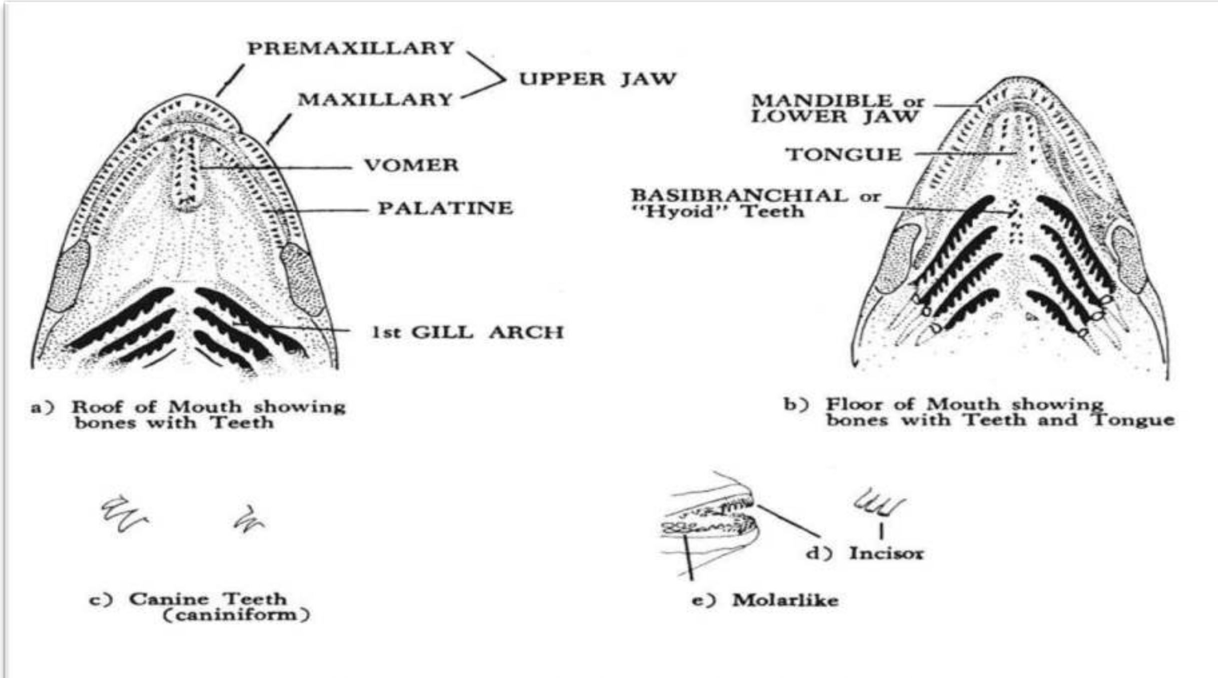
***Barbles:** Absent or Present

If Present: A- Number:

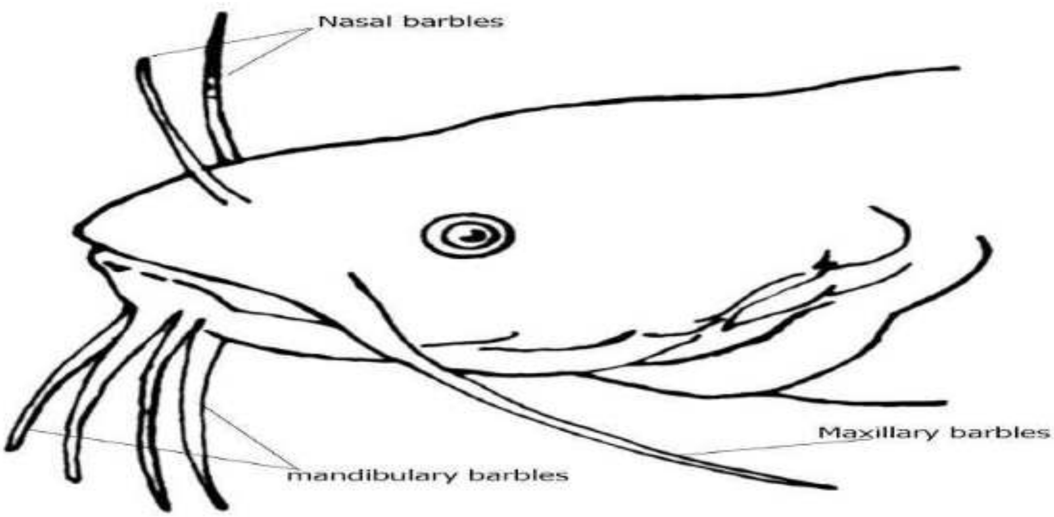
One nasal pair, One maxillary pair, Two mandibular pairs

B- Length: Short & Long

C- Branched: Branched & Not branched.



Bones and teeth inside mouth or bucal cavity.



***Operculum**

A- Connected with isthmus.

B- Separated

Overlapped & not overlapped.

Fins

***Paired fins**:

Pectoral fins:

shape: fin rays with (week – strong) spine or without.

Position: lateral, ventro-lateral, dorso-lateral

pelvic fins:

shape: fin rays with (week – strong) spine or without.

Position: ventral, ventro-lateral.

Position it for pectoral fin: posterior(abdominal), thoracic (both in the same region).

***Unpaired fines**

Dorsal fin:

Shape:(One or two parts) fin rays with spines or without spines / adipose.

Anal fin:

shape: fin rays with (week – strong) spine or without.

Position: ventral.

Caudal fin:

Shape: Pointed - Rounded - Truncate – Oval - Crescentic - Biforked.

***Fin rays:**

A- Type: simple branched

B- Number:

Rays …………... Arabic number

Spine…………… Lattin number

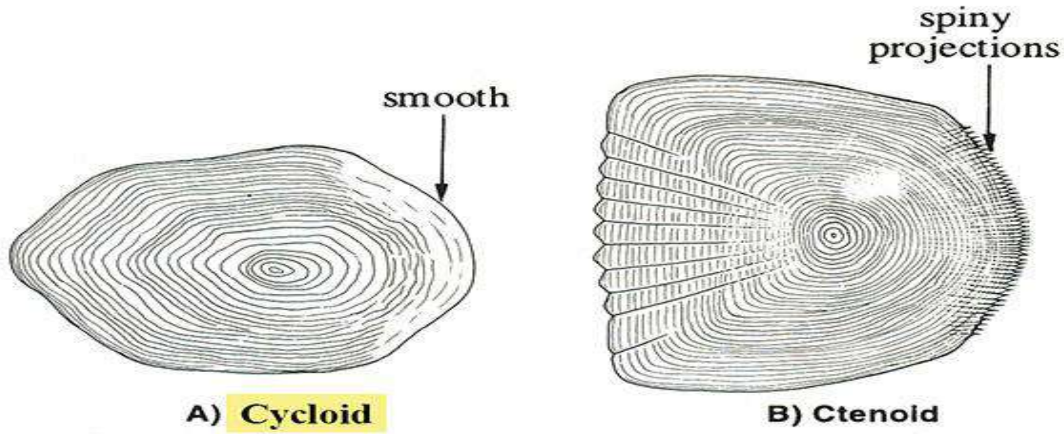
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV

***Lateral line:** One or two on each side.

Scales:

Absent & Present

If Present: Cycloid & Ctenoid



Scales

***Stomach:**

Fish stomachs differ in shape from group to group.

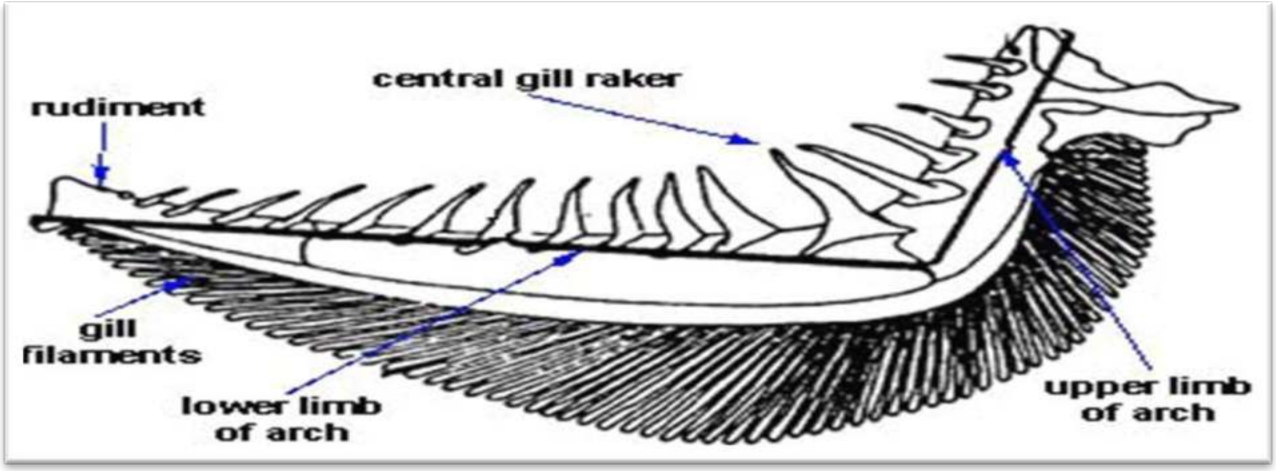
- The predators have elongated stomachs.
- Omnivorous generally have saclike stomachs.

***Intestine**:

- The predators have shortened intestines. (1/3-2/3 body length).
- herbivores, or plant eaters, have long intestines, sometimes consisting of many folds coiled (2-15x body length).

***Gill rakers:**

- long, fine, closely spaced in filter feeders.
- short and stubby in eaters of invertebrates
- shorter, widely spaced in piscivores.



*Measurements

- **The weight**
- **Body width**
- **Fulton condition factor (K factor):** It is a tool for determination of health of population and food supply.

K= (fish weight $_{gm}$/ (Forked length)^3. If no forked length, we use the **total** body length.

- **<u>Relative length of gut (RLG):</u>**

RLG= (Absolute length of gut/Slandered length of the body) × 100.

- **Gono-somatic index (GSI):**

It is a tool for measuring the sexual maturity of animal.

GSI = (Gonads weight $_{gm}$/fish weight $_{gm}$) × 100.

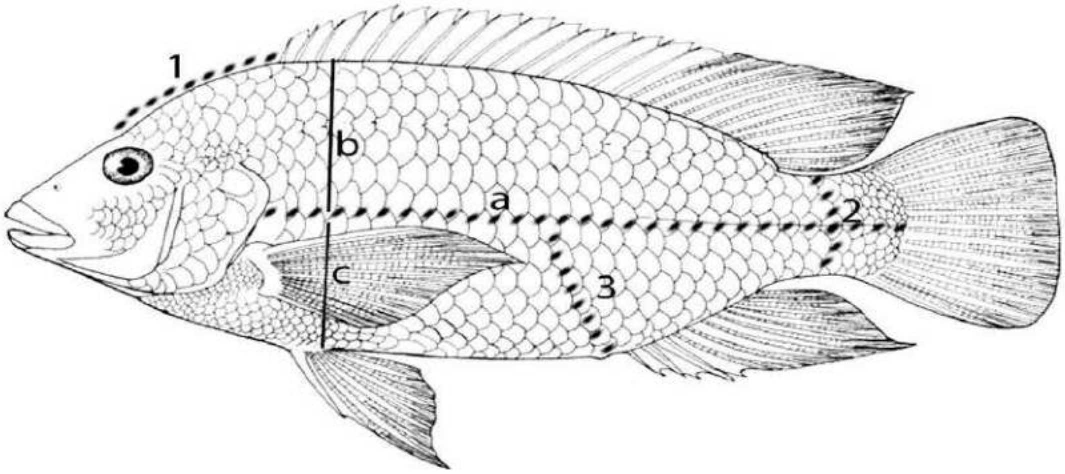
- **Scale Number: Sf * a**

Scale formula (Sf): a (b/c)

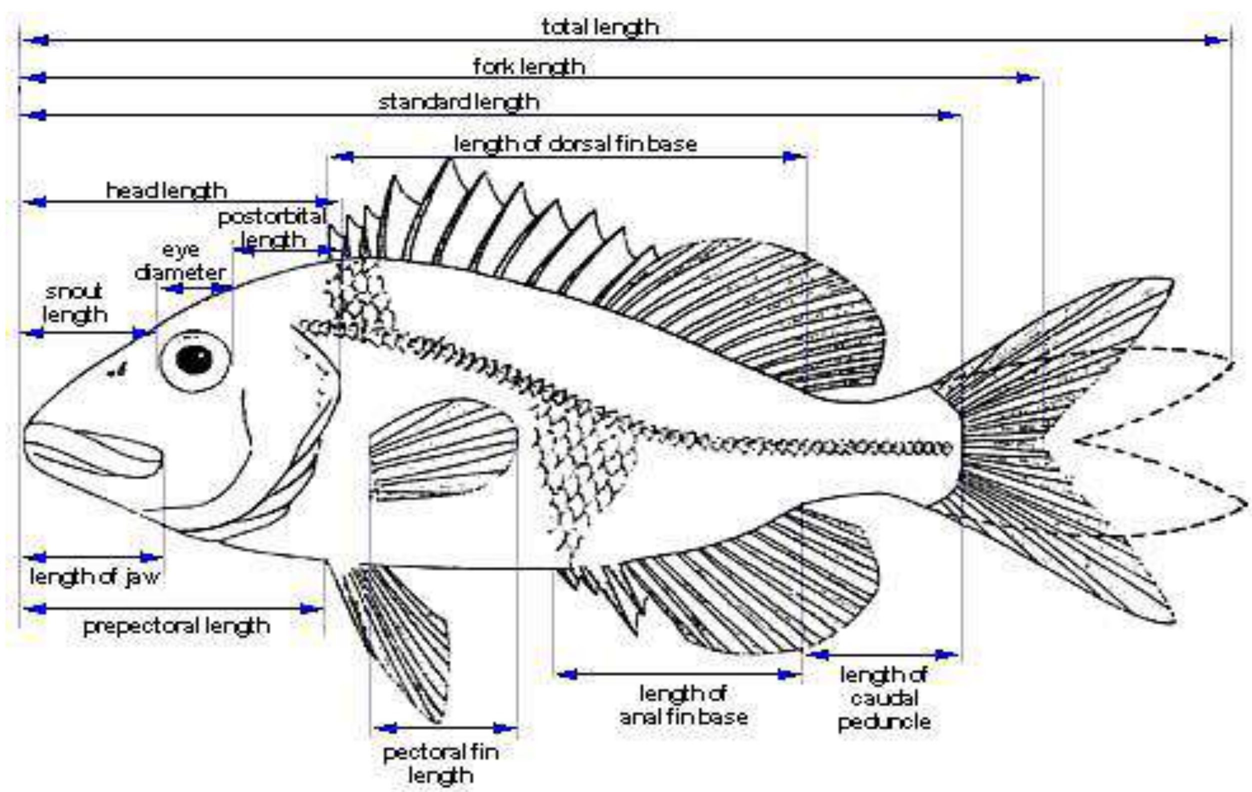
a= number of scale from the end of operculum to the end of caudal peduncle (OR : No. of scale on lateral line).

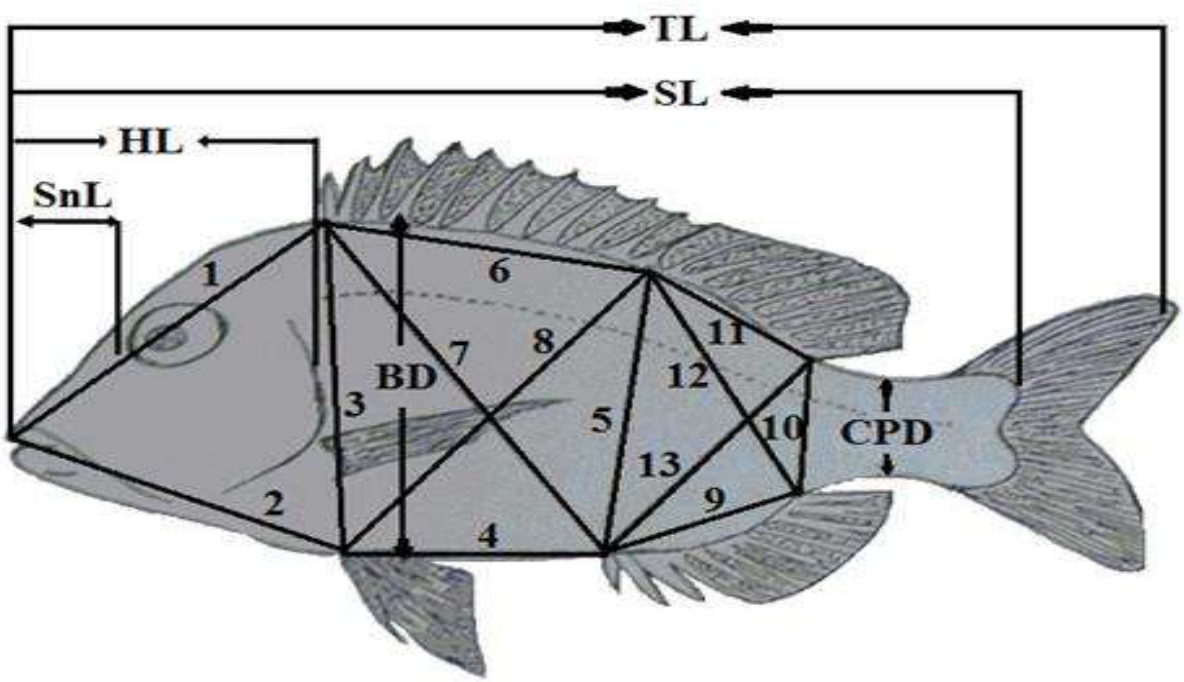
b= No. of scale from the beginning of dorsal fin to lateral line (oblique line)

c= No. of scale from the beginning of pelvic fin to lateral line (oblique line)



External measurements:





Report consists of:

1. **Description of External characters**

2. **Measurements (external-internal)**

3. **Pictures for all Body and head (dorsal, ventral, lateral) also scales, teeth, gill rakers, gonads.**

4. **comment:**
   habitat
   adaptation
   feeding
   reproduction

- **Morphometric measurements (definition of measurements in the attached diagram):**

Measurement	Abbreviation	In cm	Type of measurement
Total length	TL		***Reference length***
Fork length	FL		***Reference length***
Standard length	SL		***Reference length***
Head length	HL		***Reference length***
Length of snout	SnL		
Diameter of the eye	ED		
Postorbital length	POL		
Length of jaw	L J		
Body depth	BD		
Caudal peduncle depth	CPD		
Caudal peduncle length	CPL		
Pre-pectoral length	PRPL		
Pectoral fin length	Pf L		
Dorsal fin basal length	DFBL		
Anal fin basal length	AFBL		

Measurement	Abbreviation	In cm
The weight		
Body width	B w	
K factor:	KF	
Length of intestine	L in	
Relative length of the gut =Absolute length of the gut /Standard length of the body	**(R.L.G.)**	

Gono somatic index = (Wt. of gonads / Wt. ofbody) * 100	**(G.S.I.)**	
Scale formula: a (b/c)	(Sf)	
Scale number: Sf * a	S N	
Hepato somatic index = W t. of liver/ w t. of body) *100	H.S. I	

Color	dorsal:
	ventral:
Type of scales	
Lateral line	
Body (size and shape)	

Head characters:

Head shape – size		
Type of mouth (position and shape)		
Eye position		
Types of Barbles		
Nasal opening (position and shape)		
Types of teeth – position	upper jaw:	Lower jaw:
Gill raker numbers on the first left gill arch:		
Operculum (type)		

Fins

1. Dorsal

Shape/Single/Divided	
Color	
Modifications if found	
Origin/ Position	
Number of rays	
Number of spines	

2.Anal

Shape	
Color	
Modifications if found	
Origin/ Position	
Number of rays	
Number of spines	

3.caudal

Shape	
Color	
Modifications if found	
Origin / Position	
Number of rays	
Number of spines	

Pectoral fins:

Shape	
Color	
Modifications if found	
Origin / Position	
Number of rays	
Number of spines	

Pelvic:

Shape	
Color	
Modifications if found	
Origin / Position	
Number of rays	
Number of spines	

Fish Dissection

Objectives of dissection:

- There are both similarities and differences between the internal structures of humans and fish.
- Dissecting a fish will allow the student to see the insides and compare the organs a human body.

For example

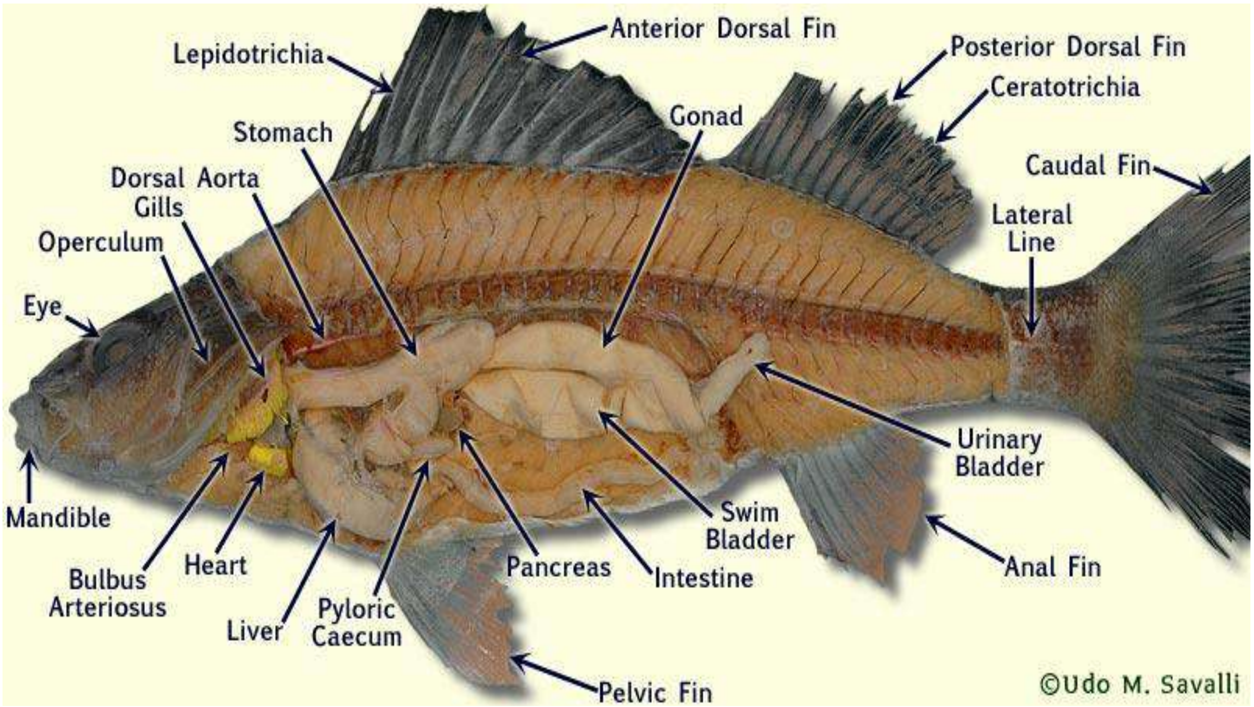
- fishes have "noses" (called **nares**) that don't look anything like our own, yet their purpose is to smell chemicals in the water.
- the **internal anatomy** will look very different from our own, however, most of the major organs are the same (e.g., **heart, stomach, liver, spleen**) and have the **same basic function**.
- A few internal structures, like the **swim bladder**, are of course unique to fishes.

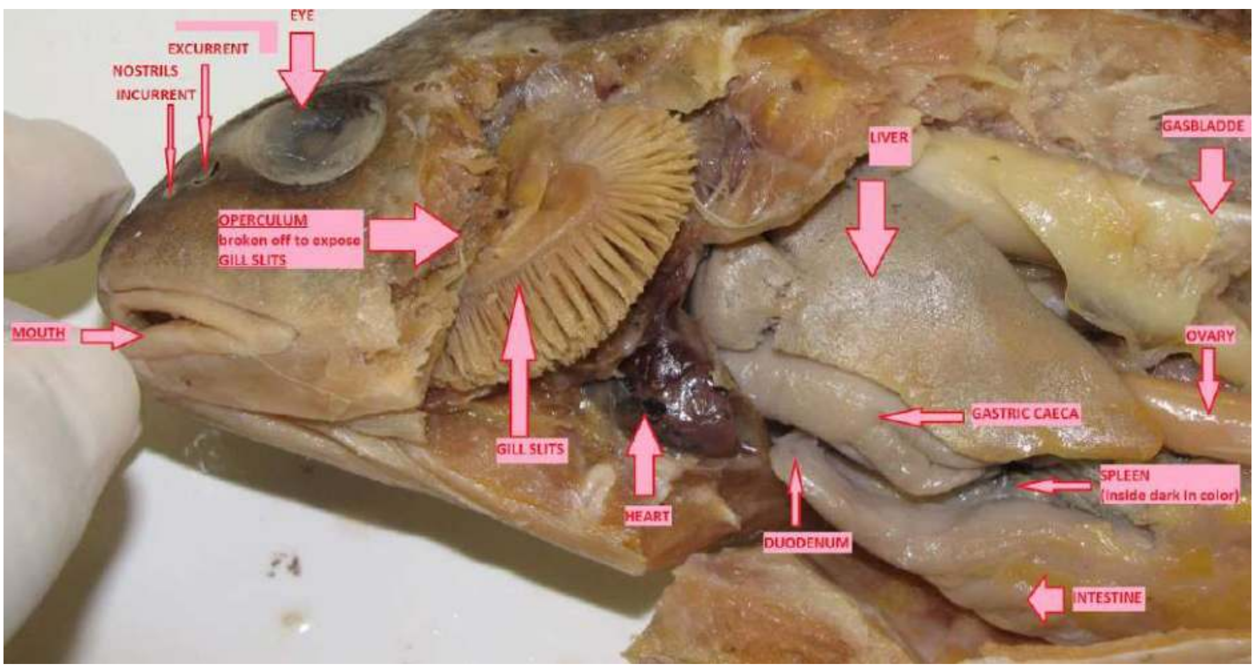
.

In this lesson we will be examining the external and internal anatomy of a bony fish and comparing this to a human

Fishes do have a few specialized structures that have no counterpart to humans.

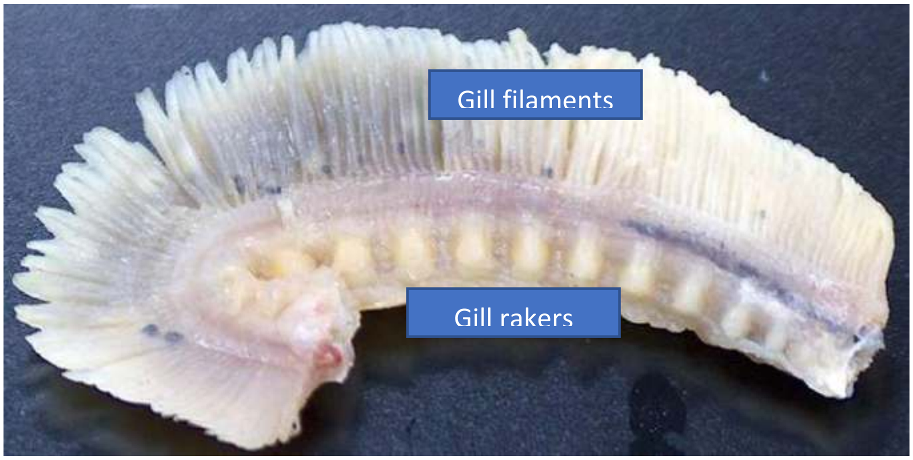
- The **lateral line:** detects physical vibrations in the water that allows the fish to sense other animals and objects in the water, even if they can't be seen.
- Many types of fishes use inner ear stones, called **otoliths**, to detect changes in body position

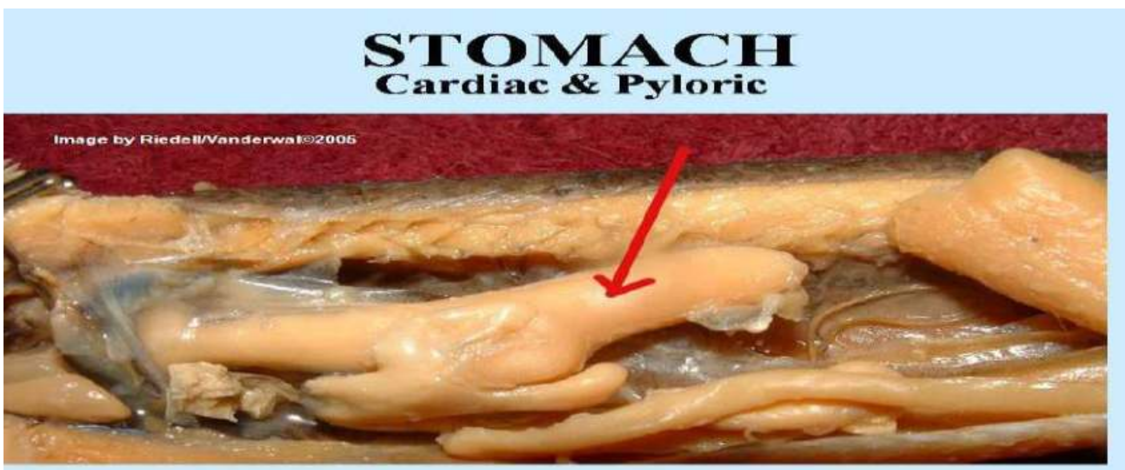

Anterior Dorsal Fin
Lepidotrichia
Posterior Dorsal Fin
Ceratotrichia
Gonad
Stomach
Caudal Fin
Dorsal Aorta
Gills
Lateral
Line
Operculum
Eye
Urinary
Bladder
Mandible
Swim
Bladder
Bulbus
Arteriosus
Heart
Pancreas
Intestine
Anal Fin
Liver
Pyloric
Caecum
Pelvic Fin
©Udo M. Savalli

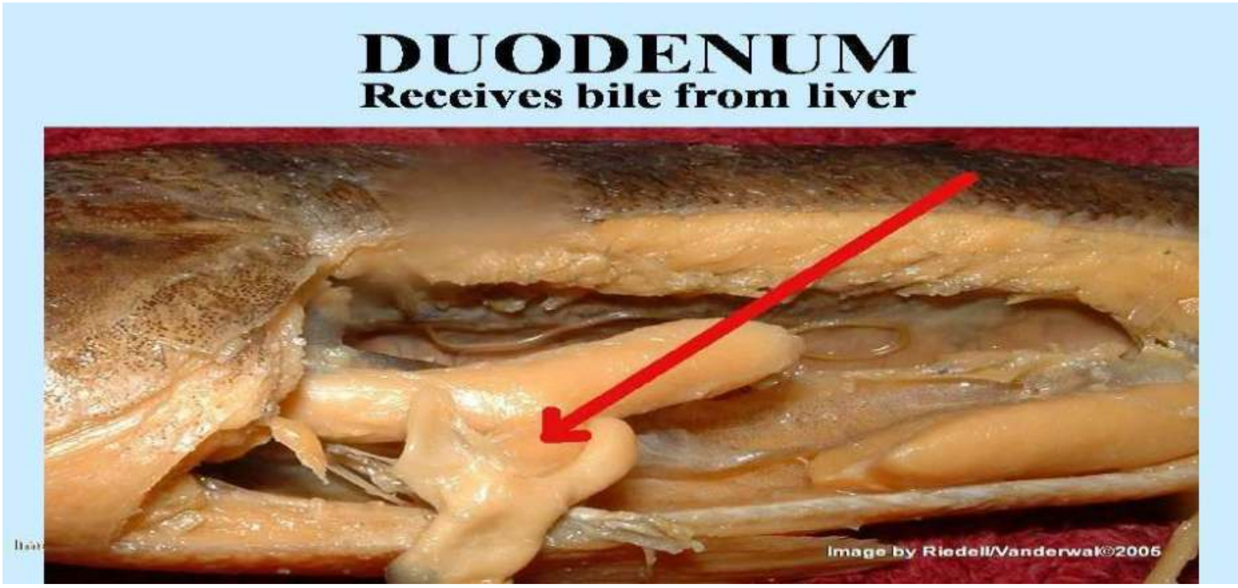

EYE
EXCURRENT
NOSTRILS
INCURRENT
LIVER
GASBLADDE
OPERCULUM
broken off to expose
GILL SLITS
MOUTH
OVARY
GASTRIC CAECA
GILL SLITS
SPLEEN
(inside dark in color)
HEART
DUODENUM
INTESTINE

FUNCTIONS OF GILLS:

1. **Gas exchange**
2. **Excrete Nitrogen waste as ammonia.**






DUODENUM
Receives bile from liver
Image by Riedell/Vanderwal©2006


INTESTINE
Absorbs nutrients.


LIVER
improved digestive gland

SPLEEN-

Produces new RBC's
Processes & destroys old worn out RBC's
Stores RBC's for release when needed

SWIM BLADDER
controls buoyancy

KIDNEY

Collects and removes nitrogen waste (ammonia)
Osmoregulation –maintain water/ion balance

HEART

Atrium receives blood from Sinus venosus

Ventricle – pumping chamber

Conus arteriosus-smoothes flow of blood out of heart

BRAIN

Image modified from:
http://www.flushing.k12.mi.us/srhigh/tippettl/biology/perch/index.html

Modifications of Fins

Fins

• Structure supports an independent evolutionary history of cartilaginous and bony fishes.
• Most fish have two sets of paired fins and four unpaired fins.
• Fins are used to propel الدفع, stabilize للاتزان and maneuver (تناور فى خدع العدو)

Internal Support for Fins:
• Supports have independent evolutionary history in bony & cartilaginous fish
• Fin rays are internal supports for fins
– Ceratotrichia (cartilaginous)
• Stiff صلب, unbranched, unsegmented
– Lepidotrichia (bony fish)
• Flexible, branched, segmented
• True spines may occur that emerge into fins.

Paired fins:

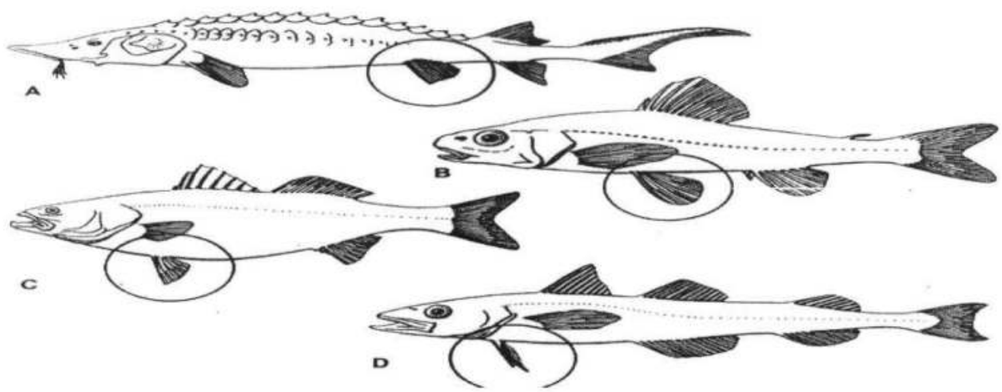
• Pelvic fins:
– Most variable in position:
1– Ancestral, = ventral, toward posterior.
2– Derived = thoracic.
3– Rarely in front of pectoral.

• Pectoral fins:
– Usually on sides.

Modifications:

- Pectoral fins modifications as wings, filaments,
  - wings: it helps the fish to fly in water for breathing or eating.
  - Filaments: it helps the fish to stand and walk.
- Pelvic and pectoral also modified into:
  - leg-like structure for walking

(Position of pelvic fins in fishes)



- Pelvic fins modifications as sucking devices

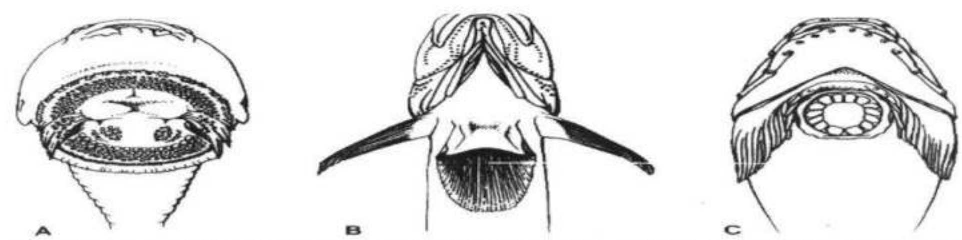


FIGURE 2–14. Pelvic fins modified as sucking devices. *A*, Clingfish (Gobiesocidae); *B*, goby (Gobiidae); *C*, Snailfish (Liparidae).

Modified dorsal fins:

1.sucking disc. 2.fishing rod and lure.

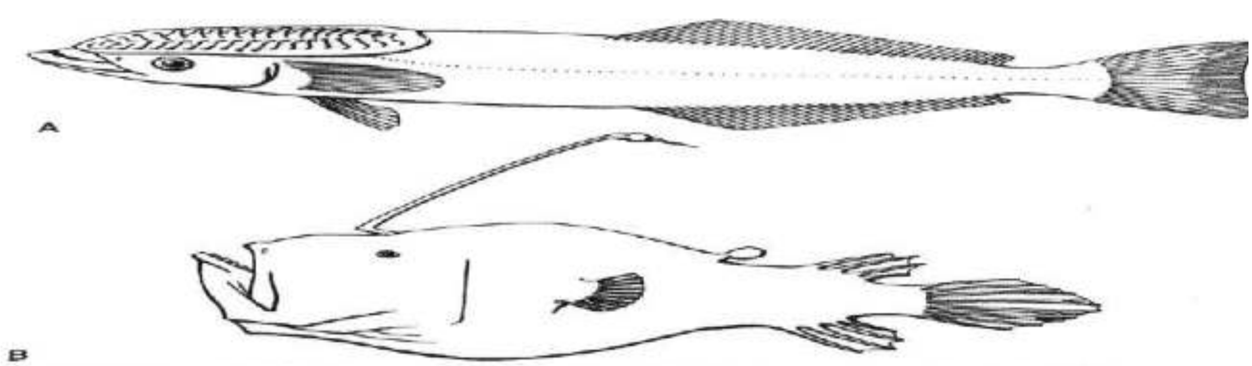


FIGURE 2–15. Modified dorsal fins. *A*, Sucking disc (remora, Echeneidae); *B*, fishing rod and lure (angler, Ceratiidae); (*B* based on Jordan and Evermann, 1900.)

EVOLUTIONARY TRENDS IN FISH MORPHOLOGY

Evolutionary trends:

- A shift in position of the paired fins (pectoral and pelvic fins).
- An increase in overall spininess (e.g., fins and scales).
- Changes in body shape.

THE PRIMITIVE FISH BODY PLAN:

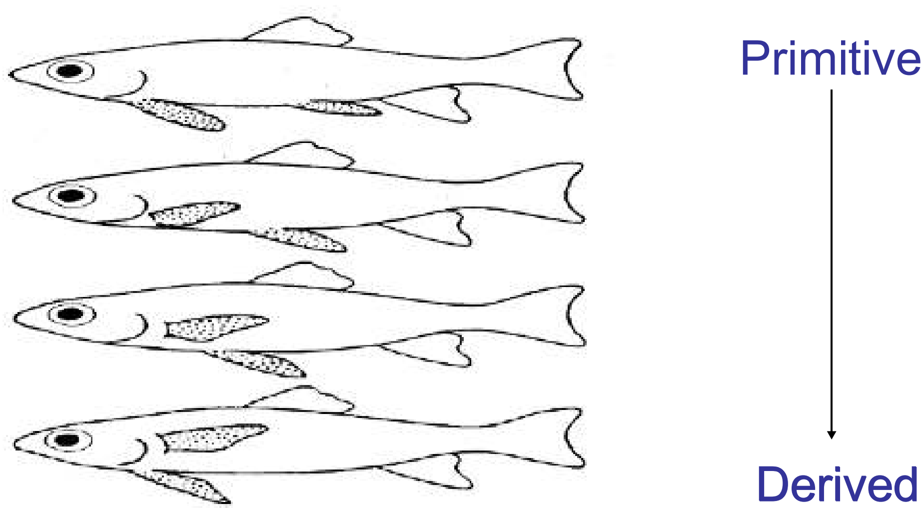
Long, skinny head and body, fins placed posteriorly, without spines, generally large adult body size; built for speed in open water; examples might include tarpon, herring, sardines, anchovies, salmon and trout.

THE DERIVED FISH BODY PLAN:

Short, deep head and body, fins placed far forward, full of spines, and generally small adult body size; built for maneuverability in complex, tight, crowded habitats; examples include squirrelfishes, cichlids, basses, surgeon fishes, angel and butterfly fishes, and a vast diversity of additional groups.

Shift in position of the pectoral and pelvic fins:

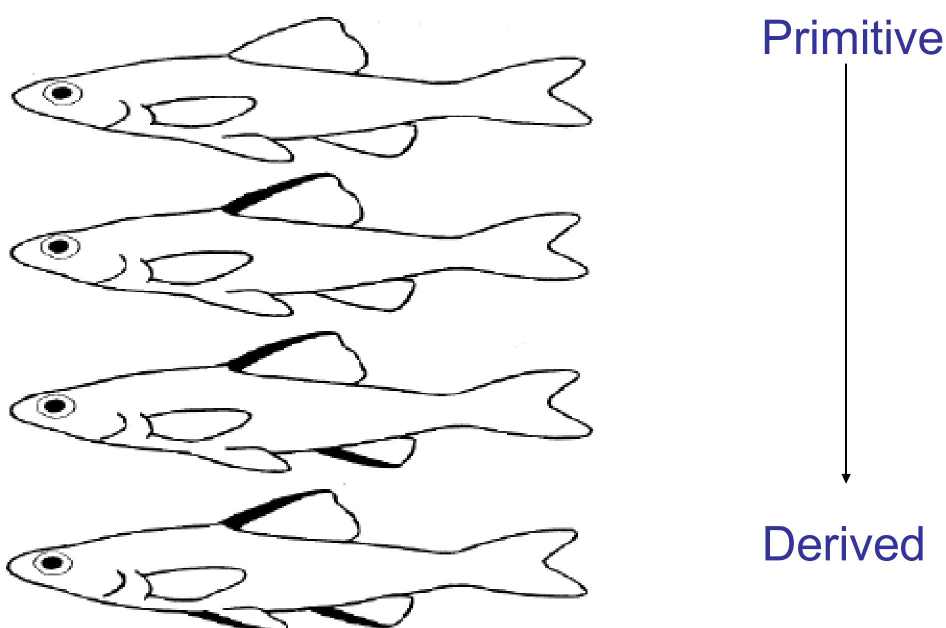
- Pelvic fins are abdominal in primitive bony fishes, but come to lie beneath the pectoral fins (thoracic) in derived fishes.
- Pectoral fins are inserted horizontally and low on the body in primitive fishes, but more vertically and high on the body in derived fishes.



Increase in overall spininess:

For example, the acquisition of fin spines:

- in primitive bony fishes: the fins are supported by soft pliable rays.
- in derived bony fishes: they are supported by stiff sharp spines.



Difference between primitive and advanced fish:

primitive fish:

- Long body.
- Pelvic fin faraway pectoral fin.
- pliable rays.

advanced fish or derived:

- Small body.
- Pelvic fin close to pectoral fin.
- Hard spines.

Pictures of Modifications

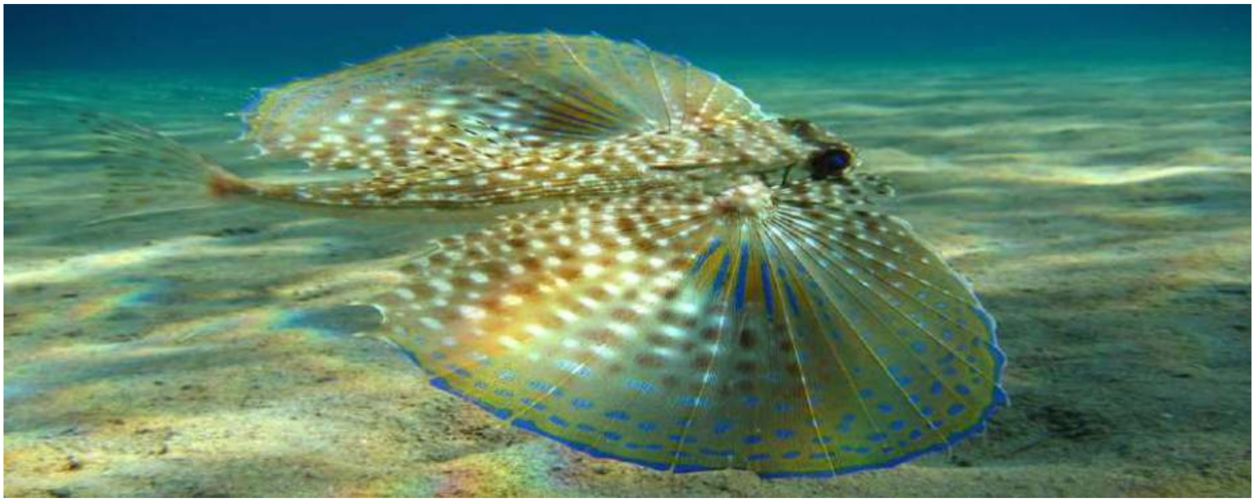
- Pelvic fins: modified into sucking, which helps a fish hold on to objects on the bottom.

- Pectoral fins modified into wings for gliding in water, pelvic fins modified into filaments for supporting for standing on seafloor .

- sea robin use their Pectoral fins for gliding around in the currents of water. Use their pelvic fins that modified into six finger-shaped spines that beneath pectoral fins to walk on the seafloor, also to find tier prey.

- Pectoral fins modified into filaments, pelvic fins modified into leg-like structure for supporting on seafloor and walking.

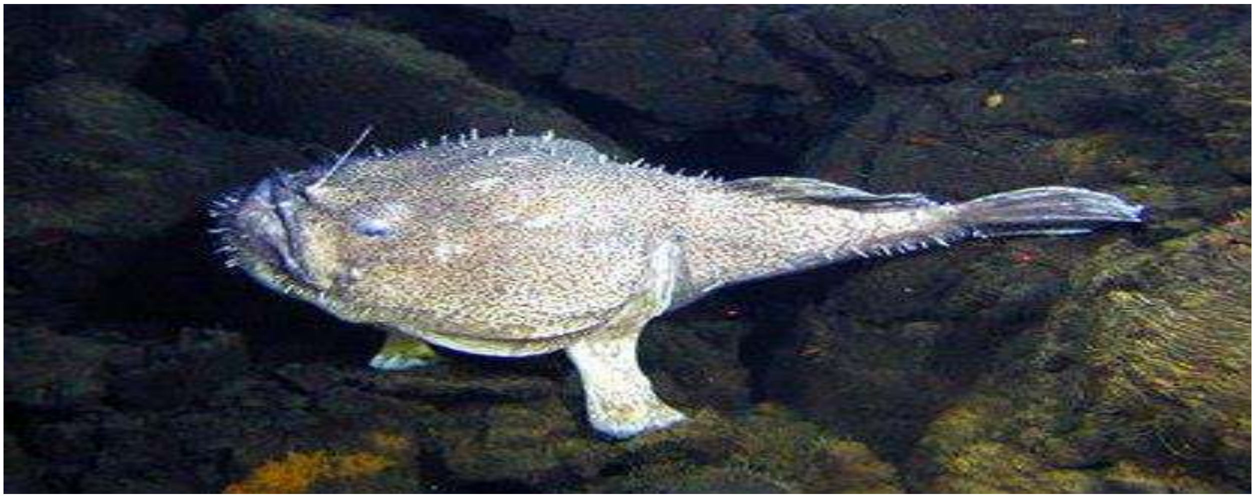
- Pectoral fins modified into wings for gliding over the water.



- Pectoral fins modified into wings for gilding in water. Advanced (indicate reasons).

- Pectoral and pelvic modified into legs-like structure for walking.

- Advanced(present strong spines- small body)
- pectoral fins modified into legs –like structure for walking.



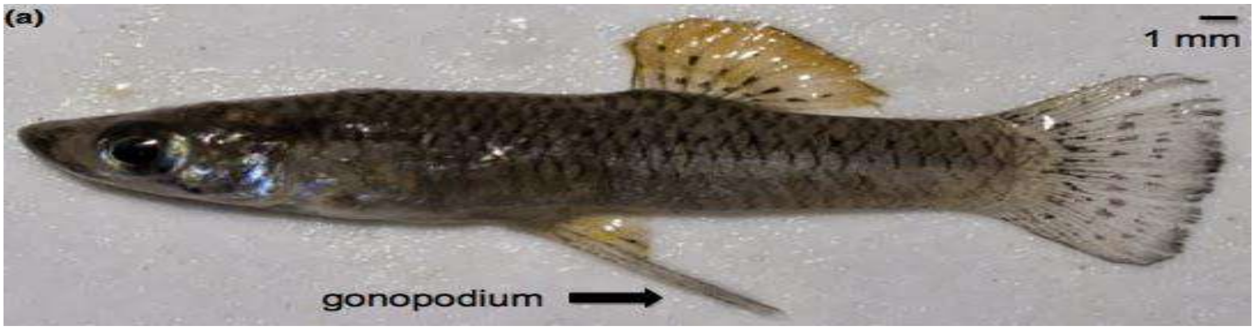
- Pectoral fins, pelvic fins and caudal fins modified into strong spines as leg- like structure supporting for standing and walking.

- Dorsal fin modified into sucking disc.

- Dorsal fin modified into a lure or rod which helps to attract the prey , advanced: small body – spines).

- Part of dorsal fin modified into light organ &advanced.

- Anal fin modified into gonopodium help in reproduction.



1-Prehensile tail used for coiling round the sea weeds.

2-Tubular mouth and snout used as sucking device.

3-Advanced:

1-with an exoskeleton of bony rings.

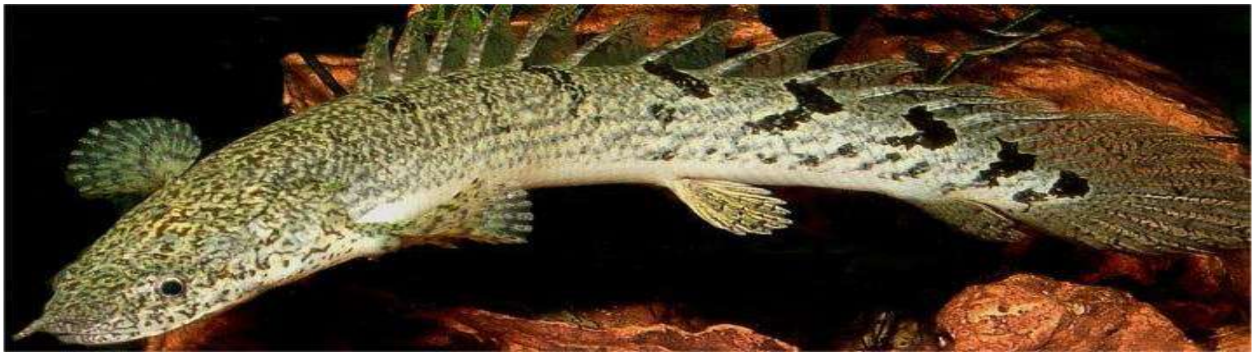
2-small body.

- Advanced: Small body- spines-pelvic close to pectoral.

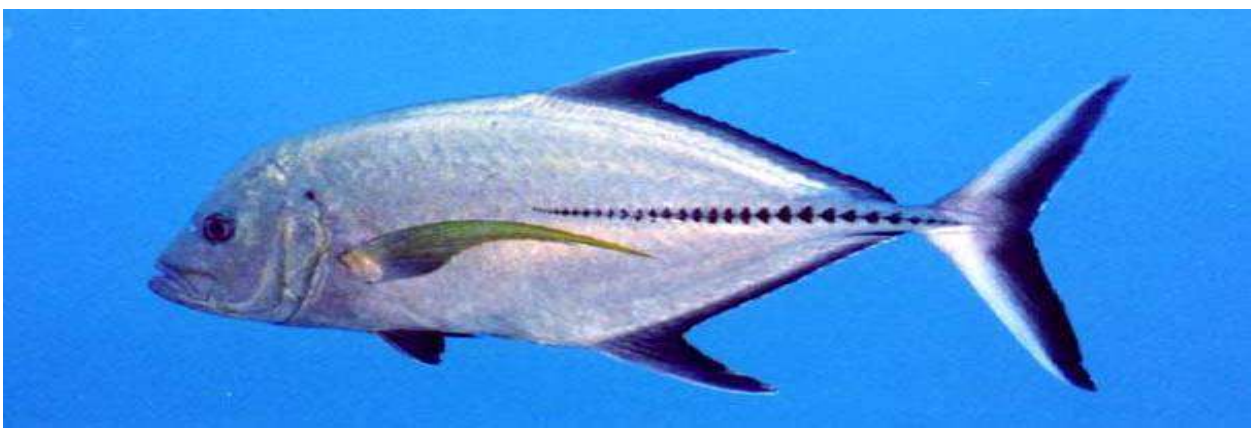
- Color for adaptation &Advanced (Small body- spines).

- Advanced: Small body- pelvic close to pectoral fins.

- Primitive: long body- long distance between pelvic and pectoral fins- not spines- dorsal fins divided into several parts.

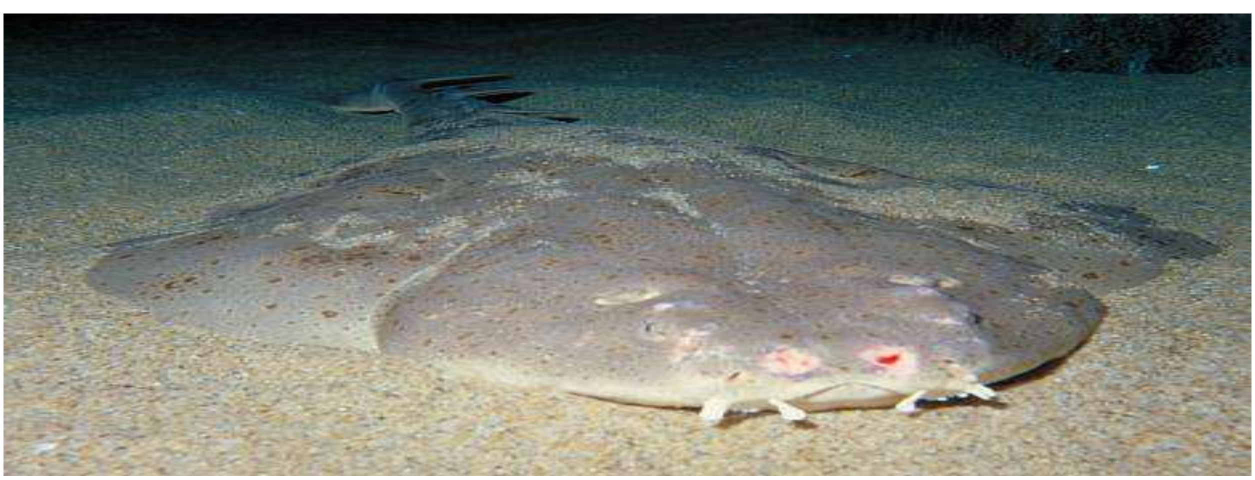


- Advanced: small body-spines- pelvic fins close to pectoral fins
- Caudal fins: lunate used it for maintaining rapid speed for long duration.



Color: for adaptation

Pectoral fins: modified into large structure used for Crawl on the sand of sea floor.



Histology of bony fishes

Histological sections in different fish organs showing basic structures of each organ pointed by arrow in the following photo sections.

Name of section:

***Section of bony fish liver showing:**

figure1-cords of hepatocytes, central vein and bile duct.

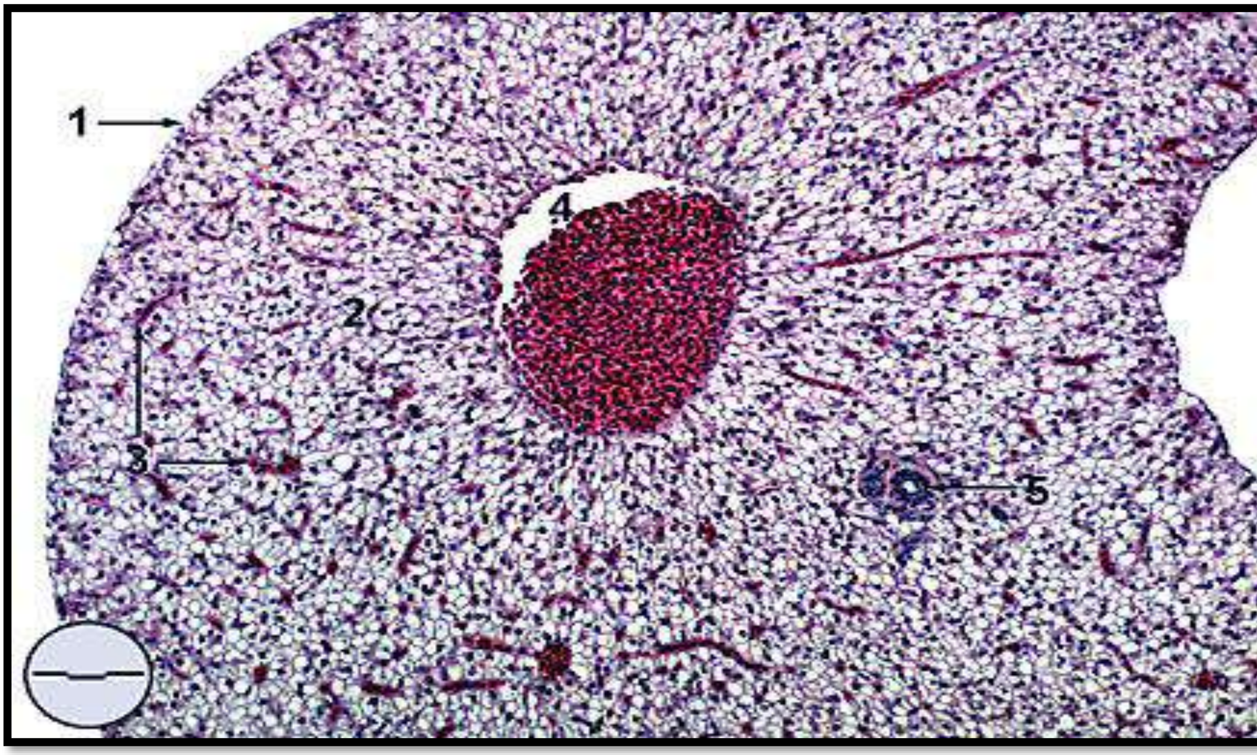


Figure 2. Cords of hepatocytes and central vein, transverse section (Formalin, H&E, Bar = 84.8 µm). 1. liver capsule; 2. cords of hepatocytes; 3. sinusoids containing red blood cells; 4. central vein; 5. bile duct.

figure2- sinusoid and bile duct

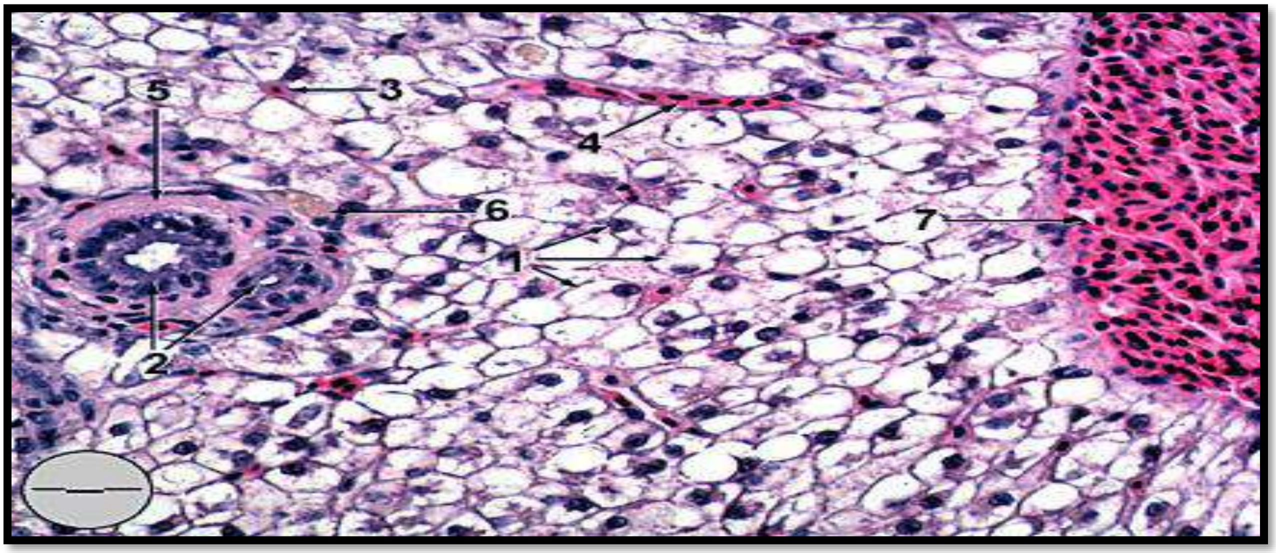


Figure 3. Sinusoids and bile ducts (Formalin, H&E, Bar = 22.8 µm).
1. hepatocytes with glycogen vacuoles and eccentric nuclei; 2. transverse section of bile ducts; 3. transverse section of a sinusoid comprised of six hepatocytes surrounding a capillary; 4. sagittal section of a sinusoid capillary; 5. connective tissue; 6. tissue macrophage; 7. central vein.

figure3- sinusoid and bile canaliculi.

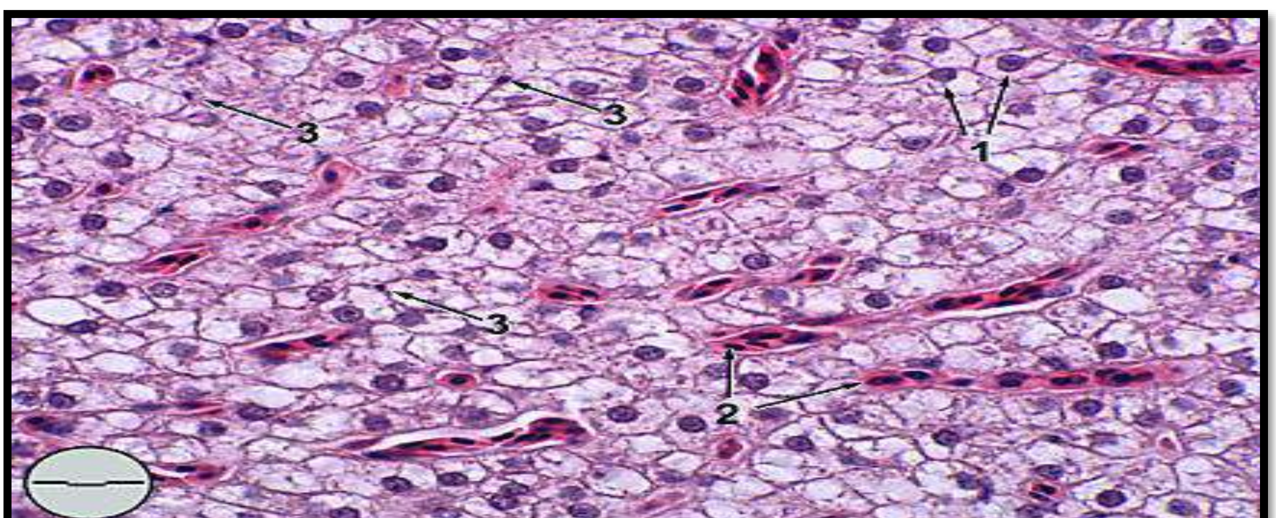


Figure 4. Sinusoids and bile canuliculi (Formalin, H&E, Bar = 15.3 µm).
1. hepatocytes; 2. sagittal section through sinusoids; 3. bile duct canuliculi.

Name of section:
Transverse section of bony fish kidney showing:
figure1- glomerulus, Bowman´s space.

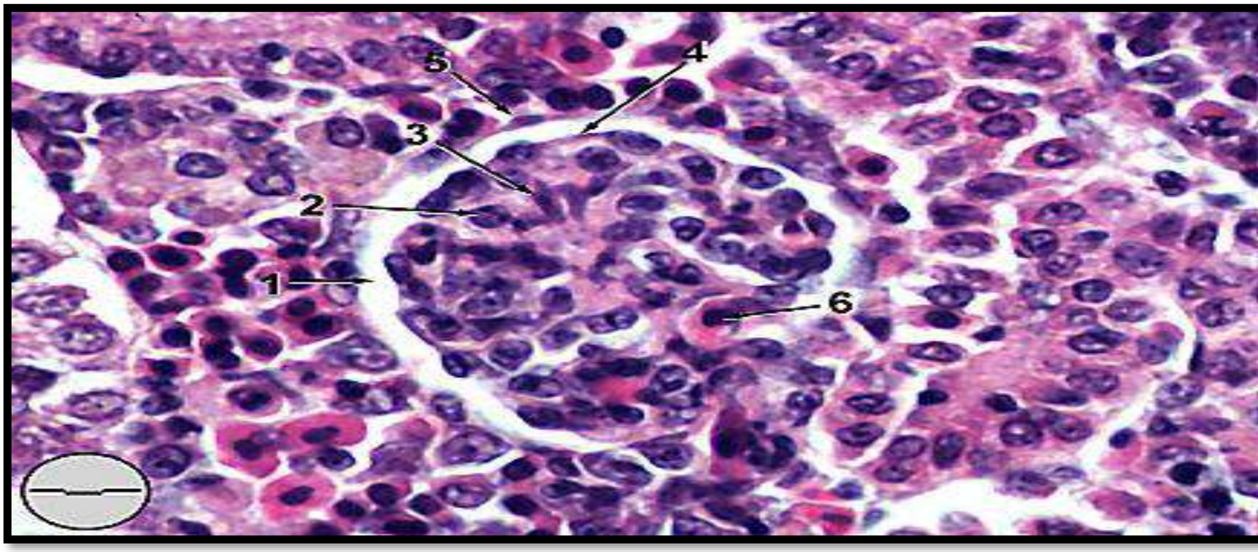


Figure 2. Glomerulus (Formalin, H&E, Bar = 10.7 μm). 1. Bowman's space; 2. endothelial cell; 3. mesangial cell; 4. visceral epithelium of the renal capsule; 5. parietal epithelium of the renal capsule; 6. red blood cell in capillary.

figure2-kideny tubules, collecting duct and brush border.

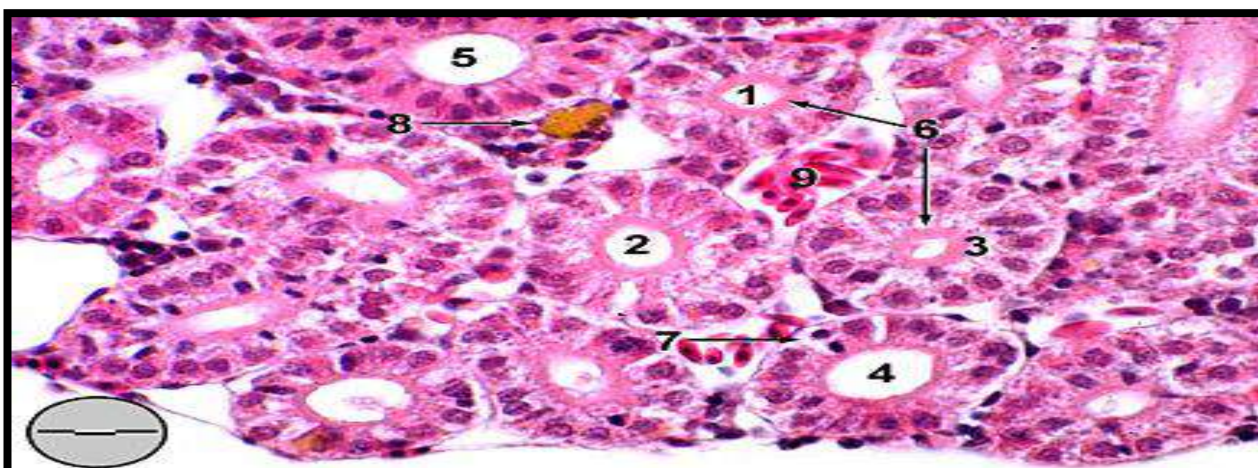


Figure 3. Kidney tubules, transverse section (2) (Formalin, H&E, Bar = 16.7 μm) 1. first proximal tubule; 2. second proximal tubule; 3. intermediate tubule segment; 4. distal tubule; 5. collecting duct; 6. brush border; 7. mitotic epithelial cell; 8. melanomacrophage; 9. red blood cells.

Name of section:
Transverse section of bony fish gills showing:

figure1: gill filament, sagittal section.

RESPIRATORY CHAPTER: Gill filament, sagittal section

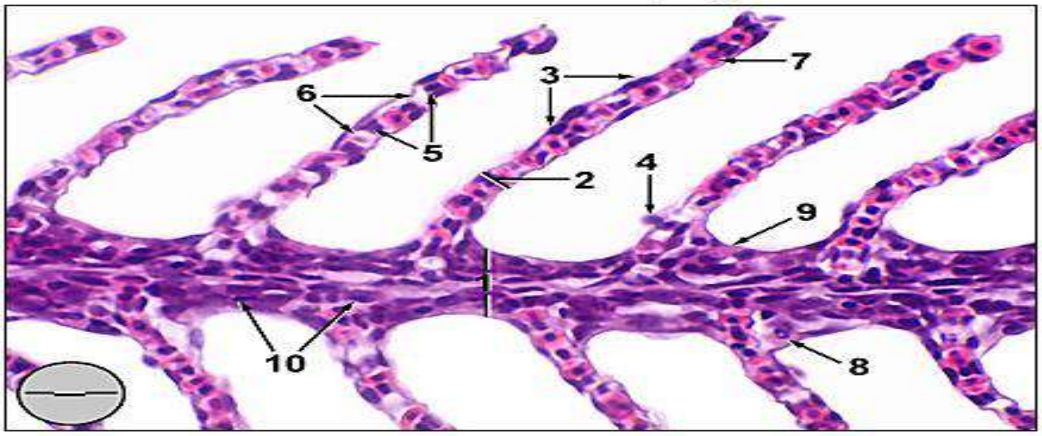


Figure 4. Gill filament, sagittal section (Formalin, H&E, Bar = 16.7 µm). 1. primary lamella; 2. secondary lamella; 3. epithelial cell; 4. mucous cell; 5. pillar cell; 6. lacuna (capillary lumen); 7. erythrocyte within capillary lumen; 8. chloride cell; 9. rodlet cell; 10. undifferentiated basal cell.

figure2: gill filament, sagittal section through cartilaginous support.

RESPIRATORY CHAPTER: Gill filament, sagittal section through cartilaginous support

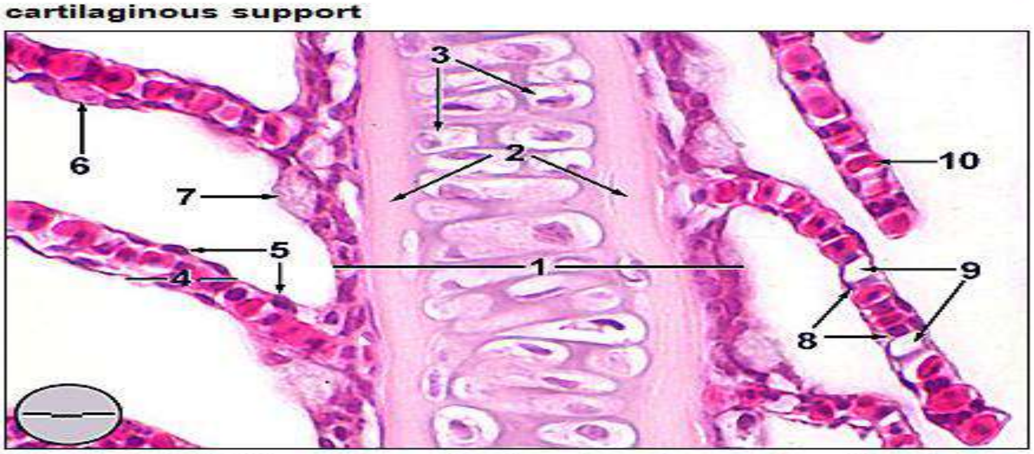


Figure 6. Gill filament, sagittal section through cartilaginous support (Formalin, H&E, Bar = 15.6 µm). 1. primary lamella; 2. extracellular cartilaginous matrix; 3. chondrocytes; 4. secondary lamella; 5. epithelial cell; 6. mucous cell; 7. chloride cell; 8. pillar cell; 9. lacuna (capillary lumen); 10. red blood cells within lacuna.

Transverse section of herbivorous fish stomach showing:

Different layers that formed stomach.

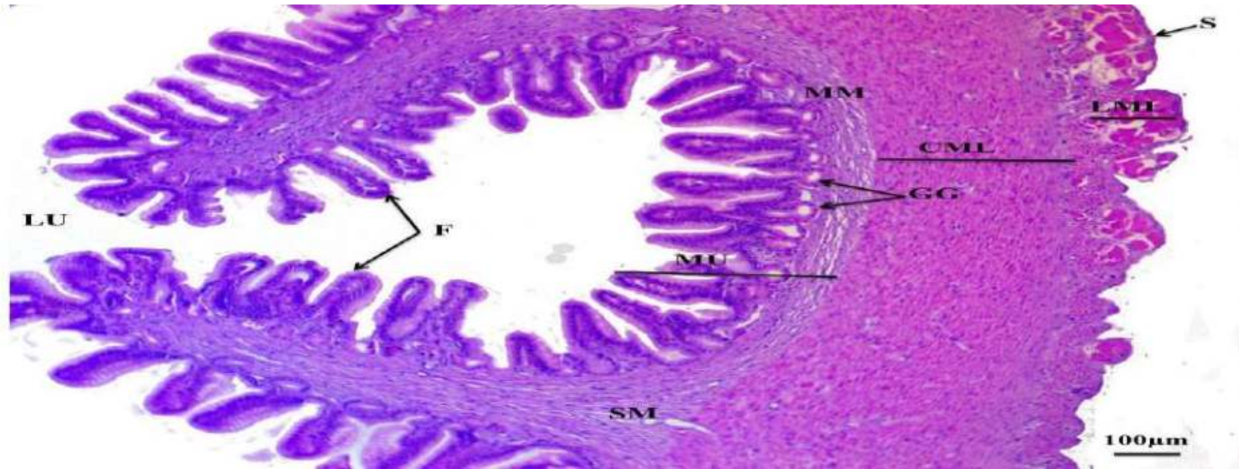


Fig. 3: Transverse section of the posterior region of the stomach of *S. rivulatus* showing MU: mucosa, SM: submucosa, CML: circular muscle layer, LML: longitudinal muscle layer, S: serosa, MM: muscularis mucosa, GG: gastric gland, LU: lumen and F: mucosal folds (H&E, ×100).

Transverse section of herbivorous fish intestine showing:

Different layers that formed intestine.

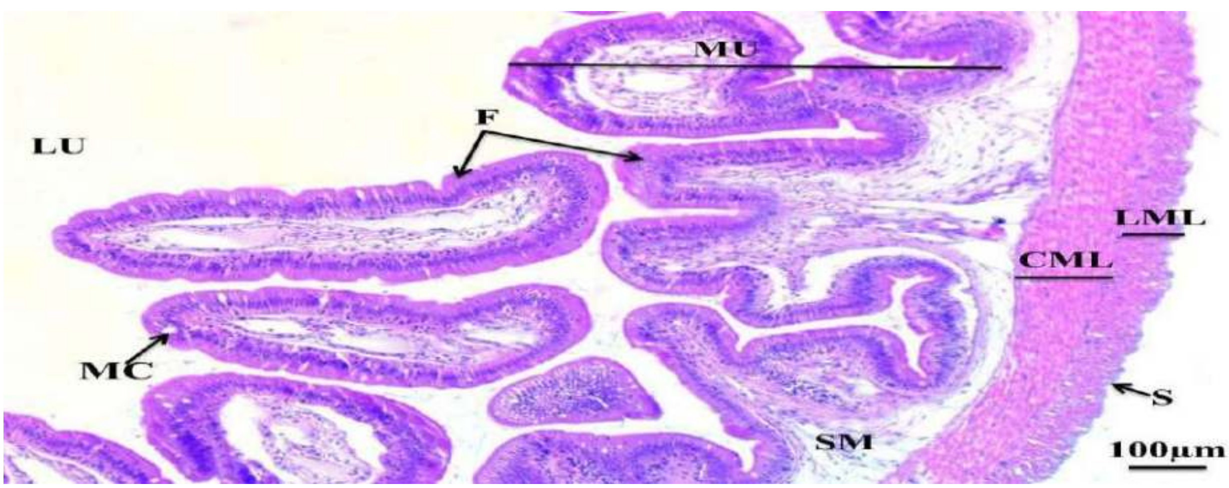
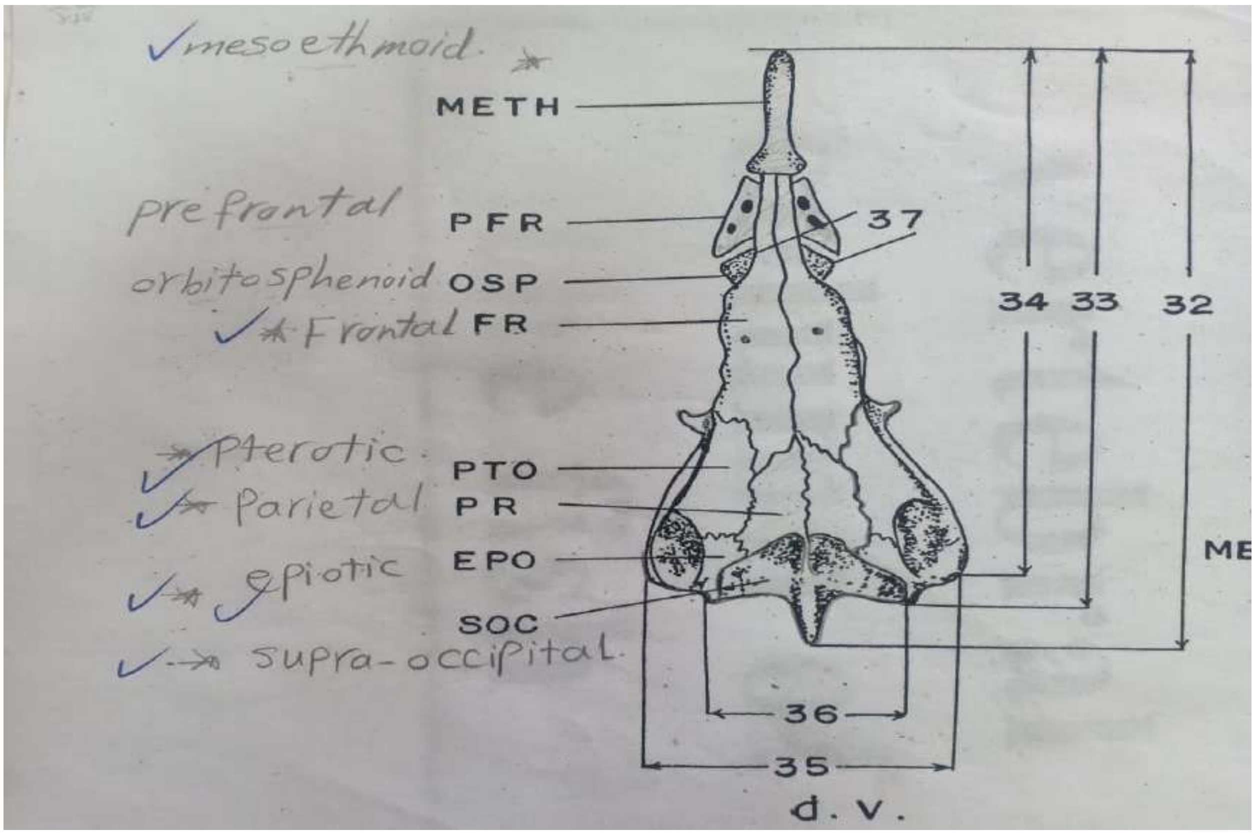


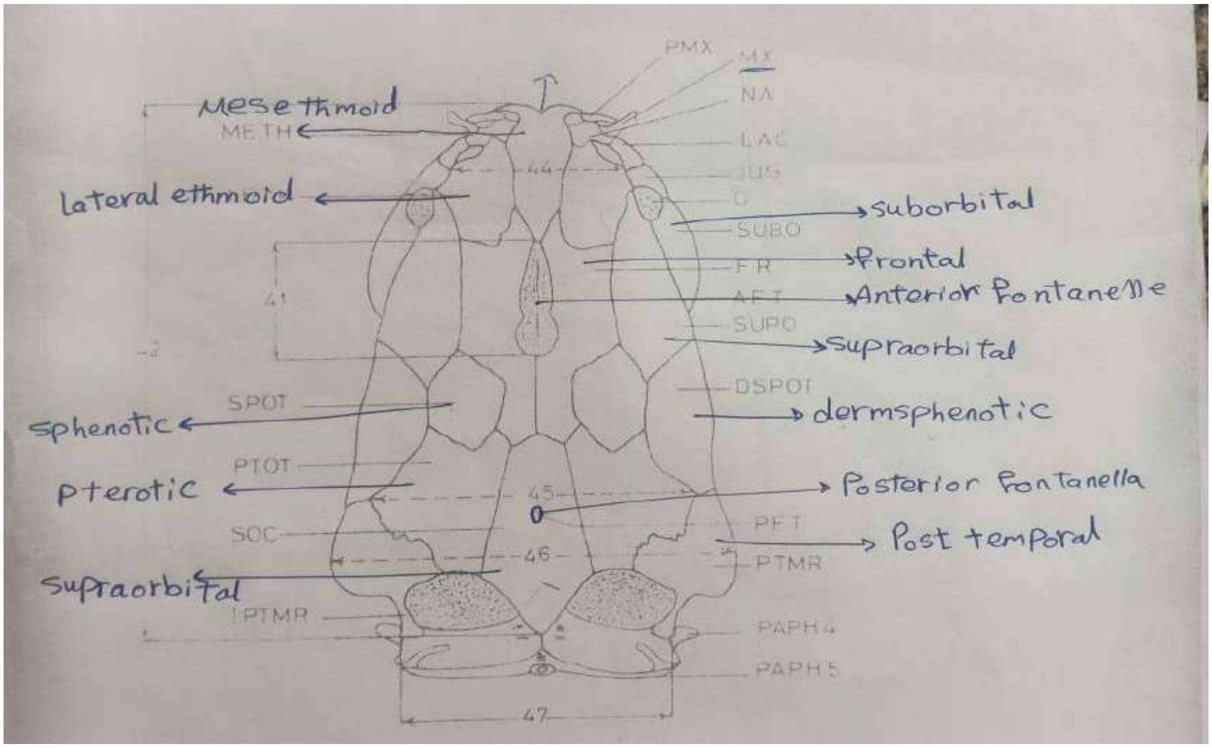
Fig. 5: Photomicrograph of transverse section of intestine of *S. rivulatus* showing MU: mucosa, SM: submucosa, CML: circular muscle layer, LML: longitudinal muscle layer, S: serosa, F: mucosal folds, MC: mucous cells, and LU: lumen (H&E, ×100).

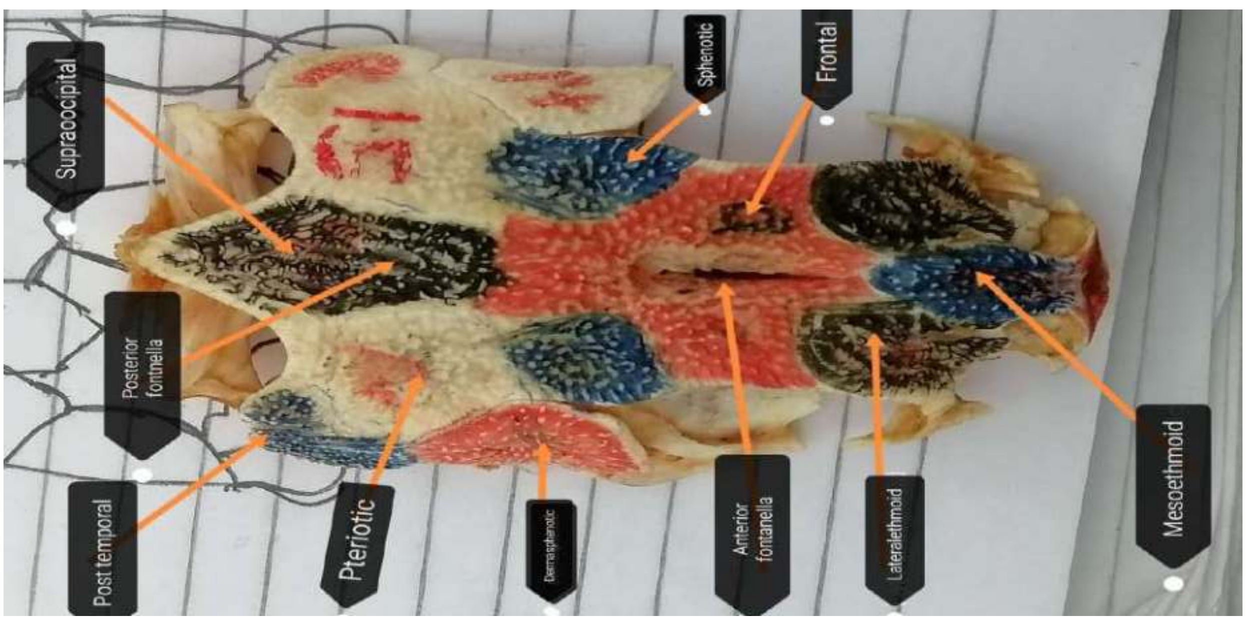
Skull of bony fishes

1. **Dorsal view of skull of *Mormyrus kannume* .**



2. Dorsal view of skull of *Clarias lazera*





3. Dorsal view of *Synodontis schall*

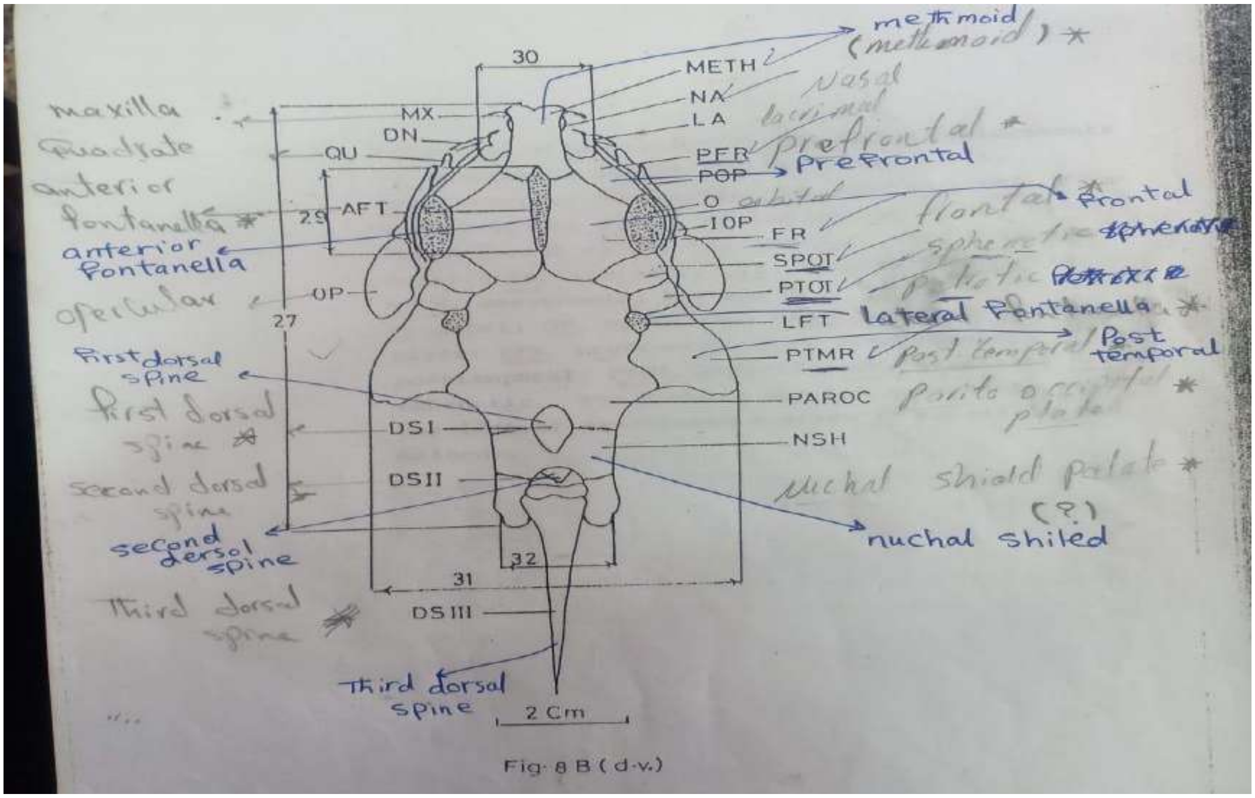
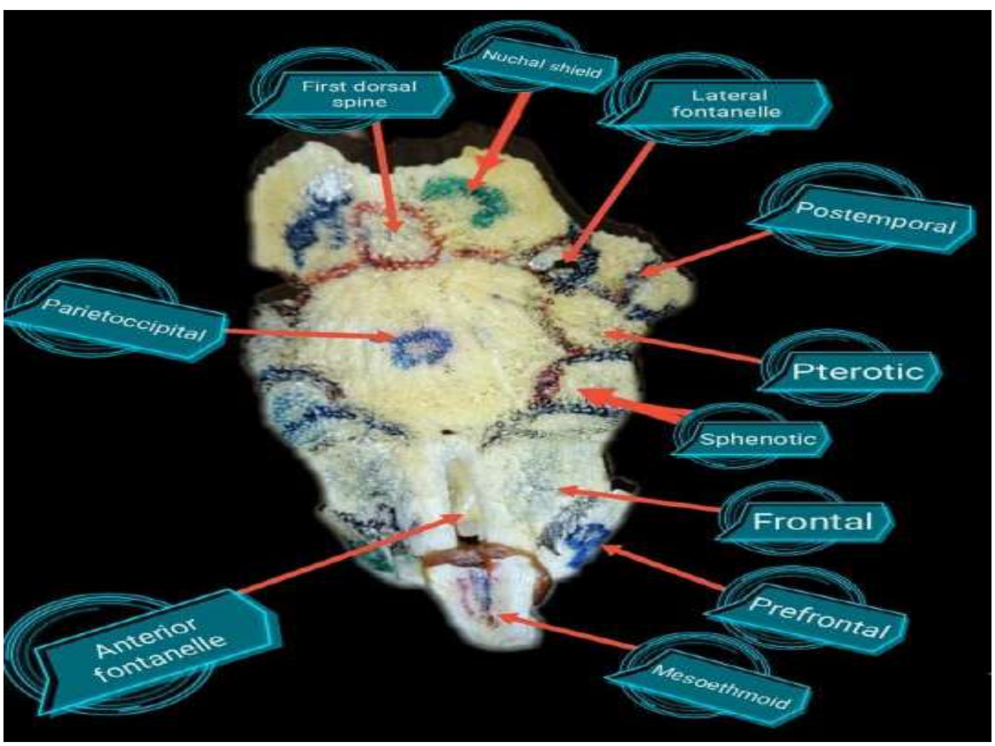


Fig. 8 B (d-v.)



Taxonomy

Classification of some bony fishes:

Kingdom : Animalia

Subkingdom : Eumetazoa

Phylum : Chordata

Subphylum : Vertebrata

Superclass : Gnathostomata

Class : Osteichthyes

- **Oreochromis niloticus niloticus البلطي النيلي**

Class : Osteichthyes

Subclass : Teleostei

Order : Perciformes

Family : Cichlidae

e.g. : Oreochromis niloticus niloticus

- **Lates niloticus قشر البياض**

Class : Osteichthyes

Subclass : Teleostei

Order : Perciformes

Family : Latidae

e.g. : Lates niloticus

- **Clarias lazera القرموط**

Class : Osteichthyes

Subclass : **Teleostei**

Order : **Siluriformes**

Family : **Clariidae**

e.g. : **Clarias lazera**

- ***Malapterurus electricus*** **الرعاش**

Class : **Osteichthyes**

Subclass : **Teleostei**

Order : **Siluriformes**

Family : **Malapteruridae**

e.g. : **Malapterurus electricus**

- ***Bagrus bayad*** **بقر البياض**

Class : **Osteichthyes**

Subclass : **Teleostei**

Order : **Siluriformes**

Family : **Bagridae**

e.g. : **Bagrus bayad**

- **Synodontis schall** **الشال**

Class : **Osteichthyes**

Subclass : **Teleostei**

Order : **Siluriformes**

Family : **Mochokidae**

e.g. : **Synodontis schall**

- ***Chrysichthyes auratus*** **الزمار**

Class	**: Osteichthyes**
Subclass	**: Teleostei**
Order	**: Siluriformes**
Family	**: Claroteidae**
e.g.	**: Chrysichthyes auratus**

- ***Labeo niloticus*** **اللبيس**

Class	**: Osteichthyes**
Subclass	**: Teleostei**
Order	**: Cypriniformes**
Family	**: Cyprinidae**
e.g.	**: Labeo niloticus**

- ***Mormyrus kannume*** ***القنومة***

Class	**: Osteichthyes**
Subclass	**: Teleostei**
Order	**: Osteoglossiformes**
Family	**: Mormyridae**
e.g.	**: Mormyrus kannume**

Zoology Department

Special Environments

(Soil Biology)

Theoretical Part

By/

Dr. Heba M. Fangary

(Fourth Year Students)

Chemistry & Zoology

2022-2023

Soil Ecosystem

What is soil?

Soil is one of the world's most important natural resources. Together with air and water it is the basis for life on planet earth. It has many important functions which are essential for life. Not only does it play the major part in allowing us to feed the world's population, but it also plays a major role in the recycling of air, water, nutrients, and maintaining a number of natural cycles, thereby ensuring that there will be a basis for life in generations to come. Without soil, the world's population neither would nor could survive.

An ecosystem is all of the organisms in a given place in interaction with their nonliving environment.

Soil as an ecosystem

The soil is a thriving ecosystem of plants and animals which play an important role in the soil. The soil is the source of many different types of food for these creatures and is also the source of their nutrition and water. The soil can also offer a range of habitats, for instance the badger's sett, the rabbit warren, the earthworm channel, numerous pores where the small creatures can exist and develop.

Most of the soil life exists out of sight, beneath the surface of the soil. Billions of organisms inhabit the upper layers of the soil, where they break down dead organic matter, releasing the nutrients necessary for plant growth.

There is a very huge range of organisms in the soil varying in size from protozoa which require the strongest of microscopes to see them, up to large burrowing animals such as badgers and rabbits which live part of the time in the soil and part of it on the soil surface. Not only is there this large range of size but there is also wide variation in what they use the soil for.

Soil Composition

While a variety of substances may be found in soils, they are categorized into four basic components: **minerals**, **organic matter**, **air** and **water**. Most introductory soil textbooks describe the ideal soil (ideal for the growth of most plants) as being composed of 45% minerals, 25% water, 25% air, and 5% organic matter. In reality, these percentages of the four components vary tremendously.

1- **Soil minerals**

The mineral portion of soil is come from the rock deposits and sediments beneath them. This mixture gives the overall **texture** of the soil, namely whether the soil is mainly sandy, loamy or clayey. The mineral grains divided into three particle-size classes: **sand, silt, and clay**. (Note: Sand, silt, and clay are collectively referred to as the *fine earth fraction* of soil). They are <2 mm in diameter. Larger soil particles are referred to as rock fragments and have their own size classes. The particle size classes are defined as follows:

Particle Name	Particle Diameter
Clay	below 0.002 millimeters
Silt	0.002 to 0.05 mm
Very fine sand Fine sand Medium sand Coarse sand Very coarse sand	0.05 to 0.10 mm 0.10 to 0.25 mm 0.25 to 0.5 mm 0.5 to 1.0 mm 1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 mm

2- **Soil Organic Matter**

Soil organic matter (SOM) is a complex mixture of substances (mainly in the top 20 cm) that can be highly variable in its chemical content. It ranges from freshly deposited plant and animal parts to the residual humus —stable organic compounds that are relatively resistant to further rapid decomposition by the soil organisms.

An important physical property of SOM is its ability to absorb and hold large quantities of water. The mass and volume of water that can be absorbed by SOM often exceed the mass and volume of the SOM itself. Organic matter plays an important part in topsoil structures and is the major 'glue' holding particles together It can improve the workability of most soils whatever their texture.

3- Soil air and water

Soil air and water are found in the pore spaces between the solid soil particles.

Soil contains varying amounts of **water** depending on the climate (seasonally, weekly, and even daily) and the water holding capacity of the soil. Water is a very important component of soils and plays a huge part in the way soils behave and in the ease with which they can be worked for agriculture and other uses. Water is held in the soil around particles and the edges of pores. It is held in these positions with various degrees of strength. Sandy soils tend to hold little water whereas clayey soils can hold much water though some of it will be unavailable because it is held strongly in tiny pores. The drier the soil becomes, generally the stronger the soil will hold onto its water. Soil water is essential for the survival and growth of plants and for maintaining soil organisms.

The remaining important ingredient is **air**. The amounts of each of these components vary in time and across the landscape. This is a magical mixture of ingredients that allows the soil to perform many vital needs of living beings.

Some properties of the soil

Two of the most important physical properties of soils are their texture and structure. One of the most important chemical properties of a soil is its acidity or alkalinity, often stated as the pH of the soil.

<u>Soil texture</u>

Soil texture refers to the size of the particles that make up the soil (organic matter is excluded from the texture classification) and how this affects the way they feel and their cultivation.

The main components of soil texture are: sand, silt and clay particles. For example, soils that are dominantly composed of sand-sized particles (**sandy soils**) feel gritty; they contain lots of pores because of the way the grains stack together. This also means that rainwater entering the soil can easily drain away through the soil which leads to the soils being quite droughty. **Clayey soils** by comparison contain many smaller pores which mean that water does not pass through the soil as freely and means they can become waterlogged in wet periods and are sometimes difficult to cultivate. A **loamy soil** contains more or less equal amounts of clay, sand and silt. Soils with high silt content and those with high clay content have greater capacities for retaining water and available nutrients than sandy soils.

From the discussion of the soil particle sizes, it should be obvious that soil texture is important in:

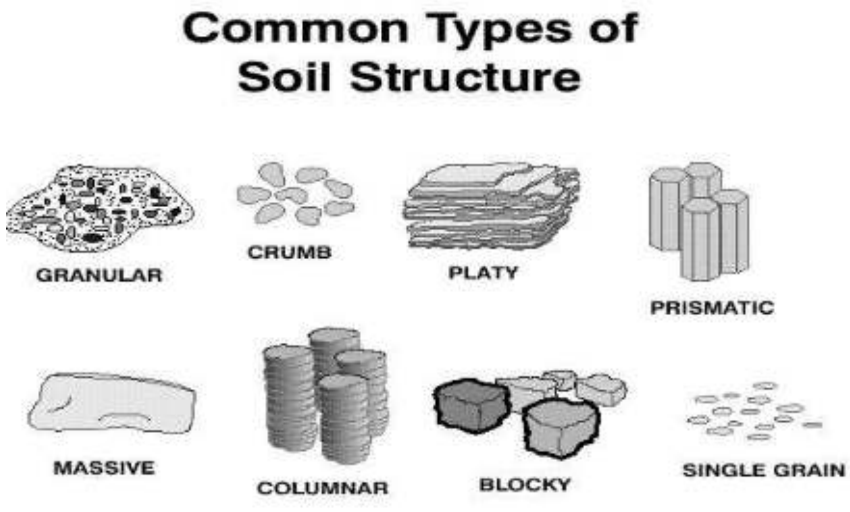
1- Determining the nutrient- holding abilities.
2- Water –holding capacity,
3- Water movement and
4- The amount and movement of soil air in a given soil.

Soil structure

The components of soil described above rarely occur as separate particles. There is, for example a strong bond between decomposed organic matter and the clay fraction of soils. In most soils, the particles are molded together into aggregates to form the architecture of the soil. Compare the architecture of a house - it is built with bricks and mortar and has entrances, rooms and corridors - a soil has the mineral particles, organic matter and these are used to build the architectural structure of the soil.

So, **the soil structure** describes the way these individual particles are assembled and bound into groups (aggregates) which separated by the pores (holes). Roots pass through these pores in search of water. Depending on the soil texture, amounts of organic matter and the way the soils are managed, the soil structure will vary with depth in the soil and from one soil type to another. The main types of soil structure are **crumb, granular, blocky, platy and prismatic**.

The best soil structures tend to be in the topsoils. This is mainly because there is usually organic matter present and this attracts huge numbers of organisms which work to decompose it. The organisms ingest the soil; create small structural units and numerous burrows in the soil. Crumb and granular structures formed in this way are ideal topsoil structures for farmers and gardeners because they contain plenty of pores through which air and water can circulate readily, and through which plant roots can readily move in search of air, water and nutrients.



Soil pH

An acid is a substance that dissolves in water to release hydrogen ions. pH is the measurement of the concentration of these hydrogen ions in a soil solution, i.e. a mixture of soil and pure water.

The pH of the soil ranges from about 3 to 8. Below 5.5 the soil is quite acidic. Above pH 7 the soil is alkaline. Soil with a pH in the range of 5.5 to 7 tends to be the most flexible and a wide range of plants can thrive within this pH range. Once the pH drops below 5.5, firmly into the acidic range, there is only a limited range of plants that like this level of acidity and can tolerate these acidic conditions. Once the pH is above 7.0, the soil tends to be colonized by a limited range of lime-loving plants.

Soils in wet climates and certainly those developed on acidic rocks, such as granite, will tend to be acidic. Soils in high rainfall areas tend to be acid because the rainfall leaches the soil of many of its nutrients which otherwise help to keep the pH higher. Acidic soils can be improved by adding lime to soil. This is a common agricultural practice where farm soils need to be maintained at a pH from 5.5 to 7 in order to grow a wide range of crops.

Soils formed in dry climates are often alkaline, i.e., with a pH above 7. Here there is a lack of rainfall to flush the nutrients out of the soil and they stay within the soil. In some dry conditions also evaporation may lead to deep-lying nutrients being brought to the surface. This can lead in some dry-climate soils to excessive amounts of salts being brought into the root zone. In extreme cases this can lead to salinization, in which the soils contain too many salts, which can prevent the growth of many crops.

The Soil Profile

Most soils have formed from rocks and sediments. Some have developed over many thousands of years by the gradual breakdown of rocks that occur beneath them and on which they lay.

Each soil consists of a series of layers, termed soil **horizons**. It is the type, nature and arrangement of these horizons that provide the clue to how soils have formed. The soil profile is the term used for the whole depth of soil including all the layers (horizons) of soil from the surface of the ground down as far as the rock or sediment some centimeters and even meters below the surface. Soil profiles are the basis for distinguishing one type of soil from another and form the basis for the names given to soils and the way we classify soils. Just as we give plants, such as daisies or bluebells, and animals such as badgers or moles, names, so we need to distinguish different types of soils and also give them names.

The soil profile is defined as a vertical section of the soil from the surface vertically down through the soil until the underlying rock or sediment is reached. If a person digs a hole in the ground and looks at the wall of that hole, he is looking at the soil's profile. The thickness varies with location, and under disturbed conditions: heavy agriculture, building sites or severe erosion for example, not all horizons will be present.

1. ***O horizon*** (organic layer).

It consists of three layers: the freshly fallen litter lying on the surface of the soil. The second layer is called **fermentation layer** where a partial decomposition occurred. The third layer (**humus layer**) is dark because of the completely decomposition of the organic matter that is occurring. The numerous organisms in this soil horizon are responsible for breaking down these additions of plants and animals and releasing the nutrients they contain to become available for the next generation of plants and animals. This O horizon is most prominent in forested areas, and often missing in cultivated soils.

2. ***A horizon***

It contains a mixture of organic and mineral components, commonly referred to as **topsoil**. As water moves down through the topsoil, many soluble minerals and nutrients dissolve. The dissolved materials leach downward into lower horizons (**leaching process**).

3. ***E horizon*** (E stands for eluviation)

It is stripped of much of its clay and sometimes staining agents, and is thus often lighter in color than the others. It is lower in organic matter than the A horizon.

4. ***B horizon***

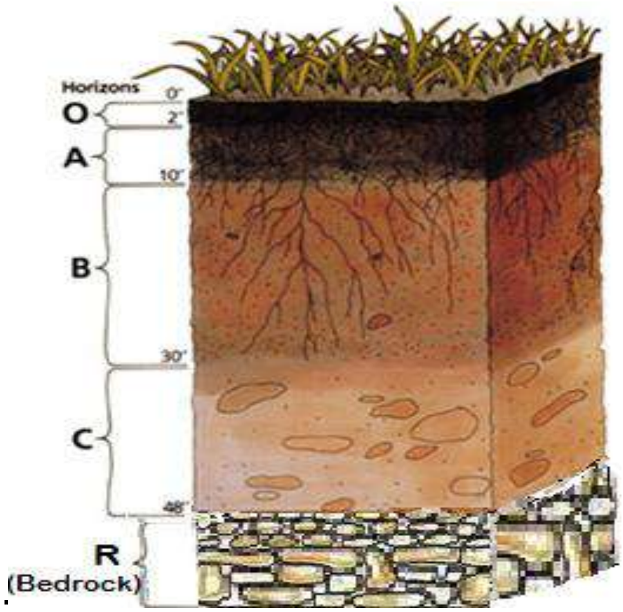
It is a zone of illuviation or accumulation (accumulated substances—clays, organic matter, iron and aluminum compounds) that have been leached from overlying horizons. It is low in organic matter.

5. ***C horizon***

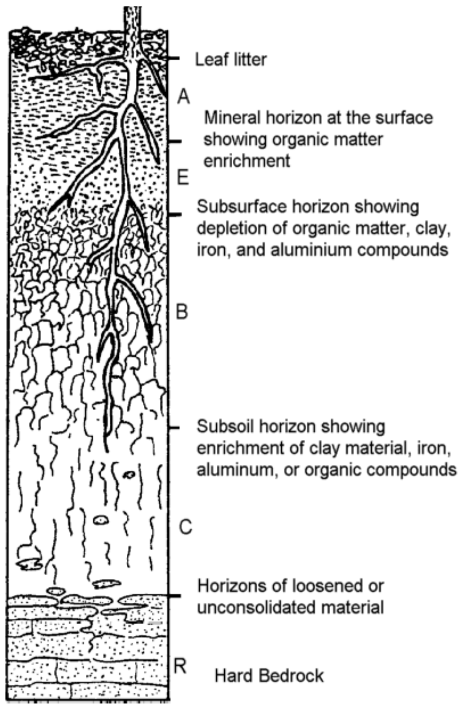
It is lightly weathered parent material. It is a transition area between soil and parent material. Partially disintegrated parent material and mineral particles may be found in this horizon. The C horizon contains fewer organisms than the horizons above and it contains very little organic matter, except where roots have penetrated the horizon.

6. **R) bedrock**

R horizons denote the layer of un-weathered bedrock at the base of the soil profile. Unlike the above layers, R horizons largely comprise continuous masses (as opposed to boulders) of hard rock that cannot be excavated by hand.



Soil Profile



How do soils form?

There are six main contributors that interact to produce soils: **parent material (rocks and sediments), climate, topography, vegetation and living creatures, time, and the effect of man**. Around the world the influence of these **soil forming factors** will be different from one country to another and this is why there are many different soils in the world.

1- **Parent material** is one of the most important influences on what type of soil develops. In some cases soils develop directly from the rock which lies beneath them. Gradually the rock will break down into smaller pieces under the effects of **weathering**, and these smaller pieces break down even further to produce soil. This fragmented rock forms the skeletal material of soils. If the rock is very hard, it can take hundreds of years just to form one centimeter of soil. If soils form on loose materials such as desert sand dunes or on more or less loose deposits left by the Ice Age, deeper soils can form quite quickly. The parent rock or sediment is the main factor responsible for the texture of the soil (i.e. whether the soil is sandy, loamy or clayey) and is also important in determining whether the soil is acid or basic and how rich it is in nutrients.

Weathering

There are three main types of weathering; physical, chemical and biological. ***Physical weathering*** is the influence of processes such as freezing and thawing, wetting and drying, and shrinking and swelling on rocks and other sediments, leading to their breakdown into finer and finer particles.

Chemical weathering is the decomposition of rocks through a series of chemical processes such as acidification, dissolution and oxidation. Some minerals, while stable within solid rock, become less stable on being more exposed to the atmosphere and so begin to alter in the rocks near the surface.

Biological weathering is the effect of living organisms on the breakdown of rock. This involves, for example, the effects of plant roots and soil organisms. Respiration of carbon dioxide by plant roots can lead to the formation of carbonic acid which can chemically attack rocks and sediments and help to turn them into soils.

2- **Climate** is the other most important soil forming influence, alongside parent material. It determines the rate of breakdown of parent rock and thus how quickly the soil will get deeper. The two main climatic influences are **temperature** and **moisture**. Higher temperature increase the rate at which breakdown of the underlying rock and thus also the release of nutrients into the soil. Rainfall and snow melt are also important in breaking down rock to form soil and in the distribution of nutrients in the soil. In hot, wet climates such as the tropics, soils tend to be deep, whereas in the cold Arctic areas, soils tend to be thin and poorly developed.

3- **Topography** is the hilliness, flatness, or amount of slope of the land. Topography generally affects the depth or thickness of soils. Steep slopes such as occur on the sides of hills and mountains generally have shallow soils because soil that does develop is regularly washed down the hillsides into the valleys below. The steep sides of mountains may lack soils altogether and be bare. By comparison flat land such as occurs in valley bottoms, flood plains of rivers or just low lying plains will have deeper soils. These flatter areas often receive sediments washed off the slopes above, which makes the flat land soils deeper.

4- **Vegetation** plays an important part in the formation of soils from solid rock. The acids released by the roots of some plants act to breakdown the rock on which the soil is forming. The vegetation on a soil is particularly important in supplying the soil with precious organic matter. There is often a close relationship between the vegetation and the soil, the vegetation supplying its dying remains to the soil and the soil converting them into nutrients so the vegetation can continue to survive and develop in years ahead. Different types of vegetation give rise to different forms of organic matter in soils.

Organisms, of which there are millions and millions in the soil, play vital parts in soil development and in enabling the soil to undertake its many roles. Organisms begin to set up their home in the soil from the moment soils begin to form. Their main role is to deal with the recycling of organic matter and releasing nutrients but they do other important things such as create pores and build the architecture of the soil. Earthworms, for example, make channels in the soil through which roots can move and water can flow to other parts of the soil.

5- It takes a long **time** for soils to develop from rock and from existing sediments. A few world soils, such as those on the old landscapes of South Africa, are millions of years old. Most world soils are, however, much younger because periods of geological turbulence such as mountain building, earthquakes and ice ages have meant that soil formation has to begin again. Most soils in the United Kingdom are just a few thousand years old, therefore, much, much younger than some of the really old world soils. It is a good thing that soils are always continuing to form and develop more every day.

6- **Human influences** can have far reaching effects on soils. Farmers have cultivated and tended their soils for centuries and farmed soils differ in many respects to those under natural vegetation, for example by having thicker topsoil due to ploughing and more nutrients because of added fertilizers. In most cases mankind has managed the soils well. In some parts of the world, though, soils have been damaged by human interference. For example, cutting down of parts of the tropical rainforest and cultivation of crops on steep slopes have led to soil erosion, which in some cases is irreversible. There is concern that with the pressures being put on our soils by human use, for example to produce more and more food, that we are damaging our soils. We must ensure this does not happen.

Soil Fauna Classification

Soil fauna have been classified by numerous authors including Kevan (1962), Schaller (1968) and Wallwork (1970). Five major groupings are widely accepted: classification based on body size; time spent in the soil; location or habitat preference; feeding strategies; and method of locomotion in the soil (Wallwork, 1970).

1- **Body size**

Body size ranges from 0.0002 cm to more than 20 cm and can be divided into microfauna, mesofauna and macrofauna.

a- **Microfauna** range in body size from 0.0002 to 0.002 cm and consist of protozoa and nematods.
b- **Mesofauna** range from slightly more than 0.002 to 1 cm and include mites, springtails, spiders, pseudoscorpions, pot-worms, insect larvae and the smaller millipedes and isopods.
c- **Macrofauna** are at least 1 cm or greater and include earthworms, the largest insects and arachnids, and the soil-dwelling vertebrates.

2- **Presence (the amounts of time organisms spend in the soil)**

1- Permanent

Some organisms of the soil fauna spend their entire lives in the soil and referred to as **geobionts** such as protozoans, nematodes, isopods, some annelid, collembola and mites.

2- Temporary

Other organisms (called **geophiles**) are temporarily associated with the soil community. This includes insects which seek for shelter, larva and pupae of insects.

3- Habitat preference

A distinction can be made between **<u>aquatic fauna</u>** living in water-filled spaces and surface films covering soil particles and the **terrestrial fauna**. To the former group belong the protozoans, copepods and certain nematods, while most of meso- and macro-fauna belong to the latter.

Another classification of soil fauna based on their location in the soil profile layers. Soil animals generally fit into one of three layers:

- **Epigeon**, or **Surface soil and litter species.** These species live in or near surface plant litter. They are typically adapted to the highly variable moisture and temperature conditions at the soil surface.
- **Hemiedaphon**, or **Upper soil species.** Some species move and live in the upper soil strata and feed primarily on soil and associated organic matter.
- **Euedaphon**, or mineral layers **or Deep-burrowing species**. Soils have numerous microhabitats and soil organisms can be classified according to their use of them.

4- Feeding strategies.

Feeding classifications include:

Carnivores, which feed on other fauna and includes: predators such as many mites, spiders, pseudoscorpions, scorpions, centipedes and some nematodes. Parasites such as parasitic insects and some nematodes.

Phytophages, which feed on green plant, root systems and woody material like nematode plant parasites and larvae of some insects.

Saprophages, which eat dead and decaying material such as isopods, millipeds, some mites, collembola and insects.

Microphytic-feeders, which feed on fungal hyphae and spores, algae, lichens and bacteria such as many mites and collembolan, ants, some nematodes and certain protozoans.

Miscellaneous feeders, which fit into two or more of the other categories (have a wide range of food materials) such as: mites, collembolan, nematodes and larvae of some insects.

5- **Locomotion.**

Distinctions are made between burrowing animals (burrow their way through the soil such as some insects and burrowing vertebrates) and those that move through the soil by making use of pore spaces, cavities or channels such as most small bodied-animals.

Role of Animals in the Soil Community

Vertebrates

Vertebrates (mice, moles, ground squirrels, etc.) are an example of soil macrofauna. They mix soil through their burrowing activity.

Annelids

Annelids (segmented worms) are another example of soil macrofauna. They are major decomposers (detritivores). The most important species of Annelida are earthworms. Earthworms are the original tillers of soil and can thus improve the rooting environment for plants and increase the amount of water that infiltrates the soil.

What do earthworms do?

Earthworms dramatically alter soil structure, water movement, nutrient dynamics, and plant growth. They are not essential to all healthy soil systems, but their presence is usually an indicator of a healthy system. Earthworms perform several beneficial functions.

Stimulate microbial activity. Although earthworms derive their nutrition from microorganisms, many more microorganisms are present in their feces or casts than in the organic matter that they consume. As organic matter passes through their intestines, it is fragmented and inoculated with microorganisms. Increased microbial activity facilitates the cycling of nutrients from organic matter and their conversion into forms readily taken up by plants.

Mix and aggregate soil. As they consume organic matter and mineral particles, earthworms excrete wastes in the form of casts, a type of soil aggregate. Charles Darwin calculated that earthworms can move large amounts of soil from the lower strata to the surface and also carry organic matter down into deeper soil layers. A large proportion of soil passes through the guts of earthworms, and they can turn over the top six inches (15 cm) of soil in ten to twenty years.

Increase infiltration. Earthworms enhance porosity as they move through the soil. Some species make permanent burrows deep into the soil. These burrows can persist long after the inhabitant has died, and can be a major conduit for soil drainage, particularly under heavy rainfall. At the same time, the burrows minimize surface water erosion. The horizontal burrowing of other species in the top several inches of soil increases overall porosity and drainage.

Improve water-holding capacity. By fragmenting organic matter, and increasing soil porosity and aggregation, earthworms can significantly increase the water-holding capacity of soils.

Provide channels for root growth. The channels made by deep-burrowing earthworms are lined with readily available nutrients and make it easier for roots to penetrate deep into the soil.

Bury and shred plant residue. Plant and crop residue are gradually buried by cast material deposited on the surface and as earthworms pull surface residue into their burrows.

Arthropods

Arthropods are fauna with a jointed exoskeleton and can belong to the macro or meso group. Arthropods range in size from microscopic to several inches in length. They include insects, such as springtails, beetles, and ants; crustaceans such as sowbugs; arachnids such as spiders and mites; myriapods, such as centipedes and millipedes; and scorpions.

Arthropods can be grouped as shredders, predators, herbivores, and fungal-feeders, based on their functions in soil. Most soil-dwelling arthropods eat fungi, worms, or other arthropods. Root-feeders and dead-plant shredders are less abundant. As they feed, arthropods aerate and mix the soil, regulate the population size of other soil organisms, and shred organic material.

WHAT DO ARTHROPODS DO?

Although the plant feeders can become pests, most arthropods perform beneficial functions in the soil-plant system.

Shred organic material. Arthropods increase the surface area accessible to microbial attack by shredding dead plant residue and burrowing into coarse woody debris. Without shredders, a bacterium in leaf litter would be like a person in a pantry without a can-opener – eating would be a very slow process. The shredders act like can-openers and greatly increase the rate of decomposition. Arthropods ingest decaying plant material to eat the bacteria and fungi on the surface of the organic material.

Stimulate microbial activity. As arthropods graze on bacteria and fungi, they stimulate the growth of mycorrhizae and other fungi, and the decomposition of organic matter. If grazer populations get too dense the opposite effect can occur – populations of bacteria and fungi will decline. Predatory arthropods are important to keep grazer populations under control and to prevent them from over-grazing microbes.

Mix microbes with their food. From a bacterium's point-of-view, just a fraction of a millimeter is infinitely far away.

Bacteria have limited mobility in soil and a competitor is likely to be closer to a nutrient treasure. Arthropods help out by distributing nutrients through the soil, and by carrying bacteria on their exoskeleton and through their digestive system. By more thoroughly mixing microbes with their food, arthropods enhance organic matter decomposition.

Mineralize plant nutrients. As they graze, arthropods mineralize some of the nutrients in bacteria and fungi, and excrete nutrients in plant-available forms.

Enhance soil aggregation. In most forested and grassland soils, every particle in the upper several inches of soil has been through the gut of numerous soil fauna. Each time soil passes through another arthropod or earthworm, it is thoroughly mixed with organic matter and mucus and deposited as fecal pellets. Fecal pellets are a highly concentrated nutrient resource, and are a mixture of the organic and inorganic substances required for growth of bacteria and fungi. In many soils, aggregates between 1/10,000 and 1/10 of an inch (0.0025mm and 2.5mm) are actually fecal pellets.

Burrow. Relatively few arthropod species burrow through the soil. Yet, within any soil community, burrowing arthropods and earthworms exert an enormous influence on the composition of the total fauna by shaping habitat. Burrowing changes the physical properties of soil, including porosity, water-infiltration rate, and bulk density.

Stimulate the succession of species. A dizzying array of natural bio-organic chemicals permeates the soil. Complete digestion of these chemicals requires a series of many types of bacteria, fungi, and other organisms with different enzymes. At any time, only a small subset of species is metabolically active – only those capable of using the resources currently available. Soil arthropods consume the dominant organisms and permit other species to move in and take their place, thus facilitating the progressive breakdown of soil organic matter.

Control pests. Some arthropods can be damaging to crop yields, but many others that are present in all soils eat or compete with various root- and foliage-feeders. Some (the specialists) feed on only a single type of prey species. Other arthropods (the generalists), such as many species of centipedes, spiders, ground-beetles, rove-beetles, and gamasid mites, feed on a broad range of prey. Where a healthy population of generalist predators is present, they will be available to deal with a variety of pest outbreaks. A population of predators can only be maintained between pest outbreaks if there is a constant source of non-pest prey to eat. That is, there must be a healthy and diverse food web.

A fundamental dilemma in pest control is that tillage and insecticide application have enormous effects on non- target species in the food web. Intense land use (especially monoculture, tillage, and pesticides) depletes soil diversity. As total soil diversity declines, predator populations drop sharply and the possibility for subsequent pest outbreaks increases.

Protozoa

Protozoa belong to soil microfauna. Protozoa are single-celled animals that feed primarily on bacteria, but also eat other protozoa, soluble organic matter, and sometimes fungi. As they eat bacteria, protozoa release excess nitrogen that can then be used by plants and other members of the food web.

WHAT DO PROTOZOA DO?

Protozoa play an important role in mineralizing nutrients, making them available for use by plants and other soil organisms. Protozoa (and nematodes) have a lower concentration of nitrogen in their cells than the bacteria they eat. (The ratio of carbon to nitrogen for protozoa is 10:1 or much more and 3:1 to 10:1 for bacteria.) Bacteria eaten by protozoa contain too much nitrogen for the amount of carbon protozoa need. They release the excess nitrogen in the form of ammonium (NH_4^+).

This usually occurs near the root system of a plant. Bacteria and other organisms rapidly take up most of the ammonium, but some is used by the plant.

Another role that protozoa play is in regulating bacteria populations. When they graze on bacteria, protozoa stimulate growth of the bacterial population (and, in turn, decomposition rates and soil aggregation.).

Protozoa are also an important food source for other soil organisms and help to suppress disease by competing with or feeding on pathogens.

Nematodes and protozoa

Protozoa and bacterial-feeding nematodes compete for their common food resource: bacteria. Some soils have high numbers of either nematodes or protozoa, but not both. The significance of this difference to plants is not known. Both groups consume bacteria and release NH_4^+.

Nematodes

Nematodes are non-segmented worms (commonly known as threadworms or roundworms) belong to soil microfauna. They are found in almost all soils in surprisingly large numbers. Those few species responsible for plant diseases have received a lot of attention, but far less is known about the majority of the nematode community that plays beneficial roles in soil.

Some are plant parasites that infest roots, some are predators that feed on other nematodes or bacteria, fungi, and protozoa. Like protozoa, nematodes have lower N requirements than many bacteria. Soil compaction generally reduces the populations of nematodes, which need adequate space between soil aggregates to move around.

An incredible variety of nematodes function at several trophic levels of the soil food web. Some feed on the plants and algae (first trophic level); others are grazers that feed on bacteria and fungi (second trophic level); and some feed on other nematodes (higher trophic levels).

WHAT DO NEMATODES DO?

Nutrient cycling. Like protozoa, nematodes are important in mineralizing, or releasing, nutrients in plant-available forms. When nematodes eat bacteria or fungi, ammonium ($NH4+$) is released because bacteria and fungi contain much more nitrogen than the nematodes require.

Grazing. At low nematode densities, feeding by nematodes stimulates the growth rate of prey populations. That is, bacterial-feeders stimulate bacterial growth, plant-feeders stimulate plant growth, and so on. At higher densities, nematodes will reduce the population of their prey. This may decrease plant productivity, may negatively impact mycorrhizal fungi, and can reduce decomposition and immobilization rates by bacteria and fungi. Predatory nematodes may regulate populations of bacterial-and fungal-feeding nematodes, thus preventing over-grazing by those groups. Nematode grazing may control the balance between bacteria and fungi, and the species composition of the microbial community.

Dispersal of microbes. Nematodes help distribute bacteria and fungi through the soil and along roots by carrying live and dormant microbes on their surfaces and in their digestive systems.

Food source. Nematodes are food for higher level predators, including predatory nematodes, soil microarthropods, and soil insects. They are also parasitized by bacteria and fungi.

Disease suppression and development. Some nematodes cause disease. Others consume disease-causing organisms, such as root-feeding nematodes, or prevent their access to roots. These may be potential biocontrol agents.

Nematodes and soil quality

Nematodes may be useful indicators of soil quality because of their tremendous diversity and their participation in many functions at different levels of the soil food web. Several researchers have proposed approaches to assessing the status of soil quality by counting the number of nematodes in different families or trophic groups.* In addition to their diversity, nematodes may be useful indicators because their populations are relatively stable in response to changes in moisture and temperature (in contrast to bacteria), yet nematode populations respond to land management changes in predictable ways. Because they are quite small and live in water films, changes in nematode populations reflect changes in soil microenvironments.

KEY TO ADULT SOIL AND LITTER INVERTEBRATES

1a. Body segmented.......................... 2

1b. Body not segmented, usually with a coiled shell. ....Gastropoda (snails)

2a. Appendages segmented...3

2b. Appendages (if present) not segmented. ....Annelida (segmented worms)

3a. Antennae present...7

3b. Antennae absent...4

4a. Three pairs of legs..Protura

4b. Four pairs of legs (pedipalps in front of legs & may appear leg-like). 5

5a. Pedipalps with pincher-like claws, abdomen segmented...Pseudoscorpionida (psuedoscorpions).

5b. Pedipalps without pincher-like claws, abdomen not segmented.........................6

6a. Cephalothorax & abdomen joined by a narrow connection. ....Araneae (spiders)

6b. Cephalothorax & abdomen joined by a broad connection. ....Acarina (mites)

7a. Three pairs of legs (Insects).......................................12

7b. More than three pairs of legs. 8

8a. Distinct head followed by a series of segments 9

8b. Distinct head absent ....Isopoda (pillbugs)

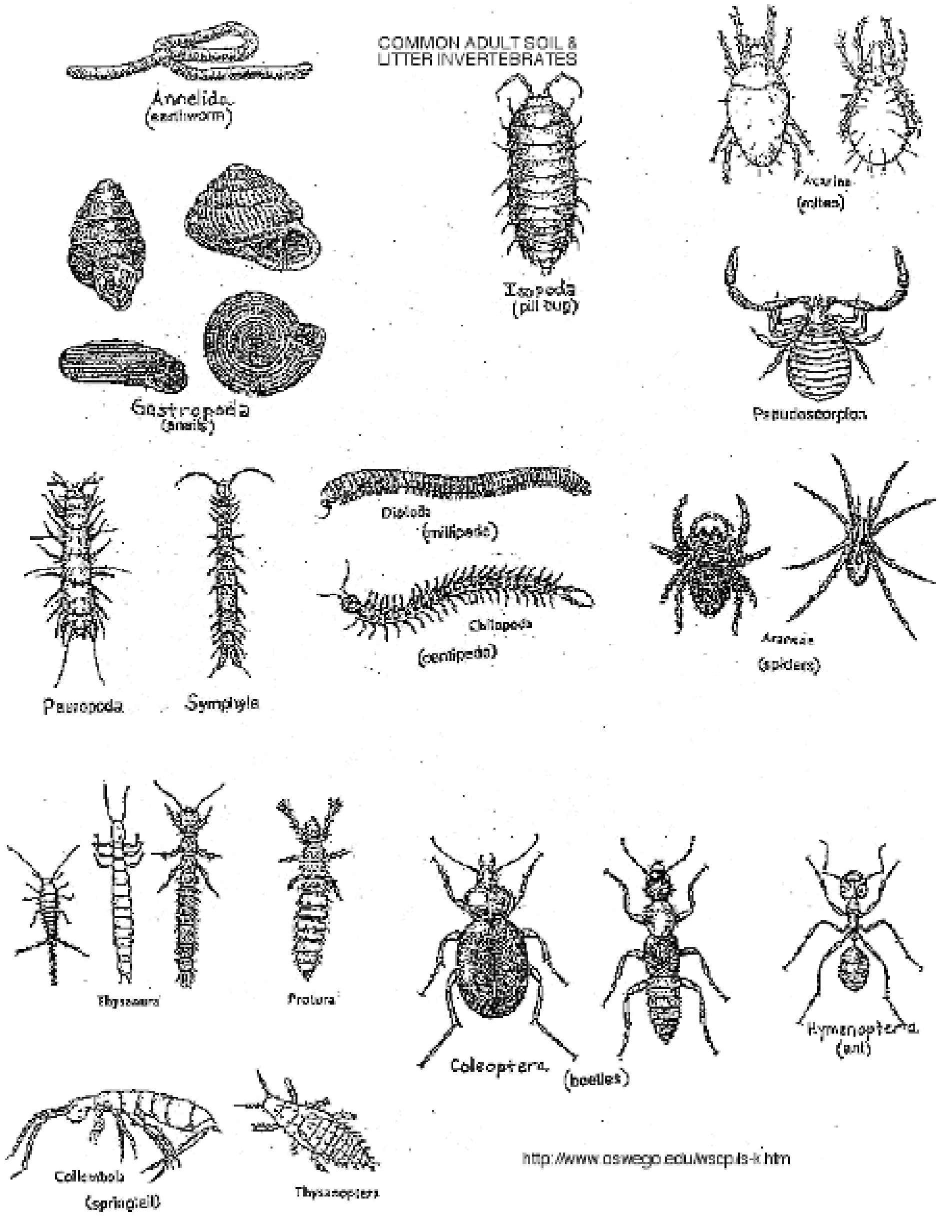
9a. 9-12 pairs of legs..10

9b. More than 12 pairs of legs 11

10a. Antennae branched......................................Pauropoda

10b. Antennae not branched...............................Symphyla

11a. Two pairs of legs on most body segments ....Diploda (millepedes)
11b. One pair of legs on each body segment ....Chilopoda (centipedes)
12a. Winged or with plate over thorax 16
12b. No wings and no plate over thorax 13
13a. Narrow-waisted, ant-like ....Hymenoptera (ants)
13b. Not narrow-waisted & ant-like 14
14a. Abdomen with 2-3 finger-like appendages on tail.............Thysanura (bristletails) **not** fork-like
14b. Abdomen without finger-like appendages 15
15a. Fork-like (2-part) jumping appendage on tail ....Collembola (springtails)
15b. No fork on tail..................................Thysanoptera (thrips)
16a. Front wings hard or leathery, covering hind wings................Coleoptera (beetles)
16b. Front wings not hard or leathery or not present..................................17
17a. Front wings thickened at base, membranous at tip, ...Hemiptera (bugs) sucking mouth parts
17b. Wings with veins, overlapping or held rooflike.............Orthoptera (grasshoppers)



Role of soil community and energy flow

Food Chains

The phrase 'food chain' is a way of indicating how energy moves through an ecosystem.

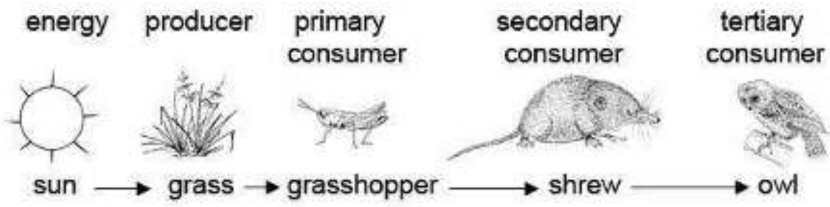
Components of a Food Chain:

- Plants or producers or **Autotrophs** - 'base' of the food chain.
- **Herbivores or primary consumers** - feed on plants; many are adapted to live on a diet high in cellulose.
- **Carnivores or secondary consumers**- feed on herbivores, omnivores & other carnivores
  - 1st level carnivore - feeds on herbivores
  - 2nd level carnivore - feeds on 1st level carnivores
  - 3rd level carnivore – feeds on 2nd level carnivores
- **Decomposers**
  - the 'final' consumer group
  - use energy available in dead plants and animals

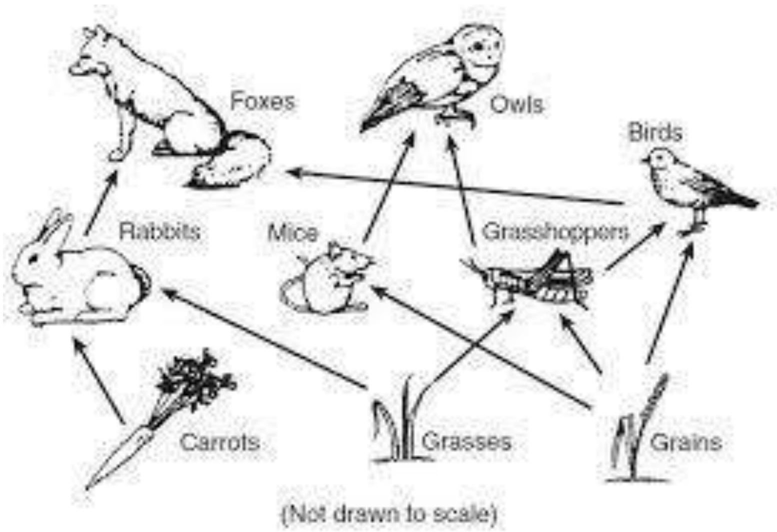
<u>Types of Food Chains:</u>

- **Grazing food chain** - The grazing food chain begins with the photosynthetic fixation of light, carbon dioxide, and water by plants (primary producers) Primary consumers or herbivores form the second link in the grazing food chain. They gain their energy by consuming primary producers. Secondary consumers or primary carnivores, the third link in the chain, gain their energy by consuming herbivores. Tertiary consumers or secondary carnivores are animals that receive their organic energy by consuming primary carnivores.
- **Detrital food chain**
  - The organisms making it up are generally smaller (like algae, bacteria, fungi, insects, & centipedes) and live in the soil.

- Decomposers process large amounts of organic matter, converting it back into its inorganic nutrient form.



- **<u>Food webs</u>** describe the transfer of energy between species in an <u>ecosystem</u>, consists of many overlapping food chains. While a <u>food chain</u> examines one, linear, energy pathway through an ecosystem, a food web is more complex and illustrates all of the potential pathways.



Significance of Food Chains and Food webs

1. They help in maintaining the ecological balance.

2. They help in understanding the feeding relations among organisms.

3. Energy flow and nutrient cycling take place through them.

4. It explains the concept of biomagnifications.

Energy Flow

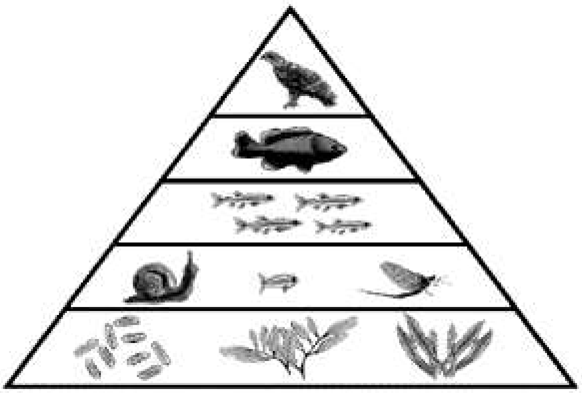
A general energy flow scenario follows:

- Solar energy is fixed by the green plants that produce sugars and other organic molecules. Once produced, these compounds can be used to create the various types of plant tissues. Primary consumers absorb most of the stored energy in the plant through digestion, and transform it into the form of energy they need, such as adenosine triphosphate (ATP), through respiration. A part of the energy received by herbivores, is converted to body heat (an effect of respiration), which is radiated away and lost from the system. The loss of energy through body heat is far greater in warm-blooded animals, which must eat much more frequently than those that are cold-blooded. Energy loss also occurs in the expulsion of undigested food by excretion .

- Secondary consumers, carnivores, then consume the primary consumers, although omnivores also consume primary producers. Energy that had been used by the primary consumers for growth and storage is thus absorbed into the secondary consumers through the process of digestion. As with primary consumers, secondary consumers convert this energy into a more suitable form (ATP) during respiration. Again, some energy is lost from the system, since energy which the primary consumers had used for respiration and regulation of body temperature cannot be utilized by the secondary consumers.
- Tertiary consumers, which may or may not be apex predators, then consume the secondary consumers, with some energy passed on and some lost, as with the lower levels of the food chain.
- A final link in the food chain are decomposers which break down the organic matter of the tertiary consumers (or whichever consumer is at the top of the chain) and release nutrients into the soil. They also break down plants, herbivores and carnivores that were not eaten by organisms higher on the food chain, as well as the undigested food that is excreted by herbivores and carnivores. Saprotrophic bacteria and fungi are decomposers.

The energy is passed on from trophic level to trophic level and each time about 90% of the energy is lost, with some being lost as heat into the environment (an effect of respiration) and some being lost as incompletely digested food. Therefore, primary consumers get about 10% of the energy produced by autotrophs, while secondary consumers get 1% and tertiary consumers get 0.1%. This means the top consumer of a food chain receives the least energy, as a lot of the food chain's energy has been lost between trophic levels. This loss of energy at each level limits typical food chains to only four to six links.

What is an energy pyramid?



Energy pyramid

An energy pyramid is a graphical model of energy flow in a community. The different levels represent different groups of organisms that might compose a food chain. From the bottom-up, they are as follows:

- **Producers** — bring energy from nonliving sources into the community
- **Primary consumers** — eat the producers, which makes them herbivores
- **Secondary consumers** — eat the primary consumers, which makes them carnivores

-

- **Tertiary consumers** — eat the secondary consumers

Why are energy pyramids shaped the way they are?

An energy pyramid's shape shows how the amount of useful energy that enters each level — chemical energy in the form of food — decreases as it is used by the organisms in that level.

Methods of Collecting and Extraction of Soil Fauna

Soil zoology has tried for a long time to find a sampling method that allows collection of the greatest fraction of fauna as possible. However, there is now a growing general agreement that a method allowing a good sampling of one community of species may fail for other communities (Southwood & Henderson, 2000). Thus sampling protocols combining different methods must be established if maximal efficacy of sampling is to be achieved.

A- Field techniques

This section includes the methods used to collect in the field the target fauna or to collect the soil samples to be carried to the laboratory for extraction.

Direct sampling

This is the basic sampling method. The researcher will locate and capture the target fauna searching for the specimens in their habitat by eyeing the ground, turning stones, searching among litter, digging around plant bases, etc. This method usually allows the capture of macrofauna only. This method allows the sampling of the upper horizons of the ground.

Collecting soil samples using an equipment

To **sample the soils** you will need:
• Sampling ring or metal cube (with a height 5 cm)
• Trowel
• Flat surface large enough to cover surface of sampling ring (e.g. paint scraper)
• Plastic bags

How to collect…..

1- We recommend soil samples are taken first thing in the morning. The ground is cooler then, and soil fauna are likely to be nearer the surface.
2- Soil fauna abundance will vary throughout the year. Soil fauna biomass tends to be greatest in the top few centimeters of soil when the soil is moist. In dry summer months soil fauna abundance made be lower or you may find that the species that are present are very different to those present in winter.
3- When sampling soils, record the date, time, ambient temperature (approx) and weather conditions (sunny, raining, overcast).

4- Push the sampling ring or cube 5 cm into the ground. If the ground is hard you can tap the ring into the soil by placing a wooden board over top and hitting it lightly with a mallet.
5- Dig around one side of the ring with a trowel.
6- Slide the scraper straight underneath the ring. This stops losing soil when you lift the sample out.
7- Place the sample into a plastic bag (labeled with date and site).

B- Laboratory extraction methods

Sampling very small animals has the disadvantage that they cannot be separated in the field. In this case, carrying samples to undergo a laboratory extraction is obligatory. According to the nature of the methods, two kinds of extractions are to be distinguished: **mechanical or passive methods**, and **dynamical or active methods**. On the other hand, samples can be manually separated under the binocular.

1. Mechanical or passive methods

They are extracted active and non active organisms. The commonest are sieving (including dry and wet sieving) and flotation.
Separation protocols are very variable, since every research team tends to modify them in order to adjust them to their particular needs.

Sieving method

Sieving method is usually employed when the size of the animals under study is appreciably different from that of the soil particles. It is often possible to separate out several different size groupings of animals by using a number of sieves of differing descending mesh sizes assembled in a series. The nest of sieves loaded on to a mechanical shaker. Wet sieving is often more efficient than the dry method, particularly for medium and small sized litter dwelling animals other than arthropods. The leaf litter sample is washed with water over a set of sieves and ending in a paper filter or fine cloth for collecting animals.

Flotation

Is a widely used technique when the specific gravity of the fauna and of the soil grains is very different. Different liquids can be used as suspension media: solutions of 25% magnesium sulphate, of sodium chloride, of 75% of zinc chloride, of sucrose or directly heptanes (Southwood & Henderson, 2000).

The basic heptanes protocol is as follows: Put the sample in a cylinder with flat stopper and add 1 l of 50% ethyl alcohol and 10 ml of heptanes. Replace stopper and invert cylinder without shaking. Allow the heptanes to rise. Repeat inversion twice. Allow the cylinder to stand for 4 h. The sediment will settle. Decant the heptanes supernatant layer into a sieve. Rinse the sieve with 95% ethanol to remove the heptanes and wash the sample into a sorting dish.

Elutriation (soil washing)

This technique lies in separating the organisms by washing the sample in a constant current of water. Thus the specimens, floating more or less, are swept and later filtered, while the sediment, being heavier, is kept in the bottom of the device. It has been used to separate arthropods and springtails but is often used to separate soil nematodes in slightly modified devices (Southwood & Henderson, 2000). The **soil washing** technique uses a washing apparatus (Fig.) made of a stack of two sieves (a coarse one on top of a medium one) placed over a settling can. This can has a pivoted lateral drainage that allows floating animals to pass into the Ladell can, which has a 0.2 mm fine phosphor-bronze sieve in the bottom. Its lower opening is immersed in the drainage tank, so that the water level in the tank is always slightly above the sieve of the Ladell can. When water is poured over the sample placed in the upper sieve, specimens are filtered: large animals are caught in the coarse sieve, medium sized animals in the medium sieve and small animals (depending upon mesh size) are washed to the Ladell can sieve, where they can be recovered.

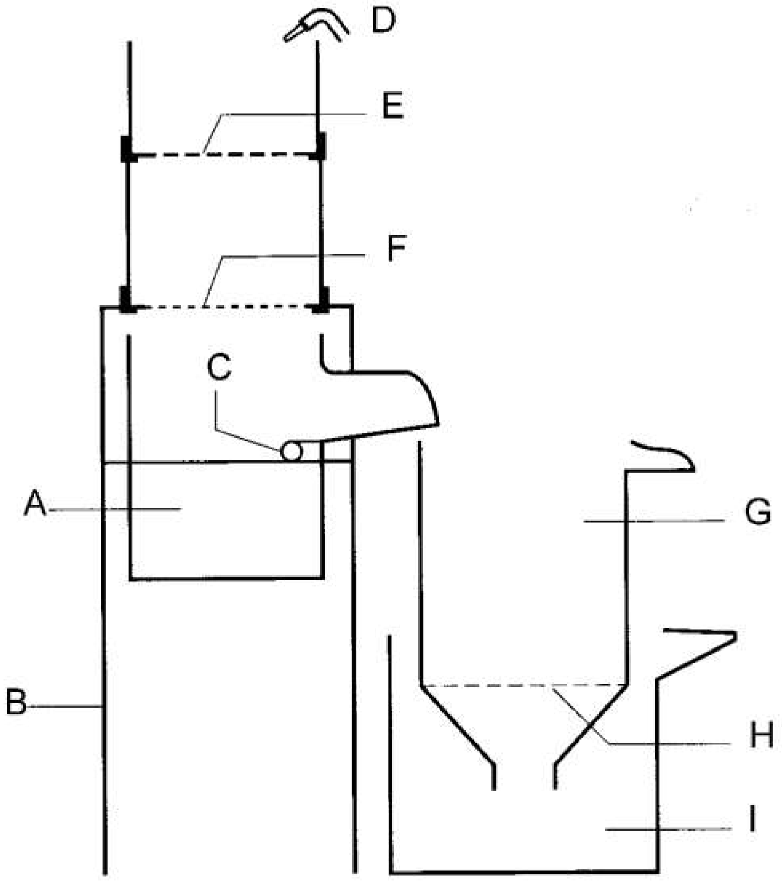


Fig.. Soil-washing apparatus, redrawn from Southwood & Henderson (2000). A = Settling can. B = Stand. C = Pivot. D = Nozzle of hose. E = Coarse sieve. F = Medium sieve. G = Ladell can. H = Fine phosphor-bronze gauze. I = Drainage tank.

One of the greatest disadvantages of the mechanical extraction techniques is the considerable amount of work involved and time consumed in separating them. Therefore, it is not surprising that many soil zoologists prefer to use behavioural techniques in which the animals do most of the work.

2- Dynamic or active methods (behavioural)

They are based on the migration of the sample organisms as a response to the alteration of the physicochemical conditions of their environment like heat, light and desiccation. The most common methods are the Berlese-Tullgren funnel and the Baermann funnel.

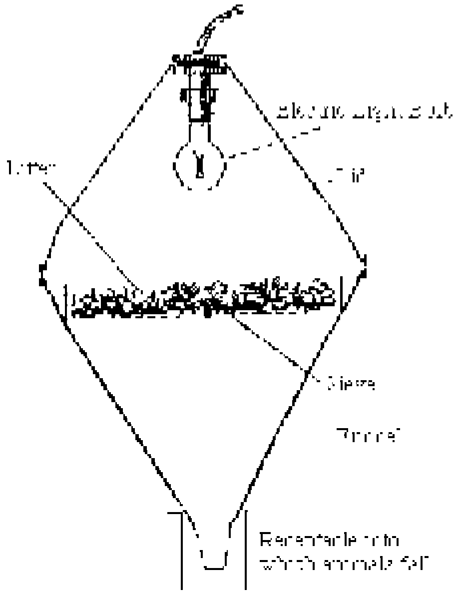
Berlese-Tullgren funnel

This technique was devised for dry samples. It was originally designed by Berlese (1905) with a hot water jacket to heat the sample and posteriorly modified by Tullgren (1918) by eliminating the jacket and adding a bulb on top. All of them are based in the negatively phototropic and positively geotropic behaviour of the soil fauna, which migrates downwards to fall in a collector container. Many small and medium-sized invertebrates (juvenile centipedes and millipedes, small insects and their larvae, mites and springtails or collembola) can be separated from soil and litter using this method. A functional Berlese funnel can be made from household items (a plastic soda bottle, cardboard, etc.). However different the shape, size, and material, every Berlese-Tullgren extractor consists of a funnel with smooth inner surface, a light source, a sieve fitting inside the funnel (mesh size 2 mm) and a container (into which the animals fall) with the appropriate killing-preserving liquid (usually 70% ethanol, added or not of up to 25% ethylene glycol; hypersaturated salt water can also be used).

A litter sample is placed on the screen (sieve) at the top of the funnel. The screen prevents soil and litter debris from falling into the collecting container. A small lamp with a low-power light bulb (10-40 Watts) heats and dries the soil from above. The light bulb should be positioned just above the litter, but not touching it, the collecting container is placed below and the top covering the sieve. As the soil dries out from the top down, the dryness stimulates the soil animals to move downward (this behavior is called positive geotaxis). This downward movement eventually causes the soil animals to fall through the sieve into a container with a preservative (usually 75% alcohol).

With the light bulb as a source of heat, the extraction can take 5-7 days, longer if a large amount of substrate is collected, or if the substrate is wet. If a power source for the light bulb is not available, for example in field conditions, the samples can be allowed to air-dry if the weather is dry and warm, although this will slow down the extraction. Air-drying will not work for wet substrates or in rainy weather.

Until ready to extract, the soil and litter containing invertebrates should be placed in plastic bags and kept in a cool, dark area. The Berlese-Tullgren extraction method gives a biased sample of soil fauna, because it is based on specific avoidance behaviour triggered by dryness and thus best captures animals that are mobile and do not desiccate easily. Immobile larvae, endophagous nymphs and some moisture-dependant invertebrates such as nematodes are not extracted by a Berlese funnel.



Berlese-Tullgren funnel

Baermann funnel

Baermann funnel is used for nematodes. The Baerman funnel is wet, however (while the Berlese funnel is dry) and does not depend on a light/heat gradient. Nematodes move out of the soil and to the bottom of the funnel because, as they move, they are denser than water and are unable to swim. The original model consisted of a glass funnel full of water, with a sieve at mid length, where the sample, wrapped in a gauze, is deposited. A later modification is the addition of a lamp heating the water, which accelerates the separation process.

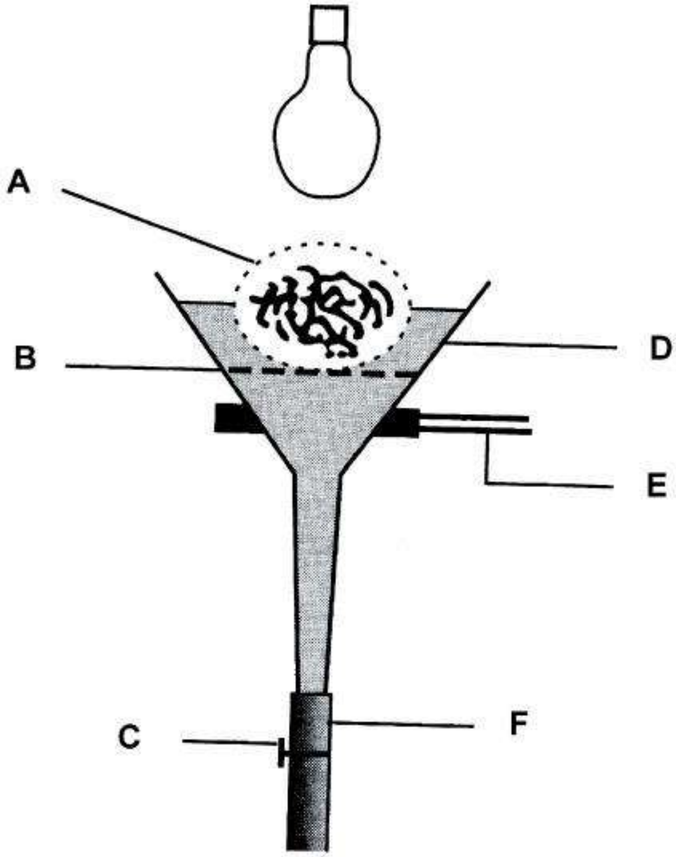


Fig. . Baermann funnel, redrawn from Southwood & Henderson (2000). A = muslin wrapped over sample. B = sieve. C = pinchcock. D = water. E = funnel stand. F = rubber tubing.

Determination of some Soil Ecological Factors

1- Soil moisture

After soil samples have been taken and returned to the lab, quick and careful procedures need to be taken. The following steps will help in drying the samples to determinate soil moisture:

1. Mix the samples in the plastic bags to ensure uniform distribution of the sample.
2. Weigh the paper plate before putting soil on the plate. This value will be needed for the calculation of soil moisture.
3. Place approximately 25 grams of wet/moist soil on the paper plate and record the weight of soil and plate.

5. Drying the sample can be done in conventional drying oven. Place the sample in the oven at 105 degree centigrade for 24 hours.
6. Weigh the sample after drying and the difference between the two weights is the soil water content.

   Percentage= (water content ÷ weight of wet sample) × 100

2- Soil temperature.

A soil thermometer is the most accurate way to take your soil's temperature. Simply stick the probe into the soil and wait to see consistent readings.

3- Soil pH

To measure the concentration of hydrogen ions in soil, use a commercially available electronic pH meter, in which a rod is inserted into moistened soil.

4- Soil organic contents

(1)- Determine and record the mass of an empty, clean, and dry porcelain dish (MP).

(2)- Place a part of dried soil in the porcelain dish and determine and record the
mass of the dish and soil sample (MPDS).

(3)- Place the dish in microwave oven at 600 c. for 8 hours.

(4)- Remove carefully the porcelain dish using the tongs (the dish is very hot), and
allow it to cool at room temperature.

(5)- Determine and record the mass of the dish containing the ash (burned soil)
(MPA).

Data Analysis:

(1) Determine the mass of the dry soil.

$$MD=MPDS-MP$$

(2) Determine the mass of the ashed (burned) soil.

$$MA=MPA-MP$$

(3) Determine the mass of organic matter

$$MO = MD - MA$$

(4) Determine the organic matter (content).

$$OM= MO/MD\ x100$$

5- <u>Determination of root biomass</u>

Root biomass help bind the soil together by forming aggregates and granular structure.

This process improves the tilth as well as the erosion resistance of the soil.

1- Weight a part of the dried soil.
2- Roots are removed from the soil by hand rinsing soil from the roots through a sieve followed by drying the removed roots
3- Weight the dried roots and this is the root biomass.

6- Soil particle size (Soil texture)

The apparatus required to do this test:-
i) A set of fine Sieves of sizes – 2mm, 600µm, 425µm, 212µm and 75µm
ii) A set of coarse Sieves of sizes – 20mm, 10mm and 4.75mm
iii) Mechanical shaker

i) Soil sample should be dried in air or in the sun. Tree roots and pieces of bark should be removed from the sample.

ii) The big clods may be broken with the help of wooden mallet. Care should be taken not to break the individual soil particles.

iii) The different soil particles can be separated in the sieves (like the method of separating soil fauna).

Factors affecting soil fauna

Soil Fauna, just like higher plants depends entirely on soil for their nutrition, growth and activity. The major soil factors which influence the faunal population, distribution and their activity in the soil are:

1- Soil moisture

Soil moisture has often been reported to be the most important environmental variable affecting both the structure and function of the soil fauna community. Generally, it seems that the abundance of all faunal groups decreases with drought. For example, **soil mites**, one of the most abundant groups of mesofauna has been found to be positively related to soil moisture across many ecosystems.

Many soft-bodied animals such as **collembolans** are sensitive to desiccation during dry conditions. To avoid drought, 1- soil animals undertake vertical movements deeper into the soil or redistribute to moist patches (Verhoef & Van Selm 1983; Didden 1993).
2- They can also enter inactive stages, or survive as dormant eggs, which are reactivated by moisture (Hopkin 1997).
** The moisture content of the litter may affect the ability of juveniles to penetrate their substrates successfully (Norton 1994).
** Moisture changes may also affect the fungal community and, thereby, have indirect effects on the fungivorous fauna and the oviposition of oribatid mites (Hågvar 1998).
** Heavy rains or flooding may lead to waterlogged conditions that cause mortality among adult collembolans and require water-resistant eggs for the populations to persist (Mertens *et al.* 1983; Tamm 1984).

2- Soil temperature

Temperature also affects many aspects in the life of soil fauna. Seasonal temperature variations commonly induce vertical movements of soil animals in the soil profile (e.g., Luxton 1981; Didden 1993). The developmental rate of collembolans, mesostigmatid and oribatid mites are often temperature-dependent (e.g., Hopkin 1997; Walter & Proctor 1999; Bhattacharya *et al.* 1978). In some collembolans, fecundity and sex ratio in the populations may also be affected (Choudhuri 1961; Snider 1973).

3- Soil Structure and Texture

The structure and texture of soil affect the distribution of burrowing animals.

1- Compact soils **(Soil compaction** is the reduction of soil volume due to external factors) or very rocky soils may reduce the rate of burrowing by earthworms, for instance (Guild, 1955), or preclude burrowing altogether. Soils that are too fine may not be suitable for burrowing, except for those animals with special adaptations (Kuhnelt, 1976). These generalities hold not only for animals that spend all their lives in the soil, but also for vertebrates such as burrowing rodents that spend varying amounts of time underground.

2- Another aspect of soil structure, the size and number of spaces between soil particles, influences the species composition and vertical distribution of non-burrowing animals. A clear, positive correlation exists between the average size of pore space in soils and the animals that inhabit them (Kuhnelt, 1958). Furthermore, the size and number of spaces in soils affect soil moisture and carbon dioxide content.

4- Aeration (soil air)

Soil aeration is difficult to separate from soil moisture because they generally correlate inversely (Kevan, 1962). Under high soil moisture level / water logged conditions, gaseous exchange is hindered and the accumulation of Co2 occurs in soil air which is toxic to microbes. The resistance of soil organisms to high carbon dioxide levels is extremely variable, and little is known about aeration requirements of many soil animals. But some species such as nematodes (Wallace, 1956) apparently depend on specific levels of oxygen for successful emergence.

5- Soil pH

The pH of soils depends to a large extent upon the soil parent material, but the kind of vegetation on the surface and the level of aerobic and anaerobic decomposition processes also influence soil pH (Kevan, 1962; Wallwork, 1976). Soil organisms vary considerably in their preferences for soil pH, but most avoid very acid soils (Kevan, 1962).

6- Soil Organic Matter:

The organic matter in the soil being the chief source of energy and food for most of the soil organisms. Organic matter influence directly or indirectly on the population and activity of soil microorganisms. It influences the structure and texture of soil and thereby activity of the microorganisms.

Zoology Department

Special Environments

(Soil Biology)

Practical Part

By/

Dr. Heba M. Fangary

(Fourth Year Students)

(Chemistry & Zoology)

2022-2023

Methods of Collecting and Extraction of Soil Fauna

1- <u>Collecting soil samples from the field using an equipment</u>

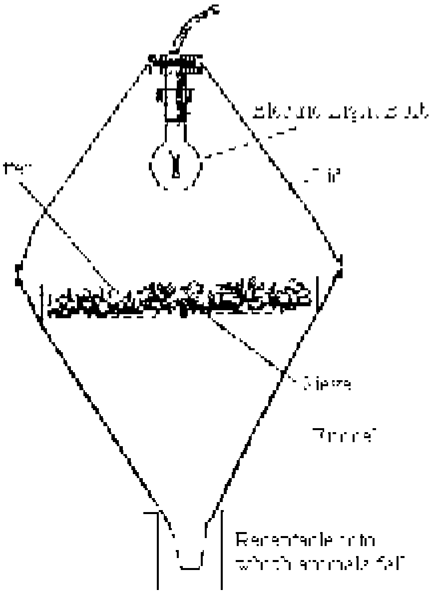
To **sample the soils** you will need:
• Sampling ring or metal cube (with a height 5 cm)
• Trowel
• Flat surface large enough to cover surface of sampling ring (e.g. paint scraper)
• Plastic bags

How to collect…..

1- We recommend soil samples are taken first thing in the morning. The ground is cooler then, and soil fauna are likely to be nearer the surface.
2- When sampling soils, record the date, time, ambient temperature (approx) and weather conditions (sunny, raining, overcast).
3- Push the sampling ring or cube 5 cm into the ground. If the ground is hard you can tap the ring into the soil by placing a wooden board over top and hitting it lightly with a mallet.
4- Dig around one side of the ring with a trowel.
5- Slide the scraper straight underneath the ring. This stops losing soil when you lift the sample out.
6- Place the sample into a plastic bag (labeled with date and site).
7- Until ready to extract, the soil and litter containing invertebrates should be placed in plastic bags and kept in a cool, dark area.

2- Laboratory extraction method (<u>Berlese-Tullgren funnel)</u>

This technique was devised for dry samples. It was originally designed by Berlese (1905) and posteriorly modified by Tullgren (1918). Many small and medium-sized invertebrates (juvenile centipedes and millipedes, small insects and their larvae, mites and springtails or collembola) can be separated from soil and litter using this method.



Berlese-Tullgren extractor consists of a funnel with smooth inner surface, a light source, a sieve fitting inside the funnel (mesh size 2 mm) and a container (into which the animals fall) with the appropriate killing-preserving liquid (usually 70% ethanol).
A soil sample is placed on the screen (sieve) at the top of the funnel. The screen prevents soil and litter debris from falling into the collecting container. A small lamp with a low-power light bulb (10-40 Watts) heats and dries the soil from above. The light bulb should be positioned just above the litter, but not touching it, the collecting container is placed below and the top covering the sieve. As the soil dries out from the top down, the dryness stimulates the soil animals to move downward (this behavior is called positive geotaxis). This downward movement eventually causes the soil animals to fall through the sieve into a container with a preservative. With the light bulb as a source of heat, the extraction can take 3-7 days.

Preserving and Preparing Specimens for light microscope

(a) Preserving: specimens preserved in 70-80% ethanol. In higher alcohol concentrations mites become brittle; at lower concentrations bacterial and fungal degradation can occur.

(b) Slide- mounting of specimens: using Hoyer·s mounting media. To make Hoyer·s, dissolve gum arabic in distilled water and let it sit over night. The next day, add the chloral hydrate and glycerine and then either filter the mixture through clean glass wool. Store Hoyer·s in a brown bottle to prevent degradation by light.

Hoyer·s Medium (Krantz 1978)

(a) Chloral hydrate	200 g
(b) Crystalline gum arabic	30 g
(c) Glycerol	20 ml
(d) Distilled water	50 ml

Simplified Key to Soil Invertebrates

1) The general shape of the organism.
   a) Shape is generally worm-like, without legs or with 6 or fewer leg-like appendages (See Figures 1, 3, 4, 5)………………………………**Go to 2**
   b) Shape is bug-like with hard exoskeletion, with at least 6 leg-like appendages (Fig. 2, 6, 7) ……………………………………………………………… …**Go to 4**

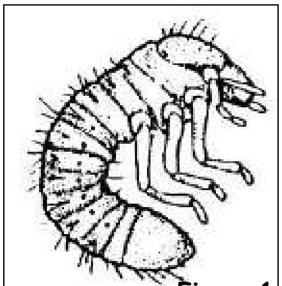


Figure 1

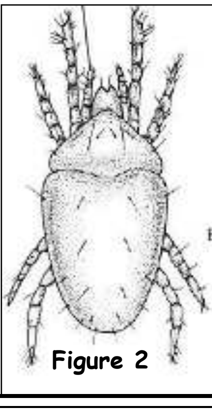


Figure 2

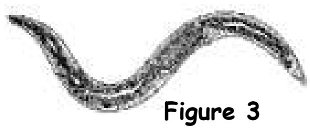


Figure 3

2) The presence or absence of appendages.
   a) No recognizable appendages (Fig. 3, 4) ………………………………………………… **Go to 3**
   b) Possesses recognizable appendages, or head capsule (Fig. 1, 5) **Insect Larvae**
3) Identification of segmentation.
   a) Lacks visible segmentation (Fig. 3) ………………………………… **Unsegmented Worm**
   b) Has visible segmentation (Fig. 4) …………………………………… **Earthworm**

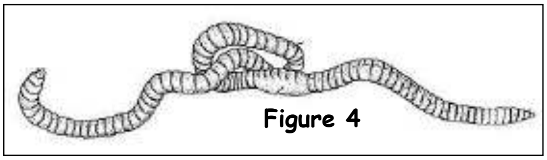


Figure 4

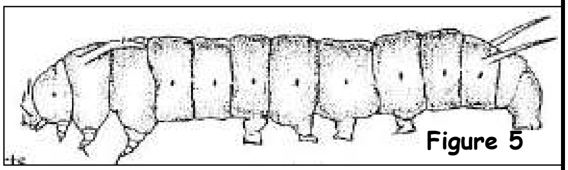


Figure 5

4) How many legs?
   a) Six legs (Fig. 6)……………………………………**Go to 5**
   b) More than six legs (Fig. 2, 7) ………… **Go to 6**
5) How many body and antennal segments?

   a) Nine or fewer body segments behind the head; antenna with four segments; hinged tail appendage often visible (Fig 8)………………………… **Springtail**

   b) Otherwise ……………………………………………..… **Other insect**

6) How many legs, again?

   c) Eight legs (Fig. 2) …………………………………… **Go to 7**
   d) More than eight legs (Fig. 7) ……………… **Myriapod**
7) Considers thorax and abdomen.

a) Thorax and abdomen separated by constricted "waist" ………………………… **Spider**

b) Thorax and abdomen fused into one (Fig. 2) …………………………………………… **Mite**

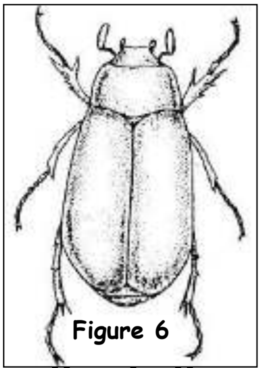


Figure 6

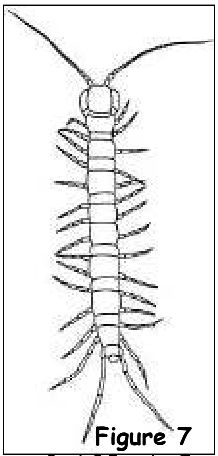


Figure 7

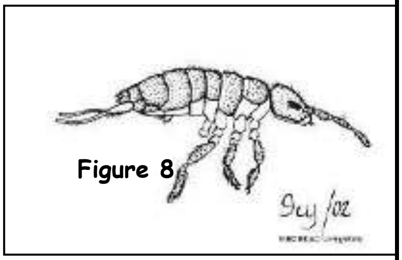


Figure 8

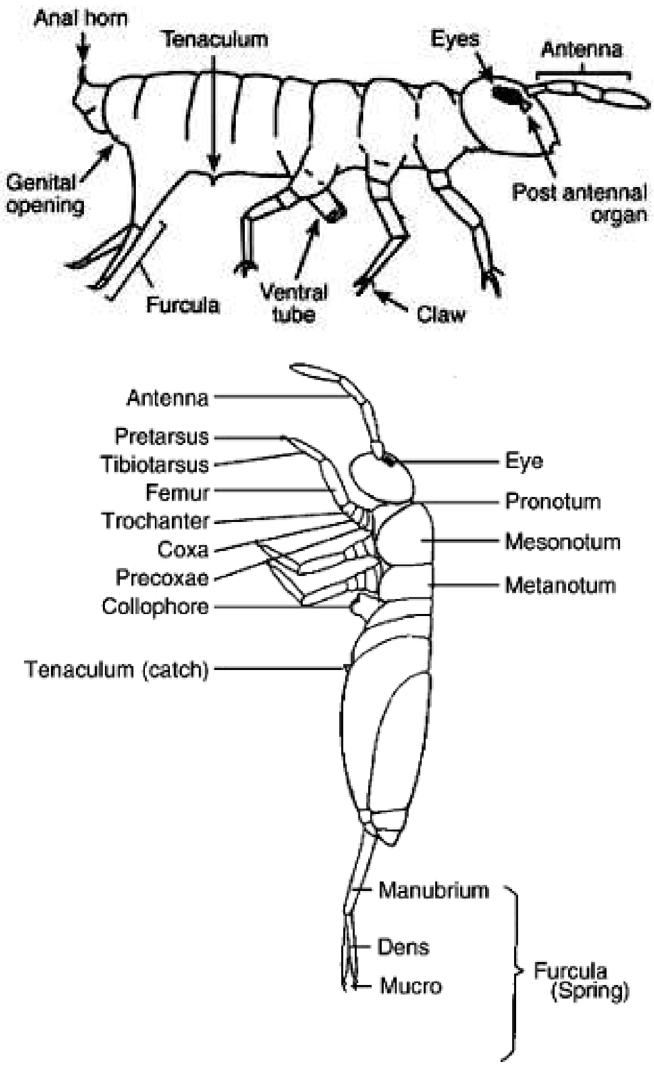
Soil collembolla

Collembola are small ([min. 0.12] 1-5 [max. 17] mm), wingless hexapods (insects) with antennae always present. Most but not all *Collembola* may be recognized by a posterior ventral forked abdominal appendage, the furca.

The body of *Collembola* basically comprises three parts: a head capsule, a thorax and an abdomen.

- **The head** bears two antennae (often 4 segments), two postantennal organs, two clusters of simple eyes (each with 8 ommatidia) and the mouthparts.
- **The thorax** with three segments, each segment bears ventrally a pair of walking limbs.
- **The abdomen** with 6 segments. The first bears a ventral tube (collophore) having two eversible vesicles. The third abdominal segment ventrally bears the tenaculum. The fourth abdominal segment ventrally bears the furca. The genital orifice opens at the ventral side of the fifth abdominal segment. The anus opens terminally at the six abdominal segment (periproct).

- The ventral tube or collophore may be helps maintain water balance in the body by absorbing moisture from the environment, also attaching the animal to the substratum.
- The furca composed of a basal <u>manubrium</u>, bearing two arms, each of them comprising a <u>dens</u> and a <u>mucro</u>. It is folded beneath the body to be used for jumping.
- The tenaculum held on the furca, and when released causes the furca snap down against substrate.



General structure of collembola

Class: Insecta

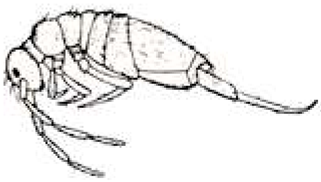
Subclass: Apterygota

Order: Collembolla

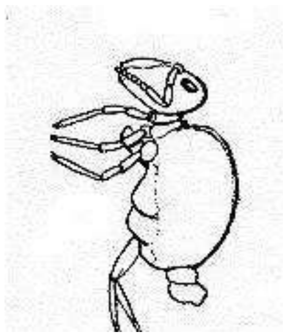
Suborder

Arthropleona | **Symphypleona**

Abdomen is elongate.
Abdomen segments distinct.



Abdomen is subglobular.
Abdomen segments indistinct.



Suborder: Arthropleona

Section

Poduromorpha

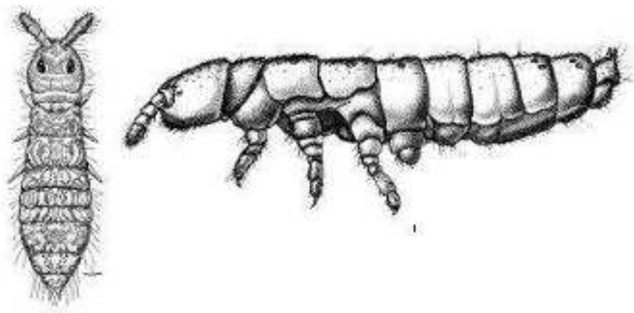
(Prothoracic tergum distinct)

Family: Neanuridae

Prothorax with setae.
Dents of furca absent or vestigial or when present relatively short.

Entomobrymorpha

(Prothoracic tergum indistinct)



General form of Poduromorpha

General form of Entomobrymorpha

Family: Neanuridae

Subfamily: Frieseinae

e.g.: *Friesea*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).
2- Thorax: the three segments (pro-, meso and metathorax) are equal, each with a pair of legs. Prothorax with setae.

3- Abodomen: elongate with six segments. The first bears short ventral tube. The fourth bears short furca. The last one is big and bears 3 anal spines.
4- The colour of the body is dark in upper part and light in lower part.

Entomobrymorpha

Family: Isotomidae

Body without scales. Body setae simple or at most sparsely ciliate. Post antennal organ present. The 4th and 3rd abdominal segments are equal.

Entomobryidae

Body with scales. Body setae long and densely ciliated. Post antennal organ absent. 4 th abdominal segment often much longer than third.

Family: Isotomidae

e.g. : *Isotomina*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).
2- Thorax: the three segments (pro-, meso and metathorax), each with a pair of legs. The prothorax redused from dorsal side, but present from ventral side.
3- Abodomen: elongate with six equal segments. The first bears short ventral tube. The fourth bears forked furca.
4- The color of body is light due to absence of scales.

Family: Entomobryidae

e.g.: *Seira*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).
2- Thorax: the three segments (pro-, meso and metathorax), each with a pair of legs. The prothorax is very small.
3- Abodomen: elongate with six segments. The 4^{th} segment equals twotimes the 3^{rd} segment. The first bears short ventral tube. The fourth bears long forked furca.
4- The color of body is dark due to presence of scales.

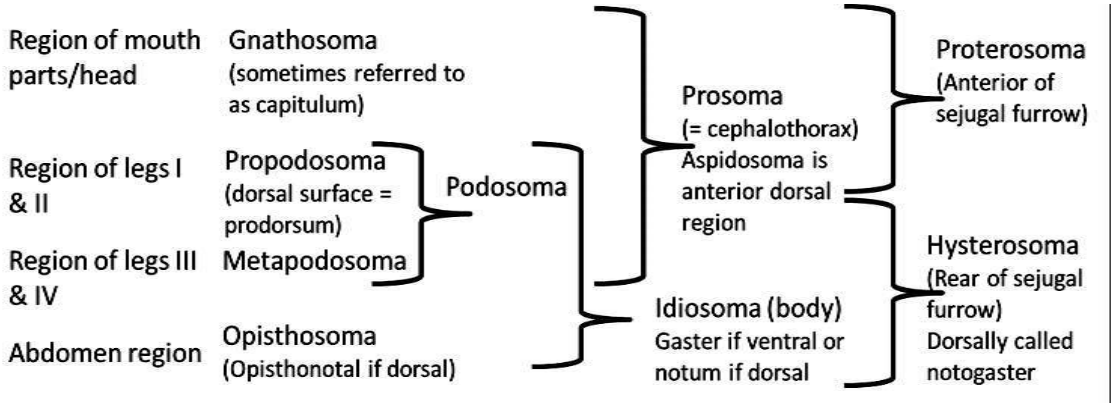
Class: Arachnida

Order: Acarina (mites)

The basic division of the acarine body is into two sections: the gnathosoma (head) and the idiosoma (main body).

- The gnathosoma bears mouthparts comprising a pair of chelicerae (often pincer like) and paired palps (or pedipalps) which are leg-like appendages.
- The idiosoma bears four pairs of legs consists of a number of segments (Tarsus – Tibia – Genu – Femur – Trochanter – Coxa).

The simple body division into gnathosoma and idiosoma is most easily seen in ticks and Mesostigmata, but can be subject to fusion and subdivision in other groups. For this reason mites in different groups often have different names for different parts of the body.



<u>Body divisions in mites.</u>

Many mites breathe through holes in their exoskeleton called stigmata (singular is stigma) which is often associated with a channel called a peritreme. These peritremes can be located on the sides of the animal (Mesostigmata), or around the mouthparts (Prostigmata), or may not be visible at all (Oribatida).

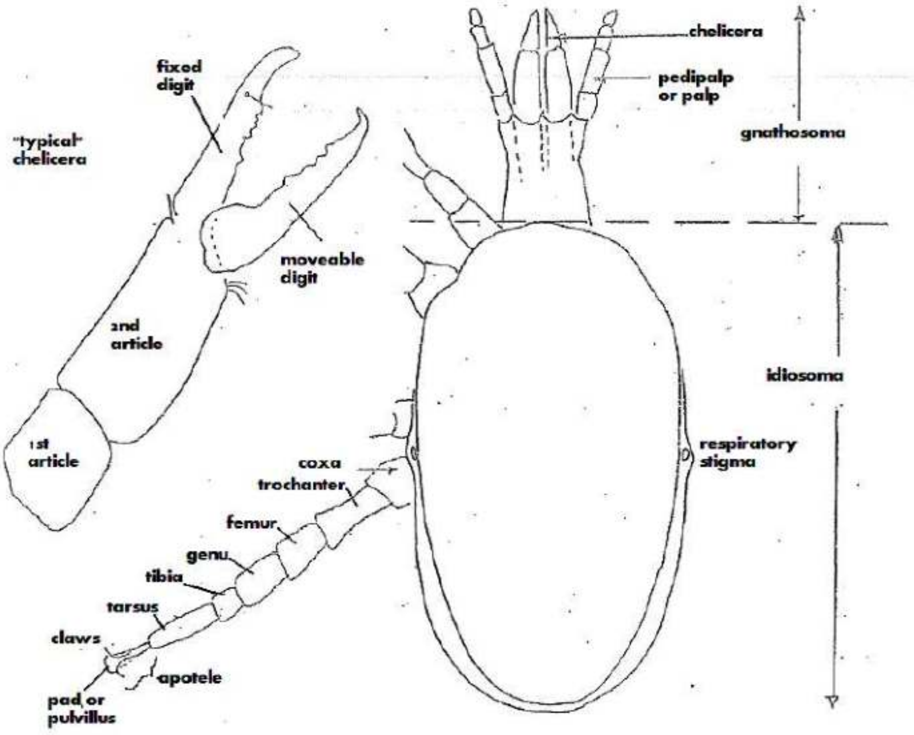
Order: Acarina

Suborder **Mesostigmata** **Sarcoptiformes**

Mesostigmata

1- The body divided into gnathosoma and idiosoma.
2- Eyes absent.
3- Have a pair of lateral stigmatal openings usually around the level of coxae II-IV, often associated with elongated peritremes.
4- Legs with 6 segments (coxa free, not fused with the ventral side).
5- First pair of legs forward facing.

6- The genital opening with undivided plates, while the anal opening with divided plates.



General form of Mesostigmata

Group: Uropodina

e.g.: ***Uropodina***

Comment:

- The body is roundish-disc shaped.
- The gnathosoma bears two chelicerae and two pedipalps. And it is not observable from the dorsal side due to extending of the dorsal shield.
- The idiosoma bears 4 legs, each leg can be withdrawn into a hollow beside it (pedifossae) found on the ventral surface.

- The stigmata between the 3-4 legs.
- The peritremes is connected.
- The genital plate with genital opening.
- The anal plate with anal plate.

Group: Gamasina

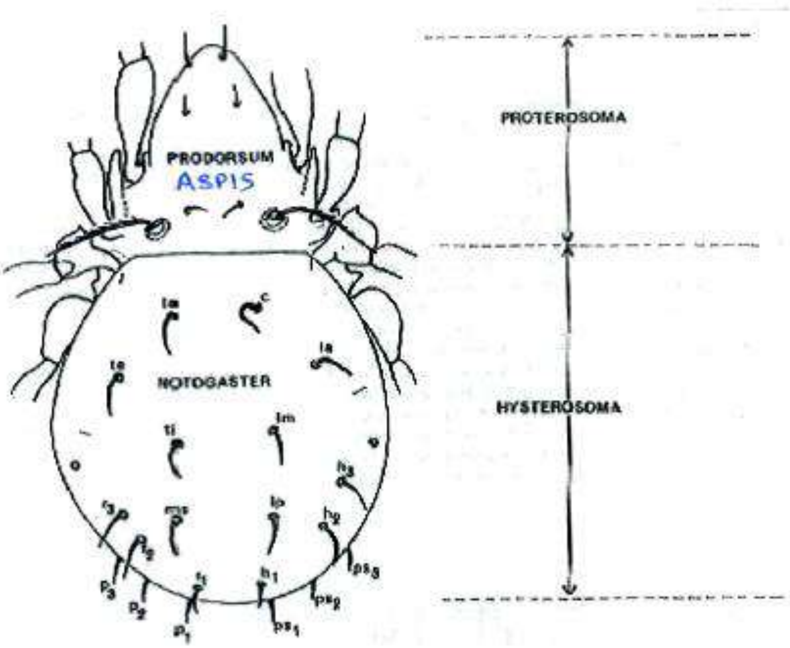
Family: Laelaptidae

e.g.: ***Pachylae laptidae***

- The Gnathosoma with 2 chelicerae and 2 pedipalps, and it observable anteriorly.
- The Idiosoma: the first pair of legs forward facing.
- The peritreme is separated.

Sarcoptiformes (Oribatida)

1- The idiosoma split into at least two sections when viewed from above (dorsal), the proterosoma and the hysterosoma. A dorsal shield called prodorsum covering the front of the proterosoma often extending far forward covering the "head". Another shield "notogaster", covering the hysterosome.
2- The gnathosoma of these mites is often hidden under the projecting front part of the proterosome called a camerostome ("chamber-hole"). The chelicerae are often hard to see, tucked deep within the camerostome.
3- Eyes and stigmata absent.
4- Legs are 5-segmented, coxa fused to the ventral side.
5- Genital and anal plates are divided.



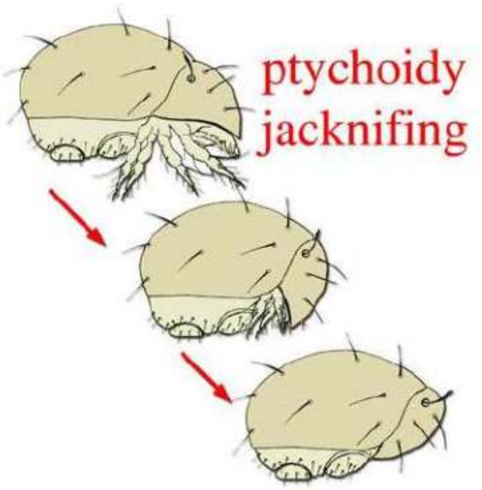
General structure of Oribatida

Group: Oribatei inferiors (lower oribatids)

Family: Phthiracaridae

e.g.: ***Rhysotritia***

- The body is generally laterally compressed (Blade of knife) and divided into the proterosoma and the hysterosoma.
- The body with a ptychoid form, which allow them to retract into a ball to protect their sort parts from predators.
- The gnathosoma is often hidden under the projecting front part of the proterosoma which called a camerostome.
- The genital and anal plates connected in one structure.



Family: Lohmannidae

e.g.: ***Lohmania***

- The genital and anal plates found in one structure.

Family: Epilohmannidae

e.g.: ***Epilohmania***

- The colour is light.
- There is a region (neck-like) between proterosima and hysterosoma.

Group: Oribatei superiors (higher oribatids)

Family: Oribatelloidae

e.g.: ***Setobates***

- Hard-bodied, dark oribatids with projections of the dorsal shield (Pteromorphs) that protect the base of the legs.
- The pteromorphs or wings are very small.

- The prodorsum shield with projecting lamellae but not connected medially with each others.
- The genital and anal plates with clearly defined space between them, and the genital plate not connected with the lamellae.
- Tibia in the leg is large.

e.g.: ***Lamellobates***

- Lamellae are larger than in Setobates and connected medially with each other and with the genital plate.
- The pteromorphs are larger than in Setobates.

Family: Galumnidae

e.g.: ***Galumna***

- Lamellae are absent or very small.
- The pteromorphs are large and auriculate.

Family: Passalozetidae

e.g.: ***Passalozetes***

- Hard-bodied, dark oribatids without pteromorphs.
- The body outer edges are darker in colour.
- The genital and anal plates with clearly defined space between them.

Family: Oppiidae

e.g.: ***Oppia***

- Hard-bodied, dark oribatids without pteromorphs.
- There are two dark spots in the sides of the body.
- The genital and anal plates with clearly defined space between them.